Bulletin 180—*Part II.* 1911

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

SEEPAGE AND RETURN WATERS

DETAILED MEASUREMENTS

THE CACHE LA POUDRE

By L. G. CARPENTER

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1911

The Agricultural Experiment Station

FORT COLLINS, COLORADO

THE STATE BOARD OF AGRICULTURE

	Term Expires
HON. R. W. CORWIN	Pueblo, 1913
HON. A. A. EDWARDS	Fort Collins, 1913
HON. F. E. BROOKS	Colorado Springs, 1915
HON. J. L. BRUSH	Greeley, 1915
HON. J. C. BELL	Montrose, 1917
HON. E. M. AMMONS	Littleton, 1917
HON. T. J. EHRHART	Centerville, 1919
HON. CHAS. PEARSON	Durango, 1919

GOVERNOR JOHN F. SHAFROTH, } Ex-officio
PRESIDENT CHAS. A. LORY, }

L. M. TAYLOR, Secretary — G. A. WEBB, Treasurer

EXECUTIVE COMMITTEE IN CHARGE

A. A. EDWARDS, Chairman

J. L. BRUSH — E. M. AMMONS

STATION STAFF

C. P. GILLETTE, M. S., Director	Entomologist
W. P. HEADDEN, A. M., Ph. D.	Chemist
G. H. GLOVER, M. S., D. V. M.	Veterinarian
W. G. SACKETT, B. S.	Bacteriologist
ALVIN KEYSER, A. M.	Agronomist
J. O. WILLIAMS, B. S. A.	U. S. Expert-in-charge Horse Breeding
E. R. BENNETT, B. S.	Horticulturist
B. O. LONGYEAR, B. S.	Assistant Horticulturist
G. E. MORTON, M. L., B. S. A.	Animal Husbandman
E. B. HOUSE, B. S., (E. E.), M. S.	Irrigation Engineer
V. M. CONE, B. S.	Irrigation Investigations
R. E. TRIMBLE, B. S.	Assistant Irrigation Engineer
P. K. BLINN, B. S.	Rocky Ford, Alfalfa Investigations
EARL DOUGLASS, M. S.	Assistant Chemist
S. ARTHUR JOHNSON, M. S.	Assistant Entomologist
B. F. KAUPP, M. S., D. V. S.	Pathologist
MIRIAM A. PALMER, M. A.	Delineator
L. C. BRAGG	Assistant in Entomology
GEORGE P. WELDON, B. S.	Grand Junction, Field Entomologist
R. S. HERRICK, B. S.	Delta, Field Horticulturist
C. L. FITCH	Potato Investigations
W. E. VAPLON	Poultry
J. W. ADAMS, B. S.	Cheyenne Wells, Supt. Plains Substation
G. D. WALTERS, B. S.	Assistant Irrigation Investigations

SEEPAGE AND RETURN WATERS

DETAILED MEASUREMENTS

THE CACHE LA POUDRE

By L. G. CARPENTER†

The following tables give the measurements in detail in the series of seepage measurements made on the various streams in Colorado under my direction in connection with the Experiment Station. In Bulletin 33, 1896, the measurements made to that time on the Poudre and Platte Rivers were given. These are repeated, inasmuch as that Bulletin is unavailable, and their need is still felt.

This Part will more especially give the measurements. The comments and results of their study are given in Part I.

The methods used in taking these measurements were a gradual development. The fact that the Poudre seemed to increase in volume after the ditches had been taken from it was a matter of comment among some of those who were conversant with the streams, and especially to Mr. B. S. La Grange, who was one of those most interested in irrigation and had so much to do with its practical development and the early administration. It was not commonly believed. The first trial was made by Mr. E. S. Nettleton, then State Engineer, at the request of Mr. La Grange, water commissioner on the Poudre.

The trial was made in October, 1885. The ditches were all shut down and no water taken from the river, except such as leaked through the headgates. This measurement showed a gain of 87 feet to the Ogilvy Ditch, below Greeley, 4 miles above the mouth of the Poudre.

A second measurement was made by Mrs. E. C. Hawkins and L. R. Hope, then connected with the State Engineer's office, in 1889, under the direction of Mr. Nettleton, who was then chief engineer of the U. S. Irrigation survey of that date. Another measurement was made by the same two under State Engineer Maxwell in 1890. The series of measurements then ceased. I took it up at the Experiment Station largely because of the fact that the funds available for the irrigation and meteorological work of the Experiment Station only amounted to about $200 per year for all field purposes and equipment and this line of investigation promised some results within reach of our means. It is practically certain that had more means been available, that other things would have been taken up, but as it proved, the results obtained were of far reaching importance.

The series of measurements show not only the absolute amount of gain from year to year, but as they have been taken during the development of an irrigated community they thus show the progressive changes. While such increase of streams is noted in irrigation countries, in most cases the changes due to the development of irrigation is lost, certainly beyond the observation of living persons.

The results give the occasion to point out, in Bulletin 33, the future importance and have furnished the basis which has been relied upon to develop a large part of the state, and especially in the Platte Valley.

The methods used developed with time. As it was impossible to cause the ditches to be shut down, the co-operation of the water commissioners and the ditches was secured, so that the ditches would be held constant during the few days of measurement. After the experience of a few years it was found to be best to divide the river into sections and to attempt to eliminate the consequences of any fluctuation in the river. Each section was thus treated separately and its gain or loss determined. The stage of water at night was recorded, and if any change, measured again in the morning. When with a party, I kept the results worked up as we

---

†738-740 Equitable Building, Denver.

proceeded so that, any inconsistencies were found at once. This practice, however, was not always possible for the observers, with the result that such inconsistencies were sometimes not discovered until the measurements were worked up at the office and when it was impossible to return to check or verify them. After a few years more pains were taken to take the stream measurements at the same place so as to be able to compare the results in the various sections from year to year. Also it was attempted to measure streams even though known to be seepage. These have definite characteristics that almost always enabled them to be recognized. They are indicated in the tables by parenthesis and are not included in the summations.

The cause of discrepancies in different years is not always evident. It is to be expected that the results will disagree from year to year, but sometimes the indications are that errors have entered, either from errors in measurement, from fluctuation in the stream or variations in the ditches. A considerable difficulty was found with the first measurement on a stream, to obtain the necessary detailed local knowledge. Sometimes the water commissioners themselves did not know the location of the headgates or their wasteways and thus information was not reliable. If an error were committed in the measurement of a stream at any place, it would show too large a gain in one section and too small a gain in another, but the aggregate of the two would not be affected. While most of the measurements were made in the late fall, when storms were not frequent, yet sometimes there was interference from this cause. It was usually impossible to wait until such unfavorable conditions passed away. The detailed measurements are therefore given complete.

After the first few years, measurements were extended to the other tributaries of the Platte, and to the Arkansas, the Rió Grande and the Uncompahgre.

Acknowledgements are due to the many who have aided in these measurements. In the earlier ones various ditch companies on the Platte and the Arkansas especially gave their aid. The water commissioners nearly always were glad to help for the information that aided them in the performance of their duties. Later, with more funds available, some allowance could be made for their time and rigs. The one who above all else has aided in the field work and in the reduction, has been Mr. Robert E. Trimble, of the Experiment Station, who began as my assistant in 1891 and continued throughout this series of nearly twenty years. To him fell nearly all of the field work. To his conscientious care the accuracy in detail is mostly due.

ORDER OF ARRANGEMENT.

The following is the order of arrangement of the measurements as given in Parts II. and III.:

PART II.

CACHE LA POUDRE.

PART III.

BIG THOMPSON.
- Little Thompson.

ST. VRAIN.
- Left Hand.
- Boulder.

CLEAR CREEK.
- Ralston.

SOUTH PLATTE.

ARKANSAS.
- Fountain.

RIO GRANDE.
- Conejos.

UNCOMPAHGRE.

CACHE LA POUDRE RIVER

*Measurement No. 1. Made October 12-15, 1885.

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
1st River Meas	127.61	.....	At gaging station
Pl. Valley & Lake Canal	.....	1.75	
Larimer Co. Canal	.....	0.58	
Jackson Ditch	.....	0.27	
Little Cache la Poudre	.....	1.00	
Larimer Co. No. 2	.....	0.53	
New Mercer	.....	0.23	
Ft. Collins Town Ditch	.....	1.14	
2nd River Meas	133.97	.....	2 1-2 m. above Ft. Collins
	127.61	139.47	Gain of 11.86
2nd River Meas.	133.97	.....	
Larimer & Well Canal	.....	1.73	
Pioneer Ditch	.....	2.60	
Ames Ditch	.....	0.69	
Lake Canal	.....	1.25	
Cache la Poudre No. 2	.....	3.22	
3rd River Meas	.....	149.99	Below No. 2 Canal
	133.97	159.47	Gain 25.50
3rd River Meas	149.99	.....	
Whitney Ditch	.....	1.58	
Greeley No. 3	.....	5.87	
4th River Meas	.....	122.91	¼ m. below No. 3.
	149.91	130.36	Loss 19.55
4th River Meas	130.36	.....	
Ogilvy Ditch	.....	38.96	
5th River Meas	.....	153.12	River 1-3 m. below Ogilvy Ditch
	130.36	192.08	Gain 30.21
	.....	.....	Total gain 48.02

CACHE LA POUDRE RIVER

Measurement No. 2. Made October 14-17, 1889.

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
1st River Meas	68.72	.....	At gaging station
Pleasant V. & L. Canal	.....	14.78	
Larimer Co. Canal	.....	0.82	
Jackson	.....	5.29	
Little Cache la Poudre	.....	6.97	
Taylor & Gill	.....	2.58	
Larimer Co. No. 2	.....	12.42	
Ft. Collins W. Works	.....	0.88	
Arthur Canal	.....	0.65	
Larimer & Weld Canal	.....	3.04	
2nd River Meas	.....	32.57	At L. & W. Canal
	68.72	79.99	Gain 11.27
2nd River Meas	32.57	.....	
Pioneer Ditch	.....	1.75	
Josh Ames Ditch	.....	1.38	
Lake Canal	.....	1.50	
Arthur Canal	.....	1.50	
Box Elder Ditch	.....	6.56	
Cache la Poudre No. 2	.....	55.18	
3rd River Meas	.....	1.50	Below No. 2 Canal
	32.57	69.36	Gain of 36.79
3rd River Meas	1.50	.....	
Whitney Ditch	.....	2.29	
Eaton Ditch	.....	0.30	
Greeley No. 3	.....	9.83	
Ogilvy Canal	.....	30.10	
4th River Canal	.....	3.48	Below Ogilvy Canal
	1.50	46.00	Gain 44.50
4th River Meas	3.48	.....	
5th River Meas	.....	9.89	Near mouth
	3.48	9.89	Gain 6.41
	.....	.....	Total Gain 98.97

*All measurements are given in cubic feet per second.

CACHE LA POUDRE RIVER

Measurement No. 3. Made October 16-18, 1890.

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
1st River Meas	80.78	.....	At gaging station
Canon Ditch	.....	0.97	
Larimer County Canal	.....	2.85	
Jackson Ditch	.....	4.12	
Little Cache la Poudre Canal	.....	4.02	
Taylor and Gill Ditch	.....	0.70	
Fort Collins Waterworks	.....	0.38	
Larimer & Weld Canal	.....	16.40	
2nd River Meas	.....	77.12	Below Larimer & Weld Dam
	80.78	106.56	Gain of 25.78
2nd River Meas	77.12	.....	
Riddle Ditch	.....	0.11	
Josh Ames Ditch	.....	1.00	
The Lake Canal	.....	1.04	
Coy Ditch	.....	0.97	
Box Elder Ditch	.....	5.73	
Cache la Poudre Canal No. 2	.....	79.87	
3rd River Meas	.....	2.06	Below No. 2 Canal
	77.12	90.78	Gain of 13.66
3rd River Meas.	2.06	.....	
4th River Meas	.....	19.31	Above Greeley (pump house)
	2.06	19.31	Gain of 17.26
4th River Meas	19.31	.....	
5th River Meas	.....	40.18	At Ogilvy Ditch
	19.31	40.18	Gain of 20.87
5th River Meas	40.18	.....	
Oglivy Ditch	.....	30.67	
6th River Meas	.....	32.73	Near mouth
	40.18	63.40	Gain of 23.22
	.....	.....	Total gain of 100.79

CACHE LA POUDRE RIVER

Measurement No. 4. Made October 28-30, 1891.

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
1st River Meas	97.58	.....	At gaging station
Canon Dith	.....	0.03	
Pleasant Valley & Lake Canal	.....	6.99	
Jackson Ditch	.....	0.00	
Little Cache la Poudre Ditch	.....	5.21	
Taylor and Gill Ditch	.....	2.16	
Larimer County Canal	.....	1.00	
New Mercer Canal	.....	0.00	
Fort Collins Waterworks	.....	0.30	
Larimer County No. 2 Canal	.....	0.64	
Arthur Ditch	.....	1.82	
Larimer & Weld Canal	.....	43.30	
2nd River Meas	.....	54.39	Below Larimer & Weld Canal
	97.58	115.84	Gain of 18.26
2nd River Meas	54.39	.....	
Pioneer Ditch	.....	0.00	
Josh Ames Ditch	.....	0.50	
The Lake Canal	.....	0.24	
Coy Ditch	.....	1.60	
Box Elder Ditch	.....	3.78	
Cache la Poudre No. 2 Canal	.....	0.50	
3rd River Meas	.....	56.48	At head of No. 2
	54.39	63.10	Gain of 8.71
3rd River Meas	56.48	.....	
Whitney Ditch	.....	0.00	
Eaton Ditch	.....	1.42	
Jones Ditch	.....	(8.13)	
Greeley No. 3 Canal	.....	32.24	
Boyd and Freeman Ditch	.....	2.42	Near pump house
4th River Meas	.....	15.30	Loss of 5.10
	56.48	51.38	
4th River Meas.	15.30	.....	
5th River Meas.	.....	53.56	Below Greeley
	15.30	53.56	Gain of 38.26

CACHE LA POUDRE RIVER

Measurement No. 4. Made October 28-30, 1891 (Continued).

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
5th River Meas	15.30	.....	
Ogilvy Ditch	.....	18.12	
Waste	5.88	.....	
6th River Meas	.....	60.72	Near mouth
	59.44	78.84	Gain of 19.40
	.....	.....	Total gain of 79.53

CACHE LA POUDRE RIVER

Measurement No. 5. Made March 10-12, 1892.

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
March 10.			
1st River Meas	65.02	.....	At gaging station
Lew Stone Creek	0.50	.....	
Canon Ditch	.....	0.00	
Pleasant Valley Canal	.....	4.38	
Jackson Ditch	.....	2.07	
Little Cache la Poudre Ditch	.....	1.08	
Taylor and Gill Ditch	.....	0.59	
Fort Collins Waterworks	.....	0.22	
Larimer County Ditch	.....	0.00	
Larimer County No. 2	.....	10.10	
New Mercer	.....	0.28	
March 11.			
Larimer & Weld Canal	.....	0.72	
Pioneer Ditch	.....	0.00	
Lake Canal	.....	0.00	
Coy Ditch	.....	(2.47)	
Dry Creek Ditch	(1.25)	.....	
Ames Slough	(7.00)	.....	
Cooper Slough	(2.43)	.....	
Box Elder Creek	(2.16)	.....	
Spring Creek	(6.04)	.....	
Box Elder Ditch	.....	0.75	
Fossil Creek	(2.72)	.....	
Near Whitney Ditch	(0.81)	.....	
March 12.			
Eaton Ditch	.....	0.10	
Whitney Ditch	.....	0.00	
2nd River Meas.	.....	102.54	Near Eaton Ditch
	65.52	122.83	Gain of 57.31
2nd River Meas	102.54	.....	
Near Fulton Bridge	1.15	.....	
Inflow above Briggs	(2.25)	.....	
Inflow near Whitney Ditch	.....	.....	
Jones Ditch	.....	0.00	
Inflow opposite Jones'	(1.35)	.....	
Inflow near Fletcher Ditch	(0.75)	.....	
Greeley Canal No. 3	.....	0.00	
Inflow	(0.90)	.....	
3rd River Meas	.....	132.75	Near pump house
	103.69	132.75	Gain of 29.06
3rd River Meas	132.75	.....	
Ogilvy Ditch	.....	1.00	
4th River Meas	.....	141.49	
	132.75	142.49	Gain of 9.74
	.....	.....	Total gain of 96.11

CACHE LA POUDRE RIVER

Measurement No. 6. Made October 5-8, 1892.

PLACE OF MEASUREMENT—	Inflow and River	Take Out	NOTES—
October 5.			
1st River Meas.	62.92	.....	At gaging station
Canon Ditch	.....	0.03	
Jackson Ditch	.....	4.51	
Little Cache la Poudre Ditch	.....	0.18	
Taylor and Gill Ditch (est.)	.....	6.25	
Larimer County Ditch	.....	0.00	
New Mercer Canal	.....	0.35	
Fort Collins Waterworks	.....	0.28	
Larimer County No. 2 Canal	.....	0.36	
2nd River Meas.	.....	66.33	100 yds above Larimer & Weld Canal
	62.92	78.29	Gain of 15.37
2nd River Meas.	66.33	.....	
Larimer and Weld Canal	.....	58.86	
3rd River Meas	.....	5.95	Below Larimer & Weld Canal
	66.33	64.81	Gain of 47.99
October 6.			
3rd River Meas.	5.95	.....	
Pioneer Ditch	.....	0.01	Near Inverness farm
Josh Ames Ditch	.....	0.89	
The Lake Ditch	.....	2.00	
Coy Ditch	.....	(0.74)	
4th River Meas.	.....	52.56	Below Lindell Mills
	72.28	120.27	Gain of 27.22
4th River Meas.	52.56	.....	
Dry Ditch	(0.95)	.....	
Ames Slough	(2.56)	.....	
Cooper Slough	(2.63)	.....	
Box Elder Creek	(2.90)	.....	
Spring Creek	(1.25)	.....	
Box Elder Ditch	.....	2.14	
5th River Meas.	.....	53.93	Below Strauss Bridge
	52.56	56.07	Gain of 3.51
October 7.			
6th River Meas.	21.03	.....	Below Strauss Bridge
Inflow below Strauss Bridge	(0.02)	.....	
Cache la Poudre No. 2 Canal	.....	1.93	
7th River Meas.	.....	21.65	Below No. 2 Canal
	21.03	23.58	Gain of 2.55
7th River Meas.	21.65	.....	
Fossil Creek	(1.33)	.....	
Whitney Ditch	.....	2.72	
8th River Meas.	.....	24.90	Below Eaton Ditch
	21.65	27.62	Gain of 5.97
8th River Meas.	24.90	.....	
Jones Ditch	.....	0.15	
Greeley No. 3	.....	32.20	
October 8.			
9th River Meas.	.....	14.36	Near Greeley pump house
	24.90	46.71	Gain of 21.81
9th River Meas.	14.36	.....	
Ogilvy Ditch	.....	29.14	
10th River Meas.	.....	2.53	Below Ogilvy dam
	14.36	31.67	Gain of 17.31
10th River Meas.	2.53	.....	
11th River Meas.	.....	31.69	At mouth
	2.53	31.69	Gain of 29.16
	.....	.....	Total gain of 145.19

CACHE LA POUDRE RIVER

Measurement No. 7. Made November 9-11, 1893.

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
November 9.			
1st River Meas.	52.47	.....	At gaging station
Canon Ditch	.....	0.48	
Pleasant Valley Canal	.....	4.69	
Larimer County Ditch	.....	0.00	
Jackson Ditch	.....	4.83	
Little Cache la Poudre Ditch	.....	0.23	
Taylor and Gill Ditch	.....	1.41	
New Mercer Ditch	.....	0.00	
Fort Collins Waterworks (est.)	.....	0.60	
Larimer County No. 2 Canal	.....	1.87	
Arthur Irrigating Canal	.....	0.00	
November 10.			
Larimer and Weld Canal	.....	(0.54)	
2nd River Meas.	.....	69.61	Below Larimer & Weld Canal
	52.47	83.72	Gain of 31.25.
2nd River Meas.	69.61	.....	
Pioneer Ditch	.....	0.45	
Josh Ames Ditch	.....	1.39	
Lake Canal	.....	0.00	
Coy Ditch	.....	2.00	
3rd River Meas.	.....	72.48	Below Hottel Mill
	69.61	76.32	Gain of 6.71
3rd River Meas.	72.48	.....	
No. 2 Feeder	.....	6.80	
Spring Creek	(0.68)	.....	
Ames Slough	(5.00)	.....	
Cooper Slough	(1.50)	.....	
Box Elder Creek	(3.70)	.....	
Box Elder Ditch	.....	1.04	
Cache la Poudre Irrig. Can. No. 2.	.....	60.03	
November 11.			
4th River Meas.	.....	9.84	Below No. 2
	72.48	77.71	Gain of 5.23
4th River Meas.	9.84	.....	
Fossil Creek	(1.35)	.....	
Whitney Ditch	.....	0.08	
Eaton Ditch	.....	0.00	
5th River Meas.	.....	4.95	Below Eaton Ditch
	9.84	5.03	Loss of 4.81
5th River Meas.	4.95	.....	
Jones Ditch	.....	0.19	
Greeley No. 3 Canal	.....	0.00	
Boyd and Freeman Ditch	.....	3.65	
6th River Meas.	.....	20.32	North of pump house
	4.95	24.16	Gain of 19.21
6th River Meas.	20.32	.....	
Ogilvy Ditch	.....	0.65	
7th River Meas.	.....	43.26	Below Ogilvy dam
	20.32	43.91	Gain of 23.59
7th River Meas.	43.26	.....	
8th River Meas.	.....	60.76	At the mouth
	43.26	60.76	Gain of 17.50
	.....	.....	Total gain of 98.68

CACHE LA POUDRE RIVER

Measurement No. 8. Made March 13-15, 1894.

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
March 13.			
1st River Meas.	99.21	.....	At gaging station
Canon Ditch	.....	0.03	
Pleasant Valley and Lake Canal.	.....	4.70	
	.....	12.60	
Larimer County Canal	.....	0.25	
Jackson Ditch	.....	6.17	
New Mercer Canal	.....	0.00	
Fort Collins Waterworks	.....	0.60	
Little Cache la Poudre Canal	.....	0.53	
Taylor and Gill Ditch	.....	5.22	
Chamberlain Ditch	.....	(2.00)	
Larimer County No. 2 Canal	.....	0.57	
Arthur Irrigating Canal	.....	0.00	
Larimer and Weld Canal	.....	25.30	
Riddle Ditch	.....	0.33	
2nd River Meas.	.....	49.18	Below Larimer & Weld Canal
	99.21	100.78	Gain of 1.57
2nd River Meas.	49.18	.....	
March 14.			
Pioneer Ditch	.....	.....	
Ames Ditch	.....	1.28	
Lake Canal	.....	0.16	
Coy Ditch	.....	0.00	
No. 2 Feeder	.....	49.70	
3rd River Meas.	.....	1.49	Below No. 2 Feeder
	49.18	52.63	Gain of 3.45
3rd River Meas.	1.49	.....	
Spring Creek	(2.78)	.....	
Ames Slough	(0.22)	.....	
Cooper Slough	(1.21)	.....	
Box Elder Ditch	.....	0.11	
Box Elder Creek	(0.24)	.....	
No. 2 Feeder	.....	(23.90	North of Timnath
March 15.			
Cache la Poudre No. 2 Canal	.....	1.43	
4th River Meas.	.....	27.17	Below No. 2
	1.49	28.71	Gain of 37.22
4th River Meas.	27.17	.....	
Fossil Creek	(0.19)	.....	
Eaton Ditch	.....	0.08	
5th River Meas.	.....	20.44	Below Eaton Ditch
	27.17	20.52	Loss of 6.65
5th River Meas.	20.44	.....	
Jones Ditch	.....	0.00	
Greeley No. 3 Canal	.....	0.12	
Boyd and Freeman Ditch	.....	0.12	
6th River Meas.	20.44	46.46	Near pump house
	20.44	46.70	Gain of 26.26
6th River Meas.	46.46	.....	
Greeley Drain Sewer	.....	(1.47)	
Ogilvy Ditch	.....	0.00	
7th River Meas.	.....	56.51	Below Ogilvy dam
	46.46	56.51	Gain of 10.05
7th River Meas.	56.51	.....	
8th River Meas.	.....	76.93	1-2 mile above mouth
	56.51	76.93	Gain of 20.42
	.....	.....	Total gain of 82.32

CACHE LA POUDRE RIVER

Measurement No. 9. Made August 20-23, 1894.

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
August 20.			
1st River Meas	268.07	.....	At gaging station
Canon Ditch	.....	0.80	
Pleasant Valley & Lake Canal	.....	23.63	
Larimer County Ditch	.....	31.39	
Jackson Ditch	.....	11.17	
New Mercer Canal	.....	3.42	
Fort Collins Waterworks	.....	0.60	
Little Cache la Poudre Canal	.....	7.87	
Taylor and Gill Ditch	.....	4.46	
Chamberlain Ditch	.....	4.53	
Larimer County No. 2 Canal	.....	0.00	
Arthur Irrigating Canal	.....	0.00	
Larimer and Weld Canal	.....	27.80	
2nd River Meas	.....	153.17	Below Larimer & Weld Canal
	268.07	268.84	Gain of 0.77
2nd River Meas	153.17	.....	
August 21.			
Pioneer Ditch	.....	0.16	
Ames Ditch	.....	2.56	
Lake Canal	.....	0.13	
Coy Ditch	.....	16.30	
3rd River Meas	.....	151.61	At Coys farm
	153.17	170.76	Gain of 17.59
3rd River Meas	151.61	.....	
Coy Ditch, waste	0.82	.....	
Coy Slough	(1.70)	.....	
Horner Supply	.....	6.39	
Chaffee Ditch	.....	2.77	
Pioneer, waste)	9.51	.....	
Horner Supply, waste)			
Spring Creek (Aug. 22)	(5.56)	.....	
Ames Slough	(0.90)	.....	
Emigh Drain Ditch	.....	(3.00)	
Cuthbertson (Aug. 22)	(0.51)	.....	
Cooper Slough (into Emigh Drain)	(0.50)	.....	
Box Elder Creek	(2.52)	.....	
Box Elder Ditch (Aug. 22)	.....	7.93	
4th River Meas	.....	141.52	At Strauss Bridge
	161.94	158.61	Loss of 3.33
August 22.			
5th River Meas	139.61	.....	At Strauss Bridge
Cache la Poudre No. 2 Canal	.....	74.27	
6th River Meas	.....	68.46	Below No. 2
	139.61	142.73	Gain of 3.12
6th River Meas	68.46	.....	
Fossil Creek	(4.58)	.....	
Whitney Ditch	.....	19.98	
Eaton Ditch	.....	10.90	
7th River Meas	.....	49.44	Below Eaton Ditch
	68.46	80.32	Gain of 11.86
7th River Meas	49.44	.....	
Jones Ditch	.....	5.28	
August 23.			
Greeley No. 3 Canal	.....	56.55	
8th River Meas	.....	0.29	Below No. 3
	49.44	62.12	Gain of 12.68
8th River Meas	0.29	.....	
Boyd and Freeman Ditch	.....	3.30	
9th River Meas	.....	18.13	Near pump house
	0.29	21.43	Gain of 21.14
9th River Meas	18.13	.....	
Greeley Drain Sewer	.....	(3.51)	
Ogilvy Ditch	.....	38.39	
Camp Bros. River Supply	.....	1.17	
Camp Bros. Solugh Supply	.....	(2.16)	
10th River Meas	.....	4.93	Below C. Bros. river supply
	18.13	44.49	Gain of 26.36
10th River Meas	4.93	.....	
11th River Meas.	.....	32.90	1-2 mile above mouth
	4.93	32.90	Gain of 27.97
	.....	.....	Total gain of 118.16

CACHE LA POUDRE RIVER

Measurement No. 10. Made October 9-14, 1895.

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
November 9.			
1st River Meas.	66.47	.....	At gaging station
Cauon Canal	.....	0.10	
Pleasant Valley & Lake Canal	.....	21.23	
Inflow from Canon Canal	0.13	.....	
Larimer County Canal	.....	0.00	
Jackson Ditch	.....	0.00	
2nd River Meas.	.....	63.53	150 yards above Mercer Ditch
	66.60	84.86	Gain of 18.26
2nd River Meas.	63.53	.....	
New Mercer Ditch	.....	0.00	
Little Cache la Loudre Ditch	.....	6.67	
Taylor and Gill Ditch	.....	4.55	
Chamberlain Ditch	.....	.....	
Larimer County No. 2 Canal	.....	0.50	
Fort Collins Waterworks (est.)	.....	0.75	
Inflow waste from T. & Gill Ditch.	3.63	.....	
Inflow waste from G. & Gill Ditch.	0.93	.....	
Arthur Ditch	.....	2.88	
3rd River Meas.	.....	54.10	Above Larimer & Weld
	68.09	69.45	Gain of 1.36
October 10.			
4th River Meas.	0.55	.....	Below Larimer & Weld
Pioneer Ditch	.....	0.28	
Seepage Ditch	(0.50)	.....	
Ames Ditch	.....	0.21	
Lake Canal	.....	3.06	
City Sewer	.....	.....	
College Sewer	.....	.....	
Coy Ditch	.....	0.01	
No. 2 Res. Supply Canal	.....	0.18	
5th River Meas.	.....	26.44	Below No. 2 Res. Supply Canal
	0.55	30.18	Gain of 29.63
5th River Meas.	26.44	.....	
Dry Creek	(1.71)	....	
Ames Slough	(0.96)	.....	
Emigh Drain	[3.68]	.....	
Cooper Slough	[0.53]	.....	
Box Elder Creek	(3.76)	.....	
Spring Creek	(6.12)	.....	
Box Elder Ditch	.....	0.00	
Seepage Ditch from Spring Creek.	[0.63]	.....	
Side Hill Ditch from Spring Creek.	[2.53]	.....	
Ditch from Cooper Slough	(1.15)	.....	
6th River Meas.	.....	32.53	At Strauss Bridge
	26.44	32.53	Gain of 6.09
October 14.			
7th River Meas.	26.24	.....	At Strauss Bridge
Cache la Poudre No. 2 Canal	.....	0.02	
8th River Meas.	.....	33.73	Below Cache la Poudre No. 2 Canal
	26.24	33.75	Gain of 7.51
8th River Meas.	33.73	.....	
Fossil Creek	(7.63)	.....	
Whitney Ditch	.....	5.72	
Eaton Ditch	.....	8.09	
9th River Meas.	.....	26.91	Below Eaton Canal
	33.73	40.72	Gain of 6.99
9th River Meas.	26.91	.....	
Seepage Ditch	(1.34)	.....	
Jones Ditch	.....	1.39	
Greeley No. 3 Ditch (Oct. 15)	.....	13.10	
10th River Meas.	.....	19.77	Below Greeley No. 3 Ditch
	26.91	34.26	Gain of 7.35
10th River Meas.	19.77	.....	
October 15.			
Greeley No. 3	.....	0.61	
11th River Meas.	.....	32.26	Below Greeley No. 3 Ditch
	19.77	32.87	Gain of 13.10

CACHE LA POUDRE RIVER

Measurement No. 10, Made October 9-14, 1895 (Continued).

PLACE OF MEASUREMENT—	River and Inflow	Out Take	NOTES—
11th River Meas..................	32.26	.....	
Waste into No. 3	[1.86]	.....	
Waste into No. 3	[0.56]	.....	
Boyd and Freeman Ditch........	.....	2.77	
12th River Meas..................	.....	62.73	At pump house
	32.26	65.50	Gain of 33.24
12th River Meas..................	62.73	.....	
Mill Power Canal	(5.40)	(4.05)	
Ogilvy Ditch	.....	0.00	
13th River Meas..................	.....	70.47	Below Ogilvy Dam
	62.73	70.47	Gain of 7.74
13th River Meas..................	70.47	.....	
Camp Ditch	.....	0.00	
14th River Meas..................	.....	116.84	1-2 mile above mouth
	70.47	116.84	Gain of 46.37
	.....	.....	Total Gain of 177.64

CACHE LA POUDRE RIVER

Measurement No. 11. Made November 11-14, 1896.

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Nov.					
11 11:15 P.M.	1st River Measurem't	33.5°	127.72	....	Gage ht., 0.83 at weir
11 12:40 P.M.	Canon Canal	34°	....	0.60	Gage ht., 0.55
11 1:30 P.M.	Pleasant & Lake	34°	....	18.34	
11 1:30 P.M.	Pleasant Valley &	.....	0.03	....	Leak from flume
	Lake Canal	35°	....	51.07	Gage ht., 0.98. Ditch drawing 0.8 from 11 a. m. to 9 p. m. and at night about 0.4 over rating flume
11 —— P.M.	Inflow fr Canon C.				
11 2:05 P.M.	Larimer Co. Canal				
11 2:50 P.M.	Jackson Ditch ...	38°	....	8.16	
11 3:30 P.M.	2nd River Measurem't	.....	....	46.66	
		.....	127.75	125.83	Loss 2.92
Nov.					
11 3:30 P.M.	2nd River Measurem't	38.5°	46.66	....	At Tobe Miller's field. Same place as in 1895
11 —— P.M.	New Mercer Ditch	.....	....	....	Fort Collins water running in upper part of ditch not measured
11 —— P.M.	City Water Works	.....	....	0.50	Estimated
11 4:30 P.M.	Little Cache la P D	38°	....	(2.09)	Closed down after meaurem't
11 —— P.M.	Taylor and Gill D	.....	....	1.56	
11 —— P.M.	Chamberlin Ditch.	.....	....	....	
11 —— P.M.	Lar. Co. No. 2 Cnl	.....	....	0.00	
12 —— A.M.	Arthur Canal	.....	....	0.00	
12 10:40 A.M.	Larimer & Weld C	.....	....	0.00	Below headgate
12 11:20 A.M.	Riddle Ditch	.....	....	5.61	Larimer & Weld Canal taking all water from 4 p. m. to 4 a. m. This renders gain or loss in this section uncertain
12 10:20 A.M.	3rd River Measurem't	.....	....	1.31	
		.....	46.66	99.82	River changing
Nov.					
12 10:20 A.M.	3rd River Measurem't	32.5°	99.82	....	Below Larimer & Weld dam
12 11:55 A.M.	Pioneer Ditch	.....	....	0.00	Too small to measure
12 11:50 A.M.	Inflow Seepage ...	48°	(0.22)	....	
12 —— A.M.	Josh Ames Ditch..	.....	....	0.01	Very largely from melting ice
12 —— A.M.	Lake Canal	.....	....	0.00	
12 12:30 P.M.	J. G. Coy Ditch...	34°	....	1.01	11.62 ft. taken from river; most wasting near head; 1.01 ft. carried about 2 miles and wastes to river
12 1:50 P.M.	Inlet of No. 2 Res.	38°	....	1.06	Running back into river
12 2:10 P.M.	Chaffee Ditch	.....	....	1.60	Running back into river
12 2:30 P.M.	4th River Measurem't	.....	....	91.69	
		.....	99.82	95.36	Loss 4.66

CACHE LA POUDRE RIVER

Measurement No. 11, Made November 11-14, 1896 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Nov.					
12 2:30 P.M.	4th River Measurem't	.....	91.69	....	At head of Cache la Poudre No. 2 Res. Supply ditch
12 3:25 P.M.	No. 2 Res. Inlet..	.....	1.06	....	
12 3:25 P.M.	Dry Creek	39°	2.44	....	Seepage intercepted above junction with No. 2 Supply, both returning to river
12 —— P.M.	Chaffee Ditch	.....	1.60	....	Not measured at inflow
12 3:50 P.M.	Ames Slough	.....	(0.52)	....	Seepage
12 4:00 P.M.	Cooper Slough ...	.....	(1.91)	....	Seepage
12 4:15 P.M.	Boxelder Creek ..	.....	(0.75)	....	Seepage, below Emigh Drain
12 4:25 P.M.	Emigh Drain	47°	....	2.14	Intercepted Cooper Slough and some additional seepage
12 4:50 P.M.	No. 2 Res. Feeder.	36°	....	....	3.35 ft. intercepted seepage not reaching river
13 10:35 A.M.	Spring Creek	46°	(4.97)	....	Seepage
13 11:05 A.M.	Seep. in Sher. field	41°	(0.81)	....	Seepage
13 11:15 A.M.	Boxelder Ditch ...	36°	....	9.49	
13 11:45 A.M.	5th River Measurem't	.....	....	79.63	
		.....	102.91	91.28	Loss 22.87
Nov.					
13 11:45 A.M.	5th River Measurem't	38°	79.63	....	The river had fallen during night 0.10 ft.
13 —— A.M.	Seepage from Res..	.....	....	1.71	
13 1:10 P.M.	Greeley No. 2 Dtch	36.5°	....	84.63	
13 —— P.M.	6th River Measurem't	.....	....	9.70	
		.....	79.63	96.04	Gain 16.41
Nov.					
13 —— P.M.	6th River Measurem't	.....	9.70	....	Below No. 2 Canal
13 2:50 P.M.	Fossil Creek	35°	(3.76)	....	Seepage
13 4:30 P.M.	Whitney Ditch ...	34°	....	1.77	About 450 ft. below headgate
13 —— P.M.	Eaton Canal	.....	....	0.02	
13 3:55 P.M.	7th River Measurem't	.....	....	18.33	
		.....	13.46	20.12	Gain 6.66
Nov.					
13 3:55 P.M.	7th River Measurem't	37°	18.33	....	Below Eaton Cnl about 250 ft
14 7:55 A.M.	Jones Ditch	33.5°	....	0.84	
14 10:20 A.M.	Greeley No. 3....	34°	....	23.13	Some wasting back below 0.93 ft. runs into No. 3 Canal from Loveland & Greeley Canal; also measured canal below waste Nov. 10, 10 a. m., 17.31 ft.
14 10:00 A.M.	8th River Measurem't	.....	....	0.13	
		.....	18.33	24.10	Gain 5.77
Nov.					
14 10:00 A.M.	8th River Measurem't	38°	0.13	....	Below dam of Greeley No. 3 Canal
14 11:50 A.M.	Waste from Greeley No. 3......	.....	8.67	....	
14 12:00 P.M.	Boyd & Freemn D	35°	....	1.18	Just below head
14 1:00 P.M.	Seepage inflow ...	.....	(0.46)	....	About ½ mile west of Greeley
14 1:10 P.M.	9th River Measurem't	.....	....	24.26	
		.....	9.26	25.44	Gain 16.18
Nov.					
14 1:10 P.M.	9th River Measurem't	45.5°	24.26	....	North of pump house nr Grly
14 2:10 P.M.	Mill Power Canal.	.....	....	1.26	At headgate
15 8:15 A.M.	Mill Power Canal.	33.5°	1.13	....	Running into river
15 8:30 A.M.	Greeley Drain Swr	.....	....	2.01	2.01 intercepted seepage, not running into river
14 2:30 P.M.	Ogilvy Ditch	.....	....	0.26	
14 3:00 P.M.	10th River Measurm't	.....	....	49.39	
		.....	25.39	52.92	Gain 27.53
Nov.					
14 3:00 P.M.	10th River Measurm't	55°	49.39	....	Below Ogilvy dam
14 —— P.M.	Camp Bros. Ditch.	.....	....	0.00	
14 —— P.M.	Inflow	39°	6.84	78.21	Waste from L. & G.
14 —— P.M.	11th River Measurm't	.....	....	....	About ½ mile above mouth
		.....	....	....	Gain 21.98

CACHE LA POUDRE RIVER.

Measurement No. 12, Made October 7-14, 1897.

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Oct.					
7 10:45 A.M.	1st River Measurem't.	58°	107.39	....	At gaging station in Canon Gage ht. 0.74 ft.
7 11:25 A.M.	Canon Ditch	66°	....	1.00	
7 12:00 M.	Pleas. V. & L. Can	59°	....	0.46	
7 12:45 P.M.	Larimer Co. Canal	60.3°	....	23.28	
7 —— P.M.	Henderson Ditch..	.....	....	0.00	
7 2:00 P.M.	Jackson Ditch ...	61.5°	....	0.59	200 yds above road crossing
7 2:40 P.M.	New Mercer Ditch.	60.8°	....	0.26	
7 3:00 P.M.	City Waterworks..	61°	....	37.51	Used chiefly for power
7 —— P.M.	2nd River Measurem't	61°	....	45.68	
		.....	107.39	108.78	Gain 1.39
Oct.					
7 3:50 P.M.	2nd River Measurem't	61°	45.68	....	Below City Waterworks
7 4:00 P.M.	Little Cache la P.	61°	....	0.91	
7 4:15 P.M.	Taylor & G. Ditch.	61°	....	8.09	
7 4:30 P.M.	Waterworks waste.	61°	32.62	....	Measured at waterworks about 0.55 ft. was being pumped to city, a loss of 4.34 ft. between riv. and waterworks, a distance of 4100 (4143) ft.
7 4:40 P.M.	Seep. below W'w'ks & New Mer. Ditch	59.5°	(1.78)	....	Seepage from City Can. & New Mercer
7 5:00 P.M.	Lar. Co. No. 2 Can	.....	....	0.47	
7 5:00 P.M.	Chamberlin Ditch.	.....	....	2.68	Measured at flume over Larimer Co. No. 2
7 5:40 P.M.	Larimer & W. Can	.....	....	12.96	
7 —— P.M.	Riddle Ditch	61°	....	0.50	
8 9:00 A.M.	Arthur Ditch	53°	....	0.88	
	3rd River Measurem't	53°	78.30	70.20	
		.....	....	96.69	Gain 18.39
Oct.					
8 10:00 A.M.	3rd River Measurem't	53°	70.20	....	Below Larimer & W. Dam, meas. suspended on account of storm
12 9:00 A.M.	At same place....	47°	65.22	....	Water about ⅛ in. lower than on the 8th
12 —— A.M.	Pioneer Ditch	.....	....	0.00	
12 —— A.M.	Inflow below Pion'r	.....	0.17	....	Largely waste from Riddle D.
12 10:40 A.M.	Hottel Mill Race.	50°	....	49.10	Near where taken from river
12 11:00 A.M.	Ames Ditch	52°	....	1.89	
12 —— A.M.	Lake Canal	.....	....	0.14	
12 11:20 A.M.	J. G. Coy Ditch...	57°	....	....	6.70 sec ft not used, most wastes into riv about ½ m. below 0.68 ft wastes about 1½ m. below
12 11:40 A.M.	Hottel Mill Race.	50.2°	53.58	....	Near Mill about 1½ m. below upper measurement
12 2:00 P.M.	Inlet No. 2 Res...	54°	....	0.87	
12 2:20 P.M.	Chaffee Ditch	57.5°	....	0.33	
	4th River Measurem't	.....	....	62.68	
		.....	118.97	115.01	Loss 3.96 feet
Oct.					
12 3:00 P.M.	4th River Measurem't.	54°	62.68	....	Below No. 2 Res. Supply
12 3:30 P.M.	Dry Cr'k & No 2 S.	56°	6.34	....	Seep. meas. near Junc. about ½ m. from river
12 —— P.M.	Ames Slough	.....	(0.25)	....	Seep. where it runs thro' box under No. 2 Res. Sup Ditch
12 3:55 P.M.	Cooper Slough ...	57.5°	(0.63)	....	Seep runn'g into Emigh drain
12 4:00 P.M.	Emigh Drain	58.8°	....	....	Seepage intercepted 0.40
12 4:20 P.M.	Box Elder Creek.	56°	(3.71)	....	Seepage water
12 —— P.M.	No. 2 Res. Supply.	.....	....	0.00	At road cross'g near gravey'd
13 8:35 A.M.	Spring Creek	51°	(3.55)	....	Seepage meas. about ¼ mile from river
13 9:05 A.M.	Box Elder Ditch..	49°8	....	1.35	
12 5:40 P.M.	Inflow near Strauss B.	.....	(0.97)	....	Seepage water
	5th River Measurem't.	.....	....	73.88	
		.....	69.02	75.23	Gain 6.21
Oct.					
12 5:10 P.M.	5th River Measurem't.	.....	73.88	....	Ab't 150 yd below Strauss B.
13 9:38 A.M.	At same place....	51°	31.70	....	Ab't 50 rods below Strauss B.
13 10:37 A.M.	Greeley No. 2 Can.	.....	....	0.14	At rating Weir
	6th River Measurem't	.....	....	41.98	
		.....	31.70	42.12	Gain 10.42

CACHE LA POUDRE RIVER.

Measurement No. 12, Made October 7-14, 1897 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Oct.					
13 11:06 A.M.	6th River Measurem't.	58°	41.98	....	Ab't 80 rods below No. 2 dam
13 12:04 P.M.	Fossil Creek	56°	(6.04)	....	At bridge near mouth, seep
13 12:20 P.M.	Inflow	62.7°	(1.48)	....	From seepage No. 2 Canal
13 12:50 P.M.	Whitney Ditch ...	57°	....	6.46	About 300 yds below head
13 1:30 P.M.	Eaton Ditch	.....	....	0.70	About 100 ft below head gate
	7th River Measurem't	.....	....	48.12	
		.....	49.50	55.28	Gain 5.78
Oct.					
13 1:50 P.M.	7th River Measurem't.	58°	48.12	....	Below headgate about 200 ft. same place as in '96
13 3:37 P.M.	W. R. Jones Ditch	57°	....	0.51	
13 4:35 P.M.	Greeley No. 3.....	.....	....	59.97	At rating flume
	8th River Measurem't.	.....	....	23.36	
		.....	48.12	83.84	Gain of 35.72 feet
Oct.					
13 5:15 P.M.	8th River Measurem't	56°2	23.36	....	Ab't 75ft below dam No 3 can
14 8:50 A.M.	Wastew'y No. 3 D.	49°5	17.99	....	Wasteing into river
14 9:07 A.M.	Greeley No. 3....	.....	....	....	32.64 ft passing down canal below wasteway
14 9:20 A.M.	Boyd & Freeman..	48°5	....	0.73	
13 —— A.M.	Inf. w. Greeley p.h.	48°5	(2.08)	....	Seepage
14 —— A.M.	Mill Race	52°8	....	5.17	At headgate
	9th River Measurem't.	.....	....	34.60	
		.....	41.35	40.50	Some change in stream during night probable. Loss 0.85
Oct.					
14 10:35 A.M.	9th River Measurem't.	52.8°	34.60	....	200 ft below head Mill Race
14 11:15 A.M.	Mill Race outlet..	52.5°	5.04	....	Running back into river
14 11:30 A.M.	Greeley Drain Sew.	.....	....	4.21	Gaged where flume crosses river 4.21 ft.
14 —— A.M.	Ogilvy Ditch	.....	....	....	Standing water
	10th River Measuremt	.....	....	66.21	
		.....	39.64	70.42	Gain 30.78
Oct.					
14 1:30 P.M.	10th River Measurem't	57.5°	66.21	....	Above Camp Bros. Ditch
14 —— P.M.	Camp Bros. Ditch.	.....	....	0.00	
14 2:20 P.M.	Waste from No. 3.	57°	7.70	....	Near Greeley cemetery
	11th River Measurem't	.....	....	97.49	About ¼ m. above mouth
		.....	73.91	97.49	Gain 23.58
					Total Gain 127.46

CACHE LA POUDRE RIVER.

Measurement No. 13, Made August 9-12, 1898.

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
9 11:10 P.M.	1st River Measurem't	69°	174.18	....	At Weir in Canon, gage ht.
9 2:00 P.M.	Canon Ditch	73°	....	0.94	At rating flume 0.94 ft.
9 2:30 P.M.	High Line Canal..	70°	....	29.51	At head
9 4:00 P.M.	Larimer Co. Canal.	72°	....	80.77	At rating flume, gage ht. 1.02
9 4:10 P.M.	Waste water	74°	0.30	....	Near Mr. Shipp's
9 4:40 P.M.	Jackson Ditch ...	76°	....	11.95	
9 5:10 P.M.	New Mercer	75.5°	....	28.66	At headgate
	City Waterw'ks D.	.....	....	0.00	Work on canal, drawing wat. thro' Mercer for use city
	2nd River Measurem't	78°	....	14.89	Below New Mercer ditch
		.....	174.48	166.72	Apparent loss of 7.76 cu. ft.
Aug.					
9 5:40 P.M.	2nd River Measurem't	75.5°	14.89	....	Below head New Mer. Ditch
9 6:00 P.M.	Little Cache la P.	74°	....	0.53	At headgate
9 6:10 P.M.	Taylor & G. Ditch.	73°	....	6.44	At headgate
9 6:45 P.M.	Chamberlin Ditch.	75°	....	2.49	
	3rd River Measurem't	76°	....	5.84	Below La Porte bridge
		.....	14.89	15.30	Gain 0.41 cu. ft.

CACHE LA POUDRE RIVER.

Measurement No. 13, Made August 9-12, 1898 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
9 6:35 P.M.	3rd River Measurem't	76°	5.84	....	Below La Porte bridge
10 10:00 A.M.	At same place....	68°	6.67	....	Below La Porte bridge
10 9:15 A.M.	N. Mer. below p.h.	63°	....	....	6.05 ft going down ditch below pump house
10 9:40 A.M.	Waterworks waste.	68°	23.09	....	
10 9:45 A.M.	Seep. below Wat'ks and New Mercer..	68°	(.96)	....	
10 —— A.M.	Lar. Co. No. 2...	.....	....	0.00	
10 11:35 A.M.	Arthur Ditch	68°	....	1.88	Near Headgate
10 11:00 A.M.	Larimer & W. Can.	67°	....	16.48	At rating flume gage ht. 0.35
10 11:05 A.M.	Riddle Ditch	67°	....	1.87	
10 11:30 A.M.	4th River Measurem't	68°	....	18.28	Below Larimer & Weld dam
		.....	29.76	38.51	Gain 8.75 cu. ft.
Aug.					
10 11:30 A.M.	4th River Measurem't	68°	18.28	....	Below Larimer & Weld Dam
10 12:15 P.M.	Pioneer Ditch	73°	....	11.96	
10 2:10 P.M.	Mill Race	81°	....	2.00	Not wasting
10 2:20 P.M.	Josh Ames Ditch..	83°	....	5.37	
10 2:35 P.M.	Lake Canal	85°	....	1.17	
10 2:50 P.M.	Mille Race at Mill.	87°	1.19	....	
10 3:10 P.M.	J. G. Coy Ditch..	84°	....	5.17	.05 cu. ft. running back at slough near farm
10 3:50 P.M.	No. 2 Res. Sup. D.	.....	....	1.37	At head gate
10 —— P.M.	Chaffee Ditch	.....	....	0.00	
	5th River Measurem't	.....	....	5.80	
		.....	19.47	32.84	Gain 13.37 cu. ft.
Aug.					
	5th River Measurem't	78°	5.80	....	Below Chaffee Ditch
10 4:30 P.M.	Waste running riv.	76°	9.51	....	0.55 seepage and probably most of the rest except 1.37 ft from rived by No. 2 Sup.
10 5:00 P.M.	Ames Slough	71°	(0.30)	....	Seepage
10 5:20 P.M.	Cooper Slough ...	71°	....	....	1.72cu.ft run'g into Emigh D.
10 5:45 P.M.	Box Elder Creek..	65°	....	....	2.63cu.ft run'g into Emigh D.
10 5:40 P.M.	Emigh Drain	.....	(6.34)	....	Where it leaves Box Elder intercepted seepage
10 —— P.M.	No. 2 Res. Supply.	.....	....	0.00	
11 9:00 A.M.	Spring Creek	64°	2.78	....	
11 9:25 A.M.	Box Elder Ditch..	64°	....	6.31	At headgate
	6th River Measurem't	73°	....	16.95	
		.....	18.09	23.26	Gain 5.17
Aug.					
10 6:40 P.M.	6th River Measurem't	73°	16.95	....	Below Strauss Bridge
11 10:05 A.M.	At same place....	69°	18.89	....	Below Strauss Bridge
11 10:25 A.M.	Seep inflow 100yds below Strauss B..	72°	(0.28)	....	
11 11:15 A.M.	Greeley No. 2 Can.	.....	....	0.20	At rating flume
	7th River Measurem't	.....	....	19.97	
		.....	18.89	20.17	Gain 1.28
Aug.					
11 11:25 A.M.	7th River Measurem't	78°	19.97	....	¼m. below Greeley No 2 dam
11 12:30 P.M.	Fossil Creek	80°	4.09	....	Near mouth
11 —— P.M.	Wastewy No. 2 Res	.....	0.00	....	
11 2:00 P.M.	Whitney Ditch ...	81°	....	14.52	
11 2:35 P.M.	Eaton Ditch	81°	....	6.48	
	8th River Measurem't	.....	....	7.31	
		.....	24.06	28.31	Gain 4.25
Aug.					
11 2:25 P.M.	8th River Measurem't	81°	7.31	....	Below Eaton Ditch
13 —— P.M.	Inflow s. Windsor.	.....	0.15	....	Seepage
11 4:30 P.M.	Jones Ditch	78°	....	0.52	
11 5:25 P.M.	Greeley No. 3....	82°	....	21.66	At rating weir
	9th River Measurem't	.....	....	0.57	
		.....	7.46	22.75	Gain 15.29
Aug.					
11 6:00 P.M.	9th River Measurem't	78°	0.57	....	Below Geeley No. 3 dam
12 9:25 A.M.	Boyd & Freeman..	68°	....	2.69	
12 10:05 A.M.	Seepage w. pump h	68.5°	1.39	....	
12 10:15 A.M.	Mill Power Canal.	71°	....	5.29	At headgate
	10th River Measuremt	.....	....	13.75	
		.....	1.96	21.73	Gain 19.77

CACHE LA POUDRE RIVER.

Measurement No. 13, Made August 9-12, 1898 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
12 10:30 A.M.	10th River Measuremt	71°	13.75	....	North of pump house
12 11:25 A.M.	Mill Power Canal.	72°	2.43	....	
12 11:40 A.M.	Greeley Drain Sew	58°	....	....	4.57 cu. ft. intercepted seep.
12 12:30 P.M.	Ogilvy Ditch	.....	....	33.47	
12 12:00 P.M.	Camp Bros. Ditch.	72°	....	2.49	
12 12:10 P.M.	Camp Bros. Sl. Sup	72°	....	....	1.63 intercepted seepage
	11th River Measuremt	.....	....	0.00	
		.....	16.18	35.96	Gain 19.78
Aug.					
12 12:00 P.M.	11th River Measuremt	.....	0.00	....	Below Camp Bros. Ditch
12 3:50 P.M.	12th River Measuremt	78°	....	33.37	¼ m. from mouth of river
		.....	0.00	33.37	Gain 33.37 cu. ft.
		.....	....	....	Total Gain 113.68

CACHE LA POUDRE RIVER.

Measurement No. 14, Made September 26-29, 1899.

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
26 9:45 A.M.	1st River Measurem't	59°	107.25	....	At Weir in Canon
26 11:35 A.M.	Canon Canal	59°	....	0.48	Near head
26 —— A.M.	Pleas' V. & L. Can	.....	....	0.00	
26 12:00 P.M.	Larimer Co. Canal.	62°	....	28.35	At rating weir
26 12:50 P.M.	Waste water	66°	0.27	....	At Post Bridge
26 1:45 P.M.	Jackson Ditch ...	66°	....	6.62	Near head
26 2:20 P.M.	New Mercer Ditch.	67°	....	0.10	Below headgate
26 2:30 P.M.	Ft C. Wat'ks Ditch	67°	....	42.21	At head
26 2:50 P.M.	2nd River Measurem't	67°	....	28.91	Below head Ft. C. wat'ks can
		.....	107.52	106.67	Loss 0.85 cu. ft. per sec.
Sept.					
26 2:50 P.M.	2nd River Measurem't	67°	28.91	....	Below head Ft. C. wat'ks can
26 4:10 P.M.	Little Cache la P.	67°	....	0.77	Near head
26 4:20 P.M.	Taylor & G. Ditch.	67°	....	9.17	Near head
26 4:30 P.M.	Chamberlin Ditch.	68°	....	0.89	
26 4:45 P.M.	Ft. Collins Wat'ks.	67°	36.82	....	Below pump house
26 5:00 P.M.	Seepage	66°	....	....	Included in wat'ks inflow 0.31
26 4:50 P.M.	Larimer Co. No. 2.	.....	....	0.07	
27 9:15 A.M.	Arthur Ditch	64°	....	0.37	Near head
26 6:10 P.M.	Larimer & W. Can.	64°	....	4.96	Near rating weir
26 6:15 P.M.	Riddle Ditch	67°	....	0.65	Near head
26 5:40 P.M.	3rd River Measurem't	67°	....	64.99	Below Larimer & Weld dam
		.....	65.73	81.87	Gain 16.14
Sept.					
27 8:35 A.M.	3rd River Measurem't	55°	62.03	....	Below Larimer & Weld dam
27 —— A.M.	Pioneer Ditch ...	.....	....	0.00	
27 9:50 A.M.	Seepage	60°	(0.27)	....	Near head of Pioneer Ditch
27 10:30 A.M.	Hottell Mill Race.	60°	....	43.15	Near head below wasteway
27 —— A.M.	Josh Ames Ditch.	.....	....	0.00	Below wasteway
27 11:00 A.M.	Lake Canal	64°	....	0.36	Near head
27 11:25 A.M.	Hottell Mill Race.	59°	46.98	....	Lower end canal at upper end of flume
27 11:40 A.M.	J. G. Coy Ditch...	65°	....	8.42	Below wasteway
27 —— A.M.	No. 2 Feeder Ditch	.....	....	0.06	Near head
27 1:45 P.M.	Chaffee Ditch....	69°	....	0.48	
27 1:00 P.M.	4th River Measurem't	69°	....	66.67	Below Chaffee Ditch and No. 2 Feeder
		.....	109.01	119.14	Gain 10.13
Sept.					
27 1:00 P.M.	4th River Measurem't	69°	66.67	....	Below Chaffee Dith and No. 2 Feeder
27 2:10 P.M.	Spring Creek	61°	(5.28)	....	Seepage
27 2:30 P.M.	Box Elder Ditch..	66°	....	4.61	At head
27 2:40 P.M.	5th River Measurem't	66°	....	61.53	Below Box Elder Ditch
		.....	66.67	66.14	Loss 0.53

CACHE LA POUDRE RIVER.
Measurement No. 14, Made September 26-29, 1899 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
27 2:40 P.M.	5th River Measurem't	66°	61.53	....	Below Box Elder Ditch
27 6:00 P.M.	Dry Creek	58°	(6.56)	....	Below No. 2 Supply
27 5:50 P.M.	Ames Slough	58°	(1.44)	....	
27 5:25 P.M.	Cooper Slough ...	58°	....	....	0.80 runs into Emigh Drain
27 5:15 P.M.	Box Elder Creek..	60°	(3.95)	....	Below Emigh Drain
27 5:00 P.M.	Emigh Drain	60°	....	0.71	Below Box Elder Creek
27 4:15 P.M.	Seepage	64°	(1.27)	....	Near Strauss Bridge
27 3:40 P.M.	6th River Measurem't	66°	....	59.70	Below Strauss Bridge
		.....	61.53	60.41	Loss 1.12
Sept.					
28 9:10 A.M.	6th River Measurem't	52°	71.94	....	Below Strauss Bridge
28 10:20 A.M.	Greeley No. 2 Can.	57°	....	65.03	At rating weir
28 11:00 A.M.	7th River Measurem't	57°	....	15.53	Below Greeley No. 2 Dam
		.....	71.94	80.56	Gain 8.62
Sept.					
28 11:00 A.M.	7th River Measurem't	57°	15.53	....	Below Greeley No. 2 Dam
30 1:00 P.M.	Intercepted Seep..	73°	....	2.68	From No. 2 Res. runs into
28 11:35 A.M.	Fossil Creek	58°	(2.64)	....	Near mouth No. 2 Ditch
28 12:15 P.M.	Whitney Ditch ...	59°	....	5.31	
28 12:35 P.M.	Eaton Ditch	64°	....	1.10	
28 12:45 P.M.	8th River Measurem't	63°	....	9.49	Below Eaton Ditch
		.....	15.53	18.58	Gain 3.05
Sept.					
28 12:45 P.M.	8th River Measurem't	63°	9.49	....	Below Eaton Ditch
28 —— P.M.	Jones Ditch	.....	....	0.00	
28 3:45 P.M.	Greeley No 3 Ditch	64°	....	22.12	Wasteway dry
28 4:15 P.M.	9th River Measurem't	63°	....	1.11	Below Greeley No. 3 Dam
		.....	9.49	23.23	Gain 13.74
Sept.					
28 4:15 P.M.	9th River Measurem't	63°	1.11	....	Below Greeley No. 3 Dam
28 5:20 P.M.	Boyd & Freeman..	63°	....	1.55	
30 9:55 A.M.	Inter. Seepage ...	51°	....	1.46	Sheep Creek Draw runs into
29 9:30 A.M.	Seepage	50°	(0.89)	....	No. 3
29 8:30 A.M.	Greeley Mill Race	52°	....	2.88	
29 8:40 A.M.	10th River Measuremt	53°	....	17.08	North of pump house
		.....	1.11	22.97	Gain 21.86
Sept.					
29 8:40 A.M.	10th River Measuremt	53°	17.08	....	North of Pump House
29 10:00 A.M.	Insinger Sewer ..	50°	....	2.92	Intercepted seepage
29 —— A.M.	Greeley Mill Race	.....	1.92	....	Near mouth
29 10:40 A.M.	Ogilvy Ditch	55°	....	34.66	At headgate
29 11:10 A.M.	Camp Bros. Ditch.	56°	(1.44)	....	Seepage inflow
29 11:30 A.M.	11th River Measuremt	56°	....	12.35	Below Camp Bros. Ditch
		.....	19.00	49.93	Gain 30.93
Sept.					
29 11:00 A.M.	11th River Measuremt	56°	12.35	....	Below Camp Bros. Ditch
29 3:00 P.M.	12th River Measuremt	64°	....	43.97	
		.....	12.35	43.97	Gain 31.62
		.....	....	....	Total Gain 133.59
29 3:40 P.M.	Lone Tree Creek..	64°	4.48	....	Runs into Platte

CACHE LA POUDRE RIVER.
Measurement No. 15, Made July-August, 1900.

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
2 11:00 A.M.	1st River Measurem't	68°	308.85	....	At weir in canon
2 1:50 P.M.	Canon Canal	68°	....	0.94	At weir
2 —— P.M.	Pleas. V. & L. Can	....	....	32.85	At head
2 3:30 P.M.	Larimer Co. Canal	69°	....	152.22	At rating flume
2 4:10 P.M.	Henderson Ditch.	.....	....	0.00	
2 —— P.M.	Waste	.....	0.39	....	
2 —— P.M.	Seepage	66°	(0.46)	....	
2 4:45 P.M.	Jackson Ditch ...	70°	....	11.12	At rating flume
2 —— P.M.	Seepage	66°	(3.92)	....	West of Bingham Hill
2 6:05 P.M.	2nd River Measurem't	70°	....	117.19	Above New Mercer Ditch
		....	309.24	314.32	Gain 5.08

CACHE LA POUDRE RIVER.
Measurement No. 15, Made July-August, 1900 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
3 9:45 A.M.	2nd River Measurem't	67°	138.02	....	Same as above
3 11:05 A.M.	New Mercer Ditch.	69°	....	8.91	At rating flume
3 11:20 A.M.	City Waterworks.	69°	....	53.80	Opposite New Mercer R. F.
3 —— A.M.	Pleas. V. & L. Dtch	.....	....	0.00	
3 12:05 P.M.	Little Cache la P.	71°	....	7.78	Near head
3 12:20 P.M.	Taylor & G. Ditch.	73°	....	10.14	Near head
3 1:40 P.M.	Chamberlin Ditch.	74°	....	2.57	
3 —— P.M.	Waste	71°	0.48	....	From Chamberlin Ditch
3 1:40 P.M.	Larimer Co. No. 2	80°	....	0.97	
3 2:20 P.M.	City Waterworks.	74°	52.72	....	Below pump house
3 —— P.M.	Seepage	.....	(0.14)	....	Below pump house
3 —— P.M.	Brown Ditch	.....	....	2.86	Taken from C. W. W. below pump house
3 5:00 P.M.	Arthur Ditch	75°	....	3.26	Near rating flume
3 3:45 P.M.	Larimer & Weld..	74°	....	14.21	At rating flume
3 —— P.M.	Riddle Ditch.....	71°	....	1.30	Near head
3 4:20 P.M.	3rd River Measurem't	74°	....	82.29	Below Larimer & Weld
		.....	191.22	188.09	Loss 3.13
July					
12 10:00 A.M.	3rd River Measurem't	67°	146.88	....	Same as above
12 12:00 M.	Pioneer Ditch ...	68°	....	0.05	
12 —— P.M.	Seepage	74°	(0.39)	....	
12 1:30 P.M.	Little Ditch	74°	....	0.94	
12 2:55 P.M.	Hottell Mill Race.	70°	....	65.85	Just below wasteway
12 3:20 P.M.	Josh Ames Ditch.	70°	....	4.91	Just below wasteway
12 3:35 P.M.	Lake Canal	70°	....	0.53	At flume by mill
12 4:22 P.M.	Hottell Mill Race.	70°	64.79	....	
12 4:40 P.M.	Coy Ditch	71°	....	0.05	
12 —— P.M.	City Sewer	54°	(2.08)	....	
12 5:20 P.M.	Chaffee Ditch	71°	....	4.46	Near head
12 —— P.M.	No. 2 Res Sup. D.	.....	....	0.00	
12 6:00 P.M.	4th River Measurem't	71°	....	120.11	Below No. 2 Res. Supply
		.....	211.67	196.90	Loss 14.77
July					
13 9:20 A.M.	4th River Measurem't	66°	112.93	....	Same as above
13 10:40 A.M.	Dry Creek	73°	159.97	....	Res. water from Long pond
13 2:30 P.M.	Spring Creek	71°	(5.75)	....	Near mouth
13 3:00 P.M.	Seepage	87°	(0.35)	....	On Sherwood place
13 3:10 P.M.	5th River Measurem't	74°	....	227.89	Above Box Elder Ditch
		.....	272.90	227.89	Changing water
July					
13 3:10 P.M.	5th River Measurem't	74°	227.89	....	Same as above
13 4:20 P.M.	Box Elder Ditch..	74°	....	2.53	Near head
13 6:12 P.M.	Seepage	67°	(0.53)	....	Above Strauss Bridge
14 10:40 A.M.	Seepage	70°	(0.65)	....	Below Strauss Bridge
13 7:00 P.M.	6th River Measurem't	71°	....	221.62	At Strauss Bridge
		.....	227.89	224.15	Loss 3.74
July					
14 9:30 A.M.	6th River Measurem't	70°	235.02	....	Same as above
14 11:10 A.M.	Seepage	67°	(0.36)	....	½ mile west of Timnath
14 11:30 A.M.	Seepage	68°	(0.28)	....	
14 11:35 A.M.	Seepage	.....	(0.13)	....	
14 2:05 P.M.	Pou. Irr. Co. No. 2	80°	....	138.00	At weir
14 2:15 P.M.	7th River Measurem't	80°	....	80.18	Below No. 2
		....	235.02	218.18	Loss 16.84
July					
14 2:15 P.M.	7th River Measurem't	80°	80.18	....	Same as above
14 3:40 P.M.	Fossil Creek	85°	(1.05)	....	Near mouth
14 4:15 P.M.	Seepage	81°	....	0.73	Intercepted by No. 2
14 5:15 P.M.	Whitney Ditch ...	86°	....	28.26	¼ mile below head
14 5:30 P.M.	Eaton Ditch	83°	....	5.39	Near head
14 6:00 P.M.	8th River Measurem't	83°	....	51.43	Below Eaton Ditch
		.....	80.18	85.81	Gain 5.63
July					
16 7:35 A.M.	8th River Measurem't	65°	65.94	....	Same as above
16 9:50 A.M.	Seepage	64°	(2.79)	....	½ m. east of Windsor
16 11:30 A.M.	Waste	71°	2.22	....	N. side ½ m. Jones Bridge
16 11:40 A.M.	Waste	82°	0.18	....	N. side ½ m. Jones Bridge
16 11:45 A.M.	Waste	69°	0.54	....	N. side ½ m. Jones Bridge
16 —— A.M.	Waste	.....	0.06	....	N. side ½ m. Jones Bridge
16 1:45 P.M.	Jones Ditch......	75°	....	5.84	Near head
16 3:10 P.M.	Greeley No. 3....	76°	....	56.74	
16 4:00 P.M.	9th River Measurem't	78°	....	12.66	Below Greeley No. 3
		.....	68.94	75.24	Gain 6.30

CACHE LA POUDRE RIVER.

Measurement No. 15, Made July-August, 1900 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
July					
16 4:00 P.M.	9th River Measurem't	78°	12.66	....	Same as above
16 5:00 P.M.	River Measure ...	78°	....	15.21	2 m. west Greeley
17 8:40 A.M.	River Measure...	70°	11.73	....	2 m. west Greeley
17 9:55 A.M.	Byd & Freeman.....	69°	....	1.09	Near head
17 11:00 A.M.	Seepage	80°	(1.18)	....	West pump house
17 —— A.M.	Seepage	.....	(1.81)	....	West pump house
17 11:20 A.M.	Greeley Mill Race	70°	....	0.70	Near head
17 11:40 A.M.	10th River Measuremt	73°	....	37.56	Mill power canal
		.....	24.39	54.56	Gain 30.17
July					
17 11:40 A.M.	10th River Measuremt	73°	37.56	....	Same as above
17 1:30 P.M.	Mill Power Canal.	79°	1.23	....	Near mouth
17 1:50 P.M.	Insinger Sewer ...	57°	(2.86)	....	Near mouth
17 —— P.M.	Insinger Sewer ...	.....	....	5.40	Intercepted
17 2:35 P.M.	Ogilvy Ditch	72°	....	52.15	At head
17 3:10 P.M.	Camp Ditch	.....	....	1.64	Intercepted
17 2:55 P.M.	11th River Measuremt	74°	....	13.83	Below Camp Ditch
		.....	38.78	73.08	Gain 34.29
July					
17 2:55 P.M.	11th River Measuremt	74°	13.83	....	Same as above
17 5:10 P.M.	12th River Measuremt	74°	....	57.22	¼ m. above mouth
		.....	13.83	57.22	Gain 43.39
					River varying from water exchanged by reservoirs

CACHE LA POUDRE RIVER

Measurement No. 16, Made August-September, 1900.

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
4 10:10 A.M.	1st River Measurem't	68°	118.32	....	At weir in canon, gage ht. .92
4 12:50 P.M.	Canon Ditch	68°	....	0.45	Near headg'te weir filled mud
4 1:20 P.M.	Pleas. V. & L. Can	68.5°	....	27.99	Near head
4 2:55 P.M.	Henderson Ditch..	72°	....	0.03	At road near Post Bridge
4 2:00 P.M.	Larimer Co. Canal	69.5°	....	57.74	At rating flume, gage ht. 1.08
4 3:00 P.M.	Seepage	72°	(0.09)	....	Near Post Bridge
4 3:20 P.M.	Jackson Ditch ...	72°	....	9.02	At rating flume, gage ht. .59
4 —— P.M.	New Mercer Ditch	.....	....	0.00	
4 4:05 P.M.	City Wat'ks Ditch	71°	....	22.60	Near head
4 4:35 P.M.	2nd River Measurem't	72°	....	4.87	Below Ft Collins wat'ks Ditch
		.....	118.32	122.70	Gain of 4.38 ft.
Sept.					
4 4:35 P.M.	2nd River Measurem't	72°	4.87	....	Same as above
4 4:30 P.M.	Pleas. V. & L. Dtch	78°	0.12	....	From Claymore Lake
4 5:10 P.M.	Lit. Cache la P. D.	69°	....	0.48	Near head at road crossing
4 5:15 P.M.	Taylor & G. Ditch	68°	....	1.30	Near head at road crossing
4 —— P.M.	Chamberlin Ditch.	.....	....	0.00	
4 —— P.M.	Lari. Co. No. 2 D.	.....	....	0.00	
4 5:40 P.M.	River	71°	....	3.56	Below head Larimer Co. No. 2
5 9:40 A.M.	River	65°	3.38	....	Below head Larimer Co. No. 2
5 9:05 A.M.	City Wat'ks Ditch	59°	21.72	....	Below pump house
5 8:55 A.M.	Seepage	66°	(0.22)	....	Runs in City Wat'ks Ditch
5 10:10 A.M.	Brown Ditch	61°	....	0.18	From City Wat'ks Ditch below the pump house
5 11:45 A.M.	Arthur Canal ...	69°	....	1.85	Near rating flume
5 11:10 A.M.	Larimer & W. Can	69°	....	26.87	At rating flume
5 —— A.M.	Riddle Ditch	.....	....	0.00	
5 —— A.M.	3rd River Measurem't	.....	....	0.00	Below Larimer & W. Dam
		.....	30.09	34.24	Gain of 4.15 ft.

CACHE LA POUDRE RIVER

Measurement No. 16, Made August-September, 1900 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
30 8:50 A.M.	3rd River Measurem't	66°	15.02	....	Same as above
30 10:20 A.M.	Seepage	70°	(0.25)	....	Near Rock Bush's place
30 10:15 A.M.	Pioneer Ditch ...	.....	....	0.00	
30 10:45 A.M.	Little Ditch	.....	....	0.00	
30 11:30 A.M.	Hottell Mill Race.	73°	....	0.12	Below wasteway
30 11:40 A.M.	Josh Ames Ditch.	.....	....	0.00	
30 11:50 A.M.	Lake Canal	78°	....	0.12	Near head
30 1:40 P.M.	Hottell Mill Race.	86°	0.52	....	
30 1:55 P.M.	City Sewer Drain.	58°	(0.67)	....	Largely drainage
30 2:20 P.M.	Coy Ditch	83°	....	13.00	Below wasteway
30 4:25 P.M.	Chaffee Ditch ...	.....	....	0.00	
30 4:25 P.M.	No. 2 Res. Sup. D.	.....	....	0.00	
30 3:50 P.M.	4th River Measurem't	80°	....	5.74	Below No. 2 Res. Sup. Ditch
		.....	15.54	18.98	Gain of 3.56 ft.
Aug.					
30 3:50 P.M.	4th River Measurem't	80°	5.74	....	Same as above
30 3:20 P.M.	Dry Creek	76°	(3.78)	....	100 yds above mouth
30 4:55 P.M.	Spring Creek	75°	(1.95)	....	Near mouth
30 5:20 P.M.	Seepage	80°	(0.08)	....	In Cuthbertson field
30 5:30 P.M.	5th River Measurem't	78°	....	11.09	Just above head Box Elder D.
		.....	5.74	11.09	Gain of 5.35 ft.
Aug.					
31 9:30 A.M.	5th River Measurem't	67°	8.67	....	Same as above
31 10:00 A.M.	Box Elder Ditch..	67°	....	2.45	Near headgate
31 11:00 A.M.	Seepage	72°	(0.09)	....	In Pither's field
31 11:15 A.M.	Box Elder Creek..	66°	(1.57)	....	Near mouth
31 11:30 A.M.	Emigh Drain D..	70°	....	0.61	Intercepted seepage
31 1:15 P.M.	6th River Measurem't	77°	....	11.75	Near Strauss Bridge
		.....	8.67	14.81	Gain of 6.14 ft.
Aug.					
31 1:15 P.M.	6th River Measurem't	77°	11.75	....	Same as above
31 1:50 P.M.	Seepage	76°	(0.05)	....	Near bluffs below Straus B.
31 —— P.M.	Seepage	75°	(0.02)	....	South of Timnath
31 2:50 P.M.	Greeley No. 2 Can	75°	....	0.97	At rating flume
31 3:15 P.M.	7th River Measurem't	82°	....	12.15	Below No. 2 Canal dam
		.....	11.75	13.12	Gain of 1.37 ft.
Sept.					
5 4:40 P.M.	7th River Measurem't	75°	9.87	....	Same as above
5 —— P.M.	No. 2 Res. Seepage	.....	....	....	Reservoir water running
5 5:40 P.M.	Fossil Creek	73°	(2.56)	....	
5 6:25 P.M.	Whitney Ditch ..	74°	....	5.43	At road crossing below head
5 6:40 P.M.	Eaton Ditch	70°	....	1.54	Near head
5 6:45 P.M.	8th River Measurem't	70°	....	5.93	Below Eaton Ditch
		.....	9.87	12.90	Gain of 3.03 ft.
Sept.					
6 8:15 A.M.	8th River Measurem't	66°	6.29	....	Same as above
6 9:50 A.M.	Reservoir water..	66°	15.44	....	From Windsor Lake
6 11:25 A.M.	Seepage	74°	(0.86)	....	Above Jones Bridge
6 12:20 P.M.	Jones Ditch	76°	....	1.41	Near head
6 2:40 P.M.	Greeley No. 3 D.	73°	....	18.66	At rating flume
6 3:05 P.M.	9th River Measurem't	74°	....	2.96	Below dam Greeley No. 3 D.
		.....	21.73	23.03	Gain of 1.30 ft.
Sept.					
6 3:05 P.M.	9th River Measurem't	74°	2.96	....	Same as above
6 4:00 P.M.	Seepage	73°	....	0.72	Sheep Creek draw intercepted by Greeley No. 3 Ditch
6 4:15 P.M.	Boyd & Freeman D	73°	....	4.05	Near headgate
6 5:15 P.M.	Seepage	72°	(1.36)	....	West of pump house
6 5:40 P.M.	Greeley Mill Race.	71°	....	1.16	Near headgate
6 5:55 P.M.	10th River Measuremt	71°	....	18.43	Below Greeley Mill Race
		.....	2.96	24.36	Gain of 21.40 ft.
Sept.					
7 8:45 A.M.	10th River Measuremt	67°	18.75	....	Same as above
7 10:10 A.M.	Greeley Mill Race	65°	0.18	....	Near mouth
7 10:15 A.M.	Insinger Sew. D..	60°	(2.69)	....	Running to river
7 10:15 A.M.	Insinger Sew. D..	60°	....	2.17	Intercepted
7 9:40 A.M.	Ogilvy Ditch	66°	....	30.31	Near headgate
7 —— A.M.	Camp Ditch	.....	....	0.00	
7 11:50 A.M.	Camp Ditch	.....	....	1.16	Slough Sup., intercept. seep.
7 11:30 A.M.	11th River Measuremt	69°	....	9.78	Below Camp Ditch
		.....	18.93	43.42	Gain of 24.49 ft.

CACHE LA POUDRE RIVER

Measurement No. 16, Made August-September, 1900 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
7 11:30 A.M.	11th River Measuremt	69°	9.78	....	Same as above
7 4:40 P.M.	12th River Measuremt	72°	....	44.63	Near mouth
		.....	9.78	44.63	Gain of 34.85 ft.
		.....	....	....	Total Gain 110.02

CACHE LA POUDRE RIVER.

Measurement No. 17, Made July-August, 1901.

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
5 10:30 A.M.	1st River Measurem't	69°	331.22	....	At gaging station
5 1:15 P.M.	Canon Ditch	70°	....	0.34	Near headgate
5 1:35 P.M.	Pleas. V. & L. Can.	70°	....	58.47	At head
5 2:30 P.M.	Waste	77°	(0.10)	....	From Canon Ditch
5 2:50 P.M.	Larimer Co. Canal	70°	....	126.14	At rating flume
5 3:30 P.M.	Henderson Ditch..	73°	....	0.33	Road crossing below head
5 4:05 P.M.	Jackson Ditch ...	71°	....	15.83	At rating flume
5 4:35 P.M.	New Mercer Ditch	72°	....	1.21	Near head
5 4:50 P.M.	City Waterworks.	72°	....	44.62	Near head
5 5:10 P.M.	2nd River Measurem't	72°	....	81.60	Below City Wat'ks Ditch
		.....	331.32	328.54	Loss 2.78
Aug.					
6 9:35 A.M.	2nd River Measurem't	66°	77.61	....	Same as above
6 10:10 A.M.	Pleas. V. Res. S'y	73°	2.23	....	At weir near mouth
6 11:10 A.M.	Lit. Cache la P. D	66°	....	21.58	Near headgate
6 11:20 A.M.	Taylor & G. Ditch.	66°	....	9.69	Near headgate
6 11:40 A.M.	Chamberlin Ditch.	67°	....	2.42	Road crossing below head
6 11:55 A.M.	Lari. Co. No. 2 D.	68°	....	0.62	Near headgate
6 12:15 P.M.	J. R. Brown Ditch	68°	....	0.51	From City Wat'ks Ditch
6 1:25 P.M.	Seepage and waste	68°	(0.74)	....	Into City Wat'ks Ditch
6 1:30 P.M.	City Wat'ks Ditch	67°	46.90	....	Near pump house
6 4:00 P.M.	Arthur Ditch	66°	....	1.94	Near rating flume
6 2:40 P.M.	Larimer & W. Can	67°	....	14.01	At rating flume
6 3:05 P.M.	Riddle Ditch	67°	....	0.65	Near head
6 3:15 P.M.	3rd River Measurem't	67°	....	102.05	Below Larimer & W. Canal
		.....	126.47	153.47	Gain 26.73
Aug.					
15 9:20 A.M.	3rd River Measurem't	67°	67.39	....	Below Larimer & W. Canal
15 —— A.M.	Ditch	.....	....	0.67	No name
15 —— A.M.	Seepage	70°	(0.15)	....	Near Rock Bush place
15 10:40 A.M.	Lytle Ditch	70°	....	0.74	Near headgate
15 11:20 A.M.	Hottell Mill Race.	72°	....	45.52	Near head
15 11:50 A.M.	Josh Ames Ditch.	77°	....	1.91	Below wasteway
15 12:05 P.M.	Lake Canal	78°	....	3.98	Near head
15 1:45 P.M.	Hottell Mill Race.	75°	46.31	....	Near mouth
15 —— P.M.	City Sewer	.....	(0.49)	....	Near mouth
15 2:25 P.M.	Coy Ditch	82°	....	7.71	Below wasteway
15 3:25 P.M.	No. 2 Res. Sup. D.	78°	....	0.53	Near headgate
15 —— P.M.	Chaffee Ditch ...	.....	....	0.00	
15 3:45 P.M.	4th River Measurem't	77°	....	61.08	Below No. 2 Res. Sup. Ditch
		.....	113.70	122.14	Gain 8.44
Aug.					
15 3:45 P.M.	4th River Measurem't	77°	61.08	....	Below No. 2 Res. Sup. Ditch
15 3:10 P.M.	Dry Creek	75°	15.28	....	Near mouth
16 9:15 A.M.	Spring Creek	63°	(4.79)	....	Near mouth
15 5:10 P.M.	5th River Measurem't	77°	....	84.83	Near head Box Elder Ditch
		.....	76.36	84:83	Gain 8.47
Aug.					
16 9:45 A.M.	5th River Measurem't	67°	104.32	....	Same as above
16 10:40 A.M.	Box Elder Ditch..	69°	....	18.27	Below wasteway
16 11:20 A.M.	Seepage	69°	(0.77)	....	In Pitcher's field
16 11:35 A.M.	Box Elder Creek..	68°	(2.02)	....	Near mouth
16 2:10 P.M.	Waste	78°	2.08	....	Near Strauss Bridge
16 11:40 A.M.	Emigh D. Ditch..	64°	....	5.06	Near mouth Box Elder Creek
16 1:00 P.M.	6th River Measurem't	75°	....	80.41	At Strauss Bridge
		.....	106.40	103.74	Loss 2.66

CACHE LA POUDRE RIVER.

Measurement No. 17, Made July-August, 1901 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
16 1:00 P.M.	6th River Measurem't	75°	80.41	....	At Strauss Bridge
16 3:00 P.M.	Cache la P. Ir Can	77°	....	5.69	At rating flume
16 3:35 P.M.	7th River Measurem't	77°	....	68.52	Below Cache la P. No. 2 dam
		.....	80.41	74.21	Loss 6.20
July					
12 11:10 A.M.	7th River Measurem't	71°	148.00	....	Same as above
12 12:15 P.M.	Waste	83°	(0.52)	....	From field being irrigated
12 1:20 P.M.	Fossil Creek	80°	17.20	....	Near mouth
12 2:05 P.M.	Inter. Seepage ...	85°	....	5.01	By No. 2 Ditch from reserv.
12 3:00 P.M.	Whitney Ditch ..	80°	....	34.77	
12 3:25 P.M.	Eaton Ditch	80°	....	14.26	Near headgate
12 3:55 P.M.	8th River Measurem't	80°	....	117.92	Below Eaton Ditch
		.....	165.72	171.96	Gain 6.24
July					
12 3:55 P.M.	8th River Measurem't	80°	117.92	....	Same as above
12 5:35 P.M.	River	81°	....	123.72	One mile east Windsor
13 8:20 A.M.	River	71°	95.35	....	One mile east Windsor
13 10:45 A.M.	Seepage	77°	2.53	....	Above Jones Ditch
14 11:35 A.M.	Jones Ditch	79°	....	9.09	At rating flume
13 1:15 P.M.	Greeley No. 3 D.	81°	....	5.21	Below Greeley No. 3 Ditch
13 1:45 P.M.	9th River Measurem't	79°	....	97.74	At rating flume
		.....	215.80	235.76	Gain 19.96
July					
13 1:45 P.M.	9th River Measurem't	81°	5.21	....	Same as above
13 3:15 P.M.	Boyd & Freeman D	83°	....	2.55	Near head
13 3:35 P.M.	Waste	75°	0.64	....	From wasteway Greeley No. 3
13 5:30 P.M.	Seepage	80°	(1.42)	....	West of pump house
13 4:35 P.M.	Greeley Mill Race.	83°	....	4.01	Near head
13 4:50 P.M.	10th River Measuremt	84°	....	27.66	Below Greeley Mill Power C.
		.....	5.85	34.22	Gain 28.37
July					
14 8:35 A.M.	10th River Measuremt	74°	25.07	....	Same as above
14 9:30 A.M.	Insinger Sewer ...	57°	....	3.90	Across river at Greeley
14 9:30 A.M.	Insinger Sewer ...	57°	(1.90)	....	Across river at Greeley
14 9:50 A.M.	Waste	68°	0.15	....	From Mill Power Canal
14 10:25 A.M.	Ogilvy Ditch	71°	....	51.49	Atheadgate
14 10:55 A.M.	Camp Ditch	74°	....	3.68	Near head
14 11:10 A.M.	Camp Sl. Sup. D.	85°	....	2.02	Intercepted seepage
14 11:15 A.M.	11th River Measuremt	.....	....	0.00	Below Camp Ditch
		.....	25.22	61.09	Gain 35.87
July					
14 11:15 A.M.	11th River Measuremt	.....	0.00	....	Same as above
14 3:10 P.M.	12th River Measuremt	79.5°	....	44.96	Near mouth
		.....	0.00	44.96	Gain 44.96
					Total Gain 167.40

CACHE LA POUDRE RIVER.

Measurement No. 18, Made July 22-27, 1902.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
July					
22 10:40 A.M.	1st River Measurem't	.....	303.61	....	At weir in canon
22 12:35 P.M.	Canon Canal	.....	....	9.30	At rating flume
22 1:15 P.M.	Pleas. V. & L. Can	.....	....	43.53	Near head
22 2:20 P.M.	Larimer Co. Canal	.....	....	130.71	At rating flume
22 3:05 P.M.	Seepage	.....	(1.46)	....	Post field
22 3:10 P.M.	Henderson Ditch..	.....	....	0.78	
22 3:15 P.M.	Waste	.....	0.39	....	From canon canal
22 3:35 P.M.	Jackson Ditch ...	.....	....	12.93	At rating flume
22 —— P.M.	New Mercer Ditch	.....	....	1.34	Leakage through gates
22 4:15 P.M.	City Wat'ks Oitch.	.....	....	41.15	Near head
22 4:45 P.M.	2nd River Measurem't	.....	....	55.44	Below City Water Wks Ditch
		.....	304.00	295.18	Loss 8.82

CACHE LA POUDRE RIVER.

Measurement No. 18, Made July 22-27, 1902 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
July					
23 9:45 A.M.	2nd River Measurem't	.....	52.29	....	Same as above
23 11:00 A.M.	Lit. Cache la P. D.	.....	....	8.94	Near headgate
23 11:15 A.M.	Taylor & G. Ditch.	.....	....	5.83	Near headgate
23 11:40 A.M.	City Wat'ks Ditch	.....	36.78	....	Below pump house
23 12:00 M.	Seepage	.....	(0.11)	....	
23 12:55 P.M.	Chamberlin Ditch.	.....	....	2.55	
23 1:00 P.M.	Larimer Co. No. 2	.....	....	0.61	Near head
23 1:20 P.M.	John Brown Ditch	.....	....	5.15	Near head
23 2:15 P.M.	Intercepted seep..	.....	....	3.56	
23 2:35 P.M.	Arthur Ditch	.....	....	1.81	Near head
23 —— P.M.	Seepage & waste..	.....	(1.25)	....	Near Fothergill's
23 —— P.M.	Larimer & W. Can	.....	....	19.78	At rating flume
23 3:50 P.M.	Riddle Ditch	.....	....	2.95	
23 3:55 P.M.	3rd River Measurem't	.....	....	51.54	Below Larimer & W. Canal
		.....	89.07	103.24	Gain 14.17
July					
24 8:55 A.M.	3rd River Measurem't	64°	51.29	....	Same as above
24 —— A.M.	Seepage	.....	(0.05)	....	Near head Pioneer Ditch
24 —— A.M.	Vandewark Ditch.	.....	....	0.00	At head
24 —— A.M.	Pioneer Ditch....	.....	....	0.00	At head
24 10:25 A.M.	Hottell Mill Race.	67°	....	29.96	Near head
24 11:10 A.M.	Josh Ames Ditch..	78°	....	0.81	Below wasteway
24 11:25 A.M.	Lake Canal	78°	....	2.15	
24 1:45 P.M.	Hottell Mill Race.	78°	30.66	....	Near mill
24 —— P.M.	City Sewer	.....	....	2.42	Intercepted
24 2:25 P.M.	Coy Ditch	84°	....	4.45	
24 —— P.M.	No. 2 Feeder.....	.....	....	0.00	
24 —— P.M.	Chaffee Ditch	.....	....	0.00	
24 3:25 P.M.	4th River Measurem't	81°	....	45.39	Below No. 2 Feeder
		.....	81.95	85.18	Gain 3.23
July					
24 3:25 P.M.	4th River Measurem't	81°	45.39	....	Same as above
24 2:45 P.M.	Dry Creek	.....	20.49	....	
24 4:30 P.M.	Spring Creek	77°	4.22	....	Near mouth
24 —— P.M.	Seepage	.....	(0.22)	....	Near mouth
24 4:50 P.M.	5th River Measurem't	79°	....	72.12	
		.....	70.10	72.12	Gain 2.02
July					
25 9:05 A.M.	5th River Measurem't	60°	76.94	....	Same as above
25 9:40 A.M.	Box Elder Ditch..	.....	....	15.11	Near headgate
25 10:40 A.M.	Box Elder Creek..	.....	(6.25)	....	Near mouth
25 11:00 A.M.	Emigh Drain	61°	....	1.13	Intercepted seepage
25 —— A.M.	Seepage waste....	.....	(1.08)	....	
25 11:45 A.M.	6th River Measurem't	63°	....	66.74	Below Strauss Bridge
		.....	76.94	82.98	Gain 6.04
July					
25 11:45 A.M.	6th River Measurem't	63°	66.74	....	Same as above
25 2:10 P.M.	Greeley No. 2 Can.	74°	....	0.75	At rating flume
25 2:30 P.M.	7th River Measurem't	72°	....	69.67	Below Greeley No. 2 Canal
		.....	66.74	70.42	Gain 3.68
July					
25 2:30 P.M.	7th River Measurem't	72°	69.67	....	Same as above
25 —— P.M.	Fossil C'k Res. out	.....	(0.40)	....	Estimated
25 —— P.M.	Waste	.....	0.61	....	From Box Elder Ditch
25 4:25 P.M.	Fossil Creek	.....	(0.74)	....	Near mouth
25 4:50 P.M.	Greeley No. 2 Can.	71°	....	0.65	Inter. seep. below seep. com.
25 5:15 P.M.	Whitney Ditch...	73°	....	13.34	
25 5:40 P.M.	Eaton Ditch	74°	....	9.55	Near headgate
25 5:50 P.M.	8th River Measurem't	74°	....	51.72	Below Eaton Ditch
		.....	70.28	75.26	Gain 4.98
July					
26 8:25 A.M.	8th River Measurem't	63°	42.93	....	Same as above
26 11:30 A.M.	Jones Ditch	70°	....	9.21	Near headgate
26 1:35 P.M.	Greeley No. 3 Can.	72°	....	50.59	
26 2:00 P.M.	9th River Measurem't	72°	....	3.65	Below Greeley No. 3 Canal
		.....	42.93	63.45	Gain 20.52

CACHE LA POUDRE RIVER.
Measurement No. 18, Made July 22-27, 1902 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
July					
26 2:00 P.M.	9th River Measurem't	72°	3.65	....	Same as above
26 —— P.M.	Sheep Creek	.....	.00	....	
26 3:30 P.M.	Boyd & Freeman D	73°	....	7.59	At headgate
26 4:25 P.M.	Seepage	77°	(1.88)	....	West of pump house
26 4:50 P.M.	Greeley Mill Race.	73°	....	1.75	Near headgate
26 5:00 P.M.	10th River Measuremt	73°	....	14.99	North of pump house
		.....	3.65	24.33	Gain 20.68
July					
27 9:10 A.M.	10th River Measuremt	67°	14.84	....	Same as above
27 9:55 A.M.	Greeley Sewer ...	59°	....	4.10	Intercepted seepage
27 10:00 A.M.	Greeley Mill Race.	69°	0.25	....	Near mouth
27 10:25 A.M.	Ogilvy Ditch	68°	....	31.03	Near headgate
27 11:00 A.M.	Camp Bros. Ditch.	.....	....	0.72	Near head
27 11:10 A.M.	Camp Bros. Slough	72°	....	1.17	Intercepted seepage
27 1:00 P.M.	11th River Measuremt	.....	....	0.00	Below Camp Bros. Ditch
		.....	15.09	37.02	Gain 21.93
July					
27 11:15 A.M.	11th River Measuremt	.....	0.00	....	Same as above
27 3:45 P.M.	12th River Measuremt	.....	....	29.11	
		.....	0.00	29.11	Gain 29.11
					Total Gain 117.54

CACHE LA POUDRE RIVER.
Measurement No. 19, Made August 3-10, 1903.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
3 1:15 P.M.	1st River Measurem't	69°	339.22	....	At weir in canon
3 1:40 P.M.	Canon Canal	69°	....	3.88	Near head
3 10:15 A.M.	Pleas. V. & L. Can	63°	....	92.86	At rating flume
3 1:50 P.M.	Waste	84°	0.33	....	¾ mile below head
3 2:40 P.M.	Larimer Co. Canal	72°	....	137.01	At rating flume
3 —— P.M.	Waste	.....	2.67	....	From Canon Canal
3 3:10 P.M.	Henderson Ditch.	71°	....	0.37	
3 3:15 P.M.	Waste	71°	2.43	....	From Post field
3 3:50 P.M.	Jackson Ditch ...	71°	....	22.79	At rating flume
3 5:00 P.M.	2nd River Measurem't	71°	....	102.37	Above head of New Mercer D.
		.....	344.65	359.28	Gain 14.63
Aug.					
6 10:00 A.M.	2nd River Measurem't	65°	88.15	....	Same as above
6 10:25 A.M.	New Mercer Ditch	65°	....	4.11	At rating flume
6 10:45 A.M.	City Waterworks.	65°	....	32.50	Near head
6 11:00 A.M.	Reservoir Water..	72°	7.28	....	From Pleas. V. & Lake Canal
6 11:30 A.M.	Lit. Cache la P. D.	65°	....	14.76	Near headgate
6 11:35 A.M.	Taylor & G. Ditch	65°	....	7.37	Near headgate
6 11:55 A.M.	Chamberlin Ditch.	71°	....	0.42	Road crossing below head
6 12:05 P.M.	Larimer Co. No. 2	68°	....	0.79	Near headgate
6 12:30 P.M.	John Brown Ditch	66°	....	4.59	Near headgate
6 1:25 P.M.	City Wat'ks Ditch	66°	31.34	....	Below pump house
6 1:30 P.M.	Seepage	75°	(0.73)	....	Run into Wat'ks Ditch
6 2:10 P.M.	Intercepted seep..	57°	....	5.22	Run into Arthur Canal
6 2:30 P.M.	Arthur Canal	73°	....	3.70	At rating flume
6 3:30 P.M.	Larimer & W. Can	72°	....	30.74	At rating flume
6 3:35 P.M.	Riddle Ditch	73°	....	2.42	At head
6 4:10 P.M.	3rd River Measurem't	72°	....	24.24	Below Larimer & W. Canal
		.....	126.77	130.86	Gain 4.11
Aug.					
6 4:10 P.M.	3rd River Measurem't	72°	24.24	....	Same as above
6 —— P.M.	Pioneer Ditch ...	.....	....	.00	
6 4:30 P.M.	Seepage	77°	(0.70)	....	Near Rock Bush place
6 —— P.M.	Vandewark Ditch.	.....	....	.00	
6 —— P.M.	Little Ditch	.....	....	.00	
6 5:05 P.M.	Hottell Mill Race.	72°	....	15.78	Near headgate
6 —— P.M.	Ditch	72°	....	0.99	No name, undecreed
6 5:35 P.M.	Josh Ames Ditch.	72°	....	5.53	Below Wasteway
6 5:35 P.M.	Lake Canal	72°	....	0.35	Near rating flume
6 6:00 P.M.	Coy Ditch	76°	....	4.64	At rating flume
6 6:00 P.M.	River	.....	....	.00	Below Coy Ditch

CACHE LA POUDRE RIVER.
Measurement No. 19, Made August 3-10, 1903 (Continued).

Hour and Date	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
17 9:15 A.M.	River	.....	.00	.00	Below Coy Ditch
17 9:15 A.M.	Hottell Mill Race.	50°	10.45	....	Near mill
17 9:35 A.M.	Ft. Collins Sewer.	57°	(1.44)	....	At mouth
17 9:45 A.M.	Waste	51°	3.72	....	From Coy Ditch
17 10:15 A.M.	Waste	52°	2.76	....	From Coy Ditch
17 —— A.M.	College Sewer ...	.....	(2.86)	....	
17 10:55 A.M.	4th River Measurem't	.....	....	34.28	Above No. 2 Feeder
		.....	41.17	61.57	Gain 20.40
Aug.					
8 —— A.M.	4th River Measurem't	.....	42.70	....	Same as above
8 9:20 A.M.	Chaffee Ditch ...	65°	....	0.91	
8 —— A.M.	No. 2 Feeder	.....	....	.00	At head
8 9:50 A.M.	Spring Creek	61°	(2.35)	....	Near mouth
7 5:55 P.M.	Dry Creek	70°	(5.19)	....	Above Long Pond Res. Wat.
7 5:35 P.M.	Reservoir Water..	75°	34.92	....	From Long Pond
7 —— P.M.	No. 2 Feeder	.....	....	44.41	Below Dry Creek
7 3:00 P.M.	Dry Creek	78°	(0.58)	....	Below No. 2 Feeder
8 10:00 A.M.	Seepage	68°	(0.11)	....	Cuthbertson field
8 10:20 A.M.	Box Elder Ditch..	68°	....	32.10	Near headgate
8 10:45 A.M.	5th River Measurem't	59°	....	16.36	Below Box Elder Ditch
		.....	77.62	93.78	Gain 16.16
Aug.					
8 10:45 A.M.	5th River Measurem't	59°	16.36	....	Same as above
8 11:10 A.M.	Fossil C'k Sup. D.	80°	....	2.95	Intercepted seepage
8 —— A.M.	Box Elder Creek..	.....	(5.18)	....	Near mouth
8 12:00 M.	Emigh Drain D...	70°	....	0.77	Intercepted seepage
8 1:35 P.M.	Waste	70°	1.04	....	At Strauss Bridge
8 1:30 P.M.	6th River Measurem't	79°	....	26.61	At Strauss Bridge
		.....	17.40	30.33	Gain 12.93
Aug.					
8 1:30 P.M.	6th River Measurem't	79°	26.61	....	Same as above
8 3:00 P.M.	Reservoir Waste..	73°	83.33	....	From Fossil Creek Reservoir
8 3:15 P.M.	Waste	74°	1.45	....	From Box Elder Ditch
8 4:10 P.M.	Cache la P. No. 2.	78°	....	4.02	At rating flume
8 4:40 P.M.	7th River Measurem't	75°	....	116.18	Below Cache la Poudre No. 2
		.....	111.39	120.20	Gain 8.81
Aug.					
8 4:40 P.M.	7th River Measurem't	75°	116.18	....	Same as above
8 5:10 P.M.	Fossil Creek	74°	(2.02)	....	Near mouth
8 6:05 P.M.	Whitney Ditch ..	.....	....	31.08	
8 6:25 P.M.	Eaton Ditch	76°	....	14.67	Below headgate
8 —— P.M.	8th River Measurem't	76°	....	69.90	Below Eaton Ditch
		.....	116.18	115.65	Loss 0.53
Aug.					
9 8:40 A.M.	8th River Measurem't	65°	75.14	....	Same as above
9 10:30 A.M.	Seepage	69°	(2.57)	....	
9 11:15 A.M.	Jones Ditch	71°	....	6.77	Near head
9 1:10 P.M.	Greeley No. 3 Can.	75°	....	89.10	At rating flume
9 1:25 P.M.	9th River Measurem't	75°	....	6.34	Below Greeley No. 3 dam
		.....	75.14	102.21	Gain 27.07
Aug.					
9 1:25 P.M.	9th River Measurem't	75°	6.34	....	Same as above
9 —— P.M.	Intercepted seep..	.....	....	0.19	Sheep Creek, by Greeley No. 3
9 2:50 P.M.	Waste	72°	0.27	....	From Greeley No. 3 Ditch at wasteway
9 3:10 P.M.	Boyd & Freem'n Ditch	75°	....	6.88	At headgate
9 4:00 P.M.	Seepage	78°	(1.79)	....	
9 4:30 P.M.	Greeley Mill Race	74°	....	2.58	Near head
9 4:45 P.M.	10th River Measuremt	73°	....	15.25	North of pump house
Aug.		.....	6.61	24.90	Gain 18.29
10 8:50 A.M.	10th River Measuremt	.....	15.88	....	Same as above
10 9:30 A.M.	Greeley Mill Race	72°	0.73	....	Near mouth
10 9:45 A.M.	Ensinger Sewer...	63°	....	4.48	Intercepted
10 —— A.M.	Waste	.....	0.75	....	From Ensinger Sewer
10 10:30 A.M.	Ogilvy Ditch	66°	....	38.23	At headgate
10 10:45 A.M.	Camp Ditch	68°	....	1.97	Below head
10 11:00 A.M.	Camp Slough Sup.	67°	....	0.71	
10 —— A.M.	11th River Measuremt	.....	....	.00	Below Camp Ditch
Aug.		.....	17.36	45.39	Gain 28.78
10 —— A.M.	11th River Measuremt	.....	0.00	....	Same as above
10 3:25 P.M.	12th River Measuremt	74°	....	35.72	Near mouth
		.....	.00	35.72	Gain 35.72
					Total Gain 186.37

CACHE LA POUDRE RIVER.

Measurement No. 20, Made Sept. 14-19, 1904.

Hour and Date	Place of Measurement	Temp. of Water	River and Inflow	Out-take	NOTES
Sept.					
14 11:45 A.M.	1st River Measurem't	58°	138.27	....	At Weir in Canon
14 —— A.M.	Canon Canal	....	....	0.00	
14 —— A.M.	Pleasant V & Lake	....	....	0.00	
14 1:40 P.M.	Larimer Co. Canal	60°	....	95.99	Near rating flume
14 —— P.M.	Henderson Ditch..	....	....	0.00	
14 2:15 P.M.	Jackson Ditch ...	65°	....	0.55	Road near head
14 2:50 P.M.	Little Cache la P.	66°	....	2.33	Near head, new place
14 3:00 P.M.	New Mercer Ditch	64°	....	0.22	Near head
14 3:15 P.M.	City Wtrwks Ditch	66°	....	38.10	Near head
14 3:40 P.M.	2nd River Measurem't	67°	....	6.52	Below City Waterworks
Sept.		....	138.27	143.71	Gain 5.44
14 3:40 P.M.	2nd River Measurem't	67°	6.52	....	Same as above.
14 —— P.M.	Taylor & G. Ditch.	....	....	0.00	
15 9:40 A.M.	Chamberlin Ditch.	60°	....	0.30	
14 4:35 P.M.	Poudre River	67°	....	7.66	At Laporte
15 9:30 A.M.	Poudre River	58°	8.55	....	At Laporte
15 —— A.M.	Larimer Co. No. 2	....	....	0.00	Below City Waterw'ks Dam
15 9:55 A.M.	John Brown Ditch.	56°	....	1.28	At head gate
15 10:30 A.M.	City Wtrwks Ditch	58°	29.78	....	Below pump house
15 11:05 A.M.	Intercepted seepage	56°	....	5.96	By Arthur Canal
15 11:25 A.M.	Arthur Canal	60°	....	11.94	At rating flume
15 12:15 P.M.	Larimer & Wl. Can	62°	....	19.10	At rating flume
15 12:25 P.M.	Riddle Ditch	....	....	1.10	Near head
15 12:45 P.M.	3rd River Measurem't.	62°	....	12.59	Below Larimer & Weld Canal
		....	44.85	59.93	Gain 15.08
Sept.					
15 12:45 P.M.	3rd River Measurem't.	62°	12.59	....	Same as above
15 1:00 P.M.	Pioneer Ditch	62°	....	2.18	
15 —— P.M.	Seepage	....	(0.15)	....	Near Rock Bush place
15 —— P.M.	Vandewark Ditch.	....	....	0.00	
15 —— P.M.	Josh Ames Ditch..	....	....	0.00	
15 1:20 P.M.	Lake Canal	66°	....	0.24	Near rating flume
15 2:40 P.M.	Hottell Mill Race.	63°	....	2.85	Near head
15 3:25 P.M.	Coy Ditch	64°	....	2.02	Below waste
15 4:00 P.M.	Poudre River ...	64°	....	11.35	Near Hottel Mill
16 9:25 P.M.	Poudre River	59°	11.99	....	Near Hottel Mill
16 9:40 A.M.	Mill Race	59°	2.84	....	In Mill flume
16 —— A.M.	Ft. Collins Sewer.	....	(0.75)	....	
16 —— A.M.	No. 2 Feeder	....	....	0.00	
16 —— A.M.	Chaffee Ditch	....	....	0.00	
16 10:55 A.M.	4th River Measurem't	64°	....	29.58	Below No. 2 Feeder
		....	27.42	48.22	Gain 20.80 cu. ft. per sec.
Sept.					
16 10:55 A.M.	4th River Measurem't.	64°	29.58	....	Same as above
16 10:15 A.M.	Dry Creek	60°	(9.85)	....	Near mouth
16 11:30 A.M.	Spring Creek	63°	(4.60)	....	Near mouth
16 11:55 A.M.	Box Elder Ditch..	65°	....	15.74	Near head
16 12:25 P.M.	5th River Measurem't	65°	....	23.25	Below Box Elder Ditch
		....	29.58	38.99	Gain 9.41 cu. ft. per sec.
Sept.					
16 12:25 P.M.	5th River Measurem't.	65°	23.25	....	Same as above
16 —— P.M.	Fossil Cr'k Res. S.	....	0.00	....	
16 2:10 P.M.	Box Elder Creek..	66°	(3.66)	....	Near mouth
16 —— P.M.	Emigh Drain Ditch	....	....	0.00	
16 3:05 P.M.	6th River Measurem't.	69°	....	28.03	At Strauss Bridge
		....	23.25	28.03	Gain 4.78 cu. ft. per sec.
Sept.					
17 10:50 A.M.	6th River Measurem't.	69°	22.27	....	Same as above
17 —— A.M.	Fossil Creek Outlet	....	....	0.00	
17 11:45 A.M.	Waste	61°	9.96	....	From Box Elder Ditch
17 —— A.M.	Greeley No. 2.....	....	....	0.33	Small leak
17 1:00 P.M.	7th River Measurem't.	66°	....	35.13	Below Greeley No. 2
		....	32.23	35.46	Gain 3.23 cu. ft. per sec.
Sept.					
17 1:00 P.M.	7th River Measurem't.	66°	35.13	....	Same as above
17 2:00 P.M.	Fossil Creek	....	(1.12)	....	Near mouth
17 2:45 P.M.	Whitney Ditch ...	67°	....	7.53	Road near head
17 3:00 P.M.	Eaton Ditch	66°	....	1.99	Near head
17 3:30 P.M.	8th River Measurem't.	67°	....	29.90	Below Eaton Ditch
		....	35.13	39.42	Gain of 4.29 cu. ft. per sec.

CACHE LA POUDRE RIVER.
Measurement No. 20, Made Sept. 14-19, 1904 (Continued).

Hour and Date	Place of Measurement	Temp. of Water	River and Inflow	Out-take	NOTES
Sept.					
17 3:30 P.M.	8th River Measurem't.	67°	29.90	....	Below Eaton Ditch
17 4:50 P.M.	Seepage	....	(2.14)	....	Above Jones Bridge
17 5:30 P.M.	Jones Ditch	67°	....	5.24	At head gate
17 6:00 P.M.	Poudre River	67°	....	41.65	1½ mile west Jones Bridge
18 10:35 A.M.	Poudre River	63°	36.07	....	1½ mile west Jones Bridge
18 10:00 A.M.	Waste	66°	3.41	....	1 mile west Farmers' Switch
18 11:30 A.M.	Greeley No. 3 Dtch	65°	....	41.55	At rating flume
18 11:35 A.M.	9th River Measurem't.	65°	....	0.51	Below Greeley No. 3
		....	69.33	88.95	Gain 19.62 cu. ft. per sec.
Sept.					
18 11:35 A.M.	9th River Measurem't.	65°	0.51	....	Same as above
18 11:50 A.M.	Sheep Creek	74°	....	1.73	Intercepted near mouth
18 1:50 P.M.	Boyd & Freeman..	71°	....	1.20	Near head
18 1:00 P.M.	Seepage	67°	(1.20)	....	West of pump house
18 1:10 P.M.	Mill Race	67°	....	0.97	Near head
18 1:25 P.M.	10th River Measurem't	77°	....	19.88	North of pump house
		....	0.51	23.78	Gain 23.27 cu. ft. per sec.
Sept.					
18 1:25 P.M.	10th River Measurem't	77°	19.88	....	Same as above
18 3:10 P.M.	Mill Race	69°	0.46	....	Near mouth
18 3:15 P.M.	Greeley Sewer	....	(3.12)	....	Going to river
18 3:40 P.M.	Ogilvy Ditch	65°	....	45.98	At head gate
18 —— P.M.	Camp Ditch	....	....	0.00	
18 3:55 P.M.	Camp Slough Sup.	71°	....	1.43	
18 4:15 P.M.	11th River Measurem't	66°	....	3.47	Below Camp Ditch
		....	20.34	50.88	Gain 30.54
Sept.					
18 4:15 P.M.	11th River Measurem't	66°	3.47	....	Same as above
19 8:30 A.M.	Intercepted Seep..	58°	....	1.49	By Ogilvy Ditch
19 8:35 A.M.	Intercepted Seep..	58°	....	0.75	By Ogilvy Ditch
19 8:45 A.M.	Waste	59°	5.13	....	From Ogilvy Ditch
19 10:00 A.M.	12th River Measuremt	60°	....	43.39	Near mouth
		....	8.60	45.63	Gain 37.03
					Total Gain 173.49

CACHE LA POUDRE RIVER.
Measurement No. 21, Made Sept. 19-23, 1905.

Hour and Date	Place of Measurement	Temp. of Water	River and Inflow	Out-take	NOTES
Sept.					
19 1:35 P.M.	1st River Measurem't	58°	124.09	....	At Weir in Canon
19 1:35 P.M.	Seepage	....	0.21	....	Below weir
19 —— P.M.	Leakage	....	1.00	....	From Poudre Valley Canal
19 2:10 P.M.	Seepage	68°	(0.90)	....	From Hook and Moore Gulch
19 10:50 A.M.	High Line Canal.	56°	....	36.87	At rating flume
19 3:40 P.M.	Seepage	59°	(0.23)	....	From Post Meadow
19 3:35 P.M.	Henderson Ditch.	64°	....	0.25	Road crossing near head
19 3:30 P.M.	Larimer Co. Canal	60°	....	21.50	At rating flume
19 4:30 P.M.	River Measurem't	60°	....	79.34	Near Post bridge
20 10:55 A.M.	River Measurem't	60°	93.75	....	Near Post bridge
20 11:35 A.M.	Jackson Ditch....	59°	....	8.11	At rating flume
20 12:30 P.M.	2nd River Measurem't	62°	....	89.22	At head of New Mercer Ditch
		....	219.05	235.29	Gain of 16.24 cu. ft. per sec.
Sept.					
20 12:30 P.M.	2nd River Measurem't	62°	89.22	....	Same as above
20 —— P.M.	New Mercer Ditch	....	....	0.00	At head
20 12:50 P.M.	Res. Water	70°	1.69	....	From Claymore Lake
20 1:50 P.M.	Little Cache la P.	64°	....	1.78	At head
20 2:05 P.M.	Taylor & G. Ditch	64°	....	12.29	At head
20 3:00 P.M.	Chamberlin Ditch	65°	....	0.99	Road crossing near head
20 —— P.M.	Larimer Co. No. 2	....	....	0.00	Below wasteway
20 2:40 P.M.	J. R. Brown.....	63°	....	0.06	At head
20 —— P.M.	Arthur Canal ...	....	....	0.00	At head
20 3:45 P.M.	Seepage	58°	....	4.89	Intercepted by Arthur Canal
20 4:10 P.M.	Larimer & Weld..	65°	....	1.71	Near rating flume
20 4:15 P.M.	Riddle Ditch	65°	....	1.40	At head
20 5:00 P.M.	3rd River Measurem't	66°	....	77.38	Below Larimer & Weld Dam
		....	90.91	100.50	Gain 9.59

CACHE LA POUDRE RIVER.

Measurement No. 21, Made Sept. 19-23, 1905 (Continued).

Hour and Date	Place of Measurement	Temp. of Water	River and Inflow	Out-take	NOTES
Sept.					
21 9:40 A.M.	3rd River Measurem't	56°	90.77	....	Same as above
21 —— A.M.	Pioneer Ditch	....	....	0.00	At head
21 —— A.M.	Vandewark Ditch.	....	....	0.00	At head
21 10:40 A.M.	Josh Ames	63°	....	1.21	Near head
21 —— A.M.	Lake Canal	....	....	0.03	Near head
21 11:05 A.M.	Coy Ditch	63°	....	2.16	Below Wasteway
21 —— P.M.	City Sewer	....	(1.40)	....	
21 2:25 P.M.	4th River Measurem't	65°	....	104.20	Above No. 2 Feeder
		....	90.77	107.60	Gain 16.83
Sept.					
21 2:25 P.M.	4th River Measurem't	65°	104.20	....	Above No. 2 Feeder
21 —— P.M.	No. 2 Feeder.....	....	....	0.75	Leak
21 —— P.M.	Chaffee Ditch ...	....	....	0.00	
21 3:00 P.M.	Spring Creek	65°	(4.29)	....	
21 —— P.M.	Dry Creek	....	(4.57)	....	
21 3:40 P.M.	5th River Measurem't	67°	....	101.63	Above Box Elder Ditch
		....	104.20	102.38	Loss 1.82 cu. ft. per sec.
Sept.					
21 3:40 P.M.	5th River Measurem't	67°	101.63	....	Same as above
21 4:00 P.M.	Box Elder Ditch..	67°	....	16.69	Near head
21 4:45 P.M.	Box Elder Creek..	64°	(3.08)	....	Near mouth
21 —— P.M.	Emigh Drain	....	....	0.00	
21 —— P.M.	Fossil Creek Feed.	....	....	0.00	
21 5:50 P.M.	6th River Measurem't	68°	....	85.14	At Strauss Bridge
		....	101.63	101.83	Gain 0.20 cu. rt. per sec.
Sept.					
22 10:30 A.M.	6th River Measurem't	61°	9.90	....	Same as above
22 11:30 A.M.	Waste	59°	10.30	....	From Box Elder Ditch
22 12:00 A.M.	Greeley No. 2 Can	68°	....	3.40	At head
22 12:20 P.M.	7th River Measurem't	68°	....	30.61	Below Greeley No. 2 Canal
		....	20.20	34.01	Gain 13.81
Sept.					
22 12:20 P.M.	7th River Measurem't	68°	30.61	....	Same as above
22 1:00 P.M.	Fossil Creek	60°	(0.84)	....	Near mouth
22 —— P.M.	Seepage	....	....	3.38	From Timnath Res. Int. No. 2
22 2:15P.M.	Whitney Ditch ..	66°	....	12.80	Road near head
22 2:30 P.M.	Eaton Canal	64°	....	3.10	Near head
22 3:00 P.M.	8th River Measurem't	64°	....	15.77	Below Eaton Canal
		....	30.61	35.05	Gain 4.44
Sept.					
22 3:00 P.M.	8th River Measurem't	64°	15.77	....	Same as above
22 4:15 P.M.	Seepage	66°	(2.49)	....	Above Jones Bridge
22 4:50 P.M.	Jones Ditch	67°	....	2.59	Near head
22 6:10 P.M.	Greeley No. 3....	70°	....	32.17	At rating flume
22 6:20 P.M.	9th River Measurem't	70°	....	0.63	Below Greeley No. 3
Sept.		....	15.77	35.39	Gain 19.62
22 6:20 P.M.	9th River Measurem't	70°	0.63	....	Same as above
23 6:00 A.M.	Boyd & Freeman.	....	....	0.00	
23 1:00 A.M.	Sheep Draw	....	....	2.78	Intercepted by Greeley No. 3
23 6:00 A.M.	Kettley Draw ...	....	....	0.29	Intercepted by Greeley No. 3
23 9:30 A.M.	Seepage	56°	(0.60)	....	West of pump house
23 9:45 A.M.	Mill Ditch	59°	....	1.45	Near head
23 10:00 A.M.	10th River Measuremt	59°	....	17.85	North of pump house
Sept.		....	0.63	22.37	Gain 21.74
23 10:00 A.M.	10th River Measuremt	59°	17.85	....	Same as above
23 10:20 A.M.	Mill Ditch	66°	0.35	....	
23 10:30 A.M.	Insinger Sewer ...	....	....	2.24	Used
23 10:30 A.M.	Insinger Sewer ...	....	(0.92)	....	Running to river
23 11:15 A.M.	Ogilvy Ditch	64°	....	29.26	At head gate
23 11:30 A.M.	Camp Ditch	64°	....	7.43	Below Slough Supply
23 11:45 A.M.	11th River Measuremt	64°	....	19.57	Below Camp Ditch
Sept.		....	18.20	58.50	Gain 40.30
23 11:45 A.M.	11th River Measuremt	64°	19.57	....	Below Camp Ditch
23 1:30 P.M.	Seepage	72°	....	1.89	Intercepted by Ogilvy Ditch
23 1:40 P.M.	Seepage	72°	....	1.26	Intercepted by Ogilvy Ditch
23 2:00 P.M.	Seepage	62°	....	4.11	Intercepted by Ogilvy Ditch
23 2:30 P.M.	Sand Creek	75°	(3.68)	....	Near mouth
23 3:45 P.M.	12th River Measuremt	69°	....	52.19	Near mouth
		....	19.57	59.45	Gain 39.88
					Total Gain 180.83

CACHE LA POUDRE RIVER.
Check Measurement.

Hour and Date	Place of Measurement	Temp. of Water	River and Inflow	Out-take	NOTES
Sept.					
29 9:00 A.M.	4th River Measurem't	....	92.79	....	Above No. 2 Feeder
30 —— P.M.	Ditch	....	....	2.57	Out Spring Creek intercepted
30 —— A.M.	No. 2 Feeder.....	....	....	0.25	At head
30 —— A.M.	Chaffee Ditch	....	....	0.00	At head
30 2:30 P.M.	Dry Creek	....	(2.37)	....	Near mouth
30 10:10 A.M.	Spring Creek	....	(4.23)	....	Near mouth
30 11:00 A.M.	5th River Measurem't	....	....	93.44	Above Box Elder Ditch
		....	92.79	96.26	Gain 3.47
Sept.					
30 11:00 A.M.	5th River Measurem't	....	93.44	....	Same as above
30 11:15 A.M.	Box Elder Ditch..	....	....	15.40	At head
30 11:50 A.M.	Fossil Creek Feed.	....	....	66.70	Road near head
30 12:10 A.M.	Box Elder Creek..	....	(0.84)	....	At mouth
30 2:00 P.M.	Ditch	....	....	2.48	Out of Box Elder, intercepted
30 1:00 P.M.	6th River Measurem't	....	....	8.86	At Strauss Bridge
		....	93.44	93.44	Gain 0

CACHE LA POUDRE RIVER
Measurement No. 22, Made September 24 October 1, 1906.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
24 12:50 P.M.	Poudre Val. Canal	60°	....	(2.42)	Above weir in canon
24 11:45 A.M.	1st River Measurem't	56°	309.76	....	At weir in canon
24 —— A.M.	Seepage	.....	(0.18)	....	Near weir
24 1:05 P.M.	Seepage	67°	(0.38)	....	Hook & Moore Glade road
24 —— P.M.	Pleas. V. & L. Can	.....	....	0.00	above mouth
24 2:00 P.M.	Larimer Co. Canal	58°	....	189.48	At rating flume
24 2:05 P.M.	Seepage	59°	(0.18)	....	From Post field
24 2:40 P|M.	Jackson Ditch ...	60°	....	20.71	At rating flume
24 3:00 P.M.	Seepage	60°	....	0.44	Intercepted by Jackson Ditch
24 4:00 P.M.	2nd River Measurem't	59°	....	92.75	Above New Mercer Ditch
		.....	309.76	303.38	Loss 6.38
Sept.					
25 10:10 A.M.	2nd River Measurem't	58°	73.12	....	Same as above
25 —— A.M.	New Mercer Ditch	.....	....	0.00	
25 10:30 A.M.	Waterworks Ditch	.....	....	(0.56)	Near head
25 10:40 A.M.	Seepage	.....	(0.95)	....	In Tobe Miller's field
25 10:50 A.M.	Lit. Cache la Pou.	59°	....	1.21	Near head
25 11:00 A.M.	Taylor & G. Ditch	60°	....	(9.60)	Not being used, wasting
25 11:15 A.M.	Chamberlin Ditch.	63°	....	(0.98)	Not being used
25 —— A.M.	John Brown Ditch	.....	....	0.00	
25 11:55 A.M.	Seepage	56°	....	0.29	From Michaud field, intercepted by No. 2
25 12:25 P.M.	Seepage	56°	(3.51)	....	Intercepted where needed by Arthur
25 —— P.M.	Arthur Ditch	.....	....	.00	At head
25 1:30 P.M.	Larimer & W. Can	67°	....	1.92	Near rating flume
25 —— P.M.	Riddle Ditch	.....	....	0.00	
25 2:10 P.M.	3rd River Measurem't	67°	....	81.95	Below Larimer & W. Canal
		.....	73.12	85.37	Gain 12.25
Sept.					
25 2:10 P.M.	3rd River Measurem't	67°	81.95	....	Same as above
25 —— P.M.	Pioneer Ditch ...	.....	....	0.00	
25 —— P.M.	Vandewark Ditch.	.....	....	0.00	
25 —— P.M.	Josh Ames Ditch.	.....	....	0.00	
25 2:40 P.M.	Lake Canal	72°	....	0.19	Below headgate
25 3:00 P.M.	John Coy Ditch..	72°	....	1.80	Below wasteway
25 3:30 P.M.	College Drain ...	61°	(0.61)	....	Near river
25 4:15 P.M.	4th River Measurem't	67°	....	105.95	Above No. 2 Feeder
		.....	81.95	107.94	Gain 25.99
Sept.					
26 9:35 A.M.	4th River Measurem't	56°	120.21	....	Same as above
25 4:50 P.M.	Seepage	63°	....	1.11	Seep. ditch from Sp'g Creek
26 9:55 A.M.	Chaffee Ditch ...	.....	....	0.59	Below headgate
26 3:55 P.M.	No. 2 Feeder	57°	....	46.61	Below Dry Creek
26 4:10 P.M.	Dry Creek	56°	(4.69)	....	Intercepted by No. 2 Feeder
26 10:20 A.M.	Spring Creek	55°	(6.70)	....	County road near mouth
26 11:10 A.M.	5th River Measurem't	57°	....	71.09	Above Box Elder Ditch
		.....	120.21	119.40	Loss 0.81

Measurement No. 22, Made September 24 - October 1, 1906 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
26 11:10 A.M.	5th River Measurem't	57°	71.09	....	Same as above
26 11:20 A.M.	Box Elder Ditch..	57°	....	2.79	Head of ditch
26 11:45 A.M.	Seepage	54°	....	3.98	Intercepted by Box Elder D.
26 —— A.M.	Box Elder Creek..	.....	(8.34)	....	
26 12:20 P.M.	Fossil Creek Feed.	57°	....	54.82	Below railroad near head
26 —— P.M.	Emigh Drain	.....	....	0.00	
26 —— P.M.	Seepage	.....	....	0.15	Intercepted by Lake Canal
26 1:10 P.M.	6th River Measurem't	57°	....	30.75	At Strauss Bridge
		.....	71.09	92.49	Gain 21.40
Sept.					
27 10:20 A.M.	6th River Measurem't	56°	22.68	....	Same as above
27 11:30 A.M.	Waste	.....	5.90	....	From Box Elder Ditch
27 11:55 A.M.	Cache la P. No. 2.	63°	....	1.48	At head
27 12:15 P.M.	7th River Measurem't	65°	....	35.72	Below Cache la P. No. 2 Can.
		.....	28.58	37.20	Gain 8.62
Sept.					
27 12:15 P.M.	7th River Measurem't	65°	35.72	....	Same as above
27 —— P.M.	Seepage	.....	....	4.34	Inter. by No. 2 Timnath Res.
27 2:05 P.M.	B. H. Eaton Ditch	63°	....	1.58	Near head
27 —— P.M.	Whitney Ditch ..	.....	....	0.00	
27 2:30 P.M.	8th River Measurem't	65°	....	39.53	Below Eaton Ditch
		.....	35.72	45.45	Gain 9.73
Sept.					
27 2:30 P.M.	8th River Measurem't	65°	39.53	....	Same as above
27 3:40 P.M.	Whitney Ditch ..	66°	....	4.37	Seepage
27 4:10 P.M.	W. R. Jones Ditch	65°	....	0.93	Headgate
27 5:15 P.M.	Greeley No. 3....	66°	....	27.49	At rating flume
27 5:30 P.M.	9th River Measurem't	66°	....	31.42	Below Greeley No. 3
		.....	39.53	64.21	Gain 24.68
27 5:30 P.M.	9th River Measurem't	66°	31.42	....	Same as above
27 6:00 P.M.	Sheep Creek	66°	....	3.82	Intercepted by No. 3
28 9:20 A.M.	Waste	57°	23.74	....	From Greeley No. 3
28 —— A.M.	Boyd Ditch	.....	....	0.00	
28 10:00 A.M.	Seepage	56°	(0.39)	....	West of pump house
28 10:20 A.M.	Greeley Mill Race	60°	....	2.03	Headgate
28 10:40 A.M.	10th River Measuremt	60°	....	74.36	North of pump house
		.....	55.16	80.21	Gain 25.05
Sept.					
28 10:40 A.M.	10th River Measuremt	60°	74.36	....	Same as above
28 —— A.M.	Waste	.....	0.19	....	Greeley mill race
28 —— A.M.	Insinger Sewer ...	.....	(4.89)	....	Going to river
28 —— A.M.	Ogilvy Ditch	.....	....	35.19	Headgate
28 —— A.M.	Camp Ditch	.....	....	0.00	
28 12:20 P.M.	11th River Measuremt	.....	....	76.64	Below Camp Ditch
		.....	74.55	111.83	Gain 37.28
Sept.					
28 12:20 P.M.	11th River Measuremt	.....	76.64	....	Same as above
28 2:15 P.M.	Seepage	67°	(1.68)	....	Inter. by Ogilvy D., wasting
28 2:25 P.M.	Seepage	63°	(1.33)	....	Inter. by Ogilvy D., wasting
28 2:30 P.M.	Seepage	67°	(6.84)	....	
28 —— P.M.	Ogilvy Waste	.....	35.19	....	
28 2:50 P.M.	Sand Creek	67°	(4.80)	....	Seepage water
28 4:00 P.M.	Seepage	66°	....	1.79	Intercepted by Ogilvy Ditch
28 3:00 P.M.	12th River Measuremt	66°	....	155.40	Near mouth Poudre
		.....	111.83	157.19	Gain 45.36
					Total Gain 216.13
Sept.					
28 4:25 P.M.	Lone Tree	.....	....	14.49	Near mouth
29 —— P.M.	Seepage	.....	....	0.45	Coal bank draw ,inter. by Larimer & Weld
29 —— P.M.	Seepage	.....	....	0.17	Inter. by Timnath Res.
Oct.					
1 —— P.M.	Seepage	.....	....	0.29	Inter. by New Mercer Ditch
2 9:30 A.M.	Seepage	.....	....	0.89	Inter. by Warren Lake
2 10:00 A.M.	Seepage	.....	....	0.76	Inter. by High Line going to Fossil Creek
2 10:25 A.M.	Fossil Creek	.....	....	2.86	Above Fossil Creek Res.
2 3:25 P.M.	Seepage	.....	....	0.19	Near Garrett place
2 3:50 P.M.	Brandis Seepage..	.....	....	2.31	Empties into Lari. & W. Can.
2 5:10 P.M.	Seepage	.....	....	0.09	Intercepted by Terry Lake
					Total Seep. 224.95

CACHE LA POUDRE RIVER

Measurement No. 23, Made September 16 - October 5, 1907.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
16 1:30 P.M.	Poudre V. Canal...	.....	....	(8.30)	Above weir
16 11:15 A.M.	1st River Measurem't	.....	230.84	....	At weir
16 —— P.M.	Seepage	.....	(0.05)	....	At weir
16 1:04 P.M.	Greeley Wat'ks...	.....	....	19.91	At head
16 10:30 A.M.	Pleas. V. & L. Can.	.....	....	1.08	Near head
16 1:10 P.M.	Hook & Moore G'ch	.....	4.59	....	A little seepage, largely waste
16 1:15 P.M.	Larimer Co. Canal	.....	....	124.14	Rating flume
16 —— P.M.	Henderson Ditch..	.....	....	0.00	
16 —— P.M.	Seepage	.....	(0.05)	....	Capt. Post field
16 2:15 P.M.	Poudre River	.....	....	(86.08)	Below Larimer Co. Canal
16 3:20 P.M.	Jackson Canal ...	.....	....	14.00	At rating flume
16 —— P.M.	Seepage	.....	....	0.36	Intercepted by Jackson Ditch
16 4:10 P.M.	2nd River Measurem't	.....	....	80.84	Above New Mercer Ditch
		.....	235.43	240.33	Gain 4.90
Sept.					
17 9:45 A.M.	2nd River Measurem't	.....	80.56	....	Same as above
17 —— A.M.	New Mercer Ditch	.....	....	(0.10)	At head
17 —— A.M.	Lar. Co. No. 2 C.	.....	....	0.00	Below wasteway
17 10:30 A.M.	Seepage	.....	(0.55	....	In Tobe Miller field
17 10:45 A.M.	Lit. Cache la P. D.	.....	....	5.55	At road crossing at head
17 10:50 A.M.	Taylor & G. Ditch.	.....	....	3.85	At road crossing at head
17 11:07 A.M.	Chamberlin Ditch.	.....	....	0.31	
17 —— A.M.	John Brown Ditch	.....	....	0.00	
17 11:40 A.M.	Seepage	.....	....	0.16	Intercepted by No. 2 Canal
17 11:45 A.M.	New Mercer Ditch	.....	....	0.75	Includes seepage intercepted
17 12:15 P.M.	Seepage	.....	(1.94)	....	Near road cross'g Arthur seep
17 12:55 P.M.	Arthur Ditch	.....	....	5.76	Below wasteway
17 2:05 P.M.	Larimer & W. Can	.....	....	1.73	Near headgate
17 —— P.M.	Riddle Ditch	.....	....	1.79	Near head
17 2:20 P.M.	3rd River Measurem't	.....	....	69.48	Below Larimer & W. dam
		.....	80.56	89.38	Gain 8.82
Sept.					
17 2:20 P.M.	3rd River Measurem't	.....	69.48	....	Same as above
17 2:57 P.M.	Pioneer Ditch ...	.....	....	1.68	At head
17 3:00 P.M.	Vandewark Ditch.	.....	....	0.33	At head
17 —— P.M.	Josh Ames Slough	.....	....	0.00	
17 3:15 P.M.	Lake Canal	.....	....	1.44	Road crossing below head
17 3:35 P.M.	Coy Ditch	.....	....	4.15	Below wasteway
17 4:05 P.M.	Seepage	.....	(0.76)	....	College drain
17 4:10 P.M.	4th River Measurem't	.....	....	81.41	Above No. 2 Feeder
		.....	69.48	89.01	Gain 19.53
Sept.					
18 9:25 A.M.	4th River Measurem't	.....	90.70	....	Same as above
18 —— A.M.	No. 2 Feeder	.....	....	0.00	
18 9:30 A.M.	Chaffee Ditch	.....	....	0.29	At head
18 10:00 A.M.	Spring Creek	.....	(5.78)	....	Road crossing near mouth
18 3:00 P.M.	Dry Creek	.....	(3.21)	....	Near mouth
18 10:20 P.M.	5th River Measurem't	.....	....	87.82	Above Box Elder Ditch
		.....	90.70	88.11	Loss 2.59
Sept.					
18 10:20 A.M.	5th River Measurem't	.....	87.82	....	Same as above
18 10:50 A.M.	Box Elder Ditch..	.....	....	15.60	Near head
18 11:20 A.M.	Intercepted seep..	.....	....	2.02	By Box Elder Ditch
18 —— A.M.	Intercepted seep..	.....	....	3.05	By Box Elder Ditch
18 —— A.M.	Fossil Ck Rs Inlet	.....	....	0.00	
18 1:55 P.M.	Intercepted Seep..	.....	(9.05)	4.26	Pitcher field
18 12:05 P.M.	6th River Measurem't	.....	....	87.26	At Strauss Bridge
		.....	87.82	112.19	Gain 24.37
Sept.					
19 9:55 A.M.	6th River Measurem't	.....	85.99	....	Same as above
19 11:10 A.M.	Fossil Ck Res Out	.....	26.51	....	
19 11:30 A.M.	Waste	.....	6.33	....	From Box Elder Ditch
19 1:05 P.M.	Cache la P. No. 2.	.....	....	57.25	Rating flume
19 —— P.M.	Intercepted Seep..	.....	....	6.72	From Timnath Reservoir
19 2:40 P.M.	7th River Measurem't	.....	....	62.76	Below Cache la Poudre No. 2
		.....	118.83	126.73	Gain 7.90
Oct.					
4 11:00 A.M.	7th River Measurem't	.....	67.74	....	Same as above
4 12:40 P.M.	Whitney Ditch ...	.....	....	0.78	Road near head
4 12:55 P.M.	B. H. Eaton Ditch	.....	....	0.57	
4 1:30 P.M.	8th River Measurem't	.....	80.14	....	Below Eaton Ditch
		.....	67.74	81.49	Gain 13.75

CACHE LA POUDRE RIVER

Measurement No. 23, Made September 16 - October 5, 1907 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Oct.					
4 1:30 P.M.	8th River Measurem't	.....	80.14	....	Same as above
4 2:30 P.M.	Waste	.....	10.02	....	From Windsor sugar factory
4 2:45 P.M.	Seepage	.....	(9.15)	....	1½ mi. southeast of Windsor
4 3:10 P.M.	Whitney Ditch ...	.....	....	0.35	Road crossing, inter, seepage
4 3:40 P.M.	Jones Ditch	.....	....	0.77	Headgate
4 —— P.M.	Greeley No. 3 Can.	.....	....	0.00	Below wasteway
4 4:45 P.M.	9th River Measurem't	.....	....	113.01	Below Geeley No. 3 Canal
		.....	90.16	114.13	Gain 23.97
Oct.					
4 4:45 P.M.	9th River Measurem't	.....	113.01	....	Same as above
4 5:50 P.M.	Sheep Creek	.....	(3.68)	....	Near mouth into No. 3
5 8:00 A.M.	Mill Race	.....	....	1.59	Near head
5 8:05 A.M.	10th River Measuremt	.....	....	142.23	North of pump house
		.....	113.01	143.82	Gain 30.81
Oct.					
5 8:05 A.M.	10th River Measuremt	.....	142.23	....	Same as above
5 —— A.M.	Insinger Sewer ...	.....	(8.89)	....	
5 9:45 A.M.	Ogilvy Ditch	.....	....	1.97	Near headgate
5 11:10 A.M.	Camp Ditch	.....	....	4.24	Contains slough supply
5 11:30 A.M.	Waste	.....	4.39	....	From sugar factory
5 11:00 A.M.	11th River Measuremt	.....	....	178.05	Below Camp Ditch
		.....	146.62	184.26	Gain 37.64
Oct.					
5 11:00 A.M.	11th River Measuremt	.....	178.05	....	Same as above
5 1:40 P.M.	Seepage	.....	(2.03)	....	Inte. by Ogilvy D., but wast'g
5 1:50 P.M.	Seepage	.....	(0.89)	....	Inter by Ogilvy D., but wast'g
5 2:00 P.M.	Seepage	.....	(5.70)	....	Inter by Ogilvy D., but wast'g
5 —— P.M.	Waste	.....	1.97	....	From Ogilvy Ditch
5 2:25 P.M.	Sand Creek	.....	(4.17)	....	Seepage near mouth
5 4:00 P.M.	12th River Measuremt	.....	....	214.07	Near mouth of Poudre
		.....	180.02	214.07	Gain 34.05
					Total Gain 204.39
Oct.					
5 4:20 P.M.	Lone Tree Creek	.....	16.42	....	Near mouth

CACHE LA POUDRE RIVER

Measurement No. 24, Made September 14-16, 1908.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
14 2:15 P.M.	Poudre Val. Canal	77°	....	1.34	Above weir
14 1:50 P.M.	1st River Measurem't	66°	272.83	....	At weir
14 —— P.M.	Seepage	.....	(0.12)	....	Near weir
14 2:25 P.M.	Canon Canal	66°	....	1.18	Near head
14 12:20 P.M.	Greeley Wtr Wks.	62°	....	6.87	Intake
14 10:50 A.M.	Pleas. V. & L. Can.	62°	....	90.26	At rating flume
14 2:35 P.M.	Hook and Moore..	71°	(1.28)	....	Road crossing
14 3:05 P.M.	Larimer Co. Canal	66°	....	26.07	At rating flume
14 —— P.M.	Henderson Ditch..	.....	....	0.00	
14 3:45 P.M.	Jackson Ditch ...	67°	....	12.07	At rating flume
14 4:00 P.M.	Intercepted Seep..	59°	....	(0.19)	By Jackson Ditch
14 5:00 P.M.	2nd River Measurem't	66°	....	149.14	Above New Mercer Ditch
		.....	272.83	285.78	Gain 12.95
Sept.					
15 11:10 A.M.	2nd River Measurem't	64°	157.76	....	Same as above
15 11:45 A.M.	New Mercer Ditch	65°	....	30.33	At rating flume
15 —— A.M.	Larimer Co. No. 2	.....	....	0.00	
15 11:55 A.M.	Reservoir Water..	68°	13.90	....	From Claymore lake
15 12:50 P.M.	Lit. Cache la P...	67°	....	4.70	Near head
15 1:05 P.M.	Taylor & G. Ditch.	67°	....	19.26	Near head
15 1:20 P.M.	Chamberlin Ditch.	68°	....	(3.17)	Wastes to river
15 1:05 P.M.	John Brown Ditch	73°	....	5.36	Near head
15 2:45 P.M.	Intercepted Seep..	55°	....	5.88	By Arthur Ditch
15 3:05 P.M.	Arthur Ditch	70°	....	12.78	At rating flume
15 4:10 P.M.	Larimer & W. Can.	71°	....	21.54	At rating flume
15 4:25 P.M.	Riddle Ditch	70°	....	4.56	At head
15 5.05 P.M.	3rd River Measurem't	70°	....	78.41	Below Larimer & W. dam
		.....	171.66	182.82	Gain 11.16

CACHE LA POUDRE RIVER

Measurement No. 24, Made September 14-16, 1908 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
22 9:40 A.M.	3rd River Measurem't	59°	41.67	....	Same as above
22 10:10 A.M.	Pioneer Ditch ...	60°	....	2.22	Near head
22 10:15 A.M.	Vandewark Ditch.	60°	....	0.12	
22 —— A.M.	Josh Ames Ditch..	.....	....	0.00	
22 —— A.M.	Lake Canal	.....	....	0.05	
22 10:40 A.M.	Coy Ditch	64°	....	0.45	Near head
23 —— A.M.	College Drain ...	.....	....	0.50	Intercepted
22 11:45 A.M.	4th River Measurem't	67°	56.76	....	Above No. 2 feeder
		.....	41.67	60.10	Gain 18.43
Sept.					
22 11:45 A.M.	4th River Measurem't	67°	56.76	....	Same as above
22 —— A.M.	No. 2 Feeder	.....	....	0.00	At head
22 11:50 A.M.	Chaffee Ditch	67°	....	0.08	At head
22 2:25 P.M.	Spring Creek	67°	(2.69)	....	Road near mouth
22 2:30 P.M.	Side Hill Ditch...	70°	....	2.93	Intercepted from Spring Cr'k
23 9:45 A.M.	Dry Creek	57°	(4.38)	....	Road near mouth
22 3:15 P.M.	5th River Measurem't	70°	....	49.87	Above Box Elder Ditch
		.....	56.76	52.88	Loss 3.88
Sept.					
22 3:15 P.M.	5th River Measurem't	70°	49.87	....	Same as above
22 3:40 P.M.	Box Elder Ditch..	71°	....	17.23	Near head
22 —— P.M.	Fossil Creek Inlet.	.....	....	0.00	
22 4:40 P.M.	Intercepted Seep..	56°	....	1.28	By Box Elder Ditch
22 4:50 P.M.	Intercepted Seep..	57°	....	2.06	By Box Elder Ditch
23 10:10 A.M.	Box Elder Creek..	56°	(2.52)	....	In Pitcher's field
23 10:45 A.M.	Intercepted Seep..	64°	....	3.22	By No. 2 Feeder
22 5:45 P.M.	6th River Measurem't	71°	....	53.94	At Strauss Bridge
		.....	49.87	77.73	Gain 27.86
Sept.					
24 10:35 A.M.	6th River Measurem't	68°	62.74	....	Same as above
24 10:45 A.M.	Waste	61°	0.97	....	From Box Elder Ditch
24 11:50 A.M.	Fossil Ck Outlet..	66°	109.21	....	Road near mouth
24 12:20 P.M.	Waste	60°	12.56	....	From Box Elder Ditch
24 1:10 P.M.	Greeley No. 2 D..	67°	....	110.38	At rating flume
24 1:50 P.M.	7th River Measurem't	67°	....	78.51	Below Greeley No. 2
		.....	185.48	188.89	Gain 3.41
Sept.					
24 1:50 P.M.	7th River Measurem't	67°	78.51	....	Same as above
24 2:50 P.M.	Intercepted Seep..	72°	....	8.00	From Timnath Reservoir
24 3:35 P.M.	Whitney Ditch ...	71°	....	21.83	Road near head
24 3:50 P.M.	B. H. Eaton Ditch	70°	....	7.34	Near head
24 4:20 P.M.	8th River Measurem't	71°	....	37.21	Below Eaton Ditch
		.....	78.51	74.38	Loss 4.13
Sept.					
25 8:50 A.M.	8th River Measurem't	61°	32.96	....	Same as above
25 9:40 A.M.	Seepage	59°	(3.58)	....	East of Windsor
25 11:30 A.M.	Jones Ditch	63°	....	5.82	At headgate
25 12:50 P.M.	Greeley No. 3....	64°	....	70.97	at rating flume
25 1:00 P.M.	9th River Measurem't	64°	....	2.95	Below Greeley No. 3
		.....	32.96	79.74	Gain 46.78
Sept.					
25 1:00 P.M.	9th River Measurem't	64°	2.95	....	Same as above
25 1:35 P.M.	Sheep Creek	74°	....	0.45	Intercepted by No. 3
25 1:50 P.M.	Boyd & Freeman..	65°	....	2.02	Near head
25 2:40 P.M.	Seepage	63°	(1.31)	....	West of pump house
25 2:50 P.M.	Mill race	63°	....	1.76	Near head
25 3:10 P.M.	10th River Measuremt	63°	21.38	....	North of pump house
		.....	2.95	25.61	Gain 22.66
Sept.					
25 3:30 P.M.	10th River Measuremt	63°	21.38	....	Same as above
25 5:30 P.M.	Greeley Sewer ...	.....	....	7.23	Intercepted
25 4:40 P.M.	Ogilvy Ditch	60°	....	49.08	150 yards below head
25 —— P.M.	Camp Ditch	.....	....	0.00	
25 —— P.M.	Camp Slough Sup.	54°	....	1.49	
25 5:05 P.M.	11th River Measuremt	69°	....	0.79	Below Camp Ditch
		.....	21.38	58.59	Gain 37.21

CACHE LA POUDRE RIVER

Measurement No. 24, Made September 14-16, 1908 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
25 5:05 P.M.	11th River Measuremt	60°	0.79	....	Same as above
26 9:40 A.M.	Seepage	49°	....	2.00	Intercepted by Ogilvy Ditch
26 9:45 A.M.	Seepage	47°	....	1.32	Intercepted by Ogilvy Ditch
26 10:00 A.M.	Waste	49°	16.01	....	From Ogilvy Ditch
26 10:30 A.M.	Sand Creek	50°	8.20	....	Road near mouth
26 11:35 A.M.	12th River Measuremt	54°	....	74.57	Near mouth of Poudre
		.....	25.00	77.89	Gain 52.89
Sept.					Total Gain 205.21
26 12:35 P.M.	Lone Tree Creek.....	.....	6.99	....	1½ miles above mouth

CACHE LA POUDRE RIVER

Section with Some Doubt.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
30 10:50 A.M.	11th River Measuremt	56°	32.76	....	Below Camp Ditch
30 11:15 A.M.	Intercepted Seep..	50°	....	1.85	By Ogilvy Ditch
30 11:20 A.M.	Intercepted Seep..	55°	....	0.92	By Ogilvy Ditch
30 11:35 A.M.	Intercepted Seep..	56°	....	7.28	By Ogilvy Ditch
30 12:05 P.M.	Waste	57°	47.96	....	From Ogilvy Ditch wasteway
30 12:30 P.M.	Sand Creek	60°	(5.68)	....	Road near mouth
Oct.					
1 —— P.M.	Waste	.....	18.73	....	From Gree. No. 3 lower waste
30 2:00 P.M.	12th River Measuremt	62°	....	138.72	Near mouth
		.....	99.45	148.72	Gain 49.27
Oct.					
6 11:35 A.M.	7th River Measurem't	56°	32.12	....	Below Greeley No. 2
6 12:10 P.M.	Intercepted Seep..	64°	(4.39)	....	From Timnath Reservoir
6 12:50 P.M.	Whitney Ditch...	57°	....	10.46	Road near head
6 1:10 P.M.	B. H. Eaton Ditch	55°	....	9.03	Near head
6 1:35 P.M.	8th River Measurem't	56°	....	22.99	Below Eaton Ditch
		.....	32.12	42.48	Gain 10.36
Oct.					
6 1:35 P.M.	8th River Measurem't	56°	22.99	....	Below Eaton Ditch
6 —— P.M.	Waste	.....	10.46	....	Whitney ditch at wasteway
6 —— P.M.	Waste	.....	9.03	....	B. H. Eaton ditch
6 2:40 P.M.	Waste	.....	9.81	....	From sugar factory
6 3:00 P.M.	Seepage	59°	(10.25)	....	East of Windsor
6 3:25 P.M.	Whitney Ditch ...	57°	....	1.56	2 miles east of Windsor
6 3:50 P.M.	Jones Ditch.. ...	59°	....	4.60	At headgate
6 —— P.M.	Greeley No. 3....	.....	....	0.00	
6 5:35 P.M.	9th River Measurem't	59°	....	72.63	Below Greeley No. 3
		.....	52.29	78.79	Gain 26.50
Sept.					Total Gain using these measurements 205.21
30 3:55 P.M.	Lone Tree Creek..	61°	....	6.78	1½ miles above mouth
30 3:30 P.M.	Cook Ditch	59°	....	10.53	Out of Lone Tree Creek

CACHE LA POUDRE RIVER

Measurement No. 25, Made May 7-27, 1909.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
May					
7 9:55 A.M.	1st River Measurem't	50°	70.81	....	Below Larimer and Weld
7 10:20 A.M.	Pioneer Ditch....	60°	....	0.19	Near head
7 10:25 A.M.	Seepage	56°	(0.38)	....	Rock Bush place
7 10:35 A.M.	Vandewark Ditch.	60°	....	0.41	Near headgate
7 —— A.M.	Josh Ames Ditch..	.....	....	0.00	
7 —— A.M.	Lake Canal	.....	....	0.00	
7 11:00 A.M.	Coy Ditch	63°	....	0.38	Below wasteway
7 11:20 A.M.	College Drain	65°	(0.47)	....	Near river
7 12:00 M.	2nd River Measurem't	65°	....	78.65	Above No. 2 Feeder
		.....	70.81	79.63	Gain 8.82

CACHE LA POUDRE RIVER

Measurement No. 25, Made May 7-27, 1909 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
May					
7 12:00 M.	2nd River Measurem't	65°	78.65	....	Same as above
7 —— P.M.	Chaffee Ditch ...	.....	....	0.00	
7 —— P.M.	No. 2 Feeder.....	.....	....	0.00	
7 —— P.M.	Spring Creek	.....	(9.43)	....	Road near mouth
7 —— P.M.	Dry Creek	.....	(6.23)	....	Near mouth
7 3:10 P.M.	3rd River Measurem't	61°	....	86.20	Above Box Elder Ditch
		.....	78.65	86.20	Gain 7.55
May					
27 10:10 A.M.	3rd River Measurem't	57°	156.60	....	Same as above
27 10:35 A.M.	Box Elder Ditch..	57°	....	12.85	At head
27 —— A.M.	Inlet Fossil Creek.	.....	....	0.00	
27 5:25 P.M.	Box Elder Creek..	65°	18.93	....	
27 —— P.M.	Seepage	.....	(2.19)	....	Near Strauss Bridge
27 12:20 P.M.	4th River Measurem't	67°	....	192.15	At Strauss Bridge
		.....	175.53	205.00	Gain 29.47
May					
27 12:20 P.M.	4th River Measurem't	67°	192.15	....	Same as above
27 —— P.M.	Outlet Fossil Ck R.	.....	32.91	....	Road near river
27 —— P.M.	Waste	.....	0.25	....	From Box Elder Ditch
27 3:15 P.M.	Greeley No. 2 D..	.....	....	178.75	At rating flume
27 3:25 P.M.	5th River Measurem't	.....	....	42.89	Below Greeley No. 2.
		.....	225.31	221.64	Loss 3.67
May					
12 12:25 P.M.	6th River Measurem't	58°	9.83	....	Same as above
12 1:25 P.M.	Seepage	.....	....	1.98	Inter. from Timnath Reser.
12 —— P.M.	Whitney Ditch...	.....	....	0.00	
12 —— P.M.	B. H. Eaton Ditch	.....	....	0.00	
12 2:25 P.M.	7th River Measurem't	63°	....	21.55	Below Eaton Ditch
		.....	9.83	23.53	Gain 13.70
May					
12 2:25 P.M.	7th River Measurem't	63°	21.55	....	Same as above
12 3:50 P.M.	River	60°	....	34.06	Road bridge s'theast Windsor
13 10:10 A.M.	River	52°	53.97	....	Road bridge s'theast Windsor
13 10:45 A.M.	Seepage	55°	....	4.02	Inter. east of Windsor
13 —— A.M.	Jones Ditch	.....	....	0.00	At headgate
13 1:05 P.M.	Greeley No. 3....	60°	....	56.43	At rating flume
13 1:15 P.M.	8th River Measurem't	61°	....	0.27	Below Greeley No. 3 .. ....
		.....	75.52	94.78	Gain 19.26
May					
13 1:15 P.M.	9th River Measurem't	61°	0.27	....	Below Greeley No. 3
13 —— P.M.	Sheep Draw	.....	....	0.10	
13 2:15 P.M.	Waste	.....	0.61	....	From Greeley No. 3
13 —— P.M.	Boyd & Freeman..	.....	....	0.00	
13 3:10 P.M.	Seepage	65°	(1.89)	....	West of pump house
13 4:05 P.M.	10th River Measuremt	62°	41.70	....	North of pump house
		.....	0.88	41.80	Gain 40.92
May					
13 4:05 P.M.	11th River Measuremt	62°	41.70	....	Same as above
14 8:40 A.M.	Insinger Sewer ...	.....	....	2.22	Intercepted at river crossing
13 5:30 P.M.	Ogilvy Ditch	56°	....	47.73	At headgate
13 5:40 P.M.	12th River Measuremt	56°	....	7.21	Below Ogilvy Ditch
		.....	41.70	57.16	Gain 15.46
May					
14 9:35 A.M.	12th River Measuremt	56°	2.33	....	Below Ogilvy Ditch
14 —— A.M.	Camp Ditch	.....	....	0.00	
14 9:55 A.M.	Camp Slough	56°	(.31)	....	
14 10:15 A.M.	Seepage	58°	....	0.44	Intercepted by Ogilvy Ditch
14 —— A.M.	Bradfield Seepage.	.....	....	9.82	Intercepted
14 10:45 A.M.	Sand Creek	.....	(4.51)	....	
14 2:15 P.M.	Waste	.....	0.97	....	From Greeley No. 3
14 12:05 P.M.	13th River Measuremt	.....	....	44.18	Near mouth
		.....	3.30	54.44	Gain 51.14
					Total Gain 182.65

CACHE LA POUDRE RIVER

Measurement No. 26, Made August 6, 1909.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
6 1:15 P.M.	1st River Measurem't	.....	124.39	....	Below Greeley No. 2
6 2:30 P.M.	Whitney Ditch ...	.....	....	34.87	Near head
6 2:45 P.M.	B. H. Eaton Ditch	.....	....	21.03	Near head
6 3:30 P.M.	2nd River Measurem't	.....	....	58.71	Below Eaton Ditch
		.....	124.39	114.61	Loss 9.78
Aug.					
6 3:30 P.M.	2nd River Measurem't	.....	58.71	....	Same as above
6 5:00 P.M.	River	.....	....	67.72	At Windsor farm
7 1:20 P.M.	River	76°	81.06	....	At Windsor farm
7 2:40 P.M.	Jones Ditch	78°	....	4.76	At headgate
7 4:15 P.M.	Greeley No. 3....	79°	....	84.26	At rating flume
7 4:30 P.M.	3rd River Measurem't	79°	....	8.89	Below Greeley No. 3
		.....	139.77	165.63	Gain 25.86
Aug.					
7 4:30 P.M.	3rd River Measurem't	70°	8.89	....	Same as above
7 5:15 P.M.	Sheep Creek	70°	....	4.81	Intercepted by No. 3
7 5:40 P.M.	Boyd & Freeman..	77°	....	10.69	Near head
8 8:40 A.M.	4th River Measurem't	69°	....	35.00	North of pump house
		.....	8.89	50.50	Gain 41.61
Aug.					
8 8:40 A.M.	4th River Measurem't	69°	35.00	....	Same as above
8 9:25 A.M.	Insinger Sewer ...	.....	(1.53)	2.86	Part used, rest wasting
8 10:00 A.M.	Ogilvy Ditch	72°	....	52.34	At headgate
8 —— A.M.	Camp Ditch	.....	....	0.00	
8 10:15 A.M.	Camp Slough D...	72°	....	1.96	
8 —— A.M.	5th River Measurem't	.....	....	0.50	Below Camp Ditch
		.....	35.00	57.66	Gain 22.66
Aug.					
8 —— A.M.	5th River Measurem't	.....	0.50	....	Same as above
8 10:45 A.M.	Seepage	76°	....	0.73	Intercepted by Ogilvy Ditch
8 10:50 A.M.	Seepage	70°	....	1.37	Intercepted by Ogilvy Ditch
8 11:00 A.M.	Seepage	75°	....	2.22	Intercepted by Ogilvy Ditch
8 —— A.M.	Sand Creek	.....	0.00	....	
8 4:10 P.M.	Bradfield Seepage.	77°	....	8.93	Intercepted
8 12:30 P.M.	6th River Measurem't	70°	....	43.25	Near mouth
		.....	0.50	56.50	Gain 56.00

CACHE LA POUDRE RIVER

Measurement No. 27, Made October 5-10, 1909.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Oct.					
5 12:20 P.M.	1st River Measurem't	.....	168.22	....	At weir
5 —— P.M.	Seepage	.....	(0.10)	....	Near weir
5 —— P.M.	Canon Canal	.....	....	0.45	Near head
5 —— P.M.	Greeley Wat'ks...	.....	....	13.18	At head
5 —— P.M.	Pleas. V. & L. Can	.....	....	0.25	
5 2:40 P.M.	Larimer Co. Canal	.....	....	44.37	At flume
5 2:40 P.M.	Anderson Ditch..	.....	....	0.07	
5 2:40 P.M.	Seepage	.....	(0.15)	....	Post's field
5 3:30 P.M.	Jackson	.....	....	20.53	At flume
5 3:50 P.M.	2nd River Measurem't	.....	....	104.69	Above New Mercer Ditch
		.....	168.22	183.54	Gain 15.32
Oct.					
6 10:20 A.M.	2nd River Measurem't	.....	108.08	....	Same as above
6 10:20 A.M.	New Mercer Ditch	.....	....	0.00	
3 10:20 A.M.	Lar. Co. No. 2 C.	.....	....	0.00	
6 11:25 A.M.	Lit. Cache la P..	.....	....	20.69	At headgate
6 11:40 A.M.	Taylor & G. Ditch	.....	....	1.02	Near head
6 —— A.M.	J. Brown Ditch...	.....	....	0.00	
6 —— A.M.	Chamberlin Ditch.	.....	....	0.00	
6 1:00 P.M.	Intercepted Seep..	.....	....	2.26	By Arthur Ditch
6 —— P.M.	Arthur Ditch	.....	....	0.25	Small leak
6 2:45 P.M.	Larimer & Weld..	.....	....	25.11	At flume
6 2:50 P.M.	Riddle Ditch	.....	....	1.22	
6 3:15 P.M.	3rd River Measurem't	.....	....	83.32	Below Larimer & Weld
		.....	108.08	133.87	Gain 25.79

CACHE LA POUDRE RIVER

Measurement No. 27, Made October 5-10, 1909 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Oct.					
6 3:15 P.M.	3rd River Measurem't	.....	83.32	....	Same as above
6 3:20 P.M.	Pioneer Ditch ...	.....	....	0.26	At Rock Bush place
6 3:40 P.M.	Seepage	.....	0.22	....	At Rock Bush place
6 3:50 P.M.	Vandewark Ditch.	.....	....	0.28	Below headgate
6 4:10 P.M.	Lake Canal	.....	....	3.02	Near head
6 4:25 P.M.	Coy Ditch	.....	....	1.76	Near head
6 4:40 P.M.	Seepage	.....	0.33	....	College drain
6 4:40 P.M.	Sugar Fac. Waste.	.....	....	9.26	Comes in 150yd below Riv. M
6 5:10 P.M.	4th River Measurem't	.....	....	77.86	Above No. 2 Feeder
		.....	83.87	92.44	Gain 8.57
Oct.					
7 9:00 A.M.	4th River Measurem't	.....	80.74	....	Same as above
7 9:45 A.M.	Chaffee Ditch ...	.....	....	0.22	At head
7 3:00 P.M.	No. 2 Feeder.....	.....	....	35.22	At flume near Dry Creek
7 10:00 A.M.	Sugar Fac. Waste	.....	9.26	....	Gain given to section above
7 3:15 P.M.	Dry Creek	.....	(1.58)	....	
7 10:30 A.M.	Spring Creek	.....	(7.90)	....	At road near mouth
7 11:30 A.M.	5th River Measurem't	.....	....	49.50	Above Box Elder Ditch
		.....	90.00	84.94	Loss 5.06
Oct.					
7 11:30 A.M.	5th River Measurem't	.....	49.50	....	Same as above
7 12:15 P.M.	Inlet Fossil Creek	.....	....	55.71	Taken at road below for seep.
7 12:30 P.M.	Box Elder Ditch..	.....	....	3.40	Taken at road below for seep.
7 2:20 P.M.	Box Elder Creek..	.....	(9.76)	....	In Pitcher's field
7 1:20 P.M.	Seepage	.....	(0.66)	....	At Strauss Bridge
7 1:20 P.M.	6th River Measurem't	.....	....	16.39	At Strauss Bridge
		.....	49.50	75.50	Gain 26.00
Oct.					
8 10:40 A.M.	6th River Measurem't	.....	7.44	....	Same as above
8 10:40 A.M.	Fossil Creek outlet	.....	0.00	....	
8 10:40 A.M.	Seepage	.....	3.40	....	Box Elder waste
8 10:40 A.M.	Greeley No. 2....	.....	....	....	
8 12:20 P.M.	7th River Measurem't	.....	....	14.98	Below Greeley No. 2
		.....	10.84	14.98	Gain 4.14
Oct.					
8 12:20 P.M.	7th River Measurem't	.....	14.98	....	Same as above
8 1:15 P.M.	Timnath Reservoir	.....	(5.60)	....	Going to river seepage
8 1:15 P.M.	Whitney Ditch ..	.....	....	0.00	
8 2:00 P.M.	Eaton Ditch......	.....	....	8.03	Near head, waste below
8 2:30 P.M.	8th River Measurem't	.....	....	15.09	Below Eaton Ditch
		.....	14.98	23.12	Gain 8.14
Oct.					
8 2:30 P.M.	8th River Measurem't	.....	15.09	....	Same as above
8 3:30 P.M.	Factory Waste ...	.....	1.41	....	Near Windsor
8 —— P.M.	Eaton Ditch	.....	....	8.03	
8 4:10 P.M.	River	.....	....	26.88	At Windsor farm
9 10:10 A.M.	River	.....	23.98	....	At Windsor farm
9 —— A.M.	Seepage	.....	13.00	....	
9 —— A.M.	Jones Ditch	.....	....	0.00	
9 —— A.M.	Greeley No. 3....	.....	....	0.00	
9 1:10 P.M.	9th River Measurem't	.....	....	45.54	Below Greeely No. 3
		.....	52.48	80.45	Gain 27.97
Oct.					
9 1:10 P.M.	9th River Measurem't	.....	45.54	....	Same as above
9 —— P.M.	Boyd & Freeman.	.....	....	0.00	
9 1:40 P.M.	Sheep Draw	.....	(3.24)	....	Inter. by No. 3 but waste at wasteway
9 3:00 P.M	Seepage	.....	(2.02)	....	West of pump house
9 4:10 P.M.	10th River Measuremt	.....	....	69.14	North of pump house
		.....	45.54	69.14	Gain 23.60
Oct.					
9 4:10 P.M.	10th River Measuremt	.....	69.14	....	Same as above
10 8:15 A.M.	Insinger Sewer ...	.....	(10.93)	....	Wasting
10 8:40 A.M.	Sugar Factory ...	.....	1.66	....	
10 —— A.M.	Ogilvy Ditch	.....	....	0.00	
10 —— A.M.	Camp Ditch	.....	....	0.00	
10 9:45 A.M.	11th River Measuremt	.....	....	101.28	Below Camp Ditch
		.....	70.80	101.28	Gain 30.48

CACHE LA POUDRE RIVER

Measurement No. 27, Made October 5-10, 1909 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Oct.					
10 9:45 A.M.	11th River Measuremt	.....	101.28	....	Same as above
10 9:50 A.M.	Camp Slough.....	.....	(1.92)	....	Seepage
10 10:20 A.M.	Seepage	.....	....	1.84	Intercepted by Ogilvy Ditch
10 10:45 A.M.	Seepage	.....	....	1.45	Intercepted by Ogilvy Ditch
10 10:30 A.M.	Seepage	.....	....	17.56	Intercepted by Ogilvy Ditch
10 —— A.M.	Ogilvy Wasteway.	.....	20.85	....	Ogilvy dry below wasteway
10 —— A.M.	Sand Creek	.....	(2.76)	....	
10 —— A.M.	12th River Measuremt	.....	....	144.87	At mouth
		....	122.13	165.72	Gain 43.59
					Total Gain 208.54

CACHE LA POUDRE RIVER

Partial Measurement No. 28, Made June 11, 1910.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
June					
11 11:10 A.M.	1st River Measurem't	69°	123.50	....	Below Greeley No. 2
11 11:45 A.M.	Seepage	70°	....	5.43	By G. No. 2 from Tim. Res.
11 12:55 P.M.	Whitney Ditch ..	72°	....	44.86	Near head
11 1:20 P.M.	B. H. Eaton Ditch	72°	....	20.94	At rating flume
11 2:00 P.M.	2nd River Measurem't	72°	....	52.12	Below Eaton Ditch
		.....	123.50	123.35	Loss 0.15
June					
11 2:00 P.M.	2nd River Measurem't	72°	52.12	....	Same as above
13 10:20 A.M.	Seepage	61°	....	4.25	Intercepted east of Windsor
11 4:10 P.M.	Jones Ditch	73°	....	9.74	At headgate
11 5:30 P.M.	Greeley No. 3.....	77°	....	58.16	At rating flume
11 5:55 P.M.	3rd River Measurem't	78°	....	1.77	Below No. 3
		.....	52.12	73.92	Gain 21.80
June					
11 5:55 P.M.	3rd River Measurem't	78°	1.77	....	Same as above
11 —— P.M.	Sheep Draw	.....	....	0.10	
11 —— P.M.	Boyd & Freeman.	.....	....	0.00	
11 7:10 P.M.	Seepage	.....	(0.30)	....	West of pump house
13 8:40 A.M.	Seeley Lake	68°	2.53	....	From Ogilvy Ditch
12 9:00 A.M.	4th River Measurem't	64°	....	28.03	North of pump house
		.....	4.30	28.13	Gain 23.83
June					
12 9:00 A.M.	4th River Measurem't	64°	28.03	....	Same as above
12 9:45 A.M.	Ensinger Sewer...	.....	(3.64)	....	At river crossing
12 10:20 A.M.	Ogilv Ditch	66°	....	42.44	At headgate
12 10:40 A.M.	Camp Ditch	71°	....	1.23	Near head
12 —— A.M.	5th River Measurem't	.....	....	0.00	Below Camp Ditch
		.....	28.03	43.67	Gain 15.64
June					
12 —— A.M.	5th River Measurem't	.....	0.00	....	Same as above
12 11:00 A.M.	Seepage	73°	....	0.20	Inter. by Ogilvy Ditch
12 11:10 A.M.	Seepage	66°	....	0.40	Inter. by Ogilvy Ditch
12 2:10 P.M.	Sand Creek	72°	(2.58)	....	Road near mouth
12 3:10 P.M.	6th River Measurem't	66°	....	36.46	Near mouth
		.....	0.00	37.06	Gain 37.06
					Total Gain 98.18

CACHE LA POUDRE RIVER.

Partial Measurement No. 29, Made July 13-14, 1910.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Outtake	NOTES—
July					
13 11:05 A.M.	1st River Measurem't	68°	67.29	....	Below Greeley No. 2
13 11:35 A.M.	Seepage	69°	....	2.80	Inter. from Timnath Res.
13 12:25 P.M.	Whitney Ditch ..	70°	....	24.39	Near head
13 12:45 P.M.	B. H. Eaton Ditch	71°	....	14.13	Near head
13 1:10 P.M.	2nd River Measurem't	73°	....	30.33	Below Eaton Ditch
		.....	67.29	71.65	Gain 4.36

CACHE LA POUDRE RIVER.
Partial Measurement No. 29, Made July 13-14, 1910 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
July					
13 1:10 P.M.	2nd River Measurem't	73°	30.33	....	Same as above
13 2:35 P.M.	Seepage	69°	....	3.22	Inter. east of Windsor
13 3:40 P.M.	Jones Ditch	75°	....	9.44	At headgate
13 5:05 P.M.	Greeley No. 3....	75°	....	51.30	At rating flume
13 5:20 P.M.	3rd River Measurem't	75°	....	4.92	Below Greeley No. 3
		.....	30.33	68.88	Gain 38.55
July					
13 5:20 P.M.	3rd River Measurem't	75°	4.92	....	Same as above
13 6:05 P.M.	Boyd & Freeman.	74°	....	8.22	Near head
13 6:40 P.M.	Seepage	73°	(0.87)	....	West of pump house
14 8:40 A.M.	4th River Measurem't	64°	....	18.43	North of pump house
		.....	4.92	26.65	Gain 21.73
July					
14 8:40 A.M.	4th River Measurem't	64°	18.43	....	Same as above
12 9:45 A.M.	Insinger Sewer ...	.....	....	3.80	River crossing
14 9:50 A.M.	Ogilvy Ditch	74°	....	31.01	At headgate
14 —— A.M.	Camp Ditch	.....	....	0.00	
14 —— A.M.	Camp Slough ...	.....	....	0.00	
14 10:10 A.M.	5th River Measurem't	71°	....	1.75	Below Camp Ditch
		.....	18.43	36.56	Gain 18.13
July					
14 10:10 A.M.	5th River Measurem't	71°	1.75	....	Same as above
14 10:30 A.M.	Seepage	.....	....	0.14	Inter. by Ogilvy Ditch
14 —— A.M.	Seepage	.....	....	0.10	Inter. by Ogilvy Ditch
14 —— A.M.	Sand Creek	.....	0.00	....	
14 5:00 P.M.	Seepage	.....	....	7.18	Inter. by Bradfield Ditch
14 2:45 P.M.	6th River Measurem't	74°	....	34.05	Near mouth
		.....	1.75	41.47	Gain 39.72
					Total Gain 132.49.

CACHE LA POUDRE RIVER.
Measurement No. 30, Made August 3-27, 1910.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
3 11:00 A.M.	1st River Measurem't	.....	212.60	....	300 yd below Grly pipe line
3 12:45 M.	Pleas. V. & L. Can	.....	....	40.00	100 yds. below headgate
3 1:15 P.M.	Hook & Moore ...	.....	0.00	....	
3 1:45 P.M.	Lar. Co. Canal...	.....	....	100.00	At rating flume
3 2:00 P.M.	Henderson Ditch.	.....	....	0.78	At bridge
3 2:15 P.M.	River	.....	....	79.75	Bridge near Lari. Co. No. 2
10 10:00 A.M.	River	.....	39.20	....	Bridge near Lari. Co. No. 2
10 11:10 A.M.	Jackson Ditch ...	.....	....	11.70	At rating flume
10 11:30 A.M.	Inter. Seepage...	.....	....	0.24	By Jackson Ditch
10 12:45 P.M.	2nd River Measurem't	.....	....	31.25	Above New Mercer Ditch
		.....	251.08	263.72	Gain 11.92
Aug.					
10 12:45 P.M.	2nd River Measurem't	.....	31.25	....	Same as above
10 —— P.M.	New Mercer Ditch	.....	....	0.00	
10 —— P.M.	Larimer Co. No. 2	.....	....	0.00	
10 —— P.M.	Reservoir Water..	.....	0.00	....	
10 1:30 P.M.	Lit. Cache la P..	.....	....	1.06	Road near head
10 1:45 P.M.	Taylor & G. Ditch	.....	....	10.28	Road near head
10 2:00 P.M.	Chamberlin Ditch.	.....	....	(1.06)	Wasting to river
10 2:20 P.M.	River	.....	....	21.99	Below bridge at La Porte
11 9:50 A.M.	River	.....	11.54	....	Below bridge at La Porte
11 —— A.M.	Inter. Seepage...	.....	....	0.72	
11 11:20 A.M.	Arthur Ditch	.....	....	1.50	At rating flume
11 12:30 P.M.	Larimer & Weld..	.....	....	6.53	At rating flume
11 —— P.M.	Riddle Ditch	.....	....	0.00	
11 1:00 P.M.	3rd River Measurem't	.....	....	6.26	Below Larimer & W. dam
		.....	42.79	48.34	Gain 5.55
Aug.					
16 9:45 A.M.	3rd River Measurem't	.....	27.15	....	Below Larimer & Weld
16 10:15 A.M.	Pioneer Ditch ...	.....	....	4.55	At headgate
16 —— A.M.	Vandewark Ditch.	.....	....	0.00	
16 10:50 A.M.	Josh Ames Ditch.	.....	....	3.52	Near head
16 —— A.M.	Lake Canal	.....	....	0.15	Near head
16 11:20 A.M.	Coy Ditch	.....	....	1.99	Near road
16 2:30 P.M.	4th River Measurem't	.....	....	25.74	Near No. 2 Feeder
		..	27.15	35.95	Gain 8.80

CACHE LA POUDRE RIVER.

Measurement No. 30, Made August 3-27, 1910 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
19 8:10 A.M.	4th River Measurem't	.....	38.81	....	Same as above
19 8:30 A.M.	Chaffee Ditch ...	.....	....	1.00	150 ft. below headgate
19 9:10 A.M.	Spring Creek	.....	(3.10)	....	Road near mouth
19 2:10 P.M.	Dry Creek	.....	(3.92)	....	Road near mouth
19 9:40 A.M.	5th River Measurem't	.....	....	37.42	Above Box Elder Ditch
		.....	38.81	38.42	Loss 0.39
Aug.					
19 9:40 A.M.	5th River Measurem t	.....	37.42	....	Same as above
19 10:20 A.M.	Box Elder Ditch..	.....	....	19.58	Near head
19 11:00 A.M.	Inlet Fossil Creek	.....	....	3.18	Near beet dump
19 1:15 P.M.	Box Elder Creek.	.....	(1.75)	....	Road near mouth
19 1:30 P.M.	Slough	.....	(0.16)	....	Road near mouth
19 11:40 A.M.	6th River Measurem't	.....	....	22.70	Below Strauss bridge
		.....	37.81	47.21	Gain 9.40
Aug.					
27 9:35 A.M.	6th River Measurem't	.....	4.96	....	Same as above
27 10:40 A.M.	Outlet Fossil Creek	.....	55.10	....	Near river
27 11:00 A.M.	Waste	.....	1.29	....	Box Elder Ditch
27 1:30 P.M.	Greeley No. 2....	.....	....	0.75	At rating flume
27 11:50 A.M.	7th River Measurem't	.....	....	69.21	Below Greeley Noo. 2
		.....	61.35	69.96	Gain 8.61

CACHE LA POUDRE RIVER.

Measurement No. 31, Made August 29 - September 1, 1910.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Aug.					
29 11:40 A.M.	1st River Measurem't	.....	114.72	....	300yd below Greeley pipe line
29 12:55 P.M.	Pleas. V. & L. Can	.....	....	43.38	100 yds. below headgate
29 1:50 P.M.	Larimer Co.	.....	....	66.78	At rating flume
29 2:10 P.M.	Henderson Ditch.	.....	....	0.80	Bridge near head
29 2:30 P.M.	Jackson Ditch ...	.....	....	10.67	At rating flume
29 2:50 P.M.	Inter. Seepage...	.....	....	0.18	By Jackson Ditch
29 3:10 P.M.	2nd River Measurem't	.....	....	12.93	Above New Mercer Ditch
		.....	114.72	134.74	Gain 20.02
Aug.					
30 9:30 A.M.	2nd River Measurem't	.....	8.65	....	Same as above
30 9:50 A.M.	New Mercer Ditch	.....	....	0.10	At headgate
30 —— A.M.	Larimer Co. No. 2	.....	....	0.25	
30 —— A.M.	Reservoir Water.	.....	0.45	....	From Claymore Lake
30 10:00 A.M.	Lit. Cache la P..	.....	....	0.84	Near head
30 10:10 A.M.	Taylor & Gill....	.....	....	5.56	Near head
30 8:30 A.M.	Seepage	.....	....	2.00	Intercepted by Arthur Ditch
30 8:50 A.M.	Arthur Ditch	.....	....	0.72	At rating flume
30 11:10 A.M.	Larimer & Weld..	.....	....	2.95	At rating flume
30 11:20 A.M.	Riddle Ditch	.....	....	0.00	
30 11:25 A.M.	3rd River Measurem't	.....	....	3.57	Below Larimer & Weld
		.....	9.10	15.99	Gain 6.89
Aug.					
30 11:25 A.M.	3rd River Measurem't	.....	3.57	....	Same as above
30 1:40 P.M.	Pioneer Ditch ...	.....	....	2.70	At rating flume
30 1:55 P.M.	Vandewark Ditch.	.....	....	0.00	
30 2:05 P.M.	Josh Ames Ditch.	.....	....	0.62	Near head
30 2:15 P.M.	Lake Canal	.....	....	0.10	
30 2:30 P.M.	Coy Ditch	.....	....	1.08	
30 3:45 P.M.	College Drain ...	.....	....	0.25	Intercepted seepage
30 3:50 P.M.	4th River Measurem't	.....	....	11.45	Above No. 2 Feeder
		.....	3.57	16.20	Gain 12.63
Sept.					
1 8:30 A.M.	4th River Measurem't	.....	8.88	....	Above No. 2 Feeder
1 8:40 A.M.	Chaffee Ditch ...	.....	....	1.40	150 ft. below headgate
1 9:20 A.M.	Spring Creek	.....	(1.68)	....	Road near mouth
1 3:30 P.M.	Dry Creek	.....	20.48	....	Road near mouth
1 9:45 A.M.	5th River Measurem't	.....	....	21.91	Above Box Elder Ditch
		.....	29.36	23.31	Loss 6.05

CACHE LA POUDRE RIVER.

Measurement No. 31, Made August 29 - September 1, 1910 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
1 9:45 A.M.	5th River Measurem't	.....	21.91	....	Same as above
1 10:25 A.M.	Box Elder Ditch..	.....	....	6.44	near beet dump
1 10:45 A.M.	Inlet Fossil Creek	.....	....	10.97	Road near mouth
1 3:00 P.M.	Box Elder Creek.	.....	....	3.34	Intercepted
1 3:15 P.M.	Slough	.....	(.25)	....	Near road
1 11:20 A.M.	6th River Measurem't	.....	....	10.27	Below Strauss bridge
		.....	21.91	31.02	Gain 9.11
Sept.					
1 11:20 A.M.	6th River Measurem't	.....	10.27	....	Same as above
1 11:55 A.M.	Outlet Fossil Cr'k	.....	9.66	....	Near river
1 12:10 P.M.	Waste	.....	0.00	....	Box Elder Ditch
1 1:15 P.M.	Greeley No. 2....	.....	....	0.40	Near head
1 1:30 P.M.	7th River Measurem't	.....	....	27.72	Below Greeley No. 2
		.....	19.93	28.12	Gain 8.19
					Total Gain 50.79

CACHE LA POUDRE RIVER.

Measurement No. 32, Made September 7-10, 1910.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
7 11:00 A.M.	1st River Measurem't	.....	133.22	....	300 yds below Greeley p. line
7 12:30 P.M.	Pleas. V. & L. Can	.....	....	36.19	100 yds. below headgate
7 1:30 P.M.	Larimer Co. Canal	.....	....	29.15	At rating flume
7 1:45 P.M.	Henderson Ditch.	.....	....	0.33	Bridge near head
7 2:10 P.M.	Jackson Ditch ...	.....	....	8.71	Near road
7 2:20 P.M.	Inter. Seepage ...	.....	....	0.20	By Jackson Ditch
7 2:45 P.M.	2nd River Measurem't	.....	....	75.06	Above New Mercer Ditch
		.....	133.22	149.64	Gain 16.42
Sept.					
9 10:00 A.M.	2nd River Measurem't	.....	33.50	....	Same as above
9 10:20 A.M.	New Mercer Ditch	.....	....	2.66	At headgate
9 —— A.M.	Larimer Co. No. 2	.....	....	0.25	At headgate
9 10:50 A.M.	Lit. Cache la P..	.....	....	1.38	Near head
9 11:00 A.M.	Taylor & Gill....	.....	....	6.67	Near head
9 8:35 A.M.	Inter. Seepage...	.....	....	1.75	By Arthur Ditch
9 9:00 A.M.	Arthur Ditch	.....	....	3.24	At rating flume
9 9:20 A.M.	Waste	.....	0.65	....	Near bridge
9 12:35 P.M.	Larimer & Weld..	.....	....	2.95	At rating flume
9 1:00 P.M.	Riddle Ditch	.....	....	0.00	
9 1:00 P.M.	3rd River Measurem't	.....	....	23.22	Below Larimer & Weld
		.....	34.15	42.12	Gain 7.97
Sept.					
9 1:00 P.M.	3rd River Measurem't	.....	23.22	....	Same as above
9 1:15 P.M.	Pioneer Ditch ...	.....	....	2.94	At rating flume
9 1:25 P.M.	Vandewark Ditch.	.....	....	0.00	
9 1:30 P.M.	Josh Ames Slough	.....	....	0.00	
9 1:30 P.M.	Lake Canal	.....	....	0.25	
9 1:45 P.M.	Coy Ditch	.....	....	12.89	
9 2:45 P.M.	College Drain ...	.....	....	0.26	Intercepted seepage
9 2:15 P.M.	4th River Measurem't	.....	....	13.15	Above No. 2 Feeder
		.....	23.22	29.49	Gain 6.27
Sept.					
10 8:30 A.M.	4th River Measurem't	.....	48.57	....	Above No. 2 Feeder
10 8:50 A.M.	Chaffee Ditch ...	.....	....	0.74	50 yds below head
10 9:45 A.M.	Spring Creek	.....	(1.76)	....	Road near mouth
10 3:35 P.M.	Dry Creek	.....	(2.10)	....	Road near mouth
10 10:05 A.M.	5th River Measurem't	.....	....	41.57	Above Box Elder Ditch
		.....	48.57	42.31	Loss 6.26
Sept.					
10 10:05 A.M.	5th River Measurem't	.....	41.57	....	Same as above
10 10:45 A.M.	Box Elder Ditch.	.....	....	1.72	Near beet dump
10 11:00 A.M.	Inlet Fos. C'k Res.	.....	....	3.30	Near beet dump
10 3:00 P.M.	Box Elder Creek.	.....	....	1.76	Intercepted
10 3:15 P.M.	Slough	.....	(1.00)	....	Near road
10 11:15 A.M.	6th River Measurem't	.....	....	44.56	Below Strauss bridge
		.....	41.57	51.34	Gain 9.77

CACHE LA POUDRE RIVER.

Measurement No. 32, Made September 7-10, 1910 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Sept.					
10 11:15 A.M.	6th River Measurem't	.....	44.56	....	Same as above
10 11:45 A.M.	Outlet Fos. Ck Res	.....	38.33	....	Near river
10 —— A.M.	Waste	.....	0.00	....	Box Elder Ditch
10 12:35 P.M.	Greeley No. 2....	.....	....	0.35	Near head
10 12:45 P.M.	7th River Measurem't	.....	....	59.32	Below Greeley No. 2
xAmount which should be added...		.....	....	35.42	
		.....	82.89	95.09	Gain 12.20

CACHE LA POUDRE RIVER.

Measurement No. 33, Made October 7-12, 1910.

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Oct.					
7 11:30 A.M.	1st River Measurem't	.....	76.09	....	At weir in canon
7 —— A.M.	Canon Canal	.....	....	0.10	Near head
7 —— A.M.	Greeley Wtr. Wks.	.....	....	5.20	At head
7 —— A.M.	Pleas. V. & L. Can.	.....	....	0.00	
7 1:25 P.M.	Larimer Co. Canal	57°	....	32.54	At rating flume
7 —— P.M.	Henderson Ditch..	.....	....	(0.25)	Wasting to river
7 2:00 P.M.	Jackson Ditch....	61°	....	1.27	Near head
7 —— P.M.	New Mercer Ditch	.....	....	0.00	
7 2:30 P.M.	2nd River Measurem't	61°	46.54	....	Same as above
		.....	76.09	85.65	Gain 9.56
Oct.					
7 2:30 P.M.	2nd River Measurem't	61°	46.54	....	Below New Mercer ditch
7 —— P.M.	Larimer Co. No. 2	.....	....	0.00	
7 —— P.M.	Chamberlin Ditch.	.....	....	0.00	None used
7 2:45 P.M.	Little Cache la P.	61°	....	0.34	Near head
7 2:55 P.M.	Taylor & G. Ditch	°61°	....	3.46	Near head
7 —— P.M.	J. R. Brown Ditch	.....	....	0.00	
7 —— P.M.	Arthur Ditch	.....	....	0.00	
7 3:40 P.M.	Larimer & Weld..	62°	....	14.94	At rating flume
7 —— P.M.	Riddle Ditch.....	.....	....	0.05	
7 4:10 P.M.	3rd River Measurem't	62°	....	38.09	Below Larimer and Weld dam
		.....	46.54	56.88	Gain 10.34
Oct.					
8 9:30 A.M.	3rd River Measurem't	53°	39.05	....	Same as above
8 —— A.M.	Pioneer Ditch ...	.....	....	0.00	
8 —— A.M.	Vandewark Ditch.	.....	....	0.08	At head
8 10:15 A.M.	Josh Ames Ditch.	.....	....	0.00	
8 10:15 A.M.	Lake Canal	59°	....	2.57	Road near head
8 —— A.M.	J. G. Coy Ditch...	57°	....	0.55	Below wasteway
8 11:15 A.M.	4th River Measurem't	58°	....	57.84	Above No. 2 feeder
		.....	39.05	61.04	Gain 21.99
Oct.					
8 11:15 A.M.	4th River Measurem't	58°	57.84	....	Same as above
8 11:25 A.M.	Sugar Factory....	.....	(1.62)	....	At river
8 4:10 P.M.	No. 2 Feeder.....	63°	....	0.25	
8 11:20 A.M.	Chaffee Ditch	61°	....	0.50	At head
8 4:05 P.M.	Dry Creek........	.....	(3.81)	....	
8 12:00 P.M.	Spring Creek	60°	(3.35)	....	Road near mouth
8 12:40 P.M.	5th River Measurem't	62°	....	66.97	Above Box Elder ditch
		.....	57.84	67.72	Gain 9.88
Oct.					
8 12:40 P.M.	5th River Measurem't	62°	66.97	....	Same as above
8 2:00 P.M.	Box Elder Ditch..	64°	....	5.34	
8 1:45 P.M.	Inlet Fossil Creek.	68°	....	0.92	Seepage
8 3:30 P.M.	Box Elder Creek..	°63°	(3.27)	....	
8 2:40 P.M.	Seepage	67°	....	(0.35)	Near Strauss bridge
8 2:30 P.M.	6th River Measurem't	65°	....	62.98	At Strauss bridge
		.....	66.97	69.24	Gain 2.27

x—The difference in discharge of the river below No. 2 Feeder between night and morning indicates an increased flow during the night. This increase evidently had not reached the point of last measurement when taken, and when added gives a result more in accord with other measures.

CACHE LA POUDRE RIVER.

Measurement No. 33, Made October 7-12, 1910 (Continued).

Date and Hour	Place of Measurement	Temp. of Wat.	River and Inflow	Out-take	NOTES—
Oct.					
10 10:15 A.M.	6th River Measurem't	55°	44.52	....	Same as above
10 12:00 M.	Box Elder	.....	0.93	....	Waste
10 11:50 A.M.	Greeley No. 2....	60°	....	15.40	At rating flume
10 11:40 A.M.	7th River Measurem't	60°	....	15.41	Below Greeley No. 2
		.....	45.45	30.81	Loss 14.64. Rejected
Sept.					
1 11:20 A.M.	6th River Measurem't	.....	10.27	....	Same as above
1 11:55 A.M.	Fossil Crk Feeder	.....	9.66	....	Near river
1 —— A.M.	Waste	.....	0.00	....	Box Elder ditch
1 1:15 P.M.	Greeley No. 2.....	.....	....	0.40	Near head
1 1:30 P.M.	7th River Measurem't	.....	....	27.72	Below Greeley No. 2
		.....	19.93	28.12	Gain 8.19
Oct.					
10 11:40 A.M.	7th River Measurem't	60°	15.41	....	Same as above
10 12:20 P.M.	Seepage	66°	....	2.43	Timnath Reservoir intercepted
10 1:10 P.M.	Whitney Ditch....	59°	....	8.53	Road near head
10 —— P.M.	B. H. Eaton.....	.....	....	0.10	At head
10 2:25 P.M.	8th River Measurem't	60°	....	12.29	Below B. H. Eaton ditch
		.....	15.41	23.35	Gain 7.94
Oct.					
10 2:25 P.M.	8th River Measurem't	60°	12.29	....	Same as above
10 3:20 P.M.	Sugar Factory....	70°	4.28	....	Near Windsor
10 4:00 P.M.	River	61°	....	19.24	At Windsor Farm
11 10:10 A.M.	River	.....	34.22	....	At Windsor Farm
10 4:30 P.M.	Seepage	.....	(2.67)	....	
11 11:30 A.M.	Jones Ditch......	.....	....	2.49	At headgate
11 12:40 A.M.	Greeley No. 3....	57°	....	0.96	Near head
11 1:10 P.M.	9th River Measurem't	57°	....	42.25	Below Greeley No. 3
		.....	50.79	64.94	Gain 14.15
Oct.					
11 1:10 P.M.	9th River Measurem't	57°	42.25	....	Same as above
11 —— P.M.	Waste	.....	0.96	....	From Greeley No. 3
11 1:35 P.M.	Sheep Creek......	68°	(1|44)	....	Above No. 3
11 2:15 P.M.	Boyd & Freeman..	57°	....	2.04	Near head
11 3:00 P.M.	Seepage	63°	(0.70)	....	West of pump house
11 3:50 P.M.	10th River Measuremt	60°	....	48.11	North of pump house
		.....	43.21	50.15	Gain 6.94
Oct.					
11 3:50 P.M.	10th River Measuremt	60°	48.11	....	Same as above
11 —— P.M.	Mill Race........	.....	....	0.00	
12 9:00 A.M.	Insinger Sewer ...	.....	(1.77)	....	
11 5:00 P.M.	Ogilvy Ditch.....	60°	....	64.09	At headgate
12 —— P.M.	Camp Ditch......	.....	....	0.00	
12 9:30 A.M.	Camp Slough.....	°52°	....	1.24	Near Camp Ditch
12 9:40 A.M.	11th River Measuremt	57°	....	6.48	Below Camp ditch
		.....	48.11	71.81	Gain 23.70
Oct.					
12 9:40 A.M.	11th River Measuremt	57°	6.48	....	Same as above
12 10:05 A.M.	Seepage	57°	(0.55)	....	
12 10:15 A.M.	Seepage	55°	(0.08)	....	
12 —— A.M.	Seepage	.....	....	....	
12 —— A.M.	Waste	.....	64.09	....	Ogilvy ditch
12 1:50 P.M.	Sand Creek	67°	(1.05)	....	Road near mouth
12 4:00 P.M.	12th River Measuremt	63°	....	115.30	Near mouth
		.....	70.57	115.30	Gain 44.73
		.....	....	....	Total Gain 159.64
Oct.					
12 2:30 P.M.	Lone Tree Creek.....	64°	2.54	....	Near mouth

SUMMARY

SEEPAGE GAINS, CACHE LA POUDRE RIVER

Results in Cubic Feet per Second

Sections	Length in Miles	1885 Oct.	1889 Oct.	1890 Oct.	1891 Oct.	1892 Mch.
Weir to New Mercer	5½	-----	11.27	-----	18.26	-----
Water Works to Larimer & Weld Ditch	3	11.86	-----	25.79		-----
Larimer & Weld Ditch to No. 2 Feeder	5	-----	-----	13.66	------	-----
No. 2 Feeder to Strauss Bridge	5	-----	36.79		------	57.31
Strauss to No. 2 Canal	3	25.50			8.71	-----
No. 2 Canal to Eaton Ditch	4	-----		17.25		-----
Eaton Ditch to No. 3 Canal	8	−19.55	44.50		−5.10	29.06
No. 3 to Greeley Power House	6	-----		20.87		
Mill Power Canal to Camp Ditch	2½	30.21		------	38.26	9.74
Camp Ditch to Mouth of Poudre	5	-----	6.41	23.22	19.40	-----
TOTAL	47	48.02*	98.97	100.79	79.53	96.11*

Sections	1902 July	1903 Aug.	1904 Sep.	1605 Sep.	1905 Chk.	1906 Sep.
Weir to New Mercer	−8.82	14.63	5.44	16.24	- ----	−6.38
Water Works to Larimer & Weld	12.92	4.11	15.08	9.59	------	12.25
L. & W. to No. 2 Supply	3.23	20.40	20.80	16.88	------	25.99
No. 2 Supply to Strauss Bridge	11.20	29.09	14.19	−1.62	3.47	20.79
Strauss to No. 2 Canal	3.68	8.81	3.23	13.81	------	8.62
No. 2 to Eaton Ditch	4.98	−0.53	4.29	4.44	------	9.73
Eaton Ditch to No. 3 Canal	20.52	27.07	19.62	19.62	------	24.68
No. 3 to Greeley Power House	20.68	18.29	23.27	21.74	------	25.05
Mill Power Canal to Camp Ditch	21.93	28.78	30.54	40.30	------	37.28
Camp Ditch to Mouth Poudre	29.11	35.72	37.03	39.88	------	45.36
TOTAL	119.43	186.37	173.49	180.83	------	216.13

*Incomplete

SUMMARY

SEEPAGE GAINS, CACHE LA POUDRE RIVER

Results in Cubic Feet per Second

1892 Oct.	1893 Nov.	1894 Mch.	1894 Aug.	1895 Oct.	1896 Nov.	1897 Oct.	1898 Aug.	1899 Sep.	1900 July Aug.	1900 Aug. Sep.	1901 Aug. July
-----	31.25	1.57	-----	18.75	−2.92	+1.39	−7.76	−0.85	5.08	4.38	−2.78
15.37			0.77	1.46	-----	+16.61	9.16	16.14	−3.13	4.15	26.73
est0.60	6.71	3.45	17.59	26.36	−5.68	−3.96	3.37	10.13	-- ---	3.56	8.44
3.51	----	27.22	−3.33	6.09	−22.87	−2.90	14.84	1.12	-----	11.49	5.81
2.52	5.23		3.12	7.51	16.41	+10.42	1.28	8.62	−16.84	1.37	−6.20
5.97	−4.81	−6.65	11.86	6.99	10.42	+13.36	8.34	−3.05	5.63	3.03	6.24
-----	----	----	12.68	7.35	5.77	+35.72	15.44	13.74	6.30	1.30	19.96
21.81	19.21	26.26	21.14	33.85	16.64	-----	21.16	21.86	30.17	21.40	28.37
17.31	23.59	10.05	26.36	7.74	25.52	+26.57	25.98	30.93	34.29	24.49	35.87
29.19	17.50	20.42	27.97	46.37	21.98	+23.88	33.37	31.62	43.39	34.85	44.96
96.28	98.68	82.32	118.17	162.47	65.27*	120.79*	125.18	134.12	*104.89	110.02	167.50

1907 Sep. Oct.	1908 Sep.	1908 Chk. Oct.	1909 May	1909 Aug.	1909 Oct.	1910 June	1910 July	1910 Aug.	1910 Aug. Sep.	1910 Sep.	1910 Avg.	No. Rec.	Avg.
4.90	12.95	------	------	------	15.32	------	------	11.92	20.02	16.42	9.56	(20)	6.37
8.82	11.16	------	------	------	25.79	------	------	5.55	6.89	7.97	10.34	(19)	10.61
19.53	18 43	------	8.82	------	8.57	------	------	8.80	12.63	6.27	21.99	(24)	10.95
21.78	23.98	------	37.02	------	20.94	------	------	9.01	3.06	3.51	12.18	(23)	9.57
7.90	3.41	-----	−3.67	------	4.14	------	------	8.61	8.19	12.20	−14.64	(22)	4.80
13.75	−4.13	10.36	13.70	−9.78	8.14	−0.15	4.36	------	------	------	7.94	(26)	5.02
23.97	46.78	26.50	19.26	25.86	27.97	21.80	38.55	------	------	------	14.15	(23)	20.66
30.81	22.66	------	40.92	41.61	23.60	23.83	21.73	------	-----	------	6.94	(21)	24.56
37.64	37.21	------	15.46	22.66	30.48	15.64	18.13	------	------	------	23.70	(28)	25.62
34.05	52.89	49.32	51.14	56.00	43.59	37.06	39.72	------	- ---	------	44.73	(29)	35.16
203.15	225.32	215.26	182.65	136.35*	208.54	98.18*	122.49	43.89	50.79	46.37	159.72		153.32

Bulletin 181 December, 1911

The Agricultural Experiment Station
OF THE
Colorado Agricultural College

ALFALFA
The Relation of Type To Hardiness

BY
PHILO K. BLINN

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1911

The Agricultural Experiment Station

FORT COLLINS, COLORADO

THE STATE BOARD OF AGRICULTURE

		Term Expires
Hon. A. A. Edwards, *President*,	Fort Collins,	1913
Hon. R. W. Corwin,	Pueblo,	1913
Hon. F. E. Brooks,	Colorado Springs,	1915
Hon. J. L. Brush,	Greeley,	1915
Hon. J. C. Bell,	Montrose,	1917
Hon. E. M. Ammons,	Littleton,	1917
Hon. T. H. Ehrhart,	Centerville,	1919
Hon. Chas. Pearson,	Durango,	1919

Governor John F. Shafroth, } *Ex-Officio.*
President Chas. A. Lory, }

EXECUTIVE COMMITTEE IN CHARGE

A. A. Edwards, *Chairman*

J. L. Brush — E. M. Ammons

STATION STAFF

C. P. Gillette, M. S., *Director*,	Entomologist
W. P. Headden, A. M., Ph. D.,	Chemist
G. H. Glover, M. S., D. V. M.,	Veterinarian
W. G. Sackett, B. S.,	Bacterioloigst
Alvin Keyser, A. M.	Agronomist
J. O. Williams, B. S. A., *U. S. Expert-in-Charge*	Horse Breeding
E. R. Bennett, B. S.	Horticulturist
B. O. Longyear, B. S.	Botanist
G. E. Morton, M. L., B. S. A.	Animal Husbandman
E. B. House, B. S., (E. E.), M. S.,	Irrigation Engineer
V. M. Cone, B. S.	Irrigation Investigations
R. E. Trimble, B. S.,	Assistant Irrigation Investigations
P. K. Blinn, B. S.	Rocky Ford, Alfalfa Investigations
Earl Douglass, M. S.,	Assistant Chemist
S. Arthur Johnson, M. S.	Assistant Entomologist
B. F. Kaupp, M S., D. V. S.,	Pathologist
Miriam A. Palmer, M. A.,	Delineator
George P. Weldon, B. S.	Assistant in Entomology
R. S. Herrick, B. S.,	Grand Junction, Field Horticulturist
C. L. Fitch,	Potato Investigations
W. E. Vaplon,	Poultry Investigations
J. W. Adams, B. S.,	Cheyenne Wells, Supt. Plains Sub-Station
G. D. Walters, B. S.	Assistant Irrigation Investigations
Ellwood D. Rood, B. A.,	Assistant Chemist

ALFALFA

THE RELATION OF TYPE TO HARDINESS.

By Philo K. Blinn.

For forty years alfalfa has been grown with marked success throughout the irrigated areas of Colorado. It has fitted our conditions so well that there has been little cause for failure aside from the lack of moisture. But it is a matter of common observation that there is a gradual loss of plants in the fields of ordinary alfalfa as they become older. In the very old fields, the stand of plants is almost invariably thin. This is usually ascribed to the overcrowding of plants. The thinning out has not usually seemed to decrease the yield of hay. The remaining plants seem to appropriate the extra space to good advantage, the increased size and number of stems making the total yield of hay almost constant. Thus the thinning out has not been regarded as a very serious injury unless it has been unusually severe, in which case it is said to have "run out" or "winter-killed." When it reaches this stage it is usually abandoned for hay production, plowed up and in time reseeded.

In recent years the Colorado Experiment Station has been receiving numerous complaints that alfalfa is not producing what it did in former years. These complaints are made in regard to both hay and seed production. Investigation seems to verify the truth of the claims. There are many local and specific causes for some of the complaints, such as, the injuries caused by grasshoppers, over-pasturing or injudicious irrigation. *There is additional cause for a general complaint in regard to alfalfa production* due to a lack of vigor and vitality in the strains commonly grown. These common types we might class as the southern or Spanish varieties. Originally the alfalfa that was planted in California and the other western states came from South America, and was in turn introduced into that country by the Spaniards during their early conquests. Most of our ordinary alfalfa can be traced to this origin.

The Colorado Experiment Station has conducted alfalfa improvement experiments since 1904. One of the results of these experiments has been to show the lack of hardiness in the southern alfalfa types. Attention was called to the contrast in seed yields and the great difference in types of plants found in the same fields. From certain choice individual plants found at different points in the Arkansas Valley in southeastern Colorado, seed was selected and saved for the beginning of an experiment in systematic seed breeding. The most promising of these selections were sown in a nursery plat April 15, 1905. In this plat was also sown some ordinary commercial seed secured from a dealer in Rocky Ford, Colo., and some imported Turkestan alfalfa from Germany, furnished by Professor W. H. Olin.

Plate No. 1 is a view of this first alfalfa nursery plat, taken just a year from the date of seeding. The six rows of the large stooled crowns in the center were sown with the Turkestan seed. Each of the four rows to the left of the Turkestan rows were sown with the seed of some choice selected plant, while the four rows, to the right of the Turkestan rows, were sown with seed of commercial stock representing ordinary alfalfa. So marked were the contrasts in this test in

Plate No. 1.—The first alfalfa nursery, one year from date of seeding. Four rows on the right sown from commercial seed; six rows in center, Turkestan alfalfa from Germany; four rows on the left seeded with seed from choice native or common alfalfa.

favor of the imported seed, that it was evident that a wider test of varieties should be made, in order to find the best stock to be used as a basis for alfalfa seed breeding.

During the season of 1906, the most promising plants in the six rows of Turkestan alfalfa were selected and saved for seed. Fifteen of these plants gave an average yield of over one and one-half ounces of seed per plant. They also seemed to possess desirable qualities for hay. The seed of each of these choice plants was saved separately. These with about fifty other varieties or strains received from Mr. J. M. Westgate of the U. S. Bureau of Plant Industry, furnished the seed for a second alfalfa nursery test. This nursery was sown April

15, 1907. It consisted of sixty-four plats, each one representing the seed of an individual selection, or a regional variety from some state or foreign country.

All the varieties in this nursery could be classed in a general way, as Medicago sativa, or common alfalfa. A few of the plats showed plants with variegated flowers. These might be classed in the variegated strains. There were marked contrasts in the type of plants and

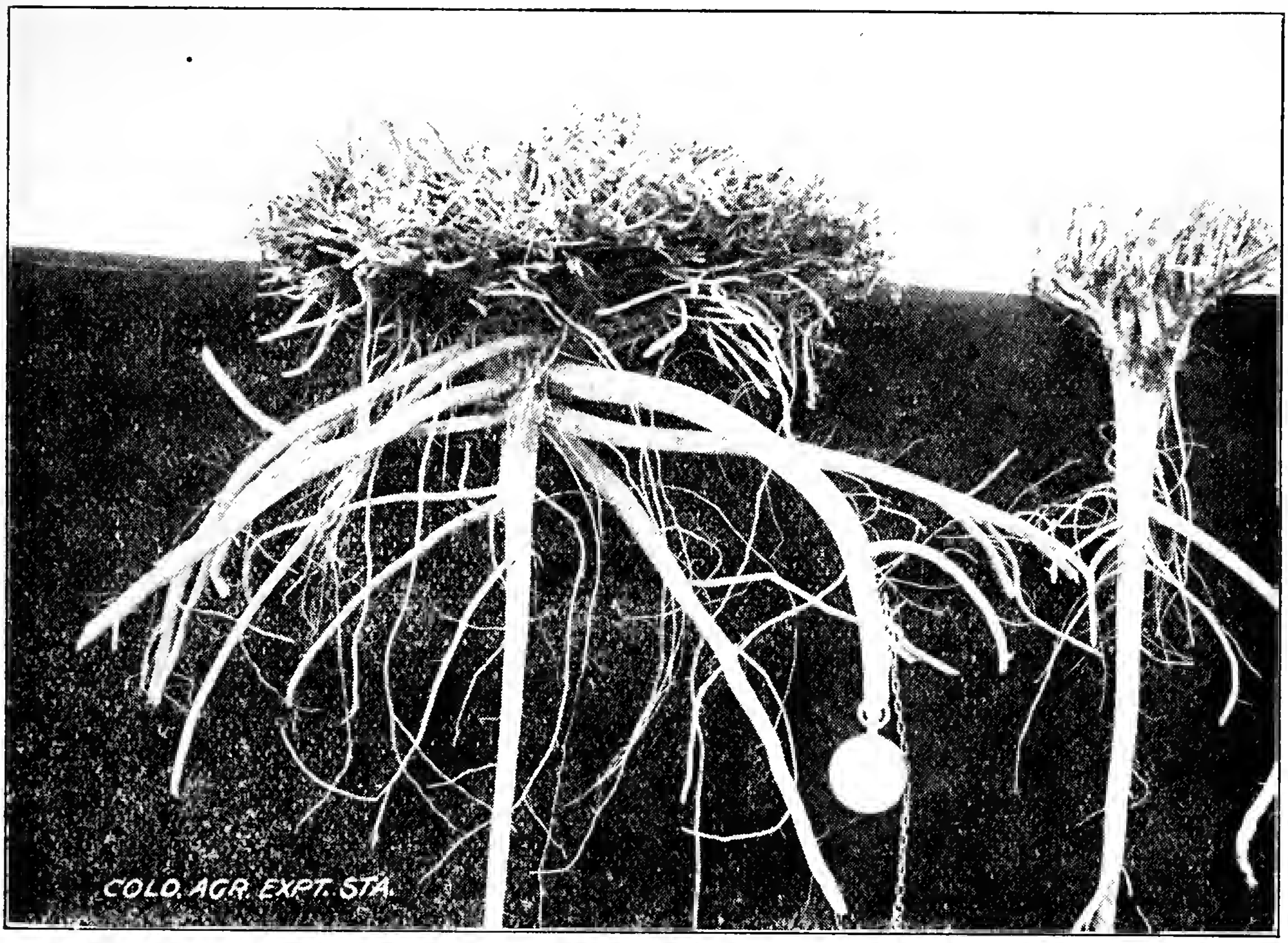


Plate No. 2.—Representative plants of the Hardy and Non-hardy type of crowns of four-year-old alfalfa taken from the same nursery, grown as single plants under the same conditions. The plant on the right, the common or Southern type; the plant on the left, a fair sample of Baltic alfalfa, a variety found growing near the little town of Baltic, South Dakota.

the character of the foliage in different plats. In some plats, there was almost as wide a range of contrasts in the different plants of the plat.

The geographical distribution of the seed that was sown in this nursery was as follows: Four from Arabia; four from Africa; four from South America; four from Spain and Mexico; eight from the Western parts of the United States; eight from the northern states and northern Europe and thirty-two plats of Turkestan alfalfa from different sources.

Each plat was planted with 200 hills; twenty inches apart each way, ten rows of twenty hills each. The plats were separated by a forty inch path between all the plats. The hills were thinned to single plants when about six weeks old, thus permitting the study of individual plants.

While the nursery was given uniform cultural care, there were marked contrasts in many traits, such as, production of seed; leafiness of the plant; coarseness of the stems; degree of resistance to late spring frosts, and some other points of practical utility.

The factor of overcrowding of the plants in the nursery had been

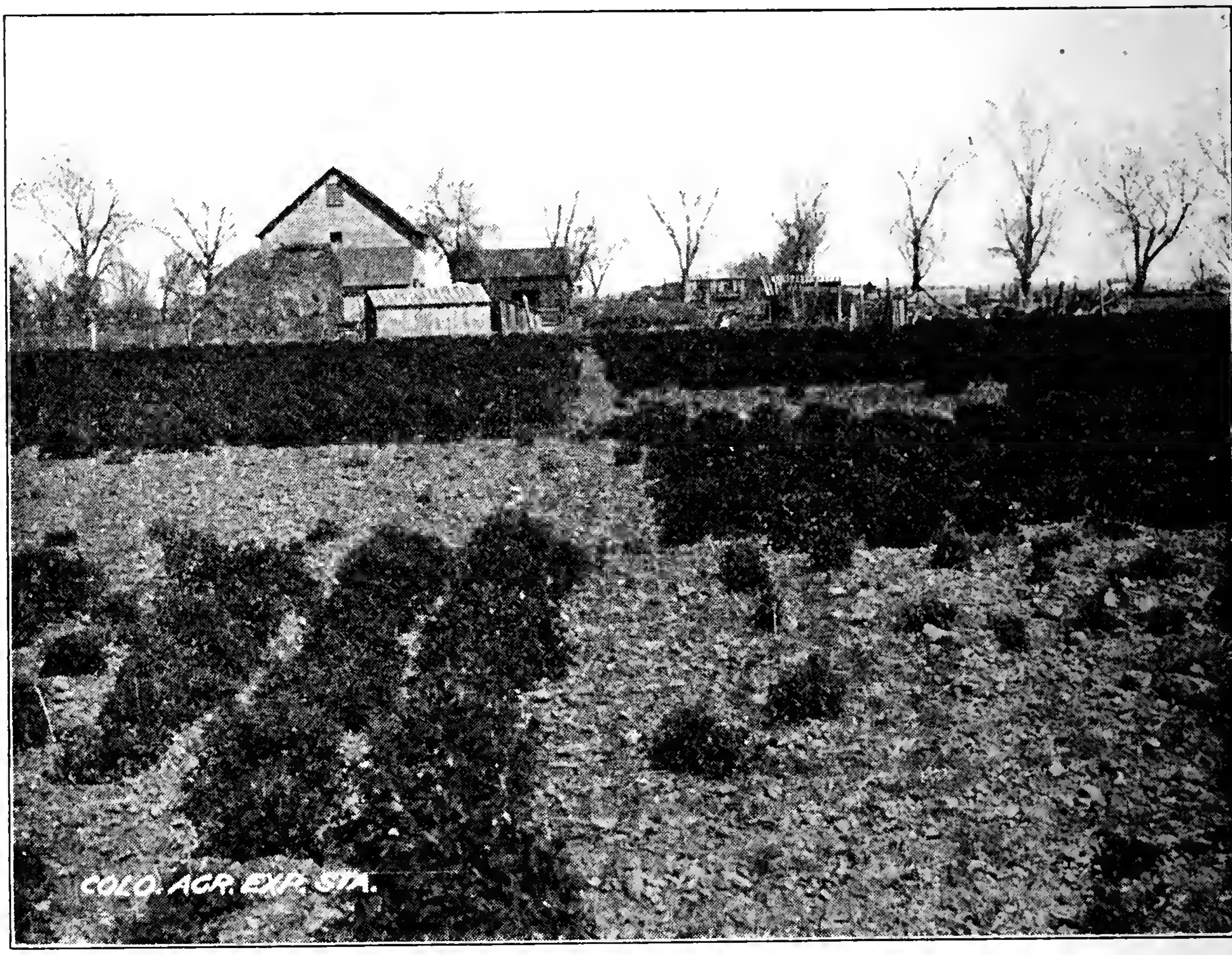


Plate No. 3.—A portion of the 1907 alfalfa nursery, taken April 25, 1911, showing the loss of plants after four winters. In the right foreground, a plat of Ecuador alfalfa; in the forground, a plat from Utah seed; in the left center, two plats of African alfalfa, all dead; in the right center, a plat of Arabian alfalfa, all dead.

eliminated by thinning the plants to single specimens. Yet after the winter of 1907-1908, over one half of the plants in all the plats seeded with Arabian and North African seed were dead, apparently from winter killing, while the plats seeded with seed from Spain, Mexico and South America had many dead plants and a good many partially killed crowns. The same was true in the native American plats. The plants were often found with just a few stems with life enough to start growth in the spring. But in the Turkestan plats and the plats sown with the northern strains of seed, there seemed to be no loss whatever from winter-killing.

During the season of 1908, the nursery was allowed to produce seed, the plants being screened. The seed was saved for future work. Irrigation was withheld to induce better seed production. The dry condition seemed to increase the frost injuries the following winter for a still greater loss of plants occurred in the same plats where the winter-killing first began. The northern strains were still free from any injury, while the plats from the Arabian and African seed were practically all dead. The loss of plants by winter-killing has con-

Plate No. 4.—Another portion of the 1907 alfalfa nursery, taken April 25, 1911, showing the portion of the nursery seeded with the Turkestan and other heavy stooling crown types, where no loss from winter-killing has occurred in four winters.

tinued to occur to some extent in the non-hardy plats for the past four winters.

Plate No. 3 is a view of a portion of the nursery, taken April 25, 1911, showing the effects of four winters. The loss of plants in several of the non-hardy plats is noticeable. Plate No. 4 is a view of another portion of the same nursery taken at the same time, showing the hardy northern strains where no loss from winter-killing has occurred.

During the past four years careful examination has been made of many hundred plants, to determine the cause of the loss of plants in one plat and not in another. Several seedings have been made and plowed up, in order to study the relative difference, if any, between the crowns where winter-killing occurred and where it did not.

Plate No. 5.—Seedlings of four months' growth under similar conditions, showing contrast in stooling habits. The crowns on the left, Spanish alfalfa, typical of our common alfalfa, upright crowns without protected buds. The crowns on the right, two Grimm's alfalfa crowns, same age, typical of the hardy type having the underground shoots.

It has been observed that a marked difference exists between the type of the crown, or the stooling habits, of the hardy and non-hardy strains. Plate No. 2 illustrates this contrast in the crowns of two four-year-old plants taken from the nursery, each representing a typical crown of the two types of plants. The distinction between these types may be better understood with younger plants. Plate No. 5 shows two very representative plants of these two types, only four months' growth from seed, both grown under the same field conditions. The non-hardy type is shown on the left. It has a compacted upright growing crown, with comparatively few buds or shoots below the surface of the soil. The buds are thus exposed to freezing, thawing and drying out which eventually weakens and kills alfalfa in the arid regions.

The hardy type is shown on the right. This is characterized by a more spreading crown, with numerous buds and shoots springing from the crown below the surface of the soil. These underground

Plate No. 6.—A fine specimen of the hardy type, Grimm's alfalfa. Soil removed three inches in depth to expose all the underground shoots.

shoots in some of the best plants of this type, have been found several inches below the surface of the soil. The bud area in this type of plant is thus protected by the soil from drying or freezing. A fine specimen of this type of plant is shown in Plate No. 6. The soil in

Plate No. 7.—A portion of the 1910 alfalfa nursery, showing the great contrasts in stooling habits under uniform conditions. The small row just to the left of the center, Elche alfalfa from Spain. The heavy crowns to the right are selections of Baltic and Turkestan alfalfa.

Plate No. 8.—A portion of a field test of the hardy and non-hardy types. On the right, Peruvian alfalfa from Colorado grown seed. On the left, Baltic alfalfa from Colorado grown seed. Field seeded March 17, 1909; view taken March 25, 1911.

Plates Nos. 9 and 10.—Two adjacent Turkestan plants, May 3, 1909, two days after freeze of 18°. No. 1, dark green foliage, practically uninjured. No. 2, light green foliage, leaves and stems entirely frozen back. (Plate from Colorado bulletin, No. 154.)

Plate No. 11.—Seedlings of the Grimm's alfalfa, six weeks from seed, showing the early stooling traits.

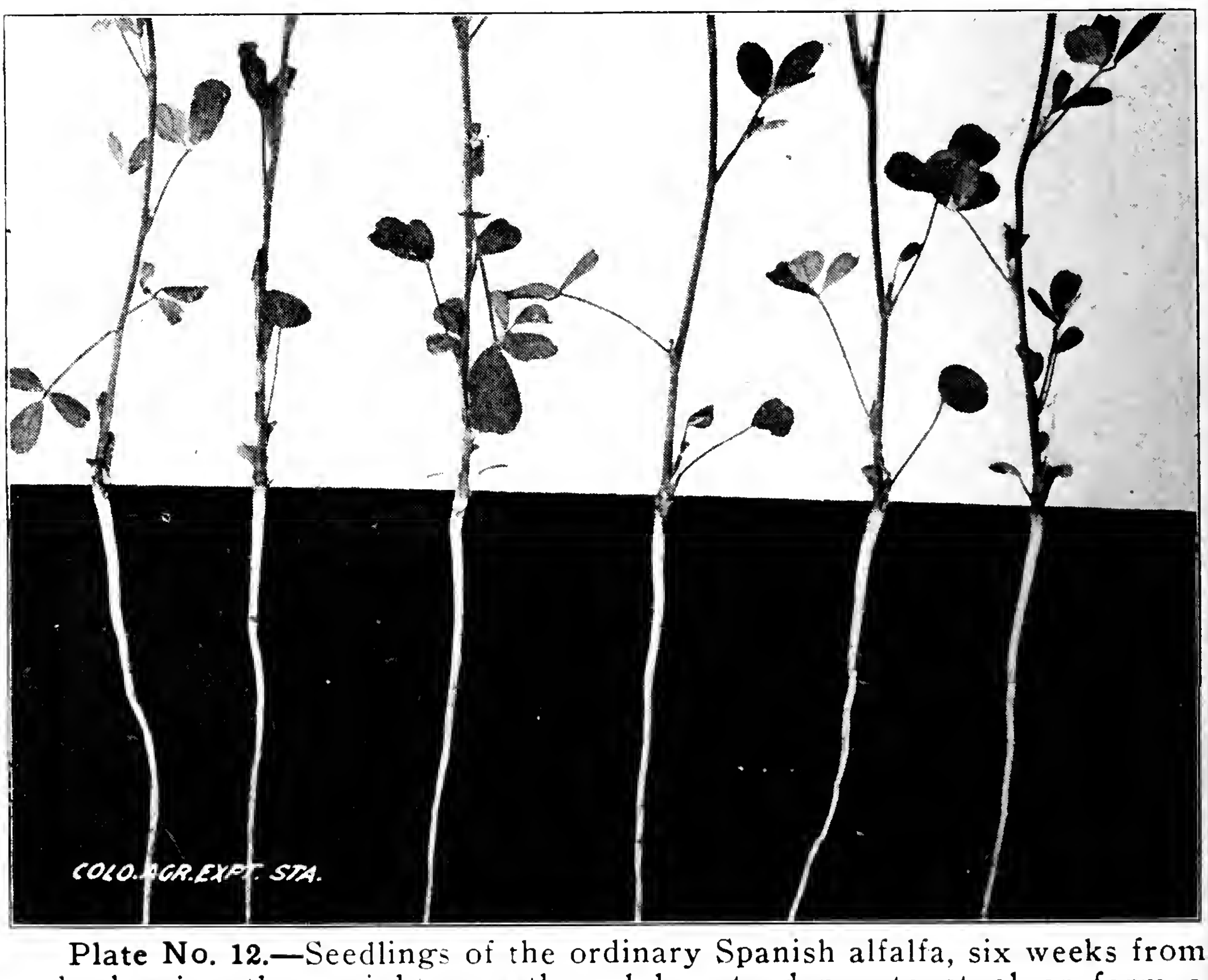


Plate No. 12.—Seedlings of the ordinary Spanish alfalfa, six weeks from seed, showing the upright growth and less tendency to stool or form a crown.

this case was removed three inches deep to expose all the underground shoots, some of which were over eight inches in length. This plant was from a nursery row of the Grimm's alfalfa, only six months growth from seed. The seed that produced this plant came from a field in northern Minnesota, over forty years of age. The budding area of such a plant is enormous. It will stand the loss of many buds without apparent injury and the soil protection will insure it against the usual winter cold.

There is also a tendency for the underground shoots to take root at some distance from the old center crown. This may be seen by observing the numerous small roots that are extending beneath the large crown in Plate No. 2. In old stools of alfalfa of this type, the original plant has been found in some cases to be dead. But it was surrounded by a ring of healthy secondary crowns formed by the underground shoots that have taken root and formed independent plants. Thus the hardy type will maintain a permanent stand of plants, while the non-hardy type which has the upright compacted crown with the buds exposed, has scarcely any tendency to take root from the crown. This will result in serious injury, in time weakening and eventually destroying the plant. Thus the stand of plants in the non-hardy type is bound to become thin.

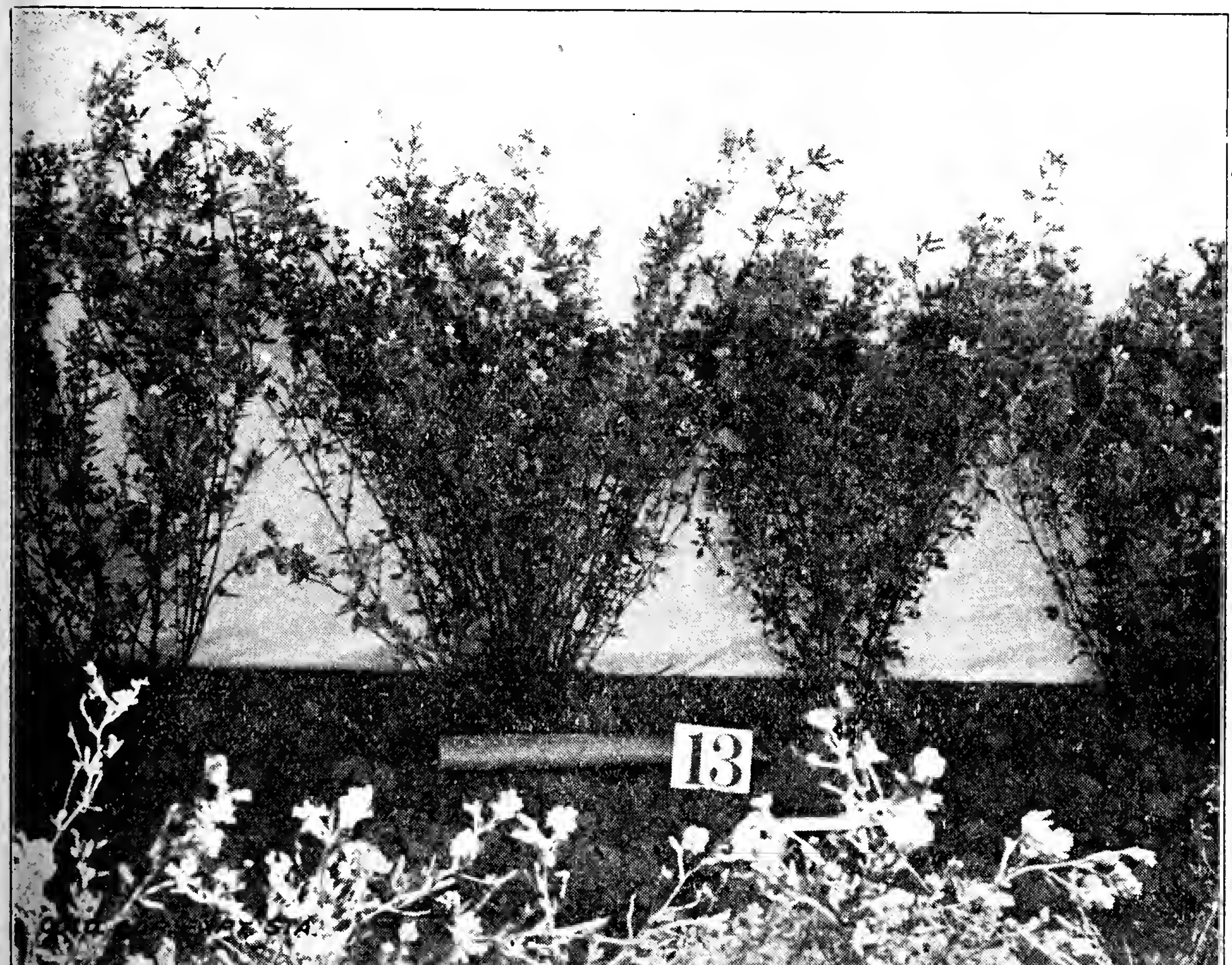


Plate No. 13.—A portion of a select nursery row, from pedigreed seed, showing the uniformity and desirable type. Plants four months' growth from seed.

The relation of the stooling habits in alfalfa to the vigor and vitality has been repeatedly shown in the nursery and field tests of the past seven years. Plates Nos. 7 and 8 are two other views showing the contrast in the stooling habits of the different types.

There seems to be a grading of the types to different degrees of hardiness. This can be seen in the irregular size and types shown in the plates in this bulletin, and in almost any field of alfalfa. This is evidently one of the reasons for the gradual loss of plants. The least hardy types are the first to be killed, the others following gradually as the conditions become more severe. There are evidently other factors that go to make up resistance to cold besides the stooling habit.

Plate No. 14.—A portion of another row in the same nursery, from commercial seed, showing the irregular types, many of which are undesirable.

There is a difference in the effects of frost on the green leaves and stems of the plants above ground. The dark colored foliage is apparently more resistant than the light green color. Plates Nos. 9 and 10 show the effects of frost on two adjacent Turkestan plants. The light green one is frozen down; the dark green one has hardly a leaf hurt.

Turkestan alfalfa, because of its stooling habits, has been mentioned in this bulletin as one of the hardy types. So far, it seems to be a desirable variety altho there is a wide variation in the different strains. There are also several objectionable features to the Turkestan alfalfa, namely, a tendency to produce a poor yield of seed and a habit of very early starting in the spring, with a correspondingly early check in growth in the fall. Thus the first crop is made light or injured by late spring frosts and the last crop is cut short by the plants beginning to become dormant. Hence, for Colorado conditions, Turkestan alfalfa has not proven to be the most desirable.

The results of the nursery tests seem to emphasize the fact that there is more significance in the TYPE OF THE PLANT from which the seed comes than in the variety name or the locality from which the seed may be derived.

The alfalfa seed commonly sold on the markets has had no special breeding outside the natural selection from winter elimination.

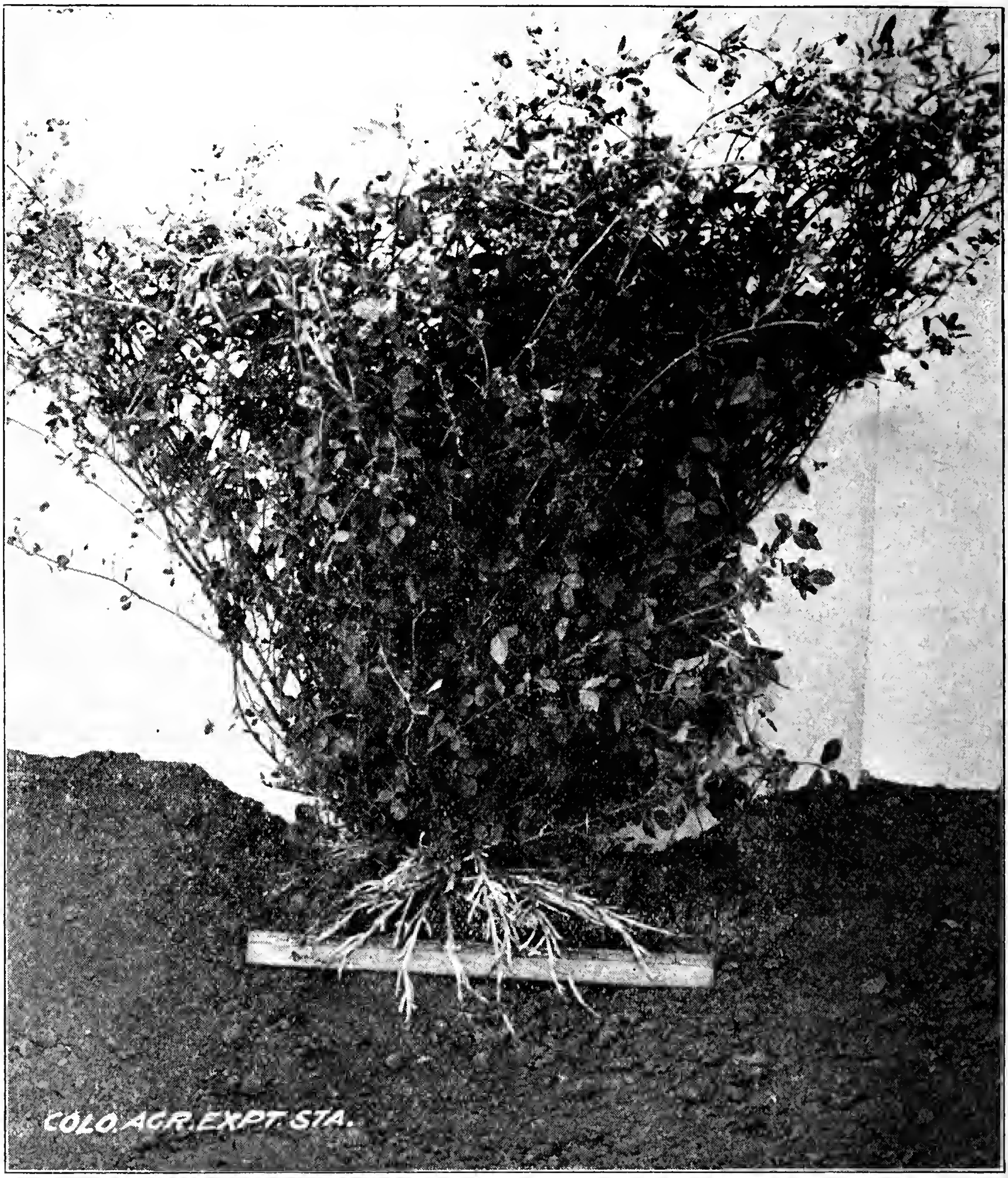
In Minnesota and in North and South Dakota, where the winter conditions are far more severe than in Colorado, the tests of alfalfa varieties for cold resistance have been very interesting. In several large variety tests, the same results have been secured, namely, the Grimm, Baltic and Turkestan varieties of alfalfa have proven to be the most hardy of a large list of alfalfas from different parts of the world. These results tally almost exactly with the results of similar tests in Colorado. All of these three strains have a distinct type of crown as compared to the type of crown found in the non-hardy varieties. The fact is *the hardy strains of alfalfa have spreading crowns with underground root stocks and shoots with buds which are protected by soil, from winter freezing.*

The non-hardy strains of alfalfa have more upright stooling crowns with the bud areas very near the surface, exposed to winter freezing, thawing and drying out. Hence, there is a decided relation between the TYPE OF THE CROWN and its tendency to winter-kill.

The stooling traits of the hardy strains are shown in the early seedling stage. This is illustrated in Plates 11 and 12. Plate No. 11 shows some seedlings of Grimm's alfalfa only six weeks from seed. Plate No. 12 shows some ordinary Spanish alfalfa the same age. Both lots were taken at the same time and under the same conditions in the field. The heavy stooling habit of the Grimm's alfalfa is very evident. The significant value of this trait can hardly be overestimated. It not only affords immunity from winter losses, but the protected underground buds are less liable to injuries from over-pasturing or attacks from grasshoppers. The spreading crown seems to be associated with a very much branched surface root system, in addition to the deep tap root. This growth habit makes surface moisture easily available. Hence, it is not surprising that the Grimm's and Baltic alfalfa should have proven to be the best type for dry conditions. This is confirmed by the dry land tests.

The Grimm's and Baltic strains of alfalfa have revealed the most promising traits in the Colorado tests, but the Baltic seems to be in the lead in seed production and slightly in the lead in hay yields. Apparently there is little difference except in seed yield, yet there are contrasts in the relative merits of different selections which are evidently transmitted. Hence, the strains of alfalfa can be made more uniform through seed selection. This is illustrated in Plates Nos. 13 and 14, which are sections from the same nursery. Plate No. 13 is a row sown with seed from selections for three generations. The plants are all desirable and relatively uniform. Plate No. 14 is another row seeded with commercial seed. It shows four markedly irregular types of plants, none of which are especially desirable. Thus the results of systematic seed selection have been very encouraging.

The conclusion is: That a hardy, desirable hay producing alfalfa, with good seed yielding tendencies, is within easy reach by means of systematic seed breeding.



A six months' old Grimm's alfalfa plant. The underground shoots three inches below the surface.

Bulletin 182 April, 1912

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

COLORADO CLIMATOLOGY

By ROBERT E. TRIMBLE

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1912

The Agricultural Experiment Station

FORT COLLINS, COLORADO

THE STATE BOARD OF AGRICULTURE

COLORADO CLIMATOLOGY

By ROBERT E. TRIMBLE

The Agricultural College has shown an active interest in meteorology from its very inception, and has maintained records since the opening of the institution. The work in this line was begun by Hon. F. J. Annis, then Professor of Chemistry, and kept up by him until he resigned his work as a professor at the College. The observations were then continued under Professor C. F. Davis and later by Professor A. E. Blount. These records are not all complete, but much credit is due these professors, pressed as they were with so many other duties, for having begun and carried on the observations under such difficulties. The rainfall records for the years 1873-74 were furnished by Mr. R. Q. Tenney, who, even at that early date, took an active interest in our climate.

In 1886 the work was put in the able hands of Dr. Elwood Mead, then a Professor in the College, and since January, 1887, the records are fairly complete. Upon the resignation of Dr. Mead in 1888, the observations were carried on by Professor V. E. Stolbrand until September 1st of that year, when Professor L. G. Carpenter was put in charge. Upon the organization of the Experiment Station, this work was transferred to it, and made a regular part of the investigations of the Section of Meteorology and Irrigation Engineering. Professor Carpenter remained in charge until January 1st, 1911, and to his long continued plan and steadfastness of purpose must be given a great deal of credit for the value of this work. I wish also to express my thanks for the interest and co-operation of the Director of the Experiment Station, Professor C. P. Gillette, and of Mr. V. M. Cone, who had charge of the Section from April 1st to July 1st, 1911, at which time the work of the Section was merged into a co-operative agreement with the Division of Irrigation Investigations of the U. S. Department of Agriculture, with the entire work under the charge and direction of Mr. Cone. The writer has served as an assistant in this Section since April 1st, 1891, and upon him has devolved the taking of the observations and the computations of this and the substations.

In the following pages free use has been made of the previous publications of this Station in this line, also the publications of the Weather Bureau, which has been for several years under the charge of Mr. F. H. Brandenburg, and especially of the article on the Climate of Colorado, by Professor A. J. Henry, in Bulletin "C," of the U. S. Weather Bureau.

Nearly all the variations of a continental climate are to be found within the borders of the State of Colorado. The natural diversities which result from its location in latitude and the many variations caused by the difference in topography, the effect of the Rocky Mountains extending through the State, are well defined in many cases and cause many complex effects. Many important local features are not apparent in the averages of the principal atmospheric conditions which make up what is known as "climate." Two-fifths of the State is highly mountainous, and the rest of it plains and high mesas. About 40% of the area is above 7,000 feet in elevation. That portion of the State lying east of the mountains, or the plains region, is crossed by a ridge which forms the watershed between the South Platte and the Arkansas rivers. The lowest point in the State is where the Arkansas river leaves the State a few miles below Holly, at an altitude of 3,370 feet, while Julesburg, 3,460 feet, on the South Platte, is the lowest point in the northeastern portion of the State.

A prominent feature of the mountain region is the number of large upland parks. North, Middle and South Park, and the San Luis Valley in the southern part, a remarkably flat, immense basin, which at one time was evidently a lake or sea bed, are all 7,000 to 10,000 feet in elevation. The average height of timber line is about 11,500 feet, varying from 10,000 to 12,000 feet.

The mean temperature of the State as a whole, is 45 degrees, and the average precipitation 15.60 inches. Our position south of the track of the majority of the storms as they cross from north of Montana to the Great Lakes and beyond, and being in the interior of the continent remote from the ocean, with our differences in altitude and diversified topography, are features which greatly modify the climate at differnet points. The usual track of storms being some distance northward, the State is generally dominated by the warm and dry quadrants of the low areas that move eastward with great regularity, and escapes in part the attendant precipitation of moisture, the high wind movement and the sharp fluctuations of temperature. Considering the great distance from the Pacific and the high mountain ranges which the westerly winds must cross, it is not surprising that the low humidity is attended by a great range of temperature.

Normal pressure distribution, with the result on the resulting direction of the winds, cause an important effect on our climate. During the winter the high pressure of the Salt Lake region remaining fairly constant, the effect this has on any locality depends upon its location, whether east or west of the mountains. To the west is found persistent cold for the latitude and altitude, especially in some of the higher valleys. The clear skies and still atmosphere cause radiation to proceed rapidly, and the topography causes a steady flow of cold air from the higher points into the valleys. On the eastern slope at such times the resulting winds are westerly, coming over the mountains, the air being warmed by compression during the descent to the foothills and plains, the mean temperature is raised considerably, and the capacity of the air for moisture is increased, so that there prevails in the eastern half of the State a long succession of relatively dry, warm and bright sunshiny days. During the summer months a low pressure is prevalent over the Salt Lake region, causing little precipitation, but this area of low pressure causes easterly winds east of the mountains and the air which is drawn up the slopes of the mountains becomes chilled by the elevation and causes precipitation during the warmer half of the year. Though distant, the influence of the Gulf of Mexico is felt to a varying extent. During the summer months when there is a general stagnation in the movement of the northern low pressure areas, sufficient time is afforded for moisture to be brought to the eastern slope, which causes increased precipitation east of the mountains during the warmer half of the year. The difference in the temperature of the two slopes is quite marked in the winter months when cold waves from north of Montana sweep southward along the eastern slope of the Rocky Mountains, but do not pass to the western slope, as the continental divide is an effective barrier. In the areas of high pressure or anti-cyclones, the greatest cold is generally confined to the lower stratum of air whose upper limit does not always reach as high as the mountain tops. As a matter of fact during these periods of low temperatures the adjacent high altitude stations experience relatively moderate temperatures, which condition, if not already in existence in the western valleys, is soon in evidence. Cold waves are the result of the transferring of cold air from the north, often increased by the radiation in the clear dry air.

The continental divide is also effective in moderating the winter temperatures of the eastern slope. When the distribution of the pressure is favorable to westerly winds, remarkable rises of temperature occur. These are called "chinook" winds. That the "chinook," or warm winds, blowing from the snow-covered mountains should be so warm and dry is explained by the fact that the air as it is forced up the western slope, owing to the high elevation, is unable to hold the moisture it contains and precipitation occurs. Its latent heat is liberated, so that the air reaches the top of the mountains colder but relatively warmer than when it began its ascent, and when in descending it is compressed, it reaches us as a warm, dry wind. Its effect in evaporating the snow on the plains has been the salvation of many herds of stock that must otherwise have perished. Locally they are accompanied by a low barometer, and soon a long wind cloud is seen like a banner lying close to the mountains, and later the wind springs up and the chinook is at hand. Chinooks are liable to occur at all seasons of the year, but the warmth is relatively greater in winter and therefore more noticeable when the mountain region is warmer in comparison with the plains than in summer, adding extra heat to the descending air.

During the heated period in July and August, high temperatures often characterize the days. However, the periods of oppressive heat, sunstrokes and heat prostrations that occur in our eastern states, especially in the large cities, are practically unknown in Colorado, owing to our low, sensible temperature, although the temperatures in this State are often as high as those reached in the eastern states. The prevailing lack of moisture in the air is favorable to increased intensity of the direct rays of the sun, but owing to the dry atmosphere, which is favorable to rapid cooling by radiation and evaporation, even the warmest days are comfortable in the shade, and are succeeded by cool nights, which prevent a tendency toward the debility incident to continued heat. Nowhere in Colorado is the air sultry or "muggy," the dryness being marked as shown by the low reading of the wet bulb thermometer, which gives the temperature of evaporation, or sensible temperature, or approximating that experienced by the body. In Colorado this temperature is not infrequently 20, 30 or 35 degrees lower than the air temperature during the hottest part of the day. The air temperature as it is commonly recorded does not necessarily indicate the sensation of heat experienced by a person, so that an estimation of the pleasantness of two locations, as judged by the air temperatures, may give an entirely erroneous impression. The term "sensible temperature" is used to describe the temperature felt on the surface of the body. The wet bulb thermometer as used indicates this. It is an ordinary thermometer covered with a piece of muslin and immersed in water. The dryness of the air takes up the water by evaporation, the greater the dryness the greater the evaporation, and since this is a cooling process, it affects the temperature experienced by one. The greater the humidity, or amount of moisture in the air, the less the evaporation, and therefore, less cooling effect. The wind is also an important factor in promoting evaporation. Hence the effect of a light freeze is to make it seem cooler than the temperature of the air would indicate, especially on a cold day.

We often hear the statement made that the climate is changing, and the popular belief that such is the case can only be explained by the generally short and defective memories of people who through exposure to them, or inconvenience, or perhaps loss from a few severe storms in the past, unintentionally exaggerate the severity and frequency of the event. Although large fluctuations occur in different years with some indication of periodical term, especially in Colorado where the range of temperature is great, there seems to be no progressive change. These fluctuations are large and often in the same direction for several successive years.

In the meteorological data for the last one hundred years, the record of some places extending still further back, there is nothing to support the idea of any permanent change in the climate having taken place, or about to take place, and the mean temperature shows no indication of any permanent change either warmer or colder. The small modifications claimed by cultivation, the planting of trees, and the erection of buildings, even of a large city, are too small to alter the mean temperature of any section of the country.

Colorado being an arid state, the amount of precipitation is at all times a vital question. Liability to a marked deficiency in rainfall in any region is a matter of grave concern to those engaged in agriculture and other interests. We often hear it stated that the rainfall is changing, that the settling up of the country and the planting of trees and building of reservoirs, forming lakes and wet places throughout the country, is causing an increase in the amount of our precipitation, but long series of observations taken at different places over the world, do not bear out that claim.

That the forests that cover the sides of the mountains exert a retarding influence in the melting snow and the drainage of the water, thus prolonging the period in which the same may be made available in irrigation, is true. Complaints are heard that the snows do not lie as long in summer as they used to before so much of the forest cover was removed, but there is no reason to believe that the amount of snow falling on the high mountains or plains either for that matter, is different from that of ages ago. In general, the precipitation seems to decrease with increase of altitude, as from the Missouri river west to near the base of the Rocky mountains, then there seems to be an increase in the amount to the tops of the higher mountains and on the crest of the range, especially on the windward side. There also seem to exist what have been termed islands of greater rainfall, where the precipitation, especially in winter, seems to be a great deal more than on the lower levels. In our case the line of lowest rainfall seems to be some 30 or 40 miles east of the foothills, and to increase to the eastward as well as westward to the summit of the mountains. The existence of islands of greater rainfall has long been noticed, several of which are found in this State. The rainfall in some of the more favored localities is at least twice as much as it is only a short distance away. These islands often occur at the sources of our larger streams, and since it is from the slowly melting snow on the high mountains that a fairly constant stream of water is available for the irrigation of the valley lands, the snowfall is very important to the well being of the people of the State, particularly those engaged in agriculture.

The months of greatest rainfall at the College are April, May, June, and July, which with that of the months of March and August, makes a total of 10.72 inches out of the total for the year, that falls during the growing season and is directly available to growing crops and ranges of the State. The rainfall of the State as a whole averages about 15 inches annually, the rainy season being in the spring and early summer months. The portion falling in the mountainous section is subject to a large run-off, and is gathered by the streams for use below, while the run-off on the plains is much smaller, being 10 to 15 per cent., but falling on a comparatively flat surface the moisture is absorbed by the soil and is directly available to the cultivated crops or natural stock range. An accurate knowledge of the rainfall or precipitation of this State is extremely desirable. All agricultural activities depend upon the amount and time of the year it is available, directly or through the aid of irrigation. Colorado, in common with a large part of the Rocky Mountain region, is occasionally visited by long dry spells. Since the distribution of pressure which brings about this condition is generally widespread, the dry periods prevail at the same time over extensive areas. During the last few years, for instance in 1910, from January 4th to April 29th, only 0.28 inches of moisture fell at Fort Collins. In 1907-08, from October 1st to May 1st, the total precipitation was only 0.82 inches, .44 of which fell in one storm in November, but fortunately this period was followed by a wet May, 5.83 inches, which was followed by favorable rainfall permitting good crops to be secured.

Absence of precipitation does not always mean drouth, especially when the soil is moist and evaporation is retarded by cloudiness and unfavorable wind conditions. Therefore, the maximum period without rainfall as a measure of the intensity of drouth must take into calculation the previous period and these other conditions. Then again the maximum period without rainfall often, in fact usually, occurs during the non-growing season, the autumn and early winter months having little or no effect on crops except that we need all the snow we can get on the high mountains for next season's supply. There is quite a wide range between the amount of precipitation in the wettest and driest years. For the wetter years the difference in amount may be two or three times the amount of the drier years. The snowfall for the winter months in Colorado is small, the average for November and December being the least in the year. However, on the crest of the range and on the high mountains, the snowfall is heavier and is stored there, especially in large drifts in the timber and gulches and north hillsides, for use in irrigation the following season. While many of the streams of the State have a good flow during May and June, they fall short during the months of July and August, at a time when some of our most valuable crops are in need of water. It is then that a supply of water stored in our reservoirs, that would otherwise go to waste and help increase the damage due to floods lower down, can be impounded and put to a beneficial use to water our best paying crops later in the season. This condition arises almost every year, because our best months for rain are April, May and June, which is the time the melting snows cause the rivers and streams to be in a flood stage, and as the rains on the plains supply sufficient moisture for growing crops, the water then flowing in the streams is available for the reservoirs. The storms during the summer months are local in character and vary considerably in the amount, from nothing to an inch or more, and in their frequency, sometimes one or more every day for ten days or two weeks, and then again they are entirely absent, no precipitation falling for three weeks or more. A general rain is not usual at this time of the year, the form being that of the thunder shower. These local storms are often so frequent that several may occur over the same valley or region on the same afternoon. The western part of the State and high mountain regions receive most of their precipitation from the westerly winds from the Pacific ocean, while east of the mountains the supply obtained from the Gulf of Mexico becomes important. The precipitation during the growing months of the year is about two-thirds of that for the entire year, and this is a very important factor, since this distribution makes our small supply more effective than it otherwise would be. In the crop season when we are subject to a long continued drouth and many farmers are ruined and destruction is widespread, one cannot fail to see that the state which would fail to develop its irrigation possibilities and reclaim its arid lands would be making a great mistake. From the mountain peaks, which collect the snows of winter, flow the streams which make crop production a certainty. The original source of all our lakes and streams is precipitation in the form of rain or snow. This is the original water supply. The guarantee to the irrigator and farmer, to the irrigation engineer and to the capitalist who finances some of our large enterprises, is the information furnished by the rainfall observers over the State that there is a sufficient and steady water supply that can be depended upon, that we shall know intelligently the amount of water available for the use of crops, and that the hydraulic engineer may have data to calculate the supply tributary to the storage reservoirs or the streams from which their canals are taken.

The normal barometer for the Station is 24.992 inches for the year. While the Station barometer has been moved two or three times, the change in elevation has been very slight and no correction has been applied for this. Only the correction for temperature has been applied. Our precipitation nearly always comes with a rising barometer. When the barometer is very low it is nearly always succeeded by wind. The precipitation is preceded by any barometer from the moderately low to the high.

The average date at which the last killing frost is likely to occur in a locality as a normal event, must often determine the limit in latitude and altitude at which a fruit or certain kinds of crops can be grown. Even in the most favored fruit regions of the State the records bring out the fact that killing frosts may be expected and will occasionally do great damage, though the smudge pot is lessening the danger and making a certainty of many years that formerly would have proved a total loss of crop. At Fort Collins the average date is May 10th to May 15th and September 15th to 20th. At Rocky Ford and Cheyenne Wells the season is a little longer.

In reporting the meteorological observations for the last twenty-five years it has been thought well to include, for purpose of comparison, the records taken for temperature and rainfall for our substations, and also the precipitation from a number of stations scattered over the State. Some of these observers reported to this Station during the early years, but during the last few years have reported altogether to the United States Weather Bureau office in Denver. They have been included here that they may be accessible along with data from our Station to people who may be interested.

The Agricultural Experiment Station at Fort Collins is located at the base of the Rocky Mountains, about four miles from the lowest foothills, beyond which the mountains rise to the summit of the range about fifty miles westward. It is located in Larimer county, about seventy-five miles north of Denver, on bench land about one mile south of and forty feet above the Cache la Poudre river. The College is in an irrigated area which extends about three miles further west, while in all other directions there are irrigated lands for a number of miles. The nearness to the mountains affects the climate in the amount and character of the clouds, in the temperature and in the direction and character of the winds. The elevation is about 5,000 feet, the latitude 40° 34′, and the longitude 105° 6′ west of Greenwich.

The maximum and minimum thermometers used are called self-registering, that is, the maximum thermometer registers the warmest temperature of the day and the minimum the coldest and the thermometers remain at the extreme point until read and reset. They are read each day so that a continuous record of the lowest and highest temperature for each day of the year is kept at each station. The difference between the maximum and minimum temperatures of the day constitutes the daily range of temperature. The average of the two gives the mean temperature. The difference between the highest and lowest temperature during the month gives the monthly range. At the end of the year we obtain the annual mean temperature, the monthly and daily means of temperature, the daily, monthly and yearly range of temperature.

The rain gage which is used to measure the precipitation has an inner receptacle that magnifies the amount ten to one, making it possible to read to one hundredth of an inch with accuracy, and though the different elements vary considerably from month to month and year to year, the averages of all the years and of all the separate months afford a fairly accurate estimate of what we may expect each year and each month. It is only from the average of a long series of observations that an accurate opinion may be formed of the temperature and precipitation of a locality, and also what is of equal importance, the extremes that are liable to come. The records in this bulletin are brought up to the end of 1911 and extend far enough back to give the average results and a fairly good knowledge of the climate of those portions of the State reported upon. That it is possible to place before the public the data from these stations depends upon a great deal of patience, care and accuracy on the part of the observers, and much credit is due those observers whose only recompense has been giving to the public a portion of their time and labor, in some cases twenty to twenty-five years, in order that we may have a knowledge of the climatology of the State in which we live.

Throughout all tables, unless otherwise stated, Fahrenheit degrees have been used.

Some of the qualities that make for health, comfort, and man's enjoyment of life are: abundance of sunshine; a pure, dry air; clear skies giving a wide daily range of temperature; freedom from heat prostrations; a low humidity, making us exempt from the raw, chilly mornings or penetrating cold, giving in its place a dry, bracing cold, usually attended by sunshine; and a favorable sensible temperature, tending to modify the cold of winter as well as the heat of summer. In winter it is usually warm in the sunshine, and in summer it is always cool in the shade. There is seldom a night in the year when a blanket covering is not comfortable. The air is healthier than at a lower altitude, because it is cleaner. Bacteria decrease rapidly as we rise in the air. Such a bracing, invigorating climate stimulates the people as a whole, to their best efforts in any line of work or endeavor.

THE ARKANSAS VALLEY SUBSTATION.

This station is located near Rocky Ford, Colorado, and was established by the Colorado Experiment Station in 1888, and records have been taken since that time. The elevation of the station is 4,180 feet. Mr. Frank L. Watrous was the observer at this station for a number of years and was succeeded by Mr. W. F. Crowley. Mr. H. H. Griffin was observer at that station from February, 1898, to February, 1903, and was succeeded by Mr. Philo K. Blinn, who is still in charge.

The season is some longer than in the northern part of the State, and the mean temperature a little higher, especially during the summer months. The climate, as well as the soil, has been found suitable to melon growing, and the Rocky Ford cantaloupe has a nation-wide reputation for quality, while the growth of wheat, alfalfa, sugar beets and other farm crops, make the Arkansas Valley famous throughout the West.

CHEYENNE WELLS STATION.

This station was established by the Colorado Experiment Station in June, 1894. It is located at Cheyenne Wells, Cheyenne county, on the Union Pacific railroad near the eastern border of the State, at an elevation of 4,280 feet.

The records were taken by Mr. J. B. Robertson, the superintendent of the substation until April, 1896, when he was succeeded by Mr. J. E. Payne, a very capable and conscientious observer, who kept the records until September, 1901. Mr. L. M. Parker took the records from that date until June, 1902, at which time Mr. J. B. Robertson was again employed by the station and was the observer until March, 1910, when he resigned and was succeeded by Mr. J. W. Adams, who has continued the work until the present time.

Lying as it does in the eastern part of the state, with no running streams of any size, the crops grown will always be limited to the rainfall of that region, but by conservation of the water supply, aided by the proper methods of tillage, much may be accomplished.

LONG'S PEAK, ESTES PARK, COLORADO.

This station was established by Mr. Carlyle Lamb, a well known guide in that region, in May, 1892, near the base of Long's Peak, and observations of precipitation and temperature were taken regularly until March, 1902, when Mr. Lamb left the Park and Mr. Enos A. Mills, the well known guide and lecturer, succeeded him, and the records have been continued by him to the present time.

The climate of Estes Park is typical of that found in this State in the high elevations, and the clear, sunshiny days and cool nights are making of the Park one of the greatest tourist resorts in the State. Strong efforts are being made to have the U. S. Government set it aside as a National Park.

The climate during the summer and fall months is delightful, and during the winter the brisk, dry cold, with plenty of sunshine, is found to have its charm to many. Often the cold wave surrounding the lower valleys is absent, owing to the fact that many of them do not extend upward to a sufficient height to affect many of the higher elevations of the State. Nature has done much in giving to this western country such grand and beautiful scenery as may be found throughout the Rocky Mountain region, and in Estes Park may be found one of the most pleasant resorts in the State.

During the winter the snowfall was not always melted; in those cases ten inches of snowfall has been taken as the equivalent of one inch of water.

COWDREY, NORTH PARK.

In 1891 Miss Lucy Bell began taking observations at what was then Pinkhampton, but was soon succeeded by Mr. George A. Barnes, and records have been kept by him at the same place, continuously since that time, although the post office now used is Cowdrey.

The temperature seems to be a little colder than formerly, and the extrement temperature of December, 1910, given as —56, seems to indicate that possibly the thermometer is not altogether reliable at that extreme temperature. The thermometer at Kremmling on that same morning registered —44 degrees. During the winters the snowfall is measured but not melted. In the computations ten inches of snowfall have been used as an equivalent of one inch of water, although during some of the cold weather when the snowfall was light, this would be rather more than the actual amount. In some cases at the College small amounts, when the weather was very cold, often take nearer 14 or 15 inches of snow to be equivalent to one inch of water.

The data from the following stations, except two or three which reported to the Experiment Station in earlier years but not during the last few years, has been obtained from the records of the United States Weather Bureau at Denver, Colorado, in charge of Mr. F. H. Brandenburg, the efficient forecast official, for the last several years. These stations are here given on account of the widespread interest in the rainfall over the different sections of the State.

TABLES I-VI—PAGES 18-23.

Daily Minimum Temperatures for twenty-five years, for the months from November to April inclusive, Fort Collins, Colorado.

TABLES VII-IX—PAGES 24-26.

Daily Maximum Temperatures for June, July and August, Fort Collins, Colorado.

TABLE X—PAGES 26-27.

Monthly Mean Dry Bulb Temperature at 7 A. M. and 7 P. M., Fort Collins, Colorado.

TABLE XI—PAGES 28-29.

Monthly Mean Wet Bulb Temperature at 7 A. M. and 7 P. M. This represents the sensible temperature, the degree of heat or cold felt by a person. Fort Collins, Colorado.

TABLE XII—PAGES 28-29.

Monthly Mean Maximum and Minimum Temperature, Fort Collins, Colorado.

TABLE XIII—PAGE 30.

Normal Daily Temperature for twenty-five years, Fort Collins, Colorado.

TABLE XIV—PAGE 31.

Monthly Mean Temperatures, Fort Collins, Colorado.

TABLE XV—PAGE 31.

Monthly mean Calories of the sun's heat at noon. Fort Collins, Colorado.

TABLE XVI—PAGES 32-33.

Extreme Monthly Maximum and Minimum Temperatures, Fort Collins, Colorado.

TABLE XVII—PAGES 32-33.

Average monthly reading of black and bright bulbs of actinometers at noon, in centigrade degrees. Fort Collins, Colorado.

TABLE XVIII—PAGE 34.

Monthly Mean Dew Point, Fort Collins, Colorado.

TABLE XIX—PAGE 34.

Monthly Mean Relative Humidity expressed in percentage of saturation of the atmosphere, Fort Collins, Colorado.

TABLE XX—PAGE 35.

Monthly Mean Terrestrial Radiation. Difference between monthly minimum and terrestrial six inches from the ground. Fort Collins, Colorado.

TABLE XXI—PAGE 35.

Monthly Mean Terrestrial Radiation Thermometer, six inches from the ground. Fort Collins, Colorado.

TABLE XXII—PAGE 36.

Monthly Mean and Normal Barometer (7 A. M. and 7 P. M.), Fort Collins, Colorado.

TABLE XXIII—PAGE 37.

Monthly Precipitation at the Colorado Experiment Station, Fort Collins, Colorado.

TABLE XXIV—PAGE 38.

Number of stormy days, with one hundredth or more of precipitation. Fort Collins, Colorado.

TABLE XXV—PAGE 38.

Monthly average wind in miles per day. Fort Collins, Colorado.

TABLE XXVI—PAGE 39.

Monthly Evaporation in inches from water surface. Fort Collins, Colorado.

TABLE XXVII—PAGES 40-41.

Monthly Mean Maximum and Minimum Temperatures at Arkansas Valley Substation, Rocky Ford, Colorado.

TABLE XXVIII—PAGES 40-41.

Extremes of Temperature of Arkansas Valley Substation, Rocky Ford, Colorado.

TABLE XXIX—PAGE 42.

Mean Monthly Temperature at Arkansas Valley Substation, Rocky Ford, Colorado.

TABLE XXX—PAGE 42.

Monthly Precipitation at Arkansas Valley Substation, Rocky Ford, Colorado.

TABLE XXXI—PAGE 43.

Monthly Mean Temperatures at the Plains Substation, Cheyenne Wells, Colorado.

TABLE I—DAILY MINIMUM TEMPERATURES FOR NOVEMBER
At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1887..........	32	32	36	28	26	39	34	29	24	24	27	26	36	39
1888..........	42	29	27	35	29	32	31	16	..	..	..	..	..	..
1889..........	20	8	24	8	**1**	9	25	21	20	28	21	7	27	12
1890..........	27	36	23	27	36	20	20	24	**6**	20	20	19	17	35
1891..........	24	22	29	33	31	34	25	27	13	40	24	14	20	19
1892..........	32	32	21	29	27	32	16	20	16	16	28	28	34	15
1893..........	25	17	13	17	22	28	39	18	23	33	17	10	24	12
1894..........	36	19	32	22	19	29	41	25	28	17	23	44	20	22
1895..........	22	36	29	26	22	9	19	24	16	16	16	16	27	17
1896..........	27	21	26	16	25	10	5	7	34	34	24	13	18	32
1897..........	22	24	29	30	13	20	28	27	18	38	22	33	37	26
1898..........	32	20	17	46	26	18	26	16	—10	**—11**	8	4	10	4
1899..........	22	**15**	16	28	28	30	20	27	27	30	24	34	31	21
1900..........	21	26	29	31	21	28	33	23	17	21	13	18	32	17
1901..........	22	30	15	29	24	39	17	31	22	27	26	14	17	15
1902..........	36	20	32	30	24	15	22	28	34	32	29	38	23	18
1903..........	24	22	24	28	22	20	25	25	19	20	19	30	23	22
1904..........	21	18	36	22	17	18	20	22	29	18	**0**	12	14	15
1905..........	**3**	4	24	27	35	25	25	25	21	17	20	22	25	21
1906..........	37	30	29	27	31	33	22	30	27	28	34	26	40	27
1907..........	38	22	23	24	22	25	29	20	18	25	3	**—1**	7	10
1908..........	30	23	22	21	20	22	22	21	22	15	—4	1	**—12**	—8
1909..........	24	27	30	28	27	29	36	21	24	27	21	25	24	17
1910..........	37	27	24	33	18	24	29	32	17	28	29	34	32	34
1911..........	17	14	11	23	24	22	18	26	19	22	**—7**	—11	2	22
Average.....	27	23	25	27	24	24	25	23	20	23	18	19	22	19

NOTE—Extreme in bold faced type.

TABLE II—DAILY MINIMUM TEMPERATURES FOR DECEMBER
At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1887..........	21	17	23	14	19	19	24	22	24	26	11	23	19	7
1888..........	11	32	12	26	19	18	27	15	18	19	20	18	18	21
1889..........	24	31	21	24	31	26	28	27	18	26	22	27	25	29
1890..........	24	25	29	16	23	20	12	**6**	15	23	24	13	20	19
1891.	34	29	25	10	14	1	**—10**	14	18	32	17	16	19	33
1892..........	19	23	21	21	30	26	14	4	2	9	8	—0	5	—10
1893..........	17	34	17	27	29	12	31	28	21	27	31	22	14	20
1894..........	28	21	—4	2	12	26	31	18	20	28	14	15	10	12
1895..........	17	10	1	8	15	21	27	20	12	31	24	19	23	24
1896..........	15	14	29	28	38	22	**0**	9	18	19	22	24	21	24
1897..........	11	3	—2	—8	7	27	19	27	28	17	18	25	22	17
1898..........	15	26	21	6	20	5	10	—1	—18	—11	1	27	3	6
1899..........	25	25	11	16	4	13	9	8	21	1	—3	19	8	**—9**
1900..........	25	24	7	23	27	23	21	19	15	13	10	16	15	13
1901..........	19	19	27	26	27	26	22	0	9	17	16	10	—15	**—31**
1902..........	16	23	17	12	24	17	13	22	24	26	19	15	26	18
1903..........	19	29	17	19	8	8	13	26	32	14	17	7	6	6
1904..........	29	24	26	17	7	8	14	11	16	18	24	8	17	12
1905..........	8	7	6	13	10	7	5	8	13	2	10	10	8	14
1906..........	21	19	27	36	30	27	22	22	18	23	27	30	29	18
1907..........	20	18	17	15	18	28	20	33	18	15	15	33	14	28
1908..........	0	—5	6	14	18	2	—1	5	13	17	19	25	25	18
1909..........	33	30	9	—15	**—19**	- -6	—18	—9	8	6	25	4	19	22
1910..........	26	26	28	22	20	11	23	22	24	23	24	29	24	17
1911..........	14	18	11	11	21	17	12	11	9	21	16	5	12	—2
Average.....	20	21	16	15	18	16	15	15	16	18	17	17	15	13

NOTE—Extreme in bold faced type.

TABLE 1—DAILY MINIMUM TEMPERATURES FOR NOVEMBER

At the Colorado Experiment Station, Fort Collins, Colorado.

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
28	32	24	15	32	19	21	27	20	18	16	—12	**—13**	6	14	16	..
..	..	..	19	22	**13**	16	20	21	16	18	26	33	30	28	15	..
17	11	18	24	29	29	26	24	30	30	26	18	18	17	15	18	..
14	11	19	21	19	18	34	18	20	21	26	12	19	21	16	20	..
13	—1	**—6**	9	18	17	31	12	26	21	26	28	45	20	12	25	..
31	13	22	26	17	25	13	28	20	20	26	**11**	14	16	32	26	..
16	20	15	9	8	9	25	1	**—13**	3	14	10	21	37	30	19	..
19	**—1**	0	22	18	35	19	24	14	24	25	30	31	21	19	21	..
20	40	28	36	19	23	26	4	4	11	5	**—3**	13	20	14	16	..
30	35	30	24	9	8	14	16	31	19	20	2	**—11**	—10	—8	—5	..
8	1	17	24	31	30	25	24	25	20	22	**—3**	2	4	1	11	..
8	20	18	38	27	16	11	7	5	16	9	13	22	24	25	19	..
24	34	25	31	17	25	26	22	31	16	17	17	18	28	28	33	..
22	26	30	10	16	13	**9**	35	28	26	13	24	30	13	13	12	..
14	20	33	31	**12**	19	24	19	27	33	19	23	20	18	20	35	..
26	14	22	20	24	23	19	23	19	23	24	16	15	18	8	**4**	..
26	18	0	**—10**	—4	7	21	23	22	22	19	20	26	22	15	18	..
18	33	22	18	29	11	27	20	15	16	11	12	21	39	20	19	..
27	24	32	27	20	20	27	30	22	21	27	25	35	15	4	8	..
33	34	21	11	—2	**—9**	11	12	17	—2	15	11	6	11	15	29	..
14	11	14	27	11	4	7	3	3	9	23	20	19	18	18	21	..
6	13	14	27	30	22	24	24	25	19	16	0	—1	10	19	15	..
11	**—3**	7	16	29	38	32	25	35	42	27	32	29	10	21	28	..
30	28	20	20	32	16	23	32	23	27	24	31	**14**	14	32	27	..
36	27	22	35	34	26	20	17	12	18	14	26	16	5	2	9	..
20	19	19	21	20	18	21	20	18	19	18	16	19	17	17	18	..

TABLE II—DAILY MINIMUM TEMPERATURES FOR DECEMBER

At the Colorado Experiment Station, Fort Collins, Colorado.

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
0	17	18	32	11	3	1	2	28	20	18	16	3	7	15	18	10
32	28	26	16	13	22	23	18	23	19	19	11	**4**	4	9	6	5
26	30	29	29	17	13	26	12	20	22	20	23	23	26	17	**3**	13
18	9	11	10	17	26	10	14	12	21	11	34	12	13	24	26	32
23	19	18	16	17	18	20	13	15	7	—5	—9	25	28	8	15	17
—17	5	—9	—3	6	4	**—17**	—15	17	17	28	17	16	14	17	22	15
33	18	17	22	14	12	18	30	27	25	7	8	8	24	14	**2**	9
23	13	13	14	20	24	17	14	18	19	—5	—13	—16	**—24**	—3	—2	—6
13	15	5	10	0	11	21	9	9	20	7	17	4	13	**—5**	20	7
13	27	22	13	10	22	22	21	15	21	15	12	18	19	14	15	27
3	**—11**	—10	—6	—2	—6	—6	6	16	13	15	12	20	25	40	29	14
8	9	13	10	16	29	21	8	12	8	13	16	20	17	13	—14	**—22**
—6	13	17	17	4	4	7	12	21	20	26	21	22	21	13	16	21
12	19	24	27	13	20	34	31	24	15	24	13	19	—3	1	—7	**—22**
—12	14	5	18	22	9	18	24	41	29	22	15	26	11	18	15	23
0	**—18**	—5	—1	25	33	13	6	21	15	10	13	21	17	7	6	8
11	17	13	14	22	13	27	14	13	**5**	21	25	16	12	8	15	17
12	26	10	22	11	29	12	25	25	13	15	7	2	**1**	8	17	27
8	15	14	9	14	14	9	11	-1	15	4	18	10	15	**—4**	—3	6
7	7	9	10	21	22	34	18	21	25	18	31	19	17	29	15	15
4	10	9	**—5**	—3	—1	8	11	25	19	22	17	27	17	17	5	10
23	25	16	**—13**	—3	—1	—3	5	9	18	18	18	24	19	25	16	16
16	14	3	—9	—2	1	—11	—10	-4	3	—4	7	15	23	9	16	21
18	18	14	15	17	20	25	18	5	14	20	**3**	10	9	6	6	12
9	12	11	21	24	15	14	1	7	15	—2	—3	**—8**	—1	1	—6	5
11	13	12	12	12	14	14	12	17	17	13	13	14	13	12	10	11

TABLE III—DAILY MINIMUM TEMPERATURES FOR JANUARY

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1887	..	..	..	..	..	..	—9	**—19**	—18	—1	8	21	23	16
1888	10	26	23	28	18	16	—15	—12	—14	18	10	9	20	—16
1889	6	4	7	7	16	18	20	11	2	19	9	19	19	17
1890	5	—2	4	8	8	8	2	9	15	21	15	**—13**	—7	4
1891	15	9	10	14	7	17	10	22	12	—13	12	—9	3	—2
1892	2	9	21	36	22	0	10	11	6	—4	**—28**	—11	—15	—6
1893	14	33	23	39	22	31	22	12	17	19	27	7	10	12
1894	15	34	13	2	—8	—16	0	1	—12	5	17	14	16	24
1905	—2	—3	0	—2	24	12	15	—3	20	22	23	18	27	32
1896	26	13	**—8**	1	14	20	7	18	28	15	22	10	2	13
1897	28	15	9	6	11	16	14	12	14	16	13	20	13	24
1898	4	14	25	18	15	**16**	26	13	12	23	10	6	6	15
1899	—8	6	22	14	5	-2	7	5	3	2	13	22	11	7
1900	10	9	23	24	16	10	14	9	25	10	11	19	25	25
1901	**—22**	—18	—4	11	13	18	14	21	13	2	—4	33	24	31
1902	19	27	15	15	23	19	24	24	27	19	14	17	18	19
1903	7	18	18	34	37	47	13	13	19	14	3	**1**	13	6
1904	12	6	7	6	13	0	9	13	13	5	18	23	10	14
1905	24	4	16	26	11	20	0	10	9	3	—12	—16	**—22**	—5
1906	10	2	16	1	26	8	16	**—4**	5	9	6	20	21	8
1907	25	—2	**—5**	10	23	20	15	12	12	14	18	20	19	11
1908	19	6	15	5	8	15	11	8	22	21	5	19	5	6
1909	11	17	24	27	3	**--3**	4	20	41	3	0	3	8	18
1910	21	9	2	—11	**—21**	—16	—6	—1	—4	2	4	6	—1	4
1911	—2	—13	**—18**	4	22	21	22	23	16	40	26	11	16	29
Average	10	9	11	13	14	12	10	9	11	11	10	11	11	12

NOTE—Extreme in bold faced type.

TABLE IV—DAILY MINIMUM TEMPERATURES FOR FEBRUARY

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1887	6	—5	0	—5	—4	10	14	18	12	5	—2	8	18	18
1888	29	29	36	27	**14**	20	27	27	31	30	25	34	37	20
1889	6	9	14	38	16	11	15	9	8	28	29	10	37	24
1890	12	33	33	38	31	26	15	14	19	19	16	6	14	14
1891	—11	—12	**—15**	—2	4	5	5	6	—14	—4	1	1	5	7
1892	22	21	17	23	8	7	—1	**—9**	—8	18	24	8	22	19
1893	—2	**—10**	7	12	32	6	1	8	31	15	26	13	14	12
1894	0	16	—3	—10	—5	6	9	17	6	3	—12	**—15**	—7	0
1895	—8	6	8	13	9	—3	—14	1	2	—2	—14	**—28**	—24	—22
1896	**4**	15	23	14	11	25	6	21	10	16	8	15	9	25
1897	10	23	22	11	19	20	24	12	14	20	16	22	9	0
1898	9	10	8	23	9	26	31	21	28	13	11	10	15	30
1899	—7	—16	—18	—31	—32	**—38**	—32	—17	—4	—5	—30	**—38**	—1	1
1900	11	14	29	14	15	15	9	—7	12	7	23	—2	—7	0
1901	5	1	9	—1	—9	—5	5	—14	**—15**	—6	—2	—4	0	7
1902	—9	**—23**	0	10	18	22	16	14	18	18	28	22	28	6
1903	18	11	6	—20	—19	—9	—21	—13	1	11	13	5	—15	—23
1904	15	13	18	13	26	26	8	12	**3**	6	12	18	34	9
1905	0	—2	—5	—4	13	10	—2	—1	8	6	—14	—25	**—27**	9
1906	17	14	18	3	**—5**	—2	3	7	6	2	10	11	15	12
1907	24	11	**—3**	3	11	26	19	24	35	15	17	21	22	16
1908	**—15**	—3	14	15	19	10	19	17	10	18	14	12	16	3
1909	14	14	14	20	15	18	14	3	—6	19	18	22	9	—6
1910	21	17	5	5	9	9	10	20	1	7	14	19	13	23
1911	33	16	28	27	21	18	19	12	11	[illegible]	18	22	17	21
Average	8	8	11	9	9	10	8	8	9	11	10	8	10	9

NOTE—Extreme in bold faced type.

TABLE III—DAILY MINIMUM TEMPERATURES FOR JANUARY
At the Colorado Experiment Station, Fort Collins, Colorado.

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
30	18	10	12	34	24	26	14	14	20	11	6	20	23	26	8	18
—28	—17	0	2	13	—8	—6	13	18	22	19	35	26	26	28	20	26
5	10	—2	**—4**	11	—3	12	8	0	3	11	1	30	28	10	16	15
—6	—2	9	14	13	—12	—4	—1	10	9	43	42	28	16	18	16	16
9	3	0	5	4	14	33	30	11	9	13	20	24	21	—11	**—16**	2
8	10	—6	—24	—8	26	—7	2	5	11	15	15	18	21	24	31	23
—2	—2	2	—1	13	4	7	12	15	28	22	4	14	34	10	18	25
24	25	26	—1	1	13	20	12	—14	**—22**	4	10	5	22	9	14	9
8	—1	15	16	15	17	17	16	13	14	14	7	—4	**—10**	10	9	1
10	13	20	24	29	20	28	24	7	15	10	23	16	17	24	21	19
10	19	23	7	9	12	20	26	20	—5	—7	—17	**—26**	—19	—9	8	8
2	10	19	6	—1	13	15	—2	4	10	—2	**—12**	0	16	16	20	11
13	27	22	7	25	22	21	27	18	22	11	19	6	0	—8	—2	**—17**
31	29	27	14	18	20	13	15	15	28	5	9	10	**—6**	—2	6	11
29	22	12	15	10	16	24	21	20	6	17	21	9	17	14	2	6
17	8	20	24	17	28	6	7	2	—5	—11	**—31**	—19	—20	—18	—15	**—7**
9	12	8	10	7	9	10	21	24	26	27	21	23	19	19	6	15
3	13	15	13	17	4	10	4	3	7	10	1	0	**—7**	13	24	12
4	14	29	30	16	22	18	19	19	24	22	19	18	25	18	17	8
15	10	21	18	30	23	5	—3	8	25	12	15	12	11	23	12	15
5	11	7	13	13	6	22	20	13	8	8	4	3	12	14	14	19
6	**—10**	21	5	15	7	20	20	5	17	18	31	10	17	19	7	—3
22	26	29	27	27	31	25	25	24	21	14	18	21	17	10	1	8
4	14	26	17	21	16	8	30	27	28	20	23	21	17	26	19	22
28	21	16	16	23	31	17	1	—5	7	24	27	30	21	28	32	45
10	11	15	10	15	14	14	14	11	13	13	12	11	13	12	12	12

TABLE IV—DAILY MINIMUM TEMPERATURES FOR FEBRUARY
At the Colorado Experiment Station, Fort Collins, Colorado.

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
20	14	30	20	8	8	**—8**	14	11	8	8	20	20	22	..	..	..
17	26	22	32	24	21	19	16	18	27	26	16	25	30	25	..	..
12	2	**—16**	0	10	—14	10	7	— 2	12	25	17	30	18	..	..	..
13	16	41	16	14	13	23	18	16	8	0	—7	**—20**	—19	..	..	..
25	24	21	18	22	10	5	16	22	33	21	9	14	2	..	..	..
7	9	19	18	20	24	25	25	29	13	17	27	28	21	23	..	..
1	16	23	14	8	24	23	23	24	17	4	18	—3	**—10**	..	..	..
—2	8	10	24	7	—4	0	1	—12	—11	11	15	33	20	..	..	..
—23	—14	30	24	10	24	29	26	29	28	32	22	26	28	..	..	..
25	21	22	14	19	17	19	27	29	11	20	20	33	18	19	..	..
20	34	21	17	5	10	14	0	— **5**	5	13	11	8	23	..	..	..
23	22	22	20	16	**7**	13	22	12	13	20	20	17	22	..	..	..
1	23	5	8	13	21	26	—4	—12	—1	17	—2	2	21	..	..	..
—17	**—23**	—18	5	17	18	26	22	28	19	31	29	20	10	..	..	..
32	23	30	19	20	18	19	10	6	11	25	28	26	24	..	..	..
19	27	25	30	30	14	23	25	20	12	31	28	35	29	..	..	..
—28	—20	—3	9	—3	5	5	8	15	20	18	5	10	11	..	..	..
17	18	24	5	4	16	22	25	48	33	49	27	36	28	20	..	..
3	23	—1	3	12	21	21	19	28	21	19	28	13	16	..	..	..
14	33	7	13	15	14	24	26	15	10	11	25	14	25	..	..	..
21	18	19	38	27	25	26	21	21	35	17	21	20	9	..	..	..
25	18	11	18	—2	5	6	2	11	30	26	23	19	26	18	..	..
—14	17	22	29	25	27	15	23	16	—5	9	27	12	23	..	..	..
10	—5	**—16**	2	2	10	6	0	4	26	26	24	18	20	..	..	..
25	24	20	20	11	—3	—8	—7	— **9**	—2	14	15	11	5	..	..	..
10	14	15	17	13	13	15	15	15	15	20	19	18	17	21	..	..

TABLE V—DAILY MINIMUM TEMPERATURES FOR MARCH

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1887	26	27	13	12	**8**	26	25	24	26	26	30	35	24	36
1888	13	11	9	4	**3**	11	15	22	20	13	19	26	30	32
1889	21	**17**	31	**17**	20	23	25	20	19	**17**	29	28	28	37
1890	**—9**	17	18	29	33	22	24	20	23	22	19	16	12	18
1891	26	34	3	10	14	4	**—4**	5	16	34	8	1	14	18
1892	24	26	32	33	33	34	28	27	26	17	20	30	25	26
1893	**—2**	12	20	4	18	16	23	36	19	29	13	16	24	6
1894	18	20	19	27	15	14	18	19	28	28	19	42	28	32
1895	15	24	14	16	20	15	21	26	21	23	18	16	4	—9
1896	13	7	5	2	14	12	18	16	31	17	22	27	18	7
1897	21	19	20	17	22	21	24	33	20	15	22	15	4	7
1898	33	13	16	25	19	15	17	24	18	24	19	18	20	29
1899	28	33	25	18	14	11	28	32	31	22	17	17	20	30
1900	30	27	29	26	22	21	21	26	33	33	30	27	28	25
1901	34	32	35	3	—4	10	19	31	26	14	28	34	27	19
1902	29	17	27	24	8	23	27	20	24	33	18	17	14	20
1903	**—10**	·6	9	17	22	24	4	7	23	19	21	28	29	28
1904	22	23	11	19	31	20	32	23	37	21	25	21	13	24
1905	37	18	31	28	36	20	27	**12**	22	28	21	23	26	26
1906	15	12	3	14	18	25	17	30	27	11	6	2	9	6
1907	5	33	27	25	23	25	28	21	33	28	27	27	**3**	13
1908	23	10	11	21	33	20	11	20	**8**	10	15	26	29	42
1909	27	31	26	31	29	25	23	11	15	19	16	**—12**	15	21
1910	36	42	24	28	27	29	22	35	29	**12**	21	20	23	30
1911	**—2**	8	14	17	27	26	26	45	33	33	35	28	23	21
Average	19	21	19	19	20	20	20	23	24	22	21	21	20	21

NOTE—Extreme in bold faced type.

TABLE VI—DAILY MINIMUM TEMPERATURES FOR APRIL

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1887	40	18	26	**16**	34	34	32	40	45	30	30	25	34	34
1888	49	45	**30**	35	46	33	37	48	44	31	**30**	**30**	36	41
1889	32	46	25	28	34	35	44	38	39	43	42	32	31	36
1890	**14**	17	32	26	46	38	41	29	19	29	33	35	32	32
1891	25	**13**	18	23	**17**	27	29	39	33	21	30	33	35	29
1892	33	23	30	31	25	24	37	24	21	34	25	36	22	20
1893	30	36	39	32	28	42	33	22	21	21	39	31	19	**8**
1894	25	29	32	22	22	26	37	38	**16**	27	33	38	34	25
1895	27	**17**	30	27	28	30	38	19	27	39	26	29	27	33
1896	**7**	7	21	30	26	30	34	41	26	30	36	35	25	39
1897	29	28	**20**	23	27	33	31	**20**	23	33	36	37	23	25
1898	21	18	32	29	**14**	27	25	25	27	29	35	35	26	33
1899	14	13	**8**	21	29	14	26	24	27	35	33	32	51	28
1900	27	29	30	32	32	29	31	32	36	24	**5**	23	31	33
1901	16	20	32	30	24	23	29	33	32	17	32	29	27	30
1902	20	25	21	24	33	38	35	46	37	23	26	34	32	**18**
1903	37	33	26	24	33	27	29	34	31	38	39	27	18	24
1904	27	21	32	26	38	27	30	28	**14**	38	39	21	30	30
1905	38	32	30	29	29	26	29	36	44	28	22	**12**	31	32
1906	30	31	**22**	30	25	26	36	37	33	43	38	39	35	27
1907	34	40	34	**41**	29	34	30	32	37	39	38	22	28	33
1908	18	**10**	16	30	21	28	31	31	24	33	25	32	35	35
1909	29	32	31	30	27	**9**	23	14	23	27	30	26	35	32
1910	31	25	40	29	**18**	23	51	28	37	38	44	35	40	36
1911	29	42	29	32	31	23	28	24	33	33	34	36	21	24
Average	27	26	26	28	29	28	31	31	30	31	29	31	30	28

NOTE—Extreme in bold faced type.

TABLE V—DAILY MINIMUM TEMPERATURES FOR MARCH

At the Colorado Experiment Station, Fort Collins, Colorado.

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
28	36	28	36	25	14	18	20	25	34	28	20	15	30	32	30	20
28	28	29	30	18	18	20	19	32	30	14	12	8	21	32	39	35
30	34	40	42	30	39	31	33	21	19	18	29	30	32	32	35	32
16	21	34	34	28	33	28	33	28	40	20	20	36	20	23	26	18
25	25	36	26	22	37	24	30	31	19	14	6	24	28	32	25	26
19	8	**—20**	—3	19	16	14	7	21	29	33	28	18	24	33	21	28
12	18	10	15	16	29	23	28	27	12	18	21	36	18	25	33	48
24	35	31	34	21	21	14	19	13	20	**10**	18	20	13	14	34	32
—18	—5	11	24	26	21	26	26	29	30	23	28	36	40	34	32	28
—7	15	20	10	22	27	45	34	32	33	47	27	40	39	28	27	24
14	18	32	24	23	16	25	15	**— 7**	6	19	27	30	29	29	30	25
20	17	13	19	26	20	9	—2	**— 6**	16	21	22	9	20	19	12	18
12	22	21	16	22	22	28	27	23	31	26	9	**—24**	—17	10	12	—9
22	21	16	20	24	25	20	21	27	29	23	26	30	**10**	22	18	23
19	20	20	19	24	17	29	29	33	25	33	20	28	20	14	**—8**	8
20	12	**2**	18	24	33	32	29	32	32	31	34	26	23	19	16	14
30	28	34	19	4	—3	7	16	— 8	6	18	29	28	29	37	36	33
22	29	21	34	32	30	28	19	18	34	15	**10**	21	25	30	33	32
40	36	36	42	30	29	28	34	32	25	32	34	35	32	20	27	37
2	—19	—19	9	**—25**	0	15	5	22	24	27	27	32	33	32	26	31
21	29	28	33	49	34	44	41	25	33	34	28	24	30	31	28	18
33	46	44	33	26	11	26	18	29	42	34	16	29	24	11	21	30
26	20	28	26	31	26	31	36	19	34	15	**10**	21	25	30	33	32
21	24	28	27	29	31	32	32	36	34	29	38	37	30	33	28	19
24	25	33	24	22	27	44	33	25	27	29	29	13	28	44	22	28
19	22	22	24	24	3	24	24	23	26	25	24	24	24	26	25	25

TABLE VI—DAILY MINIMUM TEMPERATURES FOR APRIL

At the Colorado Experiment Station, Fort Collins, Colorado.

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
30	34	33	31	30	30	34	26	30	24	28	28	40	44	40	43	..
50	43	42	32	40	36	42	48	53	53	46	48	38	37	38	37	..
44	39	41	38	**24**	27	37	35	47	29	36	45	35	38	31	31	..
33	27	28	30	38	43	41	35	42	41	32	31	32	38	36	42	..
31	31	31	39	37	41	34	37	34	38	39	39	33	36	47	38	..
28	30	32	36	29	27	**19**	22	27	33	36	43	25	36	33	42	..
26	20	24	29	24	28	25	30	35	44	30	26	26	34	25	22	..
31	34	31	31	35	28	30	39	37	38	33	39	34	36	42	40	..
38	24	25	37	31	36	32	27	32	34	35	35	44	45	50	39	..
36	31	23	14	26	30	33	35	37	34	40	37	36	41	40	37	..
35	34	31	38	35	37	39	33	39	44	31	35	40	38	32	32	..
30	39	42	23	38	36	39	32	36	25	29	31	50	21	37	42	..
24	27	36	24	39	25	22	28	29	44	37	48	31	30	31	37	..
35	39	32	12	32	34	38	41	31	36	35	30	42	43	32	32	..
27	22	**9**	29	31	32	34	47	43	36	38	40	38	42	50	41	..
24	29	30	30	34	35	38	30	23	28	41	30	29	33	33	34	..
30	30	28	39	41	27	40	30	37	43	33	37	35	30	23	**13**	..
26	23	25	25	39	41	31	35	29	38	29	36	37	43	43	39	..
23	27	30	33	34	29	21	34	39	32	33	35	41	44	34	35	..
32	33	32	39	37	30	39	38	39	43	40	33	36	28	39	38	..
42	36	21	32	24	23	**6**	20	37	25	22	23	32	30	22	**6**	..
42	39	35	47	36	33	33	34	37	39	32	27	30	30	20	36	..
32	36	36	34	29	32	28	28	25	38	27	38	28	40	29	21	..
31	21	33	28	25	36	43	28	27	25	27	30	32	39	50	42	..
16	**24**	30	36	27	40	33	35	44	40	39	33	42	44	33	30	..
32	31	30	31	33	31	32	33	34	35	34	35	35	34	37	34	..

TABLE VII—DAILY MAXIMUM TEMPERATURES FOR JUNE

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1887..........	88	82	68	74	88	92	79	72	78	87	89	92	89	90
1888..........	67	74	81	78	73	78	88	73	76	79	88	..	..	..
1889..........	62	68	65	68	85	82	70	49	54	61	74	82	86	74
1890..........	85	84	74	65	71	63	67	75	77	81	82	86	73	72
1891..........	65	71	65	58	62	72	83	84	81	68	78	78	80	77
1892..........	71	82	77	50	65	74	81	85	84	81	78	69	68	81
1893..........	71	74	64	55	60	73	93	87	77	91	**95**	93	89	80
1894..........	71	75	76	85	59	75	76	65	70	84	87	87	85	78
1895..........	66	55	55	66	77	80	80	71	60	66	77	79	81	85
1896..........	64	79	87	71	71	69	76	84	88	90	77	84	89	**91**
1897..........	..	..	..	63	61	66	68	78	74	74	73	84	80	81
1898..........	84	88	66	54	66	65	72	67	69	72	72	76	80	73
1899..........	73	72	67	70	83	63	74	64	67	82	89	72	69	69
1900..........	66	77	78	72	79	86	90	85	84	61	76	81	74	77
1901..........	70	72	71	73	70	73	86	85	73	67	71	77	82	61
1902..........	83	74	79	85	84	86	55	80	94	94	77	79	85	88
1903..........	61	62	61	62	60	70	70	70	49	53	67	70	74	64
1904..........	67	69	54	59	65	77	83	65	64	78	74	73	66	76
1905..........	79	79	85	85	78	74	78	82	76	75	77	84	85	83
1906..........	66	70	66	76	80	64	62	76	82	83	80	80	82	80
1907..........	72	70	74	70	76	72	76	70	69	75	82	86	80	84
1908..........	68	68	82	71	74	73	70	75	77	78	86	76	65	74
1909..........	63	72	80	88	90	70	69	76	69	68	73	72	74	61
1910..........	79	85	54	71	75	73	85	83	76	74	77	71	78	85
1911..........	83	81	80	83	82	81	86	82	82	78	81	84	85	84
Average.....	72	74	71	76	73	74	80	75	74	76	79	80	79	77

NOTE—Extreme in bold faced type.

TABLE VIII—DAILY MAXIMUM TEMPERATURES FOR JULY

At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1887..........	80	79	79	88	94	**97**	91	82	88	90	79	94	94	92
1888..........	84	87	89	94	90	97	83	79	87	95	**99**	95	90	89
1889..........	92	70	78	91	95	95	84	75	66	78	88	89	81	81
1890..........	85	86	80	86	88	92	90	90	89	85	86	90	**93**	78
1891..........	88	78	87	81	83	74	68	78	88	81	88	85	75	79
1892..........	87	76	74	84	90	91	71	69	79	89	85	85	86	**93**
1893..........	91	83	94	93	93	93	85	84	91	89	**95**	91	91	87
1894..........	83	90	79	71	73	73	80	89	91	**94**	**94**	82	74	80
1895..........	78	78	86	91	79	87	79	65	69	56	55	69	71	86
1896..........	91	89	79	83	89	92	81	85	89	91	93	93	**96**	90
1897..........	89	86	73	76	90	91	**95**	89	67	74	82	84	93	77
1898..........	71	69	76	85	86	88	90	85	85	84	87	79	83	85
1899..........	72	81	70	83	89	78	78	87	87	87	91	81	78	76
1900..........	80	87	85	74	84	91	82	83	92	91	92	**93**	90	**93**
1901..........	72	86	92	91	86	91	94	95	89	89	92	93	92	**97**
1902..........	76	86	79	72	71	78	82	79	63	76	86	88	85	94
1903..........	91	82	55	72	86	92	86	85	90	86	82	86	83	92
1904..........	79	73	73	77	71	56	70	80	86	84	86	86	82	85
1905..........	80	70	78	87	78	80	79	69	74	83	89	87	84	89
1906..........	81	62	70	76	79	75	69	66	74	76	75	80	76	74
1907..........	85	89	**94**	**94**	88	85	81	87	79	80	81	84	85	75
1908..........	64	73	83	**93**	78	66	81	89	92	92	85	76	82	78
1909..........	88	93	88	83	89	85	88	87	85	84	89	83	80	74
1910..........	83	80	86	89	78	83	91	88	61	79	74	80	82	93
1911..........	78	69	78	86	76	73	83	83	78	85	87	**88**	76	83
Average.....	82	80	80	84	84	84	82	82	82	84	82	82	84	85

NOTE—Extreme in bold faced type.

TABLE VII—DAILY MAXIMUM TEMPERATURES FOR JUNE
At the Colorado Experiment Station, Fort Collins, Colorado.

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
90	88	90	91	94	82	83	83	87	90	**96**	93	93	79	73	80	..
..	..	..	..	79	69	71	74	75	75	85	83	89	**97**	94	89	..
68	77	81	82	82	64	73	80	83	84	86	81	86	**90**	85	**90**	..
85	78	85	88	86	89	85	88	**92**	**92**	**92**	86	84	82	84	85	..
71	59	73	78	77	79	72	**87**	79	74	76	78	77	77	71	80	..
77	67	**74**	82	83	**86**	81	77	77	69	83	78	**86**	85	78	76	..
82	85	91	94	94	92	87	91	91	80	88	85	88	92	74	84	..
74	72	86	89	83	79	81	82	81	77	80	86	72	83	89	**91**	..
86	81	67	68	**73**	78	77	86	**89**	85	67	77	64	61	76	76	..
90	90	84	85	89	82	80	80	78	79	62	81	85	76	83	85	..
88	77	78	76	85	85	87	**90**	84	69	69	76	78	85	80	85	..
83	88	88	85	86	83	90	92	88	88	90	76	89	**97**	80	87	..
78	84	90	**96**	89	85	83	74	85	77	88	82	88	92	95	95	..
82	88	80	84	85	91	93	90	87	89	91	**94**	89	**94**	88	**93**	..
62	74	78	69	74	84	80	84	90	92	**94**	85	84	90	89	89	..
62	80	77	74	77	54	77	87	90	**96**	83	92	72	61	68	75	..
70	71	85	84	83	69	71	67	81	64	76	82	87	**92**	**86**	86	..
74	76	82	79	79	73	69	76	80	73	64	74	81	**87**	**83**	85	..
83	66	77	74	69	80	67	87	81	80	73	86	**92**	89	78	**83**	..
85	**90**	69	75	76	70	85	82	53	64	76	82	83	84	83	87	..
86	72	78	75	76	75	77	82	74	77	68	67	81	86	**88**	84	..
57	78	71	69	81	87	**92**	82	74	83	80	88	83	71	79	80	..
72	83	82	85	84	81	79	83	88	89	81	88	**94**	**94**	86	83	..
86	77	85	86	**90**	**90**	89	87	**90**	68	78	82	84	85	82	78	..
72	62	72	76	84	87	81	78	86	85	79	74	86	**92**	89	83	..
78	78	80	81	82	77	80	83	83	80	80	82	83	85	82	84	..

TABLE VIII—DAILY MAXIMUM TEMPERATURES FOR JULY
At the Colorado Experiment Station, Fort Collins, Colorado.

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
78	64	72	85	89	76	83	82	85	88	86	84	79	92	78	77	84
89	87	69	80	89	87	89	83	79	78	86	..	87	92	90	92	81
86	89	90	84	84	91	92	80	79	80	83	94	95	84	72	87	**97**
89	91	86	85	89	**93**	86	80	87	84	89	90	92	93	85	77	86
82	81	83	86	84	**89**	89	82	83	86	82	87	86	81	80	66	80
75	85	84	90	92	91	90	89	86	87	89	87	64	64	77	87	90
84	90	88	86	90	89	89	90	90	90	76	80	88	85	87	85	81
86	90	89	80	78	83	88	89	93	92	93	**94**	87	85	88	90	89
89	87	81	82	81	74	70	69	74	84	92	**93**	92	**93**	87	76	84
89	74	81	84	86	85	82	75	80	75	81	82	76	81	88	83	85
84	82	85	75	62	77	85	84	83	76	87	87	89	94	91	85	89
84	84	92	91	88	84	91	93	91	81	89	**97**	**97**	93	78	86	67
75	71	76	74	81	86	90	91	82	90	**94**	80	82	79	64	82	87
74	73	90	82	60	79	88	88	78	74	78	80	90	76	86	89	**93**
93	93	84	89	95	96	93	92	90	90	82	84	87	91	85	94	94
98	89	69	69	74	79	85	86	87	92	81	75	89	94	94	88	95
88	86	75	76	86	90	90	90	85	86	**95**	92	91	88	85	78	80
91	88	90	82	84	81	79	78	84	74	81	81	80	84	88	82	80
87	89	**91**	78	85	79	82	83	76	81	81	80	74	74	75	74	74
66	78	85	80	85	**93**	85	81	78	86	87	91	84	80	83	83	88
84	74	88	90	84	90	87	88	93	87	80	63	73	75	79	81	77
81	87	81	77	76	85	83	80	80	87	89	91	88	92	89	77	76
81	87	92	**94**	93	88	81	75	76	85	86	84	86	88	81	90	93
92	92	92	93	92	88	85	92	96	94	96	**100**	94	82	82	80	85
79	76	77	78	68	82	84	84	77	68	77	81	87	83	86	87	80
84	83	84	83	83	85	86	84	84	84	86	82	85	85	83	83	85

TABLE IX—DAILY MAXIMUM TEMPERATURES FOR AUGUST
At the Colorado Experiment Station, Fort Collins, Colorado.

Year.	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1887	90	92	95	89	75	82	**97**	84	86	87	83	83	87	84
1888	85	83	84	**88**	86	85	77	73	85	82	78	83	**88**	84
1889	78	86	84	88	94	**97**	90	89	70	79	84	89	81	84
1890	90	89	87	79	89	**95**	92	78	86	84	84	82	77	76
1891	81	78	87	90	88	90	89	88	84	90	83	92	**93**	83
1892	96	98	**99**	97	87	90	90	84	81	86	92	92	94	96
1893	79	79	87	85	87	88	87	77	82	79	88	88	**92**	86
1894	82	72	76	85	84	82	87	84	87	86	84	92	89	83
1895	83	81	82	87	84	82	87	89	76	83	90	93	86	73
1896	88	92	92	90	85	88	93	89	91	93	78	90	92	**94**
1897	86	82	74	69	82	87	86	80	81	77	86	89	87	79
1898	79	76	90	95	80	76	79	83	86	79	89	91	91	90
1899	79	88	74	70	81	83	86	86	88	88	85	85	79	87
1900	**94**	93	90	87	87	83	92	89	90	87	88	89	85	85
1901	**97**	81	77	76	85	83	80	87	88	90	78	89	88	89
1902	**100**	92	92	95	64	84	84	87	93	72	76	89	87	88
1903	82	88	94	**95**	82	81	91	90	76	78	76	78	86	87
1904	85	86	86	76	88	87	71	90	81	**91**	85	90	87	85
1905	80	83	84	88	78	80	85	86	87	87	74	75	85	83
1906	75	86	81	78	79	78	81	85	89	87	85	85	87	86
1907	78	78	80	84	88	91	90	91	**92**	90	80	87	87	88
1908	86	85	**93**	88	88	79	72	87	82	72	64	78	73	80
1909	89	84	85	89	**93**	88	87	83	88	88	86	89	88	88
1910	84	89	87	80	**76**	84	80	78	77	85	89	81	74	79
1911	80	80	78	78	82	83	87	**95**	85	77	76	82	88	89
Average	85	85	86	81	84	85	86	85	84	84	82	90	86	85

NOTE—Extreme in bold faced type.

TABLE X—MONTHLY MEAN DRY BULB TEMPERATURES
At the Colorado Experiment Station, Fort Collins, Colorado.

DATE.	January		February		March		April		May		June	
	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m
1888	....	....	....	....	....	....	....	....	....	....	....	....
1889	11.7	....	15.2	....	30.9	....	44.5	....	48.5	....	58.9	....
1890	15.8	25.7	18.8	31.0	30.4	41.6	40.8	49.8	51.1	59.7	60.0	67.0
1891	13.6	21.6	14.8	19.5	23.4	29.6	40.5	49.6	52.5	55.3	59.0	63.4
1892	13.3	20.2	21.2	27.2	27.0	34.8	39.7	44.6	47.1	51.4	59.6	64.4
1893	22.4	30.9	17.4	27.4	26.3	37.3	38.4	44.9	49.2	54.7	62.4	69.1
1894	14.3	24.6	9.0	18.8	28.2	37.8	42.7	51.4	53.3	57.0	60.3	66.2
1895	16.2	22.9	11.8	21.8	25.8	34.6	44.2	51.4	50.8	56.4	57.5	60.8
1896	20.4	29.1	23.2	32.6	27.2	34.6	41.4	49.1	54.0	58.9	62.3	67.3
1897	12.0	22.4	16.9	28.1	25.3	32.6	41.9	46.8	56.2	59.5	60.4	63.9
1898	13.8	23.4	21.8	32.0	24.5	32.8	43.3	50.6	48.8	53.0	60.4	66.7
1899	16.6	24.3	1.6	10.6	24.2	29.9	40.3	47.8	49.7	56.8	60.0	66.8
1900	19.7	28.7	15.2	23.6	29.0	39.6	39.5	44.2	54.5	60.0	63.4	69.1
1901	16.9	27.6	13.9	24.2	28.9	35.8	39.5	45.9	54.0	59.3	60.1	66.5
1902	12.2	20.6	22.4	31.2	28.6	35.6	40.8	48.2	52.9	59.2	59.5	67.1
1903	20.8	28.8	5.7	11.0	23.2	31.7	41.1	46.9	49.1	56.2	57.8	62.4
1904	15.5	29.4	24.5	37.4	30.5	42.0	40.4	49.8	51.2	56.4	58.2	62.8
1905	19.5	24.6	10.6	22.2	33.6	42.4	37.5	44.8	48.1	53.7	60.2	66.7
1906	18.8	29.2	16.5	29.6	18.9	25.8	42.4	49.5	51.1	57.4	58.1	64.0
1907	18.2	25.1	24.9	35.6	33.8	46.4	37.1	44.4	46.6	50.6	58.5	63.8
1908	18.8	26.5	19.3	31.0	33.3	41.8	44.4	53.1	48.8	55.2	57.8	64.6
1909	22.1	28.0	19.5	26.5	29.0	35.2	37.7	43.8	49.2	54.5	60.2	65.3
1910	16.6	23.3	15.0	27.7	35.4	50.0	46.1	55.5	50.8	56.2	61.8	68.1
1911	21.9	32.5	17.4	25.8	33.0	44.6	41.1	48.9	51.9	60.3	64.3	69.4
Average	17.0	25.9	16.4	26.1	28.3	37.1	41.1	48.2	50.8	56.4	60.0	65.7
Maximum	22.4	32.5	24.9	37.4	35.4	50.0	46.1	55.5	56.2	60.3	64.3	69.4
Minimum	11.7	20.2	1.6	10.6	18.9	25.8	37.1	44.2	46.6	51.4	57.5	60.8

TABLE IX—DAILY MAXIMUM TEMPERATURES FOR AUGUST
At the Colorado Experiment Station, Fort Collins, Colorado.

15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
86	**86**	90	87	85	80	85	88	59	59	73	77	83	85	73	85	77
72	68	72	83	80	81	77	80	85	86	**88**	83	81	78	82	85	83
88	82	90	89	90	78	82	84	89	93	84	90	92	90	85	83	90
86	67	80	68	56	79	81	80	84	74	76	76	82	82	85	88	78
83	86	84	84	84	83	66	74	80	88	83	63	65	80	82	83	88
96	97	88	76	82	77	80	71	78	83	85	86	85	58	73	84	87
82	83	87	89	90	76	86	84	80	80	88	81	72	77	84	82	70
89	88	**91**	87	85	84	85	80	89	83	83	82	84	89	87	88	88
90	93	**94**	74	78	88	93	87	83	85	90	91	67	67	81	86	76
92	84	85	80	84	90	74	60	74	83	79	79	86	86	85	79	83
76	85	81	77	79	83	77	83	81	91	**94**	77	83	84	79	88	91
95	82	86	92	92	93	**96**	91	77	89	93	91	93	83	96	94	90
91	80	82	84	82	86	91	85	78	84	91	92	89	**95**	87	71	85
84	88	87	87	87	86	84	82	78	71	81	86	84	89	91	91	86
88	82	89	86	86	80	84	87	86	88	89	89	87	84	85	75	84
92	92	93	88	91	88	85	86	70	84	84	77	81	80	82	80	82
82	87	88	85	88	91	92	85	87	82	78	85	79	79	82	88	94
87	83	79	80	87	85	62	79	87	87	72	86	86	80	79	80	83
87	79	**93**	83	84	91	90	91	88	84	87	90	90	91	90	84	89
89	**92**	90	91	91	85	86	87	74	81	75	70	82	86	85	77	78
87	87	90	82	64	69	74	86	86	87	84	83	76	82	75	77	75
78	79	76	79	65	71	75	61	76	83	86	77	80	87	87	87	72
93	92	77	78	83	82	90	89	92	78	92	89	86	67	78	82	85
85	75	61	81	**93**	90	92	92	87	84	64	85	89	88	92	69	83
93	85	82	88	84	87	74	65	72	64	78	86	68	81	86	89	91
87	84	85	80	83	83	82	81	81	82	83	83	82	82	84	83	84

TABLE X—MONTHLY MEAN DRY BULB TEMPERATURES
At the Colorado Experiment Station, Fort Collins, Colorado.

July		August		September		October		November		December		Year	
7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m
....	....	....	....	51.2	....	40.0	....	23.6	....	20.4	....	....	....
63.4	72.9	61.1	72.1	47.9	60.0	38.7	49.5	23.8	30.2	29.4	34.7	39.5	....
66.8	73.0	60.6	66.6	51.8	60.3	36.2	47.4	25.8	35.8	23.2	31.2	40.1	49.1
63.7	68.2	62.2	66.7	52.6	60.3	37.5	48.1	27.6	34.2	21.1	26.5	39.0	45.3
65.5	68.9	62.7	67.4	54.5	62.5	37.8	45.6	28.2	36.8	16.0	22.3	39.4	45.5
66.3	73.0	60.7	67.7	53.0	60.5	37.9	47.1	24.2	32.4	24.8	31.4	40.2	48.0
65.5	70.3	62.5	67.8	50.7	58.3	41.9	49.5	28.5	38.9	16.1	22.4	39.4	46.9
61.7	65.4	61.6	66.4	52.2	60.0	37.1	45.3	23.2	32.4	18.0	27.3	38.3	45.4
66.7	70.1	63.6	68.6	52.3	56.5	38.3	46.0	19.9	30.0	21.0	32.3	40.9	47.9
62.9	66.9	60.9	65.3	56.1	61.8	38.5	45.4	26.2	33.4	17.5	23.7	39.6	45.8
64.2	71.8	62.5	71.2	47.5	57.1	37.7	44.5	23.6	27.8	13.2	19.6	38.4	45.9
63.0	67.2	62.3	67.0	52.8	59.3	37.3	43.4	29.1	37.4	19.8	24.3	38.1	44.6
62.6	69.7	61.6	68.6	51.0	58.2	39.5	48.6	26.7	35.9	20.2	28.9	40.2	47.9
68.3	74.0	64.2	68.3	50.6	58.3	39.0	46.8	27.7	36.5	20.2	28.0	40.3	47.6
62.4	68.2	63.7	68.3	47.8	56.9	38.1	47.3	25.1	34.8	18.8	24.3	39.4	46.8
64.2	69.8	61.8	68.9	47.0	55.8	37.4	49.1	24.4	33.4	23.0	29.9	38.0	45.3
63.6	67.2	61.1	67.5	50.5	58.0	35.3	45.4	24.0	33.2	23.3	30.0	39.8	48.3
63.1	66.8	61.9	67.8	49.1	58.3	30.7	40.6	25.8	37.3	13.3	23.6	37.8	45.7
62.4	66.5	61.3	65.3	51.5	57.7	37.0	44.2	25.5	33.0	25.3	32.1	39.1	46.2
64.0	68.4	61.8	67.0	51.3	58.0	37.2	47.8	20.4	30.3	22.8	27.5	39.7	47.1
63.4	67.5	61.1	64.1	52.6	59.7	37.5	45.7	22.6	27.6	18.2	22.8	39.8	46.6
64.3	71.0	64.2	69.2	51.3	56.7	40.4	47.8	30.4	35.3	12.6	17.6	40.1	45.9
68.3	72.3	61.8	67.5	53.2	60.6	40.2	48.1	30.7	38.7	22.2	31.2	41.8	49.9
62.9	69.2	60.4	68.8	54.6	62.2	38.3	45.4	24.6	30.7	13.1	21.7	40.3	48.3
64.3	69.5	62.0	67.7	51.4	59.0	37.9	46.5	25.5	33.7	19.7	26.7	39.5	46.9
68.3	74.0	64.2	72.1	56.1	62.5	41.9	49.5	30.7	38.9	29.4	34.7	41.8	49.9
61.7	65.4	60.4	64.1	47.0	55.8	30.7	40.6	19.9	27.6	12.6	17.6	37.8	44.6

TABLE XI—MONTHLY MEAN WET BULB TEMPERATURES
At the Colorado Experiment Station, Fort Collins, Colorado.

DATE.	January		February		March		April		May		June	
	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m
1888.......	....	....	....	....	....	....	....	....	....	....	....	....
1889.......	9.9	....	13.4	....	28.7	....	39.1	....	43.3	....	53.0	....
1890.......	13.9	21.5	16.8	25.0	26.2	32.4	36.4	40.8	45.5	48.0	51.8	53.3
1891.......	12.4	19.3	12.9	17.8	21.9	26.6	35.7	40.4	47.6	48.0	53.8	55.9
1892.......	11.5	17.6	19.8	24.9	24.4	29.9	34.7	36.5	42.4	44.4	53.3	56.3
1893.......	18.1	24.8	14.7	22.3	22.7	30.2	32.3	34.7	42.2	44.8	52.6	55.1
1894.......	12.0	19.7	7.0	15.5	24.4	29.8	36.2	39.9	45.6	48.0	52.6	53.2
1895.......	14.6	19.6	10.0	18.2	22.8	27.9	37.3	39.8	44.4	45.9	52.1	52.8
1896.......	17.5	23.1	20.0	25.7	24.0	28.9	35.3	38.8	44.7	45.5	55.4	56.9
1897.......	10.5	17.7	15.6	24.0	23.6	27.8	37.1	38.3	49.9	51.0	54.9	55.4
1898.......	12.4	20.2	19.6	26.7	21.9	26.4	36.8	39.7	44.7	45.9	53.9	55.9
1899.......	14.1	20.8	0.8	9.1	21.9	26.4	34.2	37.4	43.4	45.1	51.8	53.7
1900.......	17.8	24.6	13.4	20.5	27.1	33.4	37.0	39.9	48.4	50.6	56.2	57.8
1901.......	14.4	22.6	12.6	20.6	25.0	29.6	35.7	37.9	48.0	50.3	53.9	56.6
1902.......	11.0	17.7	20.2	26.4	25.5	29.4	36.0	39.1	47.0	49.1	53.8	55.0
1903.......	18.0	24.9	4.9	9.7	22.0	29.0	35.9	38.6	44.2	46.2	53.5	55.8
1904.......	13.5	24.0	20.7	30.0	26.8	34.4	34.9	39.6	45.5	48.7	53.6	55.1
1905.......	18.3	22.4	9.9	19.4	31.0	36.6	34.8	39.2	43.9	47.0	54.8	58.6
1906.......	16.2	23.3	14.2	23.7	17.6	22.8	37.8	40.9	45.0	47.9	51.6	55.1
1907.......	16.6	22.2	22.3	29.0	29.4	35.6	32.4	36.5	42.0	43.7	51.0	53.3
1908.......	15.8	21.6	16.2	25.1	27.4	32.2	35.9	39.8	42.8	45.0	51.2	53.8
1909.......	19.9	24.6	17.1	22.9	26.7	32.0	32.8	36.0	42.1	43.6	54.4	56.9
1910.......	14.1	19.3	12.8	21.9	29.2	37.0	37.0	41.0	44.8	47.4	54.2	55.4
1911.......	19.0	26.5	15.6	21.2	28.6	35.2	35.2	38.4	44.2	47.5	55.2	57.5
Average...	14.8	21.7	14.4	21.8	25.2	30.6	35.7	38.8	44.8	47.0	53.4	55.4
Maximum.	19.9	24.9	22.3	30.0	31.0	37.0	39.1	41.0	49.9	51.0	56.2	58.6
Minimum..	9.9	17.6	0.8	9.1	17.6	22.8	32.3	34.7	42.0	43.6	51.0	52.8

TABLE XII—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES
At the Colorado Experiment Station, Fort Collins, Colorado.

DATE.	January		February		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1887.......	34.0	10.8	41.8	10.3	60.4	25.1	60.7	32.1	75.3	42.6	85.3	52.3
1888.......	42.7	10.0	52.6	25.2	52.0	20.7	73.3	40.6	66.2	41.6	79.4	51.3
1889.......	38.7	10.5	40.2	13.0	56.6	27.7	63.5	36.0	65.7	40.5	75.6	46.1
1890.......	39.8	9.6	45.0	15.0	52.9	23.2	60.0	33.1	71.2	41.0	81.2	46.8
1891.......	35.4	8.9	31.8	7.7	41.2	19.7	61.4	31.9	68.6	41.1	74.4	47.5
1892.......	35.1	7.1	39.2	16.4	45.5	21.9	58.6	29.4	61.1	38.9	76.4	46.5
1893.......	49.4	15.8	41.5	12.3	50.2	20.1	57.0	28.3	66.8	37.8	83.3	47.2
1894.......	39.4	8.4	33.7	3.7	52.4	22.5	64.6	32.1	71.6	42.8	79.3	47.1
1895.......	37.0	10.9	35.2	7.0	48.6	19.9	66.2	32.1	68.3	38.9	73.6	44.9
1896.......	49.0	16.1	49.2	17.7	46.3	21.8	62.8	30.5	72.8	41.2	81.0	49.6
1897.......	40.2	9.3	40.9	14.2	44.8	19.9	59.5	32.0	73.6	42.7	77.6	48.2
1898.......	40.7	10.6	50.6	17.6	47.9	17.5	64.5	30.8	62.7	40.4	79.8	48.2
1899.......	39.0	10.4	25.3	—5.4	41.6	17.9	60.5	28.9	69.5	38.0	79.8	47.4
1900.......	46.7	15.2	37.8	10.7	53.9	24.3	54.5	31.3	72.4	43.2	83.4	50.7
1901.......	43.8	12.6	38.4	9.4	48.1	21.2	56.9	31.1	71.1	42.8	78.3	48.3
1902.......	39.2	9.1	45.5	18.5	48.0	22.5	61.0	30.4	70.5	41.7	79.0	48.2
1903.......	44.2	16.4	28.2	—0.1	42.8	18.4	59.4	31.2	68.0	36.6	71.6	47.0
1904.......	42.7	9.4	50.4	20.2	54.7	24.4	61.0	31.3	66.2	41.2	73.5	46.4
1905.......	37.9	12.6	36.0	6.8	55.2	29.2	55.4	31.5	63.7	40.5	79.5	50.0
1906.......	49.0	12.8	48.2	12.7	36.5	13.5	60.0	34.2	69.0	40.9	76.4	47.2
1907.......	39.3	12.4	50.9	20.0	59.2	27.3	56.0	29.1	60.8	37.0	76.7	45.2
1908.......	44.4	12.0	49.0	13.3	56.4	24.2	65.1	30.6	65.5	38.3	76.4	46.5
1909.......	42.2	16.8	43.7	14.0	45.6	23.9	54.6	28.9	65.7	37.9	79.3	49.4
1910.......	40.0	10.5	42.3	10.7	65.6	28.5	67.3	33.1	66.8	40.6	80.0	49.0
1911.......	45.0	18.0	39.3	13.9	57.1	26.1	60.5	32.2	70.7	41.2	81.3	51.0
Average...	41.4	11.9	41.5	12.2	50.5	22.5	61.0	31.7	68.1	40.4	78.5	48.1
Maximum.	49.4	18.0	52.6	25.2	65.6	29.2	73.3	40.6	75.3	43.2	85.3	52.3
Minimum..	34.0	7.1	25.3	—5.4	36.5	13.5	54.5	28.3	60.8	36.6	71.6	44.9

TABLE XI—MONTHLY MEAN WET BULB TEMPERATURES
At the Colorado Experiment Station, Fort Collins, Colorado.

July		August		September		October		November		December		Year	
7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m	7 a m	7 p m
....	....	....	....	46.6	....	35.7	....	22.6	....	18.6	....	....	....
57.7	61.3	55.4	58.5	41.6	46.8	34.9	41.2	21.3	27.2	25.9	29.3	35.4	....
59.5	61.6	55.5	57.7	44.4	48.3	32.5	38.8	23.4	30.1	20.6	26.7	35.5	40.3
57.9	60.3	56.8	57.9	48.0	51.0	32.6	38.0	23.8	28.5	18.6	22.6	35.2	38.9
59.1	60.1	55.1	56.0	47.0	49.1	34.1	38.6	24.6	30.1	14.0	19.6	35.0	38.6
59.0	58.4	54.6	56.5	45.3	47.6	32.4	37.2	20.7	26.4	21.2	26.9	34.6	38.7
57.6	59.2	56.2	57.5	45.0	48.2	35.5	39.2	24.8	31.4	14.3	19.5	34.3	38.4
56.2	57.6	56.0	57.9	46.1	48.4	33.6	37.8	20.6	26.3	15.4	22.5	34.1	37.9
60.7	60.8	56.8	57.8	48.7	50.8	34.8	38.8	17.4	24.0	19.0	26.8	36.2	39.8
57.0	58.3	56.6	57.8	51.5	53.5	35.4	39.3	23.8	28.9	15.4	20.0	35.9	39.3
57.2	59.7	56.0	57.9	42.2	46.8	31.9	36.1	20.5	24.2	11.4	16.6	34.1	38.0
57.5	59.6	55.4	57.0	46.5	49.8	34.2	38.0	26.5	31.9	17.3	20.9	33.6	36.8
56.4	59.4	54.3	56.6	46.4	49.8	35.0	40.4	23.2	29.1	17.2	23.1	36.0	40.4
61.6	62.0	58.1	59.6	46.3	48.5	35.5	39.9	24.6	30.4	17.9	24.5	36.1	40.2
56.1	58.7	56.3	57.2	42.9	47.8	35.4	41.6	23.4	29.6	16.9	21.9	35.4	39.5
58.1	60.2	57.3	59.5	43.4	48.4	34.4	40.6	22.7	30.0	19.5	24.9	34.5	39.0
57.8	59.4	55.8	59.2	46.3	51.7	32.7	40.0	20.5	27.4	20.7	26.1	35.7	41.3
57.4	58.4	56.7	59.5	44.7	50.4	28.2	35.3	23.9	31.8	11.8	19.2	34.6	39.8
56.7	58.9	55.6	58.1	48.6	52.6	33.5	38.7	23.5	29.4	23.2	28.1	35.3	40.0
58.4	60.6	56.2	57.9	46.7	49.8	34.8	42.2	19.0	26.1	19.8	23.3	35.7	40.0
57.6	59.6	56.5	59.2	47.4	51.6	33.7	38.8	20.8	24.6	16.5	20.7	35.2	39.3
59.3	62.9	59.2	61.1	46.8	51.7	35.1	39.4	27.5	31.0	11.1	15.3	36.0	39.8
58.9	60.0	55.5	57.6	49.2	51.8	35.3	41.2	28.1	33.5	20.0	26.6	36.6	41.1
56.5	58.8	54.0	57.0	48.2	51.2	34.2	38.4	21.2	25.9	12.0	18.4	35.3	39.7
58.0	59.8	56.1	58.0	46.2	49.8	34.0	39.1	22.9	28.6	17.4	22.8	35.2	39.4
61.6	62.9	59.2	61.1	51.5	53.5	35.7	42.2	28.1	33.5	25.9	29.3	36.6	41.3
56.1	57.6	54.0	56.0	41.6	46.8	28.2	35.3	17.4	24.0	11.1	15.3	33.6	36.8

TABLE XII—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES
At the Colorado Experiment Station, Fort Collins, Colorado.

July		August		September		October		November		December		Year	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
84.2	54.4	83.0	51.3	79.6	46.7	64.9	31.4	54.0	23.2	43.4	15.7	64.3	33.0
87.4	58.2	81.4	51.7	78.9	43.0	64.4	36.4	48.6	24.7	48.8	17.8	64.6	35.1
84.8	51.7	86.4	52.2	74.7	39.8	64.8	36.1	44.8	19.4	51.4	22.8	62.3	33.0
87.1	55.2	80.9	51.2	77.0	39.6	63.8	31.0	54.9	21.3	49.6	18.3	63.6	32.1
82.0	51.9	83.0	49.6	78.0	44.2	67.1	30.3	48.5	21.7	41.3	16.0	59.4	30.9
83.4	53.0	86.2	48.4	82.7	42.1	63.9	31.5	52.0	22.9	36.8	9.3	60.1	30.6
88.0	53.4	83.0	50.5	78.7	41.3	65.7	31.7	49.7	17.4	47.2	20.0	63.4	31.3
85.4	52.8	85.0	51.6	76.3	41.5	68.5	34.2	57.8	23.3	40.4	10.9	62.9	30.9
79.2	51.4	83.8	51.3	80.1	41.9	63.9	29.8	48.4	19.0	43.2	14.0	60.6	29.3
84.8	55.6	85.1	53.0	72.8	44.8	64.6	31.4	45.1	16.6	49.1	19.0	63.6	33.1
83.2	50.4	82.3	51.4	80.0	47.4	64.8	32.2	51.0	20.2	39.0	11.8	61.4	31.6
85.1	53.0	87.6	52.2	78.3	38.8	61.0	31.5	44.5	16.1	37.9	9.3	61.7	30.5
81.3	52.6	84.2	51.9	80.3	42.4	60.2	31.9	56.6	24.9	42.6	12.7	60.1	29.5
83.7	52.1	86.4	49.5	73.9	43.2	67.6	32.8	53.1	21.6	47.3	16.0	63.4	32.6
90.1	54.9	85.0	52.9	75.4	42.7	66.6	32.9	56.8	23.1	40.4	15.1	62.6	32.2
82.5	49.5	85.1	52.3	74.1	39.5	64.5	33.2	49.6	22.6	39.8	14.3	61.6	31.8
84.8	52.1	85.0	51.2	74.2	39.4	67.2	31.9	53.2	19.0	49.0	15.6	60.6	29.9
80.5	50.8	82.8	51.2	76.1	42.4	66.4	31.3	59.7	19.8	47.9	15.9	63.5	32.0
80.3	51.0	85.3	51.2	79.1	41.8	60.3	26.8	53.7	22.0	45.1	8.9	61.0	31.0
78.9	51.0	83.3	51.0	73.0	44.3	62.1	30.5	46.0	21.1	48.1	21.5	60.9	31.7
83.2	52.4	82.8	51.0	75.2	42.2	67.6	32.2	49.6	16.2	45.3	15.6	62.2	31.7
82.3	52.8	78.9	52.0	79.3	44.4	61.3	31.6	49.0	15.2	37.7	11.9	62.1	31.1
85.7	55.0	85.6	54.7	73.7	44.0	66.5	32.2	50.9	24.6	30.6	5.6	60.3	32.2
86.6	55.0	82.4	52.0	76.8	46.3	69.0	33.9	54.0	26.4	44.6	17.7	64.6	33.6
79.9	52.8	81.7	50.7	77.4	46.2	59.3	31.4	47.0	17.4	37.8	9.4	61.4	32.5
83.8	52.9	83.9	51.4	77.0	42.8	64.6	32.0	51.1	20.8	43.4	14.6	62.1	31.7
90.1	58.2	87.6	54.7	82.7	47.4	69.0	36.4	59.7	26.4	51.4	22.8	64.6	35.1
78.9	49.5	78.9	48.4	72.8	38.8	59.3	26.8	44.5	15.2	30.6	5.6	59.4	29.3

TABLE XIII—NORMAL DAILY TEMPERATURES FOR TWENTY-FIVE YEARS, 1887-1911

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec
1............	25.4	**22.2**	32.8	41.3	48.6	56.1	67.2	68.4	66.2	57.3	41.5	34.2
2............	22.9	22.6	35.7	41.8	47.1	57.5	66.0	68.8	63.7	55.4	39.6	31.8
3............	25.9	24.5	31.7	42.0	47.9	56.2	65.4	68.6	64.3	53.5	42.3	29.0
4............	28.8	23.1	31.5	42.2	40.5	57.9	66.7	68.8	63.6	52.4	42.4	31.4
5............	29.0	25.2	31.6	43.4	52.1	59.0	67.3	68.5	63.5	51.4	41.0	31.7
6............	26.5	24.3	34.7	44.9	51.2	59.7	68.0	68.5	63.7	52.3	40.0	30.7
7............	26.1	23.3	36.9	46.0	52.7	61.6	67.8	68.5	63.5	52.6	39.9	29.5
8............	25.3	23.5	38.7	44.4	54.0	61.8	67.7	69.0	61.7	50.2	36.5	30.1
9............	26.4	23.8	36.7	46.5	54.2	60.7	67.0	68.6	60.4	51.6	34.7	30.8
10............	25.5	24.8	34.6	47.7	53.4	60.4	67.7	68.0	60.8	50.8	36.6	32.1
11............	23.4	24.6	36.0	46.5	53.5	62.8	69.5	67.5	59.5	49.6	32.9	31.1
12............	25.1	24.6	35.1	43.7	53.3	60.5	69.8	69.0	59.7	49.5	33.6	31.2
13............	26.6	25.8	34.1	44.3	53.3	61.2	69.0	69.7	60.4	49.4	35.4	28.3
14............	26.9	23.9	34.2	45.3	54.9	60.8	70.1	69.2	60.6	49.8	34.8	27.3
15............	24.4	25.8	33.7	44.5	55.5	60.3	68.9	**70.5**	60.1	49.9	33.6	27.0
16............	26.3	29.8	37.1	46.2	54.0	59.6	68.6	68.5	58.8	48.2	32.3	27.9
17............	27.2	28.5	37.3	44.9	55.7	61.4	68.7	68.5	59.3	47.0	32.9	26.4
18............	27.7	29.0	39.7	45.5	56.0	61.0	68.0	68.5	59.4	47.0	35.4	27.0
19............	30.3	27.7	37.0	46.8	55.7	65.7	68.1	67.5	58.3	44.4	34.8	27.1
20............	29.0	28.4	38.0	47.6	55.2	64.9	68.4	66.9	59.8	44.4	35.7	29.9
21............	29.3	29.5	38.6	46.6	54.9	65.1	68.9	66.7	58.0	45.0	36.0	28.1
22............	29.1	28.4	37.1	49.3	55.6	65.7	68.6	65.7	59.1	46.5	33.3	28.3
23............	26.3	29.0	39.2	49.9	57.0	66.5	69.1	65.6	58.4	46.0	33.6	31.0
24............	28.0	30.7	40.2	49.9	56.6	65.4	69.3	65.3	58.2	46.9	34.4	28.8
25............	26.8	33.0	38.8	49.5	55.8	65.4	69.5	65.8	57.4	44.9	33.0	27.0
26............	26.9	30.7	37.3	51.8	56.6	66.4	69.6	65.2	55.0	43.8	31.5	28.7
27............	27.1	32.3	37.7	51.7	56.5	66.9	69.7	65.9	55.1	43.6	30.8	27.7
28............	27.9	32.4	38.6	50.7	57.2	67.5	68.0	66.4	55.7	44.7	30.9	26.4
29............	28.0	34.3	39.9	47.6	58.2	67.1	68.2	66.1	56.5	44.2	31.8	26.5
30............	27.1	....	38.8	47.1	57.2	68.1	68.6	66.0	56.7	43.4	34.2	25.0
31............	27.8	....	38.9	....	57.9	....	68.4	66.3	....	42.7	....	25.7
Averages......	26.9	27.1	36.5	46.3	53.9	62.4	68.3	67.6	59.9	48.3	35.7	29.0

TABLE XIV—MONTHLY MEAN TEMPERATURE

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887.......	25.7	23.7	39.8	45.2	57.7	68.1	68.4	65.6	60.4	46.0	38.2	29.7	47.1
1888.......	22.2	37.1	37.4	55.3	54.4	68.1	72.8	66.6	61.4	49.2	33.0	31.3	49.0
1889.......	22.2	25.6	41.6	50.6	54.1	63.5	68.1	66.6	53.9	44.1	27.0	32.1	45.8
1890.......	24.7	40.0	38.0	46.5	58.0	64.0	71.1	66.1	58.3	47.4	38.1	37.8	49.1
1891.......	22.2	19.8	30.5	46.6	54.8	60.9	66.9	66.3	61.1	48.7	35.1	28.7	45.1
1892.......	21.1	27.8	33.7	44.0	50.0	61.7	68.2	67.3	62.4	47.7	37.4	23.0	45.4
1893.......	32.6	26.9	35.2	42.7	52.3	65.3	70.7	66.8	60.0	48.7	33.6	33.6	47.3
1894.......	23.9	18.7	37.4	48.3	57.2	63.2	69.1	68.3	48.9	51.3	40.5	25.6	46.9
1895.......	23.9	21.1	34.2	49.2	53.6	59.2	65.3	67.6	61.0	46.9	33.7	28.6	45.4
1896.......	32.6	33.4	34.0	46.6	57.0	65.3	70.2	69.0	58.8	48.0	30.8	34.0	48.3
1897.......	24.8	27.6	32.3	45.8	58.1	63.1	66.8	66.8	63.7	48.5	35.6	25.4	46.6
1898.......	25.6	34.1	32.7	47.7	51.6	64.0	69.0	69.9	58.6	46.3	30.3	23.6	46.1
1899.......	24.7	9.9	29.7	44.7	53.8	63.6	67.0	67.6	61.4	46.1	40.8	27.7	44.7
1900.......	30.9	24.2	39.1	42.9	57.8	67.1	67.9	68.0	58.6	50.2	37.4	31.6	48.0
1901.......	28.2	23.9	34.7	44.0	57.0	63.3	72.5	69.0	59.0	49.7	40.0	27.7	47.4
1902.......	24.2	32.0	35.3	45.7	56.1	63.6	66.0	68.7	56.8	48.8	36.1	27.1	46.7
1903.......	30.3	14.0	30.6	45.3	52.2	59.3	68.5	68.1	56.8	49.6	36.1	32.3	45.3
1904.......	26.1	35.3	39.6	46.2	53.7	59.9	65.6	67.0	59.2	48.9	39.7	31.9	47.8
1905.......	25.2	21.4	42.2	43.4	52.1	64.8	65.7	68.2	60.5	43.6	37.8	27.0	46.0
1906.......	30.9	30.5	25.0	47.1	55.0	61.8	64.9	67.2	58.7	46.3	33.6	34.8	46.3
1907.......	25.9	35.4	43.3	42.5	48.9	60.9	67.8	66.9	58.7	49.9	32.9	30.5	47.0
1908.......	28.2	31.1	40.3	47.8	51.9	61.4	67.6	65.5	61.8	46.4	32.1	24.8	46.6
1909.......	29.5	28.8	34.8	41.8	51.8	64.3	70.4	70.2	58.9	49.4	37.8	18.1	46.3
1910.......	25.3	26.5	47.1	50.2	53.7	64.6	70.8	67.2	61.5	51.5	40.2	31.2	49.1
1911.......	31.5	26.6	41.6	46.3	55.6	66.2	66.3	66.2	61.8	45.3	32.2	23.6	47.0
Average...	26.5	26.6	36.4	46.3	54.3	63.5	68.3	67.5	59.7	47.9	35.6	28.9	46.8
Maximum..	32.6	37.1	47.1	55.3	58.1	68.1	72.8	70.2	63.7	51.5	40.8	37.8	49.1
Minimum..	21.1	9.9	25.0	42.5	48.9	59.2	64.9	65.5	53.9	43.6	27.0	18.1	44.7

TABLE XV—MONTHLY MEAN CALORIES OF THE SUN'S HEAT, AT NOON

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1893.......	...	...	...	...	...	....	...	...	...	...	10.9	9.3	....
1894.......	11.6	13.4	12.8	11.1	6.7	7.9	7.4	6.6	6.1	6.2	3.1	11.3	8.7
1895.......	10.8	12.8	12.2	10.2	10.8	8.6	9.3	8.6	10.3	10.5	10.0	9.5	10.3
1896.......	9.6	11.3	12.7	11.6	9.4	10.7	9.6	10.7	10.5	11.0	11.3	8.7	10.6
1897.......	11.4	10.9	12.3	10.9	9.2	9.7	10.1	9.6	11.6	9.4	10.2	10.3	10.4
1898.......	9.2	10.0	10.3	10.3	9.9	10.2	10.0	10.6	10.8	10.0	11.1	10.7	10.2
1899.......	11.6	16.3	11.2	11.6	10.0	9.9	8.5	10.0	10.8	8.0	8.4	8.3	10.4
1900.......	10.4	11.9	10.2	10.7	8.9	9.3	8.6	9.4	11.9	10.2	7.9	10.4	10.0
1901.......	10.2	11.4	12.2	11.0	10.0	7.6	10.6	10.7	10.8	10.9	11.6	9.9	10.6
1902.......	12.2	11.2	8.9	9.7	11.2	9.6	10.1	9.0	9.9	9.9	9.6	9.4	10.0
1903.......	9.3	15.1	11.4	10.8	11.0	8.9	9.0	10.8	9.4	9.9	9.2	9.1	10.3
1904	9.3	9.6	9.9	10.9	9.2	10.3	8.9	9.9	11.3	10.9	10.2	8.5	9.9
1905.......	8.5	11.5	8.7	8.4	8.4	9.8	9.7	11.1	9.6	9.8	10.0	6.3	9.3
1906.......	9.0	9.6	13.6	10.2	10.1	11.0	8.7	9.2	8.5	12.3	12.0	7.4	10.1
1907.......	8.7	10.1	10.7	9.9	8.1	10.1	9.3	9.8	9.1	8.4	9.8	8.6	9.4
1908.......	9.7	10.1	11.0	10.2	11.3	9.1	10.4	9.2	...	...	...	10.9	....
1909.......	8.3	11.3	10.7	9.1	8.2	8.8	10.6	8.8	10.1	11.4	6.4	9.1	9.4
1910.......	9.4	9.5	10.0	10.3	10.4	10.0	10.2	9.6	9.0	9.6	7.5	9.5	9.6
1911.......	8.5	9.5	11.0	9.5	11.0	10.2	9.0	10.2	9.7	10.6	10.6	10.5	10.0
Average...	9.9	11.4	11.1	10.4	9.7	9.5	9.4	9.7	10.0	9.9	9.4	9.4	10.0
Maximum..	12.2	16.3	13.6	11.6	11.3	11.0	10.6	11.1	11.9	12.3	12.0	11.3	10.6
Minimum..	8.3	9.5	8.7	8.4	6.7	7.6	7.4	6.6	6.1	6.2	3.1	6.3	8.7

TABLE XVI—EXTREME MONTHLY MAXIMUM AND MINIMUM TEMPERATURES

At the Colorado Experiment Station, Fort Collins, Colorado.

YEAR.	January		February		March		April		May	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1887	58.0	**-19.0**	70.0	—8.0	80.0	8.0	83.0	16.0	90.0	24.0
1888	71.0	-28.0	68.0	14.0	79.0	3.0	91.0	30.0	84.0	30.0
1889	58.0	—3.5	62.0	—16.0	67.8	**-17.0**	79.0	24.0	81.0	31.0
1890	65.6	-13.0	68.3	**—20.0**	70.1	—9.0	78.0	13.8	85.0	29.1
1891	48.9	**-16.3**	46.5	—15.0	66.0	—4.1	81.9	12.9	84.6	21.3
1892	61.2	**-28.4**	55.1	—15.0	66.0	—4.1	81.9	12.9	84.6	31.2
1893	67.3	—2.2	66.7	—10.0	78.3	—1.9	78.9	7.6	88.7	23.1
1894	63.3	-22.0	54.6	—15.3	73.0	9.9	79.0	16.4	85.9	27.1
1895	57.2	—9.6	62.2	**—27.8**	80.2	-18.0	78.7	17.0	90.0	28.6
1896	67.8	—7.6	68.1	3.9	75.8	—6.8	80.0	7.0	88.3	31.0
1897	64.0	**-26.0**	59.5	—5.3	65.3	—7.0	77.2	20.0	82.3	31.6
1898	61.5	-11.8	63.7	6.7	66.3	—6.2	86.2	14.5	81.8	29.6
1899	55.0	-16.8	50.8	**—38.4**	65.7	-24.5	78.0	8.0	82.5	23.4
1900	63.0	—6.0	58.0	**—23.4**	76.9	9.7	73.9	5.1	84.7	29.8
1901	61.8	-21.7	63.0	—14.7	71.9	—7.5	81.8	8.7	82.9	31.1
1902	62.2	**-31.4**	63.0	—23.0	63.9	2.0	79.8	18.0	85.9	29.6
1903	61.3	1.0	46.0	**—28.0**	66.2	-10.0	78.2	12.8	85.1	27.4
1904	65.0	**—7.0**	69.0	3.0	70.0	10.0	79.8	14.1	82.0	28.2
1905	63.5	-22.3	66.2	**—26.8**	70.3	12.4	78.0	12.0	76.3	29.5
1906	67.8	—3.5	67.0	—5.0	69.9	**-24.6**	80.1	22.1	82.9	33.0
1907	62.6	—4.7	68.8	—2.8	80.3	2.8	80.0	5.7	83.0	19.2
1908	57.1	—9.8	68.0	**—15.0**	75.7	8.0	80.2	9.8	86.6	22.2
1909	63.8	—3.2	66.3	—14.2	60.1	-11.6	73.2	9.2	81.0	23.6
1910	64.1	**-20.8**	66.2	—15.8	79.9	11.5	86.4	17.8	87.0	28.4
1911	65.8	**-18.0**	62.3	—8.8	69.1	—2.2	75.8	16.0	83.8	26.6
Extreme	71.0	-31.4	70.0	—38.4	80.3	-24.6	91.0	5.1	90.0	19.2

NOTE — Extreme temperatures of each year indicated in black faced type.

TABLE XVII—AVERAGE MONTHLY READINGS OF BLACK AND BRIGHT BULBS OF ACTINOMETERS, AT NOON.

Colorado Experiment Station, Fort Collins, Colorado.

(Centigrade Degrees.)

DATE.	January		February		March		April		May		June	
	Blk.	Brt.	Blk.	Brt.	Blk.	Brt.	Blk.	Brt.	Blk.	Brt.	Blk.	Brt.
1893	....	....	....	....	....	....	....	....	....	....	....	....
1894	31.8	13.2	33.0	11.6	37.5	18.8	42.8	26.7	28.0	17.5	34.2	22.2
1895	28.1	10.6	32.8	12.5	40.2	21.3	39.4	24.4	43.7	28.2	39.0	26.4
1896	29.9	14.6	34.8	17.5	37.4	17.8	42.2	25.2	41.9	28.3	49.4	34.7
1897	31.0	12.8	29.5	12.4	34.6	16.2	38.7	22.4	42.1	29.2	44.6	30.9
1898	25.7	10.7	32.3	16.7	31.5	15.8	41.6	26.6	38.1	23.3	47.2	33.1
1899	28.0	11.0	37.0	11.5	32.3	14.7	39.8	22.6	42.8	28.4	48.3	34.6
1900	31.3	14.9	32.2	12.7	34.9	19.3	36.9	20.8	40.6	27.9	49.5	36.9
1901	30.2	14.1	28.8	10.3	37.9	19.3	38.9	22.5	44.0	29.7	37.8	26.7
1902	32.4	13.0	32.6	15.1	30.9	16.9	35.2	20.4	44.8	29.9	44.5	32.4
1903	28.8	13.9	35.4	11.6	33.2	15.5	40.4	24.4	45.5	29.8	39.4	26.5
1904	28.4	13.6	29.1	13.9	33.1	17.8	40.7	24.5	37.4	23.9	45.4	30.8
1905	23.0	9.2	30.6	12.0	31.8	18.5	31.5	18.7	36.2	23.7	45.5	31.7
1906	31.9	17.9	32.5	17.5	39.2	17.8	38.1	22.9	43.3	28.7	50.0	34.7
1907	26.0	11.9	36.3	20.9	39.0	22.9	34.8	19.9	34.1	21.8	45.1	31.0
1908	29.2	13.6	32.3	16.3	39.2	22.7	41.4	26.5	45.4	29.2	41.8	28.8
1909	25.9	12.6	31.8	14.1	34.0	17.3	33.3	19.2	35.1	22.9	42.1	29.7
1910	27.0	11.9	28.1	12.8	41.8	27.2	42.4	27.4	41.4	26.4	46.4	32.4
1911	29.0	15.3	34.7	15.1	37.8	21.3	36.6	22.2	44.0	28.9	48.2	34.3
Average	28.8	13.0	32.4	14.1	35.9	19.0	38.6	23.2	40.5	26.5	44.4	31.0
Maximum	32.4	17.9	37.0	20.9	41.8	27.2	42.8	27.4	45.5	29.9	50.0	36.9
Minimum	23.0	9.2	28.1	10.3	30.9	14.7	31.5	18.7	28.0	17.5	34.2	22.2

TABLE XVI—EXTREME MONTHLY MAXIMUM AND MINIMUM TEMPERATURES

At the Colorado Experiment Station, Fort Collins, Colorado.

June		July		August		September		October		November		December	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
96.0	45.0	**97.0**	50.0	97.0	44.0	91.0	32.0	88.0	11.0	78.0	-13.0	61.0	0.0
97.0	42.0	**99.0**	51.0	88.0	44.0	89.0	32.0	75.0	20.0	64.0	16.0	68.0	4.0
90.5	35.0	**97.0**	37.5	97.0	41.3	93.0	23.0	85.2	24.9	61.0	1.0	66.5	3.0
92.2	32.7	93.4	46.9	**95.3**	39.5	85.3	28.0	77.0	15.7	75.7	6.5	62.9	5.8
86.9	37.9	89.4	41.2	**93.1**	36.7	88.8	34.3	79.8	19.5	75.9	—6.2	60.0	-10.0
86.5	35.4	92.7	45.3	**99.2**	33.9	89.3	27.5	87.0	18.7	67.2	10.6	65.6	-17.4
95.0	31.3	94.9	44.2	91.7	38.3	90.0	25.7	82.0	11.8	70.7	**-12.8**	60.4	2.5
91.0	37.9	**94.4**	46.0	92.2	39.5	88.6	30.9	80.7	19.3	78.0	—1.1	64.7	**-24.0**
88.7	33.0	93.2	44.9	93.7	42.3	**95.0**	23.2	79.7	14.8	73.7	—2.9	66.7	-5.0
91.2	39.3	**95.8**	48.8	93.8	40.2	90.0	31.8	84.2	21.0	74.7	**-11.3**	66.1	0.5
90.1	35.3	**94.8**	38.9	93.5	42.7	89.8	33.8	81.7	21.5	75.6	—3.0	63.0	-10.8
97.2	36.0	97.0	44.3	95.6	43.1	90.2	29.7	85.7	16.2	71.3	-11.3	55.0	**-22.3**
96.1	36.4	94.0	44.6	95.2	39.7	94.6	29.0	86.7	23.7	69.5	15.0	63.7	-9.3
94.4	40.7	92.9	40.2	94.0	41.2	88.2	29.7	83.0	12.5	74.0	8.7	62.9	-22.0
94.4	38.2	**96.7**	47.9	96.7	43.6	86.6	29.4	82.0	25.0	69.6	12.0	64.6	**-31.0**
96.0	37.0	98.0	38.8	**99.6**	42.3	89.8	22.0	80.0	25.5	69.2	3.8	58.2	-17.6
92.5	37.0	**95.0**	36.0	94.6	41.9	92.5	26.0	81.0	20.0	71.0	-10.0	61.0	5.0
87.2	38.4	90.7	40.3	**91.0**	33.0	90.0	29.6	80.1	17.8	75.4	0.5	65.7	1.0
92.3	40.0	91.0	42.3	**93.2**	44.8	90.5	30.8	85.3	—8.0	74.0	3.4	62.2	-4.0
89.9	37.2	**92.6**	41.0	92.0	39.2	86.9	37.3	83.2	19.4	70.2	—9.3	64.5	7.0
87.7	33.9	**94.4**	44.6	91.6	45.0	85.6	31.0	81.8	22.4	70.0	—1.2	61.7	**-5.4**
91.8	37.6	**93.1**	43.6	92.8	42.5	91.9	23.4	81.0	13.5	72.2	-12.0	54.0	-13.4
94.5	41.3	94.3	48.0	92.6	46.9	84.2	30.2	81.5	16.3	76.2	—3.1	61.0	**-19.1**
90.3	38.9	**99.9**	47.0	92.6	31.7	92.0	34.5	84.7	16.1	70.0	13.6	59.7	3.4
92.0	41.2	88.0	45.1	**95.4**	37.1	89.1	32.1	80.2	14.6	66.9	-11.0	62.9	-8.0
92.7	31.3	99.9	36.0	99.6	31.7	95.0	22.0	83.0	—8.0	78.0	-13.0	68.0	-31.0

TABLE XVII—AVERAGE MONTHLY READINGS OF BLACK AND BRIGHT BULBS OF ACTINOMETERS, AT NOON.

Colorado Experiment Station, Fort Collins, Colorado.

(Centigrade Degrees.)

July		August		September		October		November		December		Year	
Blk.	Brt.	Blk.	Brt.	Blk.	Brt.	Blk.	Brt.	Blk.	Brt.	Blk.	Brt.	Blk.	Brt.
....	....	....	....	....	....	....	....	32.8	15.7	28.2	13.5	....	....
36.0	24.9	32.9	22.8	24.8	14.9	20.4	9.5	7.4	1.7	32.1	14.3	30.1	16.5
43.6	30.7	44.2	32.2	49.4	35.2	39.6	24.0	32.4	16.8	27.6	13.0	38.3	22.9
49.0	35.8	52.6	38.2	44.8	29.8	43.0	27.1	32.1	14.1	27.9	14.1	40.4	24.8
49.3	36.0	47.6	34.3	50.9	35.0	40.0	26.4	33.8	18.0	28.3	11.6	39.2	23.8
51.0	37.5	55.1	41.2	50.6	35.9	37.0	21.8	31.4	13.6	28.9	11.5	39.2	24.0
44.6	32.7	49.4	35.7	49.9	35.2	31.1	18.9	32.0	19.1	24.5	10.3	38.3	22.9
47.2	35.3	50.2	37.4	53.7	37.6	43.9	29.4	28.2	15.8	33.4	17.0	40.2	25.4
54.5	40.5	52.7	38.3	43.2	27.7	37.8	23.7	39.3	21.9	28.1	12.3	39.4	23.9
48.6	34.8	47.1	34.8	43.1	29.0	29.8	25.3	32.5	17.5	26.8	11.7	38.2	23.4
46.9	34.5	51.8	37.0	45.4	32.2	38.6	24.0	31.4	16.9	30.6	16.1	39.0	23.5
45.6	33.3	49.1	35.5	48.4	32.5	41.4	25.5	36.9	21.5	29.2	15.8	38.7	24.1
47.2	33.7	52.4	37.5	45.4	32.1	37.5	23.0	34.7	19.5	28.9	14.8	37.0	22.9
43.4	31.2	47.5	34.8	40.1	27.9	45.7	28.1	39.2	21.2	26.2	14.4	39.8	24.8
46.4	33.5	48.8	35.5	42.5	29.5	35.1	22.3	32.2	17.0	27.1	13.3	37.3	23.3
49.0	34.8	44.4	31.5	....	....	....	....	....	....	30.6	13.1	....	....
49.8	35.3	48.9	36.9	44.9	30.7	46.4	30.1	25.5	15.3	24.0	8.8	36.8	22.7
51.3	37.5	47.4	34.1	44.2	31.4	38.8	24.9	28.4	16.7	28.5	13.3	38.8	24.7
43.4	30.6	48.0	33.9	44.8	31.1	38.2	22.5	34.5	18.1	28.2	11.1	39.0	23.7
47.0	34.0	48.3	35.1	45.1	31.0	38.5	23.9	31.4	16.7	28.4	13.2	38.3	23.4
54.5	40.5	55.1	41.2	53.7	37.6	46.4	30.1	39.3	21.9	33.4	17.0	40.4	25.4
36.0	24.9	32.9	22.8	24.8	14.9	20.4	9.5	7.4	1.7	24.0	8.8	30.1	16.5

TABLE XVIII—MONTHLY MEAN DEW POINT ½ (7A + 7P)

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887.......	...	...	...	...	28.0	....	...	55.2	...	33.4	23.4	12.3	....
1888.......	28.2	24.5	21.8	42.0	40.2	48.4	54.6	51.3	45.7	32.9	25.7	15.7	36.0
1889.......	9.6	14.7	28.4	34.1	39.2	49.1	54.5	51.1	34.2	30.9	19.9	20.1	32.2
1890.......	11.2	13.0	17.7	30.3	39.0	44.2	55.4	52.2	37.5	26.2	20.2	15.6	30.2
1891.......	12.2	10.9	20.9	29.7	42.6	50.7	55.2	53.0	44.1	25.0	18.4	14.1	31.4
1892.......	10.1	19.2	21.3	25.4	37.6	49.8	55.2	49.2	38.6	30.0	18.5	12.3	30.6
1893.......	10.0	9.7	17.2	20.8	34.6	45.5	51.8	49.7	37.0	24.3	15.2	16.6	27.7
1894.......	7.4	4.8	16.5	25.9	37.6	44.7	52.6	51.6	39.6	26.6	19.1	12.2	28.2
1895.......	11.7	9.0	17.3	26.6	37.2	47.5	52.7	52.6	39.9	27.9	15.5	10.2	29.0
1896.......	10.4	12.0	19.8	26.5	32.5	50.5	56.6	51.5	46.2	30.4	12.5	15.7	30.4
1897.......	6.6	14.1	19.8	29.5	44.6	50.5	53.3	53.6	48.0	32.3	21.3	12.1	32.1
1898.......	11.0	16.2	15.2	27.3	40.4	49.1	52.2	50.6	37.0	24.0	16.5	8.4	29.0
1899.......	10.6	2.4	18.8	24.6	34.6	44.6	54.8	50.3	41.6	30.7	23.1	13.1	29.1
1900.......	15.5	11.6	24.2	34.8	43.4	51.3	51.3	49.0	42.4	30.3	17.4	10.9	31.8
1901.......	10.7	12.2	18.8	30.0	42.8	49.8	56.7	54.6	40.5	31.6	20.4	16.5	32.0
1902.......	9.9	17.0	18.3	29.0	40.8	48.2	52.6	50.7	38.9	34.3	20.9	14.0	31.2
1903.......	15.5	4.5	22.6	29.0	38.1	51.3	54.2	54.2	41.1	30.8	22.4	13.6	31.4
1904.......	10.2	15.6	21.9	27.1	41.1	50.4	54.6	53.5	45.0	31.4	15.1	17.8	32.0
1905.......	17.5	11.9	28.2	32.3	40.2	52.4	53.6	54.1	42.4	26.4	21.9	7.9	32.4
1906.......	10.3	10.2	16.6	31.7	39.2	47.7	53.9	52.9	47.8	30.8	22.6	20.4	32.0
1907.......	15.0	18.0	21.3	28.6	37.4	45.4	55.7	52.3	42.8	34.3	17.4	14.7	31.9
1908.......	9.5	12.0	17.0	23.7	35.6	45.7	54.7	55.0	44.3	30.1	18.4	14.7	30.1
1909.......	17.2	13.9	25.4	25.9	32.7	51.2	57.6	56.6	46.9	28.5	24.2	9.1	32.4
1910.......	9.9	8.6	18.3	23.2	39.2	47.5	52.7	51.2	45.3	31.5	25.4	16.7	30.8
1911.......	15.3	11.5	21.4	25.4	35.2	49.2	52.2	49.6	42.2	29.2	16.2	9.8	29.8
Average...	12.3	12.4	20.4	28.5	39.0	48.5	54.1	52.2	42.0	29.8	19.7	13.8	31.1
Maximum..	28.2	24.5	28.4	42.0	48.0	52.4	57.6	56.6	48.0	34.3	25.7	20.4	36.0
Minimum..	6.6	2.4	15.2	20.8	32.5	44.2	51.3	49.0	34.2	24.0	12.5	7.9	27.7

TABLE XIX—MONTHLY MEAN RELATIVE HUMIDITY ½ (7A + 7P) IN PER CENT OF SATURATION

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887.......	56.6	65.8	44.4	51.4	70.0	79.9	69.0	57.7	59.3	70.0	62.7	55.4	61.8
1888.......	44.6	61.5	59.7	62.6	62.2	52.5	55.8	60.2	59.7	56.2	71.2	60.5	58.9
1889.......	65.6	66.6	63.6	58.9	62.8	63.2	64.3	60.8	53.1	64.5	78.9	64.4	63.9
1890.......	75.4	68.0	52.9	63.5	59.1	51.4	61.8	69.0	52.9	60.7	70.0	65.4	62.5
1891.......	89.3	78.3	82.5	58.8	68.9	69.9	69.2	68.1	66.6	53.6	64.2	69.7	69.9
1892.......	80.0	82.6	73.2	56.2	69.1	66.2	67.4	58.9	51.6	66.1	61.3	78.1	67.6
1893.......	56.1	64.7	60.7	51.0	57.5	51.9	56.3	62.0	51.4	51.7	62.6	67.1	57.7
1894.......	63.8	70.6	56.6	48.1	55.5	54.8	60.6	63.2	61.0	50.5	62.2	76.7	60.3
1895.......	75.7	76.4	64.3	47.3	59.0	67.7	71.0	68.3	57.6	64.2	68.0	65.3	65.4
1896.......	62.1	58.6	69.7	54.6	46.6	52.6	67.7	62.8	76.1	65.7	65.1	67.2	63.2
1897.......	68.4	74.7	72.6	61.0	63.0	69.0	68.0	73.0	69.2	71.1	75.0	75.1	70.0
1898.......	75.2	67.5	62.6	52.4	71.4	62.7	60.9	59.0	60.1	55.6	72.4	73.6	64.4
1899.......	70.2	87.2	73.7	53.2	53.2	54.5	70.8	63.1	60.8	72.7	69.2	74.1	66.9
1900.......	73.3	76.4	70.6	78.8	62.6	60.5	64.5	57.8	67.6	61.9	61.0	61.0	66.3
1901.......	66.0	78.9	62.9	65.4	62.6	64.0	62.6	67.7	64.1	66.7	64.9	76.4	66.9
1902.......	78.2	70.8	61.8	58.8	61.2	62.0	65.1	60.1	64.5	74.4	72.4	75.0	67.0
1903.......	73.0	86.0	83.6	60.2	61.5	74.5	65.9	69.3	70.8	66.0	78.7	61.5	70.9
1904.......	65.5	59.5	60.3	53.5	64.9	70.5	70.1	69.3	73.2	74.0	60.2	73.6	66.2
1905.......	85.5	85.8	71.1	74.0	70.0	69.0	68.6	69.7	67.7	73.0	72.0	66.3	72.7
1906.......	60.0	63.3	81.5	61.0	60.7	63.7	70.1	70.2	79.3	71.2	80.6	74.2	69.6
1907.......	79.2	66.8	54.9	61.8	68.8	58.4	71.0	67.4	67.5	75.1	76.0	68.3	67.9
1908.......	63.4	62.8	51.3	42.4	59.2	60.0	69.7	77.4	66.8	68.0	77.9	81.2	65.0
1909.......	75.8	70.6	78.3	60.1	51.9	68.0	71.7	71.2	78.2	58.1	73.7	79.2	69.7
1910.......	70.0	62.8	41.0	37.6	62.5	56.9	56.7	64.8	69.3	63.7	71.8	68.8	60.5
1911.......	66.2	71.5	55.5	52.4	52.8	55.7	63.8	60.4	58.7	64.9	65.7	75.6	61.9
Average...	69.6	71.1	64.4	57.0	61.5	62.8	65.7	65.3	64.3	64.8	69.5	70.1	65.5
Maximum..	89.3	87.2	83.6	78.8	71.4	79.9	71.7	77.4	79.3	75.1	80.6	81.2	72.7
Minimum..	44.6	58.6	41.0	37.6	46.6	51.4	55.8	57.7	51.4	50.5	60.2	55.4	57.7

TABLE XX—MONTHLY MEAN TERRESTRIAL RADIATION

At the Colorado Experiment Station, Fort Collins, Colorado.

(Difference between Monthly Minimum and Terrestrial 6 Inches from Ground.)

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1889	9.9	9.1	8.6	5.5	7.6	7.1	6.3	7.2	7.3	5.9	6.8	6.2	7.3
1890	4.2	5.1	4.8	3.9	7.2	9.5	9.0	9.7	4.2	4.8	8.5	9.9	6.7
1891	6.5	3.6	5.3	6.8	7.4	5.3	4.4	4.2	5.4	6.0	5.5	5.0	5.4
1892	3.9	3.8	4.0	4.8	5.3	6.5	5.7	6.0	6.5	5.7	5.9	5.0	5.3
1893	5.5	5.0	3.9	4.5	5.1	7.6	5.3	4.6	6.0	5.5	4.9	4.8	5.2
1894	5.1	4.3	4.0	3.9	5.7	6.0	5.2	5.0	5.6	7.0	4.9	4.6	5.1
1895	4.5	4.1	3.9	4.9	5.6	4.2	4.3	4.1	4.3	5.1	5.4	5.9	4.7
1896	5.3	5.2	3.4	4.5	6.3	3.8	4.0	5.6	5.1	6.9	6.4	5.3	5.2
1897	4.4	4.1	3.8	4.0	5.4	4.7	5.2	4.7	4.2	4.1	4.0	4.8	4.5
1898	5.0	5.2	5.6	4.4	2.8	2.9	2.9	2.9	3.1	3.4	3.3	4.0	3.8
1899	4.2	3.3	2.4	3.3	3.7	3.8	3.6	4.9	4.7	3.6	4.6	4.5	3.9
1900	4.0	3.9	2.9	2.9	5.4	6.5	5.5	6.1	5.8	6.0	5.9	6.3	5.1
1901	5.8	5.2	4.2	4.6	7.6	7.1	7.0	5.4	6.2	6.0	7.1	3.8	5.8
1902	3.7	3.6	4.4	4.8	5.4	5.4	5.1	5.1	4.6	3.4	4.7	4.0	4.5
1903	3.8	4.5	2.4	4.7	5.2	4.3	7.5	...	5.7	5.0	4.2	...	...
1904	...	4.3	3.3	3.1	3.7	4.3	6.0	7.4	8.0	6.8	...	...	...
1905	5.0	5.3	5.2	4.2	6.3	9.3	...	...	...	...	...	...	...
1906	7.7	5.4	2.8	5.3	6.9	6.0	6.3	5.8	4.4	4.0	4.0	4.8	5.3
1907	2.8	3.9	4.7	3.9	5.8	8.4	7.8	6.5	6.0	5.4	5.4	5.7	5.5
1908	5.6	5.0	5.2	5.9	4.9	7.2	5.2	4.4	6.2	3.8	4.2	3.8	5.1
1909	2.7	3.9	2.7	2.6	6.8	7.4	5.0	4.0	3.8	4.9	3.9	3.6	4.3
1910	3.9	4.4	5.4	4.7	4.7	3.3	4.0	3.4	3.6	4.2	3.4	3.9	4.1
1911	3.6	3.2	3.1	3.2	3.6	4.1	3.4	4.5	4.3	3.3	2.9	4.1	3.6
Average	4.9	4.6	4.2	4.4	5.6	5.9	5.4	5.3	5.2	5.0	5.0	5.0	5.0
Maximum	9.9	9.1	8.6	6.8	7.6	9.5	9.0	9.7	8.0	7.0	8.5	9.9	7.3
Minimum	2.7	3.2	2.4	2.6	2.8	2.9	2.9	2.9	3.1	3.3	2.9	3.6	3.6

TABLE XXI—MONTHLY MEAN TERRESTRIAL RADIATION THERMOMETER

At the Colorado Experiment Station, Fort Collins, Colorado.

6 Inches from the Ground.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1889	...	...	...	...	...	....	...	...	...	...	...	...	....
1890	4.4	9.9	18.4	29.2	33.8	37.3	46.2	41.5	35.2	26.3	12.8	8.4	25.3
1891	2.5	4.3	14.4	25.1	33.8	42.1	47.4	45.5	38.8	20.4	16.3	11.3	25.2
1892	3.4	13.5	17.9	24.7	33.6	40.0	47.3	42.4	35.6	25.9	17.3	4.3	25.5
1893	10.3	7.3	16.2	23.8	32.7	39.6	48.1	45.9	32.8	26.2	12.5	15.2	25.9
1894	3.3	—0.6	18.4	28.2	37.0	41.0	47.6	46.5	35.9	27.1	18.4	6.2	25.8
1895	6.4	2.8	16.0	27.2	33.2	40.7	47.1	47.2	37.6	24.7	13.6	8.1	25.4
1896	10.8	12.4	18.4	26.0	35.0	45.7	51.7	47.3	40.0	24.5	10.2	13.7	28.0
1897	4.9	10.2	16.1	28.0	37.3	43.5	44.7	46.7	43.1	28.3	16.2	7.6	27.2
1898	5.6	12.4	11.9	26.4	37.6	45.3	50.1	49.3	35.8	28.0	12.8	5.3	26.7
1899	6.2	—8.8	15.6	25.6	34.3	43.6	49.0	46.9	37.4	28.4	20.3	8.2	25.6
1900	11.2	6.8	21.4	28.4	37.8	44.2	46.8	43.4	37.5	26.8	15.7	9.7	27.5
1901	6.8	4.6	18.5	26.4	35.2	41.2	48.2	48.0	34.4	26.8	16.2	11.6	26.5
1902	5.4	9.8	17.9	25.7	36.3	42.8	44.2	47.2	35.4	29.7	17.9	10.3	26.9
1903	12.6	—4.6	15.9	26.5	31.3	42.7	44.6	...	33.6	26.6	14.7	...	....
1904	...	18.2	21.0	28.2	37.5	42.0	44.7	43.8	34.4	24.6	17.4	...	....
1905	7.6	1.5	24.0	27.3	34.2	40.7	...	...	...	...	...	...	....
1906	5.6	7.3	10.8	29.0	34.8	41.2	44.7	45.2	39.9	26.5	17.1	16.7	26.6
1907	9.6	16.0	22.6	25.2	31.2	36.8	44.6	44.4	36.2	26.7	10.8	9.9	26.2
1908	6.3	8.2	19.1	24.7	33.4	39.3	47.7	47.6	38.1	27.8	11.0	8.1	25.9
1909	14.1	10.1	21.2	26.4	31.1	41.8	50.0	50.8	40.2	27.3	21.0	2.0	28.0
1910	6.6	6.2	23.2	28.3	35.9	45.7	51.0	48.6	42.8	29.7	23.3	13.8	29.6
1911	14.5	10.7	23.0	29.0	37.6	47.0	49.4	46.2	41.9	28.1	14.5	5.3	28.9
Average	7.5	7.2	13.7	26.8	34.8	42.0	47.4	46.2	37.5	26.7	15.7	9.2	26.2
Maximum	14.5	18.2	24.0	29.2	37.8	47.0	51.7	50.8	43.1	29.7	23.3	16.7	29.6
Minimum	2.5	—8.8	10.8	23.8	31.1	36.8	44.2	41.5	32.8	20.4	10.2	2.0	25.2

TABLE XXII—MONTLY MEAN AND NORMAL BAROMETER

At the Colorado Experiment Station, Fort Collins, Colorado.

½ (7A + 7P)

DATE.	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
1887	24.773	25.090	24.994	24.913	24.994	24.912	25.052	25.073	25.043	24.932	24.956	24.853	24.964
1888	24.818	24.793	24.805	24.944	24.835	24.827	25.075	25.102	25.126	24.988	25.031	24.985	24.944
1889	24.933	24.973	24.992	25.000	24.953	25.041	25.054	25.071	25.047	25.084	25.064	24.921	25.011
1890	24.906	24.889	24.918	24.998	24.942	24.965	25.065	25.188	25.074	25.014	25.130	25.034	25.010
1891	24.999	24.972	24.874	24.953	25.005	24.918	25.075	25.092	25.043	25.103	24.968	24.869	24.974
1892	24.979	24.936	24.909	24.886	24.953	24.965	25.085	25.069	25.086	25.042	24.959	24.939	24.981
1893	24.927	24.897	24.867	24.875	24.923	24.962	25.036	25.058	24.973	25.006	24.976	24.977	24.984
1894	24.875	24.939	24.886	24.921	24.978	24.956	25.133	25.130	25.012	24.975	25.084	25.025	24.956
1895	24.859	25.014	24.918	24.964	24.951	25.065	25.084	25.074	25.019	25.113	24.979	24.934	24.998
1896	24.964	24.956	24.911	24.858	24.887	25.054	25.104	25.110	25.060	25.037	24.954	25.052	24.996
1897	24.985	24.853	24.806	25.006	25.035	24.964	25.061	25.123	25.124	25.042	24.990	24.993	24.999
1898	24.917	24.995	24.878	25.002	24.940	25.006	25.064	25.057	25.027	25.039	24.927	25.039	24.991
1899	24.884	24.862	24.853	24.933	24.885	25.003	25.096	25.005	25.120	25.008	25.019	24.995	24.972
1900	25.019	24.892	24.987	24.910	24.989	25.006	25.009	24.995	25.035	25.015	25.048	25.037	24.995
1901	24.965	24.976	24.871	24.975	24.949	24.926	25.040	25.119	24.989	25.111	25.086	24.966	24.998
1902	25.026	24.888	24.836	24.923	24.920	24.952	25.036	25.058	25.040	25.054	24.936	24.954	24.970
1903	24.919	24.971	24.966	24.925	24.964	25.005	25.025	25.055	25.041	25.111	25.033	25.022	25.011
1904	24.920	24.867	24.821	24.990	24.962	25.040	25.070	25.130	25.123	25.089	25.113	24.974	25.008
1905	25.086	25.011	24.927	24.935	24.920	24.965	25.087	25.094	25.042	25.068	24.983	25.031	25.012
1906	24.973	25.003	24.982	24.983	24.919	24.962	25.129	25.066	25.083	25.068	25.020	25.007	25.016
1907	24.912	25.019	24.907	24.957	24.945	24.953	25.067	25.063	25.057	25.117	25.086	24.930	25.001
1908	25.003	24.951	24.946	24.949	24.851	24.955	25.139	25.086	25.096	25.021	25.064	24.992	25.004
1909	24.922	24.855	24.905	24.912	24.898	25.040	25.046	25.092	25.106	25.064	25.003	24.931	24.981
1910	24.977	24.960	25.030	25.003	25.037	24.990	25.064	25.080	25.085	25.044	24.978	24.977	25.019
1911	24.951	24.993	24.997	24.919	24.938	25.007	25.096	25.064	25.042	25.051	24.966	24.915	24.995
Normal	24.940	24.935	24.912	24.945	24.943	24.978	25.072	25.082	25.060	25.052	25.013	24.974	24.992
Maximum	25.086	25.090	25.030	25.006	25.037	25.065	25.139	25.188	25.126	25.117	25.130	25.052	25.019
Minimum	24.778	24.792	24.905	24.858	24.935	24.827	25.025	24.995	24.973	24.932	24.927	24.853	24.944

TABLE XXIII—MONTHLY PRECIPITATION

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1872	....	....	....	....	....	....	....	....	....	....	0.02	0.20	.....
1873	0.25	0.16	0.00	1.20	2.30	1.50	1.30	0.85	0.75	0.42	0.20	0.17	9.10
1874	0.06	0.43	1.29	0.77	2.95	0.65	3.15	0.25	0.00	1.90	0.02	0.00	10.57
1879	....	....	....	....	....	....	....	....	....	1.75	0.15	0.60	.....
1880	0.72	1.09	0.38	0.94	0.60	0.86	1.80	0.37	1.47	2.07	1.10	0.10	11.50
1881	1.10	0.55	1.45	....	....	....	....	....	....	....	....	....	.....
1882	....	....	0.17	....	4.67	3.07	1.76	0.89	2.51	0.82	0.29	....	.....
1883	1.00	1.50	0.68	....	2.51	3.18	....	1.78	1.00	1.29	T	1.33	.....
1884	1.10	0.70	1.15	3.94	4.84	....	....	....	....	0.10	1.80	0.35	.....
1885	1.77	....	....	....	....	....	....	....	....	....	....	....	.....
1886	....	....	....	....	....	....	....	....	....	0.69	1.18	0.33	.....
1887	0.86	0.23	0.45	1.10	1.23	1.96	3.05	2.12	0.54	0.43	0.15	0.00	12.12
1888	0.29	0.36	0.73	1.23	3.39	0.47	0.60	1.01	0.29	0.88	0.38	0.16	9.79
1889	0.21	0.34	0.65	2.07	3.39	2.06	0.79	0.95	0.42	3.16	0.42	0.02	14.48
1890	0.13	0.21	0.22	3.92	1.19	0.12	1.27	3.14	0.07	0.70	0.32	0.12	11.41
1891	2.32	0.15	1.21	2.14	4.07	1.30	0.17	2.06	1.02	0.20	0.60	0.46	15.70
1892	0.60	1.29	1.52	1.60	4.83	2.42	1.32	0.22	0.14	0.93	0.23	0.35	15.45
1893	0.02	0.54	0.14	1.66	1.92	0.26	0.64	0.92	0.18	0.16	0.55	0.12	7.11
1894	0.25	0.60	0.67	0.89	3.09	0.42	1.72	1.53	2.29	T	0.14	0.76	12.36
1895	0.24	1.52	0.54	1.36	3.62	3.65	3.75	1.45	0.47	1.06	0.40	0.01	18.07
1896	0.43	0.03	1.73	1.26	1.68	3.05	3.05	2.20	1.55	0.49	0.05	0.24	15.76
1897	0.18	0.54	2.15	1.39	2.06	1.69	2.65	1.74	0.75	0.75	0.67	0.67	15.24
1898	0.14	0.08	0.50	1.08	3.65	1.37	0.50	0.98	0.50	0.82	1.24	0.17	11.03
1899	0.66	1.04	1.50	1.10	1.01	1.03	4.95	0.99	0.21	3.23	T	0.47	16.19
1900	0.25	1.12	1.07	10.56	1.75	0.82	1.14	0.16	1.92	0.24	0.07	0.11	19.21
1901	0.19	0.38	1.88	3.62	7.47	2.35	0.71	0.72	2.10	0.36	0.02	1.37	21.17
1902	0.32	0.15	1.50	0.61	2.13	2.43	1.31	0.67	7.12	1.15	0.27	0.77	18.43
1903	0.16	1.60	1.03	1.50	0.63	2.23	1.06	0.86	0.87	1.70	0.18	0.07	11.89
1904	0.04	0.34	0.51	0.89	5.37	1.68	1.99	0.71	1.09	0.39	0.00	0.12	13.13
1905	0.29	0.35	1.75	6.32	4.13	0.64	2.18	1.25	0.28	2.60	0.07	T	19.86
1906	0.01	0.03	2.44	4.30	2.40	1.80	1.96	0.80	3.08	1.59	1.35	0.12	19.88
1907	0.23	0.36	0.69	2.80	2.44	0.44	2.28	1.27	0.58	0.08	0.44	0.03	11.64
1908	0.11	0.03	0.28	0.05	5.83	1.16	3.66	2.12	0.54	1.78	1.06	0.60	17.22
1909	0.02	0.90	3.35	1.34	1.06	2.59	1.98	1.45	2.10	0.08	0.79	0.58	16.24
1910	0.29	0.16	0.06	0.42	4.75	1.04	0.87	1.92	1.79	1.03	0.11	0.48	12.92
1911	0.34	1.52	0.05	1.89	0.72	1.78	1.47	0.59	0.80	0.93	0.43	0.37	10.89
Normal	0.46	0.59	0.99	2.14	2.96	1.60	1.83	1.20	1.21	1.00	0.43	0.34	14.75
Av. 25 years	0.34	0.55	1.06	2.20	2.95	1.55	1.80	1.27	1.23	0.99	0.40	0.33	14.67
Maximum	2.32	1.60	3.35	10.56	7.47	3.65	4.95	3.14	3.08	3.23	1.80	1.37	21.17
Minimum	0.01	0.03	0.00	0.05	0.60	0.12	0.17	0.16	0.00	T	0.00	0.00	7.11

TABLE XXIV—NUMBER OF STORMY DAYS (.01 OR MORE PRECIPITATION)

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887.......	6	2	1	4	6	10	11	8	3	3	1	0	55
1888.......	3	2	6	2	10	2	6	4	5	4	5	3	52
1889.......	2	3	3	8	14	7	8	6	3	8	3	1	66
1890.......	2	1	3	9	8	3	10	13	2	2	2	1	57
1891.......	5	5	12	4	13	10	4	16	11	2	6	3	91
1892.......	6	7	7	6	15	8	14	5	1	4	2	6	81
1893.......	1	5	1	6	11	4	5	10	1	3	4	3	54
1894.......	5	8	6	4	10	6	6	7	6	0	2	5	65
1895.......	4	8	4	4	11	12	14	11	3	4	7	1	83
1896.......	2	2	10	5	5	9	12	9	11	5	2	2	74
1897.......	2	6	9	7	13	12	9	12	6	6	4	5	91
1898.......	3	2	8	8	22	7	8	7	4	4	4	2	80
1899.......	6	11	11	6	8	9	13	7	3	10	0	3	87
1900.......	3	8	5	11	7	7	9	4	8	2	1	1	66
1901.......	3	7	7	7	11	8	3	12	3	2	1	8	72
1902.......	4	2	8	5	12	8	8	3	4	6	1	4	65
1903.......	3	12	2	9	7	9	6	2	6	4	2	1	63
1904.......	3	3	7	5	13	10	5	3	5	3	0	3	60
1905.......	8	7	5	10	16	10	12	6	2	7	3	0	86
1906.......	1	2	14	7	8	6	11	9	13	4	6	1	82
1907.......	4	5	4	12	15	6	13	8	4	2	1	3	77
1908.......	2	2	3	3	12	11	7	13	3	5	7	4	72
1909.......	2	4	10	11	3	13	10	9	8	3	6	6	85
1910.......	4	4	2	2	12	7	4	12	9	2	2	4	64
1911.......	2	9	3	10	7	7	8	4	3	7	6	5	71
Average...	3.4	5.1	6.0	6.6	10.8	8.0	8.6	8.0	5.1	4.1	3.1	3.0	71.8
Maximum..	6	12	14	12	22	13	14	16	13	10	7	8	91
Minimum..	1	1	1	2	3	2	3	2	1	0	0	0	52

TABLE XXV—MONTHLY AVERAGE WIND IN MILES PER DAY

At the Colorado Experiment Station, Fort Collins, Colorado.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1888.......	96	180	130	198	136	232	110	98	85	123	113	125	136
1889.......	128	162	160	184	154	108	101	92	119	115	132	148	134
1890.......	140	158	170	152	124	...	...	...	...	90	68	91	...
1891.......	96	140	150	216	171	154	145	126	137	132	188	181	145
1892.......	121	125	178	224	218	130	76	75	163	187	212	189	158
1893.......	243	251	287	297	263	186	168	153	174	196	225	246	224
1894.......	227	179	280	290	222	191	150	147	163	219	205	162	203
1895.......	202	188	255	265	203	179	146	136	160	146	175	234	191
1896.......	181	236	253	249	247	154	134	143	142	153	196	158	187
1897.......	163	201	227	220	160	143	138	114	116	152	167	178	165
1898.......	147	187	214	219	161	135	142	125	137	203	176	170	168
1899.......	213	165	198	236	182	153	113	127	123	169	147	169	166
1900.......	160	199	164	172	147	131	119	113	123	150	156	184	143
1901.......	181	153	248	178	165	127	115	110	127	124	160	183	156
1902.......	107	164	205	180	130	117	98	116	129	95	140	154	136
1903.......	192	120	114	185	167	113	109	101	102	124	156	183	139
1904.......	188	231	216	217	168	173	115	113	104	122	138	182	164
1905.......	134	129	171	169	156	161	120	98	108	114	142	129	136
1906.......	144	161	139	188	136	141	87	96	93	137	131	129	128
1907.......	119	150	172	175	146	151	91	93	106	90	96	166	130
1908.......	176	144	208	201	166	171	86	88	96	119	80	105	137
1909.......	149	177	143	192	215	108	92	98	96	147	95	117	136
1910.......	108	187	177	220	130	113	99	92	102	122	139	141	136
1911.......	170	121	174	182	153	115	144	144	156	151	220	135	155
Average...	158	171	193	209	172	147	117	113	124	141	152	161	155
Maximum..	243	251	287	297	263	232	168	153	174	219	225	246	224
Minimum..	96	120	114	152	124	108	76	75	85	90	68	91	128

TABLE XXVI—EVAPORATION FROM WATER SURFACE
At the Colorado Experiment Station, Fort Collins, Colorado.
(From Tank 3 ft. x 3 ft. About 2 Inches Above Ground Surface.) Inches.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1887.......	2.46	3.23	4.60	5.55	5.19	5.75	5.23	4.24	4.12	3.26	1.48	1.60	46.71
1888.......	...	...	...	...	4.45	7.70	7.00	4.06	3.94	2.17	1.35	0.99	.....
1889.......	1.08	1.03	2.75	4.06	3.72	4.34	5.20	5.15	5.19	3.28	0.62	1.42	37.84
1890.......	0.86	2.36	3.58	3.50	4.32	5.71	5.44	5.76	3.69	2.71	1.32	1.10	40.25
1891.......	1.89	1.90	2.23	2.24	5.03	4.97	5.72	4.91	4.12	3.62	1.74	0.75	39.12
1892.......	2.51	2.15	2.78	3.58	3.49	4.20	4.69	5.64	5.11	3.33	1.93	1.13	40.54
1893.......	...	1.52	3.79	5.40	5.12	6.12	6.41	4.73	5.04	3.79	1.05	1.88	.....
1894.......	1.14	1.15	1.95	4.61	4.66	5.01	4.74	4.88	3.77	3.75	1.64	1.22	39.52
1895.......	1.19	1.19	...	4.91	4.27	4.13	4.57	4.52	4.06	2.24	1.53	1.68	.....
1896.......	2.64	2.25	2.39	4.71	5.91	5.09	5.23	5.80	3.34	2.94	1.62	1.25	43.17
1897.......	1.80	2.20	...	3.33	4.13	4.26	4.64	4.76	3.97	2.88	1.47	0.94	.....
1898.......	1.12	1.31	2.53	4.65	3.90	5.67	7.33	6.57	5.57	4.64	1.36	0.67	45.32
1899.......	1.51	1.39	1.54	3.79	5.35	6.37	5.38	5.86	5.04	2.87	1.86	1.15	42.11
1900.......	0.96	1.55	2.32	3.12	4.53	5.51	6.26	5.43	4.55	3.74	2.10	1.54	41.61
1901.......	1.19	0.84	2.79	3.54	5.25	5.16	6.96	5.46	5.01	3.55	2.81	1.03	43.59
1902.......	0.91	1.25	1.58	4.08	5.06	5.73	5.49	6.20	4.41	2.89	1.81	0.85	40.26
1903.......	1.66	2.22	1.82	4.05	4.38	4.81	5.60	4.53	4.12	4.12	1.29	1.56	40.12
1904.......	0.91	2.74	3.32	5.64	4.04	5.72	5.13	4.08	3.27	2.77	1.57	1.24	40.43
1905.......	0.64	0.58	2.40	3.17	3.99	4.60	5.32	4.12	3.66	3.11	1.59	1.38	34.56
1906.......	1.55	1.09	4.14	3.64	4.37	5.49	4.26	4.62	3.33	3.74	1.36	0.72	38.31
1907.......	0.89	0.80	4.42	4.56	3.49	5.47	5.60	4.62	4.14	2.77	1.08	1.05	38.89
1908.......	1.04	1.60	3.96	6.17	4.70	5.61	4.52	3.79	5.03	3.18	0.89	0.26	40.15
1909.......	0.66	0.66	2.32	3.20	4.92	3.97	5.32	4.56	3.14	3.58	1.26	0.65	34.24
1910.......	0.73	2.02	...	5.29	4.54	6.46	6.59	5.15	4.49	4.38	2.05	1.54	.....
1911.......	0.64	1.21	3.35	5.39	6.58	6.94	5.86	5.61	5.42	3.62	1.70	0.98	47.30
Average...	1.30	1.59	2.88	4.26	4.62	5.37	5.58	5.00	4.30	3.32	1.54	1.14	40.90
Maximum..	2.64	3.23	4.60	6.17	6.58	7.70	7.32	6.57	5.57	4.64	2.81	1.88	46.71
Minimum..	0.86	0.58	1.54	2.24	3.49	3.97	4.26	3.79	3.14	2.17	0.62	0.26	34.24

TABLE XXVII—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

At Arkansas Valley Sub-Station, Near Rocky Ford, Colorado.

DATE.	January		February		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1888.......	....	....	....	....	....	....	....	....	....	....	....	....
1889.......	....	....	....	....	....	....	69.9	38.1	76.0	45.7	86.1	....
1890.......	47.7	....	54.5	....	62.6	....	68.1	....	78.0	....	89.2	53.2
1891.......	38.5	8.6	46.4	15.4	58.4	21.0	68.0	33.8	76.0	45.3	82.1	54.8
1892.......	40.0	12.6	50.1	20.7	50.9	23.2	68.9	32.4	72.7	42.3	84.2	52.1
1893.......	53.7	17.0	50.4	16.1	61.4	22.0	68.4	32.7	77.3	40.9	91.9	55.6
1894.......	48.1	14.5	39.0	10.0	59.8	26.8	70.7	36.2	81.1	46.9	86.8	52.2
1895.......	40.2	13.3	39.6	9.1	56.5	22.5	71.4	35.5	77.0	44.0	84.0	52.6
1896.......	52.6	18.2	52.9	18.4	57.6	21.3	73.3	35.2	81.4	45.0	91.1	55.2
1897.......	38.4	13.3	48.1	21.4	56.0	23.5	67.1	33.2	....	....	....	....
1898.......	42.6	12.7	55.9	21.1	57.5	22.6	69.4	37.6	70.6	43.6	83.7	55.3
1899.......	42.6	12.1	33.1	0.6	57.6	22.7	71.3	34.1	79.0	45.0	88.2	53.6
1900.......	48.8	20.2	47.4	14.2	63.9	26.4	61.8	35.7	76.5	46.9	88.8	55.1
1901.......	50.3	11.9	44.0	13.2	57.3	24.4	67.8	35.8	75.8	46.9	89.7	54.0
1902.......	46.5	13.1	55.4	20.3	58.1	26.0	70.0	37.7	80.0	47.8	87.0	55.0
1903.......	50.7	18.6	38.7	10.9	56.9	25.4	68.4	36.9	75.7	42.6	78.2	52.1
1904.......	45.2	12.0	58.2	18.8	63.1	27.4	67.1	35.3	73.8	44.9	81.8	51.0
1905.......	39.8	15.0	38.2	10.0	59.0	31.2	63.6	34.5	74.2	44.5	88.0	57.1
1906.......	52.9	16.7	56.0	15.7	48.5	21.0	68.1	34.9	77.3	44.6	86.8	53.0
1907.......	49.8	14.2	58.8	19.2	68.1	29.2	62.8	34.0	68.1	41.8	82.9	52.2
1908.......	50.5	13.6	49.6	19.7	66.4	28.2	70.4	33.6	76.1	40.9	87.7	56.4
1909.......	50.9	17.7	51.6	16.9	57.7	19.6	64.2	33.0	73.0	41.2	85.0	53.7
1910.......	48.0	15.2	49.4	13.5	72.6	30.9	72.2	35.9	74.7	44.1	88.0	54.5
1911.......	56.5	19.4	47.2	15.8	64.3	28.6	69.2	35.8	79.9	49.2	89.6	56.8
Average...	47.0	14.8	48.4	15.3	59.7	24.9	68.3	35.1	76.1	44.5	86.4	54.1
Maximum.	56.5	20.2	58.8	21.4	72.6	31.2	73.3	38.1	81.4	49.2	91.9	57.1
Minimum..	38.4	8.6	33.1	0.6	48.5	19.6	61.8	32.4	68.1	40.9	78.2	51.0

TABLE XXVIII—EXTREME MONTHLY TEMPERATURES

At Arkansas Valley Sub-Station, Rocky Ford, Colorado.

YEAR.	January		February		March		April		May	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1888.................	..	..	..	..	..	..	..	..	..	..
1889.................	52	**—11**	54	—3	73	20	83	31	90	32
1890.................	74	**—10**	79	—8	80	3	86	19	91	42
1891.................	54	**—8**	72	—8	72	—6	90	15	89	31
1892.................	68	—8	60	—5	75	—10	90	21	90	31
1893.................	71	5	71	**—1**	88	4	85	17	94	19
1894.................	71	—6	59	—13	80	9	87	24	93	30
1895.................	65	—11	71	**—23**	83	—3	85	19	96	31
1896.................	67	4	72	1	84	—2	87	15	94	33
1897.................	54	**—15**	65	0	74	7	85	20	..	..
1898.................	61	—10	74	12	74	2	86	23	90	30
1899.................	61	—20	60	**—32**	82	2	87	18	94	32
1900.................	67	2	67	—10	82	19	79	17	90	38
1901.................	70	**—22**	69	—5	83	10	86	16	88	37
1902.................	68	**—10**	72	—9	74	8	89	25	89	35
1903.................	70	5	61	**—15**	77	—2	85	20	87	32
1904.................	66	0	81	5	81	15	88	24	88	32
1905.................	64	—13	67	**—24**	77	18	84	19	87	32
1906.................	67	3	78	0	74	1	84	15	89	35
1907.................	72	7	78	5	92	10	88	21	90	27
1908.................	64	**—7**	72	—4	86	17	86	18	92	30
1909.................	69	**—18**	66	—9	74	—8	85	17	87	18
1910.................	74	—6	72	**—17**	85	15	91	22	92	31
1911.................	77	—15	72	—16	77	3	82	23	93	29
Extreme	77	—22	81	—32	92	—10	91	15	96	18

NOTE — Extreme temperatures of each year indicated in black faced type.

TABLE XXVII—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

At Arkansas Valley Sub-Station, Near Rocky Ford, Colorado.

July		August		September		October		November		December		Year	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
....	....	....	....	80.4	66.2	....	....	....	....	....	....	....	....
93.8	....	93.6	....	81.4	....	70.4	37.3	44.5	20.3	57.5	....	....	....
94.6	61.2	91.1	55.1	83.1	44.6	72.1	29.7	60.0	21.5	54.4	16.9	....	....
89.2	58.2	91.4	55.8	85.0	50.1	73.8	32.2	56.5	20.6	43.4	18.0	....	....
91.7	58.4	91.2	56.9	89.8	47.8	70.1	35.4	56.4	23.8	40.0	12.1	....	....
92.4	58.4	86.1	57.7	83.0	47.7	72.9	33.2	55.4	21.3	49.9	19.3	....	....
92.4	57.6	90.5	55.6	82.4	46.3	74.9	33.5	60.9	21.2	46.7	15.5	....	....
84.2	56.4	87.1	56.5	88.0	48.1	69.9	33.0	54.7	18.7	44.6	15.4	....	....
90.9	59.6	91.9	58.4	80.6	51.7	66.5	34.7	52.5	20.1	55.4	16.9	....	....
....	....	87.5	52.8	85.6	53.0	68.9	39.1	59.5	23.9	41.3	12.1	....	....
88.9	59.4	91.3	57.4	79.3	42.9	65.7	32.9	54.0	20.8	38.8	9.4	66.5	34.6
87.0	58.0	90.8	56.6	83.8	47.8	71.8	36.0	59.3	28.5	41.6	12.6	67.2	34.0
90.8	58.0	92.6	54.9	81.6	48.7	73.9	37.4	59.3	22.0	51.6	13.4	69.8	36.1
97.0	61.8	91.7	58.7	83.5	47.8	73.3	37.6	63.3	24.9	46.4	13.6	70.0	35.9
91.4	56.7	92.3	58.7	80.1	43.9	72.5	35.6	58.0	25.4	45.6	15.1	69.7	36.3
92.2	58.8	89.9	58.6	82.1	45.7	71.1	32.2	55.7	22.3	50.4	15.7	67.5	35.0
89.3	56.4	87.0	56.4	82.7	49.2	70.0	38.6	62.9	20.7	50.4	14.7	69.3	35.5
88.3	56.7	91.4	57.8	84.2	49.4	69.8	29.9	62.1	26.3	46.4	9.4	67.1	35.2
86.6	57.1	89.3	56.7	80.5	48.9	69.1	33.0	55.8	22.7	54.2	18.9	68.8	35.3
89.8	59.0	87.9	58.8	84.2	48.9	73.6	35.6	58.3	22.2	48.0	15.7	69.4	35.9
89.6	58.6	88.6	58.7	85.7	46.4	68.0	34.0	52.5	21.6	43.1	18.1	69.0	35.8
92.7	60.5	91.1	60.3	80.5	48.2	71.6	35.4	56.8	25.9	34.8	8.7	67.5	35.1
90.6	59.6	88.6	56.6	86.6	49.8	77.5	33.8	62.6	26.1	51.2	15.3	71.8	36.3
88.1	60.7	89.2	57.0	86.0	52.4	66.6	35.4	52.4	19.0	39.2	6.1	69.0	36.4
90.5	58.6	90.1	57.1	83.4	48.9	71.0	34.6	57.1	22.6	46.7	14.2	68.7	35.4
97.0	61.8	93.6	60.3	89.8	66.2	74.9	39.1	63.3	28.5	57.5	19.3	....	....
84.2	56.4	86.1	52.8	79.3	42.9	65.7	29.7	44.5	18.7	34.8	6.1	....	....

TABLE XXVIII—EXTREME MONTHLY TEMPERATURES

At Arkansas Valley Sub-Station, Rocky Ford, Colorado.

June		July		August		September		October		November		December	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
..	..	..	..	..	..	..	..	83	31	74	18	62	13
98	49	**104**	62	102	62	98	32	89	24	60	10	70	8
102	39	**104**	55	103	47	96	31	83	22	80	13	70	6
95	43	98	50	**100**	45	95	34	82	24	76	4	69	—4
97	36	102	50	**104**	43	98	36	89	25	77	14	73	**—14**
102	41	101	45	92	47	94	39	86	22	77	5	66	7
101	40	100	51	100	42	93	32	87	15	79	7	75	**—23**
97	42	98	46	97	48	**100**	28	82	16	76	—3	68	—10
101	41	98	54	100	49	97	38	85	14	81	**—5**	72	10
..	..	..	..	99	46	98	42	88	24	80	10	74	—8
99	41	99	53	**100**	52	96	32	90	20	80	2	64	**—17**
105	43	102	53	99	45	99	35	92	22	74	19	66	—20
101	48	**103**	52	96	44	95	30	88	26	77	9	70	**—21**
105	43	103	57	100	53	93	33	84	28	76	15	75	—16
103	48	102	44	**104**	50	95	30	86	25	77	9	71	—7
97	39	**101**	41	**101**	49	96	29	89	22	76	—12	68	3
94	45	**99**	49	95	44	94	40	89	21	75	5	68	**—12**
100	50	96	48	**100**	51	91	36	90	16	78	7	60	—4
99	39	98	49	98	47	90	41	88	13	78	**—1**	75	5
94	38	**97**	51	96	52	96	36	89	26	74	9	68	**—5**
101	43	**102**	51	98	50	97	27	90	20	77	6	63	4
99	44	**102**	55	98	54	93	35	89	24	78	—1	64	—13
100	41	**101**	54	98	39	95	37	90	13	81	16	67	4
99	45	95	54	**100**	47	99	36	90	14	72	—16	64	**—26**
105	36	104	41	104	39	100	27	92	13	81	—16	75	—26

TABLE XXIX—MONTHLY MEAN TEMPERATURE AT ARKANSAS VALLEY SUBSTATION, ROCKY FORD, COLORADO.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1888	...	...	...	...	...	...	...	...	73.3	56.4	38.8	35.0	....
1889	20.2	29.1	45.6	54.0	60.8	72.4	74.7	73.4	60.2	50.6	32.4	35.0	50.7
1890	21.4	30.0	38.7	48.9	56.7	71.2	77.8	73.1	63.8	50.6	40.7	35.6	50.7
1891	23.6	31.0	39.7	50.9	60.6	68.4	73.7	73.3	67.6	53.0	38.5	30.7	50.9
1892	26.3	35.4	37.0	50.7	57.5	68.1	75.1	74.1	68.8	52.7	40.1	26.0	51.0
1893	35.3	33.2	41.7	50.6	59.1	73.8	75.4	71.9	65.4	53.0	38.3	34.6	52.7
1894	31.3	24.5	43.3	53.4	64.0	69.5	75.[illegible]	73.1	64.4	54.2	41.1	31.1	52.1
1895	26.7	24.4	39.5	53.5	60.5	68.3	70.3	71.8	68.0	51.5	36.7	30.0	50.1
1896	35.4	35.7	39.4	54.2	63.2	73.2	75.2	75.2	66.3	50.6	36.3	36.2	...
1897	25.9	34.8	39.8	50.2	...	....	...	70.2	69.3	54.0	41.7	26.7	....
1898	27.6	38.5	40.1	53.5	57.6	69.5	74.2	74.4	61.1	49.3	37.4	24.1	50.6
1899	27.4	16.9	40.2	52.7	62.0	70.9	72.5	73.7	65.8	53.9	43.9	27.1	50.6
1900	34.5	30.8	45.2	48.7	61.7	72.0	74.4	73.7	65.2	55.6	40.7	32.5	52.9
1901	31.1	28.6	40.8	51.8	61.4	71.8	79.4	75.2	65.7	55.4	44.1	30.0	52.9
1902	29.8	37.8	42.1	53.6	63.9	71.3	74.1	75.6	62.0	53.7	41.7	30.5	53.0
1903	34.6	24.8	41.2	52.6	59.2	65.1	75.5	74.2	63.9	51.6	39.0	33.0	51.2
1904	28.6	38.5	45.3	51.2	59.4	66.4	72.9	71.7	66.0	54.3	41.8	32.5	52.4
1905	27.4	24.1	45.1	49.0	59.3	72.5	72.5	74.6	66.8	49.8	44.3	27.9	51.1
1906	34.8	36.0	34.8	51.5	61.0	69.9	71.9	73.0	64.7	51.0	39.2	36.5	52.0
1907	32.0	39.0	48.6	48.4	55.0	67.6	74.4	73.4	66.6	54.6	40.3	31.9	52.6
1908	32.1	34.6	47.5	52.0	58.5	72.0	74.1	73.7	66.0	51.0	37.0	30.6	52.4
1909	34.3	34.2	38.7	48.6	57.1	69.4	76.6	75.7	64.3	53.5	41.4	21.8	51.3
1910	31.3	31.4	51.7	54.1	59.4	71.2	75.1	72.6	68.2	55.7	44.4	33.3	54.0
1911	38.0	31.5	46.5	52.5	64.5	73.2	74.4	73.1	69.2	51.0	35.7	22.7	52.7
Average	30.0	31.5	42.3	51.6	60.1	70.4	74.5	73.5	65.9	52.8	39.8	30.6	51.9
Maximum	38.0	39.0	51.7	54.2	64.5	73.8	79.4	75.7	73.3	56.4	44.4	36.5	54.0
Minimum	20.2	16.9	34.8	48.4	55.0	65.1	70.3	70.2	60.2	49.3	32.4	21.8	50.1

TABLE XXX—MONTHLY PRECIPITATION AT ARKANSAS VALLEY SUBSTATION, ROCKY FORD, COLORADO.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1888	...	...	...	...	...	....	...	...	...	...	...	...	.....
1889	0.36	0.12	0.67	2.12	1.75	0.75	4.50	1.28	0.26	1.68	0.77	0.04	14.30
1890	0.34	0.15	0.15	2.97	0.29	0.77	1.14	0.74	0.08	0.00	0.30	0.00	6.93
1891	1.50	0.00	1.80	0.43	3.52	2.31	0.74	0.73	1.75	0.21	0.20	1.77	14.96
1892	0.50	0.80	1.50	0.73	3.26	3.31	1.99	3.10	0.00	0.95	0.50	0.46	17.10
1893	0.02	0.08	0.80	0.25	0.70	0.40	10.26	3.20	0.30	0.25	T	0.50	16.76
1894	0.10	0.95	0.45	0.60	4.25	0.70	1.40	0.25	0.80	0.00	0.04	0.65	10.19
1895	0.27	0.65	0.07	0.35	1.90	0.52	4.87	1.86	T	0.85	0.20	0.57	12.11
1896	0.32	0.18	0.23	0.55	1.12	0.47	2.09	0.47	1.85	1.96	0.00	0.70	9.94
1897	0.75	0.37	0.20	0.44	...	....	...	0.73	0.79	2.64	0.19	1.06	.....
1898	0.40	0.00	0.16	1.06	2.71	3.16	3.52	0.92	1.55	1.36	0.37	0.96	16.17
1899	0.98	0.55	0.32	0.28	0.99	0.78	7.00	2.22	1.43	0.63	2.40	0.98	18.56
1900	T	0.52	0.37	7.15	2.28	1.47	1.77	1.05	0.08	0.60	0.06	0.24	15.59
1901	0.20	0.10	1.00	2.36	1.34	0.23	1.48	0.74	0.48	0.25	0.00	0.50	8.68
1902	0.18	0.57	1.78	0.18	4.02	0.60	0.72	2.72	0.46	0.80	0.41	0.33	12.77
1903	T	1.05	0.18	0.56	0.28	3.94	0.42	0.87	T	1.62	0.26	0.22	9.40
1904	T	T	0.77	0.81	2.03	2 20	1.75	0.33	2.34	0.50	0.00	0.31	11.04
1905	0.05	0.11	2.11	4.67	2.13	1.56	1.30	0.45	1.48	0.10	0.41	0.02	14.39
1906	0.23	0.10	0.92	5.59	0.59	0.54	2.05	1.21	1.64	1.57	0.22	T	14.66
1907	T	T	0.00	1.84	1.85	0.69	4.96	0.78	0.33	0.88	2.00	0.26	13.59
1908	0.18	0.35	T	0.14	0.89	1.16	2.65	2.89	0.00	1.96	0.86	0.04	11.12
1909	0.15	0.15	0.65	0.95	0.75	1.21	0.65	2.53	1.72	0.90	1.07	0.14	10.87
1910	T	0.17	0.35	2.40	2.00	0.27	3.58	1.57	0.00	T	0.43	T	10.77
1911	T	0.65	0.05	0.60	0.65	0.67	1.51	0.69	0.12	1.25	0.20	1.16	7.55
Average	0.28	0.33	0.63	1.61	1.79	1.26	2.74	1.36	0.76	0.91	0.47	0.47	12.61
Maximum	1.50	0.95	2.11	7.15	4.25	3.94	10.26	3.20	2.34	2.64	2.40	1.77	18.56
Minimum	T	0.00	0.00	0.14	0.28	0.23	0.42	0.25	0.00	0.00	0.00	0.00	6.93

TABLE XXXI—MONTHLY MEAN TEMPERATURE AT PLAINS SUBSTATION, CHEYENNE WELLS, COLORADO.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1894	...	...	...	...	...	70.7	74.4	72.5	64.5	54.8	42.9	30.0	....
1895	24.3	23.2	38.2	52.3	59.7	65.9	69.0	71.6	67.6	50.6	34.8	26.7	47.8
1896	33.2	36.0	36.2	52.7	62.1	70.8	74.3	74.3	62.2	49.7	33.2	37.8	51.9
1897	25.9	31.7	35.2	48.0	62.0	68.9	74.1	70.0	69.0	53.6	39.8	26.6	50.4
1898	28.9	35.0	35.7	49.1	55.3	67.8	72.8	73.7	62.2	47.0	33.4	26.1	48.9
1899	26.4	14.9	34.9	49.8	59.5	68.8	71.8	75.6	66.3	53.4	43.4	28.1	49.4
1900	34.5	28.6	41.2	48.4	60.1	70.7	74.2	75.2	64.2	54.9	43.9	31.4	52.3
1901	30.2	24.7	36.0	47.8	58.7	71.6	78.9	74.3	64.0	54.0	43.4	29.5	51.1
1902	28.9	33.6	39.6	49.9	62.7	66.6	72.0	73.6	59.4	54.4	40.0	27.6	50.7
1903	32.0	20.9	36.2	48.5	56.0	62.0	73.4	72.4	64.0	53.0	41.3	34.1	49.5
1904	26.9	34.7	42.4	48.2	57.6	65.9	72.3	70.5	64.8	54.0	43.6	32.8	51.1
1905	27.3	18.8	44.9	47.6	55.0	69.7	69.8	74.5	67.4	48.7	43.5	30.3	49.8
1906	33.8	34.9	28.8	51.2	57.7	65.9	68.7	71.8	63.5	51.5	39.6	38.0	50.4
1907	30.1	36.5	46.8	47.8	53.4	66.4	74.5	74.1	64.8	54.8	40.4	43.0	52.8
1908	30.9	32.6	41.5	50.6	57.2	68.5	71.8	70.4	67.5	50.6	40.5	25.6	50.6
1909	26.4	33.2	35.9	45.7	55.6	66.4	74.6	74.3	63.0	50.9	40.4	18.0	48.7
1910	27.2	...	51.2	50.8	56.4	70.1	75.7	72.0	67.0	56.4	43.3	34.4	....
1911	33.8	29.2	44.6	49.2	60.9	73.3	73.5	73.0	68.7	48.5	34.7	24.7	51.2
Average	29.5	29.3	39.4	49.3	58.2	68.3	73.1	73.0	65.0	52.3	40.1	30.3	50.6
Maximum	34.5	36.5	51.2	52.7	62.7	73.3	78.9	75.6	69.0	56.4	43.9	43.0	52.8
Minimum	24.3	14.9	28.8	45.7	55.0	62.0	68.7	70.0	59.4	47.0	33.2	18.0	48.7

November, 1900, 14 days; December, 21 days.
December, 1907, 15 days.

TABLE XXXII—MONTHLY PRECIPITATION AT THE PLAINS SUBSTATION, CHEYENNE WELLS, COLORADO.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1894	...	...	...	...	...	0.48	1.99	1.03	0.14	0.14	T	0.55	.....
1895	0.67	0.27	0.16	1.67	1.49	3.90	6.38	1.22	T	0.21	0.30	0.42	15.79
1896	0.45	T	0.71	3.41	2.28	3.03	2.27	3.07	0.84	0.78	T	0.60	17.44
1897	0.26	0.10	1.58	1.20	1.44	2.32	4.19	3.24	0.92	2.73	0.10	0.20	18.18
1898	0.03	0.00	0.61	1.10	5.56	3.95	2.09	1.33	2.00	0.48	0.50	0.48	18.13
1899	0.47	0.36	0.39	0.03	2.88	1.89	3.67	0.55	0.78	T	2.49	0.55	14.06
1900	0.03	0.67	0.56	9.95	0.80	2.47	2.02	0.30	1.31	0.22	T	0.18	18.53
1901	0.15	0.38	0.71	4.02	1.18	0.90	2.63	2.59	1.12	0.49	0.02	0.25	14.44
1902	T	0.25	1.92	0.78	3.12	2.53	1.42	6.06	0.20	1.32	0.00	0.75	18.35
1903	0.34	0.79	0.23	0.94	3.71	2.63	1.87	1.89	T	T	0.75	0.13	13.28
1904	T	T	0.11	1.59	2.51	4.78	3.39	4.89	4.26	0.99	0.00	0.29	22.81
1905	0.14	0.35	2.00	5.16	2.13	2.58	2.02	1.12	2.41	0.40	0.00	T	18.31
1906	0.21	0.24	0.89	3.77	1.24	3.00	4.26	2.39	2.36	0.90	0.20	T	19.46
1907	T	T	0.13	0.72	1.10	2.86	1.98	0.95	1.28	0.25	0.25	0.20	9.72
1908	T	0.57	T	0.02	2.06	1.50	4.88	2.72	T	4.75	1.25	0.70	18.45
1909	0.42	0.16	1.85	0.45	1.96	8.62	3.63	0.78	2.93	1.15	1.43	0.27	24.82
1910	T	...	0.09	1.15	2.54	0.88	2.76	3.10	1.53	T	T	T	.....
1911	T	1.34	T	1.10	0.99	1.23	2.87	2.36	0.44	1.14	0.25	2.10	13.82
Average	0.19	0.44	0.70	2.18	2.18	2.70	3.02	2.20	1.25	0.89	0.42	0.43	16.60
Maximum	0.67	1.34	2.00	9.95	5.56	8.62	6.38	6.06	4.26	4.75	2.49	2.10	24.82
Minimum	T	0.00	T	0.02	0.80	0.48	1.42	0.30	T	T	0.00	T	9.72

TABLE XXXIII—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

At Plains Sub-Station, Cheyenne Wells, Colorado.

DATE.	January		February		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1894.......	....	....	....	....	....	....	....	....	....	....	87.9	53.5
1895.......	36.2	12.4	37.0	9.4	54.3	22.0	69.4	36.4	75.2	44.2	80.2	51.6
1896.......	47.1	19.2	50.5	21.4	50.3	22.0	69.8	35.5	76.1	48.2	87.4	54.2
1897.......	38.2	13.7	45.8	17.6	48.5	22.0	61.9	34.1	76.8	47.2	84.7	53.2
1898.......	43.3	14.5	52.2	17.8	52.9	18.5	64.2	34.0	67.3	43.4	80.9	54.6
1899.......	42.0	10.7	28.5	1.3	50.1	19.9	67.4	32.2	75.8	43.3	85.0	52.6
1900.......	47.9	21.4	42.3	14.8	56.4	26.1	59.2	37.6	74.1	46.1	85.0	56.4
1901.......	44.6	15.7	37.0	12.4	50.0	21.9	62.5	33.2	72.9	44.4	89.2	54.2
1902.......	44.1	13.7	49.0	18.1	53.1	26.0	65.6	34.2	78.1	47.2	78.7	51.5
1903.......	44.8	19.2	31.0	10.7	48.9	23.5	64.2	32.8	69.8	42.2	73.6	50.3
1904.......	43.3	10.5	53.3	16.0	60.1	24.8	65.0	31.5	70.8	44.4	80.2	51.6
1905.......	39.4	15.3	32.7	4.8	57.8	32.0	61.7	33.4	68.4	41.6	84.0	55.5
1906.......	48.4	19.3	51.6	18.2	39.4	18.2	68.1	34.3	73.5	41.9	82.6	49.3
1907.......	46.1	14.2	52.3	20.7	65.2	28.4	65.5	30.1	67.9	38.9	84.0	48.7
1908.......	45.8	15.9	47.7	17.6	58.1	24.9	70.1	31.1	74.0	40.4	85.6	51.4
1909.......	36.3	16.5	47.5	18.9	48.5	23.3	60.7	30.6	72.2	38.9	81.7	51.1
1910.......	38.5	15.9	....	....	70.6	31.8	68.1	33.3	70.0	42.9	86.4	53.8
1911.......	52.2	18.0	42.9	15.4	60.9	28.3	65.3	33.0	78.0	43.9	90.5	56.2
Average...	43.4	15.7	43.8	14.7	54.4	24.3	65.2	33.4	73.0	43.5	83.8	52.8
Maximum.	52.2	21.4	53.3	21.4	70.6	32.0	70.1	37.6	78.1	48.2	90.5	56.4
Minimum..	36.2	10.5	28.5	1.3	39.4	18.2	59.2	30.1	67.3	38.9	73.6	48.7

TABLE XXXIV—EXTREME MONTHLY TEMPERATURES

At Plains Sub-Station, Cheyenne Wells, Colorado.

YEAR.	January		February		March		April		May	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1894.................	..	..	..	..	..	..	..	..	..	..
1895.................	56	—3	68	**—15**	79	—9	84	19	96	30
1896.................	61	—6	69	7	75	6	85	10	90	34
1897.................	61	**—12**	63	9	70	7	82	26	92	37
1898.................	69	0	70	4	72	—12	84	19	89	31
1899.................	61	—17	59	**—26**	76	6	83	15	91	26
1900.................	63	—6	62	—7	83	14	79	20	87	38
1901.................	64	—17	63	—14	79	3	83	9	84	30
1902.................	68	**—14**	67	—11	70	**1**	87	21	92	35
1903.................	70	3	53	**—10**	72	—2	79	14	84	30
1904.................	65	**—11**	77	—4	76	—1	79	19	88	31
1905.................	69	—14	82	**—17**	72	18	85	18	83	28
1906.................	67	**0**	70	2	68	0	83	25	89	34
1907.................	65	0	74	0	91	10	86	14	92	20
1908.................	61	0	71	**—12**	80	10	85	12	92	30
1909.................	54	**—11**	72	—6	63	2	84	21	89	18
1910.................	64	—5	..	..	89	14	91	21	88	29
1911.................	71	**—18**	70	—5	74	4	81	21	95	27
Extreme.............	71	—18	82	—26	91	—12	91	9	96	18

NOTE — Extreme temperatures of each year indicated in black faced type.

TABLE XXXIII—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

At Plains Sub-Station, Cheyenne Wells, Colorado.

July		August		September		October		November		December		Year	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
90.2	58.7	87.2	57.7	80.8	48.3	73.4	36.2	62.0	23.9	44.6	15.3	....	....
81.2	56.7	86.1	57.2	85.1	50.2	66.3	34.9	49.0	20.7	39.2	14.2	63.3	34.2
88.4	60.2	88.9	59.7	76.0	48.4	64.4	35.1	47.3	19.1	53.6	22.0	66.6	37.1
89.8	58.4	83.2	56.7	84.2	53.8	67.4	39.8	56.0	23.6	38.9	14.3	64.6	36.2
86.7	59.0	89.2	58.2	78.4	45.9	62.6	31.4	49.2	17.6	40.4	11.8	63.9	33.9
85.1	58.6	91.5	59.8	83.0	49.6	69.1	37.2	57.9	28.9	38.3	17.9	64.5	34.3
88.9	59.4	91.8	58.6	78.3	50.1	71.1	38.7	61.4	24.0	47.0	18.1	67.0	37.6
95.6	62.2	89.3	59.4	79.1	48.8	69.7	38.2	59.5	27.2	43.6	15.4	66.1	36.1
87.9	55.6	88.7	58.6	74.6	44.3	69.3	39.4	54.0	26.0	40.3	14.8	65.3	35.8
88.0	58.8	86.8	58.1	80.7	47.3	70.8	35.2	56.7	25.9	50.7	17.5	63.8	35.1
86.5	58.1	86.5	56.4	79.9	49.7	68.3	39.7	60.3	26.9	46.6	19.0	66.7	35.7
84.6	54.9	91.0	57.9	84.2	50.7	66.9	30.5	58.2	28.9	46.2	14.3	64.6	35.0
82.4	55.0	88.3	55.3	78.1	49.0	68.9	34.1	56.8	22.5	53.3	22.8	66.0	35.0
90.5	58.4	89.5	58.8	82.3	47.2	71.8	37.9	55.6	25.2	58.8	27.2	69.1	36.3
86.0	57.5	84.9	55.8	84.8	50.2	66.4	34.9	55.1	25.9	37.8	13.5	66.4	34.9
89.0	60.1	89.8	58.8	78.0	47.9	68.8	33.0	53.1	27.6	28.7	7.4	62.9	34.5
91.8	59.6	86.5	57.5	81.4	52.6	72.8	40.0	59.2	27.4	49.3	19.5	....	....
87.5	59.4	88.4	57.5	84.8	52.6	61.9	35.2	50.1	19.3	37.8	11.6	66.7	35.9
87.8	58.4	88.2	57.9	80.8	49.3	68.3	36.2	55.6	24.5	44.2	16.5	65.7	35.6
95.6	62.2	91.8	59.8	85.1	53.8	73.4	40.0	62.0	28.9	58.8	27.2	69.1	37.6
81.2	54.9	83.2	55.3	74.6	44.3	62.6	30.5	47.3	17.6	28.7	7.4	62.9	33.9

TABLE XXXIV—EXTREME MONTHLY TEMPERATURES

At Plains Sub-Station, Cheyenne Wells, Colorado.

June		July		August		September		October		November		December	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
100	**45**	101	48	96	50	91	36	85	22	76	9	73	—14
96	38	97	50	97	48	**104**	25	79	17	70	4	62	—2
98	42	95	55	**101**	41	95	35	85	23	79	**—11**	66	12
98	**43**	**103**	48	96	51	96	37	88	21	79	3	64	—10
97	39	97	52	**98**	52	95	32	89	19	76	—12	68	**—17**
102	39	99	52	101	50	**102**	32	93	26	71	4	63	1
98	49	**100**	51	**100**	45	93	34	86	23	76	12	66	**—16**
103	38	103	58	**109**	54	90	30	83	26	76	16	72	**—21**
103	39	101	41	**104**	45	91	29	90	32	77	9	65	0
94	36	97	48	**100**	47	96	27	87	24	77	—6	70	1
94	43	**96**	51	94	41	92	32	81	18	72	12	69	—2
97	44	97	40	**100**	54	91	39	89	13	73	10	59	5
92	34	93	45	**96**	44	90	38	87	20	75	8	70	6
99	38	**100**	51	**100**	49	98	32	89	30	76	**—3**	72	15
100	40	97	48	**97**	50	97	24	86	23	76	7	47	—2
96	42	95	53	**97**	46	94	35	91	23	77	8	54	—11
99	40	**101**	43	95	39	94	40	89	16	80	11	65	9
100	50	97	55	**101**	34	97	50	86	13	63	—7	65	—18
103	34	103	40	109	34	104	24	93	13	80	—12	73	—21

TABLE XXXV—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

Near Long's Peak, Estes Park, Colorado.

DATE.	January		February		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1892.......	....	....	....	....	....	....	....	....	48.6	28.6	65.1	37.9
1893.......	....	....	27.4	9.0	36.3	14.3	40.8	19.9	53.7	27.8	69.5	37.3
1894.......	28.4	9.4	29.0	5.1	37.4	17.4	48.2	26.1	58.6	32.3	65.6	35.8
1895.......	27.7	11.0	30.0	7.1	35.6	14.3	50.6	23.5	54.9	29.9	62.6	35.2
1896.......	38.8	19.6	41.5	14.8	37.2	17.2	38.4	24.7	60.8	33.9	71.2	38.2
1897.......	35.4	12.3	29.7	8.6	33.0	12.3	43.1	21.9	57.9	32.2	62.5	36.7
1898.......	32.3	7.7	38.4	15.3	35.1	12.0	49.3	23.3	49.7	27.2	64.2	36.7
1899.......	30.9	12.6	23.9	7.0	33.6	14.0	46.6	24.3	54.6	29.2	64.3	36.0
1900.......	38.6	12.9	31.1	12.1	42.0	19.3	43.4	19.7	57.9	31.8	68.2	41.0
1901.......	34.4	12.4	31.8	10.2	33.6	14.2	43.3	20.8	55.3	32.5	64.3	37.9
1902.......	34.9	10.8	35.8	18.1	33.3	12.2	46.9	24.3	55.3	30.4	65.1	35.7
1903.......	35.3	13.7	22.4	—0.1	39.4	13.4	43.1	21.1	50.8	25.8	59.2	35.9
1904.......	30.0	8.6	36.7	16.9	40.9	22.1	47.0	21.7	51.4	29.4	60.4	34.8
1905.......	32.6	10.7	31.6	7.2	41.5	17.4	40.9	19.5	51.8	26.6	68.6	37.2
1906.......	36.2	11.6	38.0	8.9	34.3	8.1	44.9	21.2	54.6	29.2	63.8	32.6
1907.......	37.3	14.5	41.2	18.7	43.4	22.1	44.8	20.9	48.7	24.0	62.6	32.4
1908.......	44.1	20.2	39.7	15.7	41.0	19.7	49.1	23.6	52.7	27.5	61.7	33.6
1909.......	36.2	16.8	31.3	10.3	35.5	13.1	39.3	19.0	49.9	28.6	64.9	37.5
1910.......	36.8	14.4	36.3	9.6	52.3	23.1	48.7	22.7	56.5	28.1	68.2	34.4
1911.......	41.1	10.0	35.8	10.4	45.0	14.9	47.4	19.4	58.3	26.5	68.4	35.8
Average...	35.1	12.7	33.2	10.8	38.4	15.8	45.0	22.0	54.1	29.1	65.0	36.1
Maximum.	44.1	20.2	41.5	18.7	52.3	23.1	50.6	26.1	60.8	33.9	71.2	41.0
Minimum..	27.7	7.7	22.4	—0.1	33.0	8.1	38.4	19.0	48.6	24.0	59.2	32.4

TABLE XXXVI—EXTREME MONTHLY TEMPERATURES

Near Long's Peak, Estes Park, Colorado.

YEAR.	January		February		March		April		May	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1892..................	..	..	..	..	..	..	..	..	..	..
1893..................	42	**—10**	42	—9	58	—6	60	—2	70	9
1894..................	47	—14	45	**—21**	51	—10	64	10	72	19
1895..................	45	—12	49	**—23**	59	—6	62	4	69	12
1896..................	50	1	50	—7	56	—8	68	—8	78	19
1897..................	54	**—14**	48	—10	53	—11	60	1	68	23
1898..................	56	—21	52	0	52	—14	67	0	64	8
1899..................	46	—7	43	**—31**	54	—22	60	—1	65	17
1900..................	53	—12	41	—9	60	8	63	—9	70	19
1901..................	48	**—20**	45	—13	48	—6	63	—8	67	24
1902..................	51	**—15**	49	—5	45	0	63	5	67	15
1903..................	48	—7	40	**—22**	53	—8	57	—4	62	3
1904..................	45	—11	48	**—13**	52	8	61	1	65	20
1905..................	42	—13	52	**—28**	54	—4	61	4	**79**	13
1906..................	53	—12	54	—6	52	**—23**	61	2	69	18
1907..................	51	**—12**	49	1	59	5	60	—9	68	3
1908..................	55	6	55	—5	53	—6	63	0	70	11
1909..................	52	**—14**	50	—8	53	—12	54	—4	72	12
1910..................	51	—9	60	**—20**	62	0	69	10	73	14
1911..................	48	0	47	2	70	0	61	—2	70	14
Extreme............	56	—21	60	—31	70	—23	69	—9	79	3

NOTE — Extreme temperatures of each year indicated in black faced type.

TABLE XXXV—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

Near Long's Peak, Estes Park, Colorado.

July		August		September		October		November		December		Year	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
70.1	42.9	....	....	....	....	....		....	....	....	....	....	....
74.3	39.9	68.1	40.6	64.8	34.4	49.2	26.5	38.7	18.5	33.7	18.7	....	....
71.4	41.4	70.3	40.6	61.2	34.2	51.5	29.8	44.9	25.4	33.1	13.3	50.0	25.9
67.6	40.4	69.8	41.0	64.3	35.5	50.6	24.2	37.4	16.4	28.5	13.5	48.3	24.3
68.3	41.1	70.4	41.2	61.2	34.9	53.2	26.3	37.1	18.9	43.1	18.3	51.8	27.4
67.7	41.6	63.5	43.6	66.2	34.8	53.2	26.1	44.7	23.7	33.1	12.0	49.2	25.5
65.4	41.3	71.8	41.5	66.0	35.2	50.3	26.6	36.8	16.9	31.7	8.4	49.2	24.3
68.7	40.6	69.9	42.0	67.6	35.4	49.1	25.5	47.2	23.0	37.2	13.8	49.5	25.3
69.5	40.0	71.2	41.3	60.7	33.3	53.4	27.5	44.3	22.6	36.4	16.0	51.4	26.5
74.3	42.7	69.3	42.3	61.9	32.9	54.6	28.2	46.8	22.7	33.6	13.5	50.3	25.9
67.7	36.9	70.1	39.0	63.5	30.7	52.7	26.1	41.9	16.4	37.8	14.4	50.4	24.6
70.4	40.5	71.9	38.7	62.1	31.6	53.5	25.5	43.4	19.9	37.4	15.9	49.1	23.5
67.6	35.6	69.2	39.9	66.9	33.7	53.1	25.3	49.1	19.9	35.6	13.6	50.7	25.1
66.8	37.2	71.0	38.8	61.5	33.1	42.4	19.1	42.7	16.3	33.6	5.7	48.8	22.4
65.5	36.2	69.0	35.7	60.6	33.4	51.4	22.6	39.7	14.4	40.3	16.7	49.9	22.6
71.7	38.0	69.8	38.0	66.4	34.0	60.7	36.8	48.1	28.8	41.6	24.0	53.0	27.7
66.5	38.0	65.9	40.8	64.0	34.1	49.0	23.5	41.5	14.6	37.0	12.1	51.0	25.3
74.2	42.5	71.6	43.0	62.5	34.6	58.2	29.3	49.3	17.9	30.2	8.4	50.3	25.1
73.2	35.9	71.5	36.2	64.5	34.8	59.9	24.4	50.5	12.9	44.1	7.3	55.2	23.7
67.9	39.0	70.5	38.0	65.6	35.1	52.2	19.8	41.4	11.3	35.3	4.2	52.4	22.0
69.4	39.6	69.7	40.1	63.8	34.0	52.5	26.0	43.4	19.0	36.0	13.0	50.5	24.8
74.3	42.9	71.9	43.6	67.6	35.5	60.7	36.8	50.5	28.8	44.1	24.0	55.2	27.7
65.4	35.6	63.5	35.7	60.6	30.7	42.4	19.1	36.8	11.3	28.5	4.2	48.3	22.0

TABLE XXXVI—EXTREME MONTHLY TEMPERATURES

Near Long's Peak, Estes Park, Colorado.

June		July		August		September		October		November		December	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
..	..	77	35	..	..	..	..	..	..	..	..	..	..
81	22	80	31	78	30	75	19	63	14	51	—6	45	—8
75	29	**80**	35	75	32	70	21	62	15	57	—9	51	—19
76	22	**79**	32	77	35	76	17	64	12	56	—6	52	—16
85	29	78	36	78	28	74	15	67	15	62	**—9**	60	1
74	26	**78**	32	75	22	75	28	67	2	72	—4	48	—9
79	23	73	34	**81**	33	78	21	65	13	57	—12	51	**—24**
79	22	78	37	79	32	**82**	20	69	8	59	6	55	—9
81	32	78	27	79	33	72	23	64	11	55	13	50	**—27**
79	29	**82**	35	80	37	70	19	67	21	59	6	51	—14
77	26	81	27	**83**	33	74	13	65	10	60	—6	52	—2
76	19	76	31	75	29	75	12	65	4	55	—14	49	—4
70	26	**76**	28	75	24	73	22	67	9	56	—2	52	—6
76	29	76	27	**77**	32	70	25	55	—5	55	—4	58	—13
78	25	78	27	75	27	73	26	67	3	53	—17	59	—7
71	23	**80**	31	78	29	73	17	73	*31	65	10	62	0
72	26	**80**	26	76	32	76	7	65	1	60	—8	56	**—13**
78	31	**81**	36	79	33	74	20	70	16	64	—4	48	†-11
76	23	**82**	29	78	25	80	29	76	—10	56	1	58	0
80	29	74	28	79	25	78	22	64	—9	53	—7	61	**—14**
85	19	82	26	83	22	82	7	76	—10	72	—17	62	—27

*18 days. †14 days.

TABLE XXXVII—MONTHLY MEAN TEMPERATURE NEAR LONG'S PEAK, ESTES PARK, COLORADO.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1892.......	...	...	...	...	38.5	51.5	56.5	...	...	...	...	...	....
1893.......	...	18.2	25.3	30.4	40.7	53.4	57.1	54.4	49.6	37.8	28.6	26.2	....
1894.......	18.9	17.0	27.4	37.2	45.4	50.7	56.4	55.4	47.7	40.6	35.2	23.2	37.9
1895.......	19.3	18.5	25.0	37.0	42.4	48.9	54.0	55.4	49.9	37.4	26.9	21.0	36.3
1896.......	29.2	28.2	27.2	31.6	47.3	54.7	54.7	55.8	48.0	39.7	28.0	30.7	39.6
1897.......	23.8	19.1	22.6	32.5	45.0	49.6	54.7	53.5	50.5	39.6	34.2	22.6	37.3
1898.......	20.0	26.8	23.6	36.3	38.4	50.5	53.4	56.6	50.4	38.5	27.2	20.0	36.8
1899.......	21.7	15.4	23.8	35.4	41.9	50.2	54.6	56.0	51.5	37.3	35.1	25.5	37.4
1900.......	25.8	21.6	30.6	31.6	44.9	54.6	54.8	56.2	47.0	40.5	33.4	26.2	38.9
1901.......	23.4	21.0	23.9	32.0	43.9	51.1	58.5	55.8	47.4	41.4	35.1	23.6	38.1
1902.......	22.8	26.9	22.8	35.6	42.8	50.4	52.3	54.5	47.1	39.4	29.2	26.1	37.5
1903.......	24.5	11.2	26.4	32.1	38.3	47.5	55.5	55.3	46.9	39.5	31.7	26.6	36.3
1904.......	19.3	26.8	31.5	34.4	40.4	47.6	51.6	54.6	50.3	39.2	34.5	24.6	37.9
1905.......	21.6	19.4	29.4	30.2	39.2	52.9	52.0	54.9	47.3	30.7	29.5	19.6	35.6
1906.......	23.9	23.5	21.2	33.0	41.9	48.2	50.8	52.4	47.0	37.0	27.1	28.5	36.2
1907.......	25.9	29.9	32.7	32.8	36.3	47.5	54.9	53.9	50.2	*48.8	38.4	32.8	40.3
1908.......	32.1	27.7	30.4	36.3	40.1	47.6	52.2	53.3	49.4	36.2	28.8	24.5	38.2
1909.......	26.5	20.8	24.3	29.2	39.3	51.2	58.3	57.3	48.6	43.7	33.6	†19.3	37.7
1910.......	25.6	22.9	37.7	35.7	42.3	51.9	54.5	53.9	49.6	42.4	31.7	25.7	39.5
1911.......	25.5	23.1	29.9	33.4	42.4	52.1	53.4	54.2	50.4	36.0	26.4	19.8	37.2
Average...	23.9	22.0	27.1	33.5	41.6	50.6	54.5	54.9	48.9	39.2	31.3	24.6	37.7
Maximum..	29.2	29.9	37.7	37.2	47.3	54.7	58.5	57.3	51.5	48.8	38.4	32.8	40.3
Minimum..	18.9	11.2	21.2	29.2	36.3	47.5	50.8	52.4	46.9	40.7	26.4	19.3	35.6

*18 days. †14 days.

TABLE XXXVIII—MONTHLY PRECIPITATION NEAR LONG'S PEAK, ESTES PARK, COLORADO.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1891.......	...	...	...	1.80	...	....	...	...	...	...	...	1.00	.....
1892.......	0.55	1.35	1.20	2.02	3.40	1.90	3.65	0.67	0.08	0.55	0.85	0.42	16.64
1893.......	1.00	1.90	0.92	1.60	2.50	0.50	1.00	2.05	1.00	0.40	1.40	0.62	14.89
1894.......	0.40	0.65	1.40	1.65	8.90	0.45	4.10	2.90	2.47	0.35	0.82	0.97	25.06
1895.......	0.75	1.85	1.55	1.47	4.95	2.70	4.61	1.52	1.10	2.60	0.50	0.18	23.78
1896.......	0.62	0.55	2.40	1.35	1.16	0.65	3.60	2.95	1.95	1.05	0.38	0.15	16.81
1897.......	1.55	1.20	1.96	1.35	1.60	1 50	1.85	1.29	0.95	1.10	0.55	0.25	15.15
1898.......	0.40	0.45	0.59	1.73	1.82	2.06	2.94	1.53	0.81	0.60	1.60	0.60	15.13
1899.......	0.52	1.05	2.97	1.10	0.38	1.09	3.32	1.73	0.11	2.31	0.03	0.62	15.23
1900.......	0.18	0.82	0.35	6.34	0.55	0.80	0.48	0.17	1.83	1.04	0.32	0.62	13.50
1901.......	0.69	0.40	1.00	1.80	1.73	1.47	0.85	2.22	1.59	0.95	0.18	0.91	13.79
1902.......	0.35	1.00	1.36	1.32	2.90	1.40	2.40	2.79	4.42	1.60	1.00	0.75	21.29
1903.......	0.15	1.70	1.65	2.55	0.80	3.54	2.00	0.85	2.33	2.38	0.70	0.20	18.85
1904.......	0.26	0.91	1.45	0.87	5.30	2.75	1.96	6.49	1.45	2.40	T	0.94	24.78
1905.......	1.87	1.23	3.70	6.20	3.43	0.47	1.95	1.75	0.46	5.31	0.20	0.00	26.57
1906.......	0.40	0.20	4.80	4.86	1.45	0.41	3.28	1.75	2.18	2.20	1.50	0.20	23.23
1907.......	0.90	2.30	3.40	5.20	5.39	0.86	3.50	1.65	0.70	0.70	0.80	1.60.	27.00
1908.......	0.71	0.30	1.30	0.70	1.95	1.75	3.69	4.00	0.90	1.41	1.70	1.40	20.29
1909.......	1.80	1.85	5.40	6.00	1.94	1.18	3.99	2.99	1.70	0.10	1.76	T	28.71
1910.......	1.00	0.30	0.80	1.66	5.10	2.61	4.59	1.75	0.15	1.45	0.30	0.70	20.41
1911.......	1.60	1.10	1.40	3.30	0.73	1.72	3.12	1.75	0.96	2.63	3.00	0.80	22.11
Average...	0.75	1.06	1.98	2.61	2.80	1.49	2.84	2.14	1.36	1.56	0.88	0.62	20.14
Maximum..	1.87	2.30	5.40	6.34	8.90	3.41	0.48	0.17	0.08	0.10	T	0.00	13.50
Minimum..	0.15	0.20	0.35	0.70	0.38	0 41	0.48	0.17	0.02	0.10	T	0.00	13.50

TABLE XXXIX—MONTHLY MEAN TEMPERATURE ½ (12M+7A) AT COWDREY, NORTH PARK, COLORADO.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1893	19.6	19.0	29.9	33.6	...	....	...	...	...	...	...	...	....
1894	...	...	...	...	...	....	...	...	...	...	...	...	....
1895	19.6	19.4	28.0	...	...	....	60.2	62.0	54.9	42.3	28.4	17.4	....
1896	25.4	23.1	28.2	38.6	48.0	58.6	63.8	61.5	52.3	43.7	27.4	28.3	41.6
1897	18.2	23.5	27.3	40.2	53.4	56.5	61.2	61.9	57.7	43.6	35.7	20.0	41.6
1898	16.8	27.5	26.2	42.5	47.5	60.4	65.8	64.0	53.4	38.2	26.4	13.2	38.7
1899	21.8	19.1	30.8	40.1	46.7	56.6	64.3	60.4	54.6	41.3	36.4	19.1	40.9
1900	22.9	22.8	35.4	43.4	52.4	62.9	63.5	60.7	54.6	43.3	34.0	22.2	43.2
1901	23.0	24.5	29.7	40.4	53.1	58.4	70.5	63.3	51.0	44.1	34.3	22.8	42.9
1902	20.5	28.9	28.7	39.8	51.2	59.4	59.9	61.4	51.2	42.0	31.2	22.9	41.4
1903	20.8	14.1	31.3	39.9	46.0	58.3	61.7	60.6	49.4	42.2	34.1	24.5	40.2
1904	19.5	28.3	32.4	42.2	49.5	54.5	60.4	61.2	52.0	41.1	33.3	23.8	41.5
1905	26.1	20.2	36.2	40.2	46.9	59.7	61.7	62.7	54.8	38.1	34.9	14.7	41.4
1906	21.0	26.6	30.6	41.7	48.6	53.6	56.9	54.5	48.2	35.4	26.1	24.1	38.9
1907	21.9	25.3	31.2	34.5	37.8	47.2	55.0	52.6	45.7	38.9	23.8	17.1	35.9
1908	13.0	14.9	25.9	33.9	38.3	45.5	54.3	52.3	45.9	31.3	20.2	16.1	32.6
1909	20.8	18.6	24.7	30.4	37.5	49.3	56.4	55.2	45.0	35.2	26.3	7.5	33.9
1910	12.1	12.4	32.0	34.6	40.7	50.3	55.8	53.3	47.9	35.4	30.3	13.4	34.8
1911	17.5	13.2	26.9	32.3	41.2	51.0	53.1	50.8	46.1	32.4	18.4	7.4	32.5
Average	20.0	21.2	29.7	38.1	46.2	55.1	60.3	58.7	50.9	39.3	29.5	18.5	39.0
Maximum	26.1	28.9	36.2	43.4	53.4	62.9	70.5	64.0	57.7	44.1	36.4	28.3	43.2
Minimum	12.1	12.4	24.7	30.4	37.5	45.5	53.1	50.8	45.0	31.3	18.4	7.4	32.5

TABLE XL—MONTHLY PRECIPITATION AT COWDREY, NORTH PARK, COLORADO.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1890	...	...	...	...	...	....	...	...	...	0.43	0.23	0.27	....
1891	...	...	...	...	2.67	0.63	1.61	1.37	1.54	0.78	1.35	...	....
1892	...	...	...	...	...	....	...	...	...	...	0.55	1.82	....
1893	0.60	0.90	1.20	2.20	1.15	0.80	1.18	2.16	0.21	2.38	0.75	2.15	15.68
1894	1.30	1.20	3.10	3.80	0.37	0.43	1.33	0.88	1.24	0.63	0.60	0.50	15.38
1895	1.40	0.65	2.40	1.59	1.73	1.67	1.02	1.58	0.41	0.67	1.65	0.70	15.47
1896	0.37	0.55	1.05	1.95	1.52	0.70	1.81	2.28	2.02	0.52	0.60	0.30	13.67
1897	1.50	1.35	2.20	1.95	2.06	2.62	2.41	1.38	0.35	0.45	1.10	2.00	19.37
1898	0.45	0.52	1.30	0.33	2.10	0.66	0.50	0.82	0.15	1.51	2.10	1.50	11.94
1899	3.33	3.60	2.60	1.60	0.27	0.60	1.18	0.91	0.30	3.09	T	1.17	18.65
1900	1.00	3.00	1.20	4.65	0.79	0.85	0.09	0.43	0.71	0.69	0.84	0.80	14.65
1901	0.55	1.65	3.25	3.25	1.07	1.05	0.20	2.58	0.17	1.07	0.60	2.10	17.54
1902	1.00	1.20	2.40	0.85	0.63	0.16	1.29	0.81	1.11	0.62	0.10	1.75	11.92
1903	1.80	1.10	0.70	2.12	1.83	0.72	0.79	0.43	2.68	1.00	1.30	0.75	15.22
1904	1.50	0.95	1.70	1.40	0.75	1.74	1.18	2.64	0.80	0.60	0.00	1.20	14.46
1905	1.45	1.70	1.90	3.00	0.90	0.36	1.66	0.15	1.48	1.35	0.90	1.50	16.35
1906	2.20	0.40	1.90	3.20	0.91	0.85	1.90	0.72	1.52	0.90	0.50	0.00	15.00
1907	0.30	1.35	1.70	1.66	1.37	0.00	1.79	1.11	1.48	0.23	0.00	1.90	12.89
1908	0.70	0.00	1.50	0.39	1.68	0.45	0.70	1.30	1.16	0.81	0.45	1.90	11.04
1909	2.60	1.80	4.20	2.50	1.38	1.15	1.56	2.27	1.00	0.36	1.05	1.40	21.27
1910	0.75	0.20	0.20	0.90	0.90	0.40	1.27	1.01	2.20	0.43	0.55	1.20	10.01
1911	1.15	1.20	0.90	1.20	0.29	1.78	1.30	1.48	1.24	0.83	1.50	0.65	13.52
Average	1.26	1.23	1.86	2.03	1.14	0.89	1.22	1.31	1.06	0.95	0.77	1.24	14.96
Maximum	3.33	3.60	4.20	4.65	2.67	2.62	2.41	2.64	2.68	3.09	2.10	2.15	21.27
Minimum	0.30	0.00	0.20	0.33	0.27	0.00	0.09	0.15	0.15	0.23	0.00	0.00	10.01

TABLE XLI—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES*

At Cowdrey, North Park, Colorado.

DATE.	January		February		March		April		May		June	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1893	30.2	8.9	29.4	8.5	43.8							
1894	....	....	....	....	....	16.0	42.7	24.4	....	....	....	....
1895	29.1	10.1	30.4	8.3	41.1	....	....	....	....	....	....	....
1896	34.4	16.4	36.2	10.0	38.6	15.0	....	....	....	....	....	....
1897	29.7	6.8	34.5	12.5	39.3	17.7	50.3	26.9	59.8	36.3	73.8	43.4
1898	29.8	3.9	38.8	16.2	37.1	15.3	53.8	26.5	68.4	38.5	69.1	43.9
1899	30.0	13.6	29.7	8.6	41.6	15.3	56.2	28.8	58.6	36.3	76.8	44.0
1900	36.1	9.7	33.1	12.5	49.3	20.0	56.1	24.2	58.0	35.4	71.1	42.0
1901	33.8	11.9	36.7	12.3	42.2	21.5	59.0	27.8	67.0	37.7	80.0	45.8
1902	34.4	6.7	40.0	17.9	42.0	16.6	55.1	25.8	67.6	38.5	73.1	43.7
1903	32.2	9.3	27.6	0.5	45.4	15.4	52.4	27.3	66.2	36.3	75.1	43.7
1904	28.9	10.2	36.8	19.8	42.0	17.3	52.2	27.6	57.9	34.1	72.6	49.1
1905	35.7	16.6	35.2	5.1	48.1	22.8	54.4	30.0	62.6	36.4	68.4	40.5
1906	35.9	6.1	42.6	10.6	45.9	24.3	50.8	29.6	58.9	34.9	75.9	43.6
1907	31.8	12.0	37.9	12.8	41.7	15.2	57.1	26.3	63.9	33.3	70.6	36.6
1908	27.5	—1.5	31.0	—1.2	38.3	20.7	46.1	23.0	51.9	23.6	63.5	30.9
1909	31.5	10.0	34.2	2.9	43.6	13.5	49.9	17.9	52.7	23.8	63.0	28.0
1910	25.2	—0.9	26.6	—1.8	49.8	5.8	45.9	14.8	52.1	22.8	66.0	32.7
1911	28.8	6.2	29.6	—3.2	40.8	14.2	53.9	15.3	58.8	22.5	72.3	28.3
						13.0	48.1	16.5	60.4	22.0	69.4	32.6
Average	31.4	8.7	33.9	8.5	42.8	16.7	52.0	24.3	60.3	32.0	71.3	39.0
Maximum	36.1	16.6	42.6	19.8	49.8	24.3	59.0	30.0	68.4	38.5	80.0	45.8
Minimum	25.2	—1.5	26.6	—3.2	37.1	5.8	42.7	14.8	51.9	22.0	63.0	28.0

*These temperatures are read at about the time of the maximum and minimum of the day.

TABLE XLII—EXTREME MONTHLY TEMPERATURES

At Cowdrey, North Park, Colorado.

YEAR.	January		February		March		April		May	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
1893	45	—20	48	—20	60	—18	58	8	..	..
1894	..	..	..	..	..	..	..	..	..	..
1895	48	—24	54	**—33**	70	—12	..	..	..	..
1896	45	—6	48	—11	52	**—18**	66	—2	74	20
1897	50	—17	52	—7	65	—9	81	2	82	29
1898	48	—25	54	—4	55	—10	75	8	78	16
1899	46	—12	53	**—42**	62	—15	76	4	72	16
1900	48	—19	51	—23	74	9	78	2	82	29
1901	50	—16	56	**—21**	64	—4	76	—7	84	22
1902	50	**—17**	58	—4	62	—10	74	6	82	18
1903	44	—12	48	**—24**	71	—21	68	12	78	24
1904	46	—4	52	**—24**	55	—4	70	13	76	24
1905	50	—8	54	**—40**	63	—2	66	9	80	22
1906	54	**—20**	58	—8	70	—18	74	9	80	18
1907	44	—3	42	—10	60	—2	64	4	68	9
1908	42	**—28**	40	—23	54	—12	67	3	67	8
1909	46	—28	46	—18	62	—25	59	—19	66	4
1910	44	**—34**	38	—31	62	—4	70	5	78	8
1911	45	—34	44	—35	50	—16	64	—1	72	10
Extreme	54	—34	58	—35	74	—25	81	—19	84	4

NOTE — Extreme temperatures of each year indicated in black faced type.

TABLE XLI—MONTHLY MEAN, MAXIMUM AND MINIMUM TEMPERATURES

At Cowdrey, North Park, Colorado.

July		August		September		October		November		December		Year	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
....	....	....	....	....	....	....	....	....	....	....	....	....	....
....	....	....	....	....	....	....	....	....	....	....	....	....	....
74.0	46.3	78.2	45.9	71.2	38.6	59.1	25.5	39.5	17.3	27.4	7.3	....	....
78.1	49.5	76.6	46.4	66.4	38.2	60.1	27.3	35.4	19.3	39.2	17.4	54.1	29.1
75.9	46.6	79.2	44.6	73.2	42.2	57.0	30.3	44.8	26.6	27.5	12.6	54.4	28.9
81.6	49.9	81.5	46.4	73.6	33.3	49.6	26.8	37.2	15.6	24.7	1.7	53.8	26.5
79.7	48.8	77.2	43.5	74.2	34.9	53.2	29.4	48.5	24.3	28.7	9.4	54.0	27.9
81.1	46.0	78.6	42.7	71.3	37.9	57.6	28.9	45.8	22.2	33.6	10.8	57.7	28.6
90.7	49.4	78.3	48.3	67.7	34.3	59.2	29.0	45.9	22.8	31.3	14.3	56.8	28.9
76.5	43.3	77.9	44.9	66.2	36.1	55.3	28.6	41.1	21.4	32.2	13.6	54.9	27.9
76.8	46.6	78.2	43.0	63.8	35.0	58.0	26.4	46.0	21.7	34.7	14.3	53.8	26.7
75.9	44.6	76.3	46.1	67.7	36.2	55.7	26.5	49.7	17.0	33.8	13.8	54.4	28.7
77.6	45.8	79.7	45.7	72.0	37.5	51.8	24.3	49.0	20.7	29.3	0.0	55.3	27.3
74.4	39.5	73.2	35.7	64.6	31.8	50.5	20.4	39.0	13.1	35.0	13.2	54.4	23.5
72.9	37.1	70.3	34.9	63.8	27.6	57.1	20.7	40.0	7.5	29.8	4.4	50.6	21.3
73.1	35.5	69.1	35.5	64.2	27.7	46.3	16.3	35.7	4.8	26.4	5.8	48.1	17.2
77.1	35.7	73.6	36.8	62.1	27.9	56.8	13.6	41.9	10.7	21.4	—6.5	50.5	17.3
76.8	34.8	74.2	32.4	66.3	29.5	54.1	16.8	42.9	17.7	27.7	—0.9	52.4	17.3
71.0	35.1	71.0	30.6	64.9	27.3	48.6	16.1	30.8	6.1	24.3	—9.6	49.0	16.1
77.2	43.2	76.1	41.4	67.8	33.9	54.7	23.9	42.0	17.0	29.8	7.2	53.3	24.6
90.7	49.9	81.5	48.3	74.2	42.2	60.1	30.3	49.7	26.6	39.2	17.4	57.7	29.1
71.0	34.8	69.1	30.6	62.1	27.3	46.3	13.6	30.8	4.8	21.4	—9.6	48.1	16.1

TABLE XLII—EXTREME MONTHLY TEMPERATURES

At Cowdrey, North Park, Colorado.

June		July		August		September		October		November		December	
Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..	..	..	..	..	..	..
..	..	84	38	88	36	86	16	72	2	68	—4	55	—20
86	34	**88**	39	86	30	78	24	77	13	56	—6	48	5
83	33	86	37	**87**	36	84	28	78	5	68	10	59	**—24**
90	32	**94**	40	90	37	92	20	72	8	70	—12	54	**—27**
90	30	**91**	40	86	28	88	26	76	16	64	7	44	—28
94	37	**94**	32	88	34	92	25	69	14	61	—2	50	**—30**
98	32	**100**	36	98	39	82	22	74	22	60	10	46	—13
86	28	**92**	32	**92**	36	78	18	76	18	62	—2	52	—14
86	30	**94**	33	90	32	82	20	74	4	62	—3	48	—4
81	32	**89**	34	**89**	24	84	24	74	12	66	—4	50	—14
88	32	**90**	32	89	37	84	30	76	8	66	—4	49	—18
82	25	**86**	30	**86**	20	77	21	68	6	54	—19	48	—14
72	24	**80**	30	**80**	26	78	13	68	10	54	—14	46	**—30**
71	20	84	22	**85**	15	78	9	64	—9	50	—16	39	—27
80	26	**90**	26	84	28	76	11	72	—6	62	—10	36	**—56**
86	18	**87**	24	80	14	76	11	76	—1	54	—4	46	—31
80	20	79	19	**80**	20	78	12	64	—6	44	—30	37	**—42**
98	18	100	19	98	14	92	9	78	—9	70	—30	55	—56

TABLE XLIII—MONTHLY PRECIPITATION AT DENVER, COLORADO. U. S. WEATHER BUREAU.

Elevation 5,272 Feet.

Date.	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1870	1.80	1.70	0.70	2.80	0.34	0.52	0.51	0.12	2.85	0.68	0.54	0.73	13.29
1871	0.46	0.23	1.81	1.01	2.56	0.05	0.51	0.27	1.18	0.40	3.10	0.77	12.35
1872	0.55	0.22	1.71	2.09	3.74	2.07	2.69	1.75	1.57	0.68	0.69	0.29	18.05
1873	0.13	0.24	0.22	2.43	0.75	2.24	2.00	1.41	0.89	0.73	0.16	0.61	11.81
1874	0.84	0.53	0.49	1.70	2.43	1.21	3.35	0.68	1.34	0.64	0.08	0.17	13.46
1875	0.38	0.60	0.39	2.24	1.94	0.43	4.32	1.97	2.89	0.22	1.28	0.59	17.25
1876	0.21	0.11	1.80	1.22	8.57	1.10	1.16	2.03	0.60	0.12	1.50	1.70	20.12
1877	1.90	0.40	1.40	2.77	2.30	1.93	0.23	1.30	0.38	2.15	0.73	0.79	16.28
1878	0.10	0.48	1.82	0.05	2.90	2.78	1.38	2.25	1.23	0.80	0.67	1.05	15.51
1879	0.40	0.39	1.00	2.62	3.36	0.32	0.64	1.38	0.02	0.19	0.21	0.33	10.86
1880	0.38	0.32	0.21	0.31	1.11	1.22	1.38	1.46	0.89	1.37	0.83	0.10	9.58
1881	0.49	1.22	0.87	0.50	2.21	0.09	2.50	2.33	0.57	0.32	1.68	0.00	12.78
1882	0.57	0.20	0.20	1.47	2.98	4.96	0.66	1.20	0.06	0.75	0.71	0.73	14.49
1883	2.35	0.45	0.21	3.10	4.30	0.85	2.27	0.75	1.08	1.49	0.32	2.32	19.49
1884	0.22	0.86	0.93	3.33	4.61	1.47	0.65	1.71	0.13	0.21	0.19	0.76	15.07
1885	0.41	0.75	0.97	4.94	2.13	0.66	1.33	1.18	1.22	0.73	0.55	1.08	15.95
1886	0.62	0.72	2.36	2.79	0.09	2.26	0.50	1.62	0.98	0.33	1.93	0.87	15.07
1887	0.67	0.30	0.23	2.16	1.13	0.53	2.49	2.68	0.97	0.97	0.22	0.14	12.49
1888	0.11	0.37	1.15	1.71	2.66	0.29	0.41	1.51	0.11	0.77	0.33	0.09	9.51
1889	0.50	0.70	0.40	1.34	3.44	1.88	2.94	0.33	0.28	2.11	0.53	0.30	14.75
1890	0.18	0.46	0.35	2.50	2.01	T	0.79	1.89	0.17	0.64	0.30	0.04	9.33
1891	1.60	0.27	3.10	2.49	4.15	2.93	0.59	2.84	0.73	0.48	0.69	1.56	21.43
1892	0.40	0.75	1.20	1.75	2.14	1.33	1.19	0.58	T	3.92	0.44	1.32	15.02
1893	0.05	0.83	0.23	0.87	3.09	0.13	1.14	0.35	0.05	0.84	0.55	0.35	8.48
1894	0.18	0.90	0.70	3.30	3.00	0.39	2.11	1.86	1.55	0.19	0.22	0.69	15.09
1895	0.32	0.48	1.19	1.19	2.86	2.65	4.28	0.76	0.98	1.13	0.27	0.01	16.12
1896	0.25	0.24	1.43	0.93	1.27	0.89	2.80	0.97	1.81	0.84	0.10	0.31	11.84
1897	0.58	0.82	0.90	1.31	3.15	2.16	2.06	1.44	0.44	1.64	0.24	0.63	15.37
1895	0.20	0.68	0.28	1.20	4.88	0.94	0.67	0.96	0.28	1.05	0.85	0.99	12.98
1899	0.65	0.58	1.10	0.75	0.15	0.47	1.92	1.78	0.20	1.01	T	0.72	9.33
1900	0.13	0.55	0.63	8.24	0.53	1.87	1.30	0.05	0.87	0.33	0.37	0.42	15.29
1901	0.05	0.06	0.88	1.96	1.18	2.09	0.01	1.30	0.22	0.46	T	0.89	9.10
1902	0.17	0.38	0.63	0.60	1.98	1.89	1.24	0.76	3.70	0.80	0.61	0.59	13.35
1903	0.12	0.42	0.87	0.81	0.75	1.62	1.36	1.35	0.56	1.34	0.07	0.23	9.50
1904	0.04	0.17	0.94	0.74	3.27	3.54	2.13	0.60	1.77	0.40	0.04	0.41	14.05
1905	0.99	0.35	3.07	4.95	2.65	0.61	1.55	0.67	0.49	2.31	0.04	T	17.68
1906	0.17	0.06	1.88	3.67	1.45	1.51	1.21	0.88	2.72	1.98	1.30	0.01	16.84
1907	0.46	0.33	0.54	2.91	2.93	1.15	1.52	0.23	0.74	0.17	0.40	0.45	11.83
1908	0.53	0.04	0.11	0.39	2.82	1.68	2.09	3.19	0.80	1.90	1.74	0.63	15.92
1909	0.21	1.35	3.03	2.59	1.74	1.70	4.17	2.13	3.78	0.28	1.10	0.88	22.96
1910	0.16	0.35	0.96	1.38	2.50	0.20	3.47	1.79	1.00	0.21	0.16	0.71	12.89
1911	0.12	0.68	0.28	1.41	0.52	0.56	1.31	1.08	0.75	0.33	0.37	0.34	7.75
Normal	0.49	0.51	1.03	2.06	2.44	1.36	1.69	1.32	1.02	0.90	0.62	0.61	14.05
Av. last 25 yrs.	0.35	0.48	1.04	2.05	2.25	1.32	1.79	1.28	1.00	0.84	0.44	0.51	13.35
Maximum	2.35	1.70	3.10	8.24	8.57	4.96	4.32	3.19	3.78	3.92	3.10	2.32	22.96
Minimum	0.04	0.04	0.11	0.05	0.09	T	0.01	0.05	T	0.12	T	0.00	7.75

TABLE XLIV—MONTHLY PRECIPITATION AT HAMPS, ELBERT COUNTY, COLORADO.

Elevation 5,500 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1893.......	0.02	0.08	0.02	0.24	1.60	0.70	3.07	1.23	0.27	0.16	0.04	0.19	7.62
1894.......	0.07	0.29	0.54	1.11	4.10	0.51	1.65	1.23	1.19	0.05	0.02	0.17	10.93
1895.......	0.15	0.42	0.28	0.85	2.05	3.79	4.07	2.08	0.12	0.15	0.10	0.11	14.70
1896.......	0.52	0.30	1.25	1.22	1.05	0.70	3.42	2.80	0.65	0.57	0.02	0.28	12.78
1897.......	0.14	...	...	0.49	0.70	1.68	1.35	6.21	0.42	0.96	T	0.22	.....
1898.......	0.04	0.02	0.20	0.96	3.80	1.03	1.84	1.61	1.17	0.90	0.28	0.72	12.57
1899.......	0.90	0.19	2.26	1.30	0.30	1.13	2.50	2.19	0.19	0.49	0.51	0.71	12.67
1900.......	0.09	0.60	0.86	11.30	1.25	2.20	1.94	0.91	0.65	0.09	0.25	1.03	21.17
1901.......	0.34	0.07	1.50	4.24	0.83	0.98	0.38	2.58	0.52	0.81	T	0.69	12.89
1902.......	0.23	0.13	1.37	1.03	4.97	2.52	0.62	2.68	1.37	0.91	0.22	0.98	17.03
1903.......	0.20	0.76	0.21	0.53	0.75	3.73	1.90	1.40	0.44	0.53	0.09	0.14	10.77
1904.......	0.03	0.07	0.06	0.71	3.08	2.70	2.69	3.09	2.37	0.62	T	0.09	15.51
1905.......	0.08	0.58	3.48	4.86	3.98	2.04	4.72	1.27	2.23	0.23	0.13	T	23.60
1906.......	0.38	0.90	2.25	4.17	0.98	1.44	3.09	2.56	2.23	0.64	0.38	0.05	19.07
1907.......	0.15	T	0.27	2.38	1.85	0.65	2.59	1.06	0.74	0.02	0.20	0.65	10.56
1908.......	0.14	0.45	0.02	0.03	1.32	1.03	1.55	1.44	0.05	2.36	0.84	0.14	9.37
1909.......	0.41	0.56	1.24	1.52	1.77	6.20	3.94	0.82	2.34	0.85	1.15	0.78	21.58
1910.......	0.16	0.18	0.50	1.25	1.12	0.13	2.31	2.35	0.98	T	0.11	0.27	9.36
1911.......	0.12	0.82	T	1.06	2.17	0.58	4.35	4.22	0.38	1.55	0.21	0.65	16.11
Average...	0.22	0.36	0.91	2.07	1.98	1.78	2.53	2.20	0.96	0.63	0.24	0.41	14.29
Maximum..	0.90	0.90	3.48	11.30	4.97	6.20	4.72	6.21	2.37	2.36	0.51	1.03	23.60
Minimum..	0.02	T	T	0.03	0.30	0.13	0.38	0.82	0.05	T	T	T	7.62

TABLE XLV—MONTHLY PRECIPITATION AT LE ROY, LOGAN COUNTY, COLORADO.

Elevation 4,380 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1889.......	...	...	...	4.40	2.09	3.38	0.36	2.56	0.83	0.37	0.60	0.10	.....
1890.......	0.30	0.48	0.01	2.80	1.03	1.96	0.47	1.41	T	0.98	0.48	0.01	9.93
1891.......	1.70	1.00	1.99	1.35	5.02	4.84	4.69	2.89	0.67	0.14	0.37	0.94	25.60
1892.......	0.89	2.24	0.80	4.02	2.53	1.48	3.07	1.83	0.84	1.66	0.10	0.65	20.11
1893.......	0.05	1.20	0.87	0.46	2.73	1.25	1.75	0.61	0.41	0.41	0.48	0.94	11.16
1894.......	0.35	0.46	0.95	0.98	0.17	0.75	1.16	0.47	1.06	0.08	0.26	0.65	7.34
1895.......	0.73	0.88	0.40	2.43	2.05	2.94	2.56	0.79	0.42	0.11	0.47	0.12	13.90
1896.......	0.53	0.24	1.20	1.91	2.36	3.77	1.33	0.87	0.86	0.90	0.20	0.01	14.18
1897.......	0.60	0.72	1.66	1.77	3.08	2.24	1.39	2.79	0.41	2.61	0.40	0.81	18.48
1898.......	0.38	0.26	0.67	1.07	4.60	1.31	2.83	1.13	1.27	0.54	0.65	0.27	14.95
1899.......	0.50	0.33	1.21	1.57	2.93	0.28	2.17	2.38	0.88	0.30	0.23	0.44	13.22
1900.......	0.10	0.96	0.12	7.27	2.10	0.78	1.68	0.99	0.35	0.07	0.12	0.20	14.74
1901.......	0.06	0.49	1.60	2.92	0.72	2.52	0.97	4.03	0.27	0.47	T	0.89	14.94
1902.......	0.12	0.72	1.23	1.28	3.16	1.82	0.98	3.70	3.46	0.78	0.09	0.99	18.33
1903.......	0.18	1.50	0.26	1.12	0.80	1.07	1.71	3.44	0.62	0.29	0.06	0.03	11.08
1904.......	0.10	0.26	0.35	1.99	3.97	4.39	3.46	1.17	2.96	1.55	0.04	0.05	20.29
1905.......	0.17	0.30	3.28	4.70	3.88	2.48	2.56	1.96	0.78	1.93	0.12	0.02	22.18
1906.......	0.23	0.43	1.38	4.53	1.96	1.35	1.88	2.83	2.70	2.69	1.29	0.53	21.80
1907.......	0.12	0.05	0.25	0.97	2.85	2.67	2.24	4.19	1.88	T	0.66	0.69	16.57
1908.......	0.08	0.23	0.18	1.68	4.34	3.52	5.72	3.65	0.16	3.76	1.86	0.05	25.23
1909.......	0.01	1.30	1.80	1.01	1.67	4.15	1.05	2.14	2.81	0.56	0.91	1.08	18.49
1910.......	0.04	0.04	0.62	1.96	2.34	2.06	1.53	1.95	1.72	0.13	0.13	0.36	12.88
1911.......	0.32	0.24	0.10	3.13	1.74	2.21	2.50	1.68	...	...	...	0.92	.....
Average...	0.34	0.65	0.95	2.41	2.53	2.31	2.09	2.15	1.15	0.94	0.43	0.47	16.42
Maximum..	1.70	2.24	3.28	7.27	5.02	4.84	5.72	4.19	3.46	3.76	1.86	1.08	25.60
Minimum..	0.01	0.04	0.01	0.46	0.17	0.28	0.36	0.47	T	T	T	0.01	7.34

TABLE XLVI—MONTHLY PRECIPITATION AT YUMA, YUMA COUNTY, COLORADO.

Elevation 4,128 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1891.......	2.35	0.50	3.63	2.90	4.21	5.23	2.98	0.75	0.64	0.05	0.13	1.25	24.62
1892.......	0.80	1.55	0.80	3.20	3.46	1.20	4.44	1.05	0.35	1.00	T	0.62	18.92
1893.......	T	0.90	0.70	0.38	2.57	1.30	2.10	0.95	T	0.40	0.41	0.55	10.26
1894.......	0.50	0.90	1.10	0.68	0.04	1.85	0.80	0.70	2.85	0.00	0.22	0.70	10.34
1895.......	1.20	1.70	0.50	1.10	2.76	2.73	3.22	1.77	0.55	0.10	0.60	0.10	16.33
1896.......	0.60	0.20	1.25	1.82	2.06	3.98	2.59	1.04	1.02	0.78	0.30	0.20	15.84
1897.......	0.37	0.40	2.80	0.80	1.62	4.44	1.78	2.44	T	2.55	0.10	1.00	18.30
1898.......	0.30	0.20	0.31	1.55	5.80	2.70	1.86	3.62	1.00	1.50	1.45	1.10	20.39
1899.......	1.38	0.60	1.18	0.97	1.23	3.03	2.63	2.22	0.17	0.03	0.90	0.27	14.61
1900.......	0.14	1.55	0.61	8.67	1.39	0.72	1.81	2.22	0.16	0.03	0.17	0.51	17.98
1901.......	T	1.11	2.44	3.90	0.31	3.51	1.61	6.53	0.36	0.39	T	0.57	20.73
1902.......	0.07	0.56	0.95	0.67	3.76	1.91	2.70	3.33	1.68	0.78	0.20	0.73	17.34
1903.......	0.14	1.88	0.20	0.40	1.00	2.10	2.65	3.12	0.35	0.10	0.36	0.09	12.39
1904.......	T	0.70	0.25	3.37	4.26	4.98	1.65	1.28	2.92	1.07	T	0.27	20.75
1905.......	0.31	0.13	4.47	4.27	3.64	3.16	4.45	0.73	1.91	1.64	0.05	0.00	23.76
1906.......	0.38	0.51	2.36	4.45	2.01	1.98	2.44	1.23	1.19	2.92	1.17	0.12	20.76
1907.......	0.28	0.02	0.33	0.94	1.43	2.44	3.44	2.58	1.44	0.04	0.24	0.35	13.53
1908.......	0.02	0.08	0.02	1.16	2.21	3.96	5.64	3.51	0.15	5.00	2.02	T	23.77
1909.......	0.02	0.51	2.10	0.54	1.79	4.50	5.72	1.26	1.78	0.76	0.92	0.93	20.83
1910.......	T	0.04	0.45	1.16	2.38	....	...	...	...	0.23	0.02	...	.....
1911.......	0.05	0.21	0.10	2.47	1.02	1.15	1.00	2.82	1.30	1.69	0.06	0.43	12.30
Average...	0.42	0.68	1.07	2.16	2.33	2.79	2.78	2.18	0.99	1.00	0.44	0.49	17.33
Maximum..	2.35	1.88	4.47	8.67	5.80	5.23	5.72	6.53	2.92	5.00	2.02	1.25	24.62
Minimum..	T	0.02	0.02	0.38	0.04	0.72	0.80	0.70	T	0.00	T	0.00	10.26

TABLE XLVII—MONTHLY PRECIPITATION AT GARNETT, COSTILLA COUNTY, COLORADO.

Elevation 7,700 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1892.......	...	0.32	0.34	0.44	1.01	0.35	0.76	0.11	0.00	0.91	0.00	0.13	....
1893.......	T	0.63	0.06	T	0.41	T	0.62	1.80	0.94	0.00	T	0.00	4.46
1894.......	T	0.80	0.02	0.02	1.07	0.34	1.22	2.07	0.79	0.00	0.00	T	6.33
1895.......	T	0.22	0.03	0.03	2.49	0.66	3.21	1.98	T	1.10	0.10	T	9.82
1896.......	0.12	T	0.45	0.10	0.02	T	1.32	0.90	0.39	T	0.00	0.20	3.50
1897.......	0.26	0.23	0.26	0.10	1.14	0.24	0.90	0.86	0.86	1.08	0.00	0.32	6.25
1898.......	0.01	0.05	0.35	0.09	0.51	0.65	1.48	0.32	T	0.15	0.50	0.49	4.60
1899.......	T	0.06	0.03	0.00	0.07	0.18	2.32	0.93	1.91	0.82	0.38	0.26	6.96
1900.......	0.00	0.06	0.01	1.24	1.17	0.13	0.33	...	...	...	...	...	....
1901.......	...	...	...	...	...	....	...	...	...	...	...	...	....
1902.......	0.15	0.00	T	0.07	1.18	0.85	0.63	3.20	0.37	0.16	0.54	1.03	8.18
1903.......	0.01	0.28	0.23	0.59	T	2.15	0.62	0.48	0.58	0.19	T	0.05	5.18
1904.......	0.05	0.15	0.40	0.15	0.16	1.68	0.96	2.99	1.95	0.51	0.00	0.51	9.51
1905.......	0.40	0.35	0.90	0.46	0.34	0.33	1.03	1.44	0.96	T	0.87	0.00	7.08
1906.......	0.07	0.05	0.49	1.06	0.38	0.21	1.78	0.34	1.45	2.37	0.31	0.54	9.05
1907.......	0.17	T	0.00	0.79	1.57	0.45	1.23	1.98	0.31	0.63	0.35	0.14	7.62
1908.......	0.19	0.35	0.20	0.24	0.79	0.58	0.23	0.94	0.10	0.30	0.87	0.10	4.89
1909.......	0.41	0.01	0.55	0.46	0.75	0.61	0.95	1.47	1.62	1.60	0.69	0.32	9.44
1910.......	0.07	0.33	0.27	1.05	0.46	0.06	0.12	1.07	0.69	0.64	0.35	0.00	5.11
1911.......	0.03	0.50	0.04	0.46	1.00	0.55	2.39	0.88	1.56	1.12	0.37	0.18	9.08
Average...	0.11	0.23	0.24	0.39	0.76	0.53	1.16	1.32	0.80	0.64	0.30	0.24	6.72
Maximum..	0.41	0.80	0.90	1.24	2.49	2.15	3.21	3.20	1.95	2.37	0.87	1.03	....
Minimum..	0.00	0.00	0.00	0.00	T	T	0.12	0.11	0.00	0.00	0.00	0.00	....

TABLE XLVIII—MONTHLY PRECIPITATION AT DURANGO, LA PLATA COUNTY, COLORADO.

Elevation 6,530 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1886	...	...	...	...	...	....	...	...	4.20	2.29	1.44	...	.....
1887	0.46	...	...	...	...	....	...	...	...	...	...	...	.....
1889	1.70	1.60	2.30	1.00	0.60	1.30	1.90	1.40	1.30	3.10	1.97	4.18	22.35
1890	1.90	0.46	1.80	2.30	0.00	0.40	0.30	...	...	...	...	...	.....
1894	...	...	...	...	...	....	...	...	...	0.78	0.00	3.45	.....
1895	2.10	1.38	T	T	0.99	0.37	1.78	2.81	0.92	...	2.22	1.20	.....
1896	0.50	0.55	0.53	0.55	0.05	....	1.30	1.76	3.59	3.61	1.08	0.86	.....
1897	2.61	3.70	2.72	0.45	3.22	0.40	1.38	0.93	3.55	3.89	0.09	1.99	24.93
1898	2.21	0.45	1.17	1.67	1.33	0.62	3.46	0.89	0.30	0.07	0.88	3.22	16.27
1899	1.63	0.97	0.91	0.00	0.01	1.58	1.91	2.85	0.60	2.22	0.93	0.88	14.49
1900	0.29	0.42	0.18	2.15	0.82	0.13	0.02	0.48	2.60	0.55	2.22	T	9.86
1901	0.44	0.80	0.04	0.55	2.05	0.35	0.95	2.05	0.33	1.24	T	0.10	8.90
1902	0.70	0.84	0.68	0.20	0.99	0.16	0.91	2.19	2.02	0.92	0.92	2.69	13.22
1903	0.35	1.24	3.90	2.60	1.25	2.02	2.82	1.87	2.15	0.13	0.00	0.04	18.37
1904	0.13	0.31	1.77	0.56	1.06	0.47	0.78	3.13	2.14	3.39	0.00	1.17	14.91
1905	2.96	4.38	3.31	3.93	1.28	1.21	1.41	1.23	2.76	0.12	3.26	0.45	26.03
1906	1.99	0.24	4.83	1.79	1.16	0.08	2.03	1.33	2.73	0.89	2.66	3.06	22.85
1907	2.15	1.22	1.73	2.42	1.94	1.08	1.40	3.62	0.99	0.99	1.08	2.04	20.66
1908	1.48	3.98	1.15	1.90	1.68	0.24	2.39	3.99	0.77	1.65	1.13	3.64	24.00
1909	2.59	2.97	1.27	0.79	0.62	0.27	2.20	3.54	3.63	0.44	1.81	3.81	23.94
1910	1.53	0.98	0.64	0.55	0.09	0.72	0.95	1.28	0.33	2.91	1.92	0.94	12.84
1911	3.48	7.02	3.14	1.50	0.59	1.09	5.21	2.89	2.82	5.07	0.94	0.54	34.29
Average	1.56	1.76	1.69	1.31	1.04	0.69	1.74	2.12	1.99	1.80	1.23	1.80	18.73
Maximum	3.48	7.02	4.83	3.93	3.22	2.02	5.21	3.99	4.20	5.07	3.26	4.18	.....
Minimum	0.13	0.24	T	0.00	0.00	0.08	0.02	0.48	0.30	0.07	0.00	T	.....

TABLE XLIX—MONTHLY PRECIPITATION AT GRAND JUNCTION, COLORADO.

Elevation 4,608 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1885	...	...	...	1.74	...	....	1.25	1.62	0.18	...	...	...	.....
1887	...	...	...	...	0.34	0.20	1.60	1.48	1.93	1.13	1.09	0.88	.....
1888	0.98	0.39	0.87	0.58	...	....	...	...	...	...	...	...	.....
1891	...	...	...	...	...	....	0.95	...	...	...	T	...	.....
1892	...	...	1.42	1.37	0.65	0.06	0.71	0.10	0.00	1.05	0.38	0.10	.....
1893	0.22	1.77	0.63	0.30	0.79	0.09	0.11	1.20	0.87	0.80	0.92	0.51	8.21
1894	0.08	0.47	0.97	0.15	0.56	0.07	0.57	0.64	0.62	0.97	0.16	0.78	6.04
1895	1.24	0.80	0.62	0.14	0.35	0.37	1.43	2.24	0.25	0.92	2.39	0.10	10.85
1896	0.37	0.05	0.27	0.18	0.51	0.01	0.43	1.01	3.78	0.79	0.49	0.33	8.22
1897	1.00	0.80	1 05.	1.12	0.62	0.40	0.98	1.05	1.53	1.82	0.33	0.40	11.10
1898	0.55	T	1.05	0.92	1.40	0.05	T	0.57	0.10	0.25	0.25	0.31	5.45
1899	0.42	0.45	0.59	1.11	0.14	1.74	0.18	2.42	0.31	2.67	0.08	0.76	10.87
1900	0.14	0.14	0.13	1.26	0.06	0.04	0.09	0.19	1.18	0.14	0.27	T	3.64
1901	0.45	0.25	0.98	1.65	1.29	0.50	0.13	2.36	T	0.35	0.02	0.21	8.19
1902	0.37	0.44	0.45	0.13	0.37	0.04	0.81	0.77	0.85	0.43	1.10	0.50	6.26
1903	0.15	1.05	0.73	0.78	1.21	1.22	0.67	0.02	0.69	0.07	0.01	0.02	6.62
1904	0.33	0.71	0.64	0.26	1.39	0.25	0.54	1.00	0.65	0.49	0.00	0.37	6.63
1905	1.01	1.37	1.18	1.24	1.98	0.04	0.16	0.33	1.71	0.27	0.75	0.23	10.27
1906	0.40	0.40	1.45	1.78	2.74	0.04	0.34	0.56	1.43	0.50	1.23	0.74	11.61
1907	0.44	1.06	1.14	0.34	1.21	0.60	0.62	1.62	0.45	1.48	0.10	0.35	9.41
1908	0.43	0.71	0.14	0.48	0.56	0.62	0.87	0.86	0.65	3.43	0.27	1.21	10.23
1909	0.66	0.34	0.02	1.14	0.45	0.10	0.50	0.86	1.13	0.04	1.05	0.67	6.96
1910	0.38	0.14	0.11	0.32	0.26	0.25	0.96	0.60	0.92	1.26	1.30	1.11	7.61
1911	0.48	1.29	0.54	0.62	0.03	0.64	0.84	0.35	1.30	1.53	0.60	0.20	8.42
Average	0.50	0.63	0.71	0.80	0.81	0.35	0.64	0.99	0.93	0.97	0.58	0.47	8.38
Maximum	1.24	1.77	1.45	1.78	2.74	1.74	1.60	2.42	3.78	3.43	2.39	1.21	.....
Minimum	0.08	T	0.02	0.13	0.06	0 01	T	0.02	0.00	0.04	0.00	T	.....

TABLE L—MONTHLY PRECIPITATION AT MEEKER, RIO BLANCA COUNTY, COLORADO.

Elevation 6,182 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1891.......	0.55	1.21	1.73	1.22	1.90	0.20	2.27	1.66	2.04	0.11	1.23	2.10	16.22
1892.......	3.08	1.30	...	...	...	....	0.00	0.44	T	1.22	1.97	1.30	.....
1893.......	0.30	1.30	4.25	0.45	0.30	....	...	...	...	...	...	...	.....
1894.......	1.86	1.45	0.69	1.99	0.39	0.86	...	0.04	2.35	1.97	0.14	1.34	.....
1895.......	1.66	1.07	1.22	0.98	1.79	1.50	2.13	1.88	0.72	1.48	1.56	0.75	16.74
1896.......	1.24	1.37	1.83	0.39	0.54	0.16	3.56	1.35	3.66	0.28	1.43	0.47	16.28
1897.......	1.38	2.33	3.11	2.19	1.64	1.17	3.71	2.04	2.33	1.19	1.02	2.19	24.30
1898.......	0.67	0.34	0.73	0.79	2.15	0.40	1.85	2.14	0.03	2.15	1.57	0.52	13.34
1899.......	0.90	1.94	2.50	1.45	0.24	3.26	1.10	2.13	0.35	4.60	0.12	1.46	20.05
1900.......	0.54	1.03	0.26	2.14	0.69	0.49	0.45	0.91	1.50	...	...	...	.....
1901.......	0.81	0.75	2.09	1.86	2.52	1.44	0.56	2.05	0.28	0.53	0.28	1.92	15.09
1902.......	0.50	0.78	1.20	0.69	0.65	0.60	1.47	0.32	1.43	0.99	1.10	1.15	10.88
1903.......	0.77	1.77	0.80	2.46	1.66	0.68	1.40	1.11	4.42	0.92	0.47	0.41	16.87
1904.......	0.90	0.86	1.81	0.75	1.88	2.23	0.43	1.56	1.21	0.77	T	0.58	12.98
1905.......	0.93	1.55	2.58	2.04	1.78	0.08	0.77	1.01	2.47	0.46	0.73	0.56	14.96
1906.......	0.81	0.66	2.86	4.12	2.43	0.34	0.97	1.17	2.98	1.35	1.74	0.92	20.35
1907.......	1.21	0.60	0.98	0.99	2.55	1.04	2.41	2.57	3.12	0.60	0.22	1.64	17.93
1908.......	0.59	0.56	0.82	1.01	1.69	1.07	1.90	1.55	1.33	3.02	0.78	1.98	16.30
1909.......	0.66	1.03	0.79	2.62	0.97	0.90	0.59	2.91	1.95	0.61	2.53	1.04	16.60
1910.......	0.90	0.78	0.24	1.08	1.36	0.60	1.00	1.89	1.95	1.98	1.34	1.24	14.36
1911.......	1.45	1.36	0.91	0.97	0.25	1.38	0.97	1.67	1.74	2.14	1.38	0.89	15.11
Average...	1.03	1.14	1.57	1.51	1.37	0.97	1.45	1.52	1.79	1.39	1.03	1.18	15.95
Maximum..	3.08	2.33	4.25	4.12	2.55	3.26	3.71	2.91	4.42	4.60	2.53	2.19	.....
Minimum..	0.30	0.34	0.24	0.39	0.24	0.08	0.43	0.04	T	0.11	T	0.41	.....

TABLE LI—MONTHLY PRECIPITATION AT WRAY, YUMA COUNTY, COLORADO.

Elevation 3,512 Feet.

Date.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yr.
1890.......	...	...	T	T	4.44	1.42	0.62	0.25	1.09	0.45	0.25	T	.....
1891.......	1.80	0.50	1.90	4.68	2.02	4.55	2.52	0.45	1.24	0.00	0.20	0.83	20.69
1893.......	...	...	...	0.03	2.12	1.00	...	...	...	...	...	...	.....
1895.......	...	...	...	...	...	....	...	...	...	T	0.12	0.32	.....
1896.......	0.47	0.02	0.66	4.83	1.64	3.77	1.13	1.47	1.01	1.37	0.06	0.20	16.63
1897.......	0.28	0.26	1.79	1.64	3.34	4.79	1.79	2.27	0.73	2.92	0.07	0.31	20.19
1898	0.06	0.07	0.83	1.73	5.47	2.98	1.88	2.56	2.33	0.25	0.26	0.29	18.71
1899.......	0.63	0.07	0.50	0.62	1.96	1.83	2.18	1.38	0.08	T	1.16	0.33	10.74
1900.......	0.16	0.90	0.33	6.00	0.61	2.35	4.57	2.60	0.15	0.03	0.20	0.34	18.24
1901.......	T	1.37	2.51	4.02	0.28	3.40	2.05	5.36	2.11	0.43	T	0.91	22.44
1902.......	0.20	0.74	1.05	0.74	7.00	5.69	3.33	2.71	3.73	1.05	0.16	0.59	26.99
1903.......	0.25	1.98	0.16	0.54	1.95	1.55	5.16	1.48	0.69	0.34	0.25	T	14.35
1904.......	T	0.58	0.04	2.46	2.02	6.25	2.00	1.26	1.74	1.19	0.05	0.20	17.79
1905.......	0.04	0.05	3.10	5.12	2.59	3.19	2.98	0.93	2.19	1.64	0.60	T	22.43
1906.......	0.55	0.62	1.88	4.82	3.20	2.57	1.62	3.57	1.71	1.43	0.83	0.29	23.09
1907.......	0.12	0.02	0.24	0.94	2.17	1.53	3.39	3.80	1.27	0.03	0.14	0.58	14.23
1908.......	0.13	0.52	0.06	0.30	3.37	3.52	3.39	2.14	0.28	4.53	1.89	T	20.03
1909.......	0.07	0.60	2.34	0.53	1.06	6.40	1.75	0.30	0.95	1.11	1.92	0.63	17.66
1910.......	0.15	0.22	0.38	1.21	3.32	0.96	1.17	3.51	1.73	0.05	T	0.11	12.71
1911.......	0.29	0.77	0.03	4.65	2.50	1.16	0.63	0.87	0.91	2.10	0.23	1.04	15.18
Average...	0.31	0.55	0.99	2.36	2.68	3.10	2.34	2.05	1.33	1.00	0.44	0.37	17.52
Maximum..	1.80	1.98	3.10	6.00	7.00	6.40	5.16	5.36	3.73	4.53	1.92	1.04	26.99
Minimum..	T	0.02	T	T	0.28	0.96	0.62	0.25	0.08	T	T	T	10.74

Bulletin 183 May, 1912

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

Deterioration in the Quality of Sugar Beets Due to Nitrates Formed in the Soil

By WM. P. HEADDEN

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1912

The Agricultural Experiment Station

FORT COLLINS, COLORADO

THE STATE BOARD OF AGRICULTURE

	Term Expires
HON. R. W. CORWIN	Pueblo, 1913
HON. A. A. EDWARDS	Fort Collins, 1913
HON. F. E. BROOKS	Colorado Springs, 1915
HON. J. L. BRUSH	Greeley, 1915
HON. J. C. BELL	Montrose, 1917
HON. E. M. AMMONS	Littleton, 1917
HON. T. J. EHRHART	Centerville, 1919
HON. CHAS. PEARSON	Durango, 1919

GOVERNOR JOHN F. SHAFROTH, } Ex-officio
PRESIDENT CHAS. A. LORY, }

L. M. TAYLOR, Secretary — G. A. WEBB, Treasurer

EXECUTIVE COMMITTEE IN CHARGE

A. A. EDWARDS, Chairman

J. L. BRUSH — E. M. AMMONS

STATION STAFF

C. P. GILLETTE, M. S., Director	Entomologist
W. P. HEADDEN, A. M., Ph. D.	Chemist
G. H. GLOVER, M. S., D. V. M.	Veterinarian
W. G. SACKETT, B. S.	Bacteriologist
ALVIN KEYSER, A. M.	Agronomist
J. O. WILLIAMS, B. S. A.	U. S. Expert-in-charge Horse Breeding
E. R. BENNETT, B. S.	Horticulturist
B. O. LONGYEAR, B. S.	Botanist
G. E. MORTON, M. L., B. S. A.	Animal Husbandman
E. B. HOUSE, B. S., (E. E.), M. S.	Irrigation Engineer
V. M. CONE, B. S.	Irrigation Investigations
R. E. TRIMBLE, B. S.	Assistant Irrigation Investigations
P. K. BLINN, B. S.	Rocky Ford, Alfalfa Investigations
EARL DOUGLASS, M. S.	Assistant Chemist
S. ARTHUR JOHNSON, M. S.	Assistant Entomologist
B. F. KAUPP, M. S., D. V. S.	Pathologist
MIRIAM A. PALMER, M. A.	Delineator
L. C. BRAGG	Assistant in Entomology
GEORGE P. WELDON, B. S.	Assistant in Entomology
R. S. HERRICK, B. S.	Grand Junction Field Horticulturist
C. L. FITCH	Potato Investigations
W. E. VAPLON	Poultry Investigations
J. W. ADAMS, B. S.	Cheyenne Wells, Supt. Plains Substation
G. D. WALTERS, B. S.	Assistant Irrigation Investigations
ELLWOOD D. ROOD, B. A.	Assistant Chemist

DETERIORATION IN QUALITY OF BEETS DUE TO NITRATES

By WM. P. HEADDEN

We have, heretofore, considered only extreme instances of the occurrence of nitrates in some of our Colorado soils, namely, in Bulletins 155, 160 and 178. The statements of these Bulletins were scarcely believable by persons who may not themselves have seen the facts, and the number of persons who have seen them is, even now, comparatively small. The difficulty in believing the facts set forth in these bulletins lay partly, in the newness of the measure in which the nitrates occur, partly in the general doubt of the sufficiency of the agency to which their formation was attributed, but still more largely to the fixedness of conviction that these things, if they were possible, would certainly have been observed before, especially as students of soil chemistry have been diligent in their investigations of kindred subjects, if not of this.

The conditions under which the investigations, pertaining to the presence and formation of nitrates in the soil, have already been made are openly or tacitly assumed to have been so general that the conclusions arrived at are accepted as of universal application and the occurrence of large territories to which the established conclusions are only partially applicable is deemed by many very improbable. I was keenly alive to this incredulity on the part of scientific men who, because of their persistent efforts to find out the facts, hold tenaciously to such views as their observations have led them to accept as embracing the whole case. The views of men who have done the work and made their records for our benefit are most surely worthy of consideration and respect, which we most willingly accord them, but there may be other conditions and other facts than those on which they based their deductions, and their conclusions may not be of such universal application as we, for no other reason than because of our confidence in the cumulative authority of the *dicta* of various investigators, believe. I have no sympathy whatever with captious objections to honest results obtained by worthy men or caviling at established facts in order to give the caviller the air of an investigator by belittling and trying to make the results of others appear to be of no import.

In presenting the following facts which many, perhaps, will consider as even more groundless and more contradictory to general experience than the statements of the bulletins referred to, i. e., 155, 160 and 178, I accept fully all of the statements of results obtained by others as the result of experiment or of facts established by research under the conditions obtaining in those cases.

The task which I have set myself, to study the effects of nitrates upon the quality of our sugar beets, is a more difficult one than any which I have, heretofore, attempted. The subject itself, the quality of sugar beets, is not so definitely fixed as to remove it from serious discussion. We have no definite quality which is fixed. The best that we can do will be to adopt a standard for comparison and abide by it throughout. The factors influencing these qualities and the manner and extent to which they modify one another are so good as wholly unknown.

The German and French chemists have studied the composition of the beet, the questions pertaining to its culture and nutrition, the effect of fertilizers, etc., upon its sugar content and factory qualities, till they know with a high degree of accuracy what these effects are under their conditions, but their results cannot be safely accepted as necessarily holding under our Colorado conditions. If, however, we seek information on these subjects we are compelled to avail ourselves of German or at least of foreign data. So far as I am aware no serious study of the chemical composition of the sugar beet, beyond the determination of its sugar and ash content, the ordinary fodder analysis of the root and leaves and the determination and composition of the ashes had been undertaken in this country till within the past two years.

The composition of the sugar beet, in the sense just stated, i. e., its percentage of sugar, its composition as indicated by the ordinary fodder analysis and the composition of the ash, was studied by this Station for several years to determine these data for the beet as it grows under our Colorado conditions, including as great a variety of soils as was at that time feasible.

Among the factors which distinguish our problems, from those of Germany for instance, is the presence of large amounts of soluble salts in the soil. Such definite data as I have been able to find indicate that the water-soluble in ordinary arable soils varies from a few thousandths to approximately four-tenths of one percent, while our soils often carry from one to one and one-half or even two percent. The top two inches of such soils frequently carry much higher percentages, from two to eight percent or even more of water-soluble. Such conditions render our questions involved ones, making it difficult to determine the actual effect of any single factor. We constantly hear seepage and alkalization put forth as the actual causes of many of our troubles. Further, unexpected results, either good or bad, are attributed to climatic influences when no other cause seems evident.

In regard to seepage existing in many places, and that in extended areas, no one acquainted with the facts would attempt to deny. The presence of alkalis in such areas is frequent; the quantity of these salts often being very large. These conditions are evident to the average man and are both undesirable and harmful in some measure, but both of these are used to designate, in most cases, extreme conditions in respect to the amount of water and alkali present. They are further used without any definite or even approximate idea of the amount of either water or alkali which may be injurious. When crops fail in such areas, the water and the alkali are easily seen conditions to which the public has persistently attributed the failure and many other mishaps which have overtaken their crops without any question as to the actual effects of these conditions, or any regard to the possibility of there being other causes which they cannot see with their own eyes.

The questions of seepage and alkali appeal to all as serious questions, especially at first. Our soils are alkaline and so much was said about this fact, especially in the more remote past, that we all came to believe that the alkalis were much worse than we now believe them to be. Our Colorado people read of the alkali questions of California and applied all of the statements relative to the California conditions to the facts in Colorado, which was not justified. I may illustrate this by the treatment given a certain piece of land, the composition of which has been studied in considerable detail. The piece of land is rather strongly alkaline. In California they have found that the application of land plaster, ground gypsum in quantities proportioned to the amount of sodic carbonate, black alkali, present ameliorates the conditions. These parties applied land plaster in liberal quantity, perhaps as much as five tons per acre, whereas, the facts were that this land contained no sodic carbonate but was already so rich in gypsum that the mineral had crystallized out in little aggregates and veinlets, carrying many tons of it in each acre-foot of soil. Much has been said about alkali, and we are apt to apply all of the recorded evils attributed to it in accounting for troubles, the causes of which we do not more definitely know.

I began the study of this subject sixteen years or more ago, and have analyzed alkalis from very many sections of this state, likewise ground and seepage waters and also drain waters, and have further made persistent efforts to establish the amount of alkali in the soil and irrigating waters which would do damage to crops. *The limits found have been so wide that I abide by the statement made ten years ago that our alkali questions resolve themselves into questions of drainage.* Our alkali salts consisting essentially of sulfates of soda, magnesia and lime, with the chlorid and carbonate of sodium as subordinate constituents, are so mild in their action, that but little, if any, serious damage is caused by them in the quantities present, even to young plants:

EXPERIMENTS WITH BEETS ON ALKALI SOILS.

As our nitrates appear in many places at or near to the margins of alkalized areas, and further, because the poor quality of many beets is attributed to the presence of either water or alkali, or as is generally the case, to both, it will be advisable to inquire into the question of what effect these factors have upon the quality of the sugar beet. By quality we here understand the sugar content and purity because these are the factors usually considered, especially on a commercial basis. I grew beets on a piece of seeped and alkalized land for four consecutive years, using beets grown on what we were pleased to call good land for standards of comparison. This soil, sampled to a depth of ten inches, yielded from 3890 to 25500 parts of water-soluble material per million. In determining the water-soluble in these samples they were treated with water so long as the filtrate showed the presence of sulfuric acid. We were quite well aware of the fact that further treatment with water would still take a portion into solution but some point had to be taken at which to stop and we chose the point given, i. e., when the filtrate ceased to yield with baric chlorid a precipitate for sulfuric acid. This was already an extreme extent to which to carry the washing because of the presence of considerable quantities of calcic sulfate, gypsum, in the soil. We did not attempt to study the distribution except in the first and second two-inch portions of the soil. In the top two inches we found a maximum of 39300, and a minimum of 2890 parts per million; the land represented by the former sample became heavily encrusted with alkali both in summer and winter under favorable conditions of the weather. Sometimes these incrustations became as much as one-half inch thick. The salts dissolved out of the soil were essentially sulfates of calcium, magnesium, sodium and potassium. The relative quantities of these salts differed considerably without showing any definite order of distribution. The predominant salts in the aqueous extracts of the soil were the calcic and magnesic sulfates. The sodic sulfate varied from none in the second two inches of some sections up to twenty-seven percent of the water-soluble of the top two inches from other sections. The effloresced alkali consisted chiefly of sodic and magnesic sulfate, these salts forming eighty percent of the effloresced mass.

THE HIGHT OF THE WATER PLANE.

The hight of the water plane was determined daily during the second year of the experiment and weekly during the third year. There were four wells sunk in the strip of land which had a length of six hundred feet. To avoid too many details and extended explanation I will give the depth of the water plane below the surface for the months of May, June, July and August in one group, and for September, October and November in a second group. The depth of the water plane in Well A in 1897 was from 1.2 to 2.3 feet for the first period and from 2.4 to 3.3 feet for the second period;

in 1898 it was from 0.9 to 3.6 feet for the first and from 3.4 to 4.4 for the second period. In Well B in 1897 the depths were from 2.3 to 3.6 for the first and from 3.6 to 4.2 feet for the second period; in 1898 from 2.2 to 4.9 for the first and from 4.3 to 5.4 feet for the second period. In Well C in 1897 the depths were from 2.3 to 3.5 for the first and from 3.3 to 3.6 feet for the second period; in 1898 they were 1.4 to 4.3 for the first and from 3.5 to 4.7 feet for the second period. In Well D in 1897 the depths were from 2.5 to 3.6 feet for the first and from 3.6 to 4.0 feet for the second period; in 1898 they were from 2.2 to 5.8 feet for the first and from 5.4 to 6.0 feet for the second period. It will be noticed that the water plane at the end of the season of 1898 was materially lower than at any other period given but that it did not at any time fall to quite five feet below the surface during the first period, i. e., in May, June, July and August, except in Well D in 1898 and this was only for a very short period as our records show. I think that I am perfectly safe in assuming that the concensus of opinion would be that it is objectionable to have the water plane four feet or less below the surface though in the practice of sub-irrigation the water is brought to within 2.5 feet of the surface. In this ground it was only exceptionally as low as or lower than four feet. These exceptions were due to a shortage of water for irrigation and a very scanty rainfall. This land was not drained and though there were drains in some adjoining lands they were not efficient either in cutting off seepage water from flowing into or in taking the water out of this land. The average depth of the water below the surface for the two seasons mentioned would range from two and a half to three and a half feet. The surface of the ground at Well D was 3.3 feet higher than at Well A. The field had a fall of this amount, 3.3 feet in six hundred feet.

The ground water did not pass freely into the gravel below this land because of a stratum of clay lying on top of the gravel. Considerable attention was given to the composition of this ground water. Its content of dissolved salts varied greatly from time to time as its varying nearness to the surface and the richness of the soil in alkali would lead us to expect. The quantity of these salts found varied from two thousand to eight and, under conditions of continued high water, to over ten thousand parts per million. The salts held in solution were calcic, magnesic and sodic sulfate with some sodic chlorid and carbonate and almost always some potash. The nitric nitrogen was determined in a large number of samples of this ground water and was found to range from one to fourteen parts per million, mostly from two to five parts per million.

The physical condition of this soil at the beginning of our experiments was bad and while it was greatly improved by cultivation and the treatment that it received, its tilth was never good. The yield of beets ranged from eight to fifteen tons per acre.

We had in this land the following conditions: First, the presence of a large amount of the ordinary so-called alkali; second, a water-plane which varied, but which was always near the surface; third, the ground water was rich in the alkali salts, varying from two thousand to ten thousand parts per million; fourth, the physical condition of this soil was never such as one might designate as good.

This was the worst piece of land at my disposal at the time it was chosen for the purposes of our experiments. The results were, in regard to yield, from eight to fifteen tons per acre as already stated, which compared favorably with yields obtained from better lands. The beets grown on this land were compared with others of the same varieties and supposedly from the same lot of seed grown on land free from all of these objections. In this way we eliminated the questions of climatic conditions, strains of seed, etc. The plots ran lengthwise of the piece of ground and were divided into three sections for the purposes of sampling the beets. The final samples for the first season were taken October 13 and gave as averages for the three sections, Kleinwanzlebener 11.76, Vilmorin 10.94, Lion Brand 12.76, Imperial 13.65 percent sugar. Samples gathered from the farm plots on the same date gave: Kleinwanzlebener 12.32 and Vilmorin 13.02 percent sugar. In 1898 the beets grown on this bad ground gave, Kleinwanzlebener 15.2, Vilimorin 15.4, Lion Brand 14.82, Imperial 14.35, while the Kleinwanzlebener grown on one of the horticultural plots gave 15.7 and the Vilimorin 13.9 percent sugar in the beet. In 1899 only two varieties were grown on the land in question, i. e., Kleinwanzlebener and Zehringen, these varieties showing the presence of 15.77 and 15.86 percent sugar in the beet. They were harvested 10 November. The coefficients of purity were 84.0 and 84.2 respectively.

The conclusion at which we arrived, as the result of our observations of four crops grown on this land, was that neither the alkali *per se* nor the combined conditions obtaining in this land were sufficiently adverse to produce any decidedly prejudicial effect upon the composition of the beet. It may be stated that the supply of potash in this soil, as indicated by the ordinary agricultural analysis, is very abundant, 1.18 percent average of twelve analyses, and that a determination of the total potash showed 2.295 percent. The amount of phosphoric acid present was moderate or low, ranging in the twelve analyses made from 0.054 to 0.138 with an average of 0.095 percent. The nitrogen in the twelve samples referred to ranged very close to 0.10 percent, the average being 0.1020 percent. The nitrates in this soil and ground water were determined in a number of samples. The surface soil was found to be at least well supplied with this form of nitrogen as the nitric nitrogen ranged from 7.0 to 36.0 parts per million in the top two inches of soil, while in the second two inches it ranged from a trace to two parts per million. The ground water from Well A showed as the result of fifty-six determinations that the nitric nitrogen varied from 0.4 to 3.6 parts per million. These samples were taken from March 23 to May 21. The amount of nitrates in the water of a well in an adjoining piece of land was very much larger and varied much more with the rise and fall of the ground water.

We formulated our conclusions as follows:

The effect of the alkali, present in our soil, upon the sugar content of the beet is, of itself, not detrimental.

The presence of alkali increases the weight of the leaves very slightly, and has no marked influence on the date of maturing.

The amount of dry matter is the same in beets grown in alkali ground as in those grown in ground free from alkali.

The effect of the alkali upon the composition of the beet, as shown by the ordinary fodder analysis is an increase in the percentages of the ash and the crude protein and a decrease in the percentage of nitrogen-free extract. The effects of the alkali are greater upon the composition of the beet (the roots) than upon that of the leaves.

The composition of the ash of the beets did not seem to be affected by the different character of the soils experimented with, either because there was so great an abundance of available, and to the plant acceptable, mineral matter present that it was not affected by the presence of a large quantity of other salts or the composition of the ash of the sugar beet is very constant.

Again two years later we came to the same general conclusion, i. e., that the alkali *per se,* in such quantities as it is present in any portion of our plot, does not injuriously affect the percentage of sugar in the beets.

Several years later while still pursuing the alkali question my attention was directed to a piece of land that was planted to beets. Concerning the condition of this land no one could entertain a doubt. The stand of beets in the portion of the field that I visited was good, the tops were large and the promise for a crop was good. The ground between the rows was thickly incrusted with alkali and the water plane was at this time, October 4, within eighteen inches of the surface. The water used in irrigating this land was seepage water which carried 3711.4 p. p. m. A sample of this soil taken to a depth of three inches showed the presence of 3.582 percent of matter soluble in water or 143,000 pounds of water-soluble in each 4,000,-000 pounds of such soil. The alkali incrustation was not included in this sample. Calcic, magnesic and sodic sulfates constituted upwards of eighty percent of this water-soluble. As in the preceding land, potash, soluble in water, was present in quantities, calculated as sulfate, equal to 2.409 percent of the thoroughly dried water-soluble portion.

The analysis of the soil showed phosphoric acid equal to 0.10 percent, potassic oxid 0.72 percent and nitrogen equal to 0.091 percent of the air-dried soil.

The alkali incrustation varied from one to three-eights of an inch in thickness and was well distributed over the patch. This alkali consisted of sodic sulfate 54.860 percent, magnesic sulfate 25.684 percent and sodic chlorid 10.751 percent, together 91.3 percent. I was fortunate enough to obtain from the factory that purchased these beets the average yield together with the sugar content on which the factory settled for the year in question; the average tonnage was nine tons per acre; the sugar in the beets was 15.9, apparent purity 83.3; for the ensuing year the yield was ten tons per acre and the sugar content 16.0 percent.

These results fully sustain the conclusions to which we had come as the results of our experimentation on alkalized land, i. e., that our ordinary alkali *per se* is not injurious and that the question of too high a water-plane is, under some conditions at least, of far less importance than is generally supposed.

These cases are not the only, and are by no means the most striking ones that might be cited to support the view that ordinary alkali, essentially sulfates, do not necessarily cause either low tonnage of beets or low quality and that good results are quite often obtained on land in which the water-plane is higher than we suppose that it should be.

These cases have been cited and these statements made to show that the generally entertained notion which attributes poor crops, especially a failing in successive crops and a poor quality of beets to the action of the alkalis in the first and to seepage in the second place, may often be a mistaken one. There is some other factor which has been left out of the reckoning.

I may in this connection again call attention to the fact that in both of these soils there is not only an abundance of potash present but that a significant quantity of it is soluble in water, further that the ground water from my own experimental plot contained noticeable quantities of phosphoric acid. I do not know much about the ratio of phosphorus to potassium to nitrogen whcih is advantageous for the highest production of sugar or the part that soda may play in the economy of the plant but we have in my own plot soil containing essentially 0.10 (0.095) percent phosphoric acid 1.18 percent of potash (K_2O) soluble in acid, and 0.102 percent of nitrogen producing good crops and good beets, the maximum sugar content reaching 18.3 percent in the perfectly fresh beet. In the second case we have the soil with 0.10 percent phosphoric acid, 0.72 percent potash and 0.091 percent of nitrogen producing according to the record of the factory, ten tons of beets with 16.0 percent of sugar.

These facts are given to put the questions pertaining to the effects of alkali and seepage in a fuller light and to give us a basis of fact on which to found our judgment and to remove the necessity of accepting a current opinion which may be in part justified but which being based upon observation without a knowledge of the facts is for far the greater part unjustified. The general prevalence of the opinion, however, takes cognizance of a big fact that something is amiss and two things are amiss. One fact is that continued excessive irrigation of the land has already produced a considerable amount of seepage and another is that in some districts the quality of the sugar beet has deteriorated materially within the past seven or eight years. It is perfectly natural that these results should be associated in the relation of cause and effect and this has happened without sufficient regard to the facts.

In order that a better understanding of the importance of these facts may be had I will state that in 1899, which was prior to the opening of any sugar factory in the Arkansas Valley, the beets grown at our station at Rocky Ford ranged from 13.3 to 21.0 percent sugar with an average of 17.3 percent for the season. The number of samples analyzed was 52, the beets were wrapped in paper and sacked to prevent drying out. Another grower in the valley raised beets ranging from 15.3 to 21.2 percent with an average of 17.5 percent. I have been informed on the best of authority that the factory average for the years 1900, 1901 and 1902, or for the first three campaigns, was 17.5 percent or thereabouts. From that time till the present the sugar content has gradually fallen till the factory average is about 14.5 percent, and some years less than this. As there are always many fields of excellent beets it is evident that there must be very many beets below 14.0, probably even below 11.0 percent. These figures hold for the valley and do not pertain to any particular factory. While the average sugar content of these beets has fallen approximately 3.0 to 3.5 percent the beet seed breeders have improved the average beet by 1.1 percent since 1903. (This was the amount in the increase from 1903-1908 according to Schulze and Lipochitz quoted by Stift and Gredinger, p. 83.) It was to be expected that the farmer and the factory people would both become uneasy under such conditions and some answer had to be given to the serious question regarding the cause. My object is merely to state the situation so fully and clearly that the reader may realize that the problem is in the first place serious enough to justify full and detailed consideration, and second, that it cannot be answered by any *ex cathedra* statements.

In the preceding paragraphs I have given some facts which show that the beet can tolerate large quantities of our ordinary alkali and a high water-plane, which are the two causes probably most generally assigned for this deterioration of the beet. In our experiments of 1897, 1898 and 1899 to which we have referred we obtained as good beets on what we considered seeped, alkali land as were grown on land which we considered well fitted for the production of this crop, and further the beets were quite up to the standard of sugar content for that time—about 15.2 percent. In 1897, the first year that the land was cropped, they fell somewhat below the standard, but so did our beets on land entirely free from these objections. In the next two years they were quite up to the standard, our final samples for the seasons giving 15.2, 15.4, 14.8 and 15.3 for 1898, and 15.8 and 15.9 percent for 1899. The other field of alkali land, which we have described, yielded beets with 15.9 percent sugar in 1906 and 16.0 percent in 1907. The average standard according to the authorities cited at this time was about 17.85. In these cases we have such effects as we believe can justly be attributed to the alkali and the high water plane, and they do not account for the deterioration observed, despite the fact that the producers of beet seed had effected a general increase in the quantity of sugar contained in the beet. We may further add that the deterioration affects large areas, which are not involved in the questions of seepage and alkalization.

A second question raised is relative to the plant food furnished by our soils and the ratio of the various nutrients to one another. It is a fact, I think, that our beets do not ripen early; the ready answer of the expert is, add phosphoric acid, this will correct the trouble. The advice is good but the results are as a rule wholly negative. In making this statement I am fully aware that but few if any will be quite willing to accept it, because it appears to contradict the observations of many experimenters whose results, obtained with much painstaking labor, have come to be held as fixed and fundamental facts and which are known to the veriest novice. I regret the facts, but I shall endeavor to record them as we find them though I know them to be sadly out of joint with results with which they should articulate in order to be quite proper.

We can only present a partial view of this very interesting subject in this place, the biggest features of the problem and these *en masse*. We cannot enter into the questions pertaining to the effects of the individual elements of plant food or the determination of the effects of definite ratios, we will not even question which element of plant food is really the determining factor, but state our results. I applied to alternate sections of my experimental land a dressing of sheep manure at the rate of sixty-four tons per acre; the results were a prompter and better germination, the first crop of roots was objectionable in shape and only slightly increased in weight over the unmanured plots, the sugar content and coefficient of purity were both slightly depressed. We applied in this dressing nitrogen at the rate of 1,861 pounds per acre after allowing a loss of 25 percent, due to the evaporation of ammonia and ammonia salts, of phosphoric acid we added 837 pounds, equivalent to 1,573 pounds of calcic hydric phosphate and of potash (K_2O) 4,077 pounds. The effect of this dressing was still marked in the color and growth of the foliage, the next or second year after its application and the roots were of a better shape than they were the first year. The average sugar content for the season on the manured plots was a trifle low as was also the coefficient of purity. These may be considered as extreme effects, for the manure used was as unusual in quality as was the quantity applied per acre. Perhaps the slight differences in the sugar content and coefficient of purity in favor of the unmanured plots may have been due to the difference in the degree of maturity of the plants, but the experiments were continued till the end of October the first year and till November 10 the second year, which dates may be taken as the end of our growing season. The composition of the ashes of these beets was determined, but it does not present any points of sufficient interest to justify discussion. The ash (carbonated) in the fresh Kleinwanzlebener beets from the manured plots equalled 1.117 percent, from the unmanured plots it equalled 1.131 percent. The lowest percentage of carbonated ash found in any variety grown on unmanured ground was 0.94 percent. The beets grown in these experiments were not subjected to any further investigation than has already been indicated. It seems entirely superfluous to add that it would not pay anyone to apply such quantities of manure, at least not during the first two years after its application, but more moderate applications of well rotted farmyard manure to most of our lands is to be strongly advised. We have in the foregoing simply recorded our experience in applying this quantity of manure to this strongly alkalized land, the general composition of which has been given in a preceding paragraph.

Through the kindness of the management of the American Beet Sugar Company, especially through that of their former Consulting Agriculturist, Mr. W. K. Winterhalter, I am able to give the results of quite an extended series of experiments with a variety of fertilizers.* The beets from some of these plots have been subjected

*I may at this point state that after I had become fully convinced of the very general distribution of nitre-areas throughout the state, particularly after I had found a number of occurrences of it in the extreme eastern end, as to further investigation, but we will give only the general crop results in this place. The American Beet Sugar Company had made experiments with a variety of fertilizers some years previous to this with results which were not at all decisive in showing any benefit arising from their use. Mr. Winterhalter, in writing to me about their work in 1904 says, "Experiments with nitrate of soda were made by several of our growers upon small plats in their best fields, but, as in the past, we secured no results showing its benefits." Again in the same communication he refers to five particular plats on which sodic nitrate had been applied, of these he says: "Two of them produced a smaller yield than a corresponding plat which had received no nitrate and three of them showed an increase of 2,097, 605 and 357 pounds per acre respectively."

During the same year, 1904, Mr. Winterhalter, on the part of the company, carried out the following series of experiments. The fertilizers were applied just before planting the seed. In some cases the fertilizers were sown and cultivated in to a depth of four inches, in one experiment a portion of it was plowed under to a depth of eight inches. The seed was drilled in two inches deep, between May 10 and 17. All plots received two irrigations each, May 23-31, and July 17-24. The plots were harvested between October 15 and Nov. 15.

No. of Plat	Fertilizer Applied	Yield of Beets Net Pounds	Percentage Sugar 1st Sample	Percentage Sugar 2d Sample	Purity
1.	None	19,961	17.7	16.3	81.8
2.	200 lbs potassic sulfate; 270 lbs. precipitated phosphate.	21,743	18.0	16.6	81.8
3.	200 lbs. potassic sulfate; 200 lbs. dried blood	22,120	18.7	17.1	82.9
4.	None	24,026	18.9	17.3	84.3
5.	270 lbs. precipitated phosphate; 240 lbs. dried blood	23,420	18.7	17.2	84.4
6.	240 lbs. dried blood	20,223	20.6	19.0	84.2
7.	None	21,107	20.5	18.9	84.9
8.	200 lbs. potassic sulfate; 270 lbs. precipitated phosphate; 240 lbs. dried blood	21,722	17.6	16.2	81.7
9.	170 lbs. potassic sulfate; 270 lbs. precipitated phosphate; 200 lbs. nitrate of soda	21,374	17.9	16.5	81.2
10.	None	21,325	18.9	17.4	84.1
11.	270 lbs. precipitated phosphate; 200 lbs. nitrate of soda	20,842	18.5	17.0	83.3
12.	200 lbs. nitrate of soda	19.697	19.0	17.5	84.0
13.	None	17,294	19.1	17.5	85.8
14.	300 lbs. nitrate of soda	19.121	19.4	17.9	84.5
15.	None	16,370	21.0	19.3	87.1

---

well as in other portions of the Arkansas Valley, it occurred to me that a continued and excessive supply of nitre, throughout the season, especially during the later portion of the season, would account for the immature condition of the beets and perhaps some of the difficulties met with in the factories. I stated my views and reasons for them to Mr. W. M. Wiley, at that time President of the Holly Sugar Co., and examined the beets which they were then

The aggregate value of the beets yielded by the six unfertilized plot was 300.21 dollars or 50.04 dollars per acre, that of nine fertilized plots was 474.75 dollars or 52.75 dollars per acre. Five other plots received dressings of fertilizers in which the constituents were given in percentages, i. e., as ammonia 4-4½ percent, soluble phosphoric acid 8-9 percent, potash, actual K_2O, 4½-5½ percent, against these were run two check plots. The total value of the beets gathered from the two check plots; one acre each, was 109.09 dollars or 54.545 dollars per acre and from the five fertilized acres the total value was 214.60 or 42.92 dollars per acre. I have taken these plots in two groups, one favorable to the application of fertilizers which shows for the nine fertilized acres a gain of 2.73 dollars per acre over the unfertilized, the other group, unfavorable, which shows for the fire acres that received fertilizers a return of 11.62 dollars per acre less than the return from the unfertilized plots.

Mr. A. H. Danielson, formerly assistant agriculturist at this institution, carried on experiments to determine the effect of fertilizers on the yield and sugar content of beets for three years, 1903, 1904 and 1905, and formulates his results as follows: "Nitrogen in the form of nitrate of soda is the only element which has any decided effect in increasing the yield of sugar beets over the cost of application."

"Potash in the form of sulfate and phosphoric acid in the form of raw bone meal, basic slag, dissolved or acid bone and phosphate rock used alone or together have very little or no effect upon the yield.'

"There are strong indications that potash and phosphoric acid fertilizers largely, if not entirely, neutralize the effect of nitrate of soda upon the yield of sugar beets, although the quality of the beet is good." Colo. Expt. Sta. Bulletin 115, p. 23.

In 1909 Mr. Winterhalter again instituted experiments with fertilizers on a still larger scale than heretofore and continued them for two years, 1909 and 1910, and has kindly furnished me with such a detailed report of the crops of these two years that a full

---

cutting and also the Steffens waste water, and found a surprisingly large amount of nitric acid present in both. I next took up the subject with Mr. W. H. Baird, General Superintendent of the American Beet Sugar Company, who immediately interested himself in the subject. I realized fully that there were and are many questions to be settled which can be settled only by experimentally established facts, consequently in the spring of 1910 I approached Mr. Winterhalter, Consulting Agriculturist, with a proposition to make certain experiments which subsequently met with the approval of the General Manager, Mr. Howe, the General Superintendent, Mr. Baird, and the Manager, Mr. Wietzer. I am indebted to all of these gentlemen for their co-operation, especially to Mr. Winterhalter for his interest in the agricultural features of the problem and to Mr. Baird for his interest in the technical end of it. Further, our thanks are due to the officers of both companies ,the Holly and the American Beet Sugar Co., for the liberal view that they take in regard to access to and use of their data. The public will realize that much of the factory data is not of general interest and that only such as pertain directly to the questions involved in this investigation and are necessary to a complete statement of the problems may properly be considered.

statement of them in this connection will be interesting, especially as I shall, in another place, discuss the composition of these beets so that we shall see the effects upon both the crop and its composition. The area of the field used is almost exactly fourteen acres divided into one-half acre plots, so there were twenty-eight plots. The field is very nearly level but the soil of the west half may be a little lighter than that of the east half. It is all quite heavy. In 1909 six acres of this land received a dressing of stockyard manure, at the rate of twenty tons to the acre. Stockyard manure is the dung of cattle fed on alfalfa hay, beet pulp, molasses and straw to which grain is added during the final stages of feeding. This manure was plowed under to a depth of 10 inches. The other fertilizers were sown on the surface and cultivated in to a depth of four inches. There were twelve plots that received an application of stockyard manure in 1909 and sixteen that received none. There were two check plots selected, one in the west, the other in the east half, which received no fertilizer of any sort, and one plot which received no frtilizer other than the stockyard manure. In 1909, the plan of experimentation included the following fertilizers, potash, phosphoric acid, nitrogen, lime, both burnt and waste lime, and farmyard manure. The plots were divided into two groups of fourteen each and one plot in each group received the same treatment, in other words, was duplicated. The numbers on the west half run from 12 to 25 inclusive, and on the east half from 26 to 39 inclusive. The weights given are the amounts applied to each half-acre plot. P. stands for superphosphate, K. for potassic sulfate and N. for sodic nitrate.

The statement of the results shows that the returns from the west side of this field were very much better than those from the east side, though there is nothing but an arbitrarily taken line to divide them. While each combination of fertilizers was applied to two plots, one on each side of the middle line, it is evident at a glance that we can only compare the results obtained on the same side and these are so capricious that no one would venture to draw any conclusions even tentatively except of the most general sort, i. e., such as that the application of fertilizers did some good. There was only one check plot on the west side of the field; this yielded 10.1 tons of beets per acre. Two plots received an application of 20 tons stockyard manure per acre and yielded 10.3 and 12.8. Two received phosphoric acid, potash and nitrogen and the yields were 12.8 and 11.6. Two received phosphoric acid and nitrogen and the yields were 16.6 and 9.4. Two received phosphoric acid and potash and the yields were 14.2 and 14.6. Two received potash and nitrogen and the yields were 15.2 and 13.2. Two received phosphoric acid, potash, nitrogen and lime and the yields were 21.9 and 13.1, and one received waste lime alone and yielded 10.4 tons.

Plot No.	Fertilizer Applied per Acre	Tons per A.	Percent Sugar in Beets	Apparent Purity	Sugar per A.
12.	20 tons manure	10.3	14.27	81.4	2,939
18.	20 tons manure	12.8	14.62	82.8	3,742
31.	20 tons manure	11.3	13.30	79.5	3,005
13.	P. 110 and manure; K. 130, N. 200	12.8	13.92	82.2	3,558
30.	P. 110 and manure; K. 130, N. 200	11.6	14.46	82.6	3,325
14.	P. 110 and manure; K. 130	14.2	14.27	82.3	4,223
29.	P. 110 and manure; K. 130	10.6	14.53	83.4	3,074
15.	K. 130, N. 200	15.2	12.95	79.0	3,921
27.	K. 130, N. 200 and manure	8.9	14.20	82.9	2,527
16.	P. 110, N. 200 and manure	16.6	13.94	81.7	4,628
26.	P. 110, N. 200	9.7	14.56	81.4	2,824
17.	P. 110, K. 170, N. 200, Ca 4 tons and manure	21.9	13.33	80.9	5,825
28.	P. 110, K. 130, N. 200, Ca 4 tons.	9.3	14.50	82.1	2,697
19.	Nothing added	10.1	13.66	81.5	2,747
38.	Nothing added	7.2	15.10	81.7	2,174
20.	P. 250, K. 170, N. 200	11.6	13.94	82.1	3,234
37.	P. 250, K. 170, N. 200	6.5	16.30	84.8	2,119
21.	P. 250, K. 170	14.6	13.75	82.3	4,015
36.	P. 250, K. 170	8.6	15.13	83.7	2,602
22.	K. 170, N. 200	13.2	14.22	82.7	3,754
34.	K. 170, N. 200	9.9	14.46	83.1	2,863
23.	P. 250, N. 200	9.4	14.76	84.3	2,774
33.	P. 250, N. 200	7.4	12.75	79.5	1,887
24.	P. 250, K. 170, N. 200, Ca. 4 tons	13.1	14.37	83.0	3,746
35.	P. 250, K. 170, N. 200, Ca. 4 tons	8.9	14.40	82.3	2,563
25.	Ca. 10 tons, waste	10.4	14.20	81.0	2,953
39.	Ca. 20 tons, waste	6.4	14.30	82.2	1,830
32.	Ca. 20 tons, factory lime from settling pond	10.4	15.03	82.9	3,126

If we consider the east half by itself we have still more perplexing results; we have one plot without any fertilizer which yielded 7.2 tons per acre, one plot with stockyard manure, 20 tons to the acre, with a yield of 11.3 tons, two that receive phosphoric acid, potash and nitrogen with yields of 11.6 and 6.5 tons, two that received phosphoric acid and nitrogen with yields of 9.7 and 7.4 tons, two that received phosphoric acid and potash with yields of 10.6 and 8.6 tons, two that had received phosphoric acid, potash, nitrogen and lime with yields of 9.3 and 8.9 tons, two that had received waste lime in different amounts with yields of 10.4 and 6.4 tons. In one-half of the cases the minerals were applied in conjunction with and in the other half without stockyard manure. In regard to the effect of any or all of the combinations of the fertilizers used upon the tonnage no one, I think, would be willing to say more than this, that taking the east and west halves separately the plot that received the addition of nothing made the smallest return except in one case in each half, but the aggregate result in regard to tonnage shows an advantage accruing from the application of fertilizers, but this is neither large enough nor uniform enough to satisfy any one, besides, the plots which give the best returns had in every case received a dressing of farmyard manure at the rate of 20 tons per acre. While I do not consider this season's results at all satisfactory and do not intend to discuss them, I will simply point out that the interpretation of these results would be very difficult, viz., plots 17 and 24, both in the west half of the field, received the same kinds of fertilizers except that 17 had received a dressing of stockyard manure; plot 17 yielded 21.9 tons to the acre and 24 yielded 13.1 tons. I think it wholly unsafe to argue that this difference in the yield was due to the stockyard manure. In the other pair of experiments, in which the same fertilizers were employed, we have a difference, it is true, in favor of the combination of stockyard manure and minerals but in this case the difference is only 0.4 of a ton, besides the yields are very small, 9.3 and 8.9 tons per acre.

If we consider the percentage of sugar in the beets we do not find the results much more satisfactory. There is in this respect one thing evident, namely, that in regard to the percentage of sugar the east half was the better without any relation to the fertilization. We cannot justly state, so far as these experiments go, that the fertilizers have either increased or decreased this factor in the crop, or rather we can show either according to our choice of samples. These unsatisfactory results cannot be attributed to a different history for the two portions of the field, nor to differences in preparation, in time of planting, irrigation, cultivation, harvesting or testing, nor yet to hail, to insects, or to fungi which attacked or injured one half more than the other.

These experiments were repeated in 1910 on the same ground with but little variation in details and none in the plan of experimentation. The results are tabulated below. In 1909 twelve of the plots, six in either half, were dressed with stockyard manure at the rate of 20 tons to the acre or 10 tons to each half-acre, but no stockyard manure was applied in 1910, neither was the application of either the burnt lime or waste lime repeated in 1910, as the respective plots had received 4, 10 and 20 tons of these matrials per acre in 1909. The west half of the field received the same treatment as in 1909 except as already stated. The numbers are the same as before, 12-25 inclusive represent the west and 26-39 the east half.

This year again the results show a better yield on the west than on the east half, but the difference is much less than in 1909. The beets from the east half, however, are not richer in sugar than those from the west half as they were the preceding season. Plots 16 and 17 produced the heaviest crops of beets and sugar in both years, while plots 14 and 15 rank close to them. It is a question in my mind whether this may not be due to differences in the productiveness of the different plots rather than to the effects of the fertilizers

Plot No.	Fertilizer Applied per Acre	Tons per A.	Percent Sugar in Beets	Apparent Purity	Sugar per A.
12.	20 tons manure in 1909	13.36	14.6	85.9	3.911
13.	P. 110, K. 130. N. 200	13.22	13.2	82.3	3,379
14.	P. 110. K. 130	13.17	13.3	83.1	3,532
15.	K. 130, N. 200	14.16	13.3	80.9	3,723
16.	P. 110, N. 200	14.94	15.3	82.7	4,746
17.	P. 110, K. 65, N. 200, CaO 4 tons in 1909	15.90	14.0	82.3	4,463
18.	10 tons manure in 1909	13.94	15.0	80.8	4,187
19.	Nothing	12.44	13.3	79.1	3,309
20.	P. 250, K. 170, N. 200	13.41	15.4	82.8	4,071
21.	P. 250, K. 170	12.83	14.7	82.9	3,736
22.	K. 170, N 200	12.20	15.2	82.2	3,678
23.	P. 250, N. 200	11.94	14.9	82.7	3,546
24.	P. 250, K. 170, N. 200, CaO in 1909	11.59	15.4	84.4	3,560
25.	Ten tons waste lime, 1909	9.77	14.6	85.6	2,849
26.	P. 220, N. 400	14.57	13.6	82.4	3,960
27.	P. 220, K. 260, N. 100	11.75	14.5	84.4	3,397
28.	P. 220, K. 260, 4 tons CaO, 1909.	11.90	15.0	85.1	3,567
29.	K. 260, N. 100	11.74	14.9	81.7	3,514
30.	P. 240, N. 100	12.67	13.6	82.9	3,450
31.	P. 500, K. 400, N. 200	13.16	14.8	82.9	3,895
32.	CaO, 20 tons, from settling pond, 1909	10.10	13.9	80.2	2,806
33.	P. 400, N. 200	11.69	13.7	82.1	3,166
34.	K. 300, N. 200	11.10	13.7	83.2	2,929
35.	P. 400, K. 300, N. 200	12.00	14.2	82.4	3,391
36.	K. 300	10.11	14.0	81.5	2,816
37.	P. 400	10.86	14.4	83.8	3,131
38.	Nothing	10.09	14.6	83.4	2,940
39.	CaO waste 20 tons, 1909	11.30	12.4	82.1	2,676

applied. One thing seems evident, i. e., that, in experimenting with this soil, the check plots ought to alternate with the experimental plots. While this arrangement of plots would have been a little more satisfactory it would not have removed all the difficulties. Plots 17 and 31 lie end to end and each received 10 tons of stockyard manure in 1909. Plot 17 received in addition to this in 1909, P. 55, K. 65, N. 100 and burnt lime 2 tons, and yielded 21.9 tons of beets; in 1910 the same fertilizers were added with the exception of the burnt lime and yielded 15.9 tons of beets. Plot 31 received nothing in addition to the 10 tons of stockyard manure in 1909, and yielded 11.3 tons of beets; in 1910, P. 250, K. 200 and N. 100 were applied and the yield was 13.2 tons of beets. With such results I do not think it possible to distinguish how much is due to differences in the soil and how much to other causes. An inspection of all of the results will simply justify a general statement that the application of fertilizers increased the crops, but that this increase is neither great nor regular enough to commend the practice from the standpoint of profit.

It may be worth the while to indicate the composition of the fertilizers used. The Chile saltpetre, sodic nitrate, 90.62 percent nitrate, potassic sulfate 89.87 percent, equivalent to 48.50 percent

K_2O, superphosphate, total phosphoric acid 13.19 percent, water-soluble 8.35 percent, citrate soluble 2.11 percent. The waste lime carried potash 0.27, phosphoric acid 1.90, and nitrogen 0.075 percent. Ten tons of this lime carried 380 pounds of phosphoric acid, 50 pounds of potash and a small amount of nitrogen. The burnt lime was practically pure and its action as a fertilizer would be that of caustic lime. Our soils are already alkaline so there would be no soil acidity to correct and its benefit if any would probably be attributed to its action on the potash minerals or on the organic matter in the soil.

The composition of the stockyard manure is sufficiently indicated by its content of nitrogen, potash and phosphoric acid which was as follows: nitrogen 0.598, potash 0.89 and phosphoric acid 0.82 percent and a ten-ton dressing of such manure added to each half-acre, nitrogen 119.6 pounds, potash 17.8 pounds, and phosphoric acid 16.4 pounds. In addition to these and probably of considerable importance, is 2,800 pounds of organic matter which is finely divided and easily incorporated with the soil.

The crops of 1910 ought to show the residual effects, if any, of the 1909 applications, plus that of the applications of 1910. There was applied to plot 28 for instance in 1909, P. 55, K. 65, N. 100, CaO 2 tons; in 1910, P. 110, K. 130 and no nitrate or lime, but the effects of the lime applied in 1909 should still be felt in 1910. The crop in 1909 was 9.3 tons per acre, in 1910 11.9 tons, an increase of 2.6 tons. In the case of plot 15 there were added in 1909, 10 tons stockyard manure, K. 65, N. 100, in 1910 the same except that no manure was added. In 1909 the crop was 15.2 tons, in 1910 14.2 tons, a slight decrease in crop with practically the same percentage of sugar.

The results obtained in these two years, 1909 and 1910, show a slight benefit accruing from the application of the fertilizers. The results are, however, so irregular, whether we estimate the benefits in tons of beets or pounds of sugar per acre, that the application of fertilizers does not commend itself. We usually, in discussing a subject of this kind, consider the more favorable results, as they tend to show the possibilities of the practice, and excuse less favorable ones on a variety of grounds. We also are apt to take tonnage of beets as our measure of the effects produced, but the amount of sugar produced is a much better one. In 1909 we had only four plots that produced 4,000 or more pounds of sugar per acre. The maximum yield was 5,825 pounds. The plot that produced this showed an exceptionally high tonnage, 7.3 tons more than the next best yield. The fertilizers applied to this plot were phosphoric acid, P_2O_5 7.2 pounds, potash K_2O 31.72 pounds and nitrogen N. 13.60 pounds, burnt lime 2 tons, with 10 tons stockyard manure plowed under to a depth of 10 inches which contained 119.6 pounds nitrogen, 178 pounds potash and 164 pounds phosphoric acid. There were two plots that received this treatment, one as just stated produced 5,825 pounds of sugar, but the other produced only 2,697 pounds, or less than half as much and actually less than one of the plots to which nothing whatever had been added, and only 520 pounds more than the poorer of the two check plots. The lack of concordance in the results cannot be attributed to lack of careful and intelligent cultivation or any difference in treatment from the beginning of the experiment till the weighing of the beets delivered at the factory.

We find the same irregularities in the results of 1910. They are in fact so inconsistent that they lend themselves to any interpretation that one may wish to give them. The results of 1904 were likewise wholly indecisive, one series showing a small gain and the other a fourfold greater loss per acre from their use. The question of importance to the grower is whether these results faithfully indicate what he would have a right to expect from the use of fertilizers.

Three years experimentation on this subject at this station in a very different soil, one with which no fault could well be found, led to similar conclusions as far as the experiments were parallel.

The effect of fertilizers upon the yield whether it be measured by the pounds of beets or sugar is an interesting, and to the grower, an important one, but there are other questions, the importance of which is not indicated by the size of the crop.

The results show that it is doubtful whether the application of commercial fertilizers to these lands would be attended with increased profits; in other words, it is doubtful whether the increase yield will cover the increased costs. These results are not in harmony with those obtained in other sections of our country where their use has been shown to be remunerative. It would be interesting to further establish these results and determine whether they really be facts, and if facts, to ascertain the reasons for them, but our present purpose lies in another direction.

The quality of our beets leaves much to be desired. By a good quality of beets I do not merely mean a beet with a high percentage of sugar, but one which will also keep well and work well. That the supply and ratio of the various plant foods affect these properties has been repeatedly shown and is accepted as a fact and emphasis has also been placed upon the fact that the soil itself and its supply of plant food must be taken into the account.

There are two properties shown by some of our beets which are undesirable; they produce an undue amount of molasses and they do not keep well. Both of these faults may be attributed to *immaturity* of the beet at harvest time and the readiest suggestion in the way of correction would be the application of phosphoric acid. We will later give some results obtained with this fertilizer.

In regard to the production of molasses some of our beets produce as much as nine and even more percent. Molasses is here used to designate the second green syrup that goes to the Steffens house and the percentage is calculated on the beets cut. The statement is made by Ruempler that the German factories average two and one-half percent, but as the most of them produce only raw sugar this may retain a great deal of the molasses which in our factories goes to the Steffens plant. I am, however, credibly informed that some factories in this country have produced as low as two and one-half percent of molasses calculated on the beets.

It is not customary here to use artificial fertilizers and there is not enough manure produced to dress more than a small fraction of the acreage planted to beets annually. Some people are now using manure more liberally than formerly, which is much to their credit and to the benefit of our farming, but the effects of the amounts used, whether they be good or bad, constitute no factor in the questions which present themselves. I have stated the results obtained by the use of artificial fertilizers without going into any considrable discussion of the results, but will repeat that the experiments show that the application of fertilizers increases the yield of beets and in most cases the yield of sugar in pounds per acre; the duplicate trials are not concordant and the results cannot be interpreted, but seem to indicate that the question is not one of plant food but something else. The twenty-six trials, repeated a second year on the same grounds, making in all fifty-two trials and four checks, leave us in the greatest uncertainty regarding the whole matter. There is no apparent reason for this lack of agreement. The soil of the west half may be a little lighter, but this half varies as much from north to south as the field does from east to west, still the results are different on the east and west halves irrespective of the fertilizers applied, so we are left to determine or to guess whether the differences are in greater measure due to differences in the soil or to the different effects of the fertilizers applied. This is most strikingly shown by the tabulated results for 1909.

These differences cannot be attributed to differences in cultivation such as date of planting, preparation of seed bed, variety of seed, thinning, cultivation, irrigation, time of harvesting, weather conditions, attack of fungi or insects, or time of harvesting and subsequent treatment before delivery to the factory; in all these respects the conditions were alike. The amounts of the fertilizers added were neither so small as to produce no results nor so heavy as to be of themselves injurious, both extremes were avoided. These beets in regard to their sugar content were fully average beets for the season, but scarcely more than that. We do not know how the juices of these beets worked in the factory. I know that beets of the same average percentage of sugar and apparent coefficient of purity gave about seven and one-half percent of molasses when worked in a well appointed factory and I think it perfectly safe to assume that these beets gave about the same. One of the questions is, can we by the use of any particular fertilizer or combination of fertilizers obtain better results both for the grower and the factory? If we could accomplish all that we wish we would of course have a better tonnage, a higher percentage of sugar and early ripening beets that would keep well and work at the lowest possible cost in the factory. The tonnage, however, is apt to continue variable and the average low, owing to a number of factors, including the grower himself and his lack of means to provide himself with proper implements for the cultivation of his crops, in short, owing to the limitations imposed in many cases by poverty and the lack of knowledge. The questions which I proposed to study pertain rather to the factory than to the growing of the beets or to the grower, i. e., why do the beets remain green? Why are they so low in sugar? And why do they produce so much molasses?

A few years ago the beets produced on these same lands were not low in sugar (see table page 14 for percentage of sugar in crop of 1904); the percentage of sugar, on the other hand, was extremely good, but I do not know how the working of the beets then compared with their working in more recent years, and it would be very difficult for technical men in the factory to judge of this, because of the improvements in the factories made from year to year as the result of each campaign's lessons and also in methods and details of technique. Each year's problems have become more difficult but have been met by improvements in the factory and in their practice till the factory of today is a very different plant from the initial one established ten or twelve years ago. The beets, then, have deteriorated from a sugar content of 17.5 to 14.5 or 14.0 percent and in some sections almost as low as 13.0 percent. The cause must be a general one, for the very good reason that the effect is general. There are always fields of good beets but the factory average is too low, which increases the cost of working the beets and makes the grower suspicious and discontented. The grower is a difficult person to convince that there are big problems to be solved which involve him and the factory alike and which are not of any man's making, but such are the questions which I have mentioned, i. e., why are the sugar beets of large sections slow in maturing and poor in quality, or putting this question differently, why has the average beet of recent years been so poor in sugar and why has it produced so large a percentage of molasses calculated on the beet? We may safely eliminate the following possible causes: first, any lack of proper appointments in the factories, for these are of the best; second, faulty methods or processes; third, unskillful management in the factory; fourth, lack of attention in taking care of the beets; fifth, inferior seed, for only the seed of the best varieties grown and furnished by reliable parties has been used; sixth, inexperience in growing the crop, for this feature has been supervised by the factories for years; seventh, climatic influences, for these are the same now as they were from 1896-1904, when the average sugar content was from 2.5 to 3.5 percent higher than it was from 1906 up to and including the last campaign. Further, we should take into account in this connection the fact that the beet seed growers have materially increased the sugar producing qualities of the beets, without depressing their crop production within the last fifteen years, and also that the community in general, and not a few individuals, has had at least eleven years experience in the management of this crop under their respective local conditions of soil, water-supply, etc. It is not intended to so much as intimate that all of the growers of beets are wise, energetic, thrifty men who have studiously and conscientiously endeavored to solve these problems for themselves, but the factories have provided men of experience and fitness for this work to counsel and aid the growers in all possible, feasible ways, so that the changed results mentioned cannot be attributed to either the inexperience or ignorance of the general farming community. I think that the factors of this kind that have been specified as possible contributors in producing the conditions pertaining to the sugar beet problems for the past few years may be dismissed from further consideration. The only point in which some persons may disagree with me in this is in regard to the effects of climatic conditions. This is because they know that there are serious questions presenting themselves, for which there is no other ready answer rather than because they have any definite fatcs to adduce to prove that the climatic conditions have changed, or to show any relation between the changed results and the climate.

The most serious problem that presents itself in connection with the climate and its influence is probably its bearing upon the development of the leaf-spot or *Cercospora beticola*. This is a factor which it seems we will have to accept as an unavoidable one in the Arkansas Valley. In the northern part of the state it is present, but wholly negligible. I do not doubt but that the climatic conditions may be the determining factor in this difference, but so far as I know nothing is proven in this regard.

In passing it may be permissible that I should call attention to the fact that different localities within this state may be very widely separated. The Arkansas Valley is about 200 miles south of the Cache la Poudre Valley, and the Grand Valley must be 350 miles in an air line south and west and 1,000 feet lower than the farming sections of the Poudre Valley. I do not know that there is no cercospora in the Grand Valley, but I know that there has been no damage done in the valleys, either of the Grand, the Gunnison or the Uncompahgre, and while this fungus is present in the Poudre Valley sections it has done no damage. In the Arkansas Valley, however, it has been very bad, destroying the foliage of many fields. Portions of the Arkansas Valley have as great an altitude as the Grand Valley and the latter is as warm as the former. Whatever the reason may be, this fungus has, in past years, been very bad in the Arkansas Valley. I will digress further to state that the sugar content of the beets from badly infested fields is not always low nor the yield necessarily below the average. It is scarcely to be doubted but that the destruction of a very large part of the foliage of the beets in August has some effect upon both the yield and the percentage of sugar. At my request Mr. Winterhalter kindly collected the record of 127 fields affected in various degrees by the leaf-spot. The variations appear to me to be due more to other causes than to the leaf-spot as we find the leaf-spot beets from sections in which the beets are generally rich also rich and in sections which produce poor beets we find them poor. I will give only a part of this data as my object is simply to show to what extent we may be justified in entertaining serious doubts in regard to the conclusions which we almost unconsciously accept as evident or fully proven, when we see a field of beets quite denuded of its foliage, i. e., that the beets are poor.

The climatic conditions in 1910 were as favorable as we can ever expect to have them. The aggregate acreage repreesnted by these 120 fields is 2,425.5 acres. The crop grown on the land the previous year was in most of the cases beets but in some cases it was not; wheat, oats, alfalfa, melons, cantaloupes and sorghum had been grown on some of the land. One piece had been fallow and one was new sod land. These districts represent the valley for a distance of about 120 miles. The individual fields represened a range in area from two to one hundred and nine acres. The percentage of sugar in the beets are averages for the whole field. The violence of the attack can not well be described more accurately than by the general terms used. I recall a field that I visited in which I do not think that any of the plants had escaped having at least 90 percent of their foliage destroyed. I do not know what the average sugar content of the beets from this field was as they were taken to the factory but the field samples averaged something above 16.0 percent. The attack in this case was very bad. If these samples show

RECORDS OF FIELDS AFFECTED BY LEAF-SPOT, 1910.

District No.	No. of Field	Character of Soil	Attack	Av. Sugar in Beets	Yield—tons	District No.	No. of Field	Character of Soil	Attack	Av. Sugar in Beets	Yield—tons
I	1	sandy	badly af.	16.5	14.0	IX	61	sandy	very bad	12.5	13.1
I	2	"	"	16.1	12.0	IX	62	"	"	12.3	10.8
I	3	"	"	15.6	17.8	IX	63	sandy l.	medium	13.8	10.0
I	4	"	"	14.7	12.1	IX	64	"	"	15.1	11.5
II	5	"	very bad	15.0	8.9	IX	65	"	bad	14.1	9.6
II	6	"	"	14.4	12.2	IX	66	"	medium	13.2	9.8
II	7	"	"	13.5	13.4	X	67	sandy	very bad	15.9	11.4
II	8	"	"	15.7	7.4	X	68	heavy	"	13.7	12.2
II	9	"	"	15.8	7.0	X	69	sandy	light	14.7	11.1
II	10	"	"	14.9	10.6	X	70	"	"	14.1	11.5
II	11	"	"	15.5	9.5	X	71	heavy	medium	17.0	5.2
II	12	"	"	14.8	12.2	X	72	sandy	very bad	15.4	10.6
III	13	sandy loam	"	12.8	13.4	X	73	heavy	light	15.9	12.0
III	14	" "	"	13.2	15.6	X	74	"	medium	14.9	10.2
III	15	v. h. adobe	"	14.6	8.9	XI	75	sandy l.	very bad	14.7	12.1
III	16	sandy loam	"	14.4	14.4	XI	76	heavy	"	14.6	14.2
III	17	"	"	13.3	13.6	XI	77	light	"	14.3	15.7
III	18	"	"	14.9	17.0	XI	78	heavy	light	15.2	11.8
III	19	"	"	13.7	15.9	XI	79	sandy	"	17.3	10.3
III	20	"	"	12.9	12.8	XI	80	sandy l.	medium	14.3	5.7
IV	21	heavy	"	13.2	11.4	XI	81	sandy	light	15.2	13.8
IV	22	"	"	13.8	10.8	XI	82	heavy	"	15.5	11.2
IV	23	"	bad	14.7	11.8	XI	83	"	very bad	14.0	8.7
IV	24	"	"	14.7	8.7	XI	85	"	"	12.4	6.0
IV	25	light	medium	14.4	10.4	XII	85	"	"	13.2	10.9
IV	26	"	bad	14.2	13.1	XII	86	"	medium	14.0	13.3
IV	27	"	medium	13.7	9.8	XII	87	light	very bad	15.8	10.6
IV	28	"	"	16.0	15.1	XII	88	heavy	"	13.0	12.3
V	29	heavy	very bad	14.1	8.8	XII	89	"	medium	14.4	10.4
V	30	"	"	12.4	11.7	XII	90	"	"	13.7	12.9
V	31	"	"	14.5	11.4	XIII	91	sandy l.	medium	14.9	6.3
V	32	"	"	12.6	17.5	XIII	92	"	very bad	13.4	6.1
V	33	light	"	12.7	14.6	XIII	93	lt. clay	bad	12.4	11.9
V	34	"	bad	14.3	13.8	XIII	94	sandy l.	"	13.6	6.6
V	35	heavy	very bad	14.0	16.5	XIII	95	"	"	12.6	9.7
V	36	medium	bad	13.2	14.6	XIII	96	lt. clay	light	13.3	11.7
VI	37	heavy	very bad	12.8	16.5	XIII	97	sandy l.	medium	11.4	9.0
VI	38	"	"	12.3	10.7	XIII	98	"	light	14.8	8.2
VI	39	medium	"	12.6	13.3	XIV	99	hv. clay	very bad	11.7	10.1
VI	40	heavy	"	13.0	17.2	XIV	100	lt. clay	bad	12.5	7.7
VI	41	"	"	13.0	10.9	XIV	101	hv. clay	medium	14.9	9.0
VI	42	medium	bad	11.9	12.4	XIV	102	lt.clay	"	16.0	8.5
VI	43	varying	"	13.6	7.1	XIV	103	sandy l.	very lt.	12.3	7.8
VI	44	heavy	"	11.8	12.9	XIV	104	"	light	13.3	11.6
VII	45	sandy l.	very bad	14.0	12.0	XIV	105	"	"	14.1	3.7
VII	46	"	medium	14.5	9.7	XV	106	"	very bad	11.6	14.8
VII	47	heavy	very bad	14.9	12.0	XV	107	"	bad	12.1	16.4
VII	48	sandy l.	medium	13.0	10.6	XV	108	"	medium	15.7	9.4
VII	49	sandy	light	15.0	9.5	XV	109	"	"	12.0	19.5
VII	50	"	very bad	14.7	8.5	XV	110	"	very lt.	14.0	16.3
VII	51	sandy l.	"	13.6	8.1	XV	111	"	"	12.2	7.4
VII	52	"	medium	13.6	10.9	XV	112	"	light	12.8	15.1
VIII	53	sandy	very bad	12.7	15.7	XV	113	"	very lt.	14.0	8.1
VIII	54	loam	"	12.1	12.8	XV	114	"	very bad	14.9	8.6
VIII	55	"	light	12.7	13.9	XVI	115	"	light	15.2	9.3
VIII	56	"	very bad	14.2	10.0	XVI	116	lt. adobe	light	12.5	9.9
VIII	57	sandy	"	12.8	13.3	XVI	117	"	"	13.8	12.0
VIII	58	sandy l.	light	13.1	11.9	XVI	118	"	"	13.6	8.0
VIII	59	"	very bad	12.3	18.9	XVII	119	"	"	13.2	13.8
VIII	60	heavy	"	12.4	11.6	XVII	120	hv.adobe	very bad	14.8	7.7

NOTE—af.—affected. v. h.—very heavy. l.—loam. lt.—light. hv.—heavy anything they point to a relation between the yield and the percentage of sugar rather than to one between the virulence of the attack and this percentage. I do not know the actual average percentage of sugar in the crop of 1910 for the whole valley but it was about 14.0 percent and not above 14.2 percent. It is true that the leaf-spot was very prevalent in the valley during this year, and may have influenced the general average, but the results shown by this compilation of returns from 120 fields representing nearly 2,500 acres, attacked with varying degrees of virulence, leads one to question very seriously whether we have not attributed a more injurious effect to this fungus than the facts justify. We have no other way that I see of judging of these effects than the one here adopted, namely, of taking a large number of fields in the same section of country, noting the virulence of the attack and comparing the yields and average percentages of sugar obtained by taking a sample from each load of beets as it is delivered at the factory or dump. We admit that there may be errors in the determinations but when we take the average of from two loads to four hundred or more loads our approximation to the truth is very close, besides we are not dealing with differences of a tenth or two of one percent, but as a glance at the table will show, with maximum differences of several percent. A cursory examination of the tabulated results makes it evident that we cannot compare the samples of one district with those of another. We have, for instance, in District No. I, very badly affected fields of from six to twelve acres in area, giving averages ranging from 14.7 to 16.5 percent sugar and yields between 12 and 18 tons per acre, while in District No. XVI we have slightly affected fields of 15 to 20 acres in area, giving averages ranging from 12.5 to 15.2 percent of sugar in the beets and yields of from 8 to 10 tons per acre. In District No. II in which the fields are mostly about 20, but one was much larger, we have eight fields, the lowest average is 13.5 and the highest 15.75 with yields of from 7 to 12 tons. These fields were all very badly affected. In District No. VI we have likewise eight fields either badly or very badly affected. These fields vary from 12 to 65 acres in area. The lowest average percentage of sugar in these beets was 11.8, the highest 13.0, the yields ranged from 7 to 16.5 tons per acre. The irregularity of the results in a given district is altogether disconcerting. We can select from these a series of results which can be so arranged as to make it appear that the action of the leaf-spot is to lower the percentage of sugar and to lessen the tonnage of beets, which we would expect to be the case, but this would be a case of finding facts to prove a theory. The fact is we find in the same district cases of very badly affected fields yielding excellent beets, 15.9 percent sugar, and 11.4 tons and other fields only slightly affected yielding beets with 14.7 percent sugar and

11.1 tons, again 14.1 percent sugar, 11.5 tons. In another district a very badly affected field yielded 14.2 tons per acre with 14.6 percent sugar in the beets and a slightly affected field yielded 11.2 tons with 15.2 percent sugar in the beets. The 127 fields selected from different districts and showing the effects of the leaf-spot in varying degrees show a tonnage and sugar content quite up to the average. The higher percentages in some of the samples cannot be attributed to the drying out of the beets in the ground for the ground was as moist as in other fields and the beets continued to produce new leaves, in other words, to grow. Neither the percentage of sugar in the beets nor the yield of beets in the various districts show such persistent and concordant relations to the virulence of the attack as to make evident beyond doubt the kind and extent of the injury to be attributed to this disease.

I have said that it is not permissible to compare the results obtained in one district with those obtained from another, much less is it permissible to compare results obtained in one section of the state with those obtained in another; for instance, the Department of Agronomy at the College had two small fields planted to sugar beets in 1910. There was some leaf-spot on them. The fields were planted early, the varieties were good ones, the seed reliable, the cultivation and stand were also good and the soil most excellent in quality; there was no reason why either the yield of beets or the percentage of sugar should be low, but the yield was seven tons per acre and the best percentage of sugar obtained from any sample taken was 13.3 with a coefficient of purity of 79.6. The leaves on these beets were exceedingly heavy and remained green till actually frozen, about Nov. 7. No one who saw this field would for a moment think of attributing the disappointingly low yield, the low percentage of sugar and low coefficient of purity to the damage done by the leaf-spot, for while leaf-spot was present the foliage was not damaged in any noticeable degree. It would be wholly wrong to attempt to compare such a field as this with the fields in the Arkansas Valley.

There is no question but that water will drown plants and that alkali may be so excessive and of such composition as to kill them. The question to be answered is whether they have done as much damage as we think them to have done or are we attributing bad effects to these causes which are due to others? I think that we are doing the latter to a very considerable extent. There is no question but that to fertilize the soil is a good and proper thing to do. The question is how much relief have we to expect from this? We have given the best answer that we can so far as the yield of beets and the percentage of sugar is affected by the usual fertilizers used for this purpose, i. e., nitrates, ammonia salts, dried blood, superphosphate, potassic sulfate, etc., under our conditions of climate and soil. The answer is that the results have not been such as to justify any expectation of a sufficient increase in yield of beets or percentage of sugar to be at all profitable. We shall in subsequent paragraphs present their effects upon the composition of the beet.

As our chief fungus disease, up to the present time, has been the leaf-spot, which is generally supposed to be dependent upon climatic conditions for its rapid development, and no one can doubt its very rapid development and general distribution in the Arkansas Valley in 1909 and 1910, we have presented such facts as are available, and which we think properly usable in this case, to show to what extent we are justified in attributing severe damage to the crop to this cause. While the leaf-spot certainly destroys the foliage and probably affects both the sugar content and yield of beets the extent of the injury done by this fungus is not very clearly shown, at least not by the observations of 1910. There are, on the other hand, clear indications that whatever may be the influence of the leaf-spot, soil conditions are quite as potent if not more so, in determining the yield and sugar content of the crop.

After having described the effects of excessive quantities of nitrates in the soil upon the apple tree in Bulletin 155, I added, "This is the only effect of this soil condition that I wish to present at this time though there are other serious agricultural conditions which I believe we will find attributable to this cause, i. e., to an excess of nitre in the soil. Sometimes due to too much at one time as is attested by the death of apple and also other kinds of trees, sometimes to too great an aggregate supply during the season. The following may illustrate what I mean by the latter statement. It is generally conceded that the application of nitrates to the sugar beet, except in the earlier stages of its growth, is detrimental to the quality of the beet." It has been and is now recommended that if nitrate is to be used on this crop that it be applied just before planting the seed. I understand that in some parts of Germany they now apply some nitrate as late as the middle or latter part of June. Touching upon this point in Bulletin 155 I put the question as follows: "But what will be the condition of the crop if it receives a continuous supply, amounting, during the season, to 600 or 800 pounds (of nitrate) or is planted in soil which already contains several times this amount per acre? If the assumption that nitrates, when present in large quantities, injuriously affect the quality of the beet be true, then beets grown in such soils ought to be very poor in quality, but not necessarily in crop." We, at that time, October 1909, endeavored to establish the amount of nitric nitrogen in the soil of one of the fields on the College farm, a part of which was planted to beets. I think that eight parts of nitric nitrogen per million of soil may be taken as the maximum amount that occurs in ordinary soils, and I doubt whether this quantity is usually maintained throughout the season. In samples taken to a depth of two inches, October 7, 1909, we found, in a fallow spot in the beet field 12 p. p. m., in a fallow portion of another plot 22.5 p. p. m. and in the space between the beet plots 35 p. p. m. On October 18 we again found 35 p. p. m. in a fallow spot in the beet field. On the other hand, samples of soil taken on the same dates from among the beets, i. e., between the beets in the row, showed from 1 to 4 p. p. m., and samples taken between the rows showed only from 1 to 5 p. p. m., but in the space between the rows which happened to be devoid of plants, was fallow, we found 28 p. p. m. We found that in land which had been cropped to grain from 2 to 8 p. p. m., in a cornfield 8 p. p. m., in an oat field 1 p. p. m., in virgin soil from the prairies, 8 p. p. m. Again, we gave the nitric nitrogen found in 46 samples of soils taken from as many different beet fields. These samples were kindly furnished me by the Holly Sugar Co. and were taken to a depth of six inches, October 1-15, 1909. The nitric nitrogen ranged in these samples from a trace to 160 p. p. m. Seventeen of the forty-six samples contained materially above 8 p. p. m. of nitric nitrogen. I do not know where these samples were taken, in the rows, between the rows or at the edge of the field and for this reason I obtained another set of 54 samples taken from 18 fields, or three from each field as follows—in the rows of beets, between the rows and in the turn row. These samples were taken six inches deep. Of the 18 samples taken in the beet rows four of the samples showed the presence of more than 8 p. p. m., but did not exceed 15 p. p. m., one sample showed 50 p. p. m.; of those taken between the rows, five samples showed more than 8 p. p. m., with 30 p. p. m. as the maximum; of those taken in the turn rows, eight samples showed more than 8 p. p. m., with the maximum of 140 p. p. m. These data were collected to show in the first place how much nitric nitrogen we may consider as normally occurring in our soils, i. e., in good soil and under fair conditions. Our farm samples fully meet these conditions, the weather had been fair and no irrigating water had been applied for weeks, so that the nitric nitrogen had not been leached out, and as the fallow ground was covered with a thick layer of fine earth capillary action was minified and our samples give us, I believe, reliable results. They show that at this place, land in crops other than alfalfa contains less than 8 p. p. m., and that well conditioned, good soil, lying fallow, acquires nitric nitrogen in quantities very much in excess of this, up to 35 p. p. m. having been obtained. In the samples from the Arkansas Valley, which represented cultivated, and at least average fields, we found a maximum of 160 p. p. m. in the soil collected in October and taken to a depth of six inches. This quantity is very large, speaking from the standpoint from which we are accustomed to consider this question, but is very much below excessive occurrences with which we meet in case of some lands actually planted to beets. This figure, 160 p. p. m., calculated as sodic nitrate, is equal to 960 p. p. m., or taking the top six inches of soil as weighing 2,000,000 pounds, we would have 1,902 pounds of this salt within reach of a growing crop. It is not proven nor do we wish to assert that the beet crop grown on the College farm in 1909 actually used up an amount of nitrates represented by the difference between the amounts found in fallow spots in these beet plots and in the ground between the beets, but we do hold it as fully proven that the conditions obtaining in our soils make it probable that unless some prohibitive condition exist the beets grown on this particular piece of ground will be furnished with so liberal a supply of nitrates as to be detrimental to the quality of the crop. This means that this land will be apt to produce top or turnip-shaped beets, with big crowns, heavy foliage, a very moderate sugar content and a low coefficient of purity, unless the season be unusually long and permit of their maturing. The facts in this case will be taken up later.

Here be it stated with emphasis that I do not propose to explain all the ills that beset the sugar beet crop by attributing them directly or indirectly to the formation of nitrates in the soil, but I do claim that we have here an old question in such an intense form as to practically become a new one of the most serious import to the industry of producing sugar from the beet root in large sections of, if not in the whole of the state. My object has been to try to find out to what extent my views are in harmony with the facts and I am happy to believe that, in trying to do this, I have the good will of the people most directly concerned, for they have become fully convinced that there is a big problem involved which has not yet been solved. This is the real reason why I have discussed in their bigger features the questions of seepage, of alkali, of fertilizers, of the leaf-spot and their effects upon the crop and its sugar content. No one knowing very much about Colorado agriculture would deny or attempt to minify the importance of these questions; they are real questions, but, on the other hand, persons with only a very moderate knowledge of our agricutural problems or men engaged in this pursuit when brought into actual contact with problems which they cannot solve, whose solution is perhaps unknown, are apt to assign a role to known or visible agencies which belong to wholly different ones. In the estimation of the public, alkali has, from the beginnings of our agriculture, been a veritable *bete noir,* likewise an excess of water. The latter of course presents important questions but the question is whether we have not, in too great a measure laid upon these things the iniquity of our ignorance. We are likewise in danger of going to the other extreme in placing our hopes and confidence in the virtues of fertilizers. It is too late in the development of agriculture to question their benefits but it is no sin even in the presence of the learned to assert that there are limitations to their beneficent effects and that there are yet unsolved questions pertaining to their use and action. This is the frame of mind in which I approach the questions presented in this bulletin free enough I hope from prejudice to state the whole case, and frank enough to be inconsistent or even contradictory if the facts require it. I have no desire to run counter to established teachings, but simply to learn the lessons that are presented by our practice, and only wish that I were more adept in learning them.

I wish to again state that Colorado, owing to its size and position, presents a variety of conditions which many persons fail to properly consider. I have had no occasion to study the problems of the beet crop in the valleys of the Poudre, the Platte, the Uncompahgre or the Grand rivers, had I had and were I presenting the results of such a study they would in all probability be stated somewhat differently from the present ones.

This Station has published four Bulletins, 155, 160, 178 and 179, on the Fixation of Nitrogen in some Colorado Soils. The occurrence of very large amounts of nitrates in some of our soils is fully demonstrated, also that fixation takes place rapidly in them under favorable conditions and still further that nitrification takes place rapidly enough to account for very considerable quantities of nitrates in these soils.

Allusion has been made to the facts leading directly to this study, namely, the following questions which were propounded, why do not our beets ripen and keep better? Why have they fallen off in sugar content despite improvement in seed? Why do they produce so much molasses?

These questions represent facts serious enough in their importance to justify any effort to answer them and if we learn only a part of the truth we will have made some progress. The work done in the preparation of Bulletin 155 prepared me to believe it to be possible that nitrates might actually be developed on so large a scale as to account for the lengthened vegetative period of the beet; its green condition at the time of harvesting might easily account for its ready deterioration, and to this immaturity of the beet with the presence of nitrates might fairly be attributed the high percentage of molasses produced. I tested samples of Steffens waste water, molasses, and beets for nitric acid and found it present in such quantities as to be easily detected. This seemed to me more suggestive that not only the molassegenic action of the nitrates but the immaturity of the beet when harvested, due to the presence of the nitrates in the soil, might be largely accountable for the excessive quantity of molasses produced. With these facts in my possession I had no difficulty in interesting the representatives of the American Beet Sugar Company in Colorado. Mr. Winterhalter was already making experiments with artificial fertilizers, not with this phase of the problem in view but it offered me an opportunity to study it in this connection. We extended the line of experimentation to include the influence of nitrates when applied in medium quantities throughout the season upon the working or factory qualities of beets. There was placed at my disposal six acres of land, the most desirable in quality of all the lands available. It had been in beets in 1909, grown by a tenant and not manured; the soil was a sandy loam with two or three spots which were somewhat gravely. All of the land had received a dressing of ten tons of stockyard manure per acre which was plowed under to a depth of ten inches. The piece was divided into six plots of one acre each. All of which were planted with Original Kleinwanzlebener seed, crop of 1909, on April 1, 1910. One acre was chosen as a check plot, the other five acres each received a dressing of 250 pounds of Chile-saltpetre two days before the seed were planted. Beets were irrigated up April 9-11 and thinned May 23-26. On May 2 four of the fields each received a dressing of 250 pounds of nitrate; on June 1 three of the fields; June 22 two of the fields, and on July 27 one field received a dressing of 250 pounds. This gave us plots of one acre each which received the following quantities of nitrate: Field A, 250; B, 500; C, 750; D, 1,000; E, 1,250 pounds of nitrate distributed in applications of 250 pounds each at intervals of approximately four weeks, beginning March 28 and ending July 27. These fields were irrigated April 9, June 17, July 1, July 10, July 30, half of the fields on August 17 and the other half August 30. The dates given are those on which the irrigations were completed. All plots were thoroughly cultivated. In order to combat the leaf-spot, Fields A and B were sprayed with standard Bordeaux mixture, July 21, August 1, 13 and 21 and September 7; Field C was sprayed July 22, August 3, 13, 28 and September 8; Field D was sprayed July 22, August 16, 28 and September 8; Field E was sprayed July 23, August 16, 28 and September 9; Field F, the check, was sprayed July 23, August 16, 28 and September 9. The total rainfall during the season from March 28 till September 22 was 9.99 inches. One-half of each field was harvested October 6-8, the other half November 9-11. This constitutes the cultural data pertaining to these fields.

Another experiment was to see what effect, if any, the application of superphosphate, muriate of potash and sodic chlorid, used alone and in conjunction would have on beets growing in ground which was rich in nitre. I knew of a piece of land of this nature which was planted to beets, and through the kind offices of Mr. Winterhalter we obtained the permission of the owner to apply these fertilizers to test plots of about one-eighth of an acre each. The fertilizers were applied at the following rates: Superphosphate, 1,000 pounds per acre; Muriate of potash, 400 pounds per acre; Salt, sodic chlorid, 400 pounds per acre. The same quantity of each was used whether it was applied alone or in combination. The fertilizers were applied July 5 by hand and so distributed that none of the fertilizer was nearer than four inches to the plants, as it would be worked closer to them by cultivation.

I had seen the crop of beets on this land in 1909 and it was poor. I expected to see a similar but poorer crop in 1910. I saw the field in late June and the promise was only fair. I saw it again in August when all my predictions of a poor crop were thoroughly discredited so far as the promise of a crop was concerned. I do not think that I have ever seen such a growth of beet leaves They stood easily thirty-eight inches high, and later when a very large amount of foliage had been killed by the leaf-spot the remaining foliage stood thirty inches high. It seemed ridiculous that we had ever entertained a thought of modifying the growth and character of such a crop by the addition of a thousand pounds of superphosphate or a few hundred pounds of muriate of potash to the acre. The crop of roots, however, was somewhat of a disappointment and the quality of the beets was of all sorts, from good to very poor, according to the part of the field from which they were gathered.

We have now stated the lines of experimental field work for 1910: First to determine the effects of nitrates upon the quality of the beets; second, to study the effects of fertilizers on the quality of beets; third, to see whether the addition of superphosphate, phosphoric acid, potash or ordinary salt would so hasten the maturity of the beet or otherwise modify its growth as to correct the effects of an excessive amount of nitre. There can be no question about the presence of an excessive amount of this salt in this field, even at the present time.

What I have said relative to the beets produced in the different districts of the Arkansas Valley applies with full force to other districts.

STANDARDS ADOPTED.

So far as the ordinary analysis is concerned I do not know what to take as standard. We certainly cannot take German results as standards for our beets. For some reason our beets are richer in ash constituents than the German beets, and also differ in other respects, but these differences will be stated in another place. It is very difficult to determine what we should adopt as a standard beet. This is a small matter so far as the percentage of sugar is concerned because the differences are so great and the average sugar content of the beet, as it now grows in the Arkansas Valley, is so much lower than it was six and ten years ago that all will agree that the beets are poor in this respect whatever standard may be adopted. The matter is not so easy when it comes to the question of composition. It is evident that, for my purposes, I can scarcely take Colorado grown beets, on the other hand foreign beets, viz: German beets, grown under entirely different conditions of cultivation, soil, and climate, can not safely be adopted, even though the beets may have been grown from the same strains of seed. We shall very largely use German data, because it is the best to which I have access, but this will not relieve me from the necessity of using certain beets as standards of comparison. I have chosen one sample of beets from Michigan, one from Montana and one from the Poudre Valley, Colorado, for this purpose. The latter probably represents the highest grade of Colorado beets.

The following German data are taken from an article by K. Andrlik, Zeitschrift des Vereins der Deutschen Zuckerindustrie for 1903, pp. 906-937. The analyses are of fresh cossettes.

ANALYSES OF GERMAN BEETS.

	I.	II.	III.	IV.	V.	VI.
Dry substance	25.450	25.250	23.360	34.400	22.800	25.020
Sugar	16.600	16.900	15.880	16.800	14.500	17.200
Crude ash	0.800	0.806	0.919	0.813	0.784	0.746
Fine ash	0.634	0.631	0.581	0.562	0.636	0.557
Injurious ash	0.386	0.391	0.315	0.297	0.400	03.35
Total nitrogen	0.257	0.252	0.210	0.199	0.306	0.186
Proteid nitrogen	0.113	0.112	0.110	0.107	0.120	0.109
Injurious Nitrogen	0.114	0.112	0.088	0.082	0.141	0.070
Potassic oxid (K_2O)	0.292	0.297	0.228	0.218	0.242	0.254
Sodic oxid (Na_2O)	0.047	0.043	0.046	0.044	0.076	0.043
Calcic oxid (CaO)	0.042	0.046	0.064	0.065	0.054	0.060
Magnesic oxid (MgO)	0.074	0.075	0.065	0.066	0.094	0.063
Iron and alumnic oxid $(FeAl)_2O_3$	0.030	0.026	0.054	0.049	0.036	0.090
Phosphoric acid (P_2O_5)	0.094	0.093	0.084	0.085	0.042	0.084
Sulfuric acid, SO_3	0.033	0.038	0.033	0.027	0.034	0.027
Chlorin (Cl)	0.014	0.013	0.008	0.008	0.038	0.011
Insoluble	0.098	0.099	0.344	0.241	0.037	0.125

Percentage Composition of the Ash.*

	I.	II.	III.	IV.	V.	VI.
Potassic oxid, K_2O	36.500	36.970	24.900	26.790	30.900	34.030
Sodic oxid, Na_2O	5.880	5.370	5.000	5.500	9.700	5.730
Calcic oxid, CaO	5.750	5.710	7.010	7.980	0.890	7.530
Magnesic oxid, MgO	9.270	9.300	7.110	8.180	12.000	8.520
Iron and aluminic oxid $(Fe\ Al)_2O_3$	3.840	3.240	5.920	6.110	4.630	4.020
Phosphoric acid, P_2O_5	11.760	11.500	8.660	10.290	5.330	11.200
Sulfuric acid, SO_3	3.840	4.700	3.520	3.260	4.340	3.800
Chlorin, Cl	1.770	1.630	0.890	0.800	4.590	1.400
Insoluble	12.260	12.230	37.480	29.640	4.690	16.850

*These percentages have evidently been calculated on the crude ash.—H.

These analyses present the fullest statement of the composition of German beets that I have found and they represent samples of cossettes from six factories. The details of the methods used are fortunately given with sufficient fullness to enable one to know on what basis the results may be compared with others.

As already stated, I have chosen as standards of comparison one sample of beets from Montana, one from Michigan, and one from Colorado, grown in this, the Poudre Valley, section. The German results may serve as guides to aid us in judging, but not as standards of comparison for our beets. The Montana beets were grown in a sandy loam soil, probably alkaline. The Michigan beets in a non-alkaline soil, and the Colorado beets in a soil which was probably alkaline but under favorable conditions. The history of the field in which the Colorado sample was grown was as follows: soil, sandy loam, fifth year in beets, no fertilizer of any kind had been used on it; plowed 25 March 1910, seed planted 15 April, plants blocked and thinned 15 June, irrigated 10 August and 1 Sept. The supply of water was small. The yield was ten tons per acre, and the percentage of sugar in the beets as they were delivered at the factory by the wagon load was from 16 to 20 percent.

The methods of analysis used were the same throughout the season and are sufficiently indicated by the statement of the analyses.

Owing to the fact that we have exceptionally large percentages of chlorin in some of our ashes, I have in stating the composition of the pure ash given, as a rule, the metallic sodium or sodium and potassium corresponding to the chlorin to avoid including the chlorin and its oxygen equivalent in the same statement, which would introduce too big an error in cases in which the chlorin in the carbonated ash equals from six to twelve or more percent, otherwise the statement of these analyses is the conventional one, giving the acids as anhydrids and the bases as oxids. The silicic acid has been omitted from the pure ash because I fear that the larger portion of it is derived from the fine sand due to fluxing.

Andrlik states that the amounts of injurious ash and nitrogen are safe criteria whereby to judge of the quality of beets. He defines injurious ash as the sum of the alkalis, sulfuric acid and chlorin, and injurious nitrogen as the difference between the total nitrogen and the sum of the albuminoid, ammonia and amid-nitrogen. In the six analyses quoted we observe that the injurious ash varies from 0.3 to 0.4 percent of the weight of the beet, while the injurious nitrogen varies from 0.07 to 0.14 percent of the beets. I have been unable to find any statement of the lowest amount of injurious ash which is to be considered as decidedly objectionable, or stated otherwise, the permissible amount of injurious ash. In regard to the injurious nitrogen, however, it is stated that the injurious nitrogen multiplied by ten gives approximately the amount of amido-acids and betain. It is further stated that on calculating these substances on one hundred parts of sugar that we obtain from 3.7 to 9.3 parts.

ANALYSES OF BEETS ADOPTED AS STANDARDS.

See Analyses CLXXXV and CLXXXVI, page 172 for analysis of Montana beets.

	VII.	VIII.
Where grown	Michigan	Ft. Collins, Colo.
Date of harvesting	2 Nov. 1910	3 Nov. 1910
Average weight, trimmed	813.0 grams	673.0 grams
	Percent	Percent
Sugar	15.30000	18.30000
Dry matter	22.00000	24.20000
Crude, carbonated ash in dry matter	3.23500	3.33900
Crude ash in beet	0.70170	0.82038
Pure ash in beet	0.49300	0.60887
Sulfuric acid	0.02930	0.02802
Phosphoric acid	0.06236	0.07620
Chlorin	0.00285	0.01941
Sodium	0.00185	0.01262
Potassic acid	0.26382	0.31690
Sodic oxid	....	0.02538
Calcic oxid	0.04550	0.04694
Magnesic oxid	0.07573	0.07932
Ferric oxid	0.00621	0.00182
Aluminic oxid	0.00236	0.00131
Manganic oxid	0.00170	0.00170
Total nitrogen	0.22915	0.20750
Proteid nitrogen (Stutzer)	0.12305	0.08710
Ammonic nitrogen	0.00596	0.00230
Amid nitrogen	0.02160	0.00290
Amino nitrogen	0.04794	0.07479
Nitric nitrogen	0.00320	0.00096
Injurious nitrogen in beet	0.07854	0.11520
Injurious ash per 100 sugar	1.94476	2.19672
Injurious nitrogen per 100 sugar	0.51287	0.62899
Press Juice According to Ruempler.		
Total nitrogen	0.19195	0.11675
Albumin nitrogen	0.05835	0.04230
Propeptone nitrogen	0.00030	0.00790
Peptone nitrogen	?	0.00350

Ash Analyses.

	IX.		X.	
	Crude	Pure	Crude	Pure
Carbon	0.628	.....	0.480	.....
Sand	6.532	.....	2.115	.....
Silica	1.165	.....	0.112	.....
Sulfuric acid	4.117	5.944	3.415	4.602
Phosphoric acid	8.763	12.650	9.288	12.515
Chlorin	0.400	0.578	2.366	3.188
Sodium	.....	0.376	.....	2.073
Carbonic acid	20.233	.....	21.603	.....
Potassic oxid	37.055	53.496	38.627	52.053
Sodic oxid	0.255	.....	5.165	4.168
Calcic oxid	6.392	9.229	5.721	7.710
Magnesic oxid	10.641	15.361	9.656	13.011
Ferric oxid	0.873	1.260	0.214	0.295
Aluminic oxid	0.526	0.760	0.163	0.215
Manganic oxid	0.240	0.346	0.126	0.170
Loss, organic matter, etc.	(2.270)	.....	(0.603)	.....
Sum	100.090	.....	100.534	.....
Oxygen equi. to chlorin.	0.090	.....	0.534	.....
Total	100.000	100.000	100.000	100.000

"The former amount indicates a good, the latter a bad diffusion juice." It is further shown in the same article that 92.3 percent of the injurious nitrogen and from 70.9 to 80.3, usually 75.3 to 79.9 percent, of the injurious ash of the beet goes into the diffusate.

In 1910 I endeavored to obtain beets as standards for comparison with ours which we knew to be good beets and which worked well in the factory, for these reasons we chose a sample from Fort Collins with 18.3 percent sugar and one from Michigan with 15.3. We found the injurious ash in the former to equal 2.197 per 100 sugar, in the latter 1.945, the injurious nitrogen to equal 0.629 and 0.513 per 100 sugar respectively and the ratio of proteid to total nitrogen 41.9 percent and 53.7 percent. In the press juice we find the albumin nitrogen forming 36.2 and 32.0 percent respectively of the total nitrogen. The injurious nitrogen in the beet constitutes 55.5 and 34.3 percent of the total. The pure ash in the Michigan beet is approximately 83.33 percent of that in the Fort Collins beet. These are the principal feature in the composition of these beets, but it may be permissible in this place to state that the pure ash in these beets, 0.6088 and 0.4930, is quite within the range that I find given, especially by Andrlik, for Austrian or Bohemian beets. The points of interest in these ashes are that the phosphoric acid calculated on the fresh beet is fairly high, the potassic oxid is very high, which is the case with the magnesic oxid also, while the calcic oxid is low. The nitrogen is almost identical with the average found for German beets over a period of seven years by the Experiment Station of Lauchstaedt, but according to other figures I find that over 50.0 percent of the samples fall below 0.2 percent. The chlorin in these samples is quite low.

In 1911 a favorable year, I was fortunate enough to obtain through the kindness of Mr. Hans Mendelson of the Great Western Sugar Company a sample of beets grown by himself in Montana. The variety was a strain of his own production, No. 311, and had been siloed for three months or more before it was sent to me. Mr. Mendelson has kindly furnished me the following data relative to the cultivation of these beets. "The land is a sandy loam, had been planted to grain for eight years in succession up to 1909. In 1910 was planted to field peas, after harvest the field was disced, irrigated and sown to rape. This was pastured off in the fall by sheep and in the spring handled in the usual manner. The rows were 20 inches apart and the beets 8 inches apart in the rows. The growing crop showed every indication of a lack of nitrogen, still a fertilization with 200 pounds of nitrate did not produce the expected increase, indicating some other deficiency, in this case a lack of moisture in the subsoil."

These beets were of excellent shape and varied considerably in size. Their condition was perfect, they had been carefully packed and they were crisp, like freshly pulled beets. Apparently no drying out had taken place. The climatic conditions of the locality where these beets were grown are very favorable. The location was selected for this reason. There were eleven beets in the sample. The analysis follows:

ANALYSES OF MONTANA BEETS, SEASON 1911.

Fertilized with 200 Pounds Sodic Nitrate per Acre.

	CLXXXV.
Average weight of beets	566.3 grams
Av. wt. of beet trimmed	479.3 grams
	Percent
Sugar in beets	18.24000
Dry substance in beets	25.37000
Crude ash in dry substance	2.68000
Pure ash in dry substance	1.93500
Pure ash in fresh beet	0.49090
Sulfuric acid	0.01734
Phosphoric acid	0.08117
Chlorin	0.00761
Sodium	0.00495
Potassic oxid	0.25507
Sodic oxid	0.01312
Calcic oxid	0.03164
Magnesic oxid	0.07512
Ferric oxid	0.00224
Aluminic oxid	0.00086
Manganic oxid	0.00175
Total nitrogen	0.10494
Proteid nitrogen (Stutzer)	0.06995
Ammonic nitrogen	0.00199
Amid nitrogen	0.00251
Amino nitrogen	Not det.
Nitric nitrogen	None
Injurious nitrogen in beet	0.03050
Injurious ash per 100 of sugar	1.67240
Inj. nitrogen per 100 of sugar	0.16722

Press Juice According to Ruempler.

Total nitrogen	0.07797
Albumin nitrogen	0.04101
Propetone nitrogen	0.00172
Peptone nitrogen	0.00245

Ash Analysis.

	CLXXXVI. Crude	Pure
Sand	3.124	.....
Silicic acid	1.059	.....
Sulfuric acid	2.550	3.523
Phosphoric acid	11.939	16.536
Chlorin	1.119	1.550
Sodium	.....	1.008
Carbonic acid	21.225	.....
Potassic oxid	37.515	51.962
Sodic oxid	2.910	2.637
Calcic oxid	4.654	6.446
Magnesic oxid	11.049	15.304
Ferric oxid	0.330	0.457
Aluminic oxid	0.127	0.176
Manganic oxid	0.257	0.356
Loss	(2.394)	.....
Sum	100.252	.....
Oxyg. equi. to chlorin	0.252	.....
Total	100.000	100.000

These beets are, according to all the criteria whereby we judge beets, of the very best quality, the percentage of sugar is high, 18.24 percent, the injurious ash is low, 1.67 per 100 of sugar, the injurious nitrogen is only 0.16722 per 100 sugar, the ratio of proteid nitrogen based on Stutzer reagent is 66.68 percent and on the determination of albumin according to Ruempler is 52.6 of the total nitrogen in the juice. Andrlik in discussing the ratio of proteid nitrogen to the total nitrogen calls attention to the fact that the ratio of proteid nitrogen to total increases as the beet ripens and that the proteid nitrogen may reach 70 percent of the total in ripe beets with a low percentage of nitrogen. The pure ash in the fresh beet is not especially low, 0.4909 percent, but the phosphoric acid is as high as in German beets, which is not the case with Colorado beets, and there is no nitric nitrogen. In fact there are only two features in the composition of these beets which are common with those of Colorado, they are the amount of potassic oxid in the beet, 0.25507 percent in this and 0.25 to 0.56 in Colorado beets, and the ratio of the calcic to the magnesic oxid, this being about 1 to 2½. The Experiment Station at Lauchstaedt gives 0.17948 percent as the average percentage of potash for seven years for beets grown with complete fertilizers and it is essentially the same for beets grown without fertilization, 0.16959 percent. The sample from Michigan and also that from Fort Collins used as provisional standards show the same peculiarities of composition. The sugar content in these is 15.3 and 18.3, the pure ash in the beets 0.49300 and 0.60887, the phosphoric acid 0.062 and 0.076, potassic oxid 0.26382 and 0.31690, the nitric nitrogen 0.0030 and 0.0009, the injurious ash per 100 sugar 1.94476 and 2.19672, the ratio of the proteid nitrogen to the total is 53.7 and 41.9. The ratio of calcic to magnesic oxid is approximately 9:15 and 7:13.

According to these criteria our Montana sample alone equals or excells in quality No. VI of Andrlik's series. His No. VI contains for each 100 pounds of sugar 4.0 parts of injurious nitrogenous compounds (injurious nitrogen x 10) and 1.94 parts of injurious ash. The Montana sample contains 0.17 part injurious nitrogen and 1.67 parts of injurious ash per 100 of sugar, while the Michigan beets contain 5.13 parts injurious nitrogenous compounds and 1.94 parts injurious ash, and the Fort Collins beets contain 6.3 parts injurious nitrogenous compounds and 2.2 injurious ash. I do not know how much molasses these beets produced or any of the details of how they worked in the factory. We cannot, however, so far as I see, hope to obtain any better standards for our beets than these.

We took three sets of samples during the season of 1910, 23 Sept., 11 Oct., and 3 Nov., in order to follow the development of the beet so far as samples taken at such intervals might indicate it. Our battery experiments with these beets were made Nov. 10-16, 1910.

There are several classes of beets represented: First, such as were grown on ordinary, good soil, without the addition of any fertilizers; second, such as were grown on good soil with the addition of the ordinary fertilizers in various quantities and in different combinations; third, such as were grown on good soil with the application of different quantities of sodic nitrate; fourth, such as were grown on soil in which excessive quantities of nitrates had developed. As the land on which the fourth class was grown was known to us to be bad we made some experiments in the way of remedial measures. There were applied to different portions of it superphosphate, muriate of potash and sodic chlorid—so there are four sub-series under this one, i. e., one series corresponding to each of these fertilizers and a check series. Fifth: Beets grown with green manure; sixth, beets grown on College Farm at Fort Collins.

There are in addition to these, three series grown at Fort Collins in 1911.

The questions involved are unfortunately more complicated than even agricultural questions ordinarily are. We have, for instance, in the fourth class of beets, all of the questions which we have heretofore discussed. We have dry land and wet land with a comparatively low water plane, the presence of alkalis and, as the average man would judge, their absence. The presence of excessive quantities of nitrates in portions of the field and wholly different conditions in other portions. While leaf-spot was abundantly present, it was much worse in some portions of the field than in others.

The soil itself is not entirely uniform as it varies from a fine sandy loam to a more or less gravelly clay loam. These conditions undoubtedly produced their several effects and so modified one another, that it is impossible to analyze the results and correctly attribute a specific result in a given measure to each individual condition. We can only determine the extent to which for instance the application of 1,000 pounds superphosphate, 150 pounds of phosphoric acid per acre, affected the quality of this crop by means of check samples taken from the corresponding sections of adjoining rows.

It seems superfluous to state these facts, but on the other hand it is advisable in order that the reader may at least have our statement to show that we appreciate the difficulties of our problem, in some measure at least, and that we have duly considered the course that we have pursued in our work.

We have been compelled to take many samples, for the sake of confirming our observations and establishing their general validity under a variety of conditions. The difficulties presenting themselves in establishing what the composition of beets grown on unfertilized land is, are very great. The soils collected from beet fields in the Arkansas Valley at the end of the season and even those taken in January, 1910, to a depth of six inches, show by their varying quantities of nitric nitrogen how nearly impossible it is to judge of the amount of nitrates that may have been furnished to the beets during their growing period. Andrlik's experiment showed that the application of 528 pounds of Chile-saltpetre to the acre applied in three equal applications produced decidedly deleterious effects. The injurious nitrogenous substances amounted to 6.16 parts per 100 of sugar and the injurious ash to 1.89 parts per 100 of sugar in beets which had received this amount of saltpetre, against 2.36 parts injurious nitrogenous compounds, and 1.45 parts of injurious ash per 100 of sugar in beets grown without the addition of the nitrate. Apropos to these results Andrlik remarks that Chile-saltpetre applied in light and particularly in heavy applications acts unfavorably not only upon the quality of the beet, but also upon the harvest. The same author states that from 20 to 45 percent of the nitrogen and from 12 to 15 percent of the sodium oxid is appropriated by the roots. One would infer that the rest was used by the leaves or possibly remained in the soil. The former is much more possible than the latter. I have only a few determinations at my command to show how rapidly and completely the nitre applied to the soil may be appropriated by the plants. These results are very unsatisfactory but their general import is that both the rate and extent of the appropriation is rather great. Andrlik's results show that the increase of nitrogen recovered in the crop of beets was equal to 44.5 percent of the nitrogen applied as sodic nitrate in the case where the heavier application was made and 19.9 percent in the case of the lighter application. He did not consider the leaves except to mention the considerable increase in weight produced, from 2,000 to 2,400 pounds per acre. We shall, in the experiments of 1911, give some further data on this subject.

In collecting samples of beets grown without the application of fertilizers we are wholly unable to state how great or small a supply of nitrogen as nitrates they may have had during the season. The amount present at different times is variable and is influenced by so many causes that the aggregate supplied is difficult to estimate. We have among other conditions the influence of the crop itself as is shown by the work of Drs. Lyon & Bizzell, *Journal of Franklin Institute*, January-February, 1911. We made a number of determinations in 1910 to establish the different amounts of nitrates in the land cropped to beets and the same land not cropped. A single pair of these samples taken 18 October 1910 will show the difference that may be found. One of the samples was taken from a portion of a row where there were no beets; this was, then, a small spot within the patch which chanced to be without crop. Three samples were taken, the top two inches, the succeeding four inches and the succeeding six inches or twelve inches in all. The top two inches showed nitric nitrogen equivalent to 140 pounds of sodic nitrate per acre. The succeeding four inches gave 96 pounds of sodic nitrate, and the succeeding six inches gave 96 pounds sodic nitrate, or the top foot of this fallow spot which was small in area and surrounded by a luxuriantly growing crop, contained nitric nitrogen equivalent to 332 pounds of sodic nitrate per acre on this date Three other samples were taken in the same manner from a row of beets as near to this spot as was advisable with the following results. The top two inches gave 12.0 pounds, the succeeding four inches 1.7 pounds and the next six inches 2.6 pounds of sodic nitrate per acre. We have in this case a difference of 315.7 pounds between the amount of nitrate per acre in the fallow spot and that in the cropped land a few feet away. The questions in this case are: Was there as much nitrate formed in the cropped land as in the fallow land? Had the beet crop appropriated the 315.7 pounds? Or had the condition of being cropped prevented the formation of the nitrates, i. e., had the shading of the ground by a dense growth of leaves in some way retarded or prevented the formation of the nitrates or is there something in the roots of this crop which is inimical to these processes? The two sets of samples given above are not isolated ones. There are strips of land separating the series of experimental plots, and these gave, on the same date, essentially the same results; the surface foot of the fallow strip showed the presence of 321 pounds of sodic nitrate and the samples from the beet plot adjoining it 15.8 pounds. The preceding samples were taken at Fort Collins. I will give one set of samples taken at my request in the Arkansas Valley. This set of samples was taken to a depth of six inches, in the rows, between the rows and in the turn rows. The six inches of soil in the rows showed 180 pounds, that between the rows 360 pounds and that in the turn-rows 960 pounds of sodic nitrate per acre. These cases are not given for the specific purpose of raising questions relative to the formation and distribution of the nitrates in cropped and uncropped land, particularly to such as is cropped to beets, but to show that it is not safe to conclude that, because beets may have been grown without the application of fertilizers, particularly without the application of sodic nitrate, they have therefore had no abundant, perhaps prejudicial supply of nitrates. This may be true, but it is not proven by the fact that we did not add it. My fear is that the contrary is true, namely, that our beets often have a markedly prejudicial supply of nitrates furnished them during the season and that this is true in so large a percentage of beets grown for commercial purposes that the general result, in the Arkansas Valley and also elsewhere in the state, is a decided deterioration in the quality of the beets. The deterioration or the low quality of the beets in large sections is not seriously questioned but the cause thereof is not satisfactorily determined. I have considered some of the causes to which it has been attributed and have, as I believe, shown that whatever injury may be attributed to these causes, they are not sufficient to account for the facts as we find them and that there must be some other more generally applicable and at the same time sufficient cause for this deterioration.

The first class of beets to be considered is represented by beets grown on ordinarily good land without the application of any fertilizer. The sample of beets harvested 3 Nov. 1910, grown near Fort Collins, and an analysis of which has been given on page 37, has been given as a typical Colorado beet. The following samples have been taken from a variety of soils and should vary both on this account and also because they were taken from different localities. Eight of the samples were grown in 1910 and two of them in 1911.

It is a matter for general comment among the factory people that the beets grown in 1911 have worked much better than those of the past few years. I have had occasion to note that the whole development of the beet, especially in some sections, was entirely different from the usual development heretofore observed in these sections. I do not know the cause of this. It is difficult to believe it to be due to the water supply because it holds true that the development of the beets was very different in 1911 from that of previous years, for sections in which they had an abundance of water and also in some where there was a great scarcity of water.

The samples of this class have been taken from a variety of soils. Two of them were grown on virgin soil, sod land broken in the spring and planted shortly afterward to this crop. The water supply was very moderate, and while I do not know the rainfall and temperatures that they had during the season, the former may be safely assumed to be small and the latter high, as the locality was in the extreme eastern portion of the state and the land was up on the prairie far away from any flowing water. These are samples XI and XII. This field was harvested October 12-15 and averaged as delivered to the factory, 13.8 percent sugar, the separate loads ranged from 12.2 to 16.0 percent. The variety of the beets was not learned, but was probably a Kleinwanzlebener variety. Samples XIII and XIV were grown on the College Experiment Farm in 1911. No. XIII is Wohanka, richest in sugar, WZR—and No. XIV is Wohanka heaviest fielder, WER. Sample No. XV, a Kleinwanzlebener grown at Rocky Ford. Samples No. XVI and XVII, variety known only by number, College Experiment Farm. Samples No. XVIII, XIX and XX, Original Kleinwanzlebener, grown at Rocky Ford.

As we have a number of samples from this locality, I will give the rainfall for the growing season: April 2.57, May 2.14, June 0.33, July 2.99, August 1.52, September 0.03 inches. I have not the times and dates when each of the fields represented by my samples was irrigated but of some I have a complete statement of the treatment received. The importance of rainfall, i. e., the part played by rain water in our crop raising, depends upon the supply of irrigating water at our command throughout the season. In some sections this supply is always good, in others it is not. It would be too much of a digression to go into the question of the effects of water supply or irrigation at various periods of the growing season at this time. The subject has been discussed in several of the earlier bulletins of this Station. The observations recorded pertain to the crop and sugar content and not to the composition of the beet in greater detail. So far as our present purpose is concerned it may suffice to state that my observations do not justify me in making any positive assertions apropos to the subject. It is self-evident that plants must have at least a certain minimum quantity of water to keep them in a state of health and active growth. So long as this condition is fulfilled it seems that it would not matter whether this moisture is supplied by irrigating water or rainfall. This statement assumes that the condition of the soil is taken into consideration and is one of the factors determining the amount of water necessary to keep the beet in good condition and actively growing. The question of water-supply and its distribution during the growing season must be constantly considered in the study presented herewith.

ANALYSES OF BEETS, ORDINARILY GOOD SOIL.

	XI.	XII.	XIII.	XIV.
Date of harvesting	Sept. 23, 1910.		Oct. 12, 1911	
Average weight of beets	....	....	673.1 grams	788.4 grams
	Percent	Percent	Percent	Percent
Sugar	14.20000	12.40000	15.80000	15.30000
Dry substance	20.20000	19.20000	23.05400	23.07000
Soluble ash	3.25800	....	2.21250	2.29660
Insoluble ash	0.92200	....	1.18750	1.08700
Crude ash in dry substance	4.18000	....	3.40000	3.38360
Crude ash in beet	0.84436	....	0.78384	0.78060
Pure ash in beet	0.65529	....	0.55421	0.53066
Sulfuric acid	0.02460	....	0.02482	0.02281
Phosphoric acid	0.05786	....	0.06693	0.05260
Chlorin	0.09597	....	0.01129	0.01302
Sodium	0.02994	....	0:00734	0.00846
Potassium	0.05509	....	....	....
Potassic oxid	0.29559	....	0.28105	0.27639
Sodic oxid	....	....	0.05057	0.05235
Calcic oxid	0.02339	....	0.03131	0.03569
Magnesic oxid	0.05749	....	0.07010	0.06355
Ferric oxid	0.00337	....	0.00817	0.00343
Aluminic oxid	0.00108	....	0.00042	0.00263
Magnanic oxid	0.00201	....	0.00143	....
Total nitrogen	0.12530	0.13760	0.14388	0.14124
Proteid nitrogen (Stutzer)	0.06660	0.06830	0.07524	0.07154
Ammonic nitrogen	0.00200	0.00230	0.00224	0.00226
Amid nitrogen	0.00350	0.00630	0.00554	0.00564
Amino nitrogen	0.02575	0.04711	0.03817	0.04506
Nitric nitrogen	0.00358	0.00786	0.00870	0.00503
Injurious ash per 100 sugar	3.52950	....	2.37390	2.43820
Injurious nitrogen per 100 sug.	0.37440	0.48953	0.38529	0.40393
Press Juice According to Ruempler.				
Total nitrogen	....	....	0.12665	0.11869
Albumin nitrogen	....	....	0.04918	0.04772
Propetone nitrogen	....	....	0.00245	0.00564
Peptone nitrogen	....	....	0.00685	0.00537

Ash Analyses.

	XXI.		XXII.		XXIII.	
	Crude	Pure	Curde	Pure	Crude	Pure
Carbon	none	.....	none	.....	none	.....
Sand	1.391	.....	1.568	.....	1.429	.....
Silicic acid	0.217	.....	0.605	.....	1.164	.....
Sulfuric acid	2.912	3.754	3.166	4.479	2.939	4.299
Phosphoric acid	6.850	8.830	8.537	12.076	6.775	9.911
Chlorin	11.359	14.641	1.440	2.037	1.677	2.453
Sodium	.....	4.569	.....	1.324	.....	1.595
Potassium	.....	8.407	.....	.....	.....	.....
Carbonic acid	19.821	.....	24.052	.....	26.268	.....
Potassic oxid	42.852	45.109	35.851	50.712	35.601	52.080
Sodic oxid	4.776	.....	8.136	9.124	8.210	9.863
Calcic oxid	3.832	4.928	3.994	5.650	4.597	6.725
Magnesic oxid	6.803	8.773	8.941	12.648	8.186	11.975
Ferric oxid	0.410	0.517	1.042	1.474	0.421	0.615
Aluminic oxid	0.128	0.165	0.054	0.076	0.331	0.484
Manganic oxid	0.238	0.307	0.283	0.400	.....	.....
Loss	(0.969)	.....	(2.656)	.....	(2.780)	.....
Sum	102.561	.....	100.325	.....	100.378	.....
Oxygen equi. to chlorin	2.561	.....	.325	.....	.378	.....
Total	100.000	100.000	100.000	100.009	100.000	100.000

ANALYSES OF BEETS, ORDINARILY GOOD SOIL.

	XV.	XVI.	XVII.
Date of harvesting	Sept. 23, 1910.	Oct. 11, 1910.	Oct. 11,1910
Yield per acre	10.09 tons	7.0 tons	......
Average weight of beets	568.0 grams	368.24 grams	440.2 grams
	Percent	Percent	Percent
Sugar	14.40000	13.20000	13.30000
Dry substance	20.50000	20.30000	19.90000
Soluble ash	3.69100	3.70100	....
Insoluble ash	1.40700	0.87000	....
Crude ash in dry substance	5.09800	4.57100	....
Crude ash in beet	1.04509	0.92790	....
Pure ash in beet	0.88724	0.64629	....
Sulfuric acid	0.03030	0.02889	....
Phosphoric acid	0.04147	0.07342	....
Chlorin	0.13544	0.00484	....
Sodium	0.08800	0.00314	....
Potassic oxid	0.42640	0.28551	....
Sodic oxid	0.02557	0.12858	....
Calcic oxid	0.04150	0.03579	....
Magnesic oxid	0.08492	0.08122	....
Ferric oxid	0.00409	0.00217	....
Aluminic oxid	0.00324	0.00070	....
Manganic oxid	0.00475	0.00202	....
Total nitrogen	0.15630	0.18636	....
Proteid nitrogen (Stutzer)	0.06600	0.09510	0.19810
Ammonic nitrogen	0.00277	0.00060	0.10030
Amid nitrogen	0.00563	0.00640	0.00280
Amino nitrogen	0.04125	0.03711	0.00797
Nitric nitrogen	0.01104	0.02138	0.04154
Injurious ash per 100 sugar	4.90010	3.41640	0.02067
Injurious nitrogen per 100 sugar	0.56875	0.63840	......
			0.65436
Press Juice According to Ruempler.			
Total nitrogen	not done	not done	not done
Albumin nitrogen			
Propetone nitrogen			
Peptone nitrogen			

Ash Analyses.

	XXIV. Crude	XXIV. Pure	XXV. Crude	XXV. Pure
Carbon	0.894	.....	0.553	.....
Sand	1.763	.....	1.792	.....
Silicic acid	1.652	.....	1.709	.....
Sulfuric acid	2.472	3.415	3.108	4.470
Phosphoric acid	3.383	4.674	7.895	11.360
Chlorin	11.042	15.256	0.521	0.749
Sodium	.....	9.918	.....	0.487
Carbonic acid	20.923	.....	24.941	.....
Potassic oxid	34.785	48.059	30.707	44.177
Sodic oxid	11.701	2.883	14.285	19.895
Calcic oxid	3.520	4.683	3.850	5.538
Magnesic oxid	6.928	9.571	8.736	12.567
Ferric oxid	0.334	0.461	0.255	0.336
Aluminic oxid	0.264	0.365	0.075	0.108
Manganic oxid	0.387	0.535	0.218	0.313
Loss	(2.387)	.....	(1.472)	.....
Sum	102.435	.....	100.117	.....
Oxygen equi. to chlorin.	2.435	.....	0.117	.....
Total	100.000	100.000	100.000	100.000

ANALYSES OF BEETS, ORDINARILY GOOD SOIL.

	XVIII.	XIX.	XX.
Date of sampling	3 Nov.	3 Nov.	3 Nov.
Yield tons per acre	11.6	11.6	....
Average weight of beets	497.0 grams	516.8 grams	575.1 grams
	Percent	Percent	Percent
Sugar in beet	14.30000	14.20000	12.70000
Dry substance in beet	19.90000	20.20000	20.00000
Crude ash in dry substance	4.51700	4.30200	4.99400
Crude ash in beet	0.89888	0.86900	0.99880
Pure ash in beet	0.63879	....	0.71760
Sulfuric acid	0.03130	....	0.03825
Phosphoric acid	0.04634	....	0.03342
Chlorin	0.04792	....	0.05755
Sodium	0.03276	....	0.03733
Potassic oxid	0.26374	....	0.23678
Sodic oxid	0.08661	....	0.17595
Calcic oxid	0.03533	....	0.03377
Magnesic oxid	0.09053	....	0.09956
Ferric oxid	0.00198	....	0.00247
Aluminic oxid	0.00155	....	0.00106
Manganic oxid	0.00082	....	0.00146
Total nitrogen	0.20605	0.21330	0.25215
Proteid nitrogen (Stutzer)	0.08070	0.07950	0.09045
Ammonic nitrogen	0.00290	0.00245	0.00535
Amid nitrogen	0.01495	0.01410	0.01966
Amino nitrogen	0.05231	0.05110	0.04794
Nitric nitrogen	0.01718	0.01984	0.04537
Injurious nitrogen in beet	0.10950	0.11725	0.13569
Injurious ash per 100 sugar	3.23300	....	3.70300
Injurious nitrogen per 100 sugar	0.75175	0.82571	1.07246

Press Juice According to Ruempler.

	XVIII.	XIX.	XX.
Total nitrogen	0.16775	0.18295	0.23855
Albumin nitrogen	0.04410	0.04070	0.04770
Propetone nitrogen	0.00175	0.00990	0.01350
Peptone nitrogen	0.00405	0.00030	....

Ash Analyses.

	XXVI.		XXVII.	
	Crude	Pure	Crude	Pure
Carbon	0.701	.....	Trace	.....
Sand	0.791	.....	0.918	.....
Silicic acid	0.744	.....	1.578	.....
Sulfuric acid	3.482	4.899	3.828	5.327
Phosphoric acid	5.155	7.254	3.348	4.659
Chlorin	5.332	7.503	5.750	8.002
Sodium	.....	4.867	.....	5.204
Carbonic acid	23.310	.....	25.500	.....
Potassic oxid	29.391	41.288	23.710	32.997
Sodic oxid	14.483	13.820	21.663	24.530
Calcic oxid	3.919	5.515	3.382	4.707
Magnesic oxid	10.072	14.173	9.970	13.875
Ferric oxid	0.220	0.310	0.248	0.345
Alumniic oxid	0.172	0.242	0.107	0.149
Manganic oxid	0.092	0.129	0.147	0.205
Loss	(3.389)	.....	(1.148)	.....
Sum	101.203	.....	101.297	.....
Oxygen equi. to chlorin	1.203	.....	1.297	.....
Total	100.000	100.000	100.000	100.000

Samples XI and XII were grown on a light, loamy, virgin soil with a scanty supply of either rain or irrigating water. The samples were gathered rather early in the season and the beets were still growing. The quality of these beets was, as the analyses show, really good; 14.2 percent sugar in sample XI and 13.8 percent as the average sugar content of the beets as harvested. The injurious ash per 100 parts of sugar was 3.53, which is perhaps a rather large amount, but I have been unable to find any statement relative to the permissible amount of injurious ash in beets or diffusion juices. The injurious nitrogenous substances, 3.74 parts per 100 of sugar, are quite low, in fact they are lower than in either the Michigan or Fort Collins beets which we tentatively adopted as standards of comparison. and as low as Andrlik's No. VI, which he judges as a good beet. An examination of the ash analysis shows the presence of a remarkably high percentage of chlorin; 14.641 percent in the pure ash. One might, perhaps, be justified in expecting to find a corresponding amount of sodic oxid but this constituent is quite low for our beets. In the ash of the Michigan beet both of these constituents are much lower but the soda in the ash of the Fort Collins beet is much higher. The soil on which these beets grew, like all of our semi-arid soils, is alkaline, but is not charged with alkali salts as we understand the term and as has been sufficiently explained in the preceding pages. We further observe that the ash, whether we consider the crude or the pure ash, is, compard with the figures given for foreign beets since 1890, higher by at least fifty percent than the figures given by Ruempler for beets grown without the application of kainite, and materially higher than the figures for those to which this salt was applied. They are also quite as much higher than the figures given by F. Strohmer and O. Fallada for Austrian beets grown with application of phosphoric acid, salt and sodic nitrate or ammonic sulfate and it is also materially higher than the Michigan and some of our Colorado beets. That our conditions are wholly different from Austrian conditions, for instance, is indicated by the fact that though the Austrian beets were grown on land to which an application of 9.2 pounds of salt per acre had been applied the chlorin in the pure ash of eleven samples, showed a maximum of 3.27 percent of chlorin, whereas the pure ash of these beets grown on virgin ground without the application of any fertilizer, shows the presence of 14.64 percent; on the other hand, the ashes of the Austrian beets show from 9.24 to 22.39 percent of sodic oxid, while the pure ash of these beets shows the presence of 6.15 percent which is calculated as metallic sodium in the statement of the analysis. The first thought is that sodic nitrate had been applied to the Austrian beets. This is true in the case of three out of eleven, and not true of the other eight; so the presence of such notable quantities of soda cannot be attributed to the action of the sodic nitrate. The chlorin in the ashes of the Austrian beets was not uniformally increased. We see that in six cases out of nine it was increased and in three it was not. These facts do not help us explain the large amount of chlorin which forms about 20.0 percent of the injurious ash in our samples.

The total nitrogen in these beets is low; 0.125 percent. The proteid nitrogen, precipitated by Stutzer's reagent, is relatively high for Colorado beets, the other forms of nitrogen, ammonic, amid, amino and nitric, are low. The nitric nitrogen, i. e., nitrogen present in the form of nitric acid, is present in many beets in traces only. Ruempler quotes Bresler as having found 0.0065 and 0.0039 percent in two samples of beets and states that Herzfeld found it only in traces. It is stated on the other hand that some French beets have been found to be relatively rich in it. This last fact has been attributed to their use of latrine as a manure.

The samples which we are discussing have been presented for the purpose of finding out as nearly as we may what kind of beets we are justified in expecting under our ordinary conditions of soil, climate and all the other things which constitute our agricultural conditions and one of these as I have shown in Bulletins 155, 160 and 178, is the frequent if not almost universal occurrence of very unusual amounts of nitrates in our soils.

In the case represented by analyses No. XI and XII we have beets grown on virgin soil under rather adverse cultural conditions, but the beets are very good in quality and the yield was 14 tons per acre.

Analyses XIII and XIV represent beets, varieties WZR and WER, grown on as good land as we have, with a good supply of water, good cultivation, and during a favorable season, 1911. We find the beets large in size, fairly rich in sugar, also in dry matter, low in ash, low in total nitrogen and low in injurious ash and injurious nitrogenous compounds; the former amounting to 2.37 and 2.44 and the latter to 3.85 and 4.04 parts per 100 parts of sugar. These are, according to the criteria adopted, excellent beets. The nitric nitrogen, however, is present in easily determinable quantities and is higher than that of the Michigan beets or those from Fort Collins grown in 1910. These are samples taken from the check plots of some experiments and we will return to them later and will discuss more fully the conditions under which they were grown.

Analysis XV represents beets grown in 1910 on an entirely different soil, a check plot in an experimental series. The soil is a calcareous clayey one somewhat difficult to manipulate. The water supply for this land is at all times abundant. The rainfall for the growing season, April to September, was 9.58 inches. The previous crop was beets. The attack of leaf-spot on the beets in this field was not more than mediumly severe. The reaction of this soil is alkaline, and the water-soluble in samples taken to represent the first, second and third foot of soil ranges from 0.1 to 3.655. The potash in the surface foot ranges from 0.68 to 0.95, in the second foot from 0.82 to 1.07, in the third foot from 0.48 to 0.93; the phosphoric acid ranges in the first foot from 0.11 to 0.82, in the second foot from 0.16 to 0.69, and in the third foot from 0.13 to 0.88. The humus nitrogen calculated on the soil was 0.073, 0.050 and 0.025 in the different samples of the surface foot, 0.040, 0.039 and 0.041 in the second foot, 0.051, 0.053 and 0.008 in the third foot. The lowest amount of lime in this soil was found in one of the samples from the third foot and was 4.18 percent. The magnesia amounts to about 1.5 percent, but in one sample representing the second foot it falls to 0.84 percent. The available potash exceeds 0.01 percent and the available phosphoric acid in the three surface samples taken one foot deep was 0.007, 0.003 and 0.010 percent. We have abbreviated these analyses, giving the essential chemical factors supposed to influence the growth of plants. It is usually assumed that, while the beet plant is a heavy feeder, its roots are not strong foragers, but unless we are led astray by our methods, there ought to be in this soil an ample supply of the chemical elements of plant food that they require, and I saw nothing in the crop to indicate the contrary.

This is the land on which the greater number of our fertilizer experiments were made and not being satisfied in regard to the results obtained the check plots were subsequently resampled in sections of one foot each to a depth of three feet. The samples were composite, each containing three sub-samples, and were submitted to the ordinary agricultural analysis with the following results:

ANALYSES OF SOIL EXPERIMENTAL PLOT, ROCKY FORD, COLO.

Plot 19—Sampled 20 July 1911.

	XXVIIa First foot Percent	XXVIIb Second foot Percent	XXVIIc Third foot Percent
Insoluble	59.035	56.078	52.436
Silicic acid	13.220	12.220	16.200
Sulfuric acid	0.108	0.173	0.477
Phosphoric acid	0.188	0.160	0.102
Chlorin	0.043	0.031	0.028
Carbonic acid	2.984	4.592	3.212
Potassic oxid	0.887	0.813	0.934
Sodic oxid	0.727	0.677	0.581
Calcic oxid	4.940	7.100	5.450
Magnesic oxid	1.436	1.257	1.630
Ferrous oxid	0.486	0.389	0.355
Ferric oxid	4.248	4.004	4.667
Aluminic oxid	5.228	5.787	6.366
Manganic oxid	0.100	0.100	0.150
Water at 100° C.	2.428	2.454	3.402
Ignition	3.628	3.464	3.446
Sum	99.686	99.299	99.436
Oxygen equi. to chlorin	0.009	0.007	0.006
Total	99.677	99.292	99.430
Total nitrogen	0.1080	0.0770	0.0630
Humus	0.9800	0.5920	0.5620
Humus nitrogen on soil	0.0530	0.0330	0.0370
Nitrogen in humus	5.4080	5.5740	7.0460
Humus N. on total N.	49.0750	42.8600	62.8600
Nitric nitrogen	0.0016	0.0002	0.0001
Water-soluble in soil	0.3590	0.3510	1.0500
Sulfuric acid in water soluble	Not det'd	Not det'd	46.5940
Calcic oxid in water soluble	Not det'd	Not det'd	24.6550

ANALYSES OF SOIL EXPERIMENTAL PLOT, ROCKY FORD, COLO.

Plot 38—Sampled 20 July 1911.

	XXVIId First foot Percent	XXVIIe Second foot Percent	XXVIIf Third foot Percent
Insoluble	58.983	47.486	48.168
Silicic acid	10.645	16.214	16.812
Sulfuric acid	0.213	1.826	1.689
Phosphoric acid	0.201	0.201	0.166
Chlorin	0.034	0.029	0.026
Carbonic acid	3.340	3.796	3.254
Potassic oxid	0.813	0.930	0.958
Sodic oxid	0.608	0.810	0.996
Calcic oxid	5.310	6.865	6.190
Magnesic oxid	1.619	1.693	1.708
Ferrous oxid	0.760	0.378	0.307
Ferric oxid	4.581	4.818	4.922
Aluminic oxid	6.100	6.037	7.080
Manganic oxid	0.155	0.265	0.255
Water at 100° C.	3.049	4.052	3.640
Ignition	2.938	3.956	3.146
Sum	99.349	99.384	99.317
Ogygen equi. to chlorin	0.008	0.007	0.006
Total	99.341	99.377	99.311
Total nitrogen	0.0960	0.0710	0.0480
Humus	0.9500	0.6500	0.5500
Humus nitrogen in soil	0.0460	0.0330	0.0360
Nitrogen in humus	4.8420	5.0770	6.5450
Humus N. in total N.	47.9200	46.4800	75.0000
Nitric nitrogen	0.0007	0.0001	0.0001
Water-soluble in soil	0.4180	3.3850	3.6550
Sulfuric acid in water-soluble	Not det'd	54.3100	53.8600
Calcic oxid in water-soluble	Not det'd	28.8400	25.3080

The analyses show an abundance of phosphoric acid, potash, lime and magnesia. The total nitrogen in the surface samples is just about the average for our soils. The ferrous oxid is very easily extracted with dilute hydric chlorid, but is wholly insoluble in water. It is probably present as a carbonate of iron. The ferrous salt is probably without effect on the character of the crop, for we find as much ferrous oxid in other soils which produce good beets under favorable conditions. The chlorin is not excessive, and the nitric nitrogen on the date of sampling was only moderately high, still there was the equivalent of 360 pounds of sodic nitrate in the surface foot of plot 19 on 20 July and 180 pounds in plot 38 taken to the same depth. While these quantities are comparatively small, they are, especially the 360 pounds, large enough to affect the quality of the beets. I mean by this, that if we should apply 360 pounds of sodic nitrate to an acre of beets on 20 July it would without doubt affect the quality of the crop. No attempt was made to study the variation of the amount of nitrates in this soil during the season but this was done for other fields by Mr. Zitkowski, whose results are given later.

The yield from this ground was not remarkable, 10.09 tons per acre, and the quality of the beet is fully shown by the analysis. The variety was the Fairfield. The sugar content was 14.4 percent, the injurious ash per 100 parts of sugar 4.9 parts, and the injurious nitrogenous compounds amounted to 5.69 parts. The total nitrogen is not particularly high but the ratio of injurious nitrogen is quite high, approximately 60.0 percent. The nitric nitrogen in these beets is decidedly higher than that in the Fort Collins standard beets. We have 0.01104 against 0.00096 percent. The ash of these beets shows a high percentage of chlorin, 15.25 percent of the pure ash or 0.13544 percent of the fresh beet. I leave the reader to classify such beets. I do not know, except in the most general way, how these beets worked in the factory, but we can safely assume that it was none too well.

Analyses XVI and XVII represent beets grown on the College Experiment Farm in 1910. The soil is to all appearances the same as that in which the samples of 1911 were grown. These samples show the maximum sugar content found during the season. The variety was given by number. The stand was good and the yield of roots was 7.0 tons per acre. The tops were frozen before the beets were harvested, about November 16, and their weight was not ascertained, but they were very heavy. The growth of the tops was luxuriant throughout the months of September, October and November till frozen. The accompanying photographs, Plate I, show the appearance of the field, also the size of the tops and the undesirable shape of the beets. If my information be correct, some of these

Plate I. Excessive foliage and small beet.

beets were irrigated once and some twice, but I could detect no difference at all in these plots. We observe that the dry matter is no more than average, if quite that, that the sugar is low, that the injurious nitrogen is high and that the nitric nitrogen was 0.02 percent of the fresh beet. The ash shows a rather large amount of both chlorin and soda. The land on which these beets grew is free from alkali and free from excessive water, it is, in short, excellent land, but the beets were poor in both crop and quality. Analyses XVIII, XIX and XX represent samples taken from check plots in other experiments of 1910. Analyses XVIII and XIX represent beets grown on the land chosen as a check plot for our experiments with nitrates. The samples taken from this plot throughout the season, however, were so erratic that I felt that it would be unwise to attach much, if any, importance to them, therefore, as a further check I took a sample from an adjacent piece of land which had not been fertilized at all. The land on which Nos. XVIII and XIX were grown had received a dressing of manure at the rate of 10 tons per acre, which had been plowed under to the depth of 10 inches. The previous crop on this land was beets without any fertilizer. This soil was submitted to a complete analysis, which will be given in another place. It contains potash 0.76, phosphoric acid 0.108, total nitrogen 0.11, which is fully an average for Colorado soils. The available plant food is quite sufficient, if not really abundant, for instance the available phosphoric acid in the samples taken the last of March amounted to 84 pounds per acre-foot, which is almost exactly one-fiftieth of the total. The soil is a light loam somewhat gravelly in spots. The soil on which the beets, represented by Analysis XX grew, was still lighter, almost sandy. Our analyses show that these samples are all poor in quality, not only is the sugar from medium to low in percentage, but the injurious nitrogen compounds are decidedly high, 7.5, 8.3 and 10.7 parts for each 100 parts of sugar.

In considering the quality of these beets as indicated by their composition it is not enough to consider them as samples grown on apparently good ground without the application of any fertilizer, but we must also bear in mind that they are grown in different sections of the state, some of them quite distant from one another. This happens to be the case with the pair XI and XII and the pair XIII and XIV. The former pair was grown about 172 miles south and 162 miles east or about 240 miles in a straight line southeast of the latter and at an elevation of almost 2,000 feet less. These factors added to the differences in soils, water-supply, preparation of ground and subsequent cultivation forbid that we should draw our conclusions with too great a degree of confidence; but, at the same time, they lend weight to those features of inferiority which are common to all of the samples and indicate their independence of these factors. It is for the purpose of avoiding misapprehensions that I have given, at the risk of being prolix, so many details. On the other hand,' the number of samples and the various locations serve to give us a correct idea of the character of the beets that we are justified in expecting under favorable conditions and they show that these favorable conditions are not confined to the northern section of the state and the higher altitudes. While the sample of Fort Collins beets grown in 1910 with 18.3 percent sugar was undoubtedly an excellent beet as are also the College samples grown in 1911, they are no better beets than the samples grown on virgin soil in the extreme eastern portion of the Arkansas Valley, but still in Colorado, in fact, except in the percentage of sugar shown, the Arkansas Valley sample is somewhat the better, especially in regard to the amount of injurious nitrogenous substances present. Compared with the College samples of 1910 the Arkansas Valley sample is decidedly the superior one. The reader who is not familiar with the conditions in this section of the Arkansas Valley cannot appreciate the force of these facts. In this case we have samples of beets grown under very different conditions with the advantage, according to our universally accepted criteria, cultivation, supply of moisture, fertility of the soil, absence of hot drying winds, absence of fungus troubles, etc., in favor of the less advantageous returns in both crop and quality; to be specific the College crop in 1910 was 7.0 tons per acre and that on freshly broken sod land in the Arkansas Valley was 14 tons. The maximum sugar found in a field sample of the college beets was 13.3 percent, the average of the Arkansas Valley beets in load lots as delivered to the factory, was 13.8, with a maximum of 16.0 percent. The College samples show 5.7 and 6.4 parts of injurious nitrogenous substances to each 100 of sugar, while the Arkansas Valley sample shows 3.7 parts. Even two of the samples chosen as standards for our purposes, the Michigan and Colorado samples, show 0.51 and 0.63 parts injurious nitrogen. As we have given some College beets grown in 1911, it is perhaps of interest to state that the section of the Arkansas Valley under consideration produced in 1911 the best beets of any section of the state so far as my information goes. The tonnage was moderate but the sugar content averaged better than 17.5 percent and the beets worked exceptionally easily in the factory. The new lands in the Arkansas Valley produce now, as the lands about Rocky Ford did prior to 1905, excellent beets. If we consider in this connection the additional analyses XV, XVIII, XIX and XX, we find further suggestive facts. If we consider only the two factors, percentage of sugar and injurious nitrogenous compounds, these facts will become sufficiently evident. In analysis XV we have 14.4 percent sugar and 5.7 parts injurious nitrogenous compound per 100 parts sugar. While this is lower in sugar than our adopted standards with 15.3 and 18.3 it is almost as low as the lower one of them in injurious nitrogen. Analysis XVIII indicates a decidedly poor beet, while analyses XIX and XX are decidedly poorer still, particularly analysis XX, which is both low in sugar and rich in injurious nitrogenous substances, 10.7 parts per 100 sugar.

It appears from these samples that excellent beets can be produced in widely separated sections of the state but as a fact our soils do not uniformly, even under favorable conditions, produce beets of good quality, but on the contrary some of them are of decidedly bad quality. In regard to the different forms of nitrogen present we observe that the nitrogen precipitated by Stutzer's reagent, even though we know that it may carry down some amids, is low, whether we calculate it on the fresh beets or on the total nitrogen. The ammonic, amid and amino nitrogen appears to have very nearly the same ratio to the total nitrogen as I find given by others for German beets. The nitric nitrogen, however, is present in all of the analyses in noticeable quantities. As already stated this form of nitrogen has been found in some abundance in French beets. The maximum which I have found is in an analysis quoted from Ed. Urban by Ruempler in which 25.25 percent of the total nitrogen was present in this form. Ruempler further states that Bresler found only from 1.6 to 2.35 percent of the total nitrogen in the form of nitric nitrogen and that Herzfeld found in general only traces. We have in the Colorado and Michigan beets adopted as standards 0.46 and 1.4 percent of the total nitrogen present as nitrogen in the form of nitric acid; in analysis XI we have it corresponding to 2.8 percent of the total, in XIII we have 6.0 percent and we find it increasing in the series of samples till in analysis XX it amounts to 18.0 percent of the total. None of these samples were grown on manured or fertilized land except XVIII and XIX; these had received ten tons of stockyard manure per acre, which had been plowed under to a depth of ten inches. Analysis XIX shows the presence of nitric nitrogen equivalent to 9.3 percent of the total. Perhaps Analyses XVIII and XIX should have been omitted from this list, but they represent a check plot, in our experiments with nitrates of which they received none, but owing to the peculiar results obtained with samples from this ground, Sample No. XX was taken, as already explained as a further control.

We conclude that under favorable soil conditions the Colorado beet grown without the application of fertilizers is as good a beet as the beets of the other states or countries, that is that it contains as much sugar and as little injurious nitrogen. Concerning the injurious ash we are not so certain, for I have nowhere found any definite statement of the permissible amount in a good beet. In Andrlik's Sample No. V, which he indicates as a poor beet, the injurious ash amounts in the beet to 2.75 parts per 100 parts of sugar. Andrlik, however, appears to base his opinion of his beet wholly upon the amount of injurious nitrogen present. If this amount of injurious ash in the beet, 2.75 parts per 100 of sugar, be the permissible limit, our beets are as a rule too high in these ash constituents.

On the other hand I think that the relatively large amounts of injurious nitrogen compounds per 100 parts of sugar, shown by Analyses XV to XX indicate a tendency on the part of our soils to produce a low quality of beet. I further think that this tendency and its cause is indicated by the high percentage of nitrogen present as nitric acid.

THE EFFECTS OF FERTILIZERS.

We have already recorded the results obtained in a number of experiments with manure, sodic nitrate, superphosphate, potassic sulfate and two forms of lime, singly and in combination upon the sugar content and yield of beets. We were unable to determine that there was a sufficently uniform and favorable result produced to justify the use of any one or any combination of them. The question presented in the following paragraphs deals only with the composition of the beets grown irrespective of the yield of either beets or sugar.

In the preceding paragraphs we have shown that while our soil and climate may produce excellent beets we do not always harvest such, in fact, it is the decided deterioration of the general crop that has taken place in the Arkansas Valley since about 1904 that determined us to undertake this study in the hope of finding out the cause and discovering a remedy.

We have seen that some of our beets are decidedly low in quality and if this be due to the lack of proper plant food or the presence of plant food in improper ratios an investigation into the effects produced by the fertilizers mentioned may give us some hints at least how the crops may be bettered in quailty whether it is economically feasible or not.

ANALYSES BEETS GROWN WITH FERTILIZERS.

	XXVIII.	XXIX.	XXX.	XXXI.
Fertilizer per acre 1909	20 tons $CaCO_3$	250 P, 170 K	250 P, 170 K, 100 N	110 P, 130 K
Fertilizer per acre 1910	None	800 K	400 P	160 K, 100 N
Yield 1910	11.3 tons	10.11 tons	10.86 tons	11.70 tons
Date of sampling,	11 Oct.	11 Oct.	11 Oct.	11 Oct.
	Percent	Percent	Percent	Percent
Sugar in beet	14.60000	14.50000	14.10000	14.10000
Dry substance in fresh beets	20.90000	21.30000	19.70000	20.60000
Crude ash in dry substance	5.00900	4.96800	5.62600	6.49700
Crude ash in beet	1.04688	1.05718	1.10932	1.33838
Pure ash in beet	0.78047	0.81278	0.81556	1.05870
Sulfuric acid	0.02771	0.03257	0.03055	0.05118
Phosphoric acid	0.03477	0.06122	0.04848	0.10615
Chlorin	0.12746	0.14657	0.12489	0.24613
Sodium	0.08288	0.09520	0.08114	0.16004
Potassic oxid	0.37996	0.34494	0.39215	0.54874
Sodic oxid	0.00677	0.02517	0.01845	0.07745
Calcic oxid	0.03812	0.02822	0.03237	0.04873
Magnesic oxid	0.07073	0.07202	0.07642	0.09066
Ferric oxid	0.00489	0.00392	0.00491	0.00286
Aluminic oxid	0.00309	0.00073	0.00291	0.00445
Manganic oxid	0.00410	0.00213	0.00323	0.00203
Total nitrogen	0.12895	0.12320	0.10875†	0.21900
Proteid nitrogen (Stutzer)	0.07175	0.06660	0.06250	0.07495
Ammonic nitrogen	0.00100	0.00145	0.00560	0.00315
Amid nitrogen	0.00215	0.00320	0.00305	0.00620
Amino nitrogen	0.03700	0.03621	0.04071	0.03957
Nitric nitrogen	0.01034	0.00250	0.00987	0.01333
Injurious nitrogen in beet	0.05405	0.05195	0.03760	0.13470
Injurious ash per 100 sugar	4.27940	4.44450	4.59000	7.68430
Injurious nitrogen per 100 sug.	0.37020	0.35827	0.27288	0.95531

Ash Analyses.

	XXXVIII.		XXXIX.		XL.		XLI.	
	Crude	Pure	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	0.809	.....	1.482	.....	1.295	.....	0.490	.....
Sand	1.041	.....	0.794	.....	1.612	.....	0.371	.....
Silicic acid	1.419	.....	1.208	.....	1.935	.....	0.630	.....
Sulfuric acid	2.647	3.551	3.081	4.008	2.754	3.755	3.025	3.824
Phosphoric acid	3.321	4.455	5.791	7.533	4.370	5.944	6.273	7.931
Chlorin	12.175	16.331	13.864	18.036	11.258	15.313	14.546	18.390
Sodium	.....	10.619	.....	11.714	.....	9.948	.....	11.958
Carbonic acid	19.678	.....	18.117	.....	18.865	.....	16.981	.....
Potassic oxid	36.294	48.683	32.628	42.445	35.350	48.084	32.429	40.999
Sodic oxid	11.310	0.868	14.525	3.097	11.524	2.262	17.318	5.786
Calcic oxid	3.641	4.884	2.669	3.472	2.918	3.969	2.880	3.641
Magnesic oxid	6.756	9.062	6.812	8.861	6.889	9.370	5.358	6.773
Ferric oxid	0.467	0.626	0.371	0.483	0.443	0.603	0.169	0.214
Aluminic oxid	0.295	0.395	0.061	0.090	0.262	0.356	0.263	0.332
Manganic oxid	0.392	0.526	0.201	0.261	0.291	0.396	0.120	0.152
Loss	(2.502)	.....	(2.517)	.....	(2.775)	.....	(2.431)	.....
Sum	102.747	.....	103.129	.....	102.541	.....	103.283	.....
Oxygen equi. to chlorin	2.747	.....	3.129	.....	2.541	.....	3.283	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

*$CaCO_3$ indicates factory waste lime and CaO burnt lime.
†Probably too low, though the duplicates agree very well.

ANALYSES BEETS GROWN WITH FERTILIZERS.

	XXXII.	XXXIII.	XXXIV.	XXXV.
Fertilizer per acre 1909	110 P 130 K 200 N	20 tons manure 110P, 200N	4 tons CaO 20 tons manure 110P, 130K, 200N	4 tons CaO 250P 170K 200N
Fertilizer per acre 1910	240P, 100N	220P, 400N	220 P, 260K	250P,170K,200N
Yield 1910	12.60 tons	14.57 tons	11.9 tons	11.59 tons
Date of sampling,	11 Oct.	11 Oct.	11 Oct.	11 Oct.
	Percent	Percent	Percent	Percent
Sugar in beet	12.40000	13.60000	14.70000	13.70000
Dry substance in fresh beet	18.80000	21.60000	22.00000	20.10000
Crude ash in dry substance	6.38600	5.66500	5.25400	6.32600
Crude ash in beet	1.20049	1.22364	1.15588	1.25344
Pure ash in beet	0.95270	0.93754	0.91227	0.93368
Sulfuric acid	0.02906	0.04297	0.04374	0.03690
Phosphoric acid	0.06469	0.09006	0.08181	0.04795
Chlorin	0.17743	0.13328	0.14213	0.14732
Sodium	0.11823	0.08666	0.09241	0.09579
Potassic oxid	0.43681	0.43050	0.41904	0.42362
Sodic oxid	....	0.02321	0.01593	0.04788
Calcic oxid	0.04255	0.03405	0.03231	0.04062
Magnesic oxid	0.07596	0.08873	0.07940	0.08284
Ferric oxid	0.00379	0.00261	0.00310	0.00647
Aluminic oxid	0.00265	0.00485	0.00175	0.00084
Manganic oxid	0.00152	0.00062	0.00103	0.00350
Total nitrogen	0.15345	0.23270	0.17150	0.17940
Proteid nitrogen (Stutzer)	0.07175	0.08040	0.08705	0.07000
Ammonic nitrogen	0.00315	0.00710	0.00275	0.00230
Amid nitrogen	0.00620	0.01650	0.00925	0.00935
Amino nitrogen	0.03957	0.02622	0.03421	0.04171
Nitric nitrogen	0.01333	0.00832	0.00865	0.01244
Injurious nitrogen in beet	0.07233	0.12870	0.07245	0.09775
Injurious ash per 100 sugar	6.14200	5.26920	4.85200	5.48550
Injurious nitrogen per 100 sug.	0.58334	0.94632	0.62047	0.71351

Ash Analyses.

	XLII. Crude	XLII. Pure	XLIII. Crude	XLIII. Pure	XLIV. Crude	XLIV. Pure	XLV. Crude	XLV. Pure
Carbon	0.500	.....	0.640	.....	0.355	.....	0.509	.....
Sand	0.582	.....	0.747	.....	0.727	.....	0.679	.....
Silicic acid	1.006	.....	1.391	.....	1.003	.....	1.507	.....
Sulfuric acid	2.421	3.051	3.512	4.584	3.748	4.794	2.944	3.952
Phosphoric acid	5.389	6.792	7.360	9.606	7.078	8.968	3.822	5.131
Chlorin	14.780	18.626	10.892	14.216	12.296	15.580	11.753	15.779
Sodium	.....	12.412*	.....	9.243	.....	10.130	.....	10.253
Carbonic acid	18.061	.....	17.890	.....	17.327	.....	20.572	.....
Potassic oxid	37.077	45.853	35.182	45.917	36.252	45.934	33.797	45.374
Sodic oxid	12.481	.....	12.437	2.476	12.117	1.706	14.115	5.128
Calcic oxid	3.544	4.466	2.783	3.632	2.795	3.541	3.241	4.351
Magnesic oxid	6.327	7.974	7.252	9.465	6.869	8.703	6.609	8.874
Ferric oxid	0.316	0.398	0.213	0.278	0.268	0.340	0.516	0.693
Aluminic oxid	0.221	0.278	0.396	0.517	0.151	0.191	0.067	0.090
Manganic oxid	0.127	0.160	0.051	0.066	0.089	0.113	0.279	0.375
Loss	(0.503)	.....	(1.712)	.....	(1.700)	.....	(2.243)	.....
Sum	103.335	.....	102.458	.....	102.775	.....	102.653	.....
Oxygen equi. to chlorin	3.335	.....	2.458	.....	2.775	.....	2.653	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

*Includes 0.736 of potassium.

ANALYSES BEETS GROWN WITH FERTILIZERS.

	XXXVI.	XXXVII.
	4 tons CaO,	
Fertilizer per acre 1909........ 200 N	200 N	200 N 200 N
Fertilizer, pound per acre 1910	400P, 300K, 200N	500P, 400K, 200N
Yield 1910	12.0 tons	13.16 tons
Date of sampling	Oct. 11,1910	Oct. 11, 1910
	Percent	Percent
Sugar in the beet	15.30000*	13.30000
Dry substance in fresh beet	21.00000	20.10000
Crude ash in dry substance	5.03700	6.55600
Crude ash in fresh beet	1.05777	1.31776
Pure ash in fresh beet	0.79850	1.04090
Sulfuric acid	0.03315	0.03345
Phosphoric acid	0.04286	0.07948
Chlorin	0.12475	0.19978
Sodium equi. to chlorin	0.08112	0.12990
Potassic oxid	0.36291	0.45641
Sodic oxid	0.03507	0.02261
Calcic oxid	0.03764	0.03447
Magnesic oxid	0.07399	0.07865
Ferric oxid	0.00042	0.00237
Aluminic oxid	0.00474	0.00372
Manganic oxid	0.00179	0.00000
Total nitrogen	0.13760	0.17770
Proteid nitrogen (Stutzer)	0.06745	0.08035
Ammonic nitrogen	0.00145	0.00290
Amid nitrogen	0.00320	0.00720
Amino nitrogen	0.03621	00.3141
Nitric nitrogen	0.00250	0.01846
Injurious nitrogen in beet	0.06550	0.08725
Injurious ash per 100 sugar	4.16340	6.33200
Injurious nitrogen per 100 sugar	0.42810	0.65603

Ash Analyses.

	XLVI.		XLVII.	
	Crude	Pure	Crude	Pure
Carbon	0.690	.....	5.254	.....
Sand	0.460	.....	0.446	.....
Silicic acid	1.111	.....	1.039	.....
Sulfuric acid	3.134	4.152	2.538	3.213
Phosphoric acid	4.052	5.369	6.031	7.635
Chlorin	11.794	15.624	15.161	19.195
Sodium	.....	10.159	.....	12.481
Potassium	.....	.....	.....	.....
Carbonic acid	20.147	.....	18.334	.....
Potassic oxid	34.309	45.451	34.635	43.850
Sodic oxid	13.646	4.393	14.995	2.173
Calcic oxid	3.526	4.714	2.616	3.312
Magnesic oxid	6.995	9.267	5.968	7.556
Ferric oxid	0.040	0.053	0.180	0.228
Aluminic oxid	0.448	0.593	0.282	0.357
Manganic oxid	0.170	0.225	.....	.....
Loss	(2.103)	.....	(0.942)	.....
Sum	102.661	.....	103.421	.....
Oxygen equi. to chlorin	2.661	.....	3.421	.....
Total	100.000	100.000	100.000	100.000

*This is higher than the factory average by 1.2 percent and is the highest percentage of sugar found in beets from this field during the season. There were eight beets in the sample. The sample is probably not representative.

The effects of these fertilizers upon the weight of crops, the apparent coefficients of purity, and the amount of sugar produced have been given on page 19. These plots were harvested during the week or ten days subsequent to the taking of these samples and there is considerable evidence that marked changes took place in some of the plots. The samples from one of the plots, Number 24, from which the first sample was taken 6 Sept., showed a fairly uniform increase till 11 Oct., when they showed 13.2 and 13.6 percent sugar. Five days later a sample showed 15.5 percent. The plot was harvested and the beets delivered to the factory 18 Oct. and averaged 15.35 percent sugar, apparent purity 84.45. Other plots also showed increases, but no other one to such an extent as number 24. Our samples of 11 Oct. agreed with the factory averages, as well as samples of the size taken could be expected to agree, with two exceptions.

A set of eleven samples had already been taken 23 Sept. The results obtained by determining the injurious nitrogen in these are, with one exception, concordant in showing a great improvement in the quality of the beets. One sample shows a very surprising degree of improvement, but the determination of total nitrogen is apparently too low, which is mentioned in the tables. The following statement of the injurious nitrogenous compounds (injurious N x 10) in the beets on 23 Sept. and 11 Oct. may serve to indicate the changes that took place in the beets during this interval.

Injurious nitrogenous compounds per 100 of sugar in beets grown on the respective plots and sampled on the following dates:

	23 Sept. 1910	11 Oct. 1910
1	7.13	6.20
2	11.50	9.55
3	9.73	5.83
4	6.37	6.57
5	12.75	4.28
6	3.51	3.58
7	6.34	2.73
8	4.84	5.69
9	9.10	3.70
10	7.50	7.13

We see that in one case our results show an increase of 0.85 part injurious nitrogenous substances for each 100 pounds of sugar. This difference may be due to variation in the samples. We further see that in Number 5 of the table there was a remarkable improvement. This may be true, it may also be party due to the difference in the samples taken and also, which is less likely, to analytical errors.

The beets grown on this land are apparently high in injurious ash from 4.1 to 7.7 parts for each 100 of sugar, but this does not seem to be due to the action of the fertilizers though the highest amount, 7.7 parts, is found in the case of beets grown on a plot which had received 160 pounds of potassic sulfate and 100 pounds sodic nitrate per acre. On the other hand, beets from plots which had received heavier applications than this contained less than beets grown on plots which had received no fertilization. The irregularity of the results does not admit of any definite conclusion.

The apparent coefficient of purity for the beets from all of the plots ranged from 79.0 to 85.0 as they were harvested, and from 79.0 to 86.0 for the samples as taken on 11 Oct. excepting one sample which was very low. The plot on which this sample was grown had received a dressing of 120 pounds superphosphate and 50 pounds sodic nitrate.

The percentage of chlorin in the ash of the beets from these fertilized fields is high in comparison with the available data relative to the amount of chlorin in the sugar beet. According to Wolff quoted by Ruempler the average amount in beets prior to 1871 was 0.04000, ten years later it had fallen to 0.03060 percent. The average obtained at the Halle Experiment Station was nearly the same from 0.0260 to 0.0420. The maximum given by Ruempler for chlorin in fresh sugar beets is 0.242 percent, calculated on the basis of 80 percent water in the beet. In the six analyses previously quoted from Andrlik the maximum is 0.038 percent. In the Michigan beets we found 0.0029 and in our standard Fort Collins beets 0.0194 percent, but in the beets grown on this land we find the minimum to be 0.124 and the maximum 0.246 percent of the fresh beet.

The fact that our beets are apt to be rich in chlorin was shown by our earlier analyses, 1898, at which time mention was made of this fact. While manure in some experiments which we made clearly increased the amount of chlorin taken up by the beets, the high chlorin in these cases cannot be wholly attributed to the fertilizers used, for the beets from our check plot are as high in chlorin as those grown with fertilizers. The water soluble chlorin in this soil was, in the surface foot (three samples) 0.008, in the second foot 0.012, 0.013 and 0.014, and in the third foot 0.021 and 0.015 percent. These analytical results indicate not far from 1500 pounds of chlorin per acre taken to a depth of three feet, or about 2500 pounds of ordinary salt. The molassegenic properties of sodic chlorid seems to be beyond question. This quantity of salt, if it has any value as a fertilizer for beets, was perhaps more than sufficient to be of the highest advantage. The extent to which soda salts were appropriated by the by the plants shows very plainly when we consider the composition of the pure ash in which we see that sodic chloril makes up from 23. to 32. percent of the total.

The phosphoric acid in all of the samples except in the ash of the Michigan beet and in that of our standard Fort Collins beet is very low. This is exhibited plainly in the statement of the crude and even more so in that of the pure ash. The total phosphoric acid in this soil, not taking that applied to the various plots into account, was not far from 5,000 pounds per acre-foot, while the citric acid soluble for the three samples taken to represent the surface foot of soil gave 120, 280 and 400 pounds per acre foot and the succeeding two feet were well supplied. In addition to this natural supply, phosphoric acid was applied in quantities varying from zero to sixty-five pounds per acre. We cannot therefore attribute the low percentage of phosphoric acid in the ash to a lack of phosphoric acid in the soil nor to its being unavailable. We shall return to this subject briefly in a later paragraph.

We find that the injurious nitrogenous substances present in these beets are rather high. In twenty-four samples given by Andrlik, Jahres-Bericht der Zuckerfabrikation 1907 pp. 18-20 we find the range from 2.8 to 6.48 parts to 100 parts of sugar with only three samples with 6 parts or more. Of these twenty-four samples, eighteen were grown with application of farmyard manure and four with various amounts of superphosphate, potash salts, and Chile-saltpetre. Our samples show that the best ones in respect to the amount of injurious nitrogen, were those grown without any fertilizer or with potassic sulphate or superphosphate applied separately.

We have seen by the results on pages 17 and 19 that the general effects of fertilizers, applied in the quantities given, are decidedly disappointing. This is not due to the time or manner of application, for these were in accord with the practice which experience has approved as the best. Further it was not due to indifferent or insufficient cultivation, nor to a lack of water, nor to any untoward condition such as an unfavorable season or an attack of insects or of fungi. The leaf-spot was present, but its attack on these plots was not very severe. The data presented in the preceding paragraphs are intended to show a further and different purpose, i. e., to show whether any of these fertilizers or combinations of them have produced favorable effects upon the quality of the beets which is so decidedly beneficial that the interpretation is plain and beyond doubt. I think that we can safely conclude that they have not; on the contrary, it seems that we must conclude that the results obtained in these fertilizer experiments when compared with those obtained with beets grown without fertilizers, do not justify us in trying to ameliorate our conditions by these means. There are a number of things, it is true, to be taken into consideration in interpreting our results, some of which I have already stated, but which I repeat because of their importance. First: differences due to locality; this means that the localities are so remote from one another that the climatic conlitions are sufficiently different to constitute a factor in the results. Second: differences in soils. Third: differences in varieties of beets, or strains of seed used, and there are still others. While it is beyond my power to eliminate these factors, we can, I think, avoid attaching too much importance or too little importance to them, and also desist from making an excuse of them to explain things which we do not understand. We know that the climatic conditions of the Poudre Valley are very different from those of the Eastern part of the state, which lies in the Arkansas Valley, but we have already seen that this latter section of the state does produce excellent beets, not only in regard to high sugar content, but also in regard to their content of injurious ash and nitrogen. It has been proved that droughty conditions increase both the total and the injurious nitrogen in beets, but we have scarcely any better beets than have been grown in this section of the state and it follows that in considering our results, especially of 1910, we cannot justly appeal to climatic conditions as affording the explanation for adverse results which we cannot otherwise explain.

The chemical composition of the soil on which these experiments were made is given in full in connection with Analysis XV, which is a sample from one of the check plots in this series which received no fertilizer in either 1909 or 1910. The statements relative to the composition of this soil are based upon a series of fifteen analyses. I may state that this soil yields a solution with hydrochloric acid which shows the presence of ferrous salts, but not a trace when treated with water. On panning a portion of the soil no iron sulfids could be detected, only a black sand. No sulfuretted hydrogen could be detected on treatment with hydrochloric acid and lead paper. The coarse sand is composed of quartz and felspar. It seems probable that the ferrous compound present is a carbonate, siderite, possibly in combination with the calcic or magnesic carbonate, ankerite or mesitite. There is lime carbonate enough present to give a rather lively effervescence.

The available potash in 4,000,000 pounds of the surface foot of this soil was 400 pounds, of the second foot from 120 to 320 and of the third foot from 160 to 640 pounds. The phosphoric acid available in this amount of soil from the surface foot was 120, 280 and 400 pounds. The humus nitrogen calculated in like manner gives us from 1,000 to 2,000 pounds for the first foot, 1,600 pounds for the second foot and from 320 to 2,000 pounds for the third foot. Taking the average of available potash and phosphoric acid in the three sets of samples taken to a depth of three feet we obtain a supply, soluble in citric acid solution, of 773 pounds of potash and 796 pounds of phosphoric acid per acre. If we assume one-quarter of the humus nitrogen to be or to become available during the season, we have 980 pounds of nitrogen. The average yield of fresh beets for the ten plots was 11.98 tons per acre. The plant food necessary to grow 44 tons of fresh beets, practically four such crops as that actually harvested from these fields, is according to Hoffman, 320.5 pounds of potash, 157.8 pounds phosphoric acid and 345.2 pounds of nitrogen, and according to Strohmer, Briem and Fallada it is considerably less, 260.2 pounds potash, 79.4 pounds of phosphoric acid and 276.2 pounds of nitrogen. Wimmer found that about 98 pounds of soluble phosphoric acid produced this amount of beets most advantageously. It would be wholly without object to calculate how many crops the plant food in the surface three feet of this soil on the day of sampling would have sufficed to grow. All that the figures are presented for is to show that the land at the beginning of these experiments was sufficiently well supplied with plant food to have grown better crops. There is no reason that I know of to suppose that there was an injuriously large supply unless the amount of injurious ash for each 100 pounds of sugar be considered as indicating such a condition, but a comparison of Analyses XV and XXVIII with the analyses from XXXI to XXXVII inclusive, does not clearly justify such a conclusion. If anything is shown by these analyses, it is that the application of fertilizers other than potash and phosphoric applied separately has not only failed to consistently and materially increase the crop, but has actually decreased its quality so that we have a direct answer to our main inquiries. First: That the increase in crop is neither certain enough nor sufficient to justify the application of fertilizers experimented with. Second: That the quality of the beets was deleteriously rather than beneficially affected, except in two cases in which potash and phosphoric acid were applied separately.

These results are in harmony with others obtained in this state by previous experimenters, but we are not in harmony with results obtained in other states and countries. The important thing to us is that we would have little or no reason to hope for any improvement in volume and quality of our crops by the application of fertilizers even if they were at our command at prices which our people could afford.

Analysis XVIII represents beets grown with no fertilizer other than stockyard manure, 10 tons per acre, plowed under to a depth of 10 inches, while No. XX was grown on a sandy soil without any fertilizer. The water supply for this land was good in 1910. In addition to this there was a rainfall of more than 9 inches during the growing season, April to October. The quality of the beets in Analysis XX is decidedly bad so far as injurious nitrogen is concerned. It is a known fact that beets which have suffered from lack of water, drought, are poorer in quality than beets grown with plenty of water, and that beets grown on light and sandy lands are more susceptible to the influence of this condition than those grown on heavier lands. It is possible that the lightness of the land on which the beets of Analysis XX were grown may have detrimentally influenced their composition, but it was not due to a scarcity of water. The injurious nitrogenous substances for each 100 pounds of sugar in these samples were respectivey 7.5 and 10.72, the latter of which is a larger quantity than we find in the beets grown with fertilizers which show 9.46 and 9.55 parts as maxima. While the injurious nitrogen in the beets grown on the fertilized plots is undoubtedly high and was probably increased by the fertilizers used, it is not safe to conclude that these beets were lower in quality than beets grown on other lands without the application of fertilizers, for this seems not to be the case. The total nitrogen in the analyses so far given, made to include the nitric nitrogen, is not high. The total nitrogen in Analysis XXX may be considered as exceptionally low and neglected. still the total nitrogen in the other samples is not high: On the contrary it is lower than the analyses quoted from Andrlik and, as a rule, lower than the few determinations of total nitrogen that I have found given for beets in general. So far I have given twenty-one analyses of Colorado beets, in only five has the total nitrogen amounted to 0.2 percent and the maximum is 0.252 percent. Of the five samples showing 0.2 percent or more of nitrogen only one was a good beet, i. e., the one grown near Fort Collins, the others were all poor beets. These twenty-one samples of beets were grown both with and without the application of fertilizers. The total nitrogen in these samples is low rather than high and the ratio of the proteid nitrogen as determined by Stutzer's method, to the total nitrogen is often quite low, though the proteid nitrogen given by this method is apt to be too high. In the samples quoted from Andrlik, we find this ratio higher. It is as follows for the six samples given:

RATIO PROTEID TO TOTAL NITROGEN IN BEETS GIVEN BY ANDRLIK.

Number of Analysis	Total Nitrogen in Beet	Proteid Nitrogen	Ratio of Proteid to Total Nitrogen	Injurious Nitrogen per 100 Sugar
1.........	0.257	0.113	43.9	0.684
2.........	0.252	0.112	44.4	0.672
3.........	0.210	0.110	52.4	0.554
4.........	0.199	0.107	53.7	0.492
5.........	0.306	0.120	39.2	0.828
6.........	0.186	0.109	58.6	0.403

Andrlik makes no comment on the quality of these beets except to say that No. 5 is a bad beet while No. 6 is a good one. The data here given do not agree exactly with Andrlik's. He gives for the injurious nitrogen 0.930 instead of 0.828 and 0.37 instead of 0.409. Concerning the intermediate beets he makes no classification so we are left to determine where the dividing line between good and poor beets falls, so far as the injurious nitrogen per 100 of sugar is concerned. In other articles he apparently considers an amount of injurious nitrogen larger than 0.370 as objectionable as beets grown without the application of fertilizers contain as little as 0.280 injurious nitrogen per 100 sugar and when this was raised to 0.370 by the application of fertilizers he considered their influence deleterious. I therefore infer that we are safe in considering a beet carrying more than 0.450 injurious nitrogen per 100 of sugar as doubtful in quality and 0.9 or more as decidedly poor.

We will state these data in tabular form for the Colorado samples previously discussed.

RATIO PROTEID TO TOTAL NITROGEN IN COLORADO BEETS.

Number of Analysis	Total Nitrogen in Beet	Proteid Nitrogen	Ratio of Proteid to Total Nitrogen	Injurious Nitrogen per 100 Sugar
VIII	0.2075	0.0871	41.9	0.629
XI	0.1253	0.0666	53.1	0.374
XII	0.1376	0.0683	51.0	0.489
XIII	0.1439	0.0752	52.2	0.385
XIV	0.1412	0.0715	50.7	0.404
XV	0.1563	0.0660	43.0	0.569
XVI	0.1864	0.0951	51.1	0.638
XVII	0.1981	0.1003	50.6	0.654
XVIII ...	0.2061	0.0807	36.4	0.752
XIX	0.2133	0.0795	37.4	0.826
XX	0.2522	0.0905	36.0	1.073
XXVIII ..	0.1290	0.0718	55.0	0.370
XXIX ...	0.1232	0.0666	54.0	0.350
XXX	0.1088	0.0625	57.3	0.279
XXXI ...	0.2190	0.0750	34.2	0.955
XXXII ..	0.1538	0.0718	47.0	0.583
XXXIII ..	0.2330	0.0804	34.5	0.946
XXXIV ..	0.1715	0.0871	50.8	0.620
XXXV ...	0.1794	0.0700	39.0	0.714
XXXVI ..	0.1376	0.0675	49.0	0.428
XXXVII .	0.1778	0.0804	45.4	0.656

In considering the quality of these beets it is to be remembered that the injurious nitrogen is only one of the three criteria whereby we are to judge, the other two are the percentage of the sugar and the amount of injurious ash. Of these beets number VIII is the only one grown in 1910 that carries more than 15.3 percent sugar and less than 3.0 parts injurious ash per 100 of sugar, so while it is inferior to some of the other beets in respect to the injurious nitrogen contained, it is one of the best beets in the list. Of the remaining twenty samples, sixteen are from the Arkansas Valley and four from the College Experiment Farm at Fort Collins, two grown in 1910, which are decidedly poor beets, having one good quality in a moderate degree and two samples grown in 1911 which are of good quality. All of the Arkansas Valley samples were grown in 1910 and some of them are excellent beets, but some of them are very bad beets, for instance Number XX which had 12.7 percent sugar, 013669 percent injurious nitrogen in the fresh beet or 1.073 parts injurious nitrogen equal to 10.73 parts injurious nitrogenous matter per 100 parts of sugar.

I believe that the table faithfully represents the characteristics of the Arkansas Valley beets—i. e., low sugar, as a rule, low total nitrogen, a low ratio for the proteid nitrogen, a high content of injurious nitrogen, and a liberal amount of injurious ash. Our experiments with fertilizers do not give us much, if any, reason for expecting to either profitably increase the quantity or quality of our crops by their use. This is the important feature of our experiments. We may not be able to give a satisfactory explanation of the fact, but this is the finding of several independent experimenters. The only fertilizers claimed by any one to have produced good results are farmyard manure and nitrate of soda. I think that there is a general agreement in regard to the former but not in regard to the latter. It is altogether probable that favorable results have been obtaind by the use of sodic nitrate but this does not seem to have been the general result. The few favorable results obtained were probably due to conditions, which if known, were not mentioned. In the series of experiments given phosphoric acid and potash were combined with the nitrate, in the hope that we might obtain the good effects of the nitrate and neutralize its known bad effects. Our results have been given in detail and they are indifferent both in crop and quality The conviction has prevailed for a long time that sodic nitrate exercises an injurious action on the quality of the sugar beet, but this has been questioned as we will see later.

Up to the present, I have aimed to give beets grown under favorable conditions so that we might learn as far as possible what is a good crop and a good quality of beet with us. I think that the beets grown on the prairie land in the Arkansas Valley and the beets grown near Fort Collins in 1910 and also those grown on the College Farm in 1911 are good beets, the last being the best. They were taken 11 Oct. and showed 23.0 percent of dry matter, 15.8 percent sugar, 2.37 parts injurious ash and 3.85 of injurious nitrogenous matter per 100 sugar. But 1911 seems to have been an extremely favorable year. In 1910 the samples from the Arkansas Valley, taken 23 Sept. were also good though grown under somewhat adverse conditions. Dry matter 20.2, sugar 14.2, injurious ash 3.5 parts per 100 sugar and injurious nitrogenous matter 3.74 parts per 100 sugar. Our adopted standard grown in 1910 near Fort Collins gave us dry matter 24.2, sugar 18.3, injurious ash 2.197 parts per 100 sugar, injurious nitrogenous matter 6.29 parts per 100 sugar. Analyses XVIII, XIX and XX of beets grown under favorable conditions are indifferent or bad in quality, especially XX, which gave us dry matter 20.0, sugar 12.7, injurious ash per 100 sugar 3.7, injurious nitrogenous matter per 100 sugar 10.72 parts.

This is the poorest sample of beets grown on good land that we have analyzed, but we have others that are also decidedly poor, for instance our College samples grown in 1910 with dry matter 20.3, sugar 13.2, injurious ash per 100 sugar 3.42, injurious nitrogenous substances per 100 sugar 6.38. Some of the characteristics of these beets in regard to the relative quantities of the different nitrogenous groups have already been given, but there is another question which may be of importance in the general problem presented, i. e., why were the beets of the Arkansas Valley of such indiffernt or poor quality from 1904 to 1910 inclusive? They were very good prior to 1904. They were so far as our records show very good for a period of at least 8 years.

The nitrogen present in sugar beets in the form of nitric acid or nitrates is usually so small that its determination is attended with difficulty or is impracticable. What has been considered as exceptional quantities have been found in some French sugar beets. In the analyses already given we see that the nitric nitrogen varies from 0.00096 percent in the Fort Collins beets grown in 1910 to 0.04537 percent in a sample grown on good but unfertilized land in the Arkansas Valley.

While there are differences of opinion as to the effects of nitrates upon the sugar beet, I think that it is universally agreed that one effect is to prolong the vegetative period of the plant and retard its maturation, and if applied too late in the season to produce poor, green beets at harvest time. Until the last few years only general statements to this effect were made but in recent years investigations have gone further and ascertained that the nitrates increase the injurious nitrogen in beets and this is true in the case of an application of 525 pounds of sodic nitrate per acre, applied in three portions of 175 pounds each.

As elsewhere stated, the fact that I have found very large amounts of nitrates present in our soils and the further observation that the beets in the fields as they were harvested and taken to the factory appeared to be green, and further, because the juices in the factory indicated immaturity of the beets, I inferred that the presence of the nitrates in the soil was related to these facts as cause to effect. I arrived at this conclusion several years ago before the investigations of recent years had become available to me.

One of the most serious features of our problem is that it is not a question of a few pounds of nitrogen applied by or before the end of June or the early part of July, but of an unknown, often a large amount of nitrogen, furnished in July and August, of which fact we will adduce, in the proper place, what I believe to be conclusive evidence.

THE EFFECTS OF NITRATES.

We have already noticed that the nitric nitrogen in our beets is higher than that which we have found recorded except in the case of French beets, which showed the presence of 0.049 percent of nitric nitrogen as against 0.045 percent in Analysis XX. One question which we set ourselves was to ascertain on a larger scale what the effect of sodic nitrate is upon beets grown under our conditions and thus to find out whether the nitrates actually produce the conditions which we have found in our crops during the time given. To ascertain this, a piece of choice land was selected, land which was known to produce at least average crops of good beets. This land had been dressed with ten tons stockyard manure per acre. We selected six acres, five for the application of sodic nitrate and one to serve as a check plot. The unit quantity applied was 250 pounds. Each of the five plots received an application just before seeding, four weeks later four of the plots and four weeks later three of the plots received a dressing and so on till the fifth plot had received five dressings. Plot I received one application of 250 pounds 28 March; Plot 2 received two applications (500 lbs.) 28 March; and 1 June; Plot 3 received three applications (750 lbs.) 28 March, 1 June and 22 June; Plot 4 received four applications (1,000 lbs.) 28 March, 2 May, 1 June and 22 June; Plot 5 received five dressings (1,250 lbs.) 28 March, 2 May, 1 June, 22 June and 27 July. Irrigations applied 9 April, 16 June, 1 July, 9 July, 29 July, 17 August one-half of the land, and on 30 August the other half. All of the fields were sprayed with standard Bordeaux mixture to combat the leaf-spot. No. 1 as follows: 21 July, 1, 21 and 31 August and 7 September. No. 2 same as No. 1. No. 3, 22 July, 3, 13 and 28 August and 8 September. No. 4, 22 July, 16 and 28 August and 8 September. No. 5, 23 July, 16 and 28 August and 9 September. The total rainfall during the growing season was 9.9 inches. The beets received careful cultivation and the soil was kept in good condition.

The harvesting of these beets gave the following returns:

	Lbs. Sodic Nitrate	Tons Beets	Percent Sugar	Purity
Field 1........	250	16.85	14.50	83.7
Field 2........	500	15.52	14.25	82.0
Field 3........	750	14.94	13.18	79.5
Field 4........	1000	14.99	14.23	83.6
Field 5........	1250	15.96	13.83	82.2
Field 6........	None	14.47	14.90	84.5

These results do not agree throughout with the results obtained on the small samples taken for our laboratory purposes. The samples from Field 6 were anomalous throughout the season, so much so that the only object that I have in giving the results is for the sake of giving a complete record.

There were three series of samples taken of these beets, 23 September, 11 October and 3 November 1910. The third series was subjected to the fullest examination and is the most important, but the first two series will be given by themselves. They will enable us to obtain a better view of the development of the beet.

ANALYSES XLVIII TO LXIX, INCLUSIVE.

Samples Taken 23 Sept. 1910.

	Percent Sugar	% Dry Matter	Total Nitro.	Proteid Nitrogen	Ammonic Nitrogen	Amid Nitrogen	Amino Nitrogen	Nitric Nitrogen
Field 1...	14.5	19.7	0.19455	0.07345	0.01080	0.00915	0.03408	0.01820
	16.4	21.5	0.16930	0.07835	0.00460	0.01120	0.04165	0.00204
Field 2...	14.0	19.8	0.15855	0.07435	0.00645	0.00935	0.04880	0.00907
	13.7	19.7	0.20530	0.07900	0.00760	0.01258	0.02243	0.02201
Field 3...	13.8	19.4	0.25790	0.08157	0.00650	0.02245	0.04660	0.02798
	12.2	19.0	0.27810	0.08560	0.01130	0.01960	0.04228	0.04365
Field 4...	11.6	15.2	0.27573	0.08935	0.01225	0.02385	0.05755	0.03806
	12.3	17.1	0.28965	0.08270	0.00860	0.01240	0.04040	0.04110
Field 5...	12.3	17.6	0.21655	0.08155	0.00780	0.02005	0.03095	0.02500
	12.4	13.1	0.23180	0.07350	0.00895	0.02055	0.03893	0.02015
Field 6...	12.2	18.2	0.22475	0.08880	0.00780	0.02360	0.04198	0.01956
	14.4	19.7	0.15060	0.07690	0.00330	0.00555	0.03583	0.01096

ANALYSES LX TO LXXI, INCLUSIVE.

Samples Taken 11 Oct. 1910.

	Percent Sugar	% Dry Matter	Total Nitro.	Proteid Nitrogen	Ammonic Nitrogen	Amid Nitrogen	Amino Nitrogen	Nitric Nitrogen
Field 1...	16.5	17.5	0.16355	0.07465	0.00230	0.00890	0.07695	0.00925
	16.5	21.2	0.14915	0.06595	0.00155	0.00765	0.05414	0.00760
Field 2...	15.5	21.0	0.17133	0.08010	0.00275	0.00790	0.06478	0.00501
	16.3	22.6	0.22405	0.08900	0.00375	0.01285	0.05215	0.00941
Field 3...	15.8	22.1	0.25365	0.08790	0.00673	0.01960	0.06847	0.02026
	13.0	20.2	0.29395	0.09135	0.01120	0.02823	0.05366	0.04646
Field 4...	12.3	19.9	0.28390	0.09335	0.00680	0.02466	0.07186	0.04653
	12.4	19.8	0.25556	0.09395	0.00443	0.01920	0.07220	0.05051
Field 5...	12.6	18.6	0.28175	0.08590	0.00630	0.08030	0.03149	0.05404
	13.2	19.8	0.21180	0.09080	0.00345	0.01255	0.03504	0.03846
Field 6...	14.0	22.1	0.19740	0.07495	0.00245	0.00820	0.03670	0.02666
	15.4	22.2	0.19380	0.09450	0.00315	0.01165	0.04020	0.01800

Some of these beets, Fields 1 and 2, show that the beets had improved some during the 18 days between the two samplings. The sugar and dry substances had increased, the proteid nitrogen had increased, while the total nitrogen had decreased. Fields 3, 4 and 5, however, which had received respectively 750, 1,000 and 1,250 pounds of sodic nitrate per acre, showed no material improvement as measured by the percentage of injurious nitrogen in the beets on the respective dates.

	23 September	11 October
Field 3..................	0.15449	0.15180
Field 4..................	0.16811	0.14854
Field 5..................	0.11798	0.10713

The maximum decrease in injurious nitrogen in these three fields as represented by the averages of the six pairs of samples taken is only 0.02 percent. The maximum increase in the average percentage of sugar in any two pairs of samples is 1.2; which, considering that there were two pairs of samples from each field, is a very small maximum difference. The other two differences were 0.4 and 0.5 percent. On 23 Sept. the beets in Field 1 had already attained an average of 15.45 percent; those in Field 2 increased from 13.85 to 15.9 percent, an increase of 2.1 percent. These facts indicate that the beets in Field 1, to which 250 pounds of sodic nitrate had been applied, were well advanced toward maturity on 23 Sept., and as subsequent results showed, had reached their maximum by 11 Oct., while those in Field 2, to which 500 pounds of sodic nitrate had been applied in two equal portions, were later in maturing than the beets in field one, but had reached their maximum by 11 Oct. The beets in fields 3, 4 and 5 to which 750, 1,000 and 1,250 pounds in applications of 250 pounds each had been applied, were maturing only very slowly. The final laboratory samples were taken 3 Nov. and the results obtained with them are given in the following tables.

ANALYSES OF BEETS GROWN WITH APPLICATION OF NITRATES.

	LXXII	LXXIII	LXXIV	LXXV
	Field 1	Field 1	Field 2	Field 2
Date of sampling	3 Nov.	3 Nov.	3 Nov.	3 Nov.
Sodic nitrate per acre	250 lbs.	250 lbs.	500 lbs.	500 lbs.
Yield tons per acre	16.85	16.85	15.52	15.52
	Percent	Percent	Percent	Percent
Sugar in beets	15.70000	16.50000	15.30000	15.80000
Dry matter in fresh beets	21.30000	22.40000	21.40000	21.60000
Crude ash in dry matter	3.57200	3.33400	4.03700	4.75100
Crude ash fresh beet	0.76084	0.74682	0.86392	1.02622
Pure ash in fresh beet	....	0.51948	....	0.72592
Sulfuric acid	....	0.02595	....	0.03798
Phosphoric acid	....	0.03750	....	0.06096
Chlorin	....	0.02292	....	0.03099
Sodium	....	0.01490	....	0.02011
Potassic oxid	....	0.20800	....	0.30551
Sodic oxid	....	0.06222	....	0.11181
Calcic oxid	....	0.04301	....	0.04188
Magnesic oxid	....	0.09787	....	0.10766
Ferric oxid	....	0.00286	....	0.00301
Aluminic oxid	....	0.00226	....	0.00257
Manganic oxid (br.)	....	0.00199	....	0.00344
Total nitrogen	0.14470	0.14485	0.18225	0.20535
Proteid nitrogen (Stutzer)	0.06480	0.07465	0.07805	0.08010
Ammonic nitrogen	0.00190	0.00245	0.00200	0.00346
Amid nitrogen	0.00930	0.00765	0.01025	0.01500
Amino nitrogen	0.05103	0.04549	0.04613	0.02002
Nitric nitrogen	0.00181	0.00144	0.01658	0.01009
Injurious nitrogen in beet	0.06870	0.06010	0.09195	0.10679
Injurious ash per 100 sugar	....	2.12670	....	3.20500
Injurious nitrogen per 100 sug.	0.43758	0.36424	0.60051	0.68221
Press Juice According to Ruempler.				
Total nitrogen	0.11890	0.11905	0.16856	0.18690
Albumin nitrogen	0.03750	0.03750	0.04270	0.04270
Propeptone nitrogen	0.00275	0.00400	0.00035	0.00375
Peptone nitrogen	0.00185	0.00190	0.00480	0.00290

Ash Analyses.

	LXXXIV		LXXXV	
	Crude	Pure	Crude	Pure
Carbon	0.621	.....	0.345	.....
Sand	2.026	.....	1.375	.....
Silicic acid	1.804	.....	1.678	.....
Sulfuric acid	3.475	4.996	3.701	5.232
Phosphoric acid	5.021	7.218	5.940	8.397
Chlorine	3.069	4.412	3.020	4.269
Sodium	.....	2.868	.....	2.776
Carbonic acid	24.053	.....	24.178	.....
Potassic acid	27.852	40.042	29.770	42.083
Sodic oxid	11.020	11.978	13.440	15.401
Calcic oxid	5.759	8.279	4.081	5.769
Magnesic oxid	13.105	18.840	10.491	14.831
Ferric oxid	0.383	0.550	0.293	0.411
Aluminic oxid	0.303	0.435	0.250	0.353
Manganic oxid	0.266	0.382	0.335	0.474
Loss	(1.936)	.....	(1.784)	.....
Sum	100.693	.....	100.681	.....
Oxygen equi. to chlorin	0.693	.....	0.681	.....
Total	100.000	100.000	100.000	100.000

ANALYSES OF BEETS GROWN WITH APPLICATION OF NITRATES.

	LXXVI	LXXVII	LXXVIII	LXXIX
	Field 3	Field 3	Field 4	Field 4
Date of sampling	3 Nov.	3 Nov.	3 Nov.	3 Nov.
Sodic nitrate per acre	750 lbs.	750 lbs.	1,000 lbs.	1,000 lbs.
Yield, tons per acre	14.94	....	14.99	....
	Percent	Percent	Percent	Percent
Sugar in beets	15.30000	13.40000	13.40000	11.00000
Dry matter in fresh beets	20.80000	20.60000	20.00000	71.60000
Crude ash in dry matter	4.62400	5.82700	4.99200	6.23600
Crude ash in fresh beet	0.96179	1.20036	0.99840	1.10764
Pure ash in fresh beet	....	0.82238	....	0.74440
Sulfuric acid	....	0.03987	....	0.03435
Phosphoric acid	....	0.03588	....	0.02373
Chlorin	....	0.07050	....	0.06768
Sodium	....	0.04584	....	0.04401
Potassic oxid	....	0.30088	....	0.21865
Sodic oxid	....	0.18359	....	0.23728
Calcic oxid	....	0.03933	....	0.03273
Magnesic oxid	....	0.09951	....	0.08064
Ferric oxid	....	0.00496	....	0.00299
Aluminic oxid	....	Trace	....	0.00163
Manganic oxid (br)	....	0.00181	....	0.00058
Total nitrogen	0.22480	0.29610	0.26660	0.25505
Protein nitrogen (Stutzer)	0.08560	0.09080	0.07870	0.07525
Ammonic nitrogen	0.00420	0.00543	0.00590	0.00363
Amid nitrogen	0.01496	0.02666	0.02283	0.02186
Amino nitrogen	0.05176	0.07438	0.06110	0.04983
Nitric nitrogen	0.02006	0.04143	0.04008	0.06285
Injurious nitrogen in beet	0.12004	0.17321	0.16017	0.15431
Injurious ash per 100 sugar	....	4.78120	....	5.47180
Injurious nitrogen per 100 sug.	0.78456	1.29250	1.19561	1.40267
Press Juice According to Ruempler.				
Total nitrogen	0.18600	0.27065	0.25740	0.24760
Albumin nitrogen	0.04085	0.04580	0.04365	0.04120
Propeptone nitrogen	0.00100	0.00560	0.00780	0.00870
Peptone nitrogen	0.00560	0.00400	0.00120	0.00210

Ash Analyses.

	LXXXVI		LXXXVII	
	Crude	Pure	Crude	Pure
Carbon	2.417	.....	0.537	.....
Sand	0.690	.....	1.798	.....
Silicic acid	1.911	.....	1.503	.....
Sulfuric acid	3.321	4.847	3.073	4.615
Phosphoric acid	2.989	4.363	2.123	3.188
Chlorin	5.873	8.572	6.055	9.092
Sodium	.....	5.574	.....	5.912
Carbonic acid	25.836	.....	28.199	.....
Potassic oxid	25.066	36.587	19.558	29.371
Sodic oxid	20.437	22.324	26.529	31.876
Calcic oxid	3.297	4.812	2.928	4.397
Magnesic oxid	8.290	12.100	7.214	10.833
Ferric oxid	0.413	0.602	0.268	0.402
Aluminic oxid	Trace	Trace	0.146	0.219
Manganic oxid	0.150	0.219	0.063	0.095
Loss	(0.689)	.....	(1.372)	.....
Sum	101.324	.....	101.366	.....
Ogygen equi. to chlorin	1.324	.....	1.366	.....
Total	100.000	100.000	100.000	100.000

ANALYSES OF BEETS GROWN WITH APPLICATION OF NITRATES.

	LXXX	LXXXI	LXXXII	LXXXIII
	Field 5	Field 5	Field 6	Field 6
Date of sampling	3 Nov.	3 Nov.	3 Nov.	3 Nov.
Sodic nitrate per acre	1250 lbs.	1250 lbs.	....	....
Yield, tons per acre	15.96	15.96	14.47	14.47
	Percent	Percent	Percent	Percent
Sugar in beets	12.80000	14.70000	14.20000	14.30000
Dry matter in fresh beet	19.80000	21.60000	20.20000	19.90000
Crude ash in dry beet	4.92800	3.97400	4.30200	4.51700
Crude ash in fresh beet	0.97574	0.85837	0.86900	0.89888
Pure ash in fresh beet	0.68028	0.58881	....	0.63879
Sulfuric acid	0.03147	0.03335	....	0.03130
Phosphoric acid	0.02434	0.02208	....	0.04634
Chlorin	0.04389	0.01953	....	0.04792
Sodium	0.02854	0.01269	....	0.03276
Potassic oxid	0.25473	0.22820	....	0.26374
Sodic oxid	0.15964	0.12244	....	0.08661
Calcic oxid	0.03838	0.04353	....	0.03533
Magnesic oxid	0.09282	0.09773	....	0.09053
Ferric oxid	0.00358	0.00423	....	0.00198
Aluminic oxid	0.00122	0.00334	....	0.00155
Manganic oxid (br)	0.00166	0.00169	....	0.00082
Total nitrogen	0.25360	0.19140	0.21330	0.20605
Proteid nitrogen (Stutzer)	0.08475	0.07980	0.07950	0.08070
Ammonic nitrogen	0.00366	0.00315	0.00245	0.00290
Amid nitrogen	0.02246	0.01726	0.01410	0.01495
Amino nitrogen	0.05241	0.05837	0.05110	0.05231
Nitric nitrogen	0.04225	0.00949	0.00949	0.01984
Injurious nitrogen in beet	0.14273	0.09719	0.11725	0.10750
Injurious ash per 100 sugar	4.04900	3.51170	....	3.10430
Injurious nitrogen per 100 sug.	1.11510	0.66115	0.82571	0.71591
Press Juice According to Ruempler.				
Total nitrogen	0.23380	0.17820	0.18295	0.16775
Albumin nitrogen	0.04795	0.04005	0.04070	0.04410
Propetone nitrogen	0.01180	0.01060	0.00990	0.00170
Peptone nitrogen	....	0.00030	0.00030	0.00400

Ash Analyses.

	LXXXVIII		LXXXIX		XC	
	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	0.540	.....	0.588	.....	0.701	.....
Sand	1.882	.....	3.418	.....	0.791	.....
Silicic acid	1.563	.....	1.460	.....	0.744	.....
Sulfuric acid	3.225	4.626	3.880	5.656	3.482	4.899
Phosphoric acid	2.495	3.579	2.572	3.750	5.155	7.254
Chlorin	4.498	6.452	2.275	3.317	5.332	7.503
Sodium	.....	4.196	.....	2.156	.....	4.867
Carbonic acid	26.052	.....	25.827	.....	23.310	.....
Potassic oxid	26.106	37.445	26.586	38.756	29.341	41.288
Sodic oxid	20.300	23.467	16.256	20.794	14.483	13.820
Calcic oxid	3.933	5.641	5.077	7.401	3.919	5.515
Magnesic oxid	9.513	13.645	11.386	16.598	10.072	14.173
Ferric oxid	0.367	0.526	0.492	0.718	0.220	0.310
Aluminic oxid	0.125	0.179	0.389	0.567	0.172	0.242
Manganic oxid (br)	0.170	0.244	0.197	0.287	0.092	0.129
Loss	(0.245)	.....	(0.110)	.....	(3.389)	.....
Sum	101.014	.....	100.513	.....	101.203	.....
Oxygen equi. to chlorin	1.014	.....	.513	.....	1.203	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000

The samples already presented represent three classes of beets, all grown upon supposedly good ground. The first class was grown without fertilization of any sort. It is not hereby intimated that they are, because of this fact, to be considered as good beets. The second class was grown with application of various fertilizers to see if any combination used would materially improve the quantity and quality of the crop. In this place the quality alone is considered, the crop has already been stated. The third class was grown with the application of different quantities of sodic nitrate to determine what its effect upon the quality of the crop may be. The land chosen was the best available. The results obtained with the beets grown on the check plot in this case differed so little from those obtained with the application of nitrates that a sample was taken from an adjacent field, but this proved to be one of the poorest samples of all.

As we have given the nitrogen compounds precedence over the injurious ash, we will bring together the results obtained so far and it will make plain how the results stand. For this purpose we will give the total nitrogen, the nitric nitrogen, the injurious nitrogen in the beet and the injurious nitrogen per 100 parts of sugar.

FIELDS NOT FERTILIZED.

No. of Analysis	Total Nitrogen	Nitric Nitrogen	Injurious Nitrogen in Beet	Injurious Nitrogen per 100 of Sugar
VII	0.22915	0.00320	0.07854	0.51287
VIII	0.20750	0.00090	0.11520	0.62899
XI	0.12530	0.00358	0.05320	0.37440
XII	0.13760	0.00786	0.06070	0.48953
XIII	0.14388	0.00870	0.06086	0.38529
XIV	0.14128	0.00530	0.09180	0.40393
XV	0.15630	0.01104	0.08190	0.56875
XVI	0.18636	0.02138	0.08426	0.63840
XVII	0.19810	0.02067	0.08703	0.65436
XVIII	0.20605	0.01718	0.11725	0.82571
XIX	0.21330	0.01984	0.10750	0.75175
XX	0.25215	0.04537	0.13660	1.07246

EXPERIMENTS WITH FERTILIZERS.

No. of Analysis	Fertilizers *used	Total Nitrogen	Nitric Nitrogen	Injurious Nitrogen in Beet	Injurious Nitrogen per 100 of Sugar
XV	None	0.15630	0.01104	0.08190	0.56875
XXVIII	None	0.12895	0.01034	0.05405	0.37020
XXIX	150 K	0.12320	0.00250	0.05195	0.35827
XXX	200 P	0.10875	0.00987	0.03760	0.27288
XXXI	160 K, 100 N	0.21900	0.01333	0.13470	0.95531
XXXII	240 P, 100 N	0.15345	0.01333	0.07233	0.58334
XXXIII	220 P, 400 N	0.23270	0.00832	0.12870	0.94632
XXXIV	220 P, 260 K	0.17150	0.00865	0.07245	0.62047
XXXV	400 P, 300 K, 200 N	0.13760	0.00250	0.06550	0.42810
XXXVII	500 P, 400 K, 200 N	0.17770	0.08725	0.08725	0.65603

*K indicates potassic sulfate 48.55 percent K_2O; P, superphosphate 13.19 P_2O_5; N. sodic nitrate 96.60 $NaNO_3$.

EXPERIMENTS WITH SODIC NITRATE.

Samples Taken 11 Oct. 1910.

No. of Analysis	Fertilizers *used	Total Nitrogen	Nitric Nitrogen	Injurious Nitrogen in Beet	Injurious Nitrogen per 100 of Sugar
LX	250 N	0.16355	0.00925	0.07770	0.46019
LXI	250 N	0.14915	0.00760	0.07400	0.44849
LXII	500 N	0.17133	0.00501	0.08058	0.51984
LXIII	500 N	0.22405	0.00941	0.11845	0.72668
LXIV	750 N	0.25365	0.02026	0.13942	0.88237
LXV	750 N	0.29395	0.04646	0.16317	1.25520
LXVI	1,000 N	0.28390	0.04653	0.15909	1.29340
LXVII	1.000 N	0.25556	0.05051	0.13798	1.11275
LXVIII	1.250 N	0.28175	0.05404	0.10925	0.86705
LXIX	1,250 N	0.21180	0.03846	0.10500	0.79543
LXX	None	0.19740	0.02666	0.11180	0.79856
LXXI	None	0.19380	0.01800	0.08450	0.54905
Samples Taken 3 Nov. 1910.					
LXXII	250 N	0.14470	0.00181	0.06870	0.43758
LXXIII	250 N	0.14485	0.00144	0.06010	0.36424
LXXIV	500 N	0.18225	0.01658	0.09195	0.60051
LXXV	500 N	0.20053	0.01009	0.10679	0.68221
LXXVI	750 N	0.22484	0.02006	0.12004	0.78456
LXXVII	750 N	0.29610	0.04143	0.17321	1.29250
LXXVIII	1,000 N	0.26660	0.04008	0.16017	1.19561
LXXIX	1,000 N	0.25505	0.06285	0.15431	1.40267
LXXX	1,250 N	0.25360	0.04225	01.4273	1.11510
LXXXI	1,250 N	0.19140	0.00949	0.09719	0.66115
LXXXII	None	0.21330	0.00949	0.11725	0.82571
LXXXIII	None	0.20605	0.01984	0.10750	0.71591
XX	None	0.25215	0.04537	0.13660	1.07246

Analysis XX represents beets grown on a favorably located piece of land, a rather light sandy loam. This land lies immediately west of that on which we made the experiments with sodic nitrate and the sample was taken less than 200 feet west of the west end of our experimental fields. The sample was taken, because the samples taken from our check field on 23 Sept. and 11 Oct. revealed the fact that they were not consistent with themselves and that our second sample from Field 5 and first sample from Field 6, though taken about 54 feet apart, agreed much more nearly than the two samples from Field 5, which were taken within 27 feet of one another and had received 1,250 pounds of sodic nitrate per acre, whereas Field 6 had received none.

We attempted to determine the nitric nitrogen in Field 6 at stated intervals throughout the season. The field was reported flooded on 6 July and so wet on 10 Aug., eleven days subsequent to the last preceding irrigation, that samples could not be taken. I feared that the results obtained with the samples from Field 6, which lay a little lower than Field 5, might have been due to accidental causes whereby the beets might have been supplied with nitrates carried from the adjacent, higher-lying portion of Field 5. This may not have been the case but the results led me to fear that it might be, so I took the sample represented by Analysis XX, which could not have been affectd in any way by the nitrate applied to our plots. The soil samples taken throughout the season were shallow ones and at no time showed an excessive amount of nitrates.

There are no data known to me definitely showing how much nitric nitrogen is usually present in a good beet, but judging from the amount of nitric nitrogen found in samples of Bohemian molasses there could not have been a determinable quantity in the beets themselves. This assumes of course that the whole of the nitric nitrogen passes into the diffusion juices and is not destroyed during their treatment. This is in accord with the observation of others in regard to nitrates in beets, except in regard to French beets which have been found to contain appreciable quantities of nitric nitrogen. The maximum that I have found given for French beets is 0.049 percent. The sample was taken on 30 Oct. and contained 16.97 percent sugar. This is different from our beets, for we find less sugar with such percentages of nitric nitrogen. No statement is made as to whether the beets were grown with or without fertilizers. We always determined the nitric nitrogen as nitric oxid and absorbed it in a solution of ferrous chlorid, so our results are not too high. In the beets grown without fertilizers we find the nitric nitrogen constituting in the different samples, 8.3, 9.3, 10.4, 11.6 and 18.0 percent of the total nitrogen. The lowest percentages shown by the table are 0.434 Fort Collins beets, 1.397 Michigan beets, and 2.857, beets grown on new sod land near Holly in the Arkansas Valley. The sample of Montana beets shows no nitric nitrogen.

The ratio of injurious nitrogen to the sugar falls in three instances to desirably low limits, in six it is moderately high and in three it is, I think we may say, decidedly objectionable. I know of no reason why Analysis XX should not be considered in this group though the sample is quite bad; sugar 12.7, proteid nitrogen 35.82 percent of the total, amino nitrogen 0.04794, nitric nitrogen 0.04537 percent of the beet, injurous ash 3.7 per 100 sugar and injurious nitrogen 1.07246 per 100 sugar, or the latter multiplied by 10 gives 10.7246 parts injurious nitrogenous substances for each 100 of sugar.

These results obtained with beets grown on good land without the application of fertilizers give us the range in the quality of the beets which we must expect to meet with under our best conditions.

The experiments with fertilizers were made in the Arkansas Valley on land which we have already described in connection with Analysis XV, wherewith we also gave its general composition. The available plant food in it is given in the discussion of Analyses XXVIII to XXXVII. The results as shown by this statement of the relations of the different nitrogen factors indicate that a slight improvement was effected by potassic sulfate and superphosphate when applied separately, for the beets grown with the application of these fertilizers are something better in quality than those grown without any fertilizer. I have elsewhere stated that results on contiguous half-acre parcels of this land varied so greatly, that one becomes doubtful as to the value of any result. Nevertheless this appears to be the fact, i. e., that phosphoric acid and potash applied separately improved the quality of the beets but the yield was not quite so good as on the plot which received 20 tons of lime per acre in 1909 and nothing in 1910 and only equal to the yield from the plot that had received no fertilizer either year. The two applied together, XXXIV, did not improve either the crop or the quality. The results with the sodic nitrate are fortunately, in the main, consistent in showing a slight increase in the yield and a depression of the quality. But these results are not without exceptions and other inconsistencies. It happens that Analyses XV, XXVIII, XXIX, and XXX represent four successive half-acre plots and from Analysis XXX we would infer a depression of the injurious nitrogen from 0.57 or 0.37 to 0.27 per 100 sugar caused by the application of 200 pounds of superphosphate per acre and from XXIX we would infer a slight depression or at least not an increase of the injurious nitrogen, but in XXXIV where we have the two applied together and in larger but not excessive quantities we find a decided increase in the injurious nitrogen. This is not due to climatic or cultural differences, nor to differences in the soil. In Analyses XXXV, XXXVI and XXXVII we have another group which is capable of various interpretations. If any conclusion be justified by the results of these experiments it is the one stated, i. e., that potash and phosphoric acid tend to improve the quality of the crop, but not to increase it, while sodic nitrate tends to increase the crop, but to lower the quality. The actual increase, however, in either crcp or quality was so variable that no reliance can be placed in the use of these agents to increase the value of the crop, which was the purpose had in view. These features of our study agree with the gross results as heretofore stated. There were 28 experiments in this series but only these eleven samples were submitted to complete analysis. There is one point in which these analyses agree, i. e., in showing less amino nitrogen than the other samples which we have analyzed.

It is difficult to believe that the variations in half-acre pieces of land, apparently the same, may be so great as to account for the variations in the results observed in these cases, but I am convinced that this variation constitutes an important factor in our results. The effects of previous fertilization may play some part, but with mineral fertilizers this is very small.

The series of experiments with sodic nitrate was made with an entirely different object in view. It has generally been held that sodic nitrate affects the quality of the beet prejudicially. Whether this view, which has been almost universally held for a long time, was based upon definitely established data or was a general, but thoroughly well founded impression, I do not know. I have been able to find but one single series of experiments, this consisting of only two members, to definitely establish the injurious effects of sodic nitrate upon the factory qualities of beets. There may be others of very recent date but they have not come to my knowledge. The experiments to which I refer were made by Andrlik and consist of two experiments, one with about 27.0 pounds of nitrogen as sodic nitrate, the other with 81.0 pounds of nitrogen, or about 175 and 525 pounds of sodic nitrate per acre. His results were as follows: With 175 pounds of sodic nitrate per acre applied in three portions, average weight of beets 330 grams, sugar 17.2, total nitrogen 0.160, injurious nitrogen 0.040, injurious nitrogen per 100 sugar 0.233; with 525 pounds to the acre, beets 372 grams, sugar 16.4 percent, total nitrogen 0.234, injurious nitrogen 0.101, injurious nitrogen per 100 sugar 0.616. The check beets weighed 333 grams, sugar 17.8 percent, total nitrogen 0.138, injurious nitrogen 0.042, injurious nitrogen per 100 sugar 0.236. The injurious ash in the three samples was per 100 sugar, in the check 1.45, with 175 pounds saltpetre 1.57 and with 525 pounds saltpetre 1.89. Concerning these results Andrlik remarks, "The application of about 80 pounds of nitrogen per acre, 91.5 kg pro 1 ha, in the form of Chile-saltpetre acts very detrimentally." It brought about the following results: it lowered the sugar from 17.8 to 16.4, it increased the total nitrogen from 0.138 to 0.234, the injurious nitrogen per 100 sugar from 0.236 to 0.616 and the injurious ash per 100 sugar from 1.45 to 1.85. Andrlik does not say that these were bad beets, but that these changes in the beets were very detrimental. I infer from other statements that I have found, that 0.616 injurious nitrogen per 100 sugar is a decidedly objectionable quantity. This is the only intimation that I have found relative to the amount of injurious ash which may be permissible in an unobjectionable beet, and it is not clear that he intends this amount, 1.89 per 100 of sugar, to be so considered, but he specifies that the sodic oxid and injurious nitrogen in the roots have been increased three fold—the sodic oxid is given as 0.094 percent of the beet.

In regard to the effects of the sodic nitrate upon the nitrogenous constituents of the beets we have no good measure as our check samples failed us altogether, being quite as bad in quality as the beets to which we applied 750 or more pounds sodic nitrate per acre, and very decidedly poorer in quality than those to which we applied 250 pounds per acre. The fact is that the results of this experiment are not in agreement with what the results of the preceding series suggest. In the former series the application of 200 and 400 pounds of sodic nitrate in conjunction with potash and phosphoric acid which, it is agreed, tend to lessen or neutralize the bad effects of the nitrate, produced decidedly bad effects, but in this series we applied 250 pounds per acre alone and the results are favorable, but with 500 pounds per acre we have apparently passed the limits of beneficial action and with 1,000 pounds per acre applied in four equal portions at intervals of about four weeks beginning just before seeding time we reach the maximum of the deleterious effects as measured by these factors. Field 1 with 250 pounds of nitrate applied just before seeding gave us, according to our laboratory samples the best yield and the best beets, they are in fact better beets than the Michigan sample which we selected in an endeavor to obtain a standard for comparison in which we found 15.3 percent sugar, 0.229 percent total nitrogen and 0.51237 injurious nitrogen per 100 sugar. In the beets from Field 1, with 250 pounds of sodic nitrate we found 15.7 and 16.5 percent sugar, 0.14470 and 0.14485 percent total nitrogen and 0.43758 and 0.36424 part injurious nitrogen per 100 sugar. In respect to the ratio of injurious nitrogen to sugar, the beets from Field 1 were better than our Fort Collins beets which showed 0.62899 per 100 of sugar. The samples from Field 2 with 500 pounds per acre are not so good, but even these are better beets than those produced in our experiments with fertilizers and the total nitrogen is not particularly high, 0.18 and 0.20 percent, while the injurious nitrogen per 100 of sugar is 0.60054 and 0.68221 for the samples taken 3 Nov. In the other cases the total nitrogen was higher and the injurious nitrogen per 100 of sugar rose to a maximum of 1.40267. The amino nitrogen in this series rose to a maximum of 0.07438 and is above 0.045 in every case except one.

There was but little difference in the growth of the beets on Field 1 and of those on adjoining plots so far as the size of the tops and their color were concerned, they were all luxuriant and a deep green till the leaf-spot appeared. This was not the case with the three acres receiving the largest applications. On these one could easily distinguish the bigger and more abundant foliage. This difference may have been due to the larger quantity of nitrate, or to the time it was applied; be this as it may, the foliage was distinctly heavier and of a blue green color. No attempt was made to determine the weight of the tops, this would have been impossible owing to the destruction of leaves by the leaf-spot and by the wheels of the spraying outfit. There was a perceptible difference in the size and color of the fields that received the heavier applications of nitrates and the check field.

These amounts of nitrates exercised a very perceptible influence upon the physical condition of the soil, causing it to show a decided tendency to puddle and become hard. Whether this was due to the nitrate itself or to other salts formed from the nitrate as has been suggested I do not know. The number and size of the leaves on the nitre beets was larger than it is usual to find on sugar beets, besides, owing to the fulness of the foliage it was erect and not spreading or prone as we sometimes see it. The nitre beets did not seem to be so seriously attacked by the leaf-spot as the beets on adjacent land, but on counting the dead leaves on quite a number of beets to determine this point, I doubt whether there is any greater resistance shown toward the attack of the leaf-spot by nitre beets than by others. These beets were sprayed five times with standard Bordeaux mixture but I could see no conclusive evidence of benefit therefrom. The shape of the beets produced on these plots showed a decided modification of their form—as one effect of the nitrate. The beets became shorter and broader at the top as the nitrate applied increased. The photographs of some of the piles as they lay in the field at harvest time show this effect. I do not think that the shape of the beet was modified in this way by the hardness of the soil, for I have seen well shaped beets dug from harder soil than any of this, still the hardness of the soil may have had some influence, but I think that the full, excessive foliage and abnormal nutrition produced this effect. We have shown some photographs of beets grown on the College farm with excessive foliage and but seven tons of topped beets per acre. The following plates, Plates II and III, show some piles of beets as they lay on Field 2, 3, 5 and 6. The differences are evident without further description. Field 6 received no nitrate, fields 2, 3 and 5 received 500, 750 and 1,250 pounds respectively. These fields form one continuous piece of land. We shall discuss the ashes and juices of these beets in subsequent paragraphs.

The plates representing beets grown with and without the application of nitrates show very marked differences, but the beets as they were harvested and lay in the fields showed the differences even more markedly than the photographs of these piles. The variety of beets represented is the Original Kleinwanzlebener and there is no question of varietal differences. There were some variations in the quality of the soil but the differences in the shape of the beets varied with the amount of nitrogen applied and not with these. The cultivation, irrigation, spraying, etc., has been given in sufficient detail and as may be seen were essentially the same.

In order to present the extreme effects of nitre-impregnated land upon the shape of the beet I have introduced Plate IV. The lower photograph represents beets grown near Fort Collins, whose composition is given in Analysis VIII. The upper figure represents

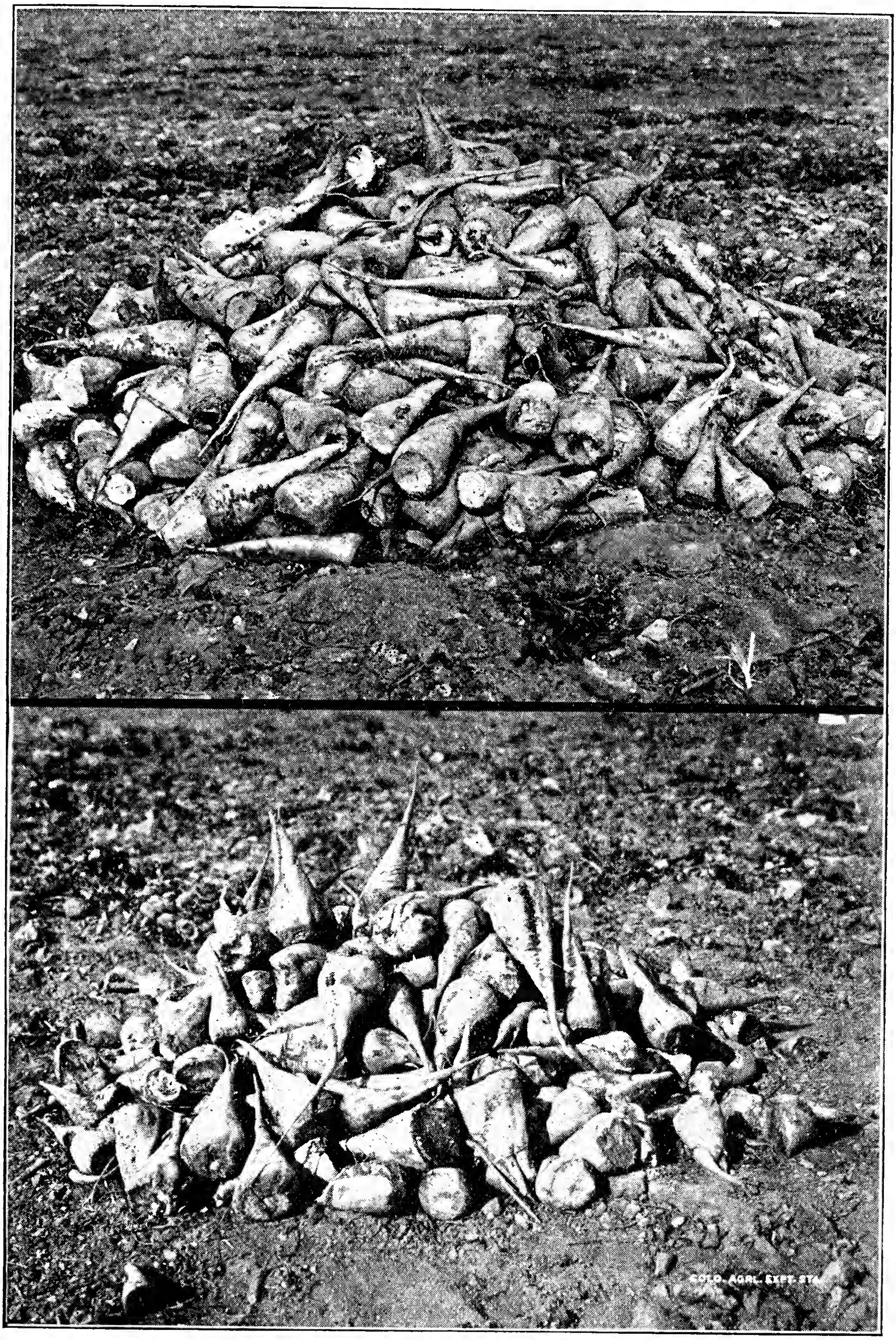


Plate II. Upper photograph represents beets grown without application of sodic nitrate, the lower one beets grown with 500 pounds per acre.

beets grown on land very rich in nitrates. The water plane at the point where these beets were grown was five feet below the surface but the ground was, as is very often the case, quite wet. The water *per se* probably had but little to do with the shape of the beets, for as

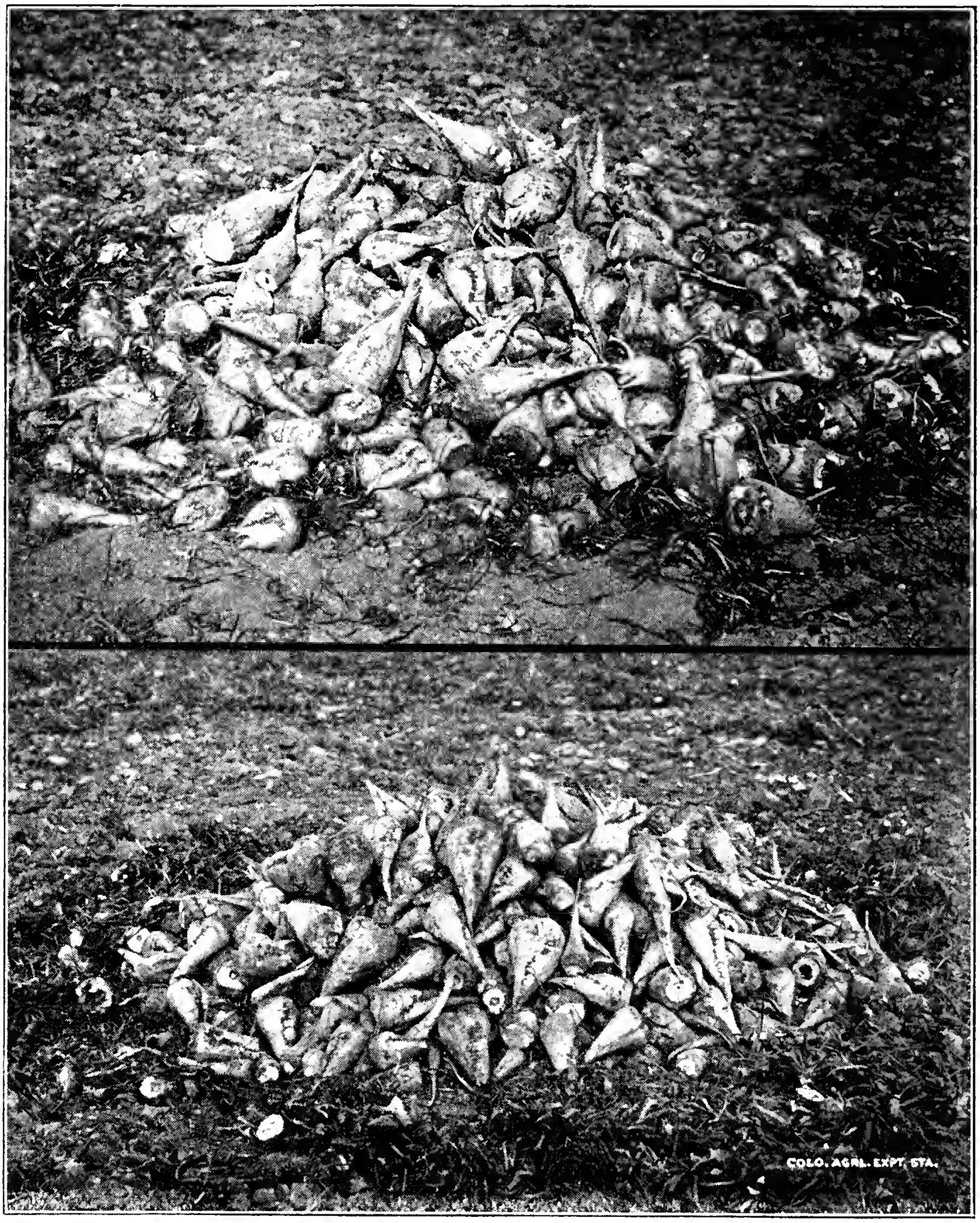


Plate III. The upper photograph represents beets grown with 1,000 pounds and the lower one beets grown with 1,250 pounds sodic nitrate per acre.

stated elsewhere we have grown well shaped beets on land in which the water plane at no time during the season fell to more than three and one-half feet below the surface and at times rose even to the surface. This land, too, was very rich in the ordinary alkali salts, a sample taken in one section of it to a depth of ten inches having yielded 2.5 percent soluble in water. This section of the field yielded, the third consecutive year that it was planted to beets, a

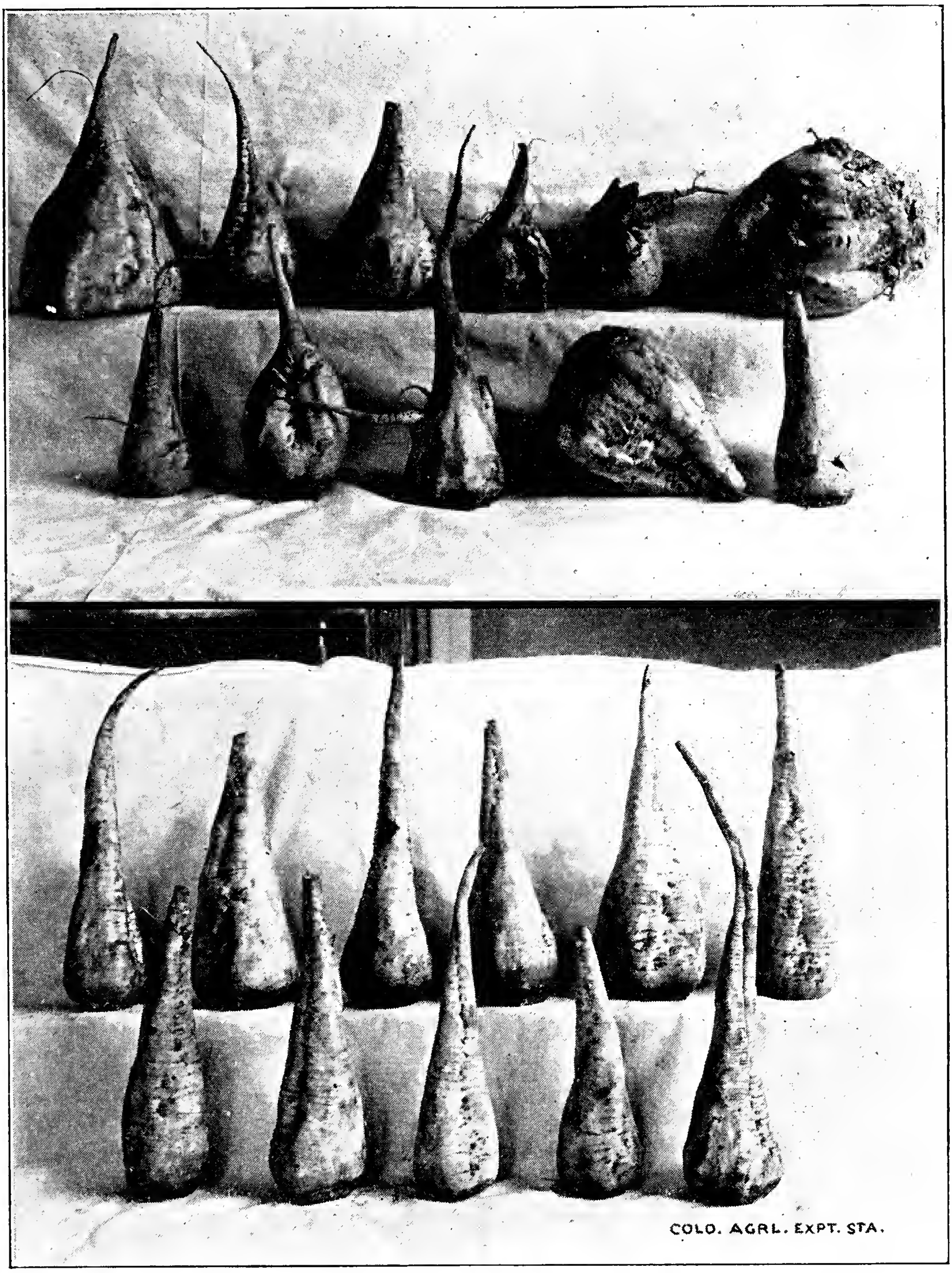


Plate IV. The upper photograph represents beets grown on land very rich in nitrates: the lower one beets grown on good land.

crop that would compare favorably in regard to shape, size and sugar content with the beets represented in Plate IV, lower figure. The beets represented in this plate grown in 1910 on a good, sandy loam, contained 18.3 percent sugar and had an apparent coefficient of purity of 83.2, while the beets grown in the undrained alkali land in 1898 contained 18.3 percent sugar and had an apparent coefficient of purity of 89.3. The shape and quality of the beets represented in Plate IV, upper figure, are undoubtedly the result of all the untoward conditions obtaining, but the chief, if not primarily the only one, is the presence of the nitrates. The analysis of these beets, Analysis No. CII, given on a subsequent page, shows that these beets had taken up a very remarkable amount of nitrogen, 0.345 percent total nitrogen with 0.0834 percent of nitric nitrogen. A knowledge of the conditions and the analytical results shown in the analyses of the beets and ash, leave no room for doubt but that the excessive quantity of nitrates in the soil was the principal cause in the production of such beets.

The results so far presented to show the effects of nitrates upon the composition of the sugar beet, agree with those of Andrlik except that in this case the application of larger amounts, 250 as against his 175 pounds, proved decidedly beneficial and even 500 pounds per acre produced results only a little less favorable than the 250 pounds. We may measure this for our present purpose by the yield of sugar as given for the beets delivered to the factory. Field 1, 250 pounds nitrate, produced 4,763 pounds and Field 2, 500 pounds nitrate, 4,377 pounds per acre. The second 250 pounds applied to Field 2 did not increase the yield, there being actually a decrease of 387 pounds. This is too small a difference to be seriously considered under our conditions, but we shall subsequently see that this is not the whole of the case. From this point, from 500 to 1,250 pounds, there was a decided deterioration of the beets, unquestionably due to the nitrates. The composition of these beets, in which the deterioration has been brought about by the application of 1,000 pounds of nitrate, is almost identical with the bad beets taken as a check and which of course, were grown without the application of nitrates or other fertilizers. These conditions are represented by Analyses LXXVIII and LXXIX, beets grown with 1,000 pounds sodic nitrate applied per acre, and Analysis XX, beets grown without nitrate. We have total nitrogen in LXXIX, 0.26660, in XX, 0.25215, nitric nitrogen 0.04008 and 0.04537, injurous ntrogen 0.16017 and 0.13660, injurious nitrogen per 100 sugar 1.19561 and 1.07246. These analyses agree better than the duplicate samples taken from the field which received 1,250 pounds of sodic nitrate. We cannot doubt the cause of the poor quality of the former beets, the high total nitrogen, the high nitric nitrogen and the high percentage of injurious nitrogen which is most clearly shown by the amount present for each 100 pounds of sugar, and especially so by converting the injurious nitrogen into its equivalent of nitrogenous substances, by multiplying it by 10—the factor 16.1 has also been suggested, we will use the lower factor—when we obtain for the two analyses in the order given, 11.96 and 10.72—amounts which are more than twice that which justifies us in classifying the beets as of poor quality. The sugar in these two samples of beets was 14.2 and 12.7 percent respectively and the injurious ash per 100 of sugar was, in LXXIX, 3.104 and in XX, 3.703 parts. As previously stated I have been unable to find a definite statement regarding the permissible amount of injurious ash in a beet. Of course a beet would not be judged by the amount of injurious ash alone, other factors are also to be taken into consideration. We do, however, find that Andrlik mentions the increase in the injurious ash from 1.45 to 1.89 parts or 0.44 part, in connection with an increase of 0.38 part of injurious nitrogen and a depression of 1.2 percent, from 17.8 to 16.4, in the sugar content as a very unfavorable action upon the quality of the beet. Again in the analyses of cossettes quoted from another article of Andrlik's, we find in Analysis VI which he says is a good beet, 1.947 parts injurious ash per 100 sugar and in V which he classifies as a poor beet, we find 2.759 parts, so in considering the injurious ash in our beets we may tentatively assume that 2.0 parts injurious ash per 100 of sugar in the beet is a reasonable limit for the permissible amount of injurious ash in an otherwise fairly good beet. Judged by this assumed standard our nitrate beets are quite bad, reaching a maximum quantity of 5.472 parts injurious ash per 100 of sugar—and our beets in general so far as they have been presented are indifferent or decidedly bad. We have presented but two samples and they were not from Colorado, in which the injurious ash is below 2.00 parts per 100 of sugar, and these have 1.67 and 1.9447 parts. Our best beets grown at Fort Collins approximate it with 2.2, 2.4 and 2.4 parts, but other Fort Collins beets are higher, 3.4 parts. The beets grown with the application of fertilizers are, in this respect, decidedly lower in quality as they show from 4.3 to 7.7 parts injurious ash per 100 of sugar. I have already called attention to the amount of chlorin in the ashes of these samples. In several of the analyses given the sodic chlorid amounts to 30 or even more percent of the pure ash and a still larger percentage of the injurious ash.

We have given the injurious nitrogen in Analyses LXXIX and XX. Analysis LXXIX is a sample of beets taken from the plot that had received 1,000 pounds of nitrate per acre in four equal applications. We find that the injurious introgen amounts to 1.403 parts per 100 of sugar. This sample shows the largest amount of nitric nitrogen of any of the samples taken from these fields and it amounts to 0.566 parts per 100 of sugar. More than one-third of the injurious nitrogen in this sample was present as nitric acid respectively as nitrates, or if we consider the nitrate to be sodic nitrate it gives us 3.4 pounds of sodic nitrate per each 100 pounds of sugar in these beets. The beets represented by Analysis XX were grown without the application of any kind of a fertilizer and we find the injurious nitrogen equal to 1.072 parts per 100 of sugar and the nitric nitrogn equal to 0.3555, almost exactly one-third of the injurious nitrogen and each 100 pounds of sugar in these beets was accompanied by 2.133 pounds of sodic nitrate. These are the maximum quantities found in these classes of beets, but they are very large, and we are certain that this was due in the one case to an application of 1,000 pounds of sodic nitrate per acre. The other also, though no nitrate was applied, must have had an excessive supply furnished by the soil itself as there is no evidence that the nitric acid is formed in the beet. An examination of our results shows our beets to contain from 0.032 which is our very lowest up to 3.4 parts of nitrates calculated as sodic nitrate for each 100 parts of sugar. The French beet previously mentioned as carrying 16.8 percent of sugar and 0.049 percent if nitric nitrigen, carried only 1.760 parts of sodic nitrate to 100 of sugar, which is only one-half as much as our maximum quantity. The sodic oxid in the ashes of these beets grown with nitre is very high, reaching a maximum of about 40.0 percent of the pure ash and nearly 0.25 percent of the weight of the fresh beet. It is lowest in the Michigan beet, of which it constitutes about 0.002 percent of the beet. It is likewise quite low in our Fort Collins standard beet and in those grown on new sod land at Holly, but is fairly high in those grown on the College Experiment Farm in 1911, 0.05 percent of the beet, and decidedly high in those grown in 1910, 0.129 percent. The chlorin in the beets grown on our plots with fertilizers is very high, constituting 15 to 19 percent of the pure ash, that this may have been the carrier of the sodium is probable, but whatever the cause the sodic oxid is quite high. The lands on which these beets were grown are, as repeatedly stated, good lands and not seeped, alkalized lands, surcharged with salts which may be considered injurious to vegetation. The maximum amount of chlorin found in the soil on which the experiments with fertilizers were made, was 0.038 percent for the total chlorin. The water soluble chlorin ranged from 0.008 to 0.021 percent, the latter was found in the third foot of soil. Beets grown with sodic nitrate are always relatively rich in chlorin.

The water-soluble in this soil is not exceptionally high for arid lands; the surface foot showed 0.10 and 0.18, the second foot 0.32 and 0.35 and the third foot 0.81 and 0.90 percent for two series of samples. These figures for the second and third foot, samples taken subsequently, were much higher. The water-soluble in this case is largely calcic sulfate. Our former studies of the sugar beet have shown that while the ash of beets grown on strongly alkalized land may contain considerable quantities of sodic oxid, it does not follow that it will contain more or even as much as that of beets grown on ordinary soil, in fact, we found it to contain less. The abundance of soluble salts alone does not determine this factor, nor do I intend to intimate what the cause of the taking up of the sodic oxid in our case is. The presence of sodic oxid in the beets grown with the application of sodic nitrate has been attributed to the nitrate. This may or may not be the controlling factor. In the cases so far given we have with a high nitric nitrogen content a large amount of sodic oxid above that necessary to furnish sodium to combine with the chlorin.

The magnesic oxid in the ashes of our beets is high and the lime low, as compared with the average data given, and both low compared with some recent data. The ratio of lime to magnesia in our beets is comparatively low, as it is usually 1:2 and sometimes 1:3. In the averages quoted from E. Wolff and others, this ratio is much more nearly 1:1. There are of course variations in this ratio in different analyses, but the observation is still true of the individual analyses that I find. Further, our beets are as a rule quite rich in ash constituents. The German beets seem to carry from 3 to 3.5 percent of crude ash or about 2.3 percent pure ash in the dry substance, whereas ours carry much larger percentages. It is rather exceptional to find a sample of beets showing less than 3.5 percent of crude ash and not at all uncommon to find from 5 to 6 percent. This is not due to the variety, to bad preparation or specifically to nitrates in the soil, at least, we do not find enough increase in the ash of beets grown with the application of nitre to justify such an inference. On the contrary, the application of 250 pounds per acre apparently produced a decided improvement in this respect, and while the crude ash in the beets grown with 750 and 1,000 pounds per acre is higher, it does not exceed the amount found in samples grown without fertilizers of any kind, so while it is very probable that the increase in ash was in part due to the action of the nitrate, it is not positive enough to remove the question beyond doubt. We have for example three samples grown without the addition of anything which show 4.3, 4.5 and 5.0 percent crude ash. We have also two samples grown with application of 750 pounds sodic nitrate, these have 4.6 and 5.8, also two with 1,000 pounds per acre and these show 5.0 and 6.2 percent. These samples are all from the same land. Samples from other land, beets grown without fertilizers, we have 5.1, 5.0 and 6.3 percent of crude ash. All that we are justified in stating is that the nitrate slightly increased the ash content of the beets, but that it can scarcely be considered the cause of the high ash content in general, unless we assume the presence of unusual amounts of nitrates in general.

The ratio between the sodic and potassic oxids varies greatly without such an apparent relation to other factors as to make it evident that this ratio is of itself an important one; for instance we have in the Michigan beets 15.3 percent of sugar, 0.70 percent of crude ash in the beet, 0.0032 percent nitric nitrogen in the beet and 0.5129 part injurious nitrogen per 100 of sugar and the ratio of sodic to potassic oxid is 1:140. In Analysis XXXVI, one of our fertilized beets, we have also 15.3 percent sugar, 1.05 percent crude ash, 0.0025 percent nitric nitrogen, 0.428 injurious nitrogen per 100 sugar and the ratio of 1:26 for the sodic to the potassic oxid. While the ratios in these samples are extreme, the quality of the beets is not very different. The amount of sugar is the same, 15.3 percent, the injurious nitrogen is less in the beets with 13.6 percent sodic oxid in the crude ash, against 0.255 percent in that of the other beet; the nitric nitrogen is also less and the injurious ash is 4.16 against 1.94 or 2.1 times as much. It is seldom in our beets that this ratio is less than 1:9 and occasionally the sodic oxid is almost equal to the potassic oxid, in one sample given it is actually greater, but the beets in this case were very low in quality and they had been grown with a heavy application of nitrate.

BEETS GROWN ON BAD LAND.

The land chosen for the experiments and observations to follow, was one which I had been observing since 1909 and which I knew to be very rich in nitrates. The land slopes to the north and west so that the south end of the field is 17½ feet higher than the north end, and the southeast corner of the field is 22 feet higher than the southwest corner. The distance across this field from east to west was not measured. The rows ran north and south and were at this place 672 feet long. On the north and west of this land is a flat area through which runs a ditch. This drainage ditch is 650 feet beyond the north end of the cultivated land under consideration. The flat land is used as a pasture, but is partly bare and at times wet. We had borings made to determine the hight of the water plane at the end of September and found it to be five feet below the surface at the lowest point of the cultivated field and only one foot about the bottom of the open ditch. Samples of this soil were taken on 22 June 1910 because we wished to apply fertilizers to see whether they would produce any effects upon the crop in quantity or quality under these conditions. For this purpose thirty rows of beets were selected. The total length of the rows was 672 feet. The extreme north end of the cultivated portion was rejected as wholly unfit for our purpose. About 550 feet of the rows was taken. The width of the land selected was thirty rows of beets or from 45 to 50 feet and the length as stated. This was divided into three sections and composite samples representing the top and second two inches of soil taken. Each composite sample consisted of eight subordinate samples. The samples are numbered from the lower to the higher ground.

		Potash Percent	Phosphoric Acid Percent	Total Nitrogen Percent	Nitric Nitrogen Percent
I	Top 2 inches.............	1.163	0.0765	0.1480	0.0280
	Second 2 inches...........	1.275	0.1913	0.1305	0.0125
II	Top 2 inches..............	0.874	0.1244	0.0920	0.0050
	Second 2 inches...........	0.960	0.1626	0.0960	0.0030
III	Top 2 inches..............	1.024	0.1626	0.0970	0.0040
	Second 2 inches...........	0.893	0.1595	0.0850	0.0030

So far as this analytical data is concrned the soil is, according to our standards, well supplied with potash and phosphoric acid, but is lacking in nitrogen. There is no other indication or proof of this except our analyses. The nitrogen determinations here given were made by the plain Kjeldahl and I have added the nitric nitrogen found to obtain the total, this was all that remained for me to do. These determinations were made when the samples were taken and are the only ones that it is proper to use. The total nitrogen was recently redetermined in these samples now 20 months old, and there is an unquestionable increase in every instance. This increase is not uniform in amount, ranging from 80 to 500 p. p. m., but is sufficient to preclude the use of the recent determinations. These determinations were made with care, taking all usual precautions and in duplicate so that I am not inclined to consider this increase due to analytical errors. We observe that the nitric nitrogen varies from 3.13 to 18.93 percent of the total. These samples represent what we consider as soil of such quality and so conditioned that the owner was justified in cultivating it with the expectation of obtaining at least an average crop. The extreme northern edge of this field was very bad and was very noticeable because the owner was trying to cultivate it, which made its condition more evident. The surface became brown and mealy during the season. A surface sample of this soil showed that it was well provided with potash, 1.118 percent, and phosphoric acid, 0.380, and was very rich in nitrates and chlorids, about 30 percent of the water-soluble. The calcic oxid in this sample was 6.070 percent and the analysis of the water-soluble indicates that the sulfuric acid is wholly combined with lime. The citric acid soluble phosphoric acid amounted to 0.023 percent. The analytical data indicated a soil well provided with potash and phosphoric acid, but decidedly low in total nitrogen, at the same time we see that the highest section of this land contained on 22 June, 1910, 93.3 pounds of nitric nitrogen in the top four inches of the soil, the next lower section 106.2 pounds and the next lower 400 pounds, and this was all land in good cultivable condition. The beets on this date presented a good stand but were not particularly promising. I do not know the details of the cultivation received throughout the season. On 6 July there were applied to five rows, superphosphate at the rate of 1,000 pounds, to 5 rows potassic chlorid at the rate of 400 pounds, to 5 rows sodic chlorid at the rate of 400 pounds, to 5 rows superphosphate at the rate of 1,000 pounds and potassic chlorid 400 pounds per acre. and to 5 rows superphosphate 1,000 pounds and sodic chlorid 400 pounds per acre. The fertilizers were applied by hand. I visited this field on 8 Aug. and the condition of the field was very promising. The foliage was exceedingly heavy, the petioles were erect, stout and long, the blades were large but did not vary more in shape than usual; they were thick and heavy in substance and very brittle. The hight of the leaves was about 36 inches, the color was from a dark to a bluish green. No difference could be detected between the rows to which the fertilizers had been applied and the rest of the field. The yield of the beets at this time promised to be very heavy indeed, the yield at harvest time was 11.7 tons and the sugar according to the factory returns was 14.14 percent. We took three sets of samples 23 Sept., 11 Oct., and 3 Nov. The average weight of the beets was not determined except for the final, 3 Nov., samples. Owing to the number of samples to be handled, only the plots to which the fertilizers were separately applied, a check plot and the very bad portion of the field—39 samples in all—were taken. The samples are numbered 1, 2 and 3. Sample 1 is uniformly taken from the highest ground and corresponds to Sample III of the soil and 3 corresponds to Sample I of the soil.

BEETS GROWN ON BAD LAND—SAMPLES TAKEN 23 SEPT.

	Sugar	Dry Substance	Total Nitrogen	Protein Nitrogen	Ammonic Nitrogen	Amid Nitrogen	Amino Nitrogen	Nitric Nitrogen
Plot With Superphosphate.								
1....	10.2	15.8	0.2126	0.0761	0.00835	0.01825	0.04407	0.02446
2....	11.3	17.1	0.2577	0.0870	0.00830	0.01330	0.07141	0.03703
3....	9.4	15.0	0.2702	0.0730	0.00980	0.02040	0.01845	0.05258
Plot With Potassic Chlorid.								
1....	10.8	17.2	0.2255	0.0737	0.00830	0.01595	0.03832	0.03376
2....	8.9	14.1	0.2782	0.0741	0.00995	0.02720	0.05042	0.05098
3....	9.0	14.1	0.2169	0.0718	0.00865	0.01410	0.01611	0.04769
Plot With Sodic Chlorid.								
1....	12.6	18.8	0.2118	0.0769	0.00775	0.01355	0.04349	0.01705
2....	11.8	17.7	0.2543	0.0807	0.00980	0.01685	0.02785	0.04500
3....	9.8	16.1	0.2752	0.0830	0.00995	0.02290	0.03729	0.04146
Check Plot.								
1....	13.0	17.4	0.2687	0.0784	0.00400	0.01150	0.04015	0.01630
2....	12.4	18.5	0.2706	0.0793	0.01625	0.02045	0.04120	0.03480
3....	10.8	17.0	0.2630	0.0721	0.01640	0.01650	0.04205	0.02798
Very Bad Section.								
1....	7.8	14.4	0.2744	0.0827	0.00850	0.02350	0.03123	0.06493

BEETS GROWN ON BAD LAND—SAMPLES TAKEN 11 OCT. 1910.

Plot With Superphosphate.

	Sugar	Dry Substance	Total Nitrogen	Protein Nitrogen	Ammonic Nitrogen	Amid Nitrogen	Amino Nitrogen	Nitric Nitrogen
1....	10.8	17.2	0.2413	0.0764	0.00230	0.02205	0.01786	0.05329
2....	11.3	18.2	0.2767	0.0873	0.00215	0.02805	0.01537	0.04351
3....	12.0	18.8	0.2527	0.0891	0.00275	0.02175	0.03114	0.03811
Plot With Potassic Chlorid.								
1....	11.4	18.8	0.3026	0.0891	0.01740	0.02620	0.02440	0.05745
2....	12.3	19.7	0.2687	0.0780	0.00530	0.02420	0.01256	0.03081
3....	13.2	18.3	0.1988	0.0868	0.00573	0.01213	0.05275	0.02537
Plot With Sodic Chlorid.								
1....	11.5	17.9	0.1945	0.0761	0.00313	0.01477	0.09680	0.02738
2....	13.1	19.6	0.2017	0.0792	0.00230	0.01580	0.12750	0.02854
3....	10.0	18.0	0.3214	0.0763	0.00855	0.02820	0.08932	0.07695
Check Plot.								
1....	11.5	17.0	0.1989	0.0850	0.00370	0.01180	0.04532	0.02853
2....	10.5	16.5	0.3070	0.0807	0.00475	0.02190	0.08209	0.06417
3....	9.0	15.5	0.2507	0.0678	0.00200	0.02205	0.06262	0.06955
Very Bad Section.								
1....	7.8	14.7	0.3301	0.0784	0.00840	0.02840	0.12559	0.09319

BEETS GROWN ON BAD LAND—SAMPLES TAKEN 3 NOV. 1910.

Plot With Superphosphate.

	Sugar	Dry Substance	Total Nitrogen	Protein Nitrogen	Ammonic Nitrogen	Amid Nitrogen	Amino Nitrogen	Nitric Nitrogen
1....	10.9	17.6	0.25860	0.0777	0.00430	0.02260	0.03365	0.04982
2....	11.8	19.0	0.24350	0.0530	0.00356	0.02083	0.03142	0.04621
3....	10.2	18.0	0.30675	0.0879	0.00879	0.03470	0.03409	0.07260
Plot With Potassic Chlorid.								
1....	13.1	20.3	0.23700	0.07495	0.00360	0.02085	0.04295	0.02501
2....	11.8	19.4	0.24715	0.08125	0.00445	0.02245	0.04154	0.04111
3....	12.2	19.5	0.34510	0.09680	0.00526	0.04430	0.03483	0.05120
Plot With Sodic Chlorid.								
1....	13.0	20.0	0.19020	0.09685	0.00185	0.01340	0.03505	0.01558
2....	12.4	18.9	0.21445	0.10030	0.00245	0.02055	0.04908	0.03713
3....	10.4	18.3	0.33970	0.11385	0.00735	0.03260	0.02757	0.08743
Check Plot.								
1....	13.2	21.0	0.24930	0.08645	0.00545	0.02160	0.03514	0.01936
2....	11.3	17.6	0.15995	0.06740	0.00200	0.00690	0.03935	0.03249
3....	12.1	18.9	0.23345	0.08845	0.00350	0.01470	0.03470	0.05310
Very Bad Section.								
1....	8.6	16.5	0.34510	0.12389	0.00520	0.03985	0.03507	0.08337

BEETS GROWN ON BAD LAND.

Samples Taken 3 Nov. 1910. Superphosphate added at the rate of 1,000 pounds per acre.

	XCI	XCII	XCIII
Section	1	2	3
Average weight of beets	751.3 grams	725.0 grams	708.7 grams
	Percent	Percent	Percent
Sugar in beets	10.90000	11.80000	10.20000
Dry substance in beets	17.60000	19.00000	18.00000
Crude ash in dry substance	7.29200	6.46400	8.03700
Crude ash in fresh beet	1.28340	1.22820	1.44680
Pure ash in fresh beet	0.94071	0.93961	1.06440
Sulfuric acid	0.03615	0.03741	0.04285
Phosphoric acid	0.04816	0.03249	0.02732
Chlorin	0.12032	0.13660	0.20047
Sodium	0.07824	0.08882	0.13036
Potassic oxid	0.44601	0.42585	0.42708
Sodic oxid	0.09925	0.07759	0.12154
Calcic oxid	0.02773	0.02358	0.02627
Magnesic oxid	0.07581	0.10875	0.07807
Ferric oxid	0.00375	0.00204	0.00201
Aluminic oxid	0.00228	0.00341	0.00584
Manganic oxid	0.00304	0.00301	0.00252
Total nitrogen	0.25860	0.24350	0.30675
Proteid nitrogen (Stutzer)	0.07770	0.05300	0.08790
Ammonic nitrogen	0.00430	0.00356	0.00305
Amid nitrogen	0.02260	0.02083	0.03470
Amino nitrogen	0.03365	0.03142	0.03409
Nitric nitrogen	0.04982	0.04621	0.07260
Injurious nitrogen in beet	0.15400	0.16611	0.18110
Injurious ash per 100 sugar	7.15570	6.49390	9.04210
Injurious nitrogen per 100 sugar	1.41290	1.40770	1.78290
Press Juice According to Ruempler.			
Total nitrogen	0.24120	0.23640	0.28040
Albumin nitrogen	0.04600	0.05020	0.05580
Propetone nitrogen	0.00200	0.00090	0.00590
Peptone nitrogen	0.00730	0.00590	0.00380

Ash Analyses.

	CIV		CV		CVI	
	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	0.373	.....	0.458	.....	0.624	.....
Sand	0.628	.....	0.600	.....	0.938	.....
Silicic acid	0.968	.....	1.224	.....	0.773	.....
Sulfuric acid	2.821	3.842	3.046	3.982	2.962	4.027
Phosphoric acid	3.758	5.119	2.645	3.458	1.890	2.567
Chlorin	9.390	12.790	11.122	14.539	13.866	18.835
Sodium	.....	8.317	.....	9.453	.....	12.246
Carbonic acid	23.616	.....	22.007	.....	20.539	.....
Potassic oxid	34.810	47.411	34.674	45.325	29.478	40.126
Sodic oxid	15.971	10.550	16.061	8.258	20.589	11.419
Calcic oxid	2.163	2.948	1.920	2.510	1.816	2.468
Magnesic oxid	5.917	8.059	6.804	11.575	5.381	7.335
Ferric oxid	0.293	0.399	0.166	0.217	0.139	0.189
Aluminic oxid	0.179	0.242	0.278	0.363	0.389	0.549
Manganic oxid	0.237	0.323	0.245	0.320	0.174	0.237
Loss	(1.017)	.....	(1.260)	.....	(3.671)	.....
Sum	102.119	.....	102.501	.....	103.129	.....
Oxygen equi. to chlorin	2.119	.....	2.501	.....	3.129	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000

BEETS GROWN ON BAD LAND.

Sampled 3 Nov. 1910. Potassic chlorid applied at the rate of 400 pounds per acre

	XCIV	XCV	XCVI
Section	1	2	3
Average weight of beets	680.4 grams	640.7 grams	487.6 grams
	Percent	Percent	Percent
Sugar in beets	13.10000	11.80000	12.20000
Dry substance in beets	20.30000	19.40000	19.50000
Crude ash in dry substance	5.36100	6.51900	7.90900
Crude ash in beets	1.08828	1.26469	1.54226
Pure ash in beets	0.78546	0.91240	1.14930
Sulfuric acid	0.03722	0.03692	0.04269
Phosphoric acid	0.02831	0.02290	0.01624
Chlorin	0.09536	0.15944	0.23275
Sodium	0.06200	0.10368	0.15133
Potassic oxid	0.38575	0.41956	0.55650
Sodic oxid	0.05478	0.05424	0.02266
Calcic oxid	0.03981	0.02935	0.03028
Magnesic oxid	0.07570	0.08105	0.09096
Ferric oxid	0.00176	0.00143	0.00247
Aluminic oxid	0.00200	0.00100	0.00167
Manganic oxid	0.00270	0.00290	0.00177
Total nitrogen	0.23700	0.24715	0.34510
Proteid nitrogen	0.07495	0.08125	0.09680
Ammonic nitrogen	0.00360	0.00445	0.00526
Amid nitrogen	0.02085	0.02245	0.04430
Amino nitrogen	0.04295	0.04154	0.03483
Nitric nitrogen	0.02501	0.04111	0.05120
Injurious nitrogen in beets	0.12760	0.13900	0.19874
Injurious ash per 100 sugar	4.81140	6.55800	8.24530
Injurious nitrogen per 100 sugar	1.04240	1.17790	1.62910

Press Juice According to Ruempler.

Total nitrogen	0.21230	0.24550	0.32870
Albumin nitrogen	0.04250	0.04550	0.06260
Propetone nitrogen	0.00380	0.00380	0.00070
Peptone nitrogen	0.01410	0.01410	0.00820

Ash Analyses

	CVII		CVIII		CIX	
	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	0.789	.....	0.909	.....	0.416	.....
Sand	0.943	.....	0.661	.....	0.615	.....
Silicic acid	0.978	.....	0.687	.....	0.983	.....
Sulfuric acid	3.420	4.739	2.919	4.046	2.768	3.715
Phosphoric acid	2.601	3.604	1.811	2.510	1.053	1.413
Chlorin	8.762	12.141	12.607	17.475	15.091	20.250
Sodium	.....	7.894	.....	11.363	.....	13.168
Carbonic acid	23.433	.....	21.995	.....	20.499	.....
Potassic oxid	35.445	49.116	33.175	45.984	36.083	48.421
Sodic oxid	13.575	6.974	15.332	5.945	14.688	1.917
Calcic oxid	3.658	5.069	2.321	3.217	1.963	2.364
Magnesic oxid	6.956	9.639	6.409	8.883	5.898	7.914
Ferric oxid	0.162	0.225	0.106	0.147	0.160	0.215
Aluminic oxid	0.184	0.255	0.081	0.112	0.108	0.145
Manganic oxid	0.248	0.344	0.229	0.318	0.115	0.154
Loss	(0.823)	.....	(3.603)	.....	(2.970)	.....
Sum	101.977	.....	102.845	.....	103.406	.....
Oxygen equi. to chlorin	1.977	.....	2.845	.....	3.406	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000

BEETS GROWN ON BAD LAND.

Sampled 3 Nov. 1910. Sodic Chlorid was applied at the rate of 400 pounds per acre.

	XCVII	XCVIII	XCIX
Section	1	2	3
Average weight of beets	725.7 grams	705.9 grams	620.8 grams
	Percent	Percent	Percent
Sugar in beets	13.00000	12.40000	10.40000
Dry substance in beets	20.00000	18.90000	18.30000
Crude ash in dry substance	5.27400	6.06000	10.17400
Crude ash in fresh beet	1.05480	1.14530	1.86180
Pure ash in fresh beet	0.77680	0.86182	1.42470
Sulfuric acid	0.02921	0.03155	0.05344
Phosphoric acid	0.03448	0.03631	0.02831
Chlorin	0.11033	0.13697	0.31200
Sodium	0.07174	0.08893	0.20327
Potassic oxid	0.37902	0.39918	0.60811
Sodic oxid	0.03993	0.06132	0.07626
Calcic oxid	0.03945	0.03235	0.03042
Magnesic oxid	0.06701	0.06891	0.10247
Ferric oxid	0.00402	0.00196	0.00316
Aluminic oxid	0.00086	0.00259	0.00432
Manganic oxid	0.00082	0.00196	0.00284
Total nitrogen	0.19020	0.21545	0.33970
Proteid nitrogen (Stutzer)	0.09685	0.10030	0.11385
Ammonic nitrogen	0.00185	0.00245	0.00735
Amid nitrogen	0.01340	0.02055	0.03260
Amino nitrogen	0.03505	0.04908	0.02757
Nitric nitrogen	0.01558	0.03713	0.08743
Injurious nitrogen in beets	0.07810	0.09215	0.18590
Injurious ash per 100 sugar	4.84820	5.78850	12.04900
Injurious nitrogen per 100 sugar	0.60077	0.74315	1.78750

Press Juice According to Ruempler.

Total nitrogen	0.16160	0.20115	0.28823
Albumin nitrogen	0.04120	0.04560	0.04960
Propetone nitrogen	0.00650	0.00410	0.00570
Peptone nitrogen	0.00620	0.00375	0.00400

Ash Analyses

	CXI		CXII		CXIII	
	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	Trace	.....	Trace	.....	Trace	.....
Sand	0.974	.....	0.461	.....	0.589	.....
Silicic acid	0.792	.....	0.969	.....	1.283	.....
Sulfuric acid	2.761	3.752	2.755	3.661	2.870	3.751
Phosphoric acid	3.266	4.438	3.170	4.213	1.520	1.987
Chlorin	10.452	14.204	11.944	15.871	16.755	21.900
Sodium	.....	9.235	.....	10.319	.....	14.268
Carbonic acid	23.020	.....	22.427	.....	20.574	.....
Potassic oxid	35.904	48.792	34.858	46.317	32.661	42.685
Sodic oxid	12.937	5.141	15.815	7.115	18.805	5.353
Calcic oxid	3.737	5.078	2.825	3.754	1.634	2.135
Magnesic oxid	6.343	8.262	6.071	7.996	5.503	7.192
Ferric oxid	0.381	0.517	0.167	0.227	0.170	0.222
Aluminic oxid	0.082	0.111	0.226	0.300	0.232	0.303
Manganic oxid (br.)	0.078	0.106	0.167	0.227	0.152	0.199
Loss	(1.626)	.....	(0.894)	.....	(1.035)	.....
Sum	102.358	.....	102.695	.....	103.783	.....
Oxygen equi. to chlorin	2.358	.....	2.695	.....	3.783	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000

BEETS GROWN ON BAD LAND.

Sampled 3 Nov. 1910. Check Plot.

	C	CI	CII	CIII
Section	1	2	3	4
Average weight of beets	788.1 grams	603.8 grams	569.8 grams	663.4 gr.
	Percent	Percent	Percent	Percent
Sugar in beets	13.20000	11.30000	12.10000	8.60000
Dry substance in beets	21.00000	17.60000	18.90000	16.50000
Crude ash in dry substance	5.99100	6.79600	7.66700	10.14100
Crude ash in fresh beets	1.25811	1.19061	1.44906	1.67326
Pure ash in fresh beet	0.94227	0.89514	1.12218	1.32875
Sulfuric acid	0.03227	0.02945	0.04150	0.04483
Phosphoric acid	0.03875	0.02007	0.03109	0.03453
Chlorin	0.15188	0.16698	0.23134	0.30396
Sodium	0.09876	0.11110	0.15042	0.19741
Potassic oxid	0.42267	0.35496	0.43686	0.51664
Sodic oxid	0.06511	0.09887	0.09923	0.09159
Calcic oxid	0.03616	0.03159	0.03537	0.03485
Magnesic oxid	0.08958	0.07253	0.08845	0.09041
Ferric oxid	0.00310	0.00287	0.00224	0.00334
Aluminic oxid	0.00151	0.00081	0.00131	0.00691
Manganic oxid	0.00250	0.00154	0.00437	0.00478
Total nitrogen	0.24930	0.15995*	0.23345	0.34510
Proteid nitrogen (Stutzer)	0.08645	0.06740	0.08845	0.12389
Ammonic nitrogen	0.00545	0.00200	0.00350	0.00520
Amid nitrogen	0.02160	0.00690	0.01470	0.03985
Amino nitrogen	0.03514	0.03935	0.03470	0.03507
Nitric nitrogen	0.01936	0.03249	0.05310	0.08337
Injurious nitrogen in beets	0.13580	0.08365	0.12680	0.17616
Injurious ash per 100 of sugar	5.62920	6.73790	7.92850	13.43300
Injurious nitrogen per 100 sug.	1.02880	0.73900	1.04790	2.04840
Press Juice According to Ruempler.				
Total nitrogen†	0.19100	0.16450	0.23335	0.29800
Albumin nitrogen	0.04290	0.04015	0.04370	0.04255
Propetone nitrogen	0.00590	0.00435	0.00760	0.00250
Peptone nitrogen	0.00542	0.00670	0.00650	0.00430

Ash Analyses

	CXIV		CXV		CXVI		CXVII	
	Crude	Pure	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	Trace	.....	Trace	.....	0.309	.....	Trace	.....
Sand	0.978	.....	0.976	.....	0.412	.....	0.874	.....
Silicic acid	0.872	.....	1.196	.....	1.230	.....	1.169	.....
Sulfuric acid	2.565	3.425	2.462	3.289	2.864	3.698	2.609	3.374
Phosphoric acid	3.080	4.112	1.717	2.294	2.140	2.763	2.010	2.599
Chlorin	12.072	16.119	14.286	19.089	15.966	20.617	17.695	22.875
Sodium	.....	10.481	.....	12.412	.....	13.405	.....	14.875
Carbonic acid	20.875	.....	21.806	.....	19.908	.....	19.064	.....
Potassic oxid	33.595	44.856	29.677	39.655	30.149	38.932	30.077	38.882
Sodic oxid	15.747	6.909	20.774	11.045	20.835	8.843	20.831	6.893
Calcic oxid	2.874	3.837	2.641	3.529	2.441	3.152	2.029	2.623
Magnesic oxid	7.120	9.507	6.064	8.103	6.104	7.882	5.263	6.804
Ferric oxid	0.246	0.328	0.240	0.321	0.155	0.200	0.194	0.251
Aluminic oxid	0.120	0.160	0.068	0.091	0.091	0.118	0.402	0.520
Manganic oxid	0.199	0.266	0.129	0.172	0.302	0.390	0.237	0.306
Loss	(2.379)	.....	(1.183)	.....	(0.697)	.....	(1.539)	.....
Sum	102.722	.....	103.219	.....	103.603	.....	103.993	.....
Ogygen equi. to chlorin	2.722	.....	3.219	.....	3.603	.....	3.993	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

*The nitrogen is remarkably low, but the duplicate determinations agree within 0.0029 percent and while the nitrogen in the juice of the siloed sample

As no ash analyses were made on the first two sets of samples, I have given the statement of the sugar, dry substance and nitrogen for the three sets in one table for the easier comparison of these data.

The essential points in the composition of the soil have been given in previous paragraphs and attention has been called to the low percentage of total nitrogen and the high ratio of the nitric nitrogen to the total, from 3.13 to 18.93 percent.

The amount of foliage and its color and the size of the beets, which averaged for all the samples taken, 3 Nov. 665.7 grams, indicate an abundant supply of nitrogen, though the average of the six composite samples taken is only 0.108 percent. The growth and color of the foliage and the total nitrogen in the beets indicate a decided excess of this element. The total nitrogen in the first beets, 38 out of the 39 samples analyzed ranged from 0.1902 to 0.3451 percent with four below 0.2000 percent. One sample fell to 0.15995 percent. The nitric nitrogen ranged from 0.0163 to 0.09319 percent. The last set of samples was submitted to an even more extended investigation, which emphasizes the very bad quality of these beets. The samples taken from the check plot show that the injurious ash ranges from 5.63 to 13.43 parts for each 100 parts of sugar and that the injurious nitrogenous substances (injurious nitrogen x 10) ranged from 7.39 to 20.48 parts per 100 of sugar. There can be no question but that these bad properties are mainly due to the excessive nitrates in the soil which in the section corresponding to the third sample of beets in each series showed on the 22 June nitric nitrogen equal to 3,240 pounds of sodic nitrate in the top four inches of soil per acre, and in the section designated as very bad land we found in soil gathered from beneath the leaves of a beet and close to the root, 8 October 1910, ntric acid corresponding to sodic nitrate equal to 0.823 percent of the air dried soil or 5,468 pounds in the top two inches of the soil.

There were only three experiments with fertilizers in which we sampled the beets, i. e., with phosphoric acid, superphosphate 1,000 pounds; potassic and sodic chlorid at the rate of 400 pounds per acre. The heavy application of superphosphate was made with the idea that the phosphoric acid thus added might cause an earlier ripening of the beets and consequently materially improve the quality of the beets. The others, potassic and sodic chlorid, were added to see if they would produce any effect upon the beets under these conditions and, if so, what. I have previously stated that in regard to the growth and appearance of the plants no difference whatsoever

---

is 0.00455 percent higher than in these beets it is still low, the lowest with one exception, of the thirteen samples given.

†These samples had been siloed for four weeks before the juices were analyzed.

could be observed between the rows to which these fertilizers had been applied, either singly or in conjunction, and the rest of the field. The growth was alike luxuriant over the whole piece of ground. The phosphoric acid did not affect the ripening in the least, so far as we could see. The samples taken at different periods, 23 Sept., 11 Oct., and 3 Nov. 1910, do not show any differences in favor of the beets grown with the application of phosphoric acid and those grown without it. We may take any single factor in the composition of the beets or all of them and there is no positive evidence of any beneficial effects accruing from the application of this amount of phosphoric acid. The amount of superphosphate added was as large as we deemed feasible and was so chosen in order ot make the ratio of phosphoric acid to the potash and nitrogen available to the crop as high as possible.

The effects produced by the other fertilizers are no more positive than those of the phosphoric acid. We must conclude, so far as these samples go, that these fertilizers have neither positively benefited nor injured the beets

Owing to a number of features in the beets grown upon such land which no one could fail to notice, questions concerning the physiological effects of these conditions necessarily presented themselves. In order to afford opportunity to study this point 100 samples were prepared in 1910, but owing to the fact that the Department of Botany had too much other work to do these samples were not examined. In 1911 I again took up this question and Mr. W. W. Robbins was kind enough to undertake to study the subject to such extent as his other duties permitted. I furnished him samples of beets grown on the bad land used for our experiments in 1910 as examples of beets grown with excess of nitre, and good beets grown on a field which, according to samples of soil tested, contained no excess of nitrates. His report is given in full as follows:

"The researches of a number of European investigators have shown that the anatomical structure of the sugar beet is correlated with sugar content. In general, beets with a high percentage of sugar have a finer structure than those with a low percentage. A cross or lengthwise section of a beet shows it to be made up, for the most part, of a ground tissue, penetrated by groups of vessels. In a cross section, these groups of vessels take a circular form, being separated from each other by parenchyma tissue. At the center of the beet the bundles are close together, forming the so-called "star." The tissue separating vessels is composed of two kinds of parenchyma cells—small cells surrounding the vessels and large ones further removed. The smaller parenchyma cells are rich in sugar, while the larger ones are principally water storage calls, poor in sugar. Hence, beets having a predominance of small celled parenchyma are richer in sugar than those in which large water storage cells predominate.

It must not be assumed from this that it would be possible to find conspicuous differences in the anatomical structure of beets varying one or two percent in sugar. Furthermore, a certain microscopical appearance is not to be associated with a given sugar content.

The question here is, "What is the effect of excessive nitrates in the soil upon the structure of the beet? Beets grown in a nitre-rich soil were compared, part for part, with beets grown in an ordinary soil. Microscopic sections of material imbedded in paraffin were cut to a thickness of about 10 microns. It was found very essential that corresponding parts of the abnormal and normal beets be compared. The most consistent and marked differences were shown by sections of the star, for here the bundles are closer together. Inasmuch as the niter beets have their sugar content depressed, as shown by chemical analysis, it was anticipated that this condition would modify their anatomy in the way mentioned above. Such was found to be the case.

A glance at the cut surfaces of a nitre and normal beet shows marked differences; the nitre beet has a glassy, watery appearance; the normal beet is yellower and not so watery. Hand razor sections of the abnormal beet slice off readily; while with the normal beet, there is a tendency for the sections to be shreddy and roll up under the razor edge. Examination with the naked eye of a normal beet cut in cross-section shows the star to be solid and compact; the small-celled parenchyma tissue forms an unbroken whitish band on either side of each ring of vessels; this band is wider on the outside of the circle of vessels than on the inner side.

In comparing this section with one from a corresponding part of a nitre beet, it will be seen that in the abnormal individual, the star is not as compact; the rays of vessels of the star are longer and further apart, being separated by large parenchyma cells. The band of whitish tissue, formed of small parenchyma cells, is not as wide in proportion to water cells; furthermore, this band is not as solid, but is broken by strips of large water-storing cells. (See Plate V.) This means that the amount of sugar storing tissue about each group of vessels is reduced, comparatively. It is very evident to one examining with the naked eye, cross sections of two beets, one abnormal—a nitre beet—the other normal, that the latter has a finer anatomy; that the ratio of small sugar-storing cells to large water-storing cells is higher; that it has more the structure of a beet rich in sugar.

Comparative microscopic examination of the beets bear out the facts as above stated. The normal beet has a greater proportion of

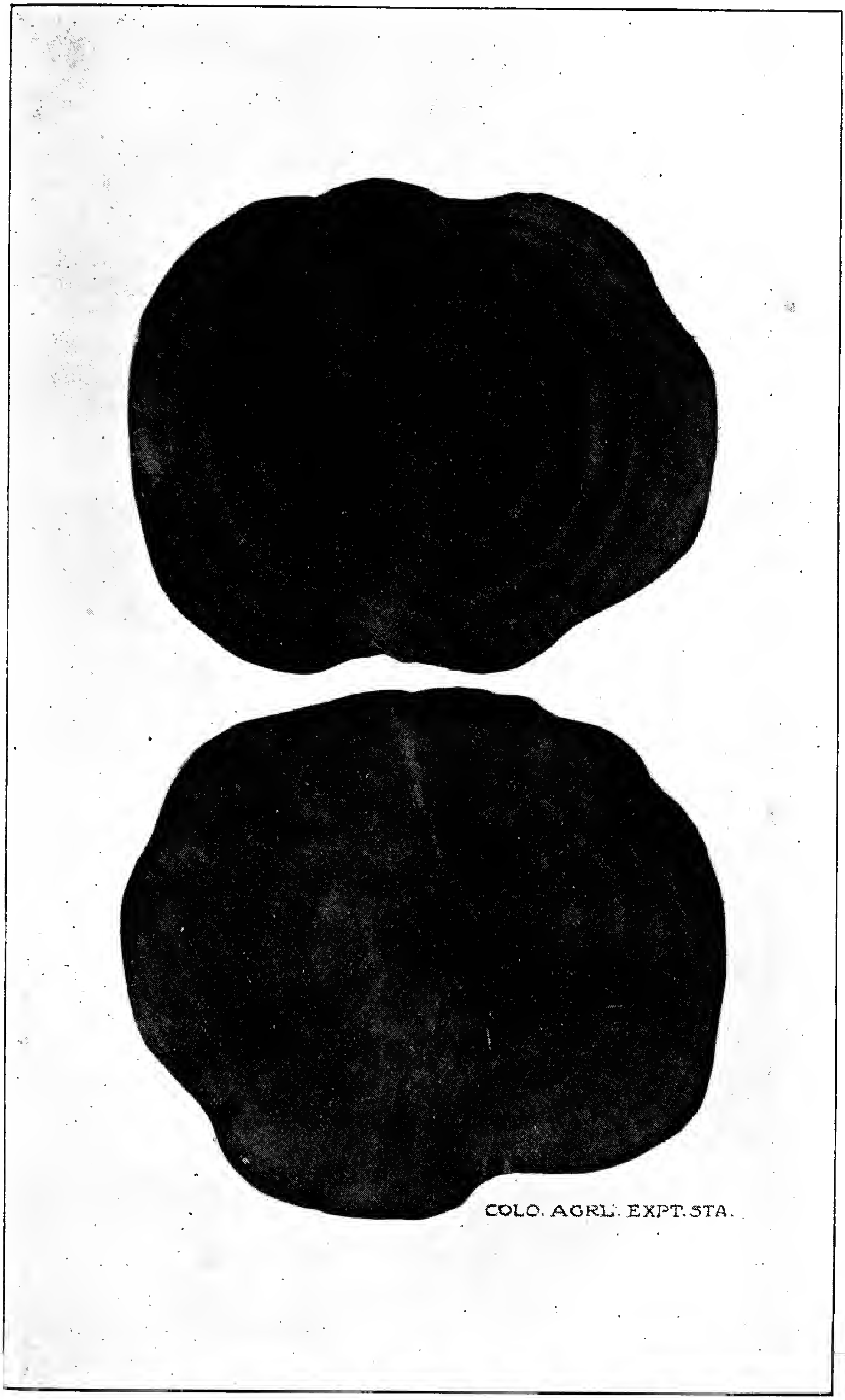


Plate V. Upper figure represents a section of a normal beet, the lower one a section of a nitric beet. Note the watery appearance of the latter and the fine-grained white rings in the former.

small celled parenchyma; the star is more compact; the groups of vessels in the star and any ring are not separated by such wide strips of large-celled parenchyma: the anatomy is finer and closer in every respect."

We will briefly consider the classes of beets so far presented in regard to the nitrogen compounds present, their general character and some of the effects produced which may be attributed to the presence of nitrates whether added to or produced in the soil. We have sought to find good beets produced in Colorado and to determine their composition. The beets grown in 1910 were evidently of medium quality, but much better in 1911, as indicated by the two samples given as representative of this year. The best Colorado samples taken in 1910 are from widely separated districts, Holly and Fort Collins, where the conditions were very dissimilar. The Holly sample was grown on newly broken sod land with a very moderate supply of water, a condition tending to lower the quality of the beets. We restate in the following table a few of the best samples:

BEST BEETS ANALYZED IN 1910.

No.	Date Harvested	Locality	Fertilizer	Av. wt., grams	Sugar, percent	Total N, percent	Nitric N, percent	Inj. N per 100 Sugar	Inj. Ash per 100 Sugar
1....	23 Sept.	Holly	None	.....	14.2	0.1253	0.00358	0.3744	3.5295
2....	3 Nov.	Fort Collins	None	673.0	18.3	0.2075	0.00090	0.6290	2.1960
3....	3 Nov.	Rocky Ford	250 lbs. $NaNO_3$	690.0	16.5	0.1449	0.00144	0.3642	2.1267
4....	3 Nov.	Rocky Ford	500 lbs. $NaNO_3$	872.0	15.8	0.2054	0.01009	0.68221	3.2050
5....	11 Oct.	Rocky Ford	None	.....	14.6	0.1290	0.01034	0.37020	4.2794
6....	2 Nov.	Michigan	....	813.0	15.3	0.2292	0.00320	0.51287	1.9446

These samples were all grown on good land, some with and others without fertilizers. Two of these samples were grown with the application of sodic nitrate, one with 250 pounds per acre, the other with 500 pounds, the latter in two portions. The first sample in the table was grown on new land, the other samples were grown on land which had been cultivated for years. The second sample represents the fifth consecutive crop of beets grown on the same land without fertilizers. The third and fourth samples were the second consecutive crop of beets on this soil. The first crop was not fertilized. This soil is well supplied with potash, 0.762 percent, also with phosphoric acid, 0.106 percent, and had an average supply of nitrogen for Colorado soils, 0.11 percent. The third, fourth and fifth samples were also the second consecutive crop of beets. The plot on which the fifth sample was grown received no fertilization of any kind either year. The soil in this case contained potash 0.95 percent, 0.012 available, phosphoric acid 0.17 percent, 0.007 available; total nitrogen, average of two samples done in duplicate, 0.10230 percent. I know nothing about the composition of the Michigan soil. This sample was obtained and submitted to examination because I was informed by men who had handled the juices in Michigan factories and also in factories in the Arkansas Valley that the Michigan juices worked much more easily than the juices from fresh beets, not frozen, thawed, rotten or otherwise deteriorated beets, in the Arkansas Valley.

The beneficial effects of sodic nitrate apparent in the third and fourth samples of this table are not in harmony with the results obtained in our other experiments with this fertilizer. Other observers, however, have found that Chile-saltpetre applied in quantities up to 340 pounds per acre may affect the quality of the beets beneficially, especially in regard to the sugar content, provided that the soil is not itself already super-saturated with nitrogen, a phrase used in the Jahresbericht der Zuckerfabrikation, 1910, p. 7, but the percentage of nitrogen in the soil experimented with and thus designated is not given. The soils on which our experiments were made would certainly not be considered, according to ordinary standards, as supersaturated, carrying a total of not more than 0.11, practically the amount considered as an adequate percentage, while the humus nitrogen amounts to 0.072 percent of the soil, showing that in this case almost two-thirds of the total nitrogen was soluble in ammonia. Another investigator, Kiehl, found as the result of his observations on 29 localities an increase in the sugar content of from 1.2 to 1.99 percent., due to the use of sodic nitrate. The conditions under which these experiments were made were not given in the abstract at my disposal. On the other hand, all the data given relative to the total nitrogen in beets grown with the addition of sodic nitrate show that it is increased, which in general is true, but in the case of the third sample, with 250 pounds of sodic nitrate, this cannot justly be asserted. The most that one can do is to hold the point as questionable, for the result actually indicates that there has been a decrease. The fourth, fifth, and sixth samples cannot be considered as checks, for the samples were not grown on the same land. This is the case in which our check plots failed us completely. The same may be said regarding the injurious nitrogen and ash. So that if we consider the third sample only, it appears that the application of 250 pounds of sodic nitrate per acre was in all respects beneficial. These favorable conclusions cannot be drawn in the case of the fourth sample, for while we have no usable check samples with which to compart it, the effects of the 500 pounds or the second 250 pounds depressed the yield by 1.3 tons per acre and the sugar by 0.7 percent. On the other hand it increased the total nitrogen from 0.14 to 0.20 percent, the nitric nitrogen practically seven-fold, the injurious nitrogen per 100 sugar 90.0 percent, and the injurious ash per 100 sugar, 50.0 percent. As I have elsewhere stated, we have, with the application of 500 pounds of sodic nitrate per acre, clearly reached the limit of its beneficial action and probably passed it and as clearly passed the limit of profit. I have made this digression from the orderly presentation of our results because of the exceptional results obtained by the application of 250 pounds of sodic nitrate per acre to this land

While the table presents our best samples of beets for 1910, it will be recognized that they show a strong tendency toward low percentages of sugar, high percentages of nitric nitrogen and high ratios for the injurious nitrogen and injurious ash per 100 of sugar. Some of them, moreover, are reasonably high in total nitrogen, and the ratio of the total nitrogen to the injurious nitrogen per 100 of sugar varies from 2.5 in the best Colorado sample to about 3.0 in the others. It is clearly stated in the table that these best samples include some grown with fertilizers, but those grown with fertilizers are not better than those grown without them, sample No. 3 excepted, for which reason I have ventured to include these best samples in one table, which exhibits the best results obtained in 1910 without fertilizers on well conditioned land from both the physical and chemical standpoints, as well as the best results obtained with fertilizers on the same kind of land.

The following table presents some further results obtained with combinations of potash, phosphoric acid, and nitrogen. The tables previously given state these results more in detail but the data here given serve our present purpose better. All of these experiments were carried out at Rocky Ford in co-operation with the American Beet Sugar Company and all of these samples were harvested 11 Oct. 1910.

There was no plot in this series to which sodic nitrate alone had been applied. None of these samples shows any betterment in quality due to the fertilizers used and neither the yield nor the percentage of sugar was improved. On the contrary, it was, in the main, depressed. The total nitrogen in two cases is rather high, in the other cases it is only moderately so. The nitric nitrogen, the injurious nitrogen and the injurious ash are quite high. The nitric nitrogen is lower in four cases than in the check sample, which is No. 5 in the preceding table. The injurious ash has been decidedly increased and while the potash and phosphoric acid applied separately seem to have depressed the injurious nitrogen, it was increased in all of the other samples. I have already stated that I believe that variations in the properties of the soils of these half-acre plots is a factor which ought not to be left wholly out of our reckoning.

We have given among our best beets two samples grown with the application of sodic nitrate 250 and 500 pounds respectively.

BEETS GROWN WITH FERTILIZERS.

	Fertilizers Used per Acre	Sugar Percent	Total Nitrogen Percent	Nitric Nitrogen Percent	Injurious N per 100 Sugar	Injurious Ash per 100 Sug.
1.....	300 pounds K*	14.5	0.12320	0.00250	0.35827	4.4445
2.....	400 pounds P	14.1	0.10875†	0.00987	0.27288	4.5900
3.....	160 pounds K					
	100 pounds N	14.1	0.21900	0.01333	0.95531	7.6843
4.....	240 pounds P					
	100 pounds N	12.4	0.15345	0.01333	0.58334	6.4200
5.....	220 pounds P					
	440 pounds N	13.6	0.23270	0.00832	0.94632	5.2692
6.....	220 pounds P					
	260 pounds K	14.7	0.17150	0.00865	0.62047	4.8520
7.....	250 pounds P					
	170 pounds K					
	200 pounds N	13.7	0.17940	0.01244	0.71351	5.4855
8.....	440 pounds P					
	300 pounds K					
	200 pounds N	15.3‡	0.13760	0.00250	0.42810	4.1634
9.....	500 pounds P					
	300 pounds K					
	200 pounds N	13.3	0.17770	0.01846	0.65603	6.3320

The 250 pounds per acre produced favorable results in all respects, yield, percentage of sugar, injurious nitrogen and injurious ash. The application of 500—or the second application of 250 pounds—depressed the crop and the percentage of sugar and increased the percentage of nitrogen and also that of the nitric nitrogen. Further, it increased the injurious nitrogen and the injurious ash per 100 of sugar. The results presented by the fertilizer experiments in which sodic nitrate was added permits the inference that this is the usual effect of the nitrate. The following tabular statement presents the results of our further experiments to study this point. The supply of plant food and water were abundant, but we furnished an over-supply of nitrates. The samples were harvested 3 Nov. 1910.

Amount of Sodic Nitrate per Acre	Sugar Percent	Total Nitrogen Percent	Nitric Nitrogen Percent	Injurious N per 100 Sugar	Injurious Ash per 100 Sug.
250 pounds..........	16.5	0.14485	0.00144	0.36424	2.1267
500 pounds..........	15.8	0.20535	0.01009	0.68221	3.2050
750 pounds..........	13.4	0.29610	0.04143	1.29250	4.7812
1,000 pounds..........	11.0	0.25505	0.04983	1.40267	5.4718
1,250 pounds..........	12.8	0.25360	0.04225	1.11500	4.0490

There can be no question about the quality of these beets nor the direct effects of the nitrate when present in these quantities. Whatever variations of soil in these acre plots may have existed to

*P stands for superphosphate 13.19% P_2O_5, K for potassic sulphate 48.55% K_2O, N for sodic nitrate 96.60% $NaNO_3$.

†See note in full statement of Analysis XXX.

‡This was a sample of eight beets. The sugar is 1.2 percent higher than the factory returns.

modify the action of the nitrates, this action has not been obliterated or so far modified as to be rendered in the least doubtful. It will be noticed that the maximum effect was produced by the application of 1,000 pounds per acre, which is a small quantity compared with the quantities which we have found in many of our soils. We will support these analytical data in subsequent paragraphs by experiments showing the factory quality of these and other beets grown on bad ground and sold to the factory, in other words, commercial beets. We will, however, next consider the analytical results obtained with beets grown on bad ground. These results, like the preceding, have already been presented in detail. The first group of results presented the effects of the soil itself without any attempt to modify them by fertilizers. This soil was already known to me as one rich in nitrates and further, one in which the nitrates were not only spreading but the accumulation had already become so great in portions of it as to exterminate the Azotobacter. The order of these samples proceeds from the best to the worst portion of the field. The samples were harvested 3 Nov. 1910.

No.	Sugar Percent	Total Nitrogen Percent	Nitric Nitrogen Percent	Injurious N per 100 Sugar	Injurious Ash per 100 Sug.
1	13.2	0.24930	0.01936	1.02880	5.6292
2	11.3	0.15995*	0.03249	0.73900	6.7379
3	12.1	0.23345	0.05370	1.04790	7.9285
4	8.6	0.34510	0.08337	2.04840	13.4330

The next group presents the results produced by superphosphate applied at the rate of 1,000 pounds per acre. The order of the samples has the same significance as in the preceding group and represent corresponding sections as is the case with the succeeding table. No experiments were made with section four.

No.	Sugar Percent	Total Nitrogen Percent	Nitric Nitrogen Percent	Injurious N per 100 Sugar	Injurious Ash per 100 Sug.
1	10.9	0.25860	0.04982	1.41290	7.1557
2	11.8	0.24350	0.04621	1.40770	6.4939
3	10.2	0.30675	0.07260	1.78290	9.0421

The superphosphate has under the conditions obtaining in this soil produced decidedly bad results. The contrary to what we had expected. If the check rows had been separated from those treated with superphosphate by a space of even thirty feet we would try to believe that the action of the phosphate was in this case just what it has proven to be in many other experiments, but that some other factor had brought about the results. We have, however, no explanation, not even the size of the samples, to modify the conclusion that the action of the phosphoric acid was decidedly bad. All of the beets suffered from attack by leaf-spot, but all suffered alike and the

*Other samples representing this section of the field taken 23 Sept. and 11 Oct. gave for total nitrogen 0.2706 and 0.3070 and nitric nitrogen 0.03480 and 0.06417. The figure should probably be 0.25995.

foliage was so abundant that the loss of a considerable number of leaves did not make a great difference in the appearance of the field.

The results produced by the potassic chlorid, 400 pounds per acre, are presented in the following statements:

No.	Sugar Percent	Total Nitrogen Percent	Nitric Nitrogen Percent	Injurious N per 100 Sugar	Injurious Ash per 100 Sug.
1....................	13.1	0.23700	0.02510	1.04240	4.8114
2....................	11.8	0.24715	0.04111	1.17790	6.5580
3....................	12.2	0.34510	0.05120	1.62910	8.2453

This amount of potassic chlorid may possibly have produced a little effect upon the quality of the beets but all the samples are still so bad that there is no reason at all for entertaining a hope that it will be feasible to profitably produce good beets by its use.

The next fertilizer used was salt, sodic chlorid. I knew that this soil was very rich in chlorin, but I also knew that it was rich in potash and used the salt just as I used the potash to determine whether it would have any effect or not, though it seemed to be a case of "carrying coals to Newcastle."

No.	Sugar Percent	Total Nitrogen Percent	Nitric Nitrogen Percent	Injurious N per 100 Sugar	Injurious Ash per 100 Sug.
1....................	13.0	0.19020	0.01558	0.60077	4.8482
2....................	12.4	0.21545	0.03713	0.74315	5.7885
3....................	10.4	0.33970	0.08743	1.78750	12.0490

The results are not decisive enough under the circumstances to justify any conclusions, but if, with a knowledge of all the conditions, one had to express an opinion, it would be that salt, sodic chlorid, gives more promise of producing good results than the other fertilizers used.

This restatement of some of the salient features in the composition of our beets gives us not only a clearer view of their quality and the characteristics of their composition, but justifies us in comparing the established quality and composition of beets grown with the application of saltpetre with the quality and composition of those grown on nitre-infected ground. For this purpose we will use first, the sample grown on newly broken sod land at Holly, Colorado, and in the extreme eastern part of the Arkansas Valley as representative of a fairly good quality of beets grown in this section; second, the sample of beets grown on desirable land with the application of 1,000 pounds Chile-saltpetre per acre, and third, the sample grown on the third section of our bad land without the application of any fertilizers.

No.	Amount of Sodic Nitrate per Acre	Sugar Percent	Total Nitrogen Percent	Nitric Nitrogen Percent	Injurious N per 100 Sugar	Injurious Ash per 100 Sug.
1.....	Virgin soil	14.2	0.12530	0.00358	0.37440	3.5295
2.....	1,000 pounds	11.0	0.25505	0.04983	1.40267	5.4718
3.....	Abundant in soil	12.1	0.23345	0.05370	1.04790	7.9285

The following effects of the nitrates are so patent that they are beyond question. The sugar has been depressed by at least 2.0 percent. The total nitrogen has been doubled. The nitric nitrogen has been increased from ten to fourteen times. The injurious nitrogen per 100 of sugar has been increased between three and four times and the injurious ash about twice. The same effects can be traced in our fertilizer experiments, though not so plainly. Further, these effects are so pronounced that no questions of water supply, cultivation, variety or strain of seed, the effect of leaf-spot, insect injury, climatic conditions, or the general conditions prevailing in our soils can in any way obscure them. How and to what extent these factors may have modified them is not a part of our present problem. These factors must be assumed to exist and to be operative.

We may now consider a few of our results obtained on samples grown on good ground without the addition of fertilizers of any kind and which may be assumed to represent beets as they are actually grown for the factories. The beets designated as grown on bad land was such a crop and they were delivered to the factory. I wish to state emphatically that the following analyses do not represent the quality of all of the crops delivered to the factories in 1910, for that would be absurd, as there are some excellent beets grown every year. If it were not so we would have more justification to attribute the low quality of our beets to climatic conditions or to some other cause acting uniformly throughout the country, which is not true. These samples do, however, represent very many crops which are actually delivered to the factories.

No.	Locality	Sugar Percent	Total Nitrogen Percent	Nitric Nitrogen Percent	Injurious N per 100 Sugar	Injurious Ash per 100 Sug.
1......	Rocky Ford	14.3	0.20605	0.01984	0.71591	3.1043
2......	Fort Collins	13.2	0.18636	0.02138	0.63840	3.4164
3......	Rocky Ford	12.7	0.25215	0.04537	1.07246	3.7030

The average percentage of sugar for these three samples is 13.7 while the average for the Arkansas Valley for the same year, 1910, was approximately 14.2 so that they are only a little below the average for the Valley. The low sugar, the high total nitrogen, the high nitric nitrogen, the large amounts of injurious nitrogen per 100 sugar, and the relatively high injurious ash per 100 sugar can scarcely be attributed to any other cause than to an excessive supply of nitrates during the season, especially in view of the results just presented as having been definitely produced by nitrates either applied to or formed in the soil. The Fort Collins sample was grown on the College Experimental Farm in the surface two inches of which we found in October nitric nitrogen equivalent to 160 pounds per acre. These samples were taken from fallow spots among the beets. Again we found in the same tract of land but not in the same place in April nitric nitrogen equivalent to 1,000 pounds of sodic nitrate in the surface two inches. We showed in Bulletin 155 that at the end of the season and even in the early part of the winter that our lands, especially the beet fields of the Arkansas Valley, contained in 1909 quantities of nitrates reaching 1,902 pounds in the surface six inches of soil. The presence at times of sufficient quantities of nitrates in our soils to produce these effects cannot be doubted, and the effects are those who are produced by excessive quantities of nitrates.

We have not heretofore laid any special stress upon the presence of nitric nitrogen in all of the samples of our Colorado beets but the results show plainly that an excess of nitrates increases the amount of this form of nitrogen in the beet from 0.0009 percent, the minimum found in a Colorado beet, to 0.04983 percent for beets grown with the application of 1,000 pounds of Chile-saltpetre and a maximum of 0.08743 percent in beets grown in very bad ground. There are other very striking effects shown by the composition of the ash, but we will take these up later.

It has been shown that the beet plant draws upon the nitrogen of the soil most heavily in June and July. Professor Remy has shown that to produce a crop of 44 tons, together with the tops per hectare (2½ acres) requires 455.4 pounds of nitrogen. The nitrogen appropriation is distributed as follows in respect to times: May, 4.4 pounds; June, 112.0 pounds; July, 212.2 pounds; August, 48.0 pounds; September 44.0 pounds, and October 35.2 pounds. In our experiments with sodic nitrate the last 250 pounds were applied on 27 July. This would appear to be too late to produce any decided effect upon the crop, and we find the maximum effect produced by the application of 1,000 pounds per acre, the last portion of which was applied on 22 June. The condition of an early supply of nitre may or may not be met in the field as it has not yet been determined during what period the most liberal amount of nitrates may be furnished to the beets by the soil, i. e., without artificial applications. It is almost certain that this will differ in various pieces of land. Our highest figures for beet fields have been obtained in early winter or spring, but we have not as yet made any systematic study of this point. In subsequent paragraphs, however, we will give the results obtained by applying nitrates to beets beginning 1 August and continuing at intervals of 14 days, till the plots had received a total corresponding to 750 pounds per acre.

The experiments with sodic nitrate in 1910 were inaugurated with the intention of running the beets thus produced in an experimental plant to see whether we actually produced the bad working qualities in these beets which had been observed in the beets grown in the Valley during the past eight years. This was carried out on a sufficiently large scale to show what we had actually accomplished in this direction. The beets were treated in all respects just as they are in any factory, sliced, subjected to diffusion, a thin juice produced, which was treated with milk of lime, carbonated, etc., and finally evaporated to a thick juice; but none of the samples were carried farther than this point except as will be given later. The dried cossettes and these thick juices were subjected to examination with the following results, which were kindly furnished me by Mr. W. H. Baird, at that time the General Superintendent of the American Beet Sugar Company. The analytical work was done by Dr. Potvliet. The designation of the fields is the same as in the preceding tables.

ANALYSES OF BEETS USED IN EXPERIMENTAL RUN.

DRIED COSSETTES.

Field	1	2	3	4	5	6	7
Sodium nitrate appl'd, lbs.	250	500	750	1,000	1,250	None	Bad L'd
Sodic nitrate in cossettes.	0.5628	0.5203	0.9005	1.1483	1.4595	0.5719	2.4320
Sodic nitrate per 100 dry substance	0.5739	0.5239	0.9126	1.1544	1.4797	0.5789	2.4870
Total nitrogen	0.9163	0.9346	1.2617	1.3673	1.5968	0.9879	1.9223
Total nitrogen per 100 dry substance	0.9342	0.9412	1.2788	1.3746	1.6167	1.0001	1.9569
Nitrate nitrogen in total nitrogen	10.1000	8.1000	11.8000	13.8000	15.0000	9.5000	20.9000
Dry substance	98.0800	99.3000	98.6700	99.4700	98.7700	98.7800	98.2300

ANALYSES OF THICK JUICES PRODUCED.

Field	1	2	3	4	5	6	7*
Sodic nitrate applied, lbs.	250	500	750	1,000	1,250	None	Bad L'd
Actual D. S.	59.1500	59.9100	46.5000	48.5100	51.6000	50.8700	46.5800
Sodium nitrate	0.3176	0.2888	0.4927	0.6422	0.7909	0.4510	2.2170
$NaNO_3$ per 100 D. S.	0.5369	0.4720	1.0595	1.3239	1.5327	0.8866	4.7590
$NaNO_3$ per 100 sugar	0.6107	0.5346	1.2226	1.5327	1.7733	1.0044	6.8420
Total nitrogen	0.3902	0.3517	0.4083	0.4472	0.5004	0.3620	0.8770
Nitrogen in 100 D. S.	0.6599	0.5870	0.8780	0.9219	0.9699	0.7116	1.8828
Nitrogen in 100 sugar	0.7506	0.6648	1.0131	1.0687	1.1219	0.8062	2.7068
Percent N. reduced	29.3000	37.6000	31.3000	32.9000	40.0000	28.8000	29.3000
Nitrate N. in total N.	13.4000	13.2000	19.9000	23.6000	26.0000	20.5000	34.2000
Sugar, per 100 D. S.	87.9100	88.2900	86.6600	86.3700	86.4300	88.2600	69.5600

These thick juices were further examined by us with the following results:

Field	1	2	3	4	5	6	7
Specific gravity	1.29900	1.28900	1.21800	1.22900	1.24200	1.24200	1.25100
Total nitrogen	0.35235	0.36885	0.37710	0.43440	0.41565	0.33427	0.99710
Ammonic nitrogen	0.00613	0.00690	0.00735	0.00760	0.00813	0.00605	0.03010
Amid nitrogen	0.00817	0.00765	0.01105	0.01190	0.01498	0.00965	0.04870
Amino nitrogen	....	0.17814	0.20386	0.21560	0.19483	0.28616	....
Nitric nitrogen	0.06034	0.05085	0.09302	0.11210	0.13430	0.08289	0.49313

The technical results agree very well with those obtained by the analysis of our field samples. Field No. 6 was intended to be a check field but as elsewhere stated it failed us. The technical re-

*These beets were taken from the very bad portion of the field and correspond to the section of the field designated by the number 4, see page 99.

sults corroborate the observations previously made upon the samples of this field for the real coefficient of the thick juice from these beets is 88.26, which is at least one point too low for beets grown on such land and in the perfect condition that these beets appeared to be at the time that they were sliced. We concluded from our analytical data that the beets grown with 250 and 500 pounds of sodic nitrate per acre were our best beets and that those grown with 1,000 pounds per acre were the poorest beets and that the excess of sodic nitrate had producd this effect. We see in considering the real coefficients of purity of these thick juices, probably the best measure of these effects, that by the application of 750, 1,000 and 1,250 pounds of sodic nitrate to the acre we have depressed it 1.89 points below a field sample grown as a check but which itself is at least 1.25 points below what the coefficient of a reasonably good thick juice should be. The lowest coefficient is found for the beets grown with 1,000 pounds sodic nitrate per acre. The beets grown in Field 7, elsewhere designated as bad land, gave a thick juice of only 69.56 coefficient of purity, which is scarcely 3.5 points above the conventional limit for molasses. The amino and nitric nitrogen in these juices present the same facts with still greater emphasis, the nitric nitrogen ranging from 13.38 percent in the best sample to 49.45 percent of the total nitrogen in the worst sample.

I stated in an earlier paragraph that our beets, specifically the beets of the Arkansas Valley, produced too much molasses. I think that the sugar technologist will agree that a thick juice with a real coefficient of purity of 87 or 86 will produce a large amount of molasses and concerning a coefficient of 69.6 there can be no question. None of these juices were boiled, so we did not study the properties of the filmasses produced from such beets but Mr. H. E. Zitkowski, the Chief Chemist at the factory, told me that he tried the thick juice of No. 7 on a small scale and that it was all that the coefficient of purity indicated, very bad.

The amount of molasses that sound beets of good quality should produce is somewhat difficult to ascertain. The statements made concerning German beets often pertain to houses producing only raw sugar which carries some of the molasses. In others, where the various green syrups are boiled several times and the saccharate is used in liming the thin juice, it is difficult to tell how much molasses the beets are producing, but in non-Steffens houses, producing granulated sugar, we can obtain a very fair approximation to a correct answer. For our purposes, I will assume that beets with 16.0 percent sugar and of good quality ought not to produce more than 5.5 percent of their weight of molasses. While this is to the best of of my knowledge, a fair estimate, it does not matter in this case whether the estimate is a point too high or a half point too low, because some of the beets in the Arkansas Valley have in years past produced from 7 to 9 percent and even more, which is clearly a very large amount, too much in fact by several percent. The explanation that I offer for this fact is evident and has already been formulated, i. e., that the soils furnish too large an aggregate amount of nitrates which effect a late maturation of the beet, which may or may not explain all of the bad qualities observed in them. Whether it does or not we have shown that the nitrates will depress the sugar content, this has long been established, increases the injurious nitrogen and the injurious ash and renders the beets rich in nitric acid. I have made ths fact evident by giving in all of the analyses presented, the nitric nitrogen present. If this be true, then the molasses should be rich in nitric nitrogen. I have never examined the saccharate for nitric nitrogen. It is probably very small in amount or entirely absent, as the Steffens waste waters are rich in it and it should not be carried down with the saccharate to any considerable extent; so that the nitric nitrogen present in molasses even in Steffens houses, would owe its origin to the beets worked and not to the saccharate. I have the determinations of the total and nitric nitrogen in a number of molasses. Some of these were furnished me by Mr. Baird and made in the laboratory of the Rocky Ford factory in connection with this work, but others of them were made in our Station laboratory. The following is a statement of the results:

TOTAL AND NITRIC NITROGEN IN MOLASSES.

		Nitrogen Total	Nitrogen Nitric	Percent of Total Nitrogen
1..........	Bohemia	2.4000	0.0067	0.28
2..........	Bohemia	2.3000	0.0032	0.14
3..........	Bohemia	2.4200	0.0042	0.19
4..........	Bohemia	2.2600	0.0082	0.37
5..........	Michigan	2.5200	0.0470	1.85
6..........	California	1.9000	0.0920	4.80
7..........	Colorado	2.1100	0.3200	15.30
8..........	Colorado	2.0700	0.4000	19.30
9..........	Colorado	1.8038	0.3715	20.60
10..........	Colorado	1.5253	0.3146	20.63
11..........	Colorado	1.8364	0.3830	20.86
12..........	Colorado	1.6999	0.3560	21.09
13..........	Colorado	2.0900	0.4400	21.20
14..........	Colorado	2.0500	0.4700	23.00
15..........	Colorado	1.5638	0.4516	28.88
16..........	Colorado	1.2798	0.1839	14.37
17..........	Colorado	1.7082	0.2737	16.04
18..........	Colorado	1.3241	0.2584	19.51
19..........	Colorado	1.8595	0.4225	22.71
20..........	Colorado	1.8699	0.1196	10.66
21..........	Colorado	1.3433	0.1560	11.62

The Colorado molasses are all lower in total nitrogen than the Bohemian and Michigan samples, but are without exception higher in their nitric nitrogen. If we compare the lowest percentage of nitric nitrogen found in the Bohemian with the highest found in a

Colorado analysis we find that the Colorado molasses contains 147 times as much. If we compare the lowest ratio for the nitric to the total nitrogen in the Bohemian samples with the highest ratio for the Colorado samples, we find the latter 206 times the former. The Colorado beets here represented produced from 5.5 to 7.5 percent of molasses, calculated on the beets cut while the Bohemian beets produced, according to the best information that I can obtain, certainly not more than 5.5 percent. Molasses Nos. 7 to 15 inclusive and also No. 20 are molasses from the seasons of 1909 and 1910, but samples 16, 17, 18, 19 and 21 are molasses from the season of 1911. Only four of the 1911 samples are from factories from which I obtained samples in 1910. It will be observed that these samples are in the main lower in nitric nitrogen than the Colorado samples of 1910 and the factories were producing less molasses calculated on the beets cut than in 1910, some of them two percent less. Two of the samples were taken at the end of the campaign and the beets being worked at that time were in bad condition and the production of molasses was on this account a little heavier than earler in the season. These molasses are a little lower in nitric nitrogen than those obtained earlier in the season, which is quite natural.

Subsequent experiments show that defoliation in early September causes the retention of the nitric nitrogen in the beets and it may be argued by some, if they know the facts, that the leaf-spot may have caused this abundance of nitric nitrogen in the molasses by having destroyed the foliage to so large an extent. The first consideration is that beets do not normally contain such quantities of nitric nitrogen and it was not produced in the beets by the leaf-spot. A second consideration is that some of the Colorado samples rich in nitric nitrogen were produced from beets free from leaf-spot.*

*NOTE—As beet molasses has become a considerable factor in fattening cattle, we are sometimes asked about the value of the nitrogen present in the molasses. It is not a part of our purpose to go into this question to any extent. It is just to state that no representation is made by he Colorado factories, so far as I know, that the molasses has any value because of its nitrogen content, but only because of its sugar or carbohydrate content. The following analyses show the forms in which the nitrogen is present or permit us to infer in what form it is present.

No.	Total Nitrogen	Ammonic Nitrogen	Amido Nitrogen	Amino Nitrogen	Nitric Nitrogen	Proteid Stutzer
1........	1.0802	0.01557	0.02323	0.22256	0.15520	0.05570
2........	1.0674	0.01478	0.02508	0.23354	....	0.05570
3........	1.2597	0.01584	0.02349	0.12332	0.02190	0.04593
4........	1.0495	0.02138	0.02191	0.14034	0.20480	0.04805
5........	1.3832	0.02033	0.03352	0.28690	0.32170	0.05306
6........	1.4372	0.02085	0.03934	0.21377	0.15320	0.05807
7........	1.0495	0.01663	0.02877	0.22941	0.12180	0.03168

As the methods of treatment in the defecation of the juices tend to remove the proteids the small amount of nitrogen indicated as present in this form by Stutzer reagent was chceked by precipitation with acetic acid and alcohol and washing with water to determine albumin which gave us from zero to 0.014 percent nitrogen in this form, a wholly negligible quantity at best. These molasses are all from the 1911 campaign and show that from one-tenth to one-quarter of all the nitrogen present in these samples was in the form of amino compounds and the rest was probably present in the form of betain. The nitrates have no food value and the other compounds are not generally believed to have much if any food value, certainly not more than an equal weight of carbohydrates.

Three samples of Steffens waste water which had been concentrated showed the presence of from 0.15 to 0.61 percent of nitric nitrogen. These figures indicate that large quantities of nitrogen as nitrates go into the waste water. I have not sufficient data relative to the individual samples to justify me in making any attempt to present the amount, either relative or absolute, thus eliminated. This amount relative to the total present must be very high, practically 100 percent. The nitric nitrogen in the Colorado molasses examined averaged in 1910 0.34 and if we assume the yield of molasses as 7.5 percent, which may be too high for some factories, but not for others, we will obtain for the average percentage of nitric nitrogen in the crop, 0.0212, whch is not far from the average indicated by the samples grown on good soils without fertilizers, 0.0229 percent. In Landw. Vers. Stat., 1900, p. 118, are given nine analyses of German molasses, four of which seem comparable to our Colorado samples. The percentages are on molasses, not on dry substance.

	Total Nitrogen	Nitric Nitrogen	Percent of Total Nitrogen Present as Nitric Nitrogen
1.	1.942	0.04157	2.14
2.	2.131	0.04252	2.00
3.	2.229	0.03637	1.63
4.	2.162	0.04157	1.93

The nitric nitrogen is given in the analyses as "nitric acid," which I have assumed to mean N_2O_5 and have calculated the elemental nitrogen on this assumption. The rest of the samples analyzed contain considerably smaller amounts of nitric acid, but they were produced from juices to which raw sugar had been added, or were the products of other methods. We do not know the percentage of the molasses calculated on the beets from which it was produced, but its weight was probably less than five percent that of the beets and even if it were much more than this the amount of nitric nitrogen would still be very much less than we meet with in the Colorado product, from one-tenth to one-twentieth as much.

These nitrates in our Colorado beets may contribute directly to

---

Ware, Cattle Feeding with Sugar Beets. Sugar and Molasses, p. 236. says, "Briem says molasses contains 8 percent digestible proteid, apparently excessive as Beyer found 1.47 percent nitrogen of which 5.3 percent was protein, 29.3 percent betain. glutamin and asparagin and 48.3 percent amid compounds, Kuehn gives from 22.7 to 75.7 or an average of 34.4 percent of the nitrogen as amids. Albuminoids are entirely absent. Authorities, such as Kuehn. Ramm and Moussen assert that these nitric substances have a very doubtful nutritive value. certainly not greater than that of carbohydrates as their use for flesh and milk production is infinitesimally small. They are mainly thrown out in the urine.

Weiske and Schulze declare that they are without nutritive value and are simply acid amids, hence it is argued that no allowance should be made for them in the calculation of rations.

Voeltz. Naehrwert der Amide der Melasse. Zeitschrift des Vereins der Deutschen Zucker Industrie 1907 p. 681, concludes "That the amid compounds of sugar beet molasses can completely play the role of the proteids in the metabolism of mature ruminates."

It does not seem probable that the nitrogen of sugar beet molasses has any considerable feeding value.

the production of molasses but I think that they are much more significant of the condition of the beets at harvest time and of the fact that the whole crop, represented by these samples of molasses, is very rich in nitric nitrogen.

In a preceding paragraph reference was made to the results obtained by Prof. Remy in regard to the amount of nitrogen required to grow 44 tons of beets with their tops, together with the distribution of this requirement in regard to time, I stated that I have made no adequate study of the amount of nitric nitrogen furnished by the soil at various times during the season. Mr. Zitkowski, however, made a study of this question in two fields and kindly placed his results at my disposal. Both fields were planted to beets and each had an abundant supply of irrigating water. The beets grown on Field A averaged 16.2 percent sugar, sampled 18 Sept., and those from Field B, sampled on the same date, averaged 12.6 percent. The soil of Field A was very "alkaline," 1.5 percent of the air-dried soil was soluble in water. The beets on 3 Oct. showed the presence of 16.0 to 17.0 percent of sugar. These fields were divided into sections and sampled to a depth of one foot from time to time. The results are given in the following table in parts per million. These data were obtained in the season of 1911.

NITRIC NITROGEN IN SOIL ON VARIOUS DATES.

Field A.

Sampled..	4 Mar.	2 June	20 June	27 June	19 July	9 Aug.	25 Aug.
I	4.9	1.2	12.5	17.0	8.5	5.4	2.5
II	3.8	37.0	27.5	28.0	30.0	22.2	12.0
III	5.8	52.8	15.0	37.0	34.0	9.0	6.2
IV	4.6	3.2	30.0	19.0	11.5	9.5	2.7
V	7.6	4.8	36.0	15.0	40.0	35.5	...
VI	3.8	8.8	31.5	27.0	35.0	11.1	...
VII	10.8	7.5	12.0	130.0	15.5	67.0	9.2

Field B.

Sampled..	4 Mar.	2 June	20 June	27 June	19 July	9 Aug.	25 Aug.
I	10.9	112.0	23.0	20.0	59.0	52.0	105.0
II	10.1	32.0	22.0	16.0	40.0	6.5	101.0
III	10.7	87.0	136.0	141.0	6.0	16.0	103.0
IV	10.6	109.0	24.0	130.0	8.0	3.1	47.0
V	20.5	69.0	14.0	96.0	8.0	6.5	333.0
VI	...	...	...	...	...	...	286.0
VII	6.1	4.1	15.0	43.0	52.0	10.5	251.0
VIII	15.3	6.7	87.0	90.0	15.0	30.5	....

I have no detailed statement of the meteorological conditions preceding the taking of the samples nor am I certain that the beets were of the same variety, though it is probable that they were. Be this as it may, it is certain that no variety with a normal sugar content of 12.6 percent was used. The object in stating these facts, however, is primarily to show how large the quantities of nitric nitrogen in our beet fields under good cultivation may be and how it varies from time to time. These fields were not examined further so far as I now know, nor were the beets. Mr. Zitkowski was fully aware of the surprising nature of the results obtained, especially of those obtained in the samples from Field B, taken 25 Aug., and had the work checked by taking a sample and determining the nitric nitrogen by the colorimetric method and as nitric oxid and obtained an agreement within one part per million, so we may feel confident that the figures gven are essentially correct. Adopting Prof. Remy's figures and giving them in terms of tons and pounds per acre, we find that to produce 17.6 tons of beets together with their tops there would be required 182 pounds of nitrogen per acre. We have further seen that approximately three-fourths of this is appropriated by the beets in June and July or such a crop at the end of the season will have used during these months 138 pounds of nitrogen. There were 21 samples from Field B examined for nitric nitrogen during the month of June. If the average of the 7 samples taken in March and that of the 25 samples taken in June show the amount of nitric nitrogen in this acre-foot of soil on these respective dates, their difference will give us an approximate idea of the gain during this period, which is 49 parts per million or taking the weight of an acre-foot of this soil at 3½ million pounds we have an actual gain of nitric nitrogen quite sufficient to furnish all of the nitrogen for a 17.5 ton crop of beets with their tops. In July and early August a very sharp decline took place, but in the latter part of August there was a very great increase, giving an average for the seven samples taken 27 Aug. of 195 p. p. m., showing the presence of nitric acid equivalent to 4,104 pounds of sodic nitrate in the acre-foot of soil sampled.

We were so situated that we could not well analyze these beets, but the facts that those grown on this field carried only 12.6 percent sugar, which is almost as low as the lowest of our nitre beets and the presence of such an abundant supply of nitrates in June and again in August justify us in assigning to the nitre a causal relation to the low percentage of sugar, and also in assuming that the other properties of these beets were those of our nitre beets. These latter beets with 12.6 percent sugar are representative of a larger portion of the crop than the former with 16 to 17 percent, for the average for the whole crop will, in some years, scarcely reach 14.0 percent, though in 1911, an admittedly good year, the average was nearer 14.5 percent.

GREEN MANURING.

We have previously given the results obtained with various fertilizers upon the tonnage of beets, the yield of sugar and the quality of beets, and have found that they do not justify us in stating that they can be applied with any hope of profit or material improvement in the quality of the crop produced. The problem is not solved to such an extent that one is justified in assigning reasons for these results except tentatively, which we will not do. We will merely state the view which has been suggested or tacitly assumed throughout, that the quality of our beets, which is the principal object of this study, is not poor or even bad because of any lack of plant food, nor because of lack of water, nor of fungus diseases, nor of attack of insects, nor of alkali, nor of excessive water, but more probably because of the bacterial flora of the soil. I have for a long time held the view that if it were possible for us to bring about different biological conditions, we would find a way to produce beets of a good quality. I am still of the opinion that a very liberal green manuring which will produce putrefactive changes in our soils gives us the most promise of success under our conditions. It was with this view in mind that the following experiments were made. These experiments were only partially successful, particularly in regard to the quantity of green crop produced. Mr. Winterhalter had previously tried green manuring and was aware of the fact that we were likely to be disappointed in this respect and so expressed himself. We planted mustard on one plot and took a piece of winter wheat for the second one. The land chosen was an adobe, a little heavier than that on which the experiments with potash, phosphoric acid and nitrogen were made and is a part of the same general tract. The stand obtained was good but the mustard came into bloom when the plants were only a few inches high and the total weight of the green matter plowed under was disappointingly small, estimated at 5½ tons per acre. The beets on both the mustard and wheat plots were planted 13 June. The stand considering the character of the soil was excellent. The variety used was the Original Kleinwanzlebener. The irrigation and cultivation was adequate, and though the beets were harvested 9 Nov., the plot on which mustard had been grown, yielded 7.9 tons of beets with 16.04 percent sugar, 84.96 purity, the wheat plot yielded 9.1 tons, 15.83 percent sugar, 83.3 purity. These are factory returns. The shape of these beets was all that could be wished though the ground was excessively hard at harvest time. The following analyses present the analytical results obtained with these beets in our laboratory.

BEETS GROWN WITH GREEN MANURE.

Harvested 9 Nov. 1911.

	CXVIII Wheat	CXIX Wheat	CXX Mustard	CXXI Mustard
Average weight of beets	437.4 grams	505.5 grams	482.8 grams	491.3 grams
	Percent	Percent	Percent	Percent
Sugar in beets	18.50000	14.60000	17.30000	16.10000
Dry substance in beets	24.40000	21.20000	24.40000	22.90000
Crude ash in dry substance	3.48400	4.89800	3.82300	3.94000
Crude ash in beets	0.85009	1.08376	0.93281	0.90226
Pure ash in beets	0.62400	....	0.69871	....
Sulfuric acid	0.02650	....	0.03249	....
Phosphoric acid	0.06711	....	0.07439	....
Chlorin	0.04062	....	0.06542	....
Sodium	0.02641	....	0.04254	....
Potassic oxid	0.32652	....	0.34521	....
Sodic oxid	0.02747	....	0.01208	....
Calcic oxid	0.02596	....	0.02478	....
Magnesic oxid	0.07580	....	0.09391	....
Ferric oxid	0.00252	....	0.00422	....
Aluminic oxid	0.00277	....	0.00093	....
Manganic oxid	0.00230	....	0.00276	....
Total nitrogen	0.17940	0.18660	0.15270	0.15490
Proteid nitrogen (Stutzer)	0.08995	0.08385	0.08500	0.08415
Ammonic nitrogen	0.00230	0.00300	0.00155	0.00170
Amid nitrogen	0.00530	0.00865	0.00345	0.00490
Amino nitrogen	0.07791	0.06306	0.03362	0.04366
Nitric nitrogen	0.00348	0.01064	0.00141	0.00332
Injurious nitrogen in beets	0.08185	0.09110	0.06000	0.06415
Injurious ash per 100 sugar	2.41900	....	2.87730	....
Injurious nitrogen per 100 sug.	0.44243	0.62398	0.34711	0.39845
Press Juice According to Ruempler.				
Total nitrogen	0.14400	0.16505	0.12245	0.11980
Albumin nitrogen	0.05100	0.04730	0.04710	0.04540
Propetone nitrogen	0.00440	0.00340	0.00340	0.00360
Peptone nitrogen	0.00460	0.00830	0.00300	0.00450

Ash Analysis.

	CXXII Crude	CXXII Pure	CXXIII Crude	CXXIII Pure
Carbon	0.177	.....	0.433	.....
Sand	0.993	.....	0.852	.....
Silicic acid	1.012	.....	0.891	.....
Sulfuric acid	3.117	4.247	3.483	4.650
Phosphoric acid	7.894	10.755	7.975	10.647
Chlorin	4.778	6.510	7.013	9.362
Sodium	.....	4.233	.....	6.088
Carbonic acid	20.583	.....	18.889	.....
Potassic oxid	38.410	52.328	37.007	49.406
Sodic oxid	7.416	4.402	7.438	1.729
Calcic oxid	3.054	4.161	2.656	3.546
Magnesic oxid	8.917	12.148	10.067	13.440
Ferric oxid	0.296	0.403	0.452	0.603
Aluminic oxid	0.326	0.444	0.100	0.134
Manganic oxid	0.271	0.369	0.296	0.395
Loss	(3.834)	.....	(4.031)	.....
Sum	101.078	.....	101.583	.....
Oxygen equi. to chlorin	1.078	.....	1.583	.....
Total	100.000	100.000	100.000	100.000

The analyses indicate that these beets are very good ones, in fact there is but one factor in this crop that we could wish were better, that is the weight of the crop. The beets are high in sugar and comparatively low in total nitrogen. The ratio of proteid nitrogen to the total, is much higher than in a great many of our beets. The ratios for the injurious ash and injurious nitrogen per 100 of sugar are low. The pure ash is also lower than we usually find it in our beets. At first sight it seems proper to attribute these improved qualities to the green manure. I am not at all disposed to draw any conclusions from these results. They would have to be extended and corroborated before it would be proper to do so.

In presenting the results of our attempt to find out whether there was such a marked difference in the yield, sugar content and coefficient of purity of beets attacked by the leaf-spot in varying degrees of severity that we might be justified in asserting the nature and extent of the injury due to this cause, I remarked, that there seemed to be a relation between a small yield and a high sugar content rather than between any other recognizable factors. It is not evident that this is equivalent to saying that this relation exists between the size of the beets and the sugar content, though such may be the fact, for though the average weight of the beets analyzed was not far from one pound each, the yield of about 8.2 tons per acre with a stand of 32,000 beets per acre shows that many of the beets were small, less than one-half pound in weight. I have the record of three other fields planted to Z. Z. Klinewanzlebener seed and to which burnt lime, 6 tons, waste lime, 30 tons, and stockyard manure, 30 tons per acre had been applied, and we have low yields and high sugar percentages for the year of application and also for the succeeding year. These beets were not analyzed but the sugar content as shown by the factory returns, especially for the second year, 17.2, 17.9 and 16.0 leave no room for doubt but that they were good beets. It is for such reasons that I am not inclined to attach much importance to the good results obtained in the green manuring experiments. The profit on such a crop of beets is too small to make it desirable for us to try to raise such crops simply because the beets are good, but it is not clear why these crops are not larger. Thirty tons waste lime or the same quantity of stockyard manure furnishes a heavy dressing of phosphoric acid, in the former, 528 pounds, and of both phosphoric acid and nitrogen in the latter case, 492 pounds of phosphoric acid and 360 pounds of the nitrogen, which ought to bring about the production of more than 6 or 8 tons of beets per acre. It is, however, true that these beets, grown with the application of green manure and on ground that was in a bad physical condition, are among the best, if not the very best, beets which we sampled in 1910.

EXPERIMENTS OF 1911.

In 1910 we added Chile-saltpetre up to 1,250 pounds per acre, making the last, the fifth application of 250 pounds on 27 July. It seems to have been established that the beet plant appropriates about three-fourths of the total amount of nitrogen used during the season in June and July and consequently only smaller amounts after 1 Aug. Our results in 1910 indicated that 1,000 pounds per acre, the fourth portion of 250 pounds applied 22 June, produced the maximum effect. This is at a time when the beet is appropriating nitrogen most actively. Our examination of soil samples shows the presence of large amounts of nitric nitrogen in our cultivated fields, especially in fallow spots later in the season. If this nitric nitrogen in the soil be, as I believe it is, primarily due to fixation there is no reason why the supply should not occur later or perhaps continue throughout the season. For this reason, and further to study the effect of large amounts of nitrates upon the ash content of the beet and particularly upon the amount of phosphoric acid appropriated, further experiments were instituted. In these we made our first application of nitrates at the rate of 250 pounds per acre 4 Aug. 1911, and three subsequent ones at the rate of 125 pounds per acre at intervals of 14 days, making the last application 28 Sept. The beets were already well developed when these experiments were begun, the tops were exceedingly heavy and very dark green in color. The varieties used were Wohanka Erntereichste and Zuckerreichste. One-tenth acre was used in each case and check plots of like size. All plots were irrigated five days after the first application of nitre. There were light showers on 1 and 2 September, about 0.14 inch of rain. On 11 September the plots were again irrigated. Cultivation was out of the question owing to the heavy, very brittle foliage. The first samples were taken from the check plots 8 Aug. All samples taken from these plots consisted of at least 18 beets each, of which a composite sample was made. The second set of samples was taken 18 Aug. and every 14 days thereafter till the beets were harvested 8 Nov., the latest possible date, because there was great danger of their being frozen in the ground. The effects of the nitre were very evident in less than a fortnight in the increased growth and deepened color of the foliage. This difference continued to become more evident till about 10 Oct. when the check plots showed unmistakable evidences of ripening while the treated plots were still in the full vigor of their growth. During the night between 20 and 21 Oct. the temperature fell to 13.6° F. and the tops were of no further use to us. The beets, however, were effectively protected by the heavy foliage and the fact that they had grown well below the surface of the ground.

Samples of these beets were photographed 15 Aug. to show the

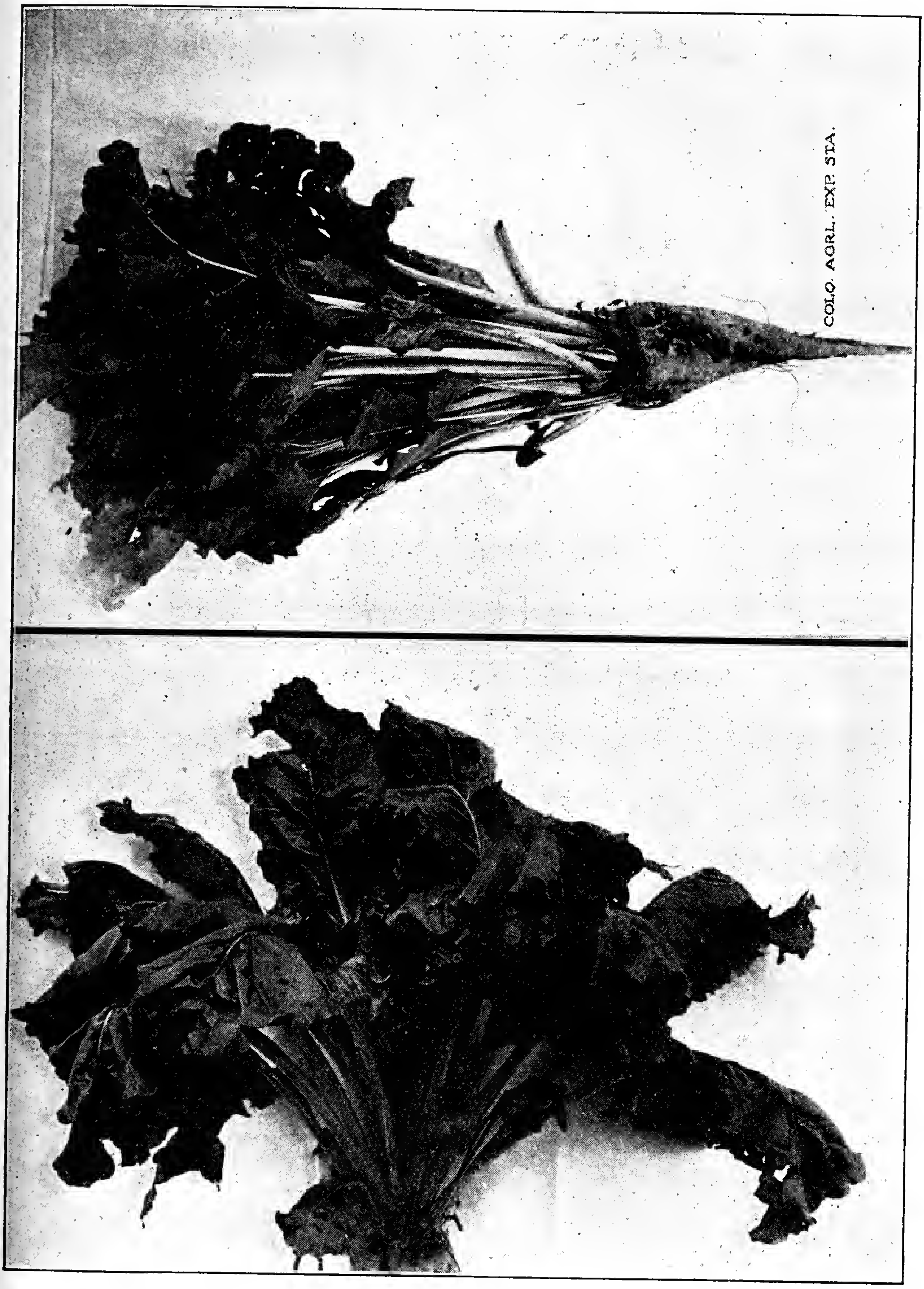


Plate VI. This plate shows development of foliage on beets 15 Aug. 1911.

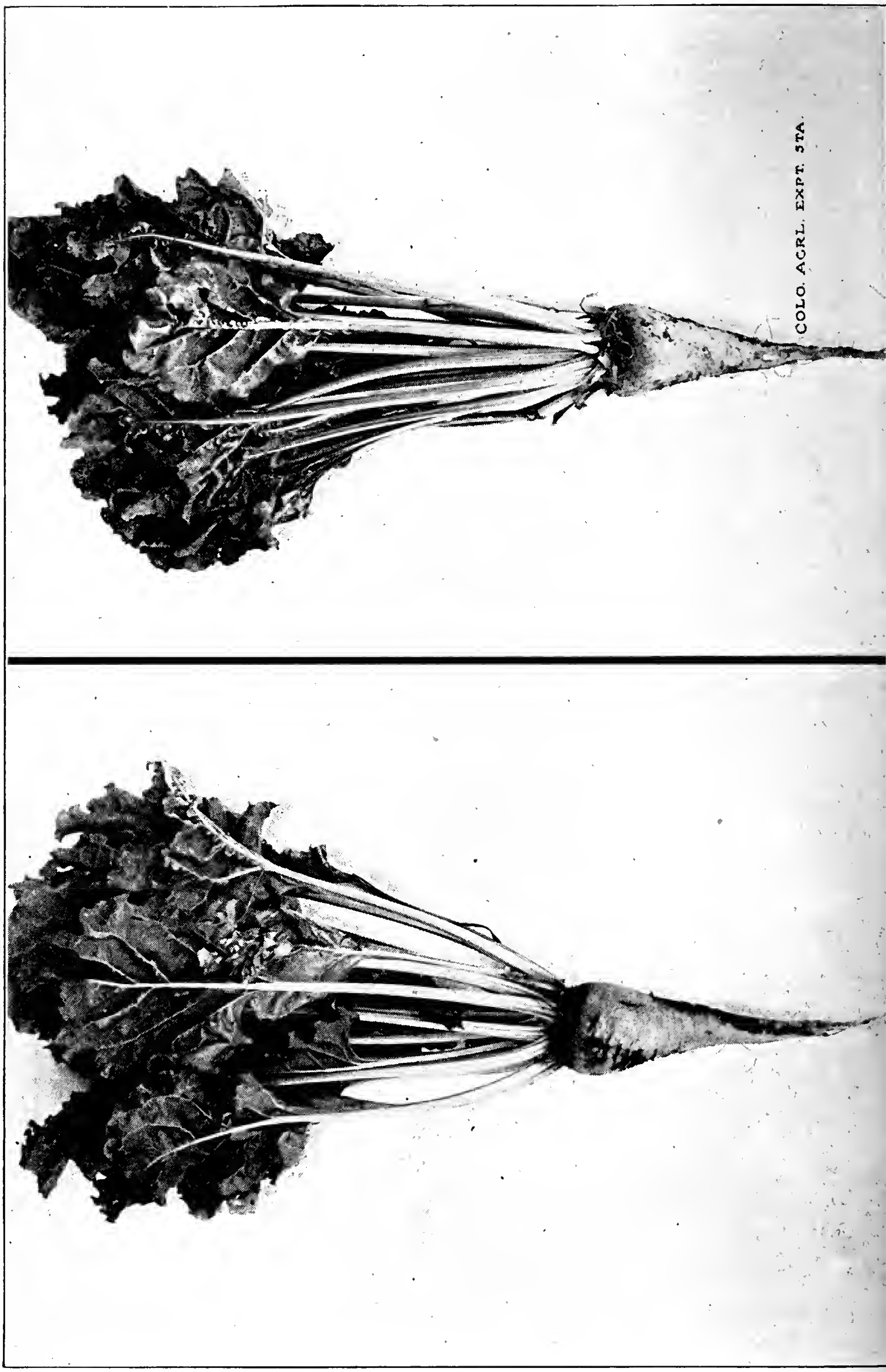


Plate VII. These beets weighed 2½ and 3 pounds each, while the tops weighed 4 pounds each.

whole plant on this date; in order to give a correct notion of the luxuriance of the tops. There are two plants of each variety. Plate VI represents Z R and Plate VII E R. Plate VI, lower figure, shows the top only of an individual of the Z R variety.

The land on which these beets were grown is abundantly supplied with nitric nitrogen, at least the samples taken in 1910 from the beet plots showed considerable quantities, fallow strips giving nitric acid equivalent to 306 pounds of sodic nitrate in the top six inches of soil on 18 Oct. 1910.

In 1911 the divisions of the farm were designated as sections and plots. The section immediately west of the beet plots, section 1700, was partly fallow, but had been cultivated throughout the season though not irrigated. It was covered with a fine soil mulch. This fallow portion was divided into three portions for the purpose of determining the nitric nitrogen in it and sixteen samples taken to the depth of two inches, and a like number to a depth of four inches from each section; these were united to form composite samples representing the respective depths. There were four samples taken from each section from the fourth to the seventh inch inclusive and united to form a composite sample. These samples were taken 14 Sept. 1911. The beets in the adjoining section were growing rapidly at this time. The nitrates, calculated as sodic nitrate, amounted to 670 pounds in the top seven inches of the south section, 517 pounds in the top seven inches of the middle section and 320 pounds in the top four inches of the north section. These determinations were made by the phenol-sulfonic acid method. We have done this, however, with other samples of the soil and found that they agreed very well with the Schloesing method. These amounts of nitrates, provided like amounts were formed in the sections occupied by the beets, are quite sufficient to account for the extraordinarily vigorous growth of tops in those sections to which we applied no nitrate. We were aware of the fact that this land furnishes many hundreds of pounds of nitrates per acre-foot of soil under favorable conditions. The deportment of the beets in 1910 as well as our analytical results had fully apprised us of this fact. The luxuriant growth of tops and their blue-green color on 1 Aug. 1911 showed it almost as certainly as our subsequent determinations.

It may be well in this connection to restate our purpose in applying sodic nitrate under such conditions. It has been shown by Prof. Remy that the greatest consumption of nitrogen by beets takes place during the months of June and July. The growth and color of the tops in July admitted of no question but that these beets had been well supplied with nitrogen during this period. Our results in 1910 showed that the application of from 250 to 750 pounds per acre, applied subsequent to 1 April and in addition to 250 pounds applied on ths date was decidedly prejudicial. The application of 250 pounds 1 May produced only a small depreciation in the value of the beets, but further applications of this amount, made at intervals of four weeks, up to 27 July, produced very bad results. The supply of nitrates furnished by our soils continues, as shown by samples taken from beet fields throughout the season, even into early winter. We wished to demonstrate what the effects of an excessive supply of nitrates late in the season may actually be.

The choice of the land known to be already well supplied with this form of nitrogen may be considered ill-advised. This was the most accessible and practically the only available land at our disposal and there are some advantages in using such land for the large supply in the check plots, in a measure protected us against exaggerated results due to the nitrate added, which might have been produced had we used land which was only moderately well supplied with or was even in need of nitrogen.

The details of the cultivation received have already been given in sufficient fullness.

The first samples were taken 8 Aug. from plots of the same varieties to which no nitrates had been applied. The data obtained from these samples will show the condition of the beets at the time we made the first application, 4 Aug., with reasonable accuracy as only four days had elapsed.

The 1911 series of experiments differ in the following essential particulars from those of 1910, the seasons though favorable were different, the soils were both productive but not alike in character, in 1910 the nitrate was all applied before 1 Aug., in 1911 none was applied until after this date. In 1910 the beets grown in the Arkansas Valley were quite severely attacked by the leaf-spot, the 1911 samples grown at Fort Collins were not affected at all, a few leaves could be found here and there showing this fungus, but they were scarce and the disease was wholly negligible, but while the varieties were standard ones in both cases, they were not the same. I regretted this but I could not help it. In 1910 our experiments were made with Original Kleinwanzlebener, in 1911 with Wokanka heaviest yielders, "ER" and richest in sugar, "Z R." There is no question but that these strains differ in some respects, among which may be included their susceptibility to varied conditions. Our results are so positive and consistent, however, that these differences in the strains of beets do not conceal them, though some differences do find expression in our results.

The land used in 1911 was part of the same field on which the college beets of 1910 were grown. This land is level, well located and the soil productive. It contains according to older analyses of general samples, potash soluble in hydrochloric acid 0.87, phosphoric acid 0.12, total nitrogen 0.147 and humus 0.426 percent. The ratio of nitric nitrogen to the total will be given in a subsequent paragraph. Composite samples of soil and subsoil were taken from these plots. Four samples each of soil and subsoil were united to form composite samples. The results were as follows:

ANALYSES OF SOIL ON WHICH EXPERIMENTS OF 1911 WERE MADE.

	CXXIV Soil	CXXV Subsoil
Insoluble	63.489	63.547
Silicic acid (soluble in sodium carbonate)	9.866	8.557
Sulfuric acid	0.094	0.069
Chlorin	0.025	0.035
Phosphoric acid	0.175	0.160
Carbonic acid	2.976	4.942
Potassic oxid	0.715	0.573
Sodic oxid	0.408	0.316
Calcic oxid	4.725	7.310
Magnesic oxid	1.258	1.376
Ferric oxid	5.663	5.337
Aluminic oxid	3.563	2.738
Manganic oxid	0.175	0.160
Water at 100° C.	2.816	2.111
Ignition	3.918	2.143
Sum	99.866	99.375
Oxygen equivalent to chlorin	.005	.008
Total	99.861	99.367
Total nitrogen	0.1426	0.0627
Humus	0.6750	0.2620
Water soluble	0.3875	0.3450

The change in color, showing the line of division between the soil and subsoil, varies from eight to twelve inches in depth. This land seems never to have received deep cultivation which is very desirable in this case. The analyses show what is clearly recognizable by the appearance of the soil itself in section, i. e., that the subsoil is richer in calcic salts, carbonate and sulfate, than the surface soil. There is no reason whatever why this subsoil should not produce quite as well as the surface soil if once loosened up. It is well supplied with plant food, nitrogen perhaps excepted, which might be considered too low for a productive soil, but it is, under our conditions probably fully sufficient. The supply of lime and magnesia is very abundant and their ratio, from four to six of lime to one of magnesia, will have some interest for us.

The analyses of 1911 samples follow in the order of their taking. The number of beets taken in each sample was eighteen. We find it very difficult to thoroughly mix the pulp from so large a sample without expressing some of the juice. In a few of the last sets of samples we took as many as fifty beets in a sample but I doubt the advisability of taking so large a number in one sample.

ANALYSES OF BEETS AND LEAVES,* SEASON 1911.

	CXXVI	CXXVII
Variety	E R	Z R
Date of sampling	8 August	8 August
Nitrate applied per acre to date	None	None
Average weight of beets	439.4 grams	441.0 grams
Average weight of leaves	619.0 grams	745.5 grams
Average weight of beets, trimmed	....	....
	Percent	Percent
Sugar in beets	9.90000	9.80000
Coefficient of purity	75.10000	73.20000
Dry substance in beets	15.48000	15.26000
Dry substance in leaves	9.53000	9.91000
Total nitrogen in beets	0.15576	0.17617
Total nitrogen in leaves	0.33578	0.33792
Proteid nitrogen in beets (Stutzer)	0.06917	0.07022
Proteid nitrogen in leaves	0.25634	0.24665
Ammonic nitrogen in beets	0.00277	0.00277
Amid nitrogen in beets	0.00568	0.00568
Amino nitrogen in beets	0.01789	0.01789
Nitric nitrogen in beets	0.02819	0.03643
Nitric nitrogen in leaves	0.05461	0.05724
Press Juice of Beets According to Ruempler.		
Total nitrogen	0.13852	0.14027
Albumin nitrogen	0.04389	0.05335
Propetone nitrogen	0.00000	0.00025
Peptone nitrogen	0.00000	0.00150

ANALYSES OF BEETS AND LEAVES, SEASON 1911.

ANALYSES.

	CXXVIII	CXXIX	CXXX	CXXXI
Variety	E R	E R Check	Z R	Z R Check
Date of sampling	18 Aug.	18 Aug.	18 Aug.	18 Aug.
Nitrate applied per acre	250 pounds	None	250 pounds	None
Average weight of beets	528.8 grams	482.0 grams	459.6 grams	455.2 grams
Average weight of leaves	786.4 grams	718.2 grams	713.2 grams	670.9 grams
Average weight of beets, trim'd	....	....	....	....
	Percent	Percent	Percent	Percent
Sugar in beets	9.30000	9.70000	9.30000	9.50000
Coefficient of purity	74.20000	74.60000	74.20000	76.00000
Dry substance in beets	15.03000	16.00000	13.69000	15.02000
Dry substance in leaves	9.07000	9.30000	9.08000	9.35000
Total nitrogen in beets	0.15312	0.15378	0.14850	0.14058
Total nitrogen in leaves	0.27522	0.27258	0.27060	0.25674
Proteid nitrogen in beets	0.07656	0.07551	0.07932	0.07997
Proteid nitrogen in leaves	0.21991	0.22097	0.22720	0.20673
Ammonic nitrogen in beets	0.00264	0.00303	0.00198	0.00211
Amid nitrogen in beets	0.00607	0.00581	0.00594	0.00568
Amino nitrogen in beets	0.02580	0.02841	0.03178	0.03625
Nitric nitrogen in beets	0.03272	0.02998	0.03086	0.02357
Nitric nitrogen in leaves	0.06125	0.03256	0.06239	0.04360
Press Juice According to Ruempler.				
Total nitrogen	0.12384	0.15297	Lost	0.12367
Albumin nitrogen	0.05277	0.05843	0.05151	0.05730
Propetone nitrogen	0.00452	?	0.00578	?
Peptone nitrogen	0.00226	0.00450	0.00101	0.00175

*By leaves we mean the blades and stems together and by beet the whole root including the crown, but they were trimmed, i. e., the crowns cut off, before they were analyzed.

ANALYSES OF BEETS AND LEAVES, SEASON 1911.

Variety	CXXXII E R	CXXXIII E R Check	CXXXIV Z R	CXXXV Z R Check
Date of sampling	1 Sept.	1 Sept.	1 Sept.	1 Sept.
Nitrate applied per acre	375 pounds	None	375 pounds	None
Average weight of beets	672.6 grams	625.3 grams	578.1 grams	510.3 grams
Average weight of leaves	945.0 grams	735.6 grams	711.8 grams	614.3 grams
Average weight beets trimmed	513.5 grams	543.4 grams	663.1 grams	469.4 grams
	Percent	Percent	Percent	Percent
Sugar in beets	11.80000	11.90000	11.60000	13.20000
Coefficient of purity	79.20000	76.20000	76.30000	82.00000
Dry substance in beets	17.02000	18.69000	17.89000	19.76000
Dry substance in leaves	9.87000	10.03000	9.83000	10.53000
Total nitrogen in beets	0.13596	0.13794	0.15196	0.13068
Total nitrogen in blades	0.50534	0.56628	0.48180	0.45102
Total nitrogen in stems	0.12144	0.10362	0.11748	0.11418
Proteid nitrogen in beets	0.07529	0.07317	0.07254	0.07418
Proteid nitrogen in blades	0.39442	0.45302	0.41870	0.42530
Proteid nitrogen in stems	0.07103	0.07238	0.07340	0.07340
Ammonic nitrogen in beets	0.00277	0.00251	0.00237	0.00251
Amid nitrogen in beets	0.00797	0.00634	0.00831	0.00568
Amino nitrogen in beets	0.02561	0.04150	0.04947	0.04244
Nitric nitrogen in beets	0.02320	0.01925	0.02702	0.01670
Nitric nitrogen in blades	0.01060	0.00730	0.01469	0.01096
Nitric nitrogen in stems	0.06412	0.03734	0.07231	0.04816
Press Juice According to Ruempler.				
Total nitrogen	0.09643	0.11480	0.12053	0.11639
Albumin nitrogen	0.03907	0.03772	0.03778	0.03742
Propetone nitrogen	0.01170	0.01464	0.01268	0.01156
Peptone nitrogen	?	?	?	?

ANALYSES.

Variety	CXXXVI E R	CXXXVII E R Check	CXXXVIII Z R	CXXXIX Z R Check
Date of sampling	14 Sept.	14 Sept.	14 Sept.	14 Sept.
Nitrate applied per acre	500 pounds	None	500 pounds	None
Average weight of beets	850.5 grams	693.0 grams	889.9 grams	689.8 grams
Average weight of leaves	907.2 grams	659.9 grams	926.1 grams	689.8 grams
Average weight beets trimmed	711.1 grams	579.5 grams	713.5 grams	634.7 grams
	Percent	Percent	Percent	Percent
Sugar in beets	13.10000	13.70000	12.85000	14.30000
Coefficient of purity	78.50000	83.50000	73.80000	78.80000
Dry substance in beets	19.40000	19.20000	17.80000	20.47000
Dry substance in leaves	10.90000	10.95000	10.58000	11.17000
Total nitrogen in beets	0.14536	0.13134	0.16236	0.13596
Total nitrogen in leaves	0.31680	0.28380	0.34425	0.38808
Proteid nitrogen in beets	0.07656	0.07022	0.07313	0.07260
Proteid nitrogen in leaves	0.22836	0.20328	0.25080	0.21648
Ammonic nitrogen in beets	0.00145	0.00172	0.00172	0.00185
Amid nitrogen in beets	0.00396	0.00660	0.00765	0.00489
Amino nitrogen in beets	0.03413	0.06223	0.04535	0.05159
Nitric nitrogen in beets	0.01932	0.01175	0.02454	0.01556
Nitric nitrogen in leaves	0.03181	0.01708	0.04398	0.01353
Press Juice According to Ruempler.				
Total nitrogen	0.12290	0.09708	0.13006	0.12090
Albumin nitrogen	0.04323	0.03289	0.03742	0.03775
Propetone nitrogen	0.00863	0.00545	0.00866	0.00469
Peptone nitrogen	?	0.00297	0.00049	0.00296

ANALYSES OF BEETS AND LEAVES, SEASON 1911.

	CXL	CXLI	CXLII	CXLIII
Variety	E R	E R Check	Z R	Z R Check
Date of sampling	28 Sept.	28 Sept.	28 Sept.	28 Sept.
Nitrate applied per acre	625 pounds	None	625 pounds	None
Average weight of beets	844.2 grams	821.8 grams	918.2 grams	746.6 grams
Average weight of leaves	836.5 grams	743.4 grams	789.1 grams	688.3 grams
Av. weight of beets, trimmed	713.6 grams	689.5 grams	759.2 grams	652.1 grams
	Percent	Percent	Percent	Percent
Sugar in beets	13.10000	14.90000	13.50000	14.80000
Coefficient of purity	78.90000	81.40000	81.40000	84.40000
Dry substance in beets	19.24000	21.06000	19.86000	21.59000
Dry substance in leaves	11.45000	11.95000	10.01000	11.80000
Total nitrogen in beets	0.15708	0.13926	0.15312	0.14190
Total nitrogen in blades	0.55572	5.04516	0.60324	0.47256
Total nitrogen in stems	0.16500	0.13646	0.15704	0.11748
Proteid nitrogen in beets	0.08184	0.08000	0.07788	0.07762
Proteid nitrogen in blades	0.46332	0.45672	0.50292	0.39600
Proteid nitrogen in stems	0.09768	0.10560	0.09610	0.09214
Ammonic nitrogen in beets	0.00356	0.00356	0.00515	0.00541
Amid nitrogen in beets	0.00818	0.00541	0.00515	0.00555
Amino nitrogen in beets	0.03768	0.05659	0.04688	0.04687
Nitric nitrogen in beets	0.02600	0.00969	0.02065	0.01065
Nitric nitrogen in blades	0.01289	None	0.02205	None
Nitric nitrogen in stems	0.08452	0.04744	0.07781	0.04609
Press Juice According to Ruempler.				
Total nitrogen	0.14056	0.12148	0.13323	0.12190
Albumin nitrogen	0.04177	0.04344	0.04638	0.04162
Propetone nitrogen	0.00420	0.00270	0.00371	0.00395
Peptone nitrogen	0.00519	0.00220	0.00296	0.00392

ANALYSES.

	CXLIV	CXLV	CXLVI	CXLVII
Variety	E R	E R Check	Z R	Z R Check
Date of sampling	12 Oct.	12 Oct.	12 Oct.	12 Oct.
Nitrate applied per acre	750 pounds	None	750 pounds	None
Average weight of beets	1,017.5 grams	894.6 grams	801.7 grams	759.2 grams
Average weight of leaves	888.3 grams	812.7 grams	900.9 grams	648.9 grams
Av. weight of beets, trimmed	834.8 grams	768.6 grams	672.7 grams	617.0 grams
	Percent	Percent	Percent	Percent
Sugar in beets	14.40000	15.30000	14.30000	15.80000
Coefficient of purity	80.40000	80.50000	79.40000	82.70000
Dry substance in beets	20.87000	23.07000	20.04000	23.05000
Dry substance in leaves	11.95000	11.30000	11.41000	12.00000
Total nitrogen in beets	0.16896	0.14124	0.16368	0.14388
Total nitrogen in blades	0.56496	0.57288	0.54177	0.50952
Total nitrogen in stems	0.17160	0.15180	0.16764	0.12938
Proteid nitrogen in beets	0.08368	0.07154	0.08104	0.07497
Proteid nitrogen in blades	0.37910	0.35798	0.43428	0.40656
Proteid nitrogen in stems	0.08447	0.10243	0.09081	0.09134
Ammonic nitrogen in beets	0.00211	0.00266	0.00066	0.00224
Amid nitrogen in beets	0.00660	0.00565	0.00778	0.00554
Amino nitrogen in beets	0.03764	0.04595	0.03811	0.03266
Nitric nitrogen in beets	0.01685	0.00563	0.01685	0.00870
Nitric nitrogen in blades	0.01208	None	0.01360	None
Nitric nitrogen in stems	0.04313	0.01956	0.07967	0.01797
Press Juice According to Ruempler.				
Total nitrogen	0.14622	0.11869	0.15074	0.11030
Albumin nitrogen	0.04796	0.04429	0.04968	0.04576
Propetone nitrogen	0.00319	0.00514	0.00413	0.00245
Peptone nitrogen	0.01905	0.00087	0.00296	0.00685

ANALYSES OF LEAVES.* 12 OCT. 1911.

	CLII	CLIII	CLIV	CLV
Variety	E R	E R Check	Z R	Z R Check
Nitrate applied per acre	750 pounds	None	750 pounds	None
Av. wt. whole leaves per beet	888.3 grams	812.0 grams	900.9 grams	648.9 grams
	Percent	Percent	Percent	Percent
Dry substance	11.95000	11.30000	11.41000	12.00000
Crude ash in dry substance	19.66000	19.72000	18.77600	20.18400
Pure ash in dry substance	13.66000	13.63000	12.88500	13.99900
Pure ash in fresh leaves	1.63260	1.54130	1.47020	1.67980
Sulfuric acid	0.15755	0.16360	0.14288	0.19240
Phosphoric acid	0.07090	0.04994	0.06252	0.05665
Chlorin	0.10443	0.11403	0.07499	0.09592
Sodium	0.06879	0.07414	0.04876	0.06237
Potassic acid	0.56674	0.53794	0.49142	0.62295
Sodic oxid	0.39007	0.30820	0.39934	0.34132
Calcic oxid	0.13765	0.16040	0.12156	0.15552
Magnesic oxid	0.11063	0.10650	0.10749	0.12636
Ferric oxid	0.01323	0.01246	0.00642	0.00829
Aluminic oxid	0.00905	0.00920	0.01131	0.01494
Manganic oxid	0.00442	0.00205	0.00351	0.00375
Total nitrogen in blades	0.56496	0.57288	0.54177	0.50952
Total nitrogen in stem	0.17160	0.15180	0.16764	0.12938
Proteid nitrogen in blades	0.37910	0.35798	0.43428	0.40656
Proteid nitrogen in stems	0.08447	0.10243	0.09081	0.09134
Nitric nitrogen in blades	0.01208	None	0.01360	None
Nitric nitrogen in stems	0.04313	0.01956	0.07967	0.01979

Ash Analyses.

	CLVI		CLVII		CLVIII		CLIX	
	Crude	Pure	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	None	.....	None	.....	None	.....	None	.....
Sand	3.022	.....	3.427	.....	1.926	.....	2.126	.....
Silicic acid	2.342	.....	2.985	.....	2.425	.....	2.557	.....
Sulfuric acid	6.706	9.650	7.342	10.616	6.673	9.719	7.985	11.513
Phosphoric acid	3.018	4.343	2.241	3.240	2.920	4.253	2.339	3.373
Chlorin	4.445	6.396	5.177	7.398	3.502	5.100	3.960	5.710
Sodium	.....	4.159	.....	4.810	.....	3.316	.....	3.713
Carbonic acid	24.552	.....	23.724	.....	25.924	.....	24.786	.....
Potassic oxid	24.127	34.719	24.140	34.904	22.951	33.426	25.720	37.086
Sodic oxid	20.495	23.892	18.310	19.997	21.717	27.162	17.540	20.319
Calcic oxid	5.859	8.431	7.192	10.408	5.677	8.268	6.421	9.258
Magnesic oxid	4.709	6.776	4.779	6.910	5.020	7.311	5.217	7.522
Ferric oxid	0.563	0.810	0.559	0.808	0.300	0.437	0.272	0.392
Aluminic oxid	0.385	0.554	0.537	0.776	0.528	0.769	0.617	0.890
Manganic oxid	0.188	0.270	0.092	0.133	0.164	0.238	0.155	0.224
Loss	(0.591)	.....	(0.702)	.....	(1.063)	.....	(1.178)	.....
Sum	101.002	.....	101.153	.....	100.790	.....	100.873	.....
Oxygen equi. to chlorin	1.002	.....	1.153	.....	0.790	.....	0.873	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

*The leaves of the beets on the check plots showed the usual signs of ripening, but those of the beets on the plots treated with nitrate did not. The check plots did not show this change until after the first of October. The leaves were frozen about 20 Oct., so these were the last samples of leaves taken for the season. The samples of beets taken on this date were analyzed so that we could have complete analyese of these samples of which the leaves and beets were both in perfect condition.

ANALYSES OF BEETS, SAMPLES TAKEN 12 OCT. 1911.

	CLX	CLXI	CLXII	CLXIII
Variety	E R	E R Check	Z R	Z R Check
Nitrate applied per acre	750 pounds	None	750 pounds	None
Average weight of beets	1017.5 grams	894.6 grams	801.7 grams	752.2 grams
Av. weight of beets trimmed	834.8 grams	768.6 grams	672.7 grams	617.5 grams
	Percent	Percent	Percent	Percent
Sugar in beets	14.40000	15.30000	14.30000	15.80000
Dry substance in beets	20.87000	23.07000	20.04000	23.05000
Crude ash in dry substance	4.01100	3.38360	3.95300	3.40000
Pure ash in dry substance	2.82460	2.31000	2.67600	2.40400
Pure ash in fresh beet	0.58950	0.53297	0.53631	0.55657
Sulfuric acid	0.02494	0.02291	0.02189	0.02493
Phosphoric acid	0.04710	0.05283	0.05457	0.06721
Chlorin	0.01913	0.01307	0.00896	0.01133
Sodium	0.01427	0.00850	0.00582	0.00737
Potassic oxid	0.27855	0.27127	0.27988	0.28225
Sodic oxid	0.10851	0.05256	0.07237	0.05078
Calcic oxid	0.02887	0.03854	0.03106	0.03148
Magnesic oxid	0.05674	0.06383	0.04745	0.07038
Ferric oxid	0.00458	0.00328	0.00610	0.00820
Aluminic oxid	0.00169	0.00259	0.00211	0.00042
Manganic oxid	0.00237	0.00000	0.00170	0.00293
Total nitrogen	0.16896	0.14124	0.16368	0.14388
Proteid nitrogen (Stutzer)	0.08368	0.07154	0.08104	0.07497
Ammonic nitrogen	0.00211	0.00266	0.00066	0.00224
Amid nitrogen	0.00660	0.00565	0.00778	0.00554
Amino nitrogen	0.03764	0.04505	0.03818	0.03266
Nitric nitrogen	0.01685	0.00503	0.01885	0.00870
Injurious nitrogen in beets	0.07657	0.06139	0.07420	0.06113
Injurious ash per 100 sugar	3.09240	2.40720	2.71970	2.38390
Injurious nitrogen per 100 sug.	0.53174	0.40125	0.51887	0.38690
Press Juice According to Ruempler.				
Total nitrogen	0.14622	0.11869	0.15074	0.11030
Albumin nitrogen	0.04796	0.04429	0.04968	0.04576
Propetone nitrogen	0.00319	0.00514	0.00413	0.00245
Peptone nitrogen	0.01906	0.00087	0.00296	0.00658

Ash Analyses.

	CLXIV		CLXV		CLXVI		CLXVII	
	Crude	Pure	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	None	.....	None	.....	None	.....	None	.....
Sand	1.831	.....	1.429	.....	1.735	.....	1.568	.....
Silicic acid	1.510	.....	1.164	.....	1.308	.....	0.605	.....
Sulfuric acid	2.979	4.230	2.939	4.299	2.758	4.081	3.166	4.479
Phosphoric acid	5.627	7.990	6.775	9.912	7.428	10.903	8.537	12.076
Chlorin	2.623	3.725	1.677	2.453	1.129	1.671	1.440	2.037
Sodium	.....	2.423	.....	1.595	.....	1.086	.....	1.324
Carbonic acid	26.237	.....	26.268	.....	26.174	.....	24.052	.....
Potassic oxid	33.276	47.252	35.601	52.082	35.264	52.186	35.851	50.712
Sodic oxid	15.248	18.391	8.201	9.864	10.107	13.494	8.136	9.124
Calcic oxid	3.449	4.897	4.597	6.725	3.914	5.792	3.994	5.650
Magnesic oxid	6.780	9.626	8.168	11.976	5.979	8.848	8.941	12.648
Ferric oxid	0.547	0.777	0.421	0.615	0.769	1.138	1.042	1.474
Aluminic oxid	0.202	0.287	0.331	0.484	0.266	0.394	0.054	0.076
Manganic oxid	0.883	0.402	.....	.....	0.214	0.317	0.238	0.400
Loss	.....	.....	(2.780)	.....	(3.210)	.....	(2.656)	.....
Sum	100.592	.....	100.378	.....	100.255	.....	100.325	.....
Oxygen equi. to chlorin	0.592	.....	0.378	.....	0.255	.....	0.325	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

ANALYSES OF BEET SAMPLES TAKEN 8 NOV. 1911.

	CLXIX	CLXX	CLXXI	CLXXII
Variety	E R	E R Check	Z R	Z R Check
Nitrate applied per acre	750 pounds	None	750 pounds	None
Average weight of beets	967.1 grams	875.0 grams	1088.5 grams	929.3 grams
Av. weigrt of beets, trimmed	819.3 grams	747.0 grams	951.0 grams	784.4 grams
	Percent	Percent	Percent	Percent
Sugar in beet	14.60000	15.60000	14.50000	15.60000
Dry substance in beet	20.21000	21.16000	21.10000	22.00000
Crude ash in dry substance	4.04000	3.67000	4.07200	3.67000
Pure ash in dry substance	2.72950	2.55850	2.80400	2.60100
Pure ash in fresh beet	0.55164	0.54139	0.59255	0.57223
Sulfuric acid	0.02495	0.02561	0.02616	0.02641
Phosphoric acid	0.04303	0.05508	0.05584	0.06256
Chlorin	0.01242	0.01439	0.01312	0.01721
Sodium	0.00808	0.00936	0.00853	0.01119
Potassic oxid	0.25865	0.26141	0.29473	0.28494
Sodic oxid	0.09844	0.06370	0.08256	0.06044
Calcic oxid	0.03006	0.03342	0.03461	0.03338
Magnesic oxid	0.06827	0.07127	0.07154	0.07201
Ferric oxid	0.00352	0.00433	0.00172	0.00193
Aluminic oxid	0.00170	0.00087	0.00108	0.00009
Manganic oxid	0.00252	0.00192	0.00109	0.00208
Total nitrogen	0.16632	0.14882	0.16698	0.14223
Proteid nitrogen (Stutzer)	0.08646	0.08474	0.08461	0.08355
Ammonic nitrogen	0.00118	0.00165	0.00258	0.00171
Amid nitrogen	0.00771	0.00593	0.00868	0.00660
Amino nitrogen	0.05319	0.05621	0.04775	0.04982
Nitric nitrogen	0.01871	0.00827	0.01421	0.00746
Injurious nitrogen in beet	0.07097	0.05651	0.07111	0.05037
Injurious ash per 100 sugar	2.75710	2.45640	2.93200	2.56530
Injurious nitrogen per 100 sug.	0.48610	0.36215	0.49041	0.32290
Press Juice According to Ruempler.				
Total nitrogen	0.14809	0.13383	0.15119	0.12314
Albumin nitrogen	0.05408	0.05439	0.04858	0.05292
Propetone nitrogen	0.00737	0.00489	0.00858	0.00040
Peptone nitrogen	0.00209	0.00256	0.00663	0.00974

Ash Analyses.

	CLXXIII		CLXXIV		CLXXV		CLXXVI	
	Crude	Pure	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	None	.....	None	.....	None	.....	None	.....
Sand	1.430	.....	1.375	.....	1.294	.....	1.398	.....
Silicic acid	1.083	.....	0.912	.....	0.756	.....	0.712	.....
Sulfuric acid	3.056	4.523	3.298	4.731	3.028	4.391	3.271	4.615
Phosphoric acid	5.270	7.800	7.093	10.175	6.499	9.423	7.748	10.932
Chlorin	11.521	2.251	1.854	2.660	1.527	2.214	2.131	3.007
Sodium	.....	1.464	.....	1.729	.....	1.439	.....	1.955
Carbonic acid	28.833	.....	26.802	.....	27.690	.....	25.955	.....
Potassic oxid	31.677	46.888	33.662	48.285	34.303	49.737	35.293	49.795
Sodic oxid	13.389	17.846	9.827	11.766	10.946	13.932	9.352	10.563
Calcic oxid	3.682	5.450	4.304	6.174	4.228	6.145	4.134	5.833
Magnesic oxid	8.361	12.375	9.177	13.163	8.326	12.073	8.918	12.583
Ferric oxid	0.431	0.638	0.556	0.799	0.200	0.283	0.239	0.337
Aluminic oxid	0.208	0.308	0.112	0.161	0.126	0.179	0.011	0.016
Manganic oxid	0.309	0.457	0.249	0.357	0.127	0.184	0.258	0.364
Loss	(1.093)	.....	(1.063)	.....	(1.294)	.....	(1.060)	.....
Sum	100.343	.....	100.418	.....	100.344	.....	100.480	.....
Oxygen equi. to chlorin	0.343	.....	0.418	.....	0.344	.....	0.480	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

ANALYSES OF BEETS. SEASON 1911.

	CXLVIII	CXLIX	CL	CLI
Variety	E R	E R Check	Z R	Z R Check
Date of sampling	26 Oct.	26 Oct.	26 Oct.	26 Oct.
Nitrate applied per acre	750 pounds	None	750 pounds	None
Average weight of beets	877.3 gram	1030.0 grams	915.0 grams	776.8 grams
Av. weight of beets, trimmed	708.8 grams	872.5 grams	760.7 grams	661.8 grams
	Percent	Percent	Percent	Percent
Sugar in beets	14.50000	16.10000	15.10000	16.70000
Coefficient of purity	78.40000	81.30000	80.70000	83.50000
Dry substance	20.92000	22.56000	21.37000	23.52000
Total nitrogen	0.18678	0.14850	0.16830	0.12276
Proteid nitrogen	0.09319	0.08579	0.08765	0.08104
Ammonic nitrogen	0.00198	0.00079	0.00449	0.00198
Amid nitrogen	0.01135	0.00647	0.00515	0.00264
Amino nitrogen	0.03266	0.03929	0.03190	0.03848
Nitric nitrogen	0.02270	0.00600	0.01444	0.00253
Press Juice According to Ruempler.				
Total nitrogen	0.17036	0.13236	0.15074	0.11030
Albumin nitrogen	0.05956	0.05564	0.05491	0.04927
Propetone nitrogen	0.01176	0.00025	0.00490	0.00245
Peptone nitrogen	?	0.00392	0.00416	0.00417

It would possibly be better to discuss the analyses of the 1911 samples just given in the next paragraphs, but I shall postpone this to make place for some other analyses.

THE EFFECTS OF DEFOLIATION.

Our efforts in 1910 to obtain some definite measure for the effects of leaf-spot upon the yield and general qualities of beets did not give us results which could be interpreted as conclusive of anything though we obtained the record of 127 fields. We found that many of these fields gave good yields of both beets and sugar and we could discover no relation between the severity of the attack and either the yield of the beets or the percentage of sugar. We did, however, observe that low yields of beets seemed to be associated with higher percentages of sugar. While this was generally true it was not always so. Beets from one section of the valley (Arkansas) could not be compared with those from other sections from the same valley for higher yields and percentages were the rule in some sections as compared with others.

An instance was given of a field which had been very severely attacked, the date of the attack is not known to me, but the field samples showed 16 or more percent of sugar, though the foliage was practically all destroyed. I take it that the injury caused by leaf-spot is due to its destruction of the leaves.

The data at my command relative to the effects of defoliating beets are not concordant. The results probably vary greatly with the stage of development of the beet, the age of the leaves removed, their number, etc. The leaf-spot destroys the oldest leaves first and the young leaves escape the attack for some time or altogether. This was markedly the case with our nitrate beets in 1910; so much so, that, owing to their abundant foliage, it seemed that they had lost but few or no leaves. This was not the case for, by counting the leaves killed by the leaf-spot on a number of beets we convinced ourselves that any judgment based upon the apparent immunity of the nitrate beets, was not at all justified by the facts.

Our observations upon the effects of the leaf-spot are by no means so definite as those recorded by Nicholson and Lyon in Neb. Bul. 67 p. 20, where they state "Where this disease proceeds this far (to the total destruction of the foliage. H.) it seriously affects the yield and sugar content of the beets. At the time of harvest, beets severely attacked produced between three and four tons less than those only mildly affected, while the sugar was fully one percent lower."

Lyon and Wiancko in Neb. Bul. 81, p. 11, refer to the effect of removing a part of the foliage, one-half in the case discussed and state, "As regards the practice of breaking off the outer leaves it woud seem that good may result since the yield secured was over two and one-half tons more per acre than the average of the ordinary treated plots. It has been argued that breaking off the leaves or otherwise bruising the beet may result in permanent injury but it was observed in this case that aside from the larger growth of the roots, the leaves were considerably healthier later in the season, being less affected by the leaf-spot than were the plots on either side." Again in their Summary and Conclusions they state that "Breaking off a part of the leaves of sugar beets at 'laying by' time did not injuriously affect the yield or quality of the crop. Beets treated in this way were less affected by 'leaf-spot' disease than those not so treated."

In Jahresbericht der Zuckerfabrikation, 1907, p. 55, the results recorded as obtained by Andrlik and Urban upon the effects of defoliation show that the removal of 70 percent of the leaves in the early part of July depressed the yield 36 percent, the yield of sugar 35 percent and the yield of dry substance 34 percent. The plants removed much less plant food, 38.8 percent less ntrogen, 34.9 percent less potash and 36.0 percent less phosphoric acid, than uninjured plants. The plant food removed with the leaves (by defoliation) was not taken into consideration. Defoliation at the end of July lowered the yield of beets by 24.0 percent, of leaves 23.0 percent, and of sugar 30.5 percent. The percentage of sugar in the beets was lowered 1.1 percent. The plants took up 30.0 percent less nitrogen, 28.0 percent less potash and 18.0 percent less phosphoric acid than uninjured plants. The removal of 19.0 percent of the leaves on 21 Aug. depressed the yield of roots by 13.0 percent, increased the leaves by 3.0 percent, did not change the percentage of sugar in the beets, but the total yield of sugar was reduced 13.0 percent. The factory qualities of the beets were improved.

A defoliation of from 50 to 94 percent depressed the yield of roots from 10 to 26 percent, the sugar in the roots from 0.5 to 2.7 percent. A moderate defoliation reduced the yield of roots from 1.0 to 14.4 percent. The percentage of sugar in the roots was not materially affected. An injurious effect became noticeable in this case only when the beets developed a heavy foliag.e.

Strohmer, Briem and Fallada, Jahresbericht der Zuckerfabrikation, 1908, p. 33, experimented on the defoliation of beets to determine the influence of the development of the beet at the time of defoliation upon the results. They claim that the effect in depressing the sugar in the beet depends upon the time that the defoliation is made. If it be made immediately prior to the period when the most active production of sugar takes place in the leaves the percentage of sugar in the harvested beets will be depressed. If it be made long enough before this period to permit the beets to develop new leaves, the percentage of sugar in the beets may be as high as in normally grown beets, but the total yield of sugar will be less than that of normally grown beets or even of beets defoliated subsequent to the period of greatest sugar production (the end of August). Their results agree with those of earlier investigators in showing that a complete defoliation of the sugar beet depresses both the yield of beets and sugar and that a partial defoliation may produce results in either direction. Their results show that defoliation on 12 July reduced the crop of roots by 37.0 percent and that of the sugar by 36.0 percent; defoliation on 30 July reduced the crop of beets 40.6 percent, that of sugar 43.3 percent; defoliation on 24 Aug. reduced the crop 23.0 percent, the sugar 25.4 percent.

The results obtained by defoliation is probably the best indication that we have of the possible effects of the leaf-spot. It is true that the expression of "badly affected," "very badly affected," etc., heretofore used in this bulletin do not give a definite measure of the extent of the defoliation, but it is the most feasible way of indicating it in our case. "Badly affected" would indicate that from 40 to 60 percent of the foliage had been destroyed and "very badly affected" would indicate that upwards of 60 percent had been destroyed. This disease was so common and severe in 1910 that I doubt whether an attack involving less than 10 to 15 percent would have received any attention at all. We counted the leaves destroyed on a considerable number of beets and the number ranged from 35 to 43. The damage which was apparent varied with different beets, some having put forth a vigorous growth of leaves during August and early September did not show the loss of this number of leaves, while others which had made a less vigorous growth of leaves subsequent to the attack looked very badly indeed. One of our plots which had suffered to this extent i. e. the loss of from 25 to 43 leaves per beet in the latter part of July and early August (25 July to 15 August) yielded 16.85 tons of beets per acre with 16.85 percent sugar. The average yield of beets in the vicinity of Fort Collins in 1910 was less than eleven tons per acre and the average percentage of sugar was about 15.5 percent. By reference to the record of the 120 leaf-spot fields given in the earlier part of this bulletin, it may be seen that their average yield was 12.4 tons beets per acre and the average sugar content was 13.9 percent. There was no leaf-spot in the Fort Collins district, but it was very prevalent in these 120 fields. The distance between the remotest of the leaf-spot fields from one another is not far from 150 miles, while that between the Fort Collins district and the nearest of the leaf-spot fields is about 200 miles. Still consideration must be given to the question of locality. The big fact, however, remains that the yield of these leaf-spot fields if fully an average one and that we cannot detect any relation between the virulence of the attack and the yield or the percentage of sugar. The time of attack, beginning about 25 July, would lead us to expect very pronounced and disastrous results. I believe that in some individual cases that very disastrous results may follow the attack, but it seems very doubtful whether the effect of this disease is generally so great as we have thought, especially upon the yield of beets and the percentage of sugar, but there are other ways that the destruction of the foliage may affect the beets. Some of these have been given in the preceding quotations from Andrlik and Urban, also from Strohmer, Briem and Fallada. I have undertaken to study some further features of the effects of defoliating the beets in two experiments, just as I have endeavored to study the effects of the nitrates to see whether the effects of defoliation are the same as those of the nitrates.

For this purpose I selected five rows of each of the two varieties experimented with and defoliated them on 6 Sept. The beets were growing rapidly at this time. The tops were removed by means of a knife, we left no leaves which had fully expanded, only the small undeveloped ones at the center of the beet. The beets put out perhaps 50 percent of a full foliage before they were checked by the freezing of the tops, which happened 20 Oct. The weather had been fine up to this date. The beets were harvested 8 Nov., almost exactly two months after defoliation. Samples of these beets were taken 1 Sept., when the results were as follows: average weight of beets, E R 625.3 grams, average weight of tops 735.6 grams, Z R average weight of beets 510.3 grams, of the tops 614.3 grams. The percentage of sugar in E R was 11.9 and in Z R 13.2. At the time of harvest the check plots gave for E R average weight of beets

875.7 grams, Z R 929.3 grams, the defoliated beets averaged E R 791.2 grams and Z R 701.3 grams. The increase in the weight of the roots from 1 Sept. to 8 Nov. was for E R normal development 250.4 grams, defoliated 165.9, Z R normal development 419.0 grams, defoliated 191.0. In the case of E R the average weight of the beets was depressed 84.5 grams or 9.6 percent of the weight of the normally developed beets, in the case of Z R the averag weight was depressed 228 grams or 24.5 percent of the weight of the normally developed beets. The latter figure, approximately 25 percent, is the same as obtained by weighing the beets produced by these rows and their check. This applies to both varieties. The percentage of sugar in the normally developed E R variety, harvested 8 Nov., was 15.6, in the defoliated beets harvested same date 14.3, in normally developed Z R 15.6, defoliated 13.2. The normally developed variety E R to which nitre had been applied contained 14.6 and the Z R variety 14.5 percent sugar. In the case of the variety E R the depression of the percentage of sugar in the beet was about the same as that produced by defoliation, 1.0 against 1.3 percent. The difference can scarcely be explained by an increase in the yield caused by the nitrate for according to the field weights given me there was a decrease in the crop caused by the nitre. This is not in harmony with our observations on the relative size of the beets during the season, according to which there should have been an increase of the crop of from 1,200 to 2,000 pounds per acre. In the case of the variety Z R the nitrate caused a depression in the percentage of sugar of 1.1 and the defoliation 2.4 percent. The yields returned to me for these plots, one-enth acre each, were for E R 23.7 and 24.3 tons per acre, for Z R 20.8 and 22.4 tons per acre. The check plots were the higher in both cases, which I fear is a clerical error due to exchanging the plots in recording them. I am personally fully convinced that this is the case, but I have given the record as it stands. The average of these yields is more than twice that of this section for 1910.

The object of our experiment was not to obtain further data regarding these factors which had previously been determined and with which our results agree in so far as they are parallel, but to see what the effect upon the principal factors in the quality of the beets for factory purposes might be. The question with us is why have the beets in the Arkansas Valley fallen off so in quality? I do not know that the yield per acre has fallen off, I do not believe that it has. The average yield for the 120 fields, representing approximately 2,500 acres, is 12.4 tons, an average which is not exceeded in any section of the state. On the other hand the sugar content averaged only 13.9 percent as they were delivered to the factory, and I may add that this is within 0.3 percent of the average for the whole valley in 1910. There are two facts which must be constantly borne in mind, one is that, for some reason, 1911 was a much more favorable year than 1910, that is the beets of 1911 worked much better than those of previous years, 1910 for instance, and that my experiments of 1911 were made at Fort Collins and not in the Arkansas Valley, in other words, that both the season and locality tended to produce beets of good quality, whereas my endeavor was to bring about the inferior quality so generally met with of late years in the Arkansas Valley. This applied to the experiments made with nitre as well as to those with defoliation. The results with nitre have been given in preceding paragraphs and the analyses of the check samples taken 8 Nov. have been given as analyses CLXX and CLXXII. Samples of these varieties were taken immediately before defoliation and on 8 Nov. The analytical results obtained on these samples 1 Sept. and 8 Nov. were as given in table.

It has already been stated that the yield of roots was depressed about 25 percent by the almost complete defoliation of the beets and that of the sugar not less than 35.7 percent in the case of the variety E R and apparently still more in the case of Z R.

The effect upon the quality of the beets was to lower the percentage of sugar, in the case of the variety E R, this decrease was 1.3 percent, in that of the variety Z R it was 2.4 percent. It also depressed the percentage of dry matter in the beets, in the case of E R 1.66 and in that of Z R 2.8 percent. It increased the pure ash in the beets very slightly, 0.003 in E R and 0.008 percent in Z R. It did not perceptibly affect the composition of the pure ash, the phosphoric acid in particular remaining very nearly the same, 10.175 against 9.876 in E R and 10.932 against 10.855 percent in the case of Z R, which is apparently an important factor. The total nitrogen in the beets was decidedly depressed, from 0.14882 to 0.12408 in E R and from 0.14223 to 0.11286 percent in Z R. The injurious ash per 100 sugar was slightly increased, from 2.456 tot 2.668 in E R and from 2.565 to 3.133 in Z R. The injurious nitrogen per 100 sugar was decreased from 0.362 to 0.326 in E R and from 0.323 to 0.136 percent in Z R. The total nitrogen in the press juice was also lowered from 0.134 to 0.102 in E R and from 0.123 to 0.092 percent in Z R. The beets of these varieties which matured normally contained 0.00827 and 0.00746 percent nitric nitrogen, the defoliated beets contained 0.01367 and 0.01584 percent, approximately twice as much. The nitric nitrogen was evidently transformed in some manner in the normally developed beets but not in the defoliated ones to anything like the same extent as appears from the fact that on 1 Sept. the beets contained, E R 0.1925, Z R 0.01670, on 8 Nov. the defoliated beets contained, E R 0.01367, Z R 0.01584 percent, while the normally developed beets contained, E R, 0.00827 and

ANALYSES OF BEETS DEFOLIATED 6 SEPT., HARVESTED 8 NOV. 1911.

	CLXXVII	CLXXVIII	CLXXIX	CLXXX
Variety	E R*	E R	Z R	Z R
Date of sampling	1 Sept.	8 Nov.	1 Sept.	8 Nov.
Average weight of beets	625.3 grams	791.2 grams	510.3 grams	701.3 grams
Av. weight of beets, trimmed	543.4 grams	701.0 grams	469.4 grams	590.0 grams
	Percent	Percent	Percent	Percent
Sugar in beets	11.90000	14.30000	13.20000	13.20000
Dry substance in beets	18.69000	19.60000	19.76000	19.27000
Crude ash in dry substance	4.64900	3.98000	3.94200	4.28000
Pure ash in dry substance	3.24960	2.77100	2.79500	3.01500
Pure ash in fresh beet	0.60735	0.54440	0.55235	0.58100
Sulfuric acid	0.02358	0.02414	0.02341	0.02462
Phosphoric acid	0.05425	0.05380	0.06435	0.06307
Chlorin	0.02314	0.01933	0.01413	0.02563
Sodium	0.01484	0.01254	0.00917	0.01666
Potassic oxid	0.31460	0.26493	0.29742	0.28042
Sodic oxid	0.09825	0.06062	0.06676	0.06624
Calcic oxid	0.02456	0.03603	0.02140	0.02808
Magnesic oxid	0.04813	0.06775	0.05010	0.07262
Ferric oxid	0.00329	0.00178	0.00301	0.00158
Aluminic oxid	0.00145	0.00126	0.00162	0.00092
Manganic oxid	0.00104	0.00193	0.00098	0.00117
Total nitrogen	0.13794	0.12408	0.13068	0.11286
Proteid nitrogen (Stutzer)	0.07317	0.06731	0.07418	0.09029
Ammonic nitrogen	0.00251	0.00105	0.00251	0.00118
Amid nitrogen	0.00634	0.00387	0.00568	0.00343
Amino nitrogen	0.04150	0.06267	0.04244	0.05071
Nitric nitrogen	0.01925	0.01367	0.01670	0.01584
Injurious nitrogen in beet	0.05592	0.05185	0.04831	0.01796
Injurious ash per 100 of sugar	3.98650	2.66820	3.11290	3.13320
Injurious nitrogen per 100 sug.	0.45922	0.32658	0.36591	0.13606
Press Juice According to Ruempler.				
Total nitrogen	0.11480	0.10178	0.11639	0.09155
Albumin nitrogen	0.03772	0.03639	0.03742	0.03389
Propetone nitrogen	0.01464	0.00356	0.01156	0.00273
Peptone nitrogen	?	0.00444	?	0.00548

Ash Analyses.

	CLXXXI.		CLXXXII.		CLXXXIV.		CLXXXIII.	
	Crude	Pure	Crude	Pure	Crude	Pure	Crude	Pure
Carbon	None	.....	None	.....	None	.....	None	.....
Sand	1.279	.....	1.095	.....	0.808	.....	0.946	.....
Silicic acid	1.001	.....	0.857	.....	0.973	.....	0.784	.....
Sulfuric acid	2.714	3.883	3.158	4.533	3.005	4.238	2.986	4.238
Phosphoric acid	6.244	8.933	6.879	9.876	8.262	11.651	7.647	10.855
Chlorin	2.663	3.810	2.472	3.551	1.814	2.559	3.107	4.410
Sodium	.....	2.477	.....	2.309	.....	1.660	.....	2.867
Carbonic acid	26.275	.....	26.989	.....	24.107	.....	26.360	.....
Potassic oxid	36.207	51.794	33.875	48.636	38.181	53.845	34.001	48.264
Sodic oxid	13.640	16.176	9.880	11.129	10.157	12.087	10.751	11.401
Calcic oxid	2.827	4.044	4.608	6.617	2.747	3.874	3.405	4.833
Magnesic oxid	5.539	7.924	8.663	12.440	6.432	9.071	8.805	12.499
Ferric oxid	0.379	0.542	0.227	0.325	0.386	0.545	0.191	0.271
Aluminic oxid	0.167	0.245	0.161	0.230	0.207	0.293	0.112	0.159
Manganic oxid	0.120	0.172	0.247	0.354	0.126	0.177	0.143	0.203
Loss	(1.546)	.....	(1.447)	.....	(3.104)	.....	(1.463)	.....
Sum	100.601	.....	100.558	.....	100.409	.....	100.701	.....
Oxygen equi. to chlorin	0.601	.....	0.558	.....	0.409	.....	0.701	.....
Total	100.000	100.000	100.000	100.000	100.000	100.000	100.000	100.000

*The samples taken 1 Sept. represent the composition of the beets at the time of defoliation. Analyses CLXX and CLXXI represent the same with normal development and harvested 8 Nov.

Z R, 0.00746 percent. It has already been pointed out that even these latter figures are high for beets grown without the application of nitrates in excess or highly nitrogenous manures. The soil in which these beets were grown contained, according to our latest analyses, Apr. 1912, 0.142 percent nitrogen and 0.063 percent in the subsoil; the nitric nitrogen in the soil was at this tme 0.0008 percent, but was very much higher in September, 1911, as is elsewhere stated.

These effects of defoliation are not those which constitute the subject of our study, especially is this the case with the nitrogen. The subject of defoliation was taken up, as previously stated, because we assume it to present the best imitation of the effects of the leaf-spot disease, and while our experiments were extremely severe the leaf-spot has often approached the same severity. These experiments answer the purpose for which they were made very well and are in full accord with later investigations of this subject, but the subject is worthy of a much fuller study for there are some very perplexing things that have been observed. A field previously referred to, which had been defoliated by the leaf-spot disease quite as severely as I defoliated these beets, produced a small yield but the beets were rich in sugar, 16 to 17.5 percent, and this could not be attributed to drying out of the beets. This is not an isolated instance though it is an extreme one.

In this attempt to determine the effects of defoliation upon the composition of the beet, we find that in addition to reducing the yield both of beets and sugar and the percentage of sugar in the beets, it reduced the percentage of dry matter, it did not positively increase the pure ash in the dry substance in one case, but in the other it did. It showed a decided depression of the total nitrogen in the beet, from 0.148 and 0.142 to 0.124 and 0.113 percent, the phosphoric acid in the fresh beet was scarcely changed. We find in the normally matured beets 0.05508 and 0.06256 and in the defoliated beets 0.05380 and 0.06307. This identity is quite as evident when the composition of the pure ash is considered in which we have for these varieties given in the same order, 10.175 and 10.932 percent in the pure ash of normally developed beets and 9.876 and 10.855 percent in that of the defoliated beets. The figures for the potash are also very similar, 0.26141 and 0.28494 in normally developed beets and 0.26493 and 0.28042 in the defoliated ones. The injurious ash per 100 of sugar was slightly increased, 0.21 and 0.57 part per 100 sugar; the injurious nitrogen was not changed or lessened. The total nitrogen in the press juice was lessened and the ratio of the proteid nitrogen to the total materially lowered. The ratio of the lime to the magnesia remained practically unchanged.

The most marked effect upon the composition of the beet was upon the content of nitric nitrogen. On 1 Sept. we found in these beets nitric nitrogen equal to 0.01925 and 0.01670 percent, in the normally matured beets on 8 Nov. we found 0.00827 and 0.00746 and in the defoliated beets harvested the same day, 8 Nov., we found 0.01367 and 0.01584 percent. It is evident that the leaves on the normally matured beets have played an important part in eliminating or transforming the nitric nitrogen between 1 Sept. and 20 Oct., when the leaves were killed by a heavy freeze. The last samples of leaves were taken 12 Oct., when we find that the blades of beet leaves to which no nitrate had been applied contained no nitric nitrogen, but the stems contained 0.01956 and 0.01797 percent for the respective varieties. On 1 Sept., five days before we defoliated the beets, both the blades and the stems contained nitric nitrogen, but on 28 Sept., the next date when the blades and stems were analyzed separately, the blades contained none which, from the amount found for the whole leaf on 14 Sept., was probably the case at this time. At all events the nitric nitrogen disappeared wholly from the blades between 1 and 28 Sept., but the stems were still quite rich, 0.01956 and 0.01797 on 12 Oct., when the nitric nitrogen in the beet had fallen to 0.00503 and 0.00870, quite as low as we found it on 8 Nov., the latest sample of the season. The decrease of nitric nitrogen in the defoliated beets from 6 Sept. till 8 Nov. was not enough to be proportional to the increased weight of the beet, so that it seems probable that the beets continued to take up some nitric nitrogen after defoliation but that no transformation of it took place. This detail statement is made for the purpose of presenting as forcefully as possible the question whether the leaf-spot disease may not by destroying the foliage to the extent that it sometimes does, be the cause of excessive amounts of nitric nitrogen which we find in our beets? I think that the facts adduced in this connection go very far to establish it as a fact, that given the nitrates in the beets at the time the fungus destroyed the foliage that it would remain in the beets, to a greater or less extent, depending upon the sufficiency of the foliage which may have escaped the fungus injury to carry on the normal functions of the beet, and in this way the leaf-spot might account for the presence of nitric nitrogen in the beets and the molasses made from them, but this only accounts for the failure of the maturing beet to eliminate, if I may use the term, the nitric nitrogen, but does not account for its presence at the time of the injury, any more than the cutting off of the leaves accounts for the nitric nitrogen present in the beets on 6 Sept. It, however, does account for the fact that we found the nitric nitrogen in the beets on 8 Nov., but nothing more. The other changes in the composition of the beet are not those which we find in the beets of the Arkansas Valley. We will go into the details of these a little later.

Our experiments of 1911 were made on land more than sufficiently well supplied with nitrogen, especially in the form of nitric nitrogen. This statement assumes that the facts pertaining to the presence of nitric nitrogen established for fallow spots in the beet-field in 1910 and in fallow ground adjacent to the beet plots in 1911 apply in the same measure to the ground actually occupied by the beets, which is an assumption and not a proven fact, but on this assumption the beets in 1911 had at their disposal up to 13 Sept., the date on which we sampled the fallow land, which, though cultivated, had not been irrigated, not less nitric nitrogen than the equivalent of 480 pounds of sodic nitrate in the top six inches of soil. The nitric nitrogen averaged 3.24 percent of the total nitrogen, which was about 0.134 percent. The determinations were made on 10 composite samples which included 124 subsamples. Experiments have shown that the application of this quantity of nitre, about 500 pounds, applied by or before 1 May, was, under the conditions of our experiments in the Arkansas Valley, more than sufficient to produce the maximum beneficial effects and was, in fact, somewhat objectionable. It has been stated that another section of this field produced in 1910 a big growth of leaves and a small crop of poor beets, 13.3 percent sugar. Had I been able to obtain land of my own choice I would not have used this, but this was kindly placed at my disposal by the Department of Agronomy, and it was the very best that they had.

My immediate object was to determine the effects of an excessive supply of nitrates upon the beets subsequent to the period of their greatest activity in appropriating nitrogen, which is during the months of June and July. The results give us at the same time a clear presentation of the effects of nitre upon the growth and composition of the beet. That nitrates prolong the period of growth and stimulate vegetation has long been established as a fact, our object was not to reconfirm this, but to study their effects upon the composition of the beets. The effects of an application of nitre at the rate of 250 pounds per acre on 4 Aug. made themselves manifest in the color and growth of the leaves in from ten to fourteen days to such an extent that it attracted the attention of casual observers. This continued to become more marked through the remainder of the season till the leaves were killed by frost. In fact it was more evident on 15 Oct. than on 15 Sept. because the beets to which no application of nitrates had been made, showed clearly the process of maturation, whereas the others did not, and this is one of the bad effects of the nitre, i. e., that it very materially delays the maturation of the beets, a statement which I have previously made in other forms. The effects upon the crop and its composition under these conditions, all of which were such as to tend to conceal or lessen the effects of the nitrates were: an increase in the size of the beet and the weight of the tops, a decrease in the percentage of sugar and dry substance in the beet by approximately one percent in each case. There was an increase of pure ash in the dry substance of from 7 to 9 percent or more. There was a decided suppression of the phosphoric acid in the beets. The potash was very high in the beets from both the treated and check plots, but it was nearly the same. These statements apply to both sets of samples, 12 Oct. and 8 Nov. The sodic oxid and chlorin were both increased, at least this was the rule. The total nitrogen showed an increase beginning in the variety Z R on 18 Aug. and in E R 14 Sept., and continued throughout the season. This increase in the samples of 8 Nov. was for E R 11.8 and for Z R 17.5 percent.

This increase in the nitrogen is perhaps more evident in the press juice than in the beets for in this it is, for the variety E R 9.0 and for Z R 18.0 percent. The ratio of albumin nitrogen was also reduced from 40 to an average of 34 percent. The injurious ash per 100 sugar, sampled 8 Nov., was increased from 12.0 to 16.0 percent, while the injurious nitrogen per 100 sugar was increased in E R 34.0 and in Z R 52.0 percent. The nitric nitrogen in the beets on 8 Nov., showed an increase of 126.3 percent in E R and 90.5 percent in Z R. These particular effects can be due to no other causes than the excessive nitrate applied, for an analysis of the results obtained both with the leaves and the beets from the check plots, as well as the quantities of nitric nitrogen found in the fallow land 13 Sept., corroborate our observations on the development of the beets, to the effect that the beets in the check plots had an abundant supply of this form of nitrogen. The beets did not at any time suffer from drought or from an attack of any enemy, and they were grown in an unusually long and favorable season. Further, the questions of seepage, of alkali and of any deficiency of plant food are completely eliminated by the location and properties of the land. The leaves were examined throughout the season and the results of these examinations alone serve to show how radical the effects of the nitrates must have been, for the nitric nitrogen in the blades of our check beets was unquestionable but it had completely disappeared by 29 Sept., while it was very abundant in the blades of the nitre beets on 12 Oct. The abundance and the persistence of this form of nitrogen in the leaf stems is very striking.

The effects of defoliation are, it is true, very marked, but they are not those produced by the nitrates. Those sufficiently interested will find a complete statement of the analytical results in analyses CLXIX to CLXXVI and CLXXVII to CLXXXVI, the former give the complete analyses of the beets normally developed, both with and without application of nitre, the latter give the complete analyses of the varieties at the time of defoliation and at the time of harvest. The defoliation evidently caused a stoppage in the development of the beet; it did not depress the phosphoric acid in the beet, it did not increase the total nitrogen in the beet, but it did arrest, apparently almost completely, the elimination or transformation of the nitric nitrogen. The extent of the defoliation was extreme, almost complete and undoubtedly arrested some functions of the plant completely, while others were disturbed to a less extent. We see for instance that the beets attained to a fair size, 791 and 701 grams, untrimmed, and this is the average weight of 50 beets in each case.

It was very advisable, in fact quite necessary, that the experiments of 1911 should be made before any interpretation of the results of 1910 should be undertaken, for however pronounced the effects of the nitrates may have been there would be misgivings, even in our own minds, as to the part *Cercospora beticola,* the leaf-spot, might have played and what the nitrates had really effected. The experiments of 1911 enable us to state, as we have done, pretty fully, what the nitrates did even when applied at a period when the rate of appropriation of nitrogen by the beet had, according to Prof. Remy, already abated very materially and was becoming still slower. Unfortunately our check field practically failed us in 1910, nevertheless, not to such an extent as to be wholly useless, though its value is very much less than we had hoped it would be.

The application of 250 pounds of nitrate per acre, 1 April, just before planting the seed, resulted in an increase in the yield of roots and sugar, and the general quality of the beets was very good, crop 16.85 tons, sugar in beets 16.85 percent. The phosphoric acid in the beets was low and the alkalis relatively high. The total nitrogen was relatively low, the ratio of proteid nitrogen to the total was better than 50 percent; in the juice, according to Ruempler, it was 31 percent, the nitric nitrogen was low for the Arkansas Valley beets, 0.00144 percent; the injurious ash and nitrogen per 100 sugar also low, the former 2.1267, the latter 0.36424. The beets from this field were among the best analyzed in 1910 and were really very good beets. We have elsewhere stated that these results are not in accord with others obtained with smaller applications of nitrate, but the soil was different.

With the application of 500 pounds per acre the field results were good, crop 15.52 tons per acre, sugar in beets 15.8 percent, but the effects upon the composition of the beet were easily recognized in the analytical results by an increase of the total ash, a very moderate amount of phosphoric acid, high alkalis, particularly soda, a marked increase in the total nitrogen, a lower ratio for the proteid to the total nitrogen, evident in the juice as well as the beet, a very large increase in the nitric nitrogen, ten times, a very decided increase in the injurious ash and nitrogen per 100 of sugar, 3.205 for the former and 0.6822 for the latter. The diffusion juice from these beets showed a considerable reduction in its percentage of nitrogen and yielded a thick juice of 88.29 purity.

With the application of 750 pounds of nitre per acre, the results were bad, crop 14.94 tons, sugar in beets 13.4, dry substance 20 against 22 with 250 pounds, pure ash in fresh beets greatly increased, 60 percent, phosphoric acid reduced from 0.0375 to 0.03588, the alkalis increased, potash to 0.30088 and the soda to 0.18359, the total nitrogen increased from 0.14485 in the beets grown with 250 pounds of nitre to 0.29610 in the beets, and 0.27065 in the juice, and the ratio of the proteid nitrogen to the total was very greatly depressed, to 16.9 percent in the juice, the nitric nitrogen increased from 0.00144 in the beets grown with 250 pounds of nitre, to 0.04143. The real coefficient of purity of the thick juice produced from these beets was 86.66.

The results obtained by the application of 1,000 pounds in four portions did not show a further reduction in the yield but the percentage of sugar and dry substance in the beets were reduced to 11.0 for the sugar and 17.6 for the dry matter; the pure ash in the beet was quite high, 0.7444, the phosphoric acid fell still further to 0.02373, the total alkali was nearly 0.46 and the soda rose to 0.23728, the total nitrogen was high both in the beets and juice, the proteid nitrogen was low and the nitric nitrogen in the beet rose to 0.06285 and the real coefficient of purity of the thick juice was 86.37.

For some reason, as stated more in detail elsewhere, the plot which received 1,250 pounds in five applications and our check plot which lay alongside of it, gave us unexpected and discordant results. The general results, however, with 1,250 pounds per acre, were the same as those with 1,000 pounds, low percentages of sugar and dry substance, low percentage of phosphoric acid, high alkalis, especially soda, high total nitrogen, low ratio for proteid nitrogen, high nitric nitrogen, high amounts of injurious ash and nitrogen per 100 sugar, 4.04 for the former and 1.1151 for the latter. The real coefficient of purity of the juice from these beets was 86.43. Though the results obtained on our check plot, probably due to a flooding in early August which also involved a part of the field which had received the application of 1,250 pounds of nitrates, were altogether unsatisfactory, still the real purity of the thick juice from these beets was 88.26, which is at least one point lower than it should be and still we see that the effect of 1,000 pounds of nitrate of soda per acre was to depress the coefficient of purity of the thick juice by 1.89 points below this and hereby probably increased the molasses which these beets would produce by from 3 to 4 percent on the weight of the beets cut, or in other words, would increase the molasses produced in a factory working such beets alone to probably 8.5 percent or possibly more on the weight of the beets cut.

Analyses VII, VIII and CLXXXV represent the best beets that I have been able to obtain, with these might be grouped Analysis XI. No. VII was grown in Michigan, VIII near Fort Collins, XI in the extreme eastern part of the Arkansas Valley in Colorado, while CLXXXV was grown in Montana. These are all good beets but the samples from Colorado and Michigan are excelled by the Montana beet and for this reason I will consider the Montana beet alone in this place and only from the standpoint of quality without any attempt to account for it. The trimmed beets from Michigan averaged 1.8, those from Fort Collins 1.5 and the Montana beets 1.06 pounds. The weight of the Arkansas Valley beets was not noted but they were only a little smaller than the Fort Collins beets and can be safely estimated at about 1.25 pounds. The Montana beets show the following qualities: high sugar content, 18.24 percent, low ash, pure ash in beet, 0.4909 percent, high phosphoric acid 0.08117 percent in beet, high potash, low soda, low total nitrogen, high ratio for proteid nitrogen both in the beet and juice, nitric nitrogen entirely wanting, injurious ash per 100 sugar very low, 1.6724, injurious nitrogen very low, 0.16722 per 100 sugar. The amount of phosphoric acid in the pure ash is fully normal, a feature which is very markedly wanting in our Colorado beets. The ash of sample VIII, given in Analysis X, approached it more nearly than any other sample that I can recall and it has 12.515 percent phosphoric acid in pure ash and 0.0762 percent in beets. I do not know what the composition of the Arkansas Valley beets was during the years previous to 1904 but our records show that the sugar content was not far from 17.5 percent—this figure is more than sustained by the average sugar content of the beets received at the factory at Rocky Ford during its first three or four campaigns. The beets given in Analysis XI are not the richest beets harvested from this field, several wagon loads sampled above 16 percent and this same territory in 1911 averaged between 17 and 18 percent sugar. The growth of the beets in 1911 was of an entirely different type from that of previous years. These facts are stated to remove the impression that there is no justification for taking a beet of such high quality as the Montana beet as a standard. The College land is probably as good as any on which beets were grown in 1910 or 1911 from which we gathered samples. The College samples 13 Oct. 1910 contained 13.3 percent sugar, were five percent lower in dry substance, and 23 percent richer in pure ash in beet than the Montana beets. The phosphoric acid was fairly high, 0.07342, the sodic oxid was high, 0.12858, the total nitrogen was 0.18636 and the nitric nitrogen

0.02138. Injurious ash per 100 sugar was 3.4164, and injurious nitrogen 0.6384. The beets grown in a part of the same field in 1911 were much better in every respect except that the phosphoric acid was much lower. This difference was not due to the date of harvesting, for the one was gathered on 11 Oct., the other on 12 Oct. When we pass to ordinarily good land in the Arkansas Valley and consider the quality of the beets grown on such land without any fertilizers we find low percentages of sugar and dry substances, high ash, low phosphoric acid, often high chlorin, high potash (alkalis), variable total nitrogen, high nitric nitrogen and large amounts of injurious ash and nitrogen per 100 sugar. Analyses XX and XXVII represent beets grown on good land but of surprisingly poor quality. This land was a sandy loam; the water supply in 1910 was good throughout the season and the cultivation was also good. The beets suffered some from leaf-spot, no fertilizers used. The percentage of sugar in the sample taken 3 Nov. was 12.7 percent; of dry substance 20.0, pure ash in beet 0.7176, phosphoric acid 0.03825, chlorin 0.03342, sodic oxid 0.17585 after deducting enough to combine with the chlorin present, total nitrogen 0.25215, nitric nitrogen 0.04537, injurious ash per 100 sugar 3.703 and injurious nitrogen per 100 sugar 1.07246. There is neither seepage nor alkali, as we usually use this term, in this land. The beets did not suffer from drought nor were they injured to any extent by the leaf-spot and yet the contrast between these and good beets is marked in every respect. I do not know the variety of these beets. Compared with either one of the samples, especially with the Montana beets, they yield very interesting results. The figures for the Montana beet are given first; sugar 18.24-12.7; dry matter 25.37-20.00; pure ash in beet 0.4909-0.7176; phosphoric acid 0.08117-0.03825; soda 0.01312-0.17595; total nitrogen 0.10494-0.25215; nitric nitrogen 0.0000-0.04537; injurious ash per 100 sugar 1.67240-3.7030; injurious nitrogen per 100 sugar 0.16722-1.07246; ratio proteid nitrogen to total nitrogen in press juice 53.0 percent—20 percent. We can almost exchange these figures for the Colorado sample throughout for those obtained in the case of beets grown with the application of 750 pounds of nitrate per acre—in other words, the results are not only identical in character but almost identical in extent.

We have just placed in juxtaposition the results obtained with the very best beets that I have analyzed and a very poor sample of beets grown on good land and under favorable conditions—the one factor, the presence of leaf-spot, excepted. We look upon the results obtained by defoliating the beets as having already eliminated this. We can, however, eliminate it still more effectively and at the same time show that we have other recourse than the comparison of the excellent beets from Montana with the bad beets grown in Colorado to show the effects of nitrates in the soil upon the quality of the sugar beet. In this case we shall use the good effects of a beneficial quantity of nitrate to show the bad effects of an excessive quantity. In this case all questions of differences of climate, soil, water-supply, cultivation, time of sowing, harvesting, variety, attack of leaf-spot or any other favorable or unfavorable condition are eliminated for the beets were grown on two acres of land in the same field separated by an intervening acre. Both plots received a dressing of sodic nitrate, the first one given 250 and the second 750 pounds per acre; sugar 16.5-13.4; dry substance 22.4-20.6; pure ash in beet 0.51948-0.82238; phosphoric acid 0.03750-0.03588; sodic chlorid 0.03782-0.10638; sodic oxid 0.20800-0.18359; total nitrogen 0.14485-0.29610; nitric nitrogen 0.00144-0.04143; injurious ash per 100 sugar 3.1267-4.7812; injurious nitrogen per 100 sugar 0.36424-1.29250; ratio proteid nitrogen to total nitrogen in press juice 31.0-17.0.

The results which we have just reviewed are such as we meet with on good lands with which, under ordinary conditions, no fault would be found. The next results are such as we meet with on bad ground, not poor ground but bad ground, land in which we meet with conditions involving the questions of seepage and alkali. This land is very rich in nitre. In Colorado Experiment Station Bulletin 155, p. 24, I stated, "We find the nitrates present in soils where there is a great deal of moisture, but in places where there is too much water, the nitre does not appear. In little valleys and saucer shaped depressions in which the lower portions are too wet, there is no visible alkali, then follows a zone where white alkali abounds and above this the nitre is formed. I do not mean to say that there may not be nitre mixed with the white alkali, but that the nitre in such cases appears in higher ground than that on which the white alkali usually appears. Furthermore, it is not intended that anyone shall infer that it is only in valleys and depressions that the nitre occurs." Again in the same bulletin, 155, p. 12, I refer to a condition met with in the soil which I described as muddy, and state, "The soil is very wet at a depth of two and a half feet and forms a real mud from this point downward, but at a depth of six feet the water came in so slowly that in order to fill a two-gallon jug we had to let the hole stand open over night. * * * I had never seen anything similar to this condition before I began to study this subject. * * * * It is surprising that the soil can be so wet and muddy for 3½ feet and that we should be unable to find a proper water-table within six feet of the surface." We met with somewhat similar conditions in portions of this land. Borings were made to determine the height of the water-plane 14 Nov. 1910; it was met with in the lowest cultivated portion of the field at five feet below the surface and one foot above the bottom of a drainage ditch 600 feet to the north and west of this point, at no other point in the line of borings did they find water within six feet of the surface. In 1897, 1898 and 1899 I grew excellent beets both in regard to crop and sugar content on land in which the water did not fall to a greater depth than four feet below the surface at any time and the soil was heavily impregnated with the white alkali common throughout the state. I have no analyses of these beets comparable to the analyses here presented, but samples taken 8 Nov. 1898 showed 17.29 and 18.24 percent sugar, the beets were of excellent shape and of medium size. The subsequent year another variety grown in the worst section of the plot gave 15.82, other samples gave 15.86 and as high as 16.34; the apparent coefficient of purity for these beets was about 84. No nitrogen determinations were made but the ash of this variety was analyzed and gave the following results for the pure ash:

ANALYSIS PURE ASH OF BEETS GROWN ON ALKALI LAND, 1899.

	Percent	Percent in Fresh Beet
Sulfuric acid	4.93	0.043
Phosphoric acid	11.48	0.100
Chlorin	11.93	0.104
Sodium	7.75	0.063
Potassic acid	48.55	0.426
Sodic oxid	1.18	0.010
Calcic oxid	3.66	0.032
Magnesic oxid	9.13	0.077
Ferric oxid	0.89	0.008
Aluminic oxid	0.24	0.002
Manganic oxid	0.26	0.002
	100.00	0.872

The injurious ash per 100 sugar in these beets was 4.18, which is higher than is desirable, but much less than one who is familiar with the conditions of the land at that time would expect. For full discussion of the soil conditions and crop see Bulletins 58 and 65 of this station. The only points presented by this analysis which are in any way abnormal for our western beets is its quantity, 0.872 percent of the fresh beet and the relatively large amount of chlorin, 0.104 percent. The excess of sodic oxid over that necessary to combine with chlorin to form sodic chlorid is very small and the phosphoric acid is very high, two features which are wanting in beets grown with the application of or in the presence of nitrates, especially the phosphoric acid which is always depressed by the nitrates. These data are presented as the most definite and reliable that I have showing the effects of excessive water and alkali, other more general information has been stated in the earlier portion of the Bulletin. The questions of water and alkali are involved in the land which we have designated as bad land and on which the samples under discussion were grown. This land had a fall of about 2.4 feet per hundred to the north, so that the south end of our field was about 18 feet higher than the north end and the excessively bad conditions prevailed in only a small portion of that planted to beets. For the purpose of our study we divided the plots into three sections, the highest, the medium and the lowest, in which the worst land that the owner had tried to cultivate was not included. A sample from this portion, however, is included with those from our check plot. These beets are represented by Analyses C, CI, CII and CIII, their ashes by Analyses CXIV, CXV, CXVI and CXVII. The variety of beets was the Original Kleinwanzlebener. The character of the beets from the various sections differed only in degree, and in this not to the extent that one would expect. We see by an inspection of the analyses that the percentage of sugar is low, 13.2 to 8.6 percent, the dry substance is low, from 21 to 16.5, the pure ash in the beets is very high, from 0.89514 to 1.32875, the phosphoric acid is very low, from 0.03875 to 0.02007. The chlorin is high, from 0.15188 to 0.30396, the potassic oxid is only moderately high, see percentage in pure ash, the sodic oxid above that required by the chlorin is moderately high. The total nitrogen is high, one sample excepted, 0.23345 to 0.3451, the nitric nitrogen is high in all samples, from 0.01936 to 0.08337, the injurious ash per 100 sugar is from 5.629 to 13.433, the injurious nitrogen from 1.02880 to 2.04840, and the ratios of albumin nitrogen to total nitrogen in press juice 22.6 to 19.0. We have in these analyses results which are altogether characteristic of the effects of nitrates and while the excessive salts in the soil may have influenced the composition of these beets they have not done so to a sufficient extent to conceal in the least these effects characteristic of the nitrates, for instance, low percentages of sugar, dry substance, phosphoric acid, high total nitrogen, high nitric nitrogen, low ratio of albumin or proteid nitrogen to total nitrogen and high ratios for the injurious ash and nitrogen per 100 pounds of sugar. The pure ash calculated on the beet and the chlorin are both high, but these effects are common to the nitrate, excessive moisture and the alkalis, so their joint effect is cumulative and the effect of one does not tend to lessen or remove the effect of the other.

Beets grown on the worst section of this land were run in an experimental plant and the diffusate treated as usual and evaporated to a thick juice, which had a real coefficient of purity of 69.56, not much better than molasses. The carbonated ash of this thick juice equalled 14.810 percent. The amount of nitrates present in the surface six inches of this soil as calculated from samples of soil taken, one of them from about the beets, actually beneath the leaves, was between 15 and 17 tons per acre.

The experiments made with sodic nitrate in 1910 and 1911 to show its effects upon the quality of beets and upon the character of the thick juice produced in the factory, together with the properties of samples of beets grown upon apparently good land, and also such as were grown upon evidently bad land show by the character and uniformity of the results that it is more than reasonable to attribute the falling off in the quality of the beets in the Arkansas Valley to the formation of excessive amounts of nitrates in the soil during the season and not to climatic conditions or to the effects of the leaf-spot. These are most certainly factors which have a decided influence upon the crop, specifically upon the bad qualities of the beets. They cause the very general production of beets with low percentages of sugar and phosphoric acid, with a high percentage of total nitrogen, especially of nitric nitrogen, and a low ratio of albumin nitrogen to the total nitrogen in the juice, with a high percentage of ash. This results in the production of abnormally high percentages of molasses, 7.5 to even 10 percent from beets which have not been frozen and subsequently deteriorated.

The general applicability of this statement is shown by the nitric nitrogen in the fifteen samples of Colorado molasses as compared with the six from other sources, especially with the four from Bohemia. The maximum ratio that we find in the latter for the nitric to total nitrogen is 0.37, while the minimum found for this ratio in any Colorado molasses examined is 10.66 and the maximum is 28.88. We need not go farther in the discussion of these results, the big fact that many of our Colorado molasses are very rich in nitrates is evident. In this connection, however, I may mention a fact observed by Dr. Potvliet in studying the thick juices prepared in our experimental work, i. e., that the nitrates in the dry substance of the thick juice was lower than it should have been to correspond with the nitrates found in the dried cossettes. This loss was very considerable, amounting to 50 percent in the case of the last beets discussed. In view of this actual loss of nitrates observed and the possibility of its taking place in the factory on a large scale as well as in the battery samples, the very large amount of nitric nitrogen found in our molasses becomes even more suggestive than it already is of the large amount in the beets worked.

The deterioration in the quality of the crop in the Arkansas Valley during the past eight years has not, of course, been accepted with indifference and no effort made to check it, on the contrary, the situation has been recognized as serious by the managers of the plants who have been responsible for the success of the companies operating in the valley. The cause of the trouble was not recognized, but was attributed to various things, climatic conditions, leaf-spot, insect injuries, seepage, alkali, etc., all of which are factors in determining the quality of the season's crop. Another thing suggested was, naturally enough, a lack of some plant food in the soil and consequently attempts were made to find out by direct experiment whether anything could be added to the soil which would produce satisfactory crops both in quantity and quality. I have recorded the results obtained in regard to the yield of both beets and sugar in the earlier pages of this bulletin, which were rather disappointing so far as commercial results were concerned. We, unfortunately, do not feel justified in modifying them in a desirable direction. We can, however, present a review of what the study of the effects of the fertilizers used, had upon the chemical composition of the beets, at least in their bolder features. The weights and combinations of fertilizers used have been given on previous pages. We had in all in 1910, 31 experiments with fertilizers, that is distinct from the nitrate experiments. The beets grown on nine of these plots and two check plots were studied with the object of determining what changes, if any, we had effected in the composition of the beets. The land on which these experiments were made has already been described and its chemical composition given in connection with the detailed statement of the analyses. The results are in harmony with those obtained when considered from the purely commercial basis. The best beets in every respect with one unimportant, partial exception were those grown on a check plot. The plots to which only potash or phosphoric acid had been applied yielded beets of quite as good quality, but the yield and sugar content were a trifle lower in both cases. Stockyard manure seemed to increase the phosphoric acid in the beets though it had been applied in 1909 and we had only a residual effect in 1910. In these experiments the effects of sodic nitrate stand in strong contrast with those obtained in the experiment in which 250 pounds were applied to the field, designated as No. 1. In this case it produced most excellent results, but in every instance in which it was used in the series of experiments under discussion it produced deleterious results though used in quantities less than 250 pounds to the acre. One effect was to increase the chlorin appropriated by the beets—for instance, the beets from check plot contained 0.12746 percent, already very high, those with potassic sulfate alone, 0.14657, with superphosphate alone, 0.12489, those with potassic sulfate and sodic nitrate, 0.24613, those with superphosphate and sodic nitrate 0.17743. The amount by which the nitrate increased the chlorin was very irregular, as are all of the results, but none of them were beneficial. The beets from the check plot were from the standpoint of composition the best beets of the eleven samples examined with possibly one partial exception.

I was and am still of the opinion that the inferiority of nitrate beets is due largely to their immaturity at the time of harvesting. This of course does not explain the depression of the phosphoric acid in the beet which certainly takes place. I do not know the function of phosphoric acid in the first year's growth of the beet except that the application of superphosphate is credited with inducing an early ripening of the beet. We saw no proof of it in these experiments but it was on this theory that I applied superphosphate at the rate of 1,000 pounds per acre to a portion of our field of very bad land. We will compare the beets from the first and third sections of this plot with those from the adjoining sections of the check plot. In the lowest part of the third section the water plane was five feet below the surface. The surface of the first sections was eighteen feet higher than the point where this boring was made. The figures for the beets from the check plot will be given first. First section: Weight of beets, 788.1-751.3. Sugar, 13.2-10.9. Dry substance, 21.0-17.6. Pure ash in beets, 0.942-0.941. Phosphoric acid, 0.03875-0.04816. Chlorin, 0.15188-0.12032. Total nitrogen, 0.2493-0.25860. Nitric nitrogen, 0.01936-0.04982. Injurious ash per 100 sugar, 5.6292-7.1557. Injurious nitrogen per 100 sugar, 1.02880-1.41290. Third Section: Weigh of beets, 569.9-708.7. Sugar, 12.1-10.2. Dry substance, 18.9-18.0. Pure ash in beets, 1.122-1.0644. Phosphoric acid, 0.03109-0.02732. Chlorin, 0.23134-0.20047. Total nitrogen, 0.23345-0.24350. Nitric nitrogen, 0.05370-0.07260. Injurious ash per 100 sugar, 7.92850-9.04210. Injurious nitrogen per 100 sugar, 1.04790-1.78290. The middle section showed no benefit from the application of this amount of superphosphate. The same results varying slightly in their measure was obtained with potassic chlorid and sodic chlorid. These chlorids, 400 pounds per acre, did not affect the amount of chlorin taken up. In five out of six cases the chlorin is lower in the samples grown with these substances than in the samples from the check.

The results obtained with mineral manures are not promising. The general results obtained with stockyard or farmyard manure are much more so than those obtained with the mineral manures. We obtained good beets with green manures but as I have already explained I am unwilling to accept the results obtained without repetition. The beets, however, grown with the mustard and wheat, were excellent in every respect except in regard to the weight of the crop—omitting this factor we have excellent beets, scarcely any better. The beets grown on the wheat ground are given first, then those grown on the mustard land. Sugar 18.5-17.3. Dry substance 24.4-24.4. Phosphoric acid 0.06711-0.07439. Chlorin

0.04062-0.06542. Total nitrogen 0.17940-0.15270; nitric nitrogen, 0.00348-0.00141. Injurious ash per 100 sugar, 2.4190-2.87730; injurious nitrogen, 0.44243-0.34711, and the ratio of the albumin nitrogen to total nitrogen in the press juice is 36 and 40 per cent respectively.

The object had in view in this bulletin has been to discover if possible the cause for the falling off of the beets grown in some sections in sugar content and in general factory qualities. That such a falling off has actually taken place is a fact beyond dispute. We have put this falling off at about three percent in sugar, and the general deterioration in factory qualities may be expressed in terms of the molasses produced at a minimum of two percent, calculated on the beets cut. There has been a variation from year to year. The year 1911, for instance, showed a considerable improvement in this respect. I may remark that the samples of molasses examined in 1911 contained much less nitric nitrogen than the samples from preceding campaigns, except from one factory. We have purposely desisted from taking up in detail the effects produced by the fertilizers used in our attempt to find, if possible, in an experimental way, some feasible means for bringing back the good qualities shown by the beets from 1893 to 1904. The real problem whose solution we have attempted is baffling, as the variety of causes assigned as producing this condition suggests, yet it seems proper that we should discuss briefly some of the salient features of these results from the standpoint of composition wholly irrespective of their technical aspects.

We were fully convinced from the beginning that we could not properly use German or Austrian or any available data as applicable to our beets. The German and Bohemian data vary considerably. I have found no recent complete analyses of German beets. The most satisfactory data that has come to my notice is contained in the Siebenter-Bericht ueber die Versuchswirtschaft Lauchstaedt, 1910, from which it appears that sugar beets grown with 528 pounds nitrate of soda, 600 pounds superphosphate, 264 pounds 40 percent potash salt per acre contained, as the average of seven years, 0.19486 percent nitrogen, 0.06923 percent phosphoric acid and 0.17948 percent of potash in the fresh beet. With the application of nitrate alone 0.20188 percent nitrogen, 0.04431 percent phosphoric acid and 0.16511 percent potash. With no fertilizer 0.20132 percent nitrogen, 0.05479 percent phosphoric acid and 0.16959 percent potash. The average percentages of sugar given for these three series are, respectively, 17.93, 17.32 and 18.29, and those for the dry substance in the beets are 25.64, 24.65 and 26.09 percent. R. F. Strohmer and O. Fallada give in Oesterreichisch-Ungarische Zeitschrift fuer Zuckerindustrie und Laudwirtschaft, XI Jahrgang, 3 Heft S. 425, the composition of beets grown with the application of phosphoric acid, nitrogen (as nitrate and ammonia salts) and soda. The results vary so little for the different sets of beets that we may consider them as within the limits of the natural variability of the plant itself. The soil experimented with was not so rich in lime, magnesia, potash, phosphoric acid or nitrogen as we find our soils to be. The general composition of the eleven samples analyzed is: average weight of beets, 253 to 384 grams. Sugar 17.2 to 19.2, average 18.2. Dry substance 24.68 to 26.54, average 25.61. Ash, apparently carbonated ash, in dry substance 2.19 to 2.55, average 2.39. Ash in beet (carbonated?) 0.61208. Total nitrogen in dry substance 0.80 to 1.29, average 0.95364, in beet 0.2445. Phosphoric acid in dry substance, 0.28 to 0.38, average 0.3082, in beet 0.07893. Potash in dry substance 0.58 to 0.84, average 0.7155, in beet 0.1833. Owing to the fact that soda in the form of sodic chlorid was applied as a fertilizer, and that sodic salts constitute a considerable percentage of our alkalis, the results obtained in regard to the effects of soda have an especial interest for us. The soda in the dry substance of these beets was from 0.18 to 0.48 percent, the average 0.2496, in the beets 0.06541. We quote the analyses of the pure ash in full, omitting the details of the experiments.

ANALYSES PURE ASH AUSTRO-HUNGARIAN BEETS.

	1	11	2	5	8	4	7	10	3	6	[illegible]
Silicic acid	2.60	2.31	1.87	2.00	2.47	2.61	3.62	4.79	3.26	1.00	1.
Sulfuric acid	3.12	4.04	3.27	2.00	2.97	2.61	4.14	3.59	3.26	5.98	2.
Phosphoric acid	15.60	18.47	13.53	12.53	14.86	17.80	19.66	17.96	15.76	13.96	14.
Chlorin	1.56	1.73	3.27	3.00	2.48	1.57	1.55	1.80	2.72	2.99	2.
Potassic oxid	43.68	33.47	34.05	38.08	38.63	36.65	30.52	31.13	41.85	34.90	38.
Sodic oxid	10.40	14.43	22.39	15.53	18.32	9.98	14.49	17.36	9.24	13.46	18.
Calcic oxid	10.92	12.12	11.66	11.53	9.91	16.75	14.48	8.98	9.24	12.47	10.
Magnesic oxid	10.92	12.12	8.86	10.52	8.92	9.42	10.82	13.77	10.33	10.96	9.
Ferric and Alumnic oxids	1.56	1.73	1.87	5.51	1.98	3.14	1.03	1.20	4.89	4.98	0.
	100.36	100.42	100.77	100.70	100.54	100.53	100.36	100.58	100.55	100.70	100.
Oxygen equi. to chlorin	0.35	0.39	0.74	0.76	0.56	0.52	0.35	0.60	0.55	0.76	0.
	100.01	100.03	100.03	99.94	99.98	100.01	100.01	99.98	100.00	99.94	100.0

Numbers 1 and 11 received no fertilizers of any sort. The authors failed to discover any relation between the amount of sodic oxid and the sugar in the beets. The ratio of the proteid nitrogen to the total in the dry substance ranged between 60 and 65 percent.

There are radical differences in the composition of these European beets as we find them represented in their literature and those which we have studied. It is not feasible to go into the details of all of our analyses, but the general results may be expressed as follows: The whole nutrition of the beet seems to be very greatly modified. The total nitrogen in our beets is decidedly lower than in the European beets except under abnormal conditions. The average total nitrogen in Lauchstaedt beets grown without fertilizers is 0.20132 percent. This average is based on seven years' observations. The average of those just quoted from Strohmer and Fallada is 0.2445 percent, that for the six samples of cossettes quoted from Andrlik is 0.233 and for twenty-three other samples also given by Anrdlik the average is 0.2285 percent. The average for the total nitrogen in our beets grown on good land without fertilizers will not exceed 0.15 to 0.18 percent. The proteid nitrogen is low, being as a rule less than 50 percent of the total in the harvested beets, and in the case of beets grown on bad ground, even with the application of superphosphate at the rate of 1,000 pounds per acre, it fell to a little less than 20 percent of the total. The European beets contain almost no nitric nitrogen, so little that the determination is seldom attempted. Further, the Bohemian molasses given in this bulletin show very little of this form of nitrogen, while it is present in our beets in liberal quantities, reaching in the case of beets grown on very bad ground 0.08 percent and is so good as never entirely wanting. The sample of Montana beets contained none and one sample from Fort Collins contained only 0.0009 percent. Usually our best, mature beets contain 0.003 or more percent. The injurious nitrogen in our beets is very high. Andrlik states that "beets poor in nitrogen contain only one-fourth to one-third of their total nitrogen, on the other hand beets rich in nitrogen contain as much as one-half of it as injurious nitrogen," Zeitschrift des Vereins der Deutschen Zuckerindustrie 1903, p. 922, and gives examples in support of his statement showing beets with from 0.224 to 0.306 percent nitrogen which contain injurious nitrogen reaching from 37.9 to 43.8 percent of the total. Four of the best samples grown by us in 1911 containing 0.14124, 0.14388, 0.14882 and 0.14223 percent total nitrogen, contained 42.55, 43.47, 37.98 and 35.43 percent of it in the form of injurious nitrogen. These beets were grown without any fertilizers and were harvested, the first pair on 12 Oct. and the second pair on 8 Nov. This shows the betterment of the beets by ripening. I may add that beets grown with application of nitrates subsequent to 1 Aug. showed an improvement also but to a less extent, the total nitrogen in these beets was essentially 0.165 percent. The injurious nitrogen in these, the same varieties as above given and harvested on the same dates, amounted to 45.33, 45.07, 42.67 and 42.58 percent of the total. We see that these percentages are very much higher than those given by Andrlik, whose beets with 0.165 percent nitrogen contained 32.1 percent of it as injurious nitrogen. This is 10.5 percent less than we find in beets of equal nitrogen content in their very best condition.

Our beets carry much less phosphoric acid as a rule than the

European beets. The Lauchstaedt beets grown with a complete mineral manure, showed for the seven year average 0.06923 percent in the beet, and beets grown without any fertilizer showed as an average for the same period 0.05479 percent. The samples given by Strohmer and Fallada with and without fertilizers give an average of 0.07155 percent in the beets. A few of our samples are as rich or richer even than these averages indicate, but the greater number of them are materially lower. The percentages of dry substance and its ash content together with the percentage of phosphoric acid in the pure ash are the factors which give us these figures. In our beets these factors are different from those of the European beets. The percentage of dry substance in our beets is materially lower, as a rule, the ash is somewhat higher, the phosphoric acid in the pure ash is very much lower. In the analyses of pure ashes given by Strohmer and Fallada, the lowest percentage given for phosphoric acid and calculated on the pure ash is 12.53 and the highest is 19.66. Of 50 ashes of Colorado beets analyzed in connection with this bulletin, only two have shown in the pure ash as much as 12 percent of phosphoric acid, these contained 12.515 and 12.076. The average of the 50 determinations using the nearest whole figure in the second decimal place is 6.78 percent. It is just to state that 13 of these samples were grown on very bad ground, but when these beets have been deducted, the average is only 8.07 percent, while the average of the Strohmer-Fallada samples is 15.6 percent. The pure ash of the Montana beet analyzed contained 16.536 percent.

The potassic oxid in our beets is higher than in the European beets. In these latter its average is not far from 0.17 percent, while in ours it is seldom as low as 0.22 and reaches as high as 0.54, ranging mostly between 0.26 and 0.44.

In regard to the sodic oxid nothing can be said, it seems to be as erratic in the European beets as in ours, and without relation to the sugar in the beet.

Our beets contain very little lime, usually a trifle over one-half as much as the European beets, but they contain rather more magnesia. The ratio of these two substances in the European beets is approximately 1:1, the calcic oxid being slightly in excess, but with our beets this ratio is approximately 1:2.

The chlorin is extremely variable in the ashes which can sometimes, but not always, be attributed to the presence of a large amount of it in the soil.

Among the subordinate constituents we often find less iron and alumina than is given for the European beets; on the other hand, manganese is seldom if ever given in their analyses. I do not remember to have seen it given at all. Ruempler, Die Nichtzuckerstoffe der Rueben, p. 31, says "Caesium and Manganese have been detected by Von Lippmann in unrecoverable (nicht gewinnbaren) traces, the former by means of the spectroscope in beets, beet leaves and beet products." We find manganese always present in the ashes of our beets and beet leaves, varying from a few hundredths to 0.3 percent in sugar beets and to 0.5 in the long red mangold.

We will recapitulate these differences, our beets (the ones that we have been studying) are larger in size, lower in sugar, lower in dry substance, higher in ash constituents, lower in nitrogen, lower in proteid nitrogen, higher in injurious ash and higher in injurious nitrogen than the European beets cited. The beets are poor in phosphoric acid and rich in potash. The soda and chlorin content is very erratic. The calcic oxid is low, about one-half as much as in European beets. while the magnesic oxid is a little higher than in these. It does not appear that the magnesic oxid is abnormally high but that the lime is abnormally low. The soils in which the beets discussed were grown are without exception rich in calcic oxid from 4.0 to 6.0 percent, also in magnesia about 1.5 percent, with carbonic acid usually about 5.0 percent. These differences must indicate great differences in the nutrition and transformation of substances in the beet.

We have a little light on some of these differences but not on all of them. We can account in some cases for the low sugar, low dry substance, higher ash, low, proteid, higher injurious nitrogen and lower phosphoric acid content. We cannot explain the higher potash and lower lime nor have we at the present time any knowledge of their significance.

A study of the effects of nitrates upon the composition of the beet shows that they increase the size of the beet and the top; reduce the percentage of sugar and dry matter; increase the ash; suppress the phosphoric acid; increase the total nitrogen; decrease the ratio of proteid nitrogen to total nitrogen and increase the nitric nitrogen even in beets grown in soil already rich in this form of nitrogen even if applied at a time when the beets are supposed to use only a small amount of nitrogen. Nitrate applied 4 Aug. to 28 Sept. 1911 in all equal to 750 pounds per acre increased the size of beets by 9.9 and 14.6 percent; reduced sugar 1.0 and 1.1 percent; dry substance 0.9 from 22.0 to 21.1; increased total nitrogen from 0.14223 to 0.16698; reduced ratio of proteid nitrogen from 60 to 50 percent, increased injurious nitrogen from 0.3229 to 0.49041 per 100 sugar; increased nitric nitrogen from 0.0083 and 0.0074 to 0.0187 and 0.0142 and suppressed the phosphoric acid in the pure ash from 10.1 to 7.8 and from 10.9 to 9.4 percent. These results were obtained with beets on excellent land free from seepage and alkali and the plants were free from the leaf-spot. This was during the season that produced the best beets that we have had for years. A like amount of nitrate in 1910 applied in three portions, beginning 28 March and making the applications four weeks apart, decreased the sugar from 16.85 to 13.4, dry substance from 22.4 to 20.6, increased the pure ash in the beet from 0.52 to 0.82; increased total nitrogen in the beet from 0.1449 to 0.2961; reduced the ratio of proteid nitrogen to total from 40 to 30 percent; increased the nitric nitrogen from 0.00144 to 0.04143 and reduced the phosphoric acid in the pure ash from 7.218 to 4.363 percent.

The averages for seven years given by the Lauchstaedt Experiment Station show that beets grown with complete mineral fertilizers contained 0.06923, those grown without the application of any fertilizer contained 0.05479, while those grown with addition of nitrate alone contained 0.04431 percent of phosphoric acid.

The effects upon the leaves which were studied in 1911 may be more freely discussed at another time, but it may be stated that the nitric nitrogen disappeared from the blades of the beets to which no nitrate had been applied about 14 Sept., while it continued in the blades of the nitrated beets up to the time that they were frozen. The nitrates seem to migrate into the petioles as these are richer in nitric nitrogen at all times than either the beets or the blades. Nitric nitrogen continued in the petioles of the leaves of beets which had not been dressed with nitrates up to the latest date that the samples were taken, 12 Oct. The amount was approximately one-fourth as much as was present in the petioles from beets which had received nitrate. The nitric nitrogen in the petioles from beets which had not been dressed with nitrate was from four to five times greater than the amount found in the beets and was larger than the amount found in the roots of those plants which had been treated with nitrate.

That the foliage of the beet plant is the efficient agent in the transformation and elimination of the nitric nitrogen taken up by the beet appears evident from the results obtained by defoliating the beet. The beets were defoliated 6 Sept. The nitric nitrogen in the roots on 1 Sept. was 0.01925 and 0.01796 percent. The beets were harvested on 8 Nov. and though the average weight of the beets had increased by 160 and 130 grams for the respective varieties the nitric nitrogen in the beets as harvested equalled 0.01367 and 0.01584 percent. The increase in the size of the beets was approximately 22 percent, the decrease in the percentage of nitric nitrogen was only 11 percent, the gain in nitric nitrogen in the roots was approximately 30 percent. Beets which had not been defoliated, the checks corresponding to these samples contained 0.00827 and 0.00746 percent nitric nitrogen. The complete destruction of the leaves stopped the transformation of the nitrates and probably other substances until the production of a new foliage, which of course began immediately, but could not be restored for those beets in the eight weeks of the season, which events proved were remaining. It would be interesting to know what the results of various degrees of partial defoliation would be, this would more perfectly imitate the action of the leaf-spot. We reserve this for the future.

The results of our fertilizer experiments were so divergent that we can use them to prove almost anything, except that they did some material good. Measured by the percentage of sugar, the injurious ash and injurious nitrogen per 100 sugar in comparison with those of the check plot, they did no good, but rather some harm.

We have seen the effects produced by excessive quantities of nitrates under conditions which leave no room for doubt in regard to them. We presented the composition of beets grown on good ground in the Arkansas Valley and also such as were produced on bad ground. We find that a sample of beets harvested 3 Nov. 1910, grown on a sandy loam, well located and free from all apparent objections, thoroughly cultivated and abundantly supplied with water, contained sugar 12.7, dry substance 20.0, pure ash in beet 0.7176, phosphoric acid in beet 0.03342, total nitrogen 0.25215, nitric nitrogen 0.04537 percent, injurious ash 3.703 and injurious nitrogen 1.07246 parts per 100 of sugar. The bad land referred to contained no free water within five feet of the surface but it was very rich in nitrates. The sample here given was grown in a bad, but not the worst section of this bad land, sugar 10.2, dry substance 18.0, pure ash in beet 1.06, phosphoric acid in beet 0.02732, total nitrogen 0.30675, nitric nitrogen 0.0726 percent, injurious ash 9.0421 and injurious nitrogen 1.7829 parts per 100 sugar. The phosphoric acid in the pure ash of this sample was only 4.659 percent and the beets were dressed with superphosphate at the rate of 1,000 pounds per acre.

In addition to these details of composition we have previously seen that beets grown with excessive nitrates produced thick juices of very low coefficient of purity, even when grown on the very best land at our disposal, and under conditions which were in every respect favorable. The depression of the coefficient of purity corresponded to an increased production of molasses over that of reasonably good beets of three percent or more. In addition to these facts we have our Colorado molasses carrying nitric nitrogen equivalent to a maximum of 28.88 percent of its total. The deterioration in the beets is characterized by the falling off of approximately three percent in the average sugar content, by yielding juices difficult to work and the production of too much molasses. This molasses is rich in nitric nitrogen as we have seen. We find the properties of the beets, whether studied in separate samples from the field or on the larger scale of factory practice agreeing in every respect with our nitrate beets. The only possible question which can obtain is in regard to the presence and source of the nitrates. We have answered this question in Bulletins 155, 160 and 178 and further in this one, using Mr. Zitkowski's figures which show the presence, and as I believe the formation of very much larger quantities of nitrates than I have ventured to apply.

SUMMARY.

The object of this bulletin is to determine whether the quality of the sugar beets grown in some sections of Colorado is such as is produced by an undue or untimely supply of nitrates and to determine whether the depreciation in the quality of beets, which fact is not questioned, may be due to a widespread and excessive supply of nitrates in the soil.

Up to 1904 the quality of the beets grown in the Arkansas Valley was excellent but since that time there has been a general depression in the quality of the beets. The percentage of sugar has fallen from an average of 17.5 percent prior to 1904 or 1905 to an average of about 14.5 percent from 1905 to 1911 inclusive. This falling off in the percentage of sugar has been persistent throughout this period and not for one year or two years only. The amount of molasses which has had to be worked by the Steffens process has been abnormally high, 7.5 percent, and sometimes even more, calculated on the beets cut.

There has been no season but that there were some sections which produced good beets so far as the percentage of sugar and crop were concerned, nevertheless the average quality of the beets has been much below what it formerly was. The causes generally thought to be operative in bringing this about may be included under the following designations: Alkali, seepage, possible lack of some plant food, or an improper ratio of the elements of plant food to one another, leaf-spot *Cercospora beticola,* and climatic conditions.

The first two are usually associated in the public mind, though some of our land is rich in alkalis but is not excessively wet.

Our observations upon the effects of alkali and water on the sugar content of the beet do not support this view. Sugar beets grown four years in succession on strongly alkalized land were as rich in sugar as beets grown on wholly unobjectionable land. The conclusions drawn from the four years' observations were that the alkali *per se* was not detrimental to the quality of the beets; that it did not affect the amount of dry matter in the beets; that it slightly increased the quantity of the ash, but that it did not affect the composition of the ash so positively that we could assign any definite effect to this cause. The water plane in portions of the land experimented with did not at any time, in the four years, fall to a greater depth than four feet and was less than three feet below the surface for a good portion of the growing season, without serious effects upon the yield or quality of the beets. These observations have been repeated many times since this series of experiments was made. Again, the conditions popularly described as seepage and alkali are not prevalent enough to justify their serious consideration as the cause of the deterioration of the general crop.

The view that the quality of the beets has fallen off because the plant food in the soil has either been exhausted or the relative quantities have been so modified that this change may be the cause, is held by some. Experiments were made in an endeavor to answer these questions, i. e., to see if we could obtain an increased yield and at the same time effect an improvement in the sugar content of the beet. These were in the beginning the objects had in view. The only probable deficiency in our soils, judging from analytical data, is in the supply of nitrogen, but experiments with different fertilizers in various combinations were made to demonstrate their value in the solution of our problems. The results obtained were disappointing, and in no case have we obtained results which justified the view that the depreciation in the sugar content of the beets was due to the lack of plant foods, or to their ratio within the limits of the quantities used in the experiments. The soil on which the experiments of 1909 and 1910 were made was sampled to a depth of three feet. The samples were taken from the check plots and showed a great abundance of both phosphoric acid and potash. The samples represent sections of one foot each. The phosphoric acid soluble in strong hydrochloric acid in the surface foot of the respective plots was 7,520 and 8,040 pounds; the potash soluble in the same medium was 35,480 and 32,520 pounds and the total nitrogen was found to be 4.320 and 3,684 pounds. The application of nitrogen either in the form of stockyard manure or in that of sodic nitrate alone or in conjunction with phosphoric acid and potash did not produce the favorable results expected. This statement applies to the yield of sugar rather than to the other qualities of the crop which form a separate question. The sugar in this whole series of beets was low, the yield very moderate, scarcely an average one, the ash in the beets was high, the pure ash in the fresh beet exceeded in some cases one percent. The results indicate that the poor quality of these beets was not due to any lack of plant food, not even of nitrogen. The moderate yield and low sugar content could not be attributed to indifferent cultivation, lack of care or intelligent management, or to injury by insect or fungi. There was some leaf-spot but it was not serious.

An effort was made to establish the effects of leaf-spot on the yield and percentage of sugar in the beet by obtaining the yield and percentage of sugar in 127 cases, on fields aggregating about 2,500 acres from 16 sections or districts of the Arkansas Valley. Some of these fields were badly affected while others were not. The yield and percentage of sugar varied greatly, but there was very decidedly greater differences in both the yield and percentage of sugar in the different districts than between the individual fields in the same district which had been attacked by the leaf-spot with varying degrees of severity. The average percentage of sugar shown by the field samples from some of the fields which had been severely affected by leaf-spot showed from 16 to 17 percent of sugar. These percentages of sugar could not in these cases be attributed to drying out of the beets in the ground. The record of 127 fields does not show with any decisiveness what the effect of the leaf-spot is. The beets grown on the College Experiment Farm showed the same characteristics in their composition as those from the Arkansas Valley and they had not suffered from the leaf-spot, so it is not at all satisfactorily shown what the effects of the leaf-spot really are. The results obtained do not show any constant or definite relation between the severity of the attack and the yield and percentage of sugar. The development of the beet at the time of the attack is probably an important factor and this cannot be given.

The thesis presented in this bulletin is that the causes mentioned as the ones to which the deterioration of the beet is due have not been shown to produce the effects assigned to them; on the contrary, it is conclusively shown that neither alkali nor seepage, except possibly in land wholly unfit for cropping, do not of themselves produce beets either low in tonnage or percentage of sugar. Further, analytical results obtained with samples of the soil as well as the results obtained by experiments with fertilizers fail to show any lack of plant food, unless the analytical results be interpreted as indicating a lack of nitrogen, which interpretation is contradicted by the results of experiments with nitrogenous fertilizers. Further, that while the leaf-spot is very serious, we have been unable to detect any such relation between the severity of the attack of this disease and either low tonnage or low quality of the beet as to justify us in attributing the general deterioration which has taken place during the past eight or ten years to this cause. Further, that while climatic conditions, late frosts in the spring, early ones in the fall, long continued hot weather, high winds, failure of water or severe and general hail storms are all factors in determining the tonnage and quality of a crop, the facts obtaining during the past ten years do not justify a serious consideration of "climatic conditions" as the cause of the deterioration, for it has continued very generally throughout a large district for a number of years in which the "climatic conditions" have been both good and bad. Further, that when insect injuries are the cause of a deteriorated crop the fact is patent and the same is true with fungi and bacteria. Neither one nor all of these causes have been shown to have brought about the deterioration of which we write. Our thesis is that the cause hereof is a soil condition which permits too generous a supply of nitric nitrogen throughout the season which in the first place prolongs the period of vegetation and delays maturation to such an extent that the beets are harvested in an immature condition and of poor quality. The tops are unduly large, the beets white and watery, of poor keeping qualities and yield juices which require heavy liming, boil badly and produce a great deal of molasses.

It has been shown by experiments that nitrates applied to beets at the rate of 528 pounds per acre affects the quality of the beet prejudiciously. A few investigators claim that the application of nitrates in three portions and in smaller quantities improve the quality. Our question is, what is the effect of larger quantities, and not whether some may be of benefit? Another consideration is in regard to the time when the nitrates become available to the crop. That nitrates applied at the time of seeding or during the early development of the plant may be beneficial, is abundantly established, while the same amount applied later might be injurious. It is shown in Bulletin 155 that many of our cultivated soils, such as had been planted to beets contained in samples taken, 1-15 Oct. nitric nitrogen corresponding to larger amounts of sodic nitrate than 528 pounds in the surface six inches of soil. The maximum found in October corresponded to 1,902 pounds of sodic nitrate in the surface six inches. In another set of samples taken in January we found the maximum of 1,680 pounds in the top six inches. We further found in October that the fallow spots in a beet field contained very large amounts, from 10 to 30 times as much as the land in the rows or between the rows, the maximum found was 1,407 pounds in the top two inches. These are quantities which would have been very prejudicial had they been available to the beets during the months of June, July and August. It is not asserted that the beets growing in other portions of these same rows had at their disposal during the growing season so large an amount of nitrates, but that it was possible for them to have had. The beets in this field had very large tops, the roots were small, the sugar content was low and the beets did not ripen during the season. The tops were killed by being frozen on 7 Nov., on which date they were entirely green and showed no signs of ripening.

Occasional mention is made of the deleterious effects of nitrates upon beets, but the statement seems to have been based upon general opinions or factory practice. Up to the time this study was begun, at most, only a few analyses had been made to determine what effects the nitrates actually have upon the composition of the sugar beet. At the present time I know of only two such, made by Andrlik. Our first step was to establish a series of experiments to demonstrate this point and to ascertain whether beets grown with known excessive quantities of nitrates possess the qualities and composition of our general crop. We applied in 1910 from 250 to 1,250 pounds of Chile-saltpetre in portions of 250 pounds each. This required six plots, five of which received nitrates while the sixth did not. Another series of experiments was made with superphosphate, potassic chlorid and salt, sodic chlorid, on a piece of bad ground which had been planted to beets to see what effect these fertilizers would have upon the crop, the ripening and composition of the beets.

As standards of comparison for quality and composition, we have chosen samples from three localities, Montana, Michigan and Colorado. The Montana sample did not come to hand till this work was nearly completed but it possesses the highest quality of any sample examined.

The beets analyzed represent several classes: First, beets grown on ordinary, good soil without fertilizers; second, beets grown on good soil with various fertilizers; third, beets grown on good soil with various quantities of nitrates alone; fourth, beets grown on soil in which large quantities of nitrates had already developed; fifth, beets grown on nitrate land with the application of phosphoric acid, potash and soda; sixth, beets grown with green manure; seventh, beets grown on College Experiment Farm at Fort Collins, 1910; eighth, beets grown with application of nitrates on College Experiment Farm, Fort Collins, in 1911; ninth, beets grown on College Experiment Farm in 1911 without application of nitrates; tenth, beets grown on the College Experiment Farm from which the tops were removed 6 Sept. 1911.

The criteria adopted to judge of the quality of our beets, though not formally enumerated, are the following: the nitric nitrogen, the phosphoric acid, the injurious ash, the injurious nitrogen, the ratio of the proteid nitrogen to the total, especially in the juice, and the percentage of sugar. Andrlik used the percentage of sugar, the injurious ash and the injurious nitrogen per 100 of sugar. I have added the nitirc nitrogen, the phosphoric acid and the ratio of the proteid nitrogen to the total nitrogen because they appear to be important factors in this study.

In regard to standards, we observe in the six samples of cossettes quoted from Andrlik that the total nitrogen is quite high, and that the ratio of the proteid to the total nitrogen is practically 59 percent. This ratio, even in his poorest sample, does not fall below

39 percent. The phosphoric acid in the fresh beets is, in his best, 0.084, and in his poorest, 0.042 percent. The injurious ash per 100 of sugar is from 1.95 to 2.75 parts; the injurious nitrogen from 0.407 to 0.975, while the sugar is from 14.5 to 17.3 percent. The nitric nitrogen in these cossettes was not determined. In the Montana beet which we had used as a standard we have for the ratio of the proteid to the total nitrogen in the press juice, 53 percent, for the phosphoric acid in the beet 0.081, for the total nitrogen 0.105, for the injurious ash per 100 of sugar 1.67, for the injurious nitrogen per 100 of sugar 0.167 part, and for the sugar 18.24 percent. There was no nitric nitrogen in these beets.

In our Fort Collins beets we have: ratio of proteid nitrogen to the total in the press juice 39.0 percent, phosphoric acid 0.076, injurious ash per 100 sugar 2.2, injurious nitrogen per 100 sugar 0.629, nitric nitrogen 0.0009, and sugar 18.3 percent. In the Michigan beet we have the ratio of proteid to total nitrogen in press juice about 30 percent, phosphoric acid 0.062 percent, injurious ash per 100 sugar 1.945, injurious nitrogen per 100 sugar 0.513, nitric nitrogen 0.0032, and sugar 15.3 percent. Of these standards the Michigan sample contains the largest amount of nitric nitrogen, has the lowest percentage of phosphoric acid, the lowest ratio for the proteid to the total nitrogen in the press juice and the lowest percentage of sugar.

The first class of beets, those grown on good soil without fertilizers, contain some samples of excellent quality—the Colorado sample chosen as a standard was such an one. We find beets grown on new land, prairie sod, grown in the Arkansas Valley meeting the standard of the Michigan beets at least, ratio of proteid to total nitrogen 52.0 percent (proteid nitrogen determined by Stutzer method, which gives higher results than the press juice treated according to Ruempler), the phosphoric acid 0.05786, injurious ash per 100 sugar 3.529, injurious nitrogen per 100 sugar 0.374, nitric nitrogen 0.00358 and sugar 14.2 percent. We find the quality of beets grown on good ground usually much poorer than the samples just given. For instance, beets grown on a good soil in 1910 gave, ratio of proteid to total nitrogen (Stutzer) 42.0 percent, phosphoric acid 0.041, injurious ash per 100 sugar 4.9, injurious nitrogen per 100 sugar 0.5687, nitric nitrogen 0.011, sugar 14.4 percent, and another sample grown on a sandy loam with an ample supply of water and good cultivation gave the following data: ratio of proteid to total nitrogen in press juice 20.0 percent, phosphoric acid in the beet 0.0334, injurious ash per 100 sugar 3.70, injurious nitrogen per 100 sugar 1.07246, nitric nitrogen in beet 0.04537, and sugar 12.70 percent. These last two samples represent a large percentage of the beets grown in some sections. The following tabular presentation of these factors for Andrlik's No. VI, the Montana sample, and for two samples of beets grown on good land, will show the contrast:

COMPARISON OF GERMAN, MONTANA AND COLORADO BEETS.

	Andrlik Nov.VI	Montana	Good Soil Colorado	Good Soil Colorado
Sugar	17.200	18.240	14.400	12.7000
Phosphoric acid	0.084	0.081	0.041	0.0334
Nitric nitrogen	.....	None	0.011	0.0454
Ratio proteid to total nitrogen.	59.000	53.000	42.000*	20.0000
Injurious nitrogen per 100 sug.	0.407	0.167	0.569	1.0725
Injurious ash per 100 sugar....	1.950	1.670	4.900	3.7000

The beets grown on unobjectionable land may be either good or very poor in quality, often as poor as the sample given in the last column but, of course, this is not always the case. The sample given in the third column is probably a fair average of the beets of this class.

Colorado soils produce under favorable conditions most excellent beets, though it seems probable that even under the best conditions our beets contain a rather large amount of ash, specifically of injurious ash. Notwithstanding this fact many of our beets during the past seven or eight years have been very low in quality. The cause for this fact is indicated by the high percentage of nitrogen present in the form of nitrates.

The second class of beets, i. e., such as were grown with fertilizers to determine their effects, was also a disappointment. The effects of fertilizers, stockyard manure, phosphoric acid, potash and nitrogen, upon the yield and sugar content of the beets proved to be disappointing in that no single fertilizer or combination of fertilizers improved either the yield or percentage of sugar so positively as to force our consent to it as a fact. The results in regard to their effects upon the quality of the beets are uniformly unfavorable, sometimes a favorable feature may be recognized, but this is more than counterbalanced by others which are unfavorable. There were eleven samples of these beets fully analyzed except that the press juice was not investigated. There were two check samples and nine samples grown with various fertilizers. The best results were obtained with the samples from one of the check plots and from the two plots which had separately received 300 pounds of potassic sulfate and 400 pounds of superphosphate per acre. The total nitrogen in the beets from these plots was low, 0.10875, 0.1232 and 0.12895 percent, the nitric nitrogen was low in the sample from the plot that received the potassic sulfate, but not especially low in the others, 0.01034 and 0.00967 percent. The pure ash in the beets from these plots was uniformly high; about 1.00 percent, the phosphoric acid in the pure ash was uniformly low, but owing to the

*Proteids determined by Stutzer's method.

high percentage of pure ash in the beet this constituent appeared about normal when calculated on the fresh beet. The beets grown with fertilizers were lower in sugar than those grown without them in eight out of nine cases. The injurious ash was higher in eight out of nine cases and the injurious nitrogen was higher in seven out of the nine. The increase in these two factors was in some cases very great, from 4.27 to 7.68 for the injurious ash per 100 sugar and from 0.37 to 0.95 for the injurious nitrogen. The nitric nitrogen fell to 0.0025 in the sample grown with the application of potash alone, but otherwise they all contained about 0.01 percent of this form of nitrogen, apparently unaffected by the amount of sodic nitrate added. The low percentage of sugar, the high percentage of pure ash with its low percentage of phosphoric acid, the high injurious ash and injurious nitrogen, with ruling high percentage of nitric nitrogen are again suggestive of too liberal or an untimely supply of nitrates. These results do not indicate a lack of any of these elements of plant food and do not justify us in looking to these as means for the amelioration of these conditions.

The third class of beets was studied to obtain a decisive answer to the question, "What are the effects of nitrates upon the composition of the sugar beet?" It is generally agreed that nitrates added in too large quantities or too late in the season lengthen the period of growth and it has been shown within the last few years that it increases the injurious nitrogen. Many of our beets are green when harvested and of course the juices often work badly. I have known of the occurrence of unusual quantities of nitrates in some of our soils for six or more years. I had already associated these facts in a causal relation several years before the investigations of recent years had become available to me. I knew of no investigation which had satisfactorily answered the query stated above, so its answer was imperative in the prosecution of this work. In 1903 Andrlik published two analyses showing that 525 pounds of sodic nitrate per acre applied in three portions depressed the percentage of sugar and increased both the injurious ash and injurious nitrogen. The amount applied, 525 pounds of Chile-saltpetre per acre, is a very moderate quantity compared with the equivalent of the nitric nitrogen that we find in many of our soils.

In order to study this subject a piece of choice land was selected and various quantities of nitrates applied from 250 to 1,250 pounds per acre, the larger quantities were applied in portions of 250 pounds each. The first application of 250 pounds was made two days before the seed was planted, the succeeding ones at intervals of four weeks up to 27 July, the date of the last application. The following tabular statements in which we include the Montana beet for comparison exhibits the results:

RESULTS OF EXPERIMENTS WITH NITRATES.

	Montana	Colo.	Colo.	Colo.	Colo.	Colo.
Sodic nitrate, pounds per acre....	200	250	500	750	1,000	1,250
	Pct.	Pct.	Pct.	Pct.	Pct.	Pct.
Sugar	18.240	16.500	15.800	13.400	11.000	12.800
Pure ash	0.491	0.519	0.726	0.822	0.744	0.680
Phosphoric acid	0.081	0.038	0.061	0.036	0.034	0.024
Nitric nitrogen	None	0.001	0.010	0.042	0.063	0.042
Total nitrogen	0.105	0.145	0.205	0.296	0.255	0.254
Ratio proteid to total nitrogen....	53.000	31.000	23.000	17.000	16.500	20.500
Injurious ash per 100 sugar.......	1.670	2.127	3.205	4.781	5.472	4.050
Injurious nitrogen per 100 sugar..	0.167	0.364	0.682	1.293	1.403	1.115

The maximum results were obtained with 1,000 pounds Chile-saltpetre per acre, but the depression of the phosphoric acid is the greatest with the 1,250 pounds. Another sample from this plot showed only 0.02205 percent phosphoric acid in the beets. The following effects of the nitrate applied are very evident, i. e., that while the 200 pounds in the case of the Montana beets and the 250 pounds in our case were decidedly beneficial the larger applications depressed the percentage of sugar. The maximum depression being 55 percent or 33.33 percent of the sugar, it increased the pure ash by 43.0 percent, it increased the nitric nitrogen from ten to sixty-three fold, it depressed the phosphoric acid from 0.038 to 0.024, about 37.0 percent, it increased the total nitrogen by 100 percent, it depressed the ratio of the proteid to the total nitrogen from 31 to 16.5, almost 50 percent, it increased the injurious ash to two and one-half times as much as the beets grown with 250 pounds of nitrate per acre contained. If the comparison be made wih the Montana beets as the standard even the beets grown with 250 pounds nitrate per acre appear inferior in the following points: the phosphoric acid is low, nitric nitrogen is present, and the ratio of the proteid nitrogen to the total is low. An examination of the detailed statement of the analyses further shows that the chlorin and the sodic oxid were both increased by the larger quantities of the nitrate. These are the points in detail which characterize our poor beets grown on good soil, i. e., the sugar is low, the pure ash is high, the phosphoric acid is low, the chlorin and soda are often high, nitric nitrogen is always present, often in considerable quantities, and while the total nitrogen may not be excessively high, the ratio of the proteid to the total nitrogen is low, the injurious ash and nitrogen per 100 of sugar are high. These characteristics, too, are the ones that persist through our series of beets grown with the application of fertilizers. It has been shown by others that the effects of sodic nitrate may be lessened but not wholly set aside by the joint application of potash and phosphoric acid. The amino nitrogen was determined throughout the series and as would be expected shows an increase as the nitrogen applied to the growing plant is increased.

These beets, grown with nitrates on the most desirable land that we could select, were tested in an experimental sugar plant and the process carried to the production of thick juices. The real coefficients of purity of these were, for the beets grown with 250 pounds nitrate per acre, 87.91, for those grown with 500 pounds per acre, 88.3, for those grown with 750 pounds 88.6, for those grown with 1,000 pounds 86.37, and for those grown with 1,250 pounds per acre 86.43. We have here a depression of the real coefficient of purity in the thick juice of 1.93 points, which signifies a tremendous increase in the amount of sugar that will go into the first green syrup or what amounts to the same thing a great decrease in the amount of granulated sugar obtained in the first crystallization. These results indicate that this cause, nitrates in the soil, is fully adequate to account for the production of an undue amount of molasses which is another of the undesirable qualities of these beets, because it overtaxes the crystalizer capacity of the factories and necessitates the recovery of a large percentage of the sugar by the Steffens process.

The fourth class of beets studied were such as were grown on very bad soil. We had several objects in view, principally, however, to determine the quality of the beets produced and the effects of phosphoric acid, potash and salt, sodic chlorid, upon beets grown under these conditions. The land chosen was excellent for these purposes, for owing to the fact that it had a decided slope it enabled us to make our observations on more and less objectionable land, which involved no questions of composition, etc., at the same time The depth to the water-plane was determined by borings made at the end of September and was found to be five feet in the lowest portion of the cultivated area. This depth was only one foot above the bottom of the drainage ditch. This soil was sampled to a depth of four inches in two sections each two inches deep. The potash, soluble in hydrochloric acid, the phosphoric acid, total nitrogen and nitirc nitogen were determined in these samples. The averages of the six determinations of potash, phosphoric acid and total nitrogen were for the potash 1.15 (0.874 to 1.275), for phosphoric acid 0.1461 (from 0.0765 to 0.1913), and for total nitrogen 0.1081 (from 0.0850 to 0.1480). The supply of potash and phosphoric acid is abundant but that of total nitrogen is rather moderate. The ratio of the nitric nitrogen found to the total nitrogen was 19.00 percent in the top two inches of the worst, and 3.5 percent in the second two inches of the best portion of the field. In parts per million of the soil the nitric nitrogen ranged from 30 parts in the second two inches of the third and second sections to 280 parts in the top two inches of the first or worst section of the land. These samples were composite, each containing eight subordinate samples. The growth of the beet tops on this field was very luxuriant, they stood at a hight of 36 inches on 8 Aug., and were erect because they were so abundant that they could not spread out. The color was a bluish green. The yield according to the factory returns was 14.14 tons per acre. We took three sets of samples, 39 individual samples in all. The analytical results are quite consonant in the indications relative to the quality of these beets throughout the season. We will again use the Montana beet as standard because we consider it the best beet that we have analyzed and is the only one that we have found entirely free from nitric nitrogen, though a Fort Collins standard beet contained only 0.0009, a very small amount. The following tabular statement presents the principal features in the composition of these beets:

	Montana	Check Best (1st) Section	Check Bad (2d) Section	Check Worst Land	Phosphoric Acid Best (1st) Section	Phosphoric Acid Bad (3d) Section	Potassium Chlorid Bad (3d) Section	Sodium Chlorid Bad (3d) Section
Sugar	18.240	13.200	12.100	8.600	10.900	10.200	12.200	10.400
Pure ash in beet	0.491	0.942	1.122	1.327	0.941	1.064	1.149	1.425
Phosphoric acid	0.081	0.039	0.031	0.034	0.048	0.027	0.016	0.028
Nitric nitrogen	None	0.019	0.053	0.083	0.050	0.073	0.051	0.087
Total nitrogen	0.105	0.245	0.233	0.345	0.259	0.307	0.345	0.340
Ratio proteid to total nitrogen	53.000	22.460	18.730	14.280	19.080	19.900	19.900	17.210
Inj. ash per 100 sug.	1.670	5.629	7.930	13.433	7.156	9.042	8.245	12.049
Inj. nit. per 100 sug.	0.167	1.029	1.048	2.048	1.413	1.783	1.629	1.788

These results are identical in kind with those produced by the sodic nitrate but much greater in degree, but not at all in proportion to the amount by which the nitric acid in this soil exceeded that applied in our experiments with the nitrate. We find that we reached our maximum effect with 1,000 pounds of nitrate applied in four portions. One thousand pounds nitrate applied per acre would add but 83 p. p. m. of nitric nitrogen provided it were uniformly mixed with the surface six inches of soil which we here consider as weighing 2,000,000 pounds. We have as a matter of fact on 22 June, 70 p. p. m. in the top four inches of the soil in the best part of this field, and 405 p. p. m. on this date in the worst portion of the field taken to the same depth. The best portion of these plots reaches a hight of 18 feet above the worst portion. The beets from the first section of the check, the best section, have a composition very similar to that of those grown with 750 pounds of nitrate applied in three portions which corresponds to 62.5 p. p. m. nitric nitrogen, calculated on the top six inches of soil. We place these results side by side that the similarity may be easily seen. The figures are all calculated on the fresh beet or on 100 of sugar.

	Montana Beets	Beets Grown with 750 Pounds Nitrate	Beets Grown on Best Portion of Bad Land
Sugar	18.240	13.400	13.200
Pure ash	0.491	0.822	0.942
Phosphoric acid	0.081	0.036	0.039
Nitric nitrogen	None	0.041	0.019
Total nitrogen	0.105	0.296	0.245
Ratio proteid to total nitrogen	53.000	16.920	22.460
Injurious ash per 100 sugar	1.670	4.781	5.629
Injurious nitrogen per 100 sug.	0.167	1.292	1.029

This statement shows how similar these two samples are and how widely they differ from the very excellent sample from Montana. It has already been conclusively shown that the poor quality of the second sample given in this table was caused by the 750 pounds of sodic nitrate applied to the beets in three portions, the last application being made by the first of June. The results obtained with those beets to which phosphoric acid in the form of superphosphate was applied are worthy of careful consideration, for the effects produced are the reverse of what was anticipated and the beets are very low in quality. These results are not quite consonant with those observed in the case in which we used superphosphate alone in our series of fertilizer experiments but are more nearly in harmony with the results obtained from its use in conjunction with the nitrates.

The beets grown with the application of various quantities of Chile-saltpetre in 1910 and one sample grown on very bad land, i. e., land very rich in nitrates, were treated in an experimental factory for the production of thick juices. This was done to determine whether the practical, technical results were the same as those obtained on the large scale by various factories in the Valley. We have stated the results obtained showing a depression of the real coefficient of purity by 1.93 points. The real coefficient of purity of the thick juice produced from the beets grown on very bad land was 69.56, only a few points higher than the real coefficient of purity of molasses. The nitric nitrogen in these thick juices ranged from a minimum of 0.05 to a maximum of 0.49 percent. These juices were not boiled, in other words we did not actually determine the amount of molasses produced or its composition. We did, however, examine in all 21 samples of molasses from various sources, 4 from Bohemia, 1 from California, 1 from Michigan and 15 from Colorado. The Colorado molasses are lower in total nitrogen than the Bohemian and Michigan samples but very much higher in nitric nitrogen. The largest amount of nitric nitrogen found in the Bohemian molasses was 0.0082 percent, while the largest amount found in Colorado molasses was 0.400 percent. The nitric nitrogen in Colorado molasses was lower in 1911 than in 1910 and it was a matter of general comment that the juices worked much better in

1911 than for years past. The Steffens waste-water is rich in nitrates, a concentrated sample of this showed the presence of 0.61 percent nitric nitrogen or practically 3.6 percent sodic nitrate.

The amount of nitric nitrogen in the soil of two beet fields was determined on seven different dates during the season of 1911, each field was divided into seven sections for the purpose of sampling and the samples were taken to a depth of one foot. In one field the minimum quantity was reached in August, in the other the maximum was reached on the same date. The minimum found in any sample from the first field was 2.5 parts nitric nitrogen per million of soil, 25 August, and the maximum 130 p. p. m., 27 June, the minimum found in any sample from the second field was 3.1 p. p. m., 9 August, and the maximum 333.0 p. p. m., 25 August. The sugar in the beets from the first field on 18 September was 16.2 percent, while it was only 12.6 percent in those from the second field.

The results obtained with green-manuring appear to be encouraging, but there are a number of facts which we have observed which indicate that the few results obtained with green-manure may not have been due to it but to other conditions. We have, therefore, laid but little stress upon the results though the beets grown by this method were of very good quality, sugar 17.3, pure ash 0.6987, phosphoric acid 0.0743, nitric nitrogen 0.0014, total nitrogen 0.1527, ratio proteid to total nitrogen 38.48, injurious nitrogen per 100 sugar 0.3471, and injurious ash per 100 sugar, 2.8743. This represents a very good beet compared with the average Colorado beets heretofore presented. This subject is worthy of further study, the work done is not sufficient to justify any conclusions.

It has been shown by Prof. Remy that beets appropriate about three-fourths of all the nitrogen that they use in the months of June and July. In our experiments with sodic nitrate in 1910, the maximum effect was produced by the application of 1,000 pounds, in four portions, the last one having been applied 22 June or about the middle of the period of most active appropriation of nitrogen. Our observations on the amount of nitric nitrogen in our soils indicate the presence of large quantities much later in the season. In order to study the effects of nitrates applied subsequent to this period of most rapid appropriation, we made an experiment in duplicate in 1911, beginning 4 August. In 1910 our last application was made 27 July and it apparently produced but little effect in addition to that produced by the application up to and including 22 June. The points had in view in the 1911 experiments were whether an abundant supply of nitrates during August and September would produce any effect upon the composition of the beet. We applied during August and September sodic nitrate corresponding to 750 pounds per acre. We made four applications, the first one at the rate of 250 and the subsequent ones at the rate of 125 pounds per acre. The land used for these experiments was already abundantly supplied with nitric nitrogen and the growth of the beets was luxuriant. The effects of the nitrates applied became noticeable within a few days and became more marked as the season advanced. The beets on the check plots showed signs of ripening by 10 October, while those on the nitre-plots remained entirely green. The beet tops on the nitre-plots were bigger and had a deep green color up to the time when they were killed by frost, 20 October. The average weight of the beets was slightly increased as well as the ripening delayed.

The composition of the beets and leaves was determined at the time of the first application of nitrate was made and every 14 days thereafter till the beets were harvested 8 November. The last sample of leaves was taken 12 October because they were frozen on 20 October. The effect of the nitrate upon the composition of the leaves was noticeable 18 August or 12 days after its application and also upon the composition of the beets, the total nitrogen both in the beets and in the press juice being higher than in those from the check plots, the first sample of which complete analyses of both leaves and beets were made was taken 12 October. The leaves of the beets to which nitrate had been applied were still green, while those on the check plots had just begun to show ripening. The leaves were separated into blades and stems for the purpose of the nitrogen determinations but the ash was prepared from the whole leaf. The differences in the composition of the leaves on this date are smaller than one would expect, especially as the check plots were very evidently maturing while the others were not. The total nitrogen in the blades was not very different in the two samples and was very nearly the same as it had been in the earlier samples. The total nitrogen in the stems, petioles, on the other hand, was higher than it had been in earlier samples, and was higher in those of the beets that had received nitre than in those from the check plots. The greatest differences were shown in the nitric nitrogen present. The first samples of leaves which were divided into blades and stems were taken 1 September. The blades in these samples showed the presence of nitric nitrogen, those from the beets which had been dressed with nitre approximately 50 percent more than those from the check plots. The blades from the variety E R contained, on this date, 1 Sept., 0.01060 and 0.00730 percent nitric nitrogen respectively. The next samples of leaves that were divided into blades and stems were taken 28 Sept. The blades of the same variety E R contained on this date 0.01289 and 0.0000 percent of nitric nitrogen, in other words, the nitric nitrogen had entirely disappeared from the blades of the leaves from the check plots, while the amount in the blades of the others had increased. Each leaf, blade and stem was carefully wiped with a damp cloth before final sampling, so that the danger of external, mechanical contamination was guarded against. The next and last samples of leaves for the season was taken 12 Oct., when we obtained the following results: E R 0.01208, E R check 0.0000 percent. The stems or petoiles for the same variety E R and dates were as follows: 1 Sept. 0.06412 and 0.03734, 28 Sept. 0.08452 and 0.04744 and on 12 Oct. 0.04313 and 0.01956 percent. While the nitric nitrogen had been completely eliminated from the blades by 28 Sept. it remained very abundant in the stems till 12 Oct., and was almost twice as abundant in those of beets which had been treated with nitre as in those of beets from the check plots. The nitric nitrogen present in the beets on these dates was, 1 Sept. 0.02320 and 0.01925,, 28 Sept. 0.02600 and 0.00969, and on 12 Oct. 0.01685 and 0.00503 percent, which for the beets that had been treated with nitre and for the three dates is about one-third of the amount found in the stems.

The final samples of beets in these experiments were taken 8 Nov., the leaves of course had been ruined for our purposes by the freeze of 20 Oct. The results of the experiment may be stated as follows: Chile-saltpetre applied at the rate of 750 pounds per acre in four applications between 4 Aug. and 28 Sept., both dates included, increased the average weight of the beets, and also that of the tops; it decreased the percentage of sugar by one percent, it decreased the dry substance in the beet by about one percent, it increased the pure ash in the beet slightly, it decreased the phosphoric acid in the pure ash by about two percent and apparently had the opposite effect upon the phosphoric acid in the ash of the leaves; it increased the nitric nitrogen in the beet about twice, it increased the injurious nitrogen per 100 sugar and the injurious ash to a slight extent, and also depressed the ratio of the albumin to the total nitrogen. These are again the specific points in which our Colorado beets show their inferiority in comparison with the best beets. These experiments not only establish more firmly the effects of the nitrates upon the composition and quality of the beets but show that a development of them quite late in the season may be decidedly injurious. The effect upon the phosphoric acid contained in the pure ash or in the beet is also fully corroborated. The season of 1911 produced the best beets that we have had for several years and they worked exceptionally well in the factories; the piece of land on which these beets were grown was as good as any that we have and the nitre was applied late in the season, so that the effects of the amount of nitre added are probably as small as we would ever be likely to obtain. This view does not rest solely upon the general report of persons in charge of factories whose judgment alone ought to be acceptable, but is also indicated by the properties of the beets grown on these plots without the addition of nitre as compared with those produced by the same land in 1910, when the crop was 7 tons per acre against a minimum of 20.8 tons in 1911. The maximum sugar content was 13.3 in 1910 against 16.7 percent for 1911.

Our observations on the effects of leaf-spot in 1910 could not be interpreted as showing any definite effect of this disease upon the crop or quality of the beets. Many of the fields that were severely attacked showed large yields and high percentages of sugar, while other fields in the same districts which were much less severely attacked showed a great variety of results. Assuming that the effect of the leaf-spot upon the yield and quality of the beets is due wholly to the destruction of the foliage we tried to imitate this action by defoliating the beets rather late in the season to determine the kind of changes that it would produce in the quality of the beets. There is a fair quantity of data on the general effects of defoliation scattered through the literature of the sugar beet, but nothing upon its effects upon the composition and quality of the beet. We defoliated some beets on 6 Sept., a date at which the beets were already well developed. All the leaves were removed because we have seen fields of beets so badly attacked by the leaf-spot that scarcely any leaves at all were left, and though it was late in the season, our beets were green and growing very rapidly. We had no leaves in this case to examine so our investigations were confined to the roots. The defoliated beets continued to increase in size, attaining weights of 701 and 590 grams for the trimmed beets. The beets that developed normally were larger by 46 and 190 grams. The percentage of sugar in the defoliated beets was quite low, 14.2 and 13.2 percent. Sugar in the variety with 13.2 percent remain stationary from the time of defoliation till harvest, the other variety increased from 11.9 to 14.2 after defoliation. The total nitrogen in the beets was materially lowered, normally developed beets contained 0.14882 and 0.14223, the defoliated ones 0.12408 and 0.11286 percent. Neither the amount of pure ash nor that of the phosphoric acid was affected; the injurious ash per 100 sugar was increased in one case but not in the other; the injurious nitrogen per 100 sugar was reduced in both cases, while the total nitrogen in the juice was also reduced; the albumin nitrogen was reduced to a still greater extent, so that the ratio of albumin to total nitrogen was depressed three percent in one and six percent in the other. The nitric nitrogen in the normally developed beets fell to 0.0082 and 0.00746 percent but in the defoliated beets it remained nearly the same as at the time of defoliation, being at the end of the season, 0.01367 and 0.01584 percent, whereas at the time of defoliation the respective percentages were: 0.01925 and 0.01670. The beets grown on the plots that had received applications of nitrates had on 1 Sept. 0.02320 and

0.02702, and on 8 Nov. 0.01871 and 0.01421 in these cases the beets had, it is true, increased in size by 50 percent or more but the decrease is greater than would be required by the increase in size provided no changes had taken place in the nitric nitrogen in the beets. In the normally developed beets without nitre, the nitric nitrogen fell in this time from 0.01925 to 0.0082 and from 0.01670 to 0.00746. It would seem that by removing the leaves we had practically stopped the transformation of the nitric nitrogen in the beet. The actual loss of nitric nitrogen over the apparent loss due to increase in size is only 11 percent of the nitric nitrogen present at the time of defoliation. It seems evident that the transformation of the nitrates took place in the leaves. The nitric nitrogen in the stems on 1 Sept., the earliest date on which we examined the blades and stems separately was almost exactly five times as much as in the blades, by 28 Sept. it had entirely disappeared from the blades but persisted in the stems till 12 Oct., the latest date on which we examined the leaves when we found in the stems of beets grown without addition of nitre 0.01956 and 0.01797 for the two varieties E R and Z R.

Defoliation produced big changes in the beets but the character of these changes does not appear to be the same as those produced by an excess of nitrates, nor do these beets have the characteristic qualities of the beets grown on bad ground nor of the low quality beets grown on good ground, see Analysis XX, in which we have high percentages of pure ash, nitric nitrogen, total nitrogen, both in the beets and in the press juice, the injurious ash and nitrogen per 100 sugar are high, especially the injurious nitrogen, on the other hand, the phosphoric acid is decidedly low, whereas in the defoliated beets it is quite high, i. e., for Colorado beets. The only point that they really seem to have in common is a low percentage of dry substance. These results greatly strengthen the conclusions at which we arrived in 1910 relative to the problematical influence of the leaf-spot upon the quality of the beets in the Arkansas Valley. There is no question but that the destruction of the leaves even as late as 1 Sept. is prejudicial to the beets in several ways, but the composition of the beets is quite different from that of the poor beets produced in the Valley even on good ground, which, on the other hand, do have the composition and qualities of beets grown with an excessive supply of nitrates. The leaf-spot disease is serious enough and affects the crop prejudicially, if it is equivalent only to defoliation, but it cannot be held accountable for the general deterioration of the beets complained of throughout the Arkansas Valley.

A comparison of our beets with German beets shows them to be of larger size and to contain less sugar, less dry substance, more ash constituents, less total nitrogen, less proteid nitrogen, always some nitric nitrogen, often considerable quantities of it, more injurious ash per 100 of sugar, more injurious nitrogen per 100 of sugar, less phosphoric acid—which apparently correlates with the presence of nitric nitrogen, more potassic oxid and very much less calcic oxid, about one-half as much, though our soils are very rich in calcic oxid carrying from 4.0 to 6.0 percent of it. Manganese is always present in small quantities, from 0.02 to 0.50 percent of the ash.

The deterioration that we have endeavored to study may be summed up as consisting of a decided falling off in the percentage of sugar and the production of unusual quantities of molasses. These properties are often if not always accompanied by poor keeping qualities. The molasses produced are characterized by very large amounts of nitric nitrogen. Our experiments demonstrate that these properties in the beets are produced by nitrates applied to the soil and that the beets so produced are identical in composition with many, if not with the greater portion of the beets delivered to the factories. Further, our investigations have proven that these soils contain varying, often very large amounts of nitric acid or nitrates, much larger than we have shown is necessary to produce exceedingly poor beets. Further, our experiments show that while the beet is probably most susceptible to the prejudicial effects of larger amounts of nitrates in June and July an abundant supply in August and September will affect the beets prejudicially.

Our conclusion is that the increased production of nitric nitrogen in our irrigated soils over large sections is the chief cause for the deterioration of our beets.

INDEX

Page

INDEX OF ANALYSES

ILLUSTRATIONS.

Bulletin 184 June 1912

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

I. THE AMMONIFYING EFFICIENCY OF CERTAIN COLORADO SOILS

BY

WALTER G. SACKETT

II. ALGAE IN SOME COLORADO SOILS

BY

W. W. ROBBINS

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1912

The Agricultural Experiment Station

FORT COLLINS, COLORADO

THE STATE BOARD OF AGRICULTURE

		Term Expires
Hon. A. A. Edwards, *President*,	Fort Collins,	1913
Hon. R. W. Corwin,	Pueblo,	1913
Hon. F. E. Brooks,	Colorado Springs,	1915
Hon. J. L. Brush,	Greeley,	1915
Hon. J. C. Bell,	Montrose,	1917
Hon. E. M. Ammons,	Littleton,	1917
Hon. T. H. Ehrhart,	Centerville,	1919
Hon. Chas. Pearson,	Durango,	1919

Governor John F. Shafroth, } *Ex-Officio.*
President Chas. A. Lory, }

EXECUTIVE COMMITTEE IN CHARGE

A. A. Edwards, *Chairman*

J. L. Brush — E. M. Ammons

STATION STAFF

C. P. Gillette, M. S., *Director*,	Entomologist
W. P. Headden, A. M., Ph. D.,	Chemist
G. H. Glover, M. S., D. V. M.,	Veterinarian
W. G. Sackett, B. S.,	Bacterioloigst
Alvin Keyser, A. M.	Agronomist
J. O. Williams, B. S. A., *U. S. Expert-in-Charge*	Horse Breeding
E. R. Bennett, B. S.	Horticulturist
B. O. Longyear, B. S.	Botanist
G. E. Morton, M. L., B. S. A.	Animal Husbandman
E. B. House, B. S., (E. E.), M. S.,	Irrigation Engineer
V. M. Cone, B. S.	Irrigation Investigations
R. E. Trimble, B. S.,	Assistant Irrigation Investigations
P. K. Blinn, B. S.	Rocky Ford, Alfalfa Investigations
Earl Douglass, M. S.,	Assistant Chemist
S. Arthur Johnson, M. S.	Assistant Entomologist
B. F. Kaupp, M S., D. V. S.,	Veterinary Pathologist
Miriam A. Palmer, M. A.,	Delineator
George P. Weldon, B. S.	Assistant in Entomology
R. S. Herrick, B. S.,	Grand Junction, Field Horticulturist
C. L. Fitch,	Potato Investigations
W. E. Vaplon,	Poultry Investigations
J. W. Adams, B. S.,	Cheyenne Wells, Supt. Plains Sub-Station
Ellwood D. Rood, B. A.,	Assistant Chemist
Paul S. Jones, B. S.,	Assistant Irrigation Investigations
W. W. Robbins, M. A.,	Assistant Botanist

THE AMMONIFYING EFFICIENCY OF CERTAIN COLORADO SOILS.

By Walter G. Sackett.

INTRODUCTION.

In a former bulletin (1) the writer has called attention to the power of many cultivated Colorado soils to fix atmospheric nitrogen through the agency of *Azotobacter,* both in the soil and in mannite solutions. The investigation referred to was undertaken for the purpose of determining the source of the nitrogen from which the excessive nitrates, present in some of our soils, might have been derived. The results of this work point clearly to the atmosphere as the source of the nitrogen and to Azotobacter as the medium by which it is transformed from a gaseous into a proteid form, and subsequently transferred as such to the soil.

With an ample and reasonably constant supply of protein thus assured, our efforts have been directed, more recently, toward a study of the transformation of the combined nitrogen into ammonia the first step in the formation of nitrates from the complex nitrogen molecule. In the present investigation, we have determined the ammonifying efficiency of some thirty Colorado soils, many of which are known to be affected with the niter trouble. I use the term *ammonifying efficiency* in the sense in which it has been employed by Stevens (2), to denote not only the presence of ammonifying organisms in the soil which are capable of exercising their specific function under favorable conditions, but also the suitability of the soil as a medium in which the process of ammonificaton may proceed advantageously.

The soils under examination have been collected from a wide range of territory representing orchard land, sugar beet, oat and alfalfa fields, barren wastes and raw land. They include a variety of soil types, and almost all have been under cultivation and irrigation at one time or another.

The proteid nitrogen for our experiments has been supplied in four different forms:—Cottonseed meal, dried blood, alfalfa meal and flaxseed meal. These have been employed rather than soluble forms such as peptone and gelatin since the latter could not be used in a practical way under field conditions, and, furthermore, the results obtained from substances of this kind would be of little practical value outside of the pure scientific interest attached. On the other hand, by making use of some of the more common nitrogenous fertilizers, we have been able to learn something of the availability of the nitrogen in these materials

(1). Bacteriological Studies of the Fixation of Nitrogen in Certain Colorado Soils. Bul. 179 Colorado Experiment Station, 1911.

(2) Stevens, F. L. and Withers, W. A., Studies in Soil Bacteriology III. Concerning methods for determination of nitrifying and ammonifying powers. Cent. f. Bakt. Abt. II., Bd. 25, No. 1-4, p. 64, 1909.

with reference to our soils, and consequently we are in a better position to recommend their use when such a practice becomes necessary.

METHODS.

In collecting the soil samples, every precaution has been taken to eliminate exterior contaminations. All surface debris was removed before opening up the soil, and all instruments and containers were thoroughly sterilized. Unless otherwise stated, the samples were taken to a depth of three inches; the soil in each case was removed with a sterilized spatula and placed in double, sterilized, paper sugar sacks. All samples were shipped by express to the bacteriological laboratory of the Experiment Station in order to minimize the time in transit, during which interval, if unduly prolonged, the soil flora might undergo changes. This statement is deemed necessary since many of the samples were taken more than five hundred miles from Fort Collins. Immediately upon arrival at the laboratory, each soil was spread out upon a sheet of heavy, sterilized, manilla paper and thoroughly mixed. It was next divided into two unequal portions, the larger part being allowed to dry in the air in diffused light, while the remaining portion was transferred in a moist condition to a sterilized Mason fruit jar. As soon as the soils were air dry, which seldom requires more than twenty-four hours in our atmosphere, each was ground in a glass mortar, sterilized with mercuric chloride and subsequently rinsed with boiled, distilled water, and passed through a thirty meash wire sieve. From each sample prepared in this manner, ten 100-gram portions were weighed out, and eight of these were transferred to deep culture dishes, 10 x 4 cm., similar to the ordinary Petri dish only deeper; the two remaining lots were analyzed at once for ammonia. A weighed amount of each of the four nitrogenous materials, employed to furnish the organic nitrogen, corresponding to 100 m. g. of toal nitrogen was added to each of two 100 gram portions of soil. It was thoroughly mixed with the soil by constant stirring with a sterilized glass rod for five minutes. Each preparation was then inoculated with 10 c. c. of its respective soil infusion. corresponding to 5 grams of the fresh soil. The infusions were made by shaking 100 grams of undried soil with 200 c. c. of sterile, distilled water, and after allowing it to stand for thirty minutes for the coarser particles to settle, the required amount of the turbid suspension was drawn off with a sterile pipette and distributed uniformly over the surface of the soil in the culture dish. In addition, each basin received sufficient sterile, distilled water to give the soil its optimum moisture content, approximately 20 per cent. Additional quantities of water were used for the organic matter at the rate of 1.5 c. c. for each gram of material. All of the cultures were kept in the incubator for seven days at a temperature of 28° - 30° C. At the end of this time, the contents of each dish were transferred to a copper distilling flask with 250 c. c. of ammonia—free water and distilled with 7 grams of heavy, calcined magnesia to liberate the free ammonia. The distillates were received in N/10 sulphuric acid and subsequently titrated with standard solutions to determine the amount of ammonia formed during the experiment.

The various nitrogenous substances employed to furnish the proteid nitrogen contained total nitrogen as follows:

Cottonseed meal..........	7.8463 per cent. total nitrogen
Dried blood..............	13.0503 per cent. total nitrogen
Alfalfa meal..............	2.5053 per cent. total nitrogen
Flaxseed meal............	3.7507 per cent. total nitrogen

To obtain 100 m. g. of total nitrogen from these materials the following amounts were taken:

Cottonseed meal..........................	1.2744 grams
Dried blood..............................	0.7662 grams
Alfalfa meal.............................	3.9915 grams
Flaxseed meal............................	2.6661 grams

The ammonia originally present in the soils was determined, and, although of negligible quantity in many cases, corrections have been made for it in the results of the analyses. The ammonia found is given in Table No. 3, page 19.

HISTORY, CHARACTER AND AMMONIFYING EFFICIENCY OF THE SOILS UNDER STUDY.

SAMPLE NO. 1.

The orchard from which this sample was obtained was first brought to my attention in the summer of 1910 because of the appearance of niter burning on some of the apple trees. This is an old orchard, and two of the trees were in a very serious condition at that time. I visited it again in the fall of 1911, when I collected the present sample, and both of the trees affected in 1910 were dead, while seven others, all Ben Davis, were in a critical state. The soil is a heavy, adobe clay and was moist from recent rains. The nitrogen fixation test in mannite solution, made one year previously, gave an increase of 11.3483 m. g. of nitrogen per 100 c. c. of solution in thirty days. The nitrogen recovered as ammonia from the different organic materials in seven days was as follows:

From cottonseed meal 46.63%; dried blood 37.02%; alfalfa meal 17.55%; flaxseed meal 3.01%.

SAMPLE NO. 2.

This represents a portion of another orchard in a heavy clay soil adjacent to No. 1. No losses had been incurred here as yet from niter, although at this time, fall 1911, six large trees were unquestionably affected. A young orchard to the north, with alfalfa between the rows of trees, was in a very thrifty condition. An adjoining orchard of possibly ten to twelve acres belonging to the same owner had suffered considerable injury from niter for the past three years. The land had been manured heavily, but, so far as checking the destruction, no benefit could be observed.

The ammonification test with this soil showed the following amounts of nitrogen recovered as ammonia in seven days:

From cottonseed meal 42.31%; dried blood 47.04%; alfalfa meal 12.78%; flaxseed meal 8.09%.

SAMPLE NO. 3.

Sample No. 3 is a sandy loam, and was obtained from a large orchard where niter burning was first observed in 1910. The number of trees involved was rather large, but the damage done up to the spring of 1912 had not been serious. This is one of the few tracts where the trouble is present, and yet where it has made little real progress. Each succeeding year a few more trees become affected, but the orchard, as a whole, is holding its own. Oats had been sown as a shade crop when I sampled the soil in the fall of 1911. The ammonification tests gave the following percentages of nitrogen recovered in seven days as ammonia:

From cottonseed meal 25.92%; dried blood 18.03%; alfalfa meal 12.06%; flaxseed meal 6.30%. In view of the small amount of injury and the slow rate at which it is moving, the relatively low ammonifying efficiency as brought out by these results is very interesting. Compared with the two preceding samples taken from orchard were dead, and the trees on the remaining acre were in ammonification of cottonseed meal and dried blood was less than half as rapid. If the same holds true of nitrification, it is easy to understand why the nitrates have not become excessive as yet.

SAMPLE NO. 4.

This soil comes from an orchard where no excessive niter had manifested itself previous to 1911. In driving through the country, I had passed by this place frequently in former years, but had never observed anything unusual about either the trees or the soil. The high nitrates had been very destructive within half a mile of this locality, and whole orchard tracts, embracing ten to twenty acres, had been wiped out. By October, 1911, two acres of this orchard were dead, and the trees on the remaining acre were in all stages of burning. The soil, a sandy loam, was very brown both in the orchard and along the ditch banks. I have not seen it yet this year, but I should be very much surprised to find a single tree alive. The results of the ammonification tests on this soil point again to the close relation between excessive nitrates, as measured by the destruction of vegetation, and the high ammonifying efficiency. The following percentages of nitrogen were recovered as ammonia from the different nitrogenous materials:

From cottonseed meal 44.62%; dried blood 46.93%; alfalfa meal 12.40%; flaxseed meal 1.12%.

SAMPLE NO. 5.

Here we have another bearing orchard of probably twenty acres, seven of which had been killed by niter previous to 1911, and the trees from that portion had been pulled out. The land had been planted to oats in the spring of 1911, but judging from the scattering stubble which I saw in the fall, the original stand had been very poor. Many more trees were either dead or dying at this time, and the prospects were that the entire tract would be gone by the end of 1912. My sample, a sandy loam, was taken beside a badly burned tree in that part of the orchard where the injury was most active at that time. The nitrogen recovered as ammonia with this soil was as follows:

From cottonseed meal 38.63%; dried blood 36.78%; alfalfa meal 21.08%; flaxseed meal 20.10%. It will be seen from these figures that the yields from the alfalfa and flaxseed meals are much higher than those obtained with any other soil. Because of an unavoidable delay, the ammonia determinations on this series were not made until after eleven days, and the prolonged incubation period will probably account for the increase obtained here.

SAMPLE NO. 6.

This soil presents a very interesting history. It comes from a forty acre tract, twenty acres of which had been in alfalfa, and the remainder was bearing orchard. In 1907, barren spots began to appear here and there in the alfalfa, and brown patches on the soil, indicative of niter, were observed in the orchard. It was not long before the trees commenced to die in a manner that we have since come to associate with excessive nitrates. Here, as we have noticed so frequently elsewhere, a few trees in the innermost part of the orchard succumbed first, and with these as a focal center, the trouble spread with such marvelous rapidity that by the spring of 1909 all of the alfalfa had been destroyed and fifty per cent. of the trees were lost. The year 1909 saw the remaining trees perish, save for parts of six rows on one side of the orchard next to a dtich. During 1910, the three inside rows were killed, and the fourth and fifth were burning. During 1911 the fourth and fifth died and the sixth was burning. (Fig. 1.) I am sure I do not know where we could find a more beautiful illustration of the formation and spread of nitrates from a central point than is given by the regular succession in which row after row of trees went down before the approaching wave of niter. From 1909 to 1911, the orchard was a barren waste, where absolutely nothing would grow, not even the commonest weed. (Fig. 2) The Azotobacter flora had been exterminated entirely from the surface layers of this area, although soil taken near one of the surviving trees in row five next to the outside row mentioned above gave a vigorous growth of Azotobacter and a fixation of 12.4689 m. g. of nitrogen per 100 c. c. of mannite solution.

When I visited this place in the fall of 1911 to secure my sample

Figure I.

Figure 2.

Figure 3.

for ammonification, I was overwhelmed with astonishment, to put it mildly, to see the whole barren portion almost entirely covered with saltbush (Atriplex) waist high. Unfortunately, before I was able to obtain a photograph of this, the owner had burned over the area to destroy the weeds. However, I did get a picture later, after the fire had swept across, which will convey to the reader some idea of the luxuriance of the vegetation, although it gives no adequate conception of the height of the growth. (Fig. 3.) During the winter and spring of 1910 and 1911, the precipitation was unusually heavy in this region. The accumulation of nitrates in the surface layers had evidently been carried down by leaching until the concentration of the salts had been reduced to a point where the weeds could grow, and when once established, they had utilized the nitrates to the best of their ability in making a rank growth. This was the first instance in which we had ever observed anything that even suggested self reclamation of a niter area. Since then, one other locality has come to our notice.

The soil is a clay loam, and the sample for the ammonification experiment was taken between two burning trees in the last surviving row. The results of the examination give the following percentages of nitrogen recovered as ammonia from the nitrogenous fertilizers:

From cottonseed meal 43.47%; dried blood 23.55%; alfalfa meal 8.72%; flaxseed meal .10%.

SAMPLE NO. 7.

This sample was obtained from an orchard where the niter trouble has been very severe for the past three years. The first trees died in 1908, and the owner, believing that they were short of plant food, had given that section of the orchard a heavy dressing of stable manure. The next year, the attack started in with renewed vigor, in spite of the fertilizer, and has grown rapidly worse until five or six acres of a once profitable orchard are worthless. The soil is a sandy loam and the ammonification test gave the following results:

From cottonseed meal, 46.40% of the total nitrogen was recovered as ammonia; dried blood 32.75%; alfalfa meal 10.61%; flaxseed meal 3.99%.

SAMPLE NO. 8.

This soil was obtained from a young orchard which has been reset for the past eight or nine years with the hope of getting a successful stand. Many of the trees died the same year that they were put out, while some have struggled along for three and four seasons just able to keep alive. Occasionally, a tree is found which shows no symptoms of niter and which is making a good growth. The space between the trees is planted to alfalfa, and in many parts of the orchard barren spots are visible. Before this shade crop was put in, one had no difficulty at all in discerning the brown color of the soil and the dark stains on the irrigating furrows, so characteristic of *A. chroococcum*. The soil is a clay loam and the sample for the ammonification experiment was taken from a bare spot where a tree had died.

The percentages of nitrogen recovered as ammonia were as follows:

From cottonseed meal 51.98%; dried blood 47.98%; alfalfa meal 15.30%; flaxseed meal 1.12%.

SAMPLE NO. 9.

I visited this orchard the last time in the fall of 1911 at picking season, and the picture it presented was indeed a deplorable sight. Tree after tree had died loaded with half grown fruit. Many were bending to the ground with beautiful red apples, but there was not enough vitality left in the body to bring them to maturity. Occasionally there was a tree, scattered among these, which appeared perfectly normal, and again there would be those that showed the injury in a mild degree, possibly a little burning on the water sprouts or on a small limb. Five acres of the orchard were lost during 1910 and at least three acres more last year. The distribution of the trouble was different in this case from what we ordinarily find; the trees were not dying in any particular section as a whole, but were scattered throughout the tract, alternately good and bad. This was the first and most serious outbreak of niter in this region, which is approximately twenty miles from the orchards described previously. My sample was collected near a dying tree on October 4, 1911. The soil is a loam, inclining to clay. The results from the ammonification test are as follows:

From cottonseed meal 36.25% nitrogen recovered as ammonia; dried blood 32.46%; alfalfa meal 12.08%; flaxseed meal .87%.

SAMPLE NO. 10.

Two years ago, while looking over the orchard just described, I was called into a neighboring orchard to pass an opinion on some dying apricot trees. A glance at the soil revealed the brown stain of niter on the irrigating furrows, and a dozen burning apple trees confirmed the observation. I took a sample of this soil and found that it was capable of fixing 10.15725 m. g. of nitrogen per 100 c. c. of mannite solution in thirty days. Before leaving the orchard, I hunted around rather carefully to see if there were many trees in a serious condition, but so far as I could discover they were all confined to a limited section of two rows. When I went back there last October to get another sample of soil for my ammonification work, I was unable to locate either the brown soil or the affected trees, and a diligent search failed to reveal any more trees which were suffering. The sample which I secured was taken in a peach orchard adjacent to the block of apples referred to, and to the best of my knowledge represents a normal orchard soil, if the vigor of peach trees can be taken as any indication. It might be described as a loam, inclining to clay. The following results were obtained in the ammonification test:

From cottonseed meal 28.33% of the nitrogen was recovered as ammonia; dried blood 23.57%; alfalfa meal 4.97%; flaxseed meal 8.15%.

SAMPLE NO. 11.

Sample No. 11 was collected in October, 1911, from an orchard some distance from any that has been described previosly, and until this season no niter trouble had been in evidence. About thirty trees in all, in one corner, were dying in a typical fashion. The soil is a clay loam and was rather moist from a recent shower, making it difficult to determine the presence of any brown color. The percentages of nitrogen recovered as ammonia in the ammonification test were as follows:

From cottonseed meal 47.58%; dried blood 51.17%; alfalfa meal 13.59%; flaxseed meal 12.15%.

SAMPLE NO. 12.

In the spring of 1910, the trees from about four and one-half acres of this orchard were pulled up and consigned to the wood pile, and the land was planted to corn. This was another case of a twenty year old orchard killed by niter in less than two years. The corn failed to make any growth, and much of it never came through the ground. The whole surface was covered with a hard, brown crust beneath which the soil was mealy and ashy in character. The soil is an elegant sandy loam, with splendid natural drainage. More as an experiment than anything else, this ground was planted to cantaloupes in 1911. Here and there a plant became established and succeeded fairly well, but the crop as a whole was a failure. This spring, 1912, the tract was planted to oats, notwithstanding the brown, mealy condition of the soil. The grain which is immediately adjacent to the irrigating furrows, where the niter appears to have been partially removed, seems to be making a pretty good growth, but that between the furrows, where the niter is still concentrated, is at a standstill. The ammonification results on this sample give the following percentages of nitrogen recovered as ammonia:

From cottonseed meal 38.81%; dried blood 20.67%; alfalfa meal 7.19%; flaxseed meal .38%.

SAMPLE NO. 13.

This soil is a clay loam from an alfalfa field and was selected from a locality where the nitrate trouble has been serious in neighboring orchards. Material collected from this same piece of ground in 1910 fixed 10.15925 m. g. of nitrogen in thirty days per 100 c. c. of mannite solution, so there is no question about the presence of Azotobacter. A chemical analysis of the soil does not show excessive nitrates. The alfalfa is perfectly healthly, is making a splendid growth, and, so far as the eye can detect, both the crop and the soil are normal. The sample for ammonification was secured March 27, 1912. The results of the test show the following percentages of nitrogen recovered as ammonia:

From cottonseed meal 45.11%; dried blood 41.15%; alfalfa meal 7.36%; flaxseed meal 7.71%.

SAMPLE NO. 14.

The next soil comes from an orchard on the edge of a mesa one hundred and fifty feet above the surrounding country. Ten apple trees had died here in 1910 with all the symptoms of niter and about fifty more in 1911. The soil is a clay loam in good condition of tilth with no evidence of any brown color due to Azotobacter or other signs indicative of excessive nitrates save the burning of the apple leaves. To all appearances, the trouble is in the incipient stage. The ammonification test follows: From cottonseed meal 47.73% nitrogen was recovered as ammonia; dried blood 52.33%; alfalfa meal 16.56%; flaxseed meal 3.99%.

SAMPLE NO 15.

About one mile back on the mesa mentioned above, is an area where the high nitrates have done a great deal of damage the past two years, particularly to bearing apple orchards. This sample comes from such a place, where it was thought at first that the injury was due to faulty drainage. Accordingly, in 1910, an experienced engineer was employed to put in the proper amount of tile at the correct depth, but the trees have continued to die in spite of the drain. Practically two of the seven acres of this orchard are worthless today. Many of the trees were dead outright when I saw the place last fall, while others were struggling along with just life enough to put out a dwarfed, stunted foliage. The soil is a sandy loam and was collected near a burning tree, October 24, 1911. The ammonification tests give the following percentages of nitrogen recovered as ammonia in seven days: From cottonseed meal 49.07%; dried blood 50.78%; alfalfa meal 15.86%; flaxseed meal 1.82%.

SAMPLE NO. 16.

This sample was obtained from an orchard in the same region as Number 15, but not adjoining it. The soil is a red, sandy loam, and because of this peculiar color it has always been rather difficult to detect any brown discoloration, although there is no question about the excessive nitrates for nearly twenty acres of bearing orchard have been ruined since 1910. Here, as in the preceding orchard, the trees appear to be dying gradually rather than going in one season as is the case so often. Near the farm house where the surface of the soil has not been disturbed by cultivation, the characteristic brown color and mealy condition are quite apparent. The nitrogen fixing power of this soil in 1910 amounted to 7.1451 m. g. of nitrogen per 100 c. c. manite solution in thirty days. The ammonification experiment gave the following amounts of nitrogen recovered as ammonia in seven days: From cottonseed meal 47.10%; dried blood 52.64%; alfalfa meal 13.69%; flaxseed meal .21%.

SAMPLE NO. 17.

After giving considerable attention to the biological activities in cultivated soils, I was interested in knowing whether raw adobe clay, which had never received any cultivation, and which had never been disturbed since the time it was formed by the weathering of the underlying shale possessed any ammonifying powers. A previous examination for Azotobacter had failed to show the presence of this genus. To this end, I selected an adobe hill where this type of topography prevailed, in a section of the country where agriculture was absolutely out of the question. The hill was about eight miles from the nearest town, a half mile from the wagon road, inaccessible, and arose abruptly from the edge of a stream to a height of 150 to 200 feet. Because of its location, I doubt if many human beings had ever ascended it, and, in fact, I see no reason for any one to have done so unless on a mission similar to mine. There was no vegetation whatever upon it, and aside from a few bird tracks and one lonely spider, I saw no evidence of animal visitations. While collecting my sample from the highest point of the hill, I noticed numerous pockets of white crystals, presumably calcium sulphate, distributed through the soil. Although the very surface was dry, the clay was moist below the top half inch. I was indeed surprised to learn from the results of the ammonification work on this soil that the cottonseed meal had given up 37.37% of its nitrogen as ammonia; dried blood 23.67%; alfalfa meal 12.75%; flaxseed meal 2.87%.

SAMPLE No. 18.

This sample comes from a field which had been in sugar beets in 1910 and in oats in 1911. The soil is a hard clay with considerable gravel, and the crops have not done well in late years because of the poor drainage conditions. The underlying shales appear to have formed a series of basins which retain the irrigating waters and thus interfere with natural drainage. Recently, extensive tile drains have been laid, and the trouble from excessive water should soon be lessened. In addition to the seeped condition of the land, niter has done some damage on this mesa, although not in the field which we are considering now. My purpose in taking a sample of this soil was to have something to compare with the next sample which was obtained from a neighboring field where both water and niter had been destructive. The ammonification results follow:

From cottonseed meal, 28.02% of the nitrogen was recovered as ammonia; dried blood 39.79%; alfalfa meal 2.83%; flaxseed meal 5.26%.

SAMPLE No. 19.

This represents a field which was planted to barley in 1910 but the nitrates which had been accumulating for years had become so concentrated by this time that nothing could grow except next to the irrigating furrows where the water appears to have reduced the salts to a degree of partial tolerance. In 1910, the soil, a gravelly clay, was dark brown and mealy beneath the surface crust. When I visited the ranch in March, 1912, extensive drains were being installed, but it was too early to expect any benefit. The moist condition of the soil made it rather difficult at this time to detect the characteristic brown color, so prominent in the years before. However, the soil was becoming mealy in spots as it dried out. The ammonification results obtained from this sample are as follows:

From cottonseed meal 44.72% of nitrogen was recovered as ammonia; dried blood 47.74%; alfalfa meal 13.06%; flaxseed meal 2.55%. A comparison of these figures with those of the preceding sample is quite striking when it is remembered that No. 18 is the same kind of a soil secured from a nearby field, but where the niter had not manifested itself. Soil No. 18 liberated only 30.68% of the nitrogen of cottonseed meal as ammonia, while No. 19 set free 45.70%; the former gave 42.45% with dried blood the latter 46.72%; the former 5.49% with alfalfa meal; the latter 14.04%; the better soil gave higher returns from the flaxseed meal, the ratio being 7.92 to 3.53.

Sample No. 20.

Our next case presents a very interesting history. In 1908 the field was planted to oats but it was only a short time until a number of brown, mealy patches, on which nothing would grow, developed on the higher places. It should be mentioned in passing that seepage had given some trouble in former years, and for that reason the growing of alfalfa on that piece of ground had been abandoned. In 1909 the land was planted to sugar beets, but the stand was very poor; there were great barren areas of half an acre in extent where nothing would grow. These bare spots were decidedly brown and mealy. The beet crop was almost a total failure, and that fall the field was seeded to winter wheat. The spring of 1910 brought no relief, for the whole twenty-five acres of wheat perished long before harvest. The greater part of the tract remained a barren waste all that summer, with not even a Russian thistle growing on it. As has been mentioned before, the precipitation for the winter and spring of 1910 and 1911 was unusually heavy and prolonged, and whether it was due to the leaching resulting from this, or to some other unknown cause, I know not, but in 1911 the whole area blossomed out in a most luxuriant growth of saltbush and Russian thistles chest high. So far as our present observations go, this field and No. 6 are the only instances where niter areas have shown any tendency toward recovery. The surface of the soil was moist and green with a moss protonema when I took my sample in October, 1911. It is a clay loam and mealy in spots beneath the brown crust. The results of the ammonification experiment are as follows:

From cottonseed meal, 48.23% nitrogen was recovered as ammonia in seven days; dried blood 38.98%; alfalfa meal 9.81%; flaxseed meal 5.07%.

Sample No. 21.

Sample No. 21 was taken in the fall of 1911 from an orchard where the niter injury was first observed in 1909. During 1909 and 1910 approximately two and a half acres had been killed, and the remainder of the trees were unquestionably affected in 1911 but the progress of the trouble seemd to have been retarded from some cause. In place of the trees being entirely destroyed in a month to six weeks, as is frequently true, these dragged along, half leaved out and sickly looking, throughout the season. I am unable to say whether they came out in leaf this spring or not. I obtained a sample of this soil in 1910 and found it to possess marked nitrogen fixing powers. In thirty days it gave an increase of 9.807 m. g. of nitrogen per 100 c. c. of mannite solution. The soil is a clay loam and shows the brown stain of the Azotobacter pigment readily. The ammonification test made from soil secured in October, 1911, gave the following:

From cottonseed meal 47.87% nitrogen recovered as ammonia; dried blood 49.16%; alfalfa meal 12.22%; flaxseed meal .77%.

SAMPLE NO. 22.

This sample comes from a ninety acre orchard, where the trees have been dying from excessive nitrates since 1908. During the winter of 1911 and 1912, the manager took out approximately two hundred and fifty dead apple trees from one corner of the orchard to say nothing of those removed here and there from other parts. A nitrogen fixation test made on this soil two years ago gave an increase of 8.89635 m. g. of nitrogen per 100 c. c. mannite solution in thirty days. At this time, the characteristic brown stain was very perceptible on the irrigating furrows, and today in some parts of the orchard the entire surface bears this same color. The orchard had been seeded to oats as a shade crop when I took my first sample for ammonification on October 27, 1911. The grain was about knee high and the stand was very thin. It was raining hard at this time, so it was impossible to tell anything about either the brown color or physical condition of the soil. The soil is a sandy loam and was collected beside a burning tree in that section of the orchard which was subsequently grubbed out. The results of the ammonification experiment are as follows:

From cottonseed meal 39.89% nitrogen was recovered as ammonia; dried blood 31.38%; alfalfa meal 11.63%; flaxseed meal 1.54%.

SAMPLES NOS. 23, 24, 25 AND 26, 27, 28.

The samples were all collected from the orchard described as No. 22 and represent two vertical sections. Two large trenches had been dug to ascertain the level of the ground water; one in the lowest part of the section from which the trees had been removed, and the other back in the orchard on higher ground where the trees were just beginning to burn. In the first hole the water plane was found to be four feet eight inches from the surface, while in the second, no water was struck at eight feet. Judging by the eye, the latter was in ground four to five feet higher than the former. The face of each trench was cut down as smooth and clean as possible with a shovel, and then the surface inch of this face was removed at the point where the sample was to be taken with a sterile spatula. After cutting out this surface block very carefully, the sample proper was taken with a second sterilized spatula. These precautions were taken in order to avoid the danger from surface contaminations which were almost certain to have been carried down with the shovel. In this manner, three samples were obtained from each hole at three different depths; namely, (1) the surface three inches; (2) 18th to 24th inches; (3) 56th to 60th inches. Samples Nos. 23, 24, and 25 came from hole No. 1, and Nos. 26, 27, and 28 from No. 2. Nos. 23 and 26 represent the surface portions; Nos. 24 and 27, the section at 18 to 24 inches; and Nos. 25 and 28, the samples at 56 to 60 inches from the respective holes.

The soils are so unlike in physical character at the different depths in the two excavations that a brief description is necessary to a clear understanding and correct interpretation of the results obtained in the ammonification experiments. No. 23 is a sandy loam, more or less mealy from excessive niter; No. 24 is a mixture of sand and gravel with abundant moisture; No. 25 was taken near the bottom of the hole in the water bearing stratum, and consists of coarse sand and gravel, thoroughly saturated with water. The top 13 inches of soil from hole No. 2 was frozen and sample No. 20, taken from this portion, is a sandy loam, not mealy; No. 27 is a clean, sharp, dry gravel with neither sand nor soil present. This material is so coarse that practically nothing passed through a wire sieve with 20 meshes to the inch, and in preparing the sample, it was put through a 10 mesh sieve instead of the usual 30 mesh; No. 28 is a fine, moist sand with almost no gravel.

The ammonification results with these six soils are given in the the following table.

Table No. 1. Ammonification by Samples Nos. 23 to 28.

		Per cent. nitrogen recovered as ammonia in 7 days from:			
No.	Source	Cottonseed meal	Dried blood	Alfalfa meal	Flaxseed meal
23	Surface 3 in.	45.32	30.47	17.93	6.20
24	18 to 24 in.	48.29	39.25	26.27	1.12
25	56 to 60 in.	47.45	34.04	15.41	.84
26	Surface 3 in.	50.85	44.76	26.24	9.53
27	18 to 24 in.	22.62	46.37	34.85	.91
28	56 to 60 in.	38.53	46.72	28.82	.87

Comparing the results from the surface samples of the two holes, Nos. 23 and 26, it is very clear that the excessive nitrates in the former have depressed ammonification. On the whole, ammonification has been more active in the soils outside of the heavy niter area. The ammonification of flaxseed meal is accomplished almost entirely by the surface flora, this function disappearing very rapidly in the first two feet. Bacteria capable of ammonifying cottonseed meal, dried blood and alfalfa meal appear to occur almost uniformly throughout the first five feet. No. 24 gave the highest yields of ammonia of any of the samples from hole No. 1, except with flaxseed meal, due, possibly, to its loose, open texture. No. 27 gave the highest percentages of ammonia from dried blood and alfalfa meal, but was strikingly deficient in the microorganisms necessary for the destruction of cottonseed meal. No. 26 gave the largest amounts of ammonia from cottonseed meal and flaxseed meal. The large percentages of ammonia produced by Nos. 25 and 28 are worth noting in view of the fact that these are both deep soils in which one would hardly expect to find active ammonifying bacteria.

SAMPLE NO. 29.

A truck garden on the outskirts of a mining town furnished the next sample. This soil is of particular interest since previous to its present ownership, it was held as a placer gold claim. The elevation is some 3000 feet higher than the country from which the

Table No. 2. The Ammonifying Efficiency of Certain Colorado Soils.

No.	Source	Character of Soil	Total nitrogen used=100 mgs. Per cent. nitrogen recovered as ammonia in 7 days from: Cottonseed meal Per cent. mgs.	mgs.	Aver.	Dried blood Per cent. mgs.	mgs.	Aver.	Alfalfa meal Per cent. mgs.	mgs.	Aver.	Flaxseed meal Per cent. mgs.	mgs.	Aver.
1	Orchard	Heavy abode c'ay	45.81	46.86	46.33	37.06	36.99	37.02	17.55	17.55	17.55	2.87	3.15	3.01
2	Orchard	Heavy adobe clay	43.85	40.77	42.31	47.08	47.00	47.04	12.54	13.03	12.78	8.48	7.70	8.09
3	Orchard	Sandy loam	25.50	26.34	25.92	18.06	18.00	18.03	12.12	12.00	12.06	6.16	6.44	6.30
4	Orchard	Sandy loam	45.11	44.13	44.62	46.79	47.07	46.93	12.05	12.75	12.40	1.12	1.12	1.12
5	Orchard	Sandy loam	38.81	38.46	38.63	36.85	36.71	36.78	20.59	21.57	21.08*	19.40	20.80	20.10*
6	Orchard	Clay loam	43.36	43.59	43.47	23.12	23.89	23.55	8.69	8.76	8.72	.14	.07	.1
7	Orchard	Sandy loam	46.37	46.44	46.40	33.48	32.02	32.75	10.71	10.51	10.61	3.71	4.27	3.99
8	Orchard	Clay loam	51.98	51.98	51.98	48.54	47.42	47.98	14.64	15.97	15.30	1.19	1.05	1.12
9	Orchard	Clay loam	36.78	35.73	36.25	31.87	33.06	32.46	12.05	12.12	12.08	1.05	.70	.87
10	Orchard	Clay loam	28.30	28.37	28.33	23.47	23.68	23.57	4.76	5.18	4.97	8.34	7.85	8.14
11	Orchard	Clay loam	47.49	47.70	47.58	51.07	51.28	51.17	14.15	13.03	13.59	12.12	12.19	12.15
12	Cantaloupes	Sandy loam	39.93	37.69	38.81	20.60	20.74	20.67	7.02	7.36	7.19	.07	.70	.38
13	Alfalfa	Clay loam	45.95	44.27	45.11	40.00	42.31	41.15	7.92	6.80	7.36	7.50	7.92	7.71
14	Orchard	Clay loam	48.68	46.79	47.73	52.75	51.91	25.33	16.04	17.09	16.56	3.71	4.27	3.99
15	Orchard	Sandy loam	48.69	49.46	49.07	48.25	53.31	50.78	16.04	15.68	15.86	1.54	2.10	1.82
16	Orchard	Sandy loam	47.00	47.21	47.10	52.40	52.89	52.64	13.73	13.66	13.69	0.0	.42	.21
17	Adobe hill	Raw adobe clay	37.06	37.69	37.37	23.47	23.88	23.67	12.75	12.75	12.75	2.80	2.94	2.87
18	Beet field	Hard gravelly clay	28.09	27.95	28.02	39.72	39.86	39.79	2.73	2.94	2.83	4.91	5.61	5.26
19	Barley field	Clay loam	45.81	43.64	44.72	47.00	48.48	47.74	13.38	12.75	13.06	2.94	2.17	2.55
20	Beet field	Clay loam	48.20	48.27	48.23	39.44	38.53	38.98	9.39	10.23	9.81	4.34	5.81	5.07
21	Orchard	Clay loam	47.98	47.77	47.87	48.45	49.88	49.16	12.54	11.91	12.22	.84	.70	.77
22	Orchard	Sandy loam	40.91	38.88	39.89	32.22	30.54	31.38	11.56	11.70	11.63	1.40	1.68	1.54
23	Orchard	Sandy loam	44.83	45.81	45.32	30.40	30.54	30.47	19.05	16.81	17.93	5.32	7.08	6.20
24	Orchard	Sand and gravel	47.77	48.82	48.29	38.25	39.86	39.05	26.20	26.34	26.27	1.26	.98	1.12
25	Orchard	Coarse sand, almost gravel	47.49	47.42	47.45	35.38	32.71	34.04	15.34	15.48	15.41	.98	.70	.84
26	Orchard	Sandy loam	50.72	50.99	50.85	44.69	44.83	44.76	26.41	26.48	26.44	9.81	9.25	9.53
27	Orchard	Clean sharp gravel	22.83	22.42	22.62	46.23	46.51	46.37	34.18	35.52	34.85	.98	.84	.91
28	Orchard	Moist sand and gravel	38.39	38.67	38.53	46.79	46.65	46.72	28.23	29.42	28.82	.91	.84	.87
29	Truck patch	River bottom sandy loam	20.32	21.86	21.09	25.08	25.08	25.08	.77	.7	.73	3.43	2.80	3.11
30	Beet field	Clay loam	35.03	35.59	35.31	11.21	11.00	11.10	7.85	8.13	7.99	1.05	1.61	1.33
31	Beet field	Clay loam	27.53	29.42	28.47	21.30	19.83	20.56	2.52	2.24	2.38	7.57	7.57	7.57

* Determination made after 11 days.

other samples were obtained, and the tract is 36 miles from the nearest recorded case of niter. The soil is a deep river bottom silt loam and is in a most productive condition, the owner having obtained 240 sacks of potatoes per acre in 1911. All kinds of vegetables, together with strawberries, are grown here very successfully. The soil has been heavily manured, and for that reason, I expected to find it abundantly stocked with all kinds of ammonifying bacteria. My expectatons were not fulfilled, however, for the ammonifying efficiency was less than any of the other soils examined and only about half as great as the general average for the niter soils. From cottonseed meal, 22.49% of the nitrogen was recovered as ammonia; dried blood 26.48%; alfalfa meal 2.13%; flaxseed meal 3.11%.

SAMPLES NOS. 30 AND 31.

These soils were taken from an entirely different part of the state than any of the others and come from a sugar beet field where very interesting soil conditions maintain. The tract, as a whole, is on high ground, but slopes rather rapidly from all sides into a hollow or basin near the center. This is wet and white with alkali much of the time. Between this part and the higher surrounding portion lies a zone which slopes gently toward the basin proper. Although planted to beets for two successive years, none have grown next to the white alkali at any time, and during 1911 none grew anywhere in this zone, not even at a considerable distance from the alkali, where a stand had been obtained in former years. The soil in this belt was brown, encrusted, and mealy, but not white. Immediately adjacent to the white alkali, it was wet and muddy, but the belt proper carried about the optimum amount of moisture for growing crops. The boundary of the white area appears to remain about the same from year to year, but the surrounding brown zone is moving gradually up the slope a little farther each year, the progress for 1911 having been at least 100 feet. With the advancing line of nitrates, the beets have been forced to recede, and each year the limit for their growth is set a little farther back. Sample No. 30 was collected from the brown, mealy niter zone where nothing grew, and No. 31 from that part of the field where there was a good

Table No. 3. Nitrogen as Ammonia Originally Present in 100 Grams of Soil.

Soil No.	Milligrams Nitrogen as Ammonia	Soil No.	Milligrams Nitrogen as Ammonia	Soil No.	Milligrams Nitrogen as Ammonia
1	.4203	11	.9807	21	.8406
2	.7005	12	.8406	22	.8406
3	.4203	13	1.1208	23	.2802
4	.2802	14	.1401	24	0.0000
5	.4203	15	.5604	25	.1401
6	.7005	16	1.2609	26	0.0000
7	.2802	17	0.0000	27	0.0000
8	.1401	18	2.6619	28	0.0000
9	1.2609	19	.7005	29	3.5025
10	1.1208	20	.9807	30	.4203
				31	1.2609

stand of beets, and where the soil, a clay loam, was normal to all appearances. Except for the low ammonification produced with the dried blood, No. 30 behaved much the same as other niter soils, while No. 31 was very similar to a normal soil.

The results follow:—No. 30, from cottonseed meal, 35.31% nitrogen was recovered as ammonia; dried blood 11.10%; alfalfa meal, 7.99%; flaxseed meal, 1.33%.

No. 31, from cottonseed meal, 28.47%; dried blood, 20.56%; alfalfa meal, 2.38%; flaxseed meal, 7.57%.

DISCUSSION OF RESULTS.

Niter Soils and Normal Soils.

A careful examination of the ammonia determinations given in Table No. 2 points very strongly to the niter soils as being superior to our normal soils in ammonifying efficiency. This becomes more apparent when typical soils are selected from each class, although this property is quite evident from the results as a whole.

While some ammonia may have resulted from a reduction of the nitrates present, as a matter of fact, I think that there is little ground for believing that this is the case. A number of these soils have been examined quantitatively for nitrates, and the amounts present are not sufficient to account for the ammonia formed. In the light of this fact, any hypothesis for the formation of ammonia based upon the reduction of nitrates appears to be without foundation.

Four soils are given in Table No. 4 which have never shown any indication of excessive nitrates either by a brown color or by injury to vegetation. The soils presented in Table No. 5 were all collected from areas where the niter is just now beginning to be very active in the destruction of trees. In this connection, let me emphasize this point, that these samples were not taken from old niter areas where everything had been killed, bacteria included, but they were obtained either from new localities, or, in case they did come from the sites of well established niter spots, from the margins of such areas where the accumulation of nitrates was in progress rather than completed.

Table No. 4. Ammonifying Efficiency of Normal Soils.

			Per cent. nitrogen recovered as ammonia in 7 days from:			
No.	Source	Character	Cottonseed meal	Dried blood	Alfalfa meal	Flaxseed meal
3	Orchard	Sandy loam	25.92	18.03	12.06	6.30
10	Orchard	Clay loam	28.33	23.57	4.97	8.14
18	Beet Field	Gravelly clay	28.02	39.79	2.83	5.26
29	Truck patch	Silt loam	21.09	25.08	.73	3.11

Table No. 5. Ammonifying Efficiency of Niter Soils.

			Per cent. nitrogen recovered as ammonia in 7 days from:			
No.	Source	Character	Cottonseed meal	Dried blood	Alfalfa meal	Flaxseed meal
11	Orchard	Clay loam	47.58	51.17	13.59	12.15
14	Orchard	Clay loam	47.73	52.23	16.56	3.99
16	Orchard	Sandy loam	47.10	52.64	13.69	.21
21	Orchard	Clay loam	47.87	49.16	12.22	.77
26	Orchard	Sandy loam	50.85	44.76	26.44	9.53

With cottonseed meal and dried blood, the ammonification has been almost twice as great in the niter soils as in the normal ones, while with alfalfa it has been from three to twelve times as much; the results from the flaxseed meal are so variable and irregular that any conclusions drawn from these figures would be little more than conjecture.

Ammonification of Flaxseed Meal.

In practically every culture that contained flaxseed meal, there was a heavy mycelial growth covering the entire substratum and filling the dish nearly to the cover, in some instances. This was especially noticeable with flaxseed meal, although occasionally a limited amount of a similar growth appeared in the presence of the alfalfa meal. What relation these fungi may have had to the relatively small omounts of ammonia recovered from the two substances mentioned is an open question. On this point Lipman (1) suggests the following:

"Is it because substances possessing a large proportion of non-nitrogenous compounds fail to undergo ammonification entirely or is it because the ammonia produced in the course of their decomposition is rapidly changed back into protein substances? As to the first assumption it is hardly in accord with facts now known * * * * It seems more likely that some ammonia was produced out of these materials, but on account of the relatively large supply of carbohydrates, molds and acid producing bacteria utilized the ammonia formed for the development of their body substances. In other words, whatever ammonia was produced, was utilized effectively for the development of mycelia and of bacterial cells. It seems reasonable to suppose, further, that the substances rich in protein favor the development of an alkaline reaction on account of the larger amounts of ammonia and ammonium carbonate formed. The alkaline reaction favors, in its turn, the vigorous growth of the more typical putrefactive organisms capable of causing fairly intense cleavage of protein compounds."

Comparative Studies.

In almost any investigation, a comparison of one's results with the work of others along similar lines leads either to a confirmation of truths, or to the discovery of new facts. Such a comparative study has been made between some of our soils and those from other localities in the United States, and the differences in ammonifying efficiency brought out in this way have been most striking as the figures given in Table No. 6 indicate. The methods employed by the different experimenters have been practically the same, so the results should be comparable. The two points which stand out most prominently in the tabulation of these results are:—First, in degree of ammonifying efficiency, the niter soils of Colo-

(1) Lipman, Jacob G., The Availability of Nitrogenous Materials as Measured by Ammonification. Cent. f. Bakt. Abt. II. Bd. 31, No. 1-4, p. 64, 65, 1911.

rado far exceed the soils from the other regions cited; second, the degree of ammonifying efficiency manifested by our normal soils is about the same as that of other soils, with a slight difference in favor of the Colorado samples.

The first four samples in Table No. 6 represent four localities in the state and three distinct types of soil where nitrates are making their presence manifest by injury to apple trees. No. 17 came from the top of an adobe hill, and is as nearly raw land as can be found in Colorado, in fact, it might be classified more correctly as a weathered shale than as soil. The last three were obtained from widely separated districts, and may be considered normal arable soils so far as the presence of excessive nitrates and crop yields are concerned. The soil nubmers given in the above table correspond to the sample descriptions given in the preceding pages.

The character of New Jersey soil No. 1 is not recorded in the text from which I have secured the analysis, but No. 2 is given as a silt loam. Calcium carbonate was added to the latter soil along with the cottonseed meal and linseed meal to neutralize any organic acids that might be formed during ammonification. This may account for the close agreement between the New Jersey and Colorado results in the one case, since our soils contain an abundance of carbonate normally.

Table No. 6. Ammonifying Efficiency of Colorado Soils Compared With Other Soils.

		Per cent. nitrogen	recovered	as ammonia in	7 days from:
Soil	Character	Cottonseed meal	Dried blood	Alfalfa meal	Flaxseed meal
Colorado 2	Heavy clay	42.31	47.04	12.78	8.09
Colorado 8	Clay loam	51.98	47.98	15.30	1.12
Colorado 14	Clay loam	47.73	52.33	16.56	3.99
Colorado 16	Sandy loam	47.10	52.64	13.69	.21
Colorado 17	Raw adobe clay	37.37	23.67	12.75	2.87
Colorado 10	Sandy loam	28.33	23.57	4.97	8.14
Colorado 18	Gravelly clay	28.02	39.79	2.83	5.26
Colorado 29	River bot. silt	21.09	25.08	.73	3.11
New J. 1 (1)	Unknown	4.95	16.74	....	....
New J. 2 (2)	Silt loam, limed	41.18	56.63	....	46.06
Iowa (3)	Marsball loam	29.82	24.18	....	....
Calif. (4)	L. Sandy loam	....	18.99	....	....
N. Car. (5) No. 2069	Unknown	31.86	....	....	....
N. Car. No. 1931	Unknown	22.06	....	....	....

The California sample is described as a "light sandy loam free from alkali, from a walnut grove in Southern California—fairly well supplied with humus, owing to the careful system of green

(1). Marshall's Microbiology, p. 254. The ammonia determinations were made after 6 days

(2). Lipman, Brown and Owen. The availability of nitrogenous materials as measured by ammonification. Cent. f. Bakt., Abt., II., Bd. 31, No. 1-4 p. 49, 1911.

(3). Brown, P. E. Some Bacteriological Effects of Liming. Research Bul. No. 2, Iowa Exp. Sta.

(4). Lipman Chas. B. Toxic Effects of "Alkali salts" in Soils on Soil Bacteria. I. Ammonification. Cent. f. Bakt., Abt. II., Bd. 32, No. 1-2, p. 58, 1911. Ammonia determinations made after 4 days.

(5). Stevens and Withers. Studies in Soil Bacteriology, II. Ammonification in soils and in solutions. Cent. f. Bakt., Abt. II., Bd. 23, No. 21-25 1909.

manuring which was practiced on it, and containing a vigorous flora ammonifying bacteria." The ammonia determinations with this soil were made after four days in place of seven as with the others.

The Iowa sample carries the following description:—"The soil was typical of the Wisconsin Drift, being classed by the Bureau of Soils as Marshall loam. It was obtained from an experimental plot to which no lime had ever been applied—which, during the preceding five years had been continually in corn and which prior to that time had been in a general farming rotation."

With the exception of the New Jersey figures, the percentages given in Table No. 6 are based upon blood meal containing 13.05 per cent. of total nitrogen, and cottonseed meal with 7.84 per cent. total nitrogen. In the New Jersey work, Lipman states that the blood meal and cottonseed meal used contained respectively 13.18 per cent. and 6.405 per cent. total nitrogen.

The California and Iowa samples fall considerably below the cultivated Colorado soils, containing nitrates, in ammonifying efficiency, although the figures for the former may be low on account of the four day experimental period in place of seven. New Jersey No. 1 appears to be greatly inferior to our soils, while No. 2 compares very favorably. It is interesting to note, in passing how much more available linseed meal seems to be with the limed New Jersey soil than with ours. While the former gives 46.06 per cent. nitrogen as ammonia, few Colorado soils will produce to exceed 13 per cent. and the majority less than 3 per cent.

SUMMARY.

The power to transform organic nitrogen into ammonia is a property common to many cultivated Colorado soils.

Soils in the incipient stage of the niter trouble appear to surpass our normal soils in ammonifying efficiency.

Compared with soils from other localities, our niter soils excel in ammonifying efficiency to a very marked degree.

Nineteen of the thirty-one soils examined have ammonified cottonseed meal more readily than the other nitrogenous materials employed; the remaining twelve have broken down the dried blood most easily; twenty-six have formed ammonia from alfalfa meal more readily than from flaxseed meal, and with five the reverse has been true.

The maximum per cent. of ammonia produced in seven days by any soil from 100 m. g. of nitrogen as cottonseed meal was 51.98%; as dried blood 25.64%; as alfalfa meal 34.85%; as flaxseed meal 12.15%.

52.

ALGAE IN SOME COLORADO SOILS.

By W. W. Robbins.

INTRODUCTION.

It has been experimentally demonstrated by Professor Walter G. Sackett (1) that many of the cultivated soils of Colorado possess the power to fix free atmospheric nitrogen. This fixation takes place in the soils themselves as well as in culture solutions. *Azotobacter chroococcum* is found to be the chief nitrogen fixing organism. It is now well known that unprecedented quantities of nitrates accumulate in certain soils of Colorado, resulting in so-called "niter areas"; the quantities are such as to kill off not only higher types of plants but the nitrogen fixing organisms themselves. The evidence brought to light by Dr. W. P. Headden (2), showing that the accumulation of these nitrates is not due to seepage or ground waters is too clear and certain to admit of dispute. Added to this are the results brought forward by Professor Sackett that certain of our soils have a high nitrogen fixing power. Naturally, the unusual accumulation of nitrates is thought to be due to the fixation of free atmospheric nitrogen by the soils themselves, accompanied by ammonification and nitrification.

As our soils are poor in organic matter, it seemed difficult to account for the source of energy that would be necessary to support such a rich nitrogen fixing flora. If it could be shown that our soils have an abundance of algae present, this condition would, at least, be highly suggestive that the energy for *Azotobacter* was being supplied in large part by these chlorophyl-bearing organisms Hence it was that, with this in mind, the present preliminary study of the algae in our soils was undertaken.

I am indebted to Professor Sackett for the problem and for many laboratory facilities extended to me in the course of this study. The soil samples were collected by him.

HISTORICAL.

It is well known that certain bacteria and algae enter into a symbiotic relationship, in which the latter furnish the bacteria with the necessary energy in the form of carbohydrates, while the bacteria supply the algae with nitrates. MM. Bouilhac and Guistiniana (3) showed that *Nostoc punctiforme* and *Anabaena,* when associated with bacteria, grew well on sand supplied with mineral nutrients in which nitrogen and organic material were lacking. Furthermore, the mixture could accumulate enough nitrogen to

(1) Sackett, Walter G., Bacteriological Studies of the Fixation of Nitrogen in Certain Colorado Soils. Colorado Agricultural Exp. Sta., Bull. 179, pp. 1-42, 1911.

(2) Headden, W. P. The Fixation of Nitrogen in Some Colorado Soils. Colorado Agricultural Exp. Sta., Bull. 155, pp. 1-48, 1910, and Bull. 178, pp. 1-96, 1911.

(3) MM. Bouilhac and Guistiniana. Sur une culture de sarrasin en presence d'un melange d'algues et bacteries. Compt. rend. de l'Acad. T. CXXXVII, pp. 1274-1276, 1903. Sur des cultures de diverses plantes superieures en presence d'un melange d'algues et de bacteries. Comp. rend. de l'Acad. T. CXXXVIII, pp. 293-296, 1904.

enable certain higher plants to develop normally. Without algae, however, there was a comparatively slight growth of the higher plants. These experiments are not conclusive but they are indicative of the close relationship existing between algae and bacteria in the soil. More than that, they lead one to believe that in these experiments algae supplied carbohydrates for the nitrogen fixing bacteria which in turn furnished nitrates essential for the normal development of the higher plants.

Dr. Hugo Fisher (1) speaks of the symbiosis existing between *Azotobacter chroococcum* and *Oscillatoria*. He is of the opinion that *Azotobacter* occurs abundantly between the algal filaments, the algae furnishing carbohydrates, the bacteria nitrates. Frank (2) found that there was an increase in the nitrogen content of a nitrogen-poor sand on which algae developed in the light, while the same sand if kept in the dark did not increaes in nitrogen. Soil bacteria were present in both cases. Schloesing and Laurent (3), working along the same lines, showed that soil containing both bacteria and algae could fix free nitrogen in large quantities while the same soil covered with quartz to prevent algal growth did not increase in nitrogen. The above workers assumed that the algae in their mixtures had the power to fix free nitrogen. This assumption was later proven to be erroneous, at least for green algae (Chlorophyceae).

In 1894, P. Kossowitsch (4), working with pure cultures of green algae, species of *Cystococcus* and *Stichococcus*, demonstrated that these alone could not assimilate the free nitrogen of the air. Later, in 1900, Kruger and Schneidewind (5), using pure cultures of green algae, species of *Stichococcus*, *Chlorella* and *Chlorothecium*, substantiated the results of Kossowitsch and proved that the green algae they used did not have the power to fix free atmospheric nitrogen. It is highly probable that none of the green algae possess this power. They further showed that when inorganic or organic nitrogen was excluded from the nutrient solution, all the species of algae in pure culture made no noticeable growth. There was abundant growth, however, when the same sub-stratum was supplied with combined nitrogen. In neither of the above pure cultures of algae was there any nitrogen fixation. But in the same medium, both an abundant development of algae and a fixation of nitrogen took place if pure cultures of the algae were inoculated with *Azotobacter*. In the latter case fixation is, of course, attributed to *Azotobacter*, while algae furnished them with the organic matter necessary for their life.

---

(1) Fisher, H., Ueber Symboise von Azotobakter mit Oscillarien. Cent. f. Bakt. Abt. II., Bd. XII., p. 267, 1904.

(2) Frank, A. B., Ueber den experimentellen Nachweis der Assimilation freien Stickstoffes durch erdbewohnende Algen. Berichte d. deutschen botan. Gesellschaft. Bd. VII., p. 5, 1889.

(3) Schloesing and Laurent. Recherches sur la fixation de l'azote libre par les plantes, Annales de l'Institut Pasteur T. VI., p. 65 W. 824, 1892.

(4) Kossowitsch, P., Untersuchungen ueber die Frage, ob die Algen freien Stickstoff fixieren. Botan. Zeitg., Bd. LII, p. 97, 1894.

(5) Kruger and Schneidewind. Sind niedere, chlorophyllgrune Algen imstande, den freien Stickstoff zu assimilieren? Landwirtsch. Yahrb. Bd. XXIX., p. 771 ff., 1900.

Attempts to secure pure cultures of blue-green algae (Cyanophyceae) have been attended with failure and hence there are no reliable experiments which prove that these possess the ability to assimilate free nitrogen. Our further studies will be directed to clearing up the relations of the blue-green algae to *Azotobacter chroococcum* and nitrogen fixation. It is a significant fact that the blue-greens are by far the most abundant algae in all Colorado soils examined.

METHODS.

In each case the samples included the surface 3 to 4 inches of soil. Any debris on the surface was first removed. The samples were taken during October, 1911, and brought from the field to the laboratory in sterilized, double, sugar sacks. In the laboratory, the soil was transferred to sterilized Mason jars.

Florence flasks, 500 c. c. capacity, were filled to their greatest diameter with ground quartz which was previously washed free from all suspended matter. These were sterilized in an autoclave for 30 minutes at 120° C., in a moist condition. Each flask was plugged with sterile cotton. After removing flasks from the autoclave they were so placed as to get a smooth, horizontal surface of the substratum.

For inoculation 20 g. of each soil sample were shaken up for 5 minutes in 50 c. c. of sterile, distilled water. An amount of suspension material corresponding to 10 g. of soil, i. e. 25 c. c., was drawn off with a sterile pipette and distributed as evenly as possible over the ground quartz surface.

With the above precautions, contamination was impossible; the abundant algal growth which appeared in all but two flasks assuredly represents only those forms existing in the soils used for inoculation. Of course, it is quite well known that sterile, distilled water is essential; tap water may carry both vegetative and reproductive parts of algae.

The flasks, 22 in number, containing as many different soil samples, were placed in the greenhouse in a sunny place. Later they were removed to a shady situation in the botanical labratory where they grew fully as well as in the greenhouse. Each flask was tipped to one side so as to offer both a moist sand and a free water surface for the algae to grow on.

A number of species of algae which appeared in the flask cultures were transferred to a 1% agar medium in which soil extract was used as the nutrient solution. The soil extract was prepared by filtering soil in Pasteur-Chamberland, unglazed porcelain filters. In preparing Petri dish cultures, a small bit of algal material was removed from the flasks and shaken up vigorously in a test tube with about 2 c. c. of distilled water. Platinum wire loops from this were transferred to tubes of liquid 1% agar at 42° C. These were shaken and then poured into Petri dishes. Algal growth never failed to appear in these agar cultures and in many cases within 2 or 3 weeks. In some instances subsequent reinoculations to agar were made from the Petri dishes.

DESCRIPTIONS OF SOIL ALGAE.

Hereinafter is included a brief description of each algal species found in the samples of soil examined. Although most of these species are described in the books on algae (1), it seemed desirable to give here complete descriptions and illustrations of all the species found in the soils examined. The reader will thus gain a better idea of the nature of the algal forms which, up to date, have been found in our soils. Some of the descriptions are taken from Tilden's Minnesota Algae. Credit is due Miss Nellie Killgore who made most of the drawings and both colored plates.

It will be noted that with but two exceptions, all the species found in the soil samples belong to the blue-green algae (Cyanophyceae). It will be recalled that the blue-greens include the simplest kinds of algae. They are characterized by simple asexual methods of reproduction and by the presence of a blue pigment, phycocyanin, in addition to a green pigment; the mixture results in a blue-green color. The plant body may be unicellular or multicellular. Unicellular forms may be single or grouped into colonies; multicellular species are mostly filamentous. It is worthy of note that the blue-grees found in the soils examined are all filamentous. Furthermore the largest proportion of them belong to the one family Nostocaceae. This family includes members usually possessing thick, gelatinous or mucous sheaths surrounding the trichomes, or rows of cells. Other families of blue-green, (Oscillatoriaceae, Stigonemaceae and Rivulariaceae) represented in the soil, also have gelatinous coverings to the trichomes. I mention the fact that forms of algae which have gelatinous sheaths predominate here, because I believe that bacteria find in these sheaths a highly favorable nutritive medium. Kossowitsch and Schloesing and Laurent observed that in their cultures which showed nitrogen fixation in great amounts, *Nostoc,* a blue-green alga with gelatinous sheaths, was the dominant form present. Again, the presence of this sheath probably accounts for the difficulty experienced in attempting to get such algae in pure cultures, free from their accompanying bacterial and fungal flora. The gelatinous coatings undoubtedly harbor a host of bacteria. European investigators have experienced but comparatively little difficulty in getting the unicellular green algae in pure cultures. On the other hand, I find no recorded instance of pure cultures of such forms as *Nostoc*. Green algae do not as a rule have such thick coverings of gelatinous material as members of the blue-greens.

We have succeeded in getting the green alga so abundant in Sample 7 practically pure, while our efforts in this regard with blue-greens

(1) The writer has made most use of Tilden's Minnesota Algae and De Toni's Sylloge Algarum, Vol. 5, the Myxophyceae.

are unsuccessful. We hope, however, to overcome the difficulties and obtain absolutely pure cultures of the most dominant blue-greens occurring in our soils. With such pure cultures we will be in a position to test their supposed nitrogen fixing power, and their role in the soil.

A number of the species appear to be undescribed. Although it has been possible to follow these for some months with considerable care and satisfaction through to spore production and growing both in flasks on sterile ground quartz and in 1% aqueous agar, these will, for the present, be designated by letters until further study of them is made. It has been impossible to identify certain other forms on account of their immaturity. For example *Stigonema* and *Rivularia* specimens were in developmental stages.

It was anticipated that the systematic study of algae occurring on and in the surface layers of soil would be attended with difficulty. This is largely due to the fact that no previous studies of soil algae have, to our knowledge, been made; furthermore, the descriptions of many species are totally inadequate and undifferentiating. It is needless to say that a systematic study of these soil organisms is highly essential. It is our purpose to continue the systematic study of the algal flora of Colorado soils as well as its relation to nitrogen fixation.

Oscillatoria formosa Bory. Plate I., fig. 1. Soil capillarity tube. Plant mass dark blue green; trichomes straight, elongate, usually slightly constricted at joints; apex of trichome somewhat obtuse and briefly tapering or rotund, hooked, not capitate; calyptra none; cells 2.5-5 mic. long; transverse walls finely granulate; cell contents bright blue-green.

Phormidium inundatum Kuetzing. Plate I., fig. 2. Soil samples 9, 10, and soil capillarity tube. Filaments somewhat straight, fragile; scattered in the flask cultures among other algae; sheaths thin; trichomes 3-5 mic. in diameter, straight or curved, not constricted at joints; apex of trichome straight, briefly tapering, not capitate; apical cell obtuse conical; calyptra none; cells 4-8 mic. in length; transverse walls covered with protoplasmic granules.

Phormidium subuliforme Gomont. Plate I., fig. 3. Soil sample 10. Filaments scattered throughout other algae; trichomes 2-2.8 mic. in diameter, straight, constricted at joints; apex of trichome gradually tapering, bent or twisted, not capitate; apical cell more or less acute-conical; calyptra none; cells 6-8 mic. in length; transverse walls indistinct; cell contents homogeneous or coarsely granular, blue-green.

Phormidium tenue (Meneghini) Gomont. Plate I., fig. 4. Soil samples 4, 10, 11, 16, 18 and soil capillarity tube. Plant mass thin, membraneous, expanded, pale blue-green; filaments elongate, straight, entangled; sheaths thin; trichomes 1-2 mic. in diameter, straight, somewhat constricted at joints; apex of trichome at first straight becoming tapering and bent; cells 2.5-5 mic. in length; transverse walls usually indistinct.

Phormidium valderianum (Delponte) Gomont. Plate I., fig. 5. Soil samples 13, 15. Filaments flexuose, densely entangled, here scattered throughout other algae; trichomes 2-2.5 mic. in diameter, straight not constricted at joints, apex of trichome not tapering; apical cell rotund; calyptra none; cells 3.3-6.7 mic. in length; transverse walls marked by two or four protoplasmic granules; cell contents blue-green.

Microcoleus vaginatus (Vaucher) Gomont. Plate I., figs. 6, 7. Soil capillarity tube. Filaments forming entangled and twisted threads, dark olive or black in color; sheaths cylindrical, more or less unequal in outline, agglutinated, pointed and closed at the apex, or open and gradually disappearing, at times entirely diffluent; trichomes 3.5-7 mic. in diameter, not constricted at joints, many within the sheath, closely crowded, usually twisted into cords, the portion extending from the shealth straight; apex of trichome gradually tapering and capitate; outer membrane of apical cell thickened into a depressed conical calyptra; cells 3-7 mic. in length; transverse walls frequently granulated.

Nostoc "A". Plate III., figs. 3, 4. Soil samples 1, 10, 11, 13, 21. Plant mass gelatinous, irregularly expanded, at first bright blue-green, becoming light olive or pale pea-green; filaments mostly straight sometimes loosely entangled or rarely spirally rolled; sheaths colorless, indistinct, becoming confluent; trichomes 5.2-6.7 mic. in diameter; cells different in shape, usually short depressed-spherical or barrel-shaped, 3.9-6.2 mic. in length, at first bright blue-green becoming grayish-green, the granules large and conspicuous; heterocysts yellowish-green, spherical, spherical-depressed or a little longer than wide, 6-8.3 mic. in diameter, 6-8 mic. in length; gonidia 6-8 mic. in diameter, 8-13 mic. in length, oval to oblong, separated, often irregularly disposed, grayish-green; wall of gonidium smooth, colorless. Habitat: cultivated soil.

A small form of the above species (Plate I., fig. 8) occurs in samples 11 and 21. Trichomes 3.6-4.7 mic. in diameter; heterocysts 4.3-5.9 mic. in diameter; gonidia 5.2-6.7 mic. in diameter, 7.8-11 mic. in length.

Nostoc "B". Plate III., figs. 5, 6, 7, 8, 9. Soil samples 1, 2, 4, 6, 8. 10, 11, 15, 16, 20. Plant mass bluish-white becoming yellowish with age, shapeless; filaments 15-20 mic. in diameter, flexuous, entangled, pale blue-green; trichomes 3-4.5 mic. in diameter, single in each colorless sheath; cells barrel-shapel or cylindrical, 3-6.5 mic. in length; heterocysts globose to elongate, 3.5-5.5 mic. in diameter, 5-5.2 mic. in length; gonidia numerous, separate, spherical to oval, brownish, 4.5-5.5 mic. in diameter 5-6.5 mic. in length; walls smooth. Habitat: cultivated soil.

Nostoc "C". Plate III., figs. 10, 11. Soil sample 4. Plant mass gelatinous-membranaceous, bright olive or dark colored; filaments flexuous, entangled; trichomes 3.6-4 mic. in diameter; cells depressed-spherical, barrel-shaped or ellipsodial, blue-green, 3.6-5.7 mic. in length; heterocysts subglobose or oblong 5-5.2 mic. in diameter; gonidia oval, in long series, 5.2-6.2 mic. in diameter, 7.8-9 mic. in length; wall of gonidium smooth, deep amber. Habitat: cultivated soil.

Nostoc commune Vaucher. Plate I., fig. 13. Soil samples 1, 2, 5, 8, 11, 15, 16. Plant mass gelatinous, not assuming here any definite form; filaments flexuous, entangled; sheaths colorless or brownish; trichomes 4.5-6 mic. in diameter; (In samples 1 and 2, the trichomes are smaller, measuring 4-5 mic. in diameter) cells depressed-spherical or barrel-shaped; heterocysts 5.7-7 mic. in diameter, somewhat spherical; gonidia unknown.

Anabaena "A". Plate IV., figs. 6, 7, 8. Soil samples 1, 2, 5, 10, 13, 14, 18. Plant mass gelatinous, dark green; trichomes 2.8-4 mic. in diameter, straight or flexuous; cells barrel-shaped, 3.9-5.2 mic. in length; heterocysts spherical to ovoid, 4-5 mic. in diameter. 4.6-5.4 mic. in length; gonidia ovoid when young, becoming cylindrical, solitary or in series contiguous to heterocysts, 5-6 mic. in diameter, 10-18 mic. in length; wall of gonidium smooth, colorless. Habitat: cultivated soil.

Nodularia armorica Thuret. Plate I., figs. 9, 10. Soil sample 21. Filaments 10-11 mic. in diameter, entangled; sheaths thin; cells depressed, one-half as long as diameter; heterocysts compressed, somewhat larger than the cell; gonidia depressed-spherical, yellowish-brown, in series, 10-12 mic. in diameter, 9 mic. in length; end walls of gonidia transversely truncate, projected.

5-15 mic. in diameter. yellow green, often changing to shades of red by exposure. This is the common green alga found everywhere on soil, moist rocks, walls, trunks of trees, etc. In the soil capillarity tube, the orange yellow or reddish brown spots are due to this species.

Navicula sp. (Diatom) Plate II., fig. 18. Soil sample 10. Plants brownish, boat-shaped, bivalved, the valves marked by fine, parallel striations; individuals 4.8-5.2 mic. in diameter, 28-68 mic. long.

DESCRIPTIONS OF FLASK CULTURES.

Here follows a brief description of the general nature of the algal growth and an enumeration of the species occurring in each flask. All flasks were inoculated between November 25 and 28, 1911. In some cases a slight green tinge to the water or quartz surface appeared within one month after inoculation. In most cases, however, no growth was apparent until the first part of February, 1912. The abundant development of the algae in sampe No. 1 is typical of the majority of cases. Plate IV., fig. 10 is a water color drawing of this flask culture.

Sample No. 1.—SOIL: heavy clay, orchard. **GROWTH:** vigorous, covering the surface of the sand with a dark green coating and extending several centimeters above and below the sand surface on the sides of the flask. In places the growth is brownish-black, due to **Stigonema. ALGAE: Nostoc "A", Nostoc "B", Nostoc commune, Anabaena "A", Stigonema** sp.

Sample No. 2—SOIL: sandy loam, orchard. **GROWTH:** at first blue-green, becoming grayish-green or yellowish in color; covering quartz and water surface and sides of flask. **ALGAE: Nostoc "B", Nostoc commune, Anabaena "A", Rivularia "A".**

Sample No. 3.—SOIL: sandy loam, orchard. **GROWTH:** none.

Sample No. 4—SOIL: sandy loam, orchard: **GROWTH:** substratum covered with a yellowish-green scum. **ALGAE: Phormidium tenue, Nostoc "B", Nostoc "C".**

Sample No. 5.—SOIL: sandy loam, orchard. **GROWTH:** substratum wholly covered with a dark green mass; algae also extending for some distance below the sand surface along the sides of the flask. **ALGAE: Nostoc commune, Anabaena "A".**

Sample No. 6.—SOIL: clay loam, orchard. **GROWTH:** substratum entirely overgrown, at first blue-green, becoming yellowish-green. **ALGAE: Nostoc "B".**

Sample No. 7.—SOIL: sandy loam, orchard. **GROWTH:** the first evidence of algal growth appeared in this sample; this was one month after inoculation and was due to the unicellular green alga. The scum occurred on the quartz, water and sides of flask. **ALGAE: Rivularia "A" Stigonema** sp., unicellular green alga.

Sample No. 8.—SOIL: clay loam, orchard. **GROWTH:** scanty; scum thin. **ALGAE: Nostoc "B", Nostoc commune.**

Sample No. 9.—SOIL: clay loam, orchard. **GROWTH:** substratum covered with a gray-green scum: algae also extending upon the sides of the flask. **ALGAE: Phormidium inundatum, Nodularia harveyana, Nodularia "A", Stigonema** sp.

Sample No. 10.—SOIL: clay loam, orchard. **GROWTH:** plant mass blue-green covering the entire substratum. **ALGAE: Phormidium inundatum, Phormidium subuliforme, Phormidium tenue, Nostoc "A", Nostoc "B", Anabaena "A", Navicula.**

Nodularia harveyana (Thwaites) Thuret. Plate I., figs. 11, 12. Soil samples 9, 13, 14, 15, 16, 21, 22. Filaments long and straight, 6 mic. in diameter; sheaths thin, colorless, distinct; cells 5.2 mic. in diameter, 1.5-3.9 mic. in length; heterocysts depressed, 5.2-5.4 mic. in diameter, 4.6-5.2 mic. in length; gonidia in long series between the heterocysts, 6.5-8 mic. in diameter, 5.2-7.8 mic. in length, yellowish-brown.

Nodularia "A". Plate IV., figs. 2, 3, 4, 5. Soil sample 9. Filaments long and straight, 7-8.5 mic. in diameter; sheath colorless, distinct; cells disc-shaped 5.2-7.5 mic. in diameter, 1.5-2.5 mic. in length; heterocysts depressed, mostly occuring in pairs, yellowish-green, 7.1-7.8 mic. in diameter, 4.4-5.6 mic. in length; gonidia spherical-depressed or spherical, brownish, 7.2-8.3 mic. in diameter, 5.4-7.7 mic. in length; wall of gonidium smooth. Habitat: cultivated soil.

Stigonema "A". Plate II., fig. 1, and Plate III., figs. 1, 2. Soil sample 16. Plant mass rust colored; filaments 20-46 mic. in diameter; sheath lamellose, constricted at joints, the outermost layers colorless, the inner ones yellowish or yellowish-brown, with a special envelop about each cell; trichomes single within each sheath; heterocysts terminal or intercalary, yellowish or orange-colored, 3.6-5 mic. in diameter, 5 mic. in length, oval or pear-shaped; cells spherical, oval, oblong or cylindrical, 4-5.2 mic. in diameter, 5.2-10 mic. in length, often attenuated; apical cell elongate, conical; gonidia (?) oval, the ends slightly attenuate, greenish brown, 5-5.7 mic. in diameter, 7-10 mic. in length; wall of gonidium smooth.

Stigonema sp. Here are grouped a number of polymorphic, transition forms of what appear to be one or more species of **Stigonema.** These forms are very abundant in the samples but the stages of development are not such as to permit one to come to any definite conclusions as to their identity. They are described and figured here as a record of algae found in cultivated soils. Soil samples 14, 22. Plate II., fig. 3, and Plate IV., fig. 9. Trichomes contorted, in sac-like gelatinous, colorless envelopes; cells irregular in shape 5.2-6.5 mic. in diameter; heterocysts terminal or intercalary, 5.2 mic. in diameter. Soil sample 22. Plate II., fig. 2, Probably a gonidial stage of the above. Sheath inflated at the ends; heterocysts terminal orintercalary;gonidia brownish, 6.5-7.8 mic. in diameter, 5.2 mic. in length; wall of gonidium smooth. Soil sample 21. Plate II., fig. 4. Numerous elongated colonies in which the trichomes are highly contorted; cells irregular in shape, 4.6-6.5 mic. in diameter. Soil samples 7, 18, 20. Plate III., figs. 13, 14, 15, 16, 17, 18. Numerous spherical and oblong colonies of many sizes; cells 3.8-4.2 mic. in diameter, irregular in shape. Soil samples 1, 9. Plate II., fig. 4. Floating dark-brown crust; cells 5.2 mic. in diameter, irregular in shape; heterocysts 3.3 mic. in diameter, terminal or intercalary, some of them becoming thick-walled and granular.

Rivularia "A". Plate II., figs. 5, 6, 7, 8, 9, 10. Soil samples 2, 7, 18, 20. Numerous developmental stages are present in the above samples. Filaments 7-10 mic. in diameter tapering; sheaths colorless, close; basal cells 5.2-6 mic. in diameter, 2.6-5 mic. in length.

Rivularia "B". Plate II., figs. 11, 12. Soil sample 16. Filaments scattered in the sample; filaments branched; sheaths thin, ragged along the edges; basal cells 8-8.4 mic. in diameter, shorter than wide; heterocysts hemispherical, yellowish-green, 7.5 mic. in diameter.

Unicellular green alga. Plate II., figs. 15, 16, 17. Soil samples 7, 19. Plant mass bright yellow green; both motile and resting bodies present; motile individuals elongate, 3.3-5.2 mic. in diameter, 5-11 mic. in length; flagella 2 in number at anterior end, slightly longer than body; resting bodies spherical, varying much in size, usually 10-12 mic. in diameter.

Pleurococcus vulgaris Meneghini. Plate II., figs. 13, 14, soil capillarity tube. Unicellular, spherical forms, single or gathered into clusters. Cells

Sample No. 11.—SOIL: clay loam, orchard. **GROWTH:** thick, dark blue-green scum covering the substratum and extending up the sides of flask; the growth on the quartz surface is tuberculate. **ALGAE: Phormidium tenue, Nostoc "A", Nostoc "B", Nostoc commune.**

Sample No. 12.—SOIL: sandy loam, garden patch. **GROWTH:** unfortunately this flask was broken before identifications of the algae were made; the plant mass extended completely over the substratum.

Sample No. 13.—SOIL: clay loam, alfalfa field. **GROWTH** an ample development irregularly expanded, forming a thick coating on the substratum. **ALGAE: Phormidium valderianum, Nostoc "A", Anabaena, "A", Nodularia harveyana.**

Sample No. 14.—SOIL: clay loam, orchard. **GROWTH:** plant mass spreading on the quartz and sides of flask as a thick, dark-blue, gelatinous mass. **ALGAE: Nostoc "A", Anabaena "A", Nodularia harveyana, Stigonema** sp.

Sample No. 15.—SOIL: sandy loam, orchard. **GROWTH:** abundant, blue-green, becoming yellowish-green due to the formation of gonidia. The minute dark green colonies between the quartz and sides of flask some distance below the surface are colonies of **Nostoc "B". ALGAE: Phormidium valderianum, Nostoc "B", Nostoc commune, Nodularia harveyana.**

Sample No. 16.—SOIL: red, sandy loam, orchard. **GROWTH:** quartz, water surface and sides of flask grown over with a blue-green gelatinous scum, becoming rust colored. **ALGAE: Phormidium tenue, Nostoc "B", Nostoc commune, Nodularia harveyana, Rivularia "B", Stigonema "A".**

Sample No. 17.—SOIL: raw soil, adobe hill. **GROWTH:** none.

Sample No. 18.—SOIL: hard, gravelly clay, beet field. **GROWTH:** light, blue-green scum covering the quartz surface. **ALGAE: Phormidium tenue, Anabaena "A", Rivularia "A", Stigonema** sp.

Sample No. 19.—SOIL: clay loam, beet field. **GROWTH:** about the second month after inoculation a slight green growth became evident, which later disappeared entirely. **ALGAE:** unicellular green alga.

Sample No. 20.—SOIL: clay loam, orchard. **GROWTH:** plant mass forming a thick, gelatinous layer over the whole substratum. Several darker or olive green masses here and there prove to be **Stigonema. ALGAE: Nostoc "B", Rivularia "A", Stigonema** sp.

Sample No. 21.—SOIL: sandy loam, orchard. **GROWTH:** the algal growth in this flask is the most vigorous of all. The sand, surface of water and sides of glass on all sides up to the neck of the flask are coated with a thick, mucous layer which was at first bright blue-green, but later became pale blue-green. This abundant development is due largely to **Nostoc "A". ALGAE: Nostoc "A", Nostoc "B", Nodularia armorica, Nodularia harveyana, Stigonema** sp.

Sample No. 22.—SOIL: river bottom silt, truck patch. **GROWTH:** substratum grown over with a dark, brownish-green mass. **ALGAE: Nodularia harveyana, Stigonema** sp.

It is difficult to see, from the limited number of samples examined, any relation between soil type and abundance of algal development. Algae were found to be present in a variety of soils, for example, sandy loam, clay loam, heavy clay, hard, gravelly clay, heavy adobe and river bottom silt. While in samples Nos. 8 and 19, a clay loam, there was slight growth, in samples Nos. 6, 11, 13, 14, and 20, all of similar kind of soil, the development was vigorous, in most instances totally covering the substratum in the

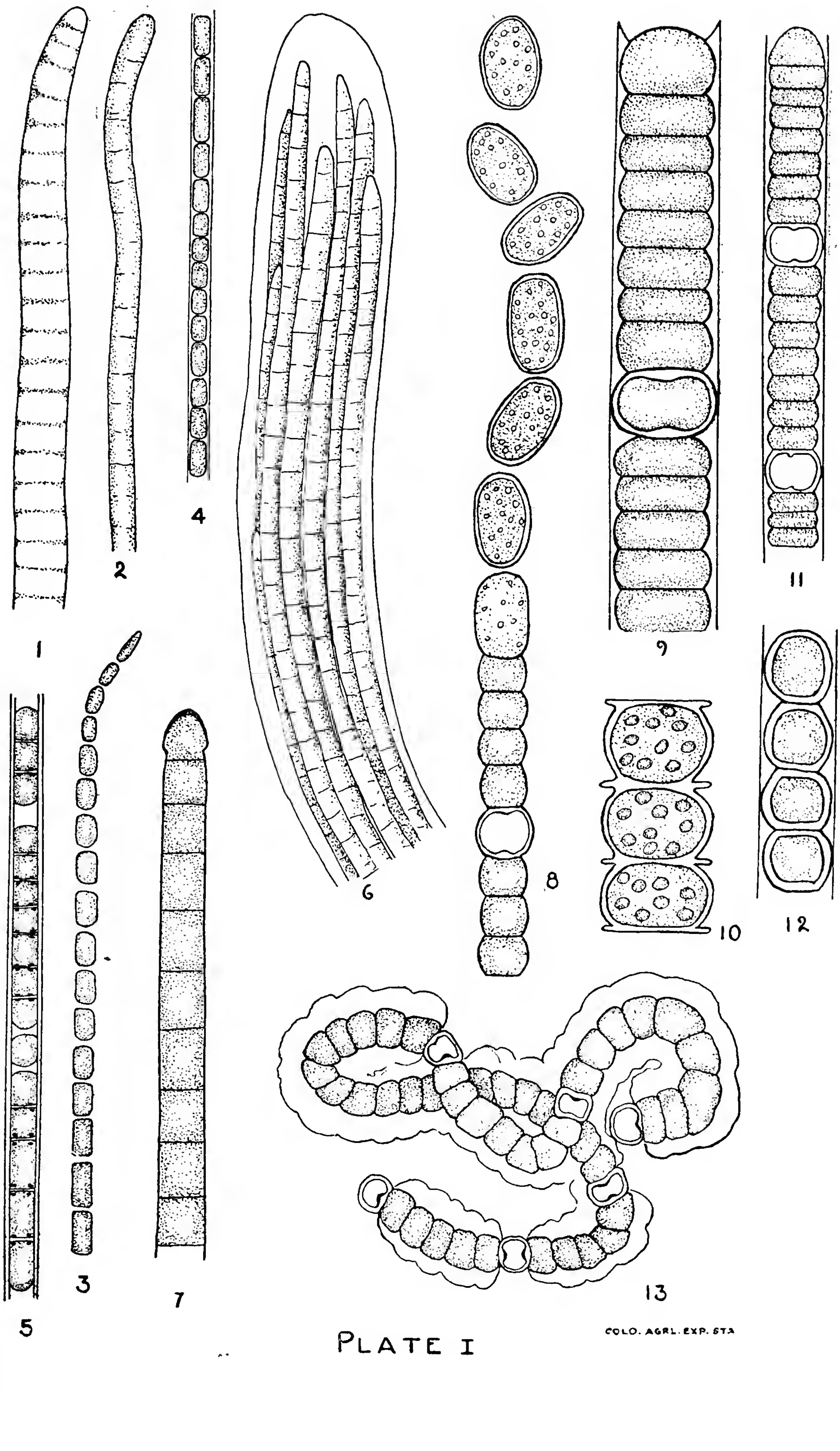


PLATE I

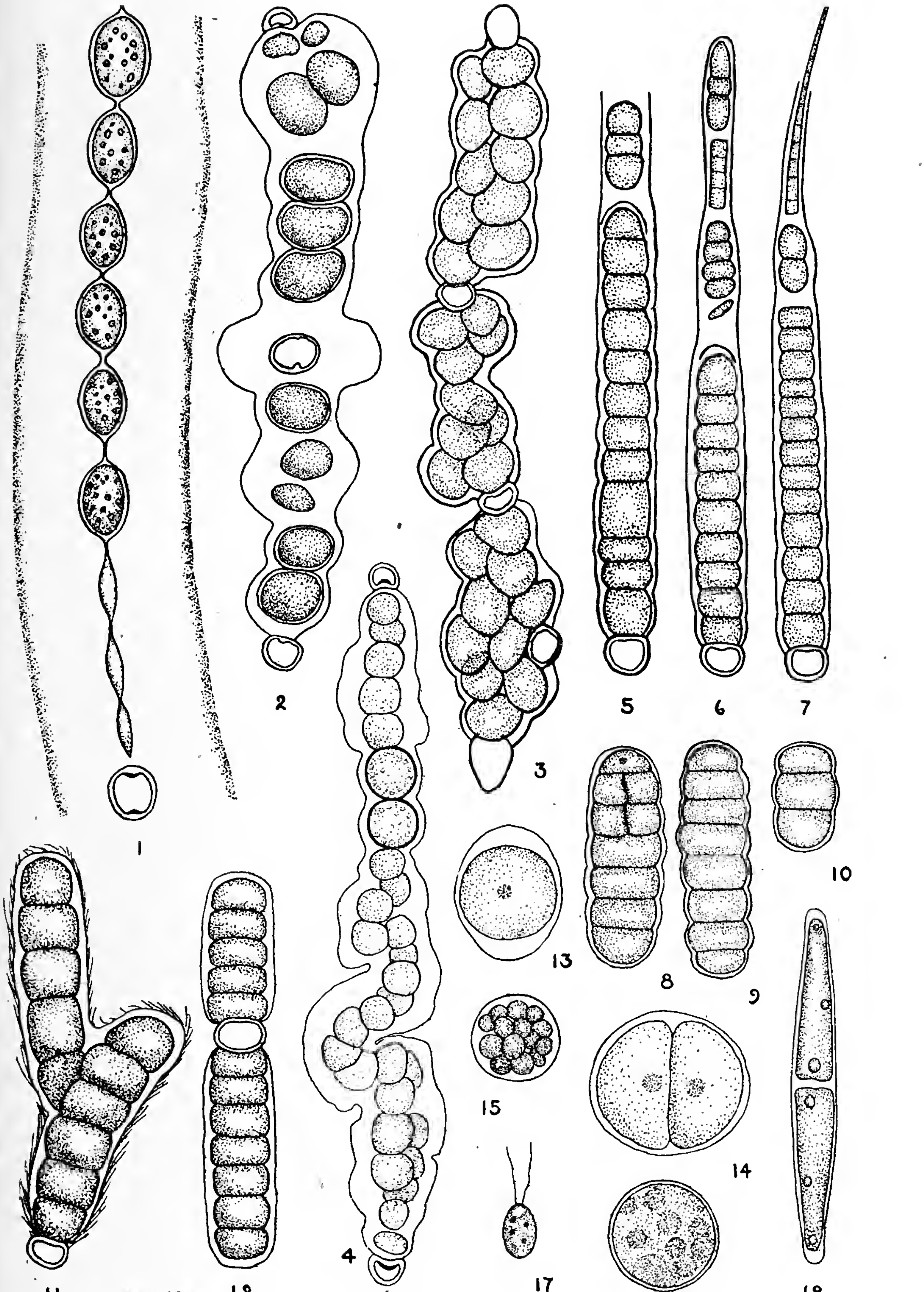
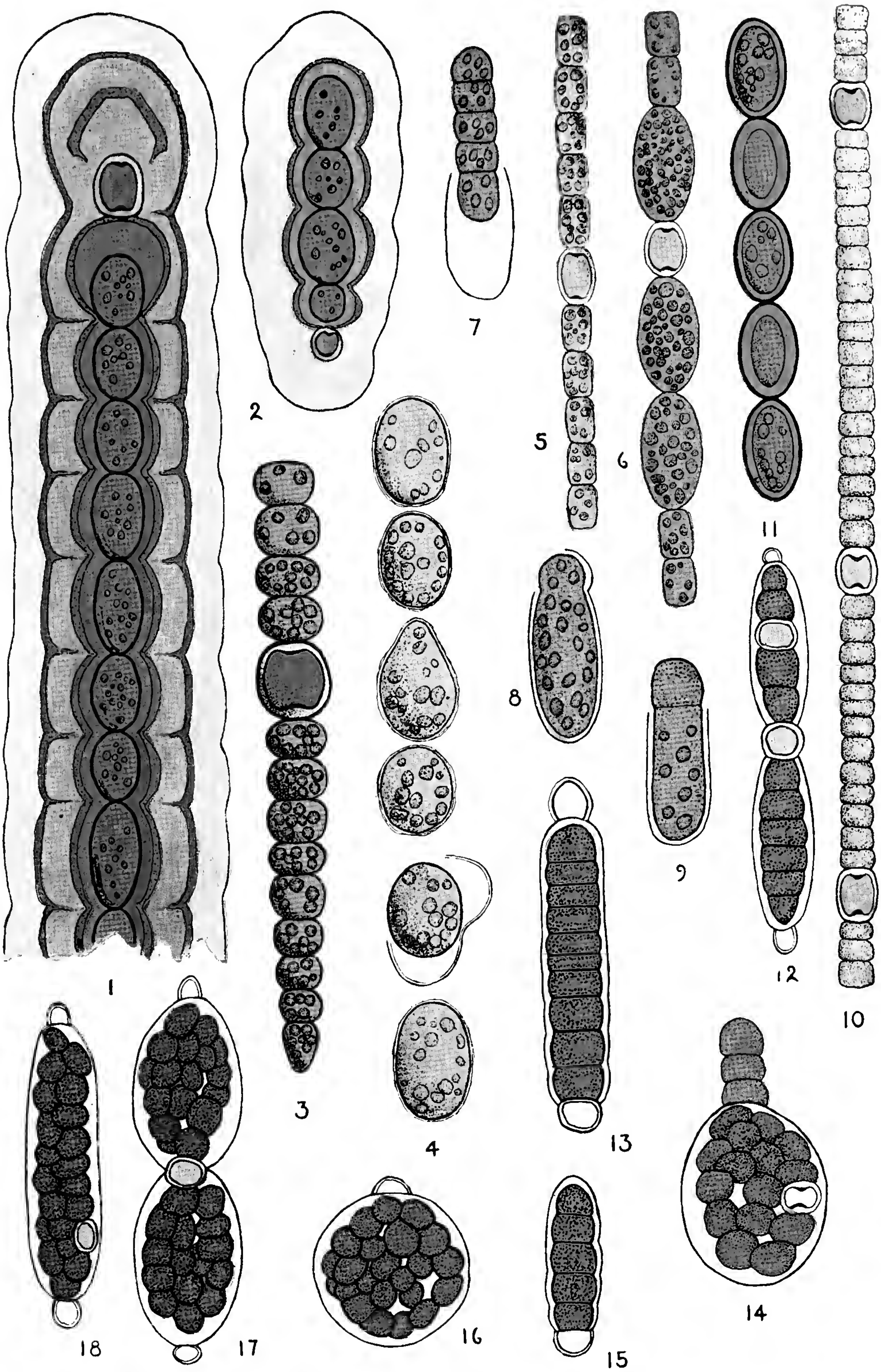
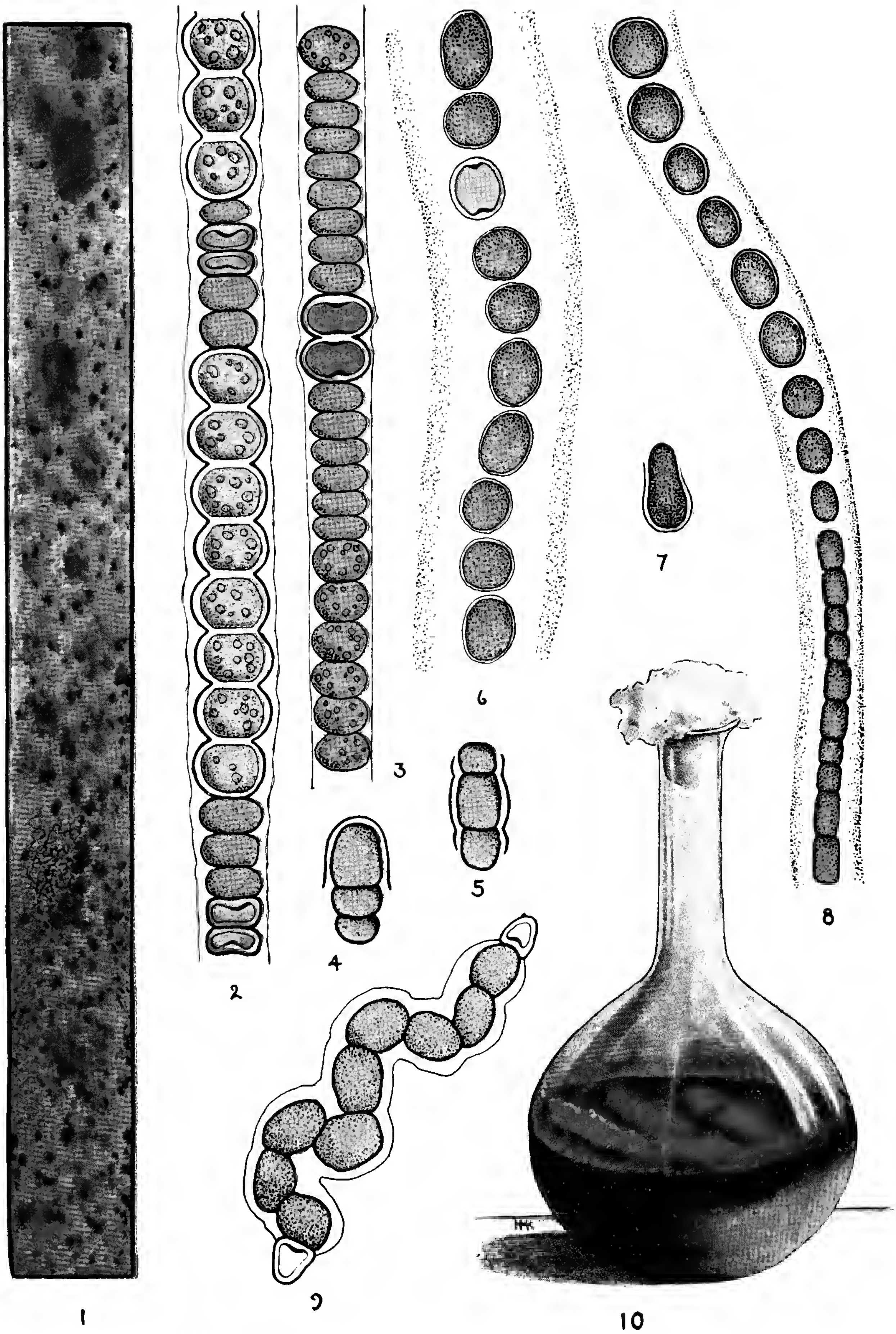


PLATE II.



COLO. AGRL. EXP. STA. NELLIE M KILLGORE

PLATE III.



COLO. AGRL. EXP. STA. NELLIE M KILLGORE

PLATE IV.

Table No. 1. Occurrence of Algae in Soil Samples.

Soil samples	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	Tube.
Anabaenia "A"	*	*			*					*			*	*				*					
Microcoleus vaginatus																							*
Navicula sp.										*													
Nodularia "A"									*														
Nodularia armorica																					*		
Nodularia harveyana									*				*	*	*	*					*	*	
Nostoc "A"	*									*	*			*							*		
Nostoc "B"	*	*		*		*		*		*	*				*	*				*			
Nostoc "C"				*																			
Nostoc commune	*	*			*			*			*				*	*							
Oscillatoria formosa																							*
Phormidium inundatum									*	*													
Phormidium subuliforme										*													
Phormidium tenuc				*						*	*					*		*					*
Phormidium valderianum													*		*								
Pleurococcus vulgaris																							*
Rivularia "A"		*					*											*		*			
Rivularia "B"																*							
Stigonema "A"																*							
Stigonema sp.	*						*		*					*				*		*	*	*	
Unicellular green alga							*																

flask. No algae appeared in sample No. 17, a raw soil from an adobe hill. Lack of mositure is undoubtedly an unfavorable factor in this case. In this connection, it should be said that cultivation, resulting in better aeration of the soil, is unquestonably favorable to increased activities of soil algae as well as other soil organisms. I can ascribe no reason for the non-occurrence or non-development of algae in Sample No. 3, a sandy loam from an orchard. It must be understood that the conditions under which all samples were grown were similar. It will be seen from Table I that the most prevalent species of algae in the 22 soil samples are *Phormidium tenue, Nostoc* "A", *Nostoc* "B", *Nostoc commune, Anabaena* "A", *Nodularia harveyana* and *Stigonema* sp. These not only occur in a greater number of samples, but they form, as a rule, the greater portion of the algal mass in the flasks.

DESCRIPTION OF SOIL CAPILLARITY TUBE.

Mr. V. M. Cone, irrigation engineer in this Station, called our attention to the appearance of an abundant growth of algae in some soil tubes used in testing capillarity. One of these was chosen for examination of the algae it contained.

The soil, a sandy loam, had been replaced foot for foot in a tube, 1 inch in diameter, making a 5-foot column. The tube was placed in the laboratory about one foot from a wall, hence the algae grew only on the lighted side. Unfortunately, no data were secured as to the date of appearance of the algae, although it is known that development was first conspicuous in the third foot of soil. Finally, the first two feet exhibited the greatest development. There was algal growth, however, in every foot of soil except the fifth. It is not to be understood by this that algae grow at a depth of 4 feet or even 1 foot below the soil surface. It is very probable that surface waters continually carry spores from upper to lower soil layers; there the spores remain quiescent for a short period, finally dying unless favorable conditions are restored either by natural or artificial means. Extreme precautions are necessary in taking samples to prevent contamination of one soil layer with another. Again, it is essential that the tubes or vessels containing the soil, be previously sterilized; dust sticking to the sides may be a possible source of contamination. By a glance at the soil capillarity tubes showing algae growing in the first four feet, one might gain the notion that they grew at such depths under field conditions. Yet when the above possible sources of contamination of the lower soil layers are considered, the appearance of algae in the lower layers of the tubes in question, looses its significance.

The algae occur in the capillarity tube in patches ranging in size from mere specks to areas one or more inches in diameter. (Plate IV., fig. 1). The patches are, for the most part, irregularly circular in outline. The yellowish-green to reddish areas are *Pleurococcus;* the dark-green areas are mostly *Oscillatoria formosa* and *Phormidium tenue;* the olive-colored colonies are *Phormidium tenue*. Here and there are interlacing masses of dark-olive or black threads, visible to the naked eye; these are *Microcoleus vaginatus.*

DISCUSSION.

It is well known that many different kinds of algae inhabit the soil. As a rule, it is generally understood that such a soil is necessarily muddy or very moist. In such cases the algal growth is visible to the naked eye, forming on the soil a characteristic plant mass. The soils from which the foregoing 22 samples were taken were, with the exception of No. 17, just ordinary cultivated soils, with a varying water content. The samples were representative of soils in rather widely separated localities in Colorado. At the time of collection, during October, 1911, no algae were noticeable on the soil surface; furthermore, one would not ordinarily think of such soils as being moist enough to support an algal flora. And yet, cultures from these soils, with but two exceptions, samples Nos. 3 and 17, revealed the presence in them of a considerable number of species of algae and a healthy development of these.

It is unquestionably true that during favorable seasons of the year, there is developed in certain of our soils a rich growth of algae. This is probably confined to the surface layers. To what depth algae extend will depend largely upon the texture of the soil, its ventilation and methods of cultivation. It is probably true, however, that the top crust of soil, the first inch or less, is usually too dry to favor algae. Irrigation may play a part in determining the distribution of soil algae. Whether or not our unirrigated soils possess an algal flora remains to be found out. But it can be readily understood how the turning of water on to an unirrigated area would introduce from the streams an abundance of algae. Although evidence is still insufficient, it is within the bounds of reason to believe, from these preliminary investigations, that all of our ordinary cultivated soils, especially those under irrigation, are far richer in algae than is usually supposed to be the case. More than this, we venture to assert that soil algae play a far more important role in soil fertility than is generally believed. Unquestionably, the organic matter furnished by soil algae must be reckoned with as an important source of energy for the nitrogen fixing organisms.

SUMMARY.

Algae occur abundantly in many cultivated soils of Colorado.

Twenty-one different species of algae were found in the soils examined.

With but two exceptions, all the species found belong to the blue-green algae (Cyanophyceae.)

The family Nostocaceae is best represented.

There is a predominance of forms possessing thick, gelatinous sheaths.

The algae occur in a variety of soil types, for example, sandy loam, clay loam, heavy clay, hard, gravelly clay, heavy adobe and river bottom silt.

The most prevalent species of algae are *Phormidium tenue, Nostoc spp., Anabaena sp., Nodularia harveyana and Stigonema sp.*

In many Colorado soils, algae may be considered as an important source of energy for *Azotobacter*.

EXPLANATION OF PLATES.

PLATE I.

Fig. 1. Oscillatoria formosa.
Fig. 2. Phormidium inundatum.
Fig. 3. Phormidium subuliforme.
Fig. 4. Phormidium tenue.
Fig. 5. Phormidium valderianum.
Fig. 6. Microcoleus vaginatus, filaments within sheath.
Fig. 7. Microcoleus vaginatus, single fliament.
Fig. 8. Nostoc "A", small form
Fig. 9. Nodularia armorica.
Fig. 10. Nodularia armorica, gonidia.
Fig. 11. Nodularia harveyana.
Fig. 12. Nodularia harveyana, gonidia.
Fig. 13. Nostoc commune.

PLATE II.

Fig. 1. Stigonema "A", gonidia (?).
Figs. 2, 3, 4. Stigonema sp
Figs. 5, 6, 7. Rivularia "A".
Figs. 8, 9, 10.. Rivularia "A", young forms.
Figs. 11, 12. Rivularia "B", young forms.
Figs. 13, 14. Pleurococcus vulgaris.
Fig. 15. Unicellular green agla, resting form, the contents dividing up into motile bodies.
Fig. 16. Unicellular green alga, resting stage.
Fig. 17. Unicellular green alga, motile body.
Fig. 18. Navicula, a diatom.

PLATE III.

Figs. 1, 2. Stigonema "A".
Fig. 3. Nostoc "A", vegetative filament.
Fig. 4. Nostoc "A", gonidia.
Fig. 5. Anabaena "A", vegetative filament.
Fig. 6. Anabaena "A", filament producing gonidia.
Figs. 7, 8, 9. Anabaena "A", germinating gonidia.
Fig. 10. Nostoc "C", vegetative filament.
Fig. 11. Nostoc "C", gonidia.
Figs. 12, 13, 14, 15, 16, 17, 18. Stigonema sp., developmental forms.

PLATE IV.

Fig. 1. Soil capillarity tube a 10-inch section from the 7th to 17th inch.
Fig. 2. Nodularia "A", filament producing gonidia.
Fig. 3. Nodularia "A", vegetative filament.
Figs. 4, 5. Nodularia "A", germinating gonidia.
Fig. 6. Nostoc "B", gonidia.
Fig. 7. Nostoc "B", germinating gonidium.
Fig. 8. Nostoc "B", vegetative cells and gonidia.
Fig. 9. Nostoc "B", vegetative cells and gonidia.
Fig. 10. Flask culture of soil sample No. 1.

R R Hudelson

ulletin 185 September 1912

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

SOME POULTRY DISEASES

By B. F. KAUPP

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1912

The Agricultural Experiment Station

FORT COLLINS, COLORADO

The State Board of Agriculture

		Term Expir
HON. A. A. EDWARDS, President	Fort Collins,	1913
HON. R. W. CORWIN	Pueblo,	1913
HON. F. E. BROOKS	Colorado Springs,	1915
HON. J. L. BRUSH	Greeley,	1915
HON. J. C. BELL	Montrose,	1917
HON. E. M. AMMONS	Littleton,	1917
HON. T. H. EHRHART	Centerville,	1919
HON. CHAS. PEARSON	Durango,	1919

GOVERNOR JOHN F. SHAFROTH, Ex-Officio.
PRESIDENT CHAS. A. LORY, Ex-Officio.

Executive Committee in Charge

A. A. EDWARDS, Chairman

J. L. BRUSH E. M. AMMONS

Station Staff

C. P. GILLETTE, M. S. Director .... Entomologis
W. P. HEADDEN, A. M., Ph. D. .... Chemis
G. H. GLOVER, M. S., D. V. M. .... Veterinaria
W. G. SACKETT, B. S. .... Bacteriologis
ALVIN KEYSER, A. M. .... Agronomis
J. O. WILLIAMS, B. S. A., U. S. Expert-in-Charge .... Horse Breedin
E. R. BENNETT, B. S. .... Horticulturis
B. O. LONGYEAR, B. S. .... Botanis
G. E. MORTON, M. L., B. S. A. .... Animal Husbandma
E. B. HOUSE, B. S., (E. E.), M. S. .... Irrigation Enginee
V. M. CONE, B. S. .... Irrigation Investigation
R. E. TRIMBLE, B. S. .... Assistant Irrigation Investigation
P. K. BLINN, B. S. .... Rocky Ford, Alfalfa Investigation
EARL DOUGLASS, M. S. .... Assistant Chemis
S. ARTHUR JOHNSON, M. S. .... Assistant Entomologis
B. F. KAUPP, M. S., D. V. S. .... Veterinary Pathologis
GEORGE P. WELDON, B. S. .... Assistant in Entomolog
C. L. FITCH .... Potato Investigation
W. E. VAPLON .... Poultry Investigation
J. W. ADAMS, B. S. .... Cheyenne Wells, Supt. Plains Sub-Station
ELLWOOD D. ROOD, B. A. .... Assistant Chemi
PAUL S. JONES, B. S. .... Assistant Irrigation Investigation
W. W. ROBBINS, M. A. .... Assistant Botanis
S. VAN SMITH, B. S. .... Assistant Horticulturis

Some Poultry Diseases Met With in Colorado

By B. F. KAUPP

When we consider the price of individual birds of common stock, most f us are apt to give little thought to the magnitude of the poultry industry f the United States or of our own State.

With the increase in value of birds, particularly pure bred, some of hich are worth as much as the average dairy cow, it is evident that more ttention to their diseases is needed.

It is estimated that the poultry population of Colorado is approximately ,700,000, of which about 2,500,000 are chickens, 100,000 turkeys, 50,000 ucks, and 50,000 geese and other birds.

It is estimated that 15,000,000 dozen eggs and 25,000,000 pounds c hickens are consumed in Colorado annually. Of this quantity consumed, is probable, according to the estimates made by Mr. W. E. Vaplon, of the oultry Department of this Station, that only about one-half is produced ithin the State. He further estimates that there is imported into the State nnually about $4,000,000 worth of eggs and poultry products. It will thus e seen that there is excellent opportunity, in this State, for increased pro- uction of this kind of foods.

With these facts before me, and with the additional stimulus of frequent equests for information on diseases of poultry, I undertook the task of udying these diseases, and have been greatly aided by the Poultry Depart- ent of the college and others, particularly local poultry raisers. The present aper gives a brief account of this work. I have endeavored to give illus- ations which will aid poultry people to recognize disease conditions and mptoms, and to understand the treatment of sick birds and the means of adicating contagion when such exists.

Plate I is a drawing made by Mr. W. E. Landt, from a healthy hen, epared in the laboratory for the purpose. It is hoped that this object lesson, ith the explanation which will be found on the opposite page, will be helpful a better understanding of the anatomy of the hen.

The paper includes parasitic and other diseases, as well as a brief discus- on of methods of detecting hens with diseased ovaries, and non-layers due other causes. The non-laying hen is too expensive to keep.

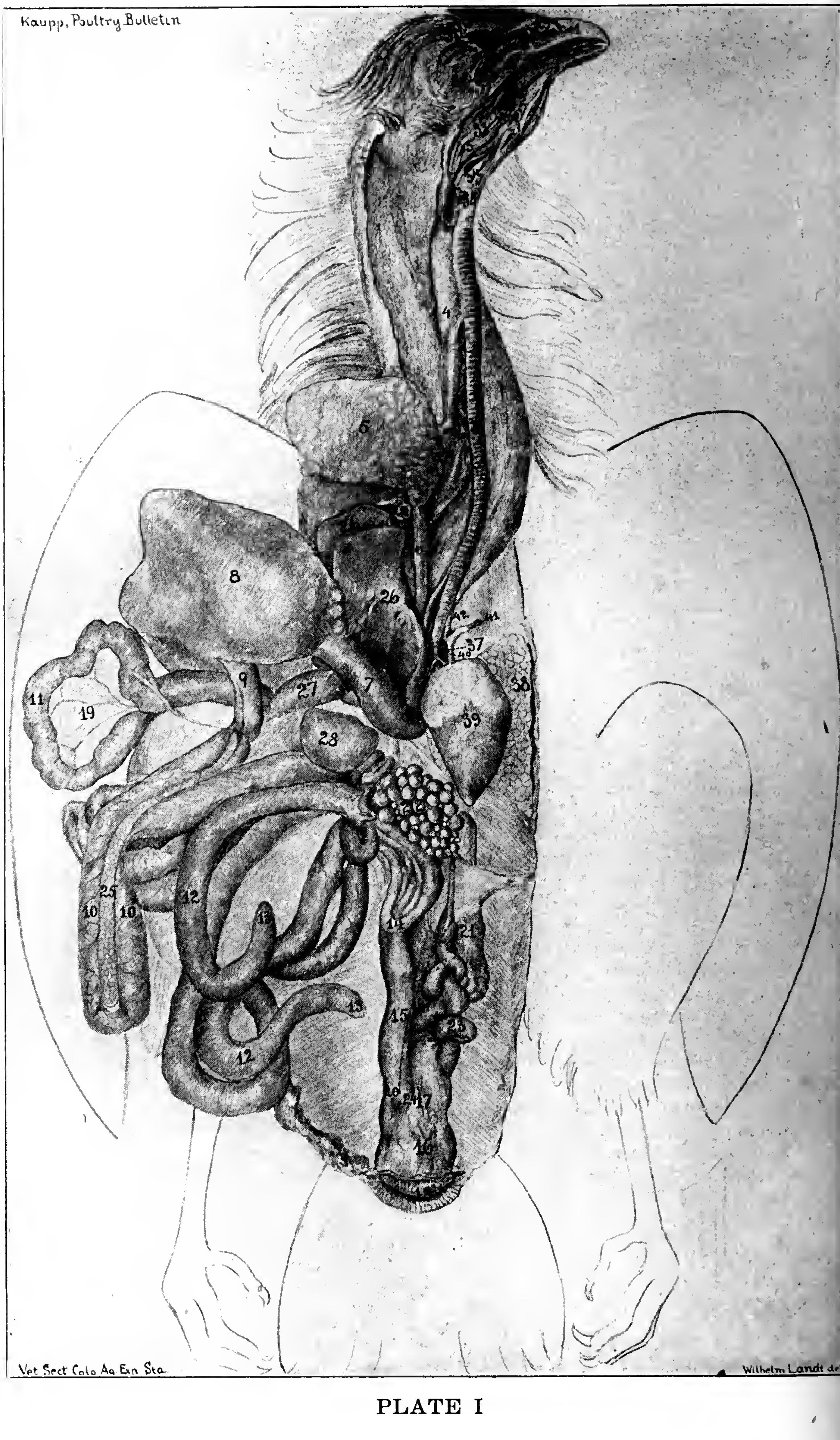

Kaupp, Poultry Bulletin
4
6
8
26
37
38
9
27
7
11
19
39
28
25
10
10
12
13
14
21
13
15
12
16
Vet Sect Colo Ag Exp Sta
Wilhelm Landt del.

PLATE I

THE NORMAL VISCERAL ANATOMY OF THE HEN

Digestive and Genito-Urinary Tracts

At 1 is the beak; 2, the tongue; 3, the pharynx (throat), through which e food passes to the oesophagus or gullet (4); 5, the crop, a storehouse or anary where the food accumulates during feeding. From the crop the od passes through the second portion of the oesophagus; 6, a part of the dominal organs laid over to the left so that the proventriculus or true omach (7), lays over the liver (26). The second portion of the oesophagus pties into the proventriculus in whose walls are found secreting glands nilar to those in the true stomach of higher animals. The food, after being aked in this fluid, passes into the gizzard (8), a muscular organ, where e grain and other coarse particles are ground with the aid of grit by the ntractions of the muscular walls. From here the food passes into the odenum (9). At 10 is shown the loop of the first portion of the small estines in which is located the pancreas (25), which pours its digestive cretion into the small intestines. At 11 is represented the floating portion the small intestines, supported by the mesentary, a web-like membrane 9) carrying the blood vessels in their course to that part. Numbers 12 d 13 represent the caeca or two blind guts, the blind extremities being at . These empty into the balance of the intestine at 14. At 15 is shown e rectum or straight gut, which is joined by the egg sac (23) at 17, forming e cloaca or common pouch (16). At 20 the ureter from the kidney (21) pties the secretion from that gland into the rectum. The cloaca com-nicates through the anus (18) with the external world. The right ovary rishes as the hen develops so that only one ovary, the left, remains, which ndicated by 22. The egg canal (23) has a muscular wall for the purpose forcing the egg along as it develops; it is also provided with glands which in the formation of the albumin, egg shell, etc. This sac at its anterior l receives the ovum (yolk) from the ovary as soon as it is mature. At is seen the liver, which has been turned back and is crossed by the pro-ntriculus (7). At 27 is the gall bladder, where the bile (liver secretion) stored up till active digestion takes place in the small intestines when it is ured out into the latter. At 28 is the spleen, a blood forming organ.

The Respiratory Tract and Heart.

The air passes from the nostrils (29) through the nasal passage, in-lated by the dotted line, enters the pharynx through the opening (posterior res) at 33; 32 is the turbinated bone of the right nasal chamber; 30, the ntal, and 31, the maxillary (**infra-orbital**) sinuses, analagous to the same the higher animals. The air passes through the pharynx (3) into the ynx (35) through the opening or glottis (34). From the larynx the air sses through the trachea or windpipe (36). At 37 there is noted a flat-ed portion, the false larynx, provided with vocal cord-like structures— organ of sound. Just below this point will be noted the bifurcation anching) of the trachea to the lungs. At 38 is the left lung. The heart is led down so that these parts are brought into view. At 39 is the heart; the main artery (aorta) leading from it; 42, its branch supplying the k and head; and 41, the left wing.

PARASITIC DISEASES

LICE

There have been four genera of lice studied in this laboratory, namely, **nopon, Goniodes, Goniocotes, and Lipeurus.**

THE LARGE HEN LOUSE—**Menopon biseriatum.** This is the largest se found upon the hen. It is about one-twelfth of an inch in length, light color, with mouth parts arranged for mastication as illustrated in Fig. 2-a. e free extremities of the legs are provided with hooklets which aid in hold-on.

The smaller variety of this genus, **Menopon pallidum,** also has be studied, but is far less common in this state. This louse is found on you and old chickens.

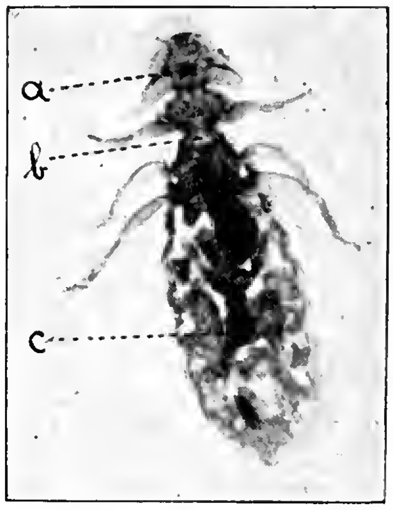


Fig. 2.

Figure 2.—**Menopon biseriatum** (from a hen), greatly enlarged; a, head. whi is provided with mouth parts; b, thorax provided with three pairs of legs; abdomen. .

THE TURKEY LOUSE—**Goniodes stylifer.** This louse is found turkeys and is thicker than the one just described. Like it, the mouth pai are arranged for mastication. It is illustrated in Fig. 3.

Lipeurus infuscatus. This is another louse that may infest chicker A study of Fig. 5 shows it's mouth parts and legs similar to the other lic Its general shape is different. It is not so common as the large hen lou

THE PIGEON LOUSE—**Lipeurus baculus.** This is a long, slender, lig colored louse with mouth parts arranged for biting, and its legs are pı vided with hooklets which aid it in holding to the feathers. It is illustrat in Fig. 7.

Goniocotes hologaster.—This is still another louse that sometimes i fests chickens. In many respects it resembles the louse of the turkey, but is a distinct species. It is illustrated in Fig. 6. Like the others, its mou parts are arranged for biting.

LIFE HISTORY.—The females are slightly larger than the males. T females lay oval, white, or whitish-yellow eggs (nits) and securely ceme them to the barbs of the feathers. This is illustrated in Fig. 4. The li hatch in from ten days to two weeks in warm weather, by breaking open t ends of the eggs. The young have much the same shape as the adults, but a usually lighter in color. The males are usually less numerous than t females.

CONDITIONS PRODUCED.—Chicks hatched in the incubator are fr from lice and stay free until placed with lousy hens or chicks, or in lou quarters. Lice produce much irritation. The effect of large numbers up chickens is quite marked. The hens scratch and pick at the feathers, sho signs of being drowsy, may refuse to eat, and in growing birds, body d velopment is interfered with. Young chicks often sit around, moping, wi wings hanging down, and finally in a week or two may die. For this reaso brooder chicks thrive better, grow faster, and are free from many ailmen than chicks hatched by the hen. It has been said that a lousy bird will ha more of a tendency to dust than one not lousy.

The effect upon the older birds is not so severe as upon younger one but it is shown in condition of flesh and low production of eggs. The irrit tion is sometimes so severe that hens desert their nests. Their combs ma become dark.

Birds unable to rest day or night become emaciated and die.

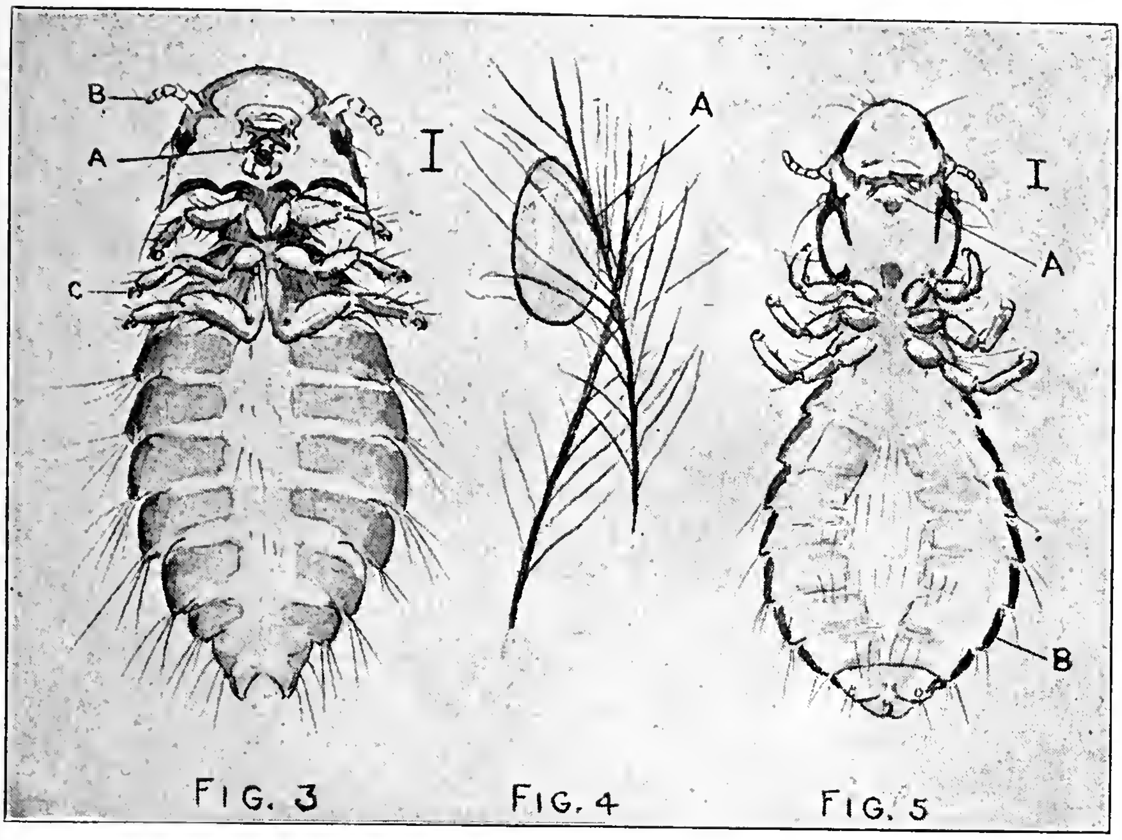


Figure 3.—**Goniodes stylifer,** (from a turkey), ventral view; a, mouth parts; ıntennae; c, legs, provided with hooklets on the free extremity of the last ments. To the right of the head is a line indicating the actual size of the se.

Figure 4.—An egg of the turkey louse. The egg is cemented to the barb of feather at a.

Figure 5.—**Lipeurus infuscatus,** (from a hen), female; a, mouth parts; b, ab- ıen.

To find the lice, part the feathers; the lice will be found running over skin or bases of the feathers. A favorite location for the lice is under wings where the temperature is warmer, although they may be found any part of the body.

Lice may be found at all seasons of the year, but are more common in hotter months of July and August. In these months, conditions are more orable to their propagation.

TREATMENT OF INFESTED BIRDS AND ERADICATION OF LICE.— chickens should be dusted with insect powder (pyrethrum) or pyrethrum sulphur equal parts, or a combination of these with tobacco dust, which be secured from a tobacco factory. This powder can best be dusted ong the feathers by aid of a powder gun, which can be secured at a drug e. It can also be placed in the dusting places. In ridding the birds of , it will be well to keep in mind that frequent dusting with powder will necessary, as the eggs or nits are not all likely to be killed by the powder. ther means of ridding chickens of lice is to dip them in a five per cent ition of Creolin, Kreso dip, or the same per cent of Zenoleum.

After the flock has been freed from lice, care should be exercised that infestation is not brought about by the introduction of lousy birds. The house in which lousy birds are located should be thoroughly and fre- ntly cleaned and the walls whitewashed. The whitewash should contain t some parasiticide as carbolic acid five per cent, creolin five per cent, or osive sublimate one part to a thousand. The roosts should be scrubbed 1 boiling water, and after drying in the sun, should be saturated with osene. If the hen house be tightly closed and thoroughly fumigated with hur, it will aid in destroying lice or other parasites that may be in the ks and crevices and difficult to reach with the whitewash. The litter straw should be removed from the nests and burned, and the nests should lisinfected and new straw provided. Before refilling with straw, an inch laked lime should be placed in the bottom.

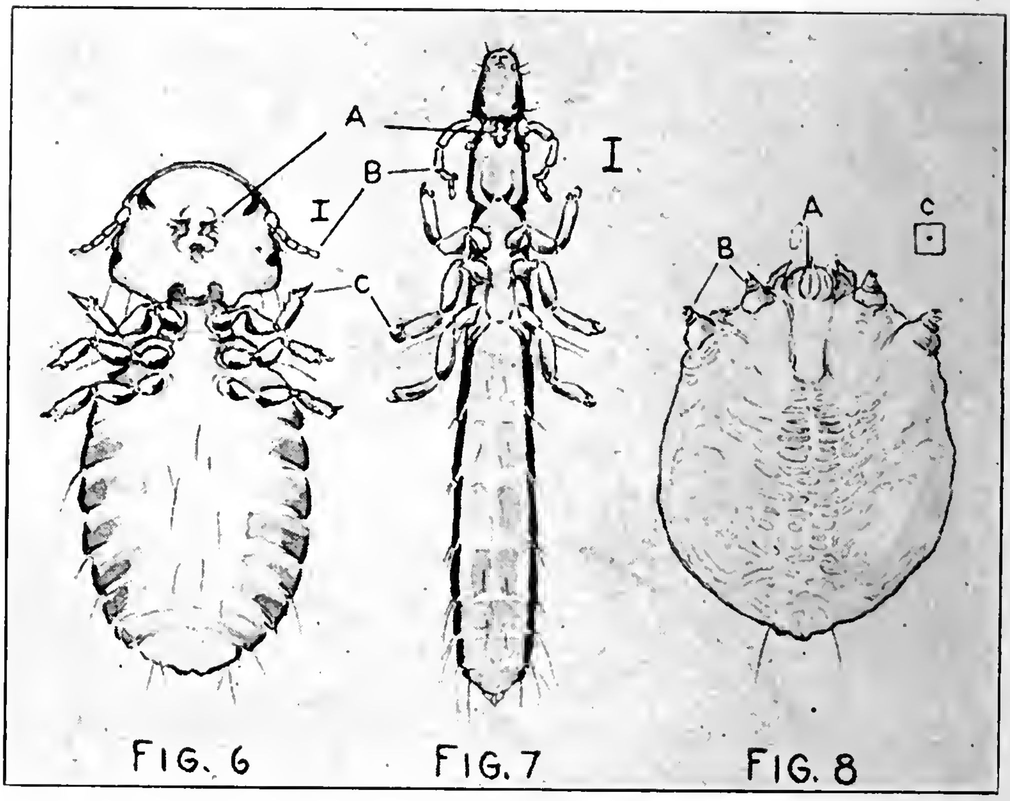


Figure 6.—**Goniocotes hologaster,** a louse (from a hen), ventral view; a, mout parts; b, antennae; c, hooklets on free extremity of leg. The small mark to th right indicates the natural size.

Figure 7.—**Lipeurus baculus,** from the pigeon. Letters indicate same parts a in Fig. 6.

Figure 8.—**Sarcoptes mutans,** variety **gallinae,** the scab parasite producin scaly legs in the hen. a, the mouth parts with which it wounds the skin an causes serum to exude; b, the short legs; c, the small dot indicates its natural siz

MITES

Scaly Legs (Scabies)

This disease is caused by a parasite (**Sarcoptes mutans** variety **gallinae**) which belongs to the same family as the scab parasite of cattle, horses, shee hogs, cats and dogs. The parasite is often called a mite, owing to its sma size. In Fig. 8 its size is indicated by a small mark, to the right of the draw ing of the parasite, which is magnified 100 times. In the drawing, note th short, strong, stubby legs, and the mouth parts arranged for biting.

CONDITION PRODUCED.—This parasite attacks chickens, turkeys, an cage birds, but the writer has not observed it on geese and ducks. It attack the unfeathered portion of the leg above the foot and often the top portion o the toes. The minute parasite crawls under the scale of the legs and ther irritates the tissue, for the purpose of obtaining food with the mouth part as pictured in the drawing referred to above. As a result of this irritatior a vesicle or small blister appears. The blister, practically microscopic in size after a time ruptures, the serum dries, and makes a minute scale. As th parasites become more numerous, by continually irritating the parts, the cause a piling up of scab and the leg presents an appearance like Fig. 9. Th parasites can be found as minute white specks in the serum between the sca and leg. Both legs are usually affected at the same time. Itching is presen and the birds may be noted to pick at the parts. Itching is more intense a night. The bird may become weak, stop laying and even may die.

LIFE HISTORY.—The female mite lays her eggs under the scabs where in about ten days, if conditions are favorable, they hatch. The larvae (young mites) now moult several times and finally arrive at the mature stage.

The tearing off of scabby patches favors the escape of the parasite, and other birds become infested by being placed in quarters occupied by infested birds, or by introducing an infested one into the flock.

TREATMENT.—Soak the scabby patches with soapy water and the

Fig. 9

Figure 9.—Photograph of scaly legs (scabies), natural size. This is due to the ıb parasites, illustrated in Fig. 8. a, shows large scabby masses piled up; b, the ales of the legs which have been forced out of place by the gradually forming ıterial, due to dried serum and accumulating dirt as a result of the irritation used by the scab parasite.

ıbs can be easily removed. After removal of all scabs possible, with a nail ush, scrub thoroughly with kerosene or a kerosene emulsion made as llows:

Kerosene, ½ gallon; common soap, 2 ounces; water, ¼ gallon. Dissolve e soap in boiling water; add this solution boiling hot to the kerosene, and r with an egg beater. When ready to use, take one part of the emulsion d add to it nine parts of water.

The lime and sulphur dip used warm and scrubbed thoroughly under the ıles is very effective. The lime and sulphur dip is made as follows:

Unslaked lime, ⅓ pound; sulphur, 1 pound; water, 4 gallons. This xture should be boiled for two hours. The lime acts as a solvent for the lphur.

Other antiseptics which are parasiticides may be used. Isolate diseased ·ds and avoid reinfestation by the introduction of new birds to the flock.

CHIGGER, **Trombidium holosericeum**

DESCRIPTION.—The chigger is a very small mite, as shown by th mark by the side of Fig. 10. The body, oval in shape, is provided, in th adult state, with four pairs of legs. The terminal end of the leg is provide with two hooklets which enable it to hold to objects and to move abo easily. It is provided with conical shaped mouth parts illustrated in Fig. 1

LIFE HISTORY.—The mites lay their eggs in cracks and crevices an filth of the hen houses. The eggs hatch in a few days, if conditions are favo able, and multiply very rapidly in the hotter months of summer, July an August.

CONDITIONS PRODUCED.—By means of its mouth parts the mi wounds the skin and sucks blood. When engorged it is blue to red color, du to the blood taken into its digestive tract. During the summer of 1911, th writer studied one flock of chickens in which the infested birds showed sym toms similar to birds infested by lice. The hosts became unthrifty and cease laying and the setting hens with feathers ruffled, deserted their nests an many died. Many were found dead under the roosts in the mornings. Exam ination of the nests, roosts and the birds revealed millions of the parasite This was in the month of August.

TREATMENT.—Give the same treatment as for lice. Absolute clea liness, and plenty of kerosene on the roosts and air slaked lime on floors an in nests is essential.

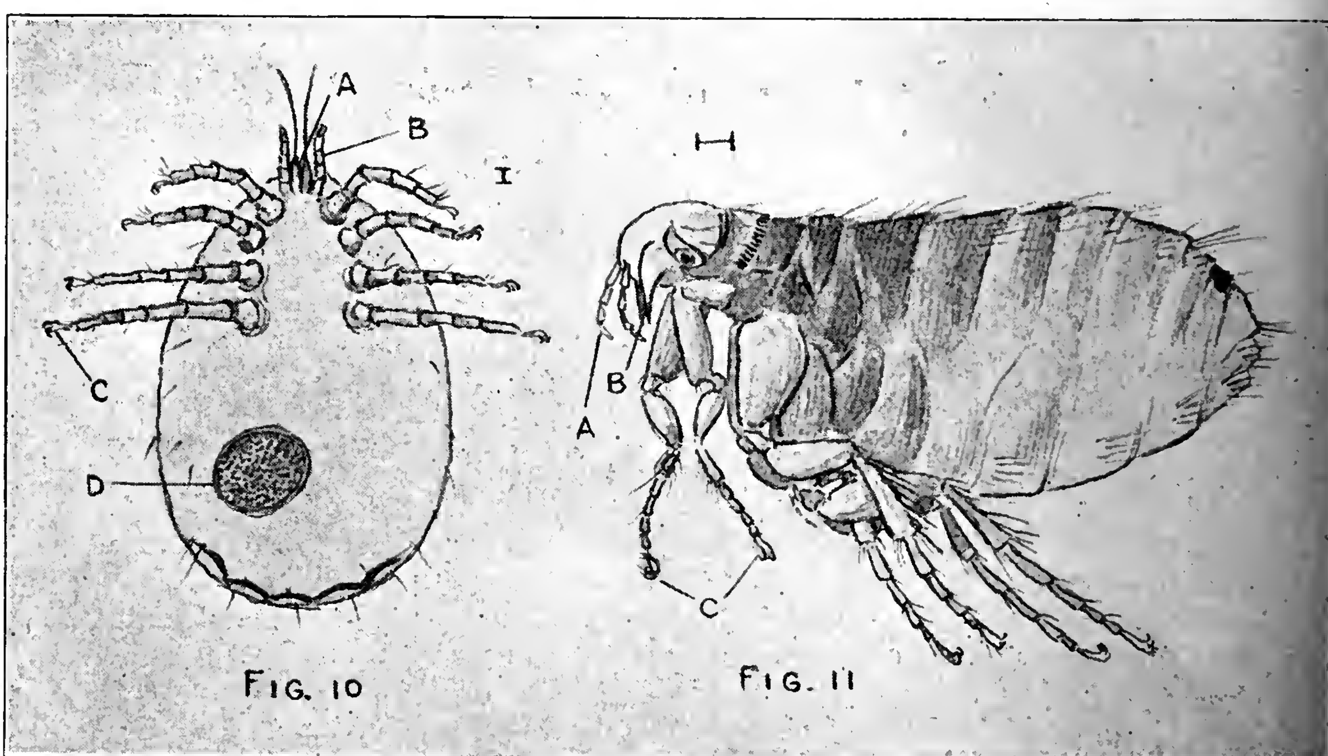


Figure 10.—The chicken chigger, **Trombidium holosericeum**, ventral view. a mouth parts; b, palpi; c, hooklets on the free extremity of leg, with which th mite holds on; d, uterus filled with eggs. The small mark to the right indicates it natural size.

Figure 11.—The chicken flea, **Pulex avium**. a, antennae; b, stylette wit which it wounds the skin; c, hooklets on free end of legs. Note the stout leg which give the flea great power to jump.

FLEA

THE CHICKEN FLEA (**Pulex avium**)

DESCRIPTION.—This flea resembles, to some extent, the fleas of dogs, s and man. A microscopic study shows it to be a distinct species for ds. It is illustrated in Fig. 11. It is provided with jointed feelers (anten-), mouth parts for wounding the skin and sucking blood, and legs pro- ed with hooklets on the free extremities. The posterior legs are longest, ing them great power to jump. The body is flattened laterally and is wn in color.

LIFE HISTORY.—The female lays about twenty brown, oval eggs, in filth of the hen house, where they hatch in a few days, if the weather be rm. They are now in a worm-like stage and practically microscopic in . They develop rapidly into the adult stage. (Illustrated in Fig. 11.)

CONDITION PRODUCED.—One outbreak of flea infestation was studied ring the past summer. The presence of the fleas was first noticed by the ects getting upon persons whenever they went into the hen house. In- tigation showed the fleas in large numbers. It is noteworthy in this out- ak that all lice and chiggers disappeared from the flock. Although these asites irritate the skin and suck blood, no effect upon these birds was ed by the owner. Perhaps it was because the birds were largely out of rs. Symptoms similar to those produced by lice have been recorded.

TREATMENT.—Dipping the hens in five per cent Kreso Dip rid these ds of fleas, and the premises treated as indicated under "Lice" were rid the pest.

LARGE ROUND WORM, (**Ascaris inflexa**)

DESCRIPTION.—This is quite a common worm, found in the first por- n of the intestinal tract of chickens. It is round, white or yellowish-white color, and from one to two inches in length. Its natural size is illustrated Fig. 12. The male is smaller than the female, and it has a complete diges- tract and robs the bird of nutrients. Ten per cent of the birds examined the laboratory during the past three years have been found to be in- ed by this worm.

LIFE HISTORY.—This worm reproduces by laying eggs, microscopic in , which pass out with the feces. Other birds become infested by drinking eating food contaminated or soiled with the excrement of the infested ds. In this way, one infested bird introduced into the flock, may spread disease to all birds of the flock.

CONDITION PRODUCED.—A few worms may produce no noticeable ct upon the health of the bird. At times they are found in large masses, tructing the bowel and causing constipation, diarrhoea, catarrh of the vel and possibly, irritation sufficiently to cause inflammation. There may a loss of appetite, unthrifty condition, unkept appearance of plumage, l, languid and droopy wings, emaciation, loss of color to comb and mucous nbranes; and death may occur in a few weeks.

Careful examinations by opening the digestive tracts of the birds killed food purposes keeps one informed as to whether parasitism is present in flock. If there are worms present in the birds, one will occasionally note t worms are passed in the feces. Reports have been made that worms wering this description have been found in eggs. By referring to Fig. will be seen that a live worm, possessing power of movement as these rms do, passing into the cloaca (No. 16) from the rectum (No. 15) can s up the egg canal (No. 23) and thus be incorporated in the albumen of egg, as it is formed around the yolk. It is not beyond a possibility that following described worm (**Heterakis papillosa**) may, at times, do the e thing. These conditions are probably rare.

TREATMENT.—It is necessary to keep the yard and hen house clean. e should be scattered on the floor and about the yard, and the birds should watered and fed from a clean though made for the purpose and disinfected ly and so constructed that birds cannot step into it. If possible, birds uld be moved occasionally upon new ground. The parasite eggs in the excrement removed from the hen house may be destroyed by mixing with u slaked lime.

The birds may be given one teaspoonful of turpentine followed by tablespoonful of olive oil. If the crop be full, the dose of turpentine shou be doubled. Five to ten grain doses of powdered araca nut is good treatme and can be mixed with the soft feed, and fed from a clean trough. The are nut also acts as a cathartic.

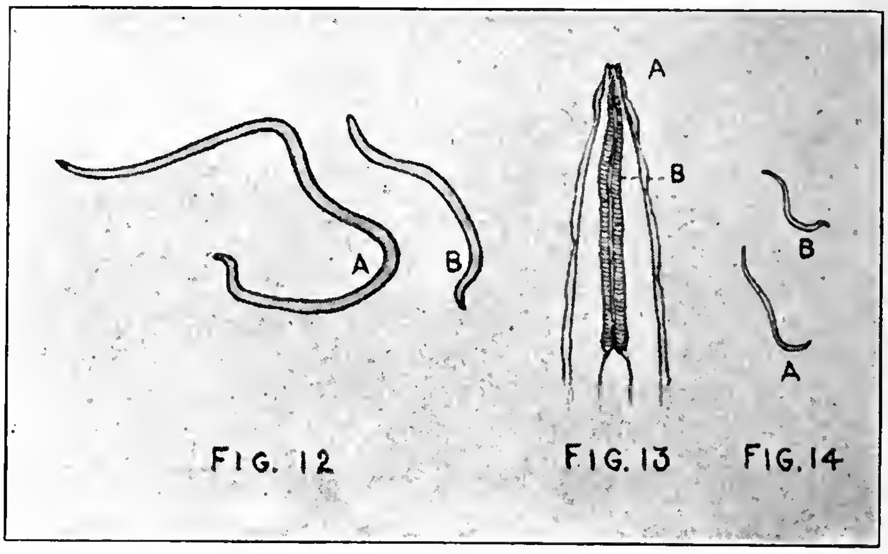


Figure 12.—**Ascaris inflexa,** round worms from the first portion of the in testines of a hen. Natural size. a, female; b, male.

Figure 13.—**Heterakis papillosa,** round worm, head end only, from the caecu (blind gut) of a hen, magnified; a, mouth; b, oesophagus (gullet).

Figure 14.—**Heterakis papillosa,** natural size; a, female; b, male.

SMALL ROUND WORM, (**Heterakis papillosa**)

DESCRIPTION.—This worm is much smaller than the preceding (**Ascar inflexa**) and is found principally in the caecum or blind pouches of the in testinal tract. It is white in color and one-fourth to one-half inch in lengt Figure 14 shows the worm natural size. It has been found in more tha 50 per cent of the birds examined in this laboratory during the past thre years.

LIFE HISTORY.—So far as known, the life history is the same as fo the worms in the first part of the intestines described above.

CONDITION PRODUCED.—When in large numbers, the worms produc considerable irritation and an unthrifty condition. Figure 13 shows th head part of the worm provided with papillae. It takes in food and robs it host of nutrients.

TREATMENT.—Areca nut in the food as prescribed for the preceding.

THE GIZZARD WORM, (**Spiroptera hamulosa**)

DESCRIPTION.—Figure 15 shows the gizzard worm, male and female natural size. It will be noted that the female is larger than the male. The taper abruptly at both ends.

LIFE HISTORY.—Birds become infested by taking ova or young im mature worms into the digestive tract, with contaminated food or water.

CONDITION PRODUCED.—This worm has been found in one outbrea in which one gizzard was sent to this laboratory. It produces tumors in th walls of the gizzard and thus weakens and interferes with the normal func tion of the organ. The chickens thus affected show unthrifty condition, di gestive derangements, and many birds die.

TREATMENT.—This is difficult, owing to the fact that the worm cause the formation of tumors in the walls of the gizzard in which they live Turpentine and olive oil as prescribed for the large round worm are indi cated. Powdered areca nut may be tried as prescribed before for worms.

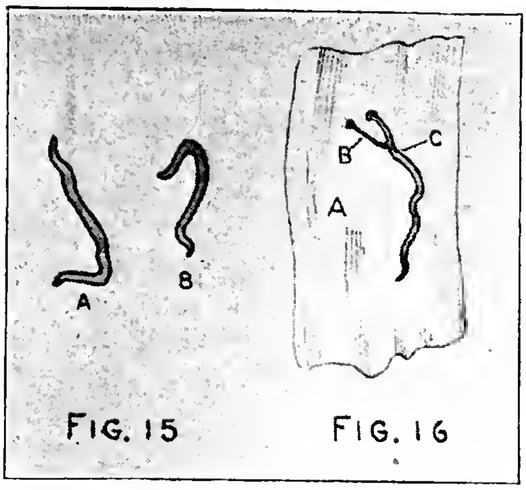


Figure 15.—The gizzard worm, **Spiroptera hamulosa,** natural size; a, female; b, male.

Figure 16.—**Syngamus trachealis** (gape worm), attached to the mucous membrane (inner lining) of the trachea; natural size; a, mucous membrane; b, male; c, female.

THE GAPE WORM OR FORKED WORM, (Syngamus trachealis)

DESCRIPTION.—The male is very small as compared with the female. Figure 16 illustrates these worms as always found; B, the male; C, the female; and A, the mucous membrane to which they are attached. It will be noted that the male is scarcely one-half inch in length while the female is one inch and sometimes a trifle longer. The mouth parts are surrounded by a capsular arrangement with which to hold firmly to the mucous membrane of the trachea (wind pipe). These worms wound the mucous membrane and suck blood.

LIFE HISTORY.—The female produces eggs, which escape from her body only after the parent worm is expelled from the bird and the body decomposed. The embryos thus escaping from the decomposing female live in the earth, water, or earthworms. Thus, chicks drinking contaminated water or eating infested earth worms in turn become infested, or if the chick should pick up an expelled female containing the mature eggs, the embryos would be liberated in the stomach of the chick, in which case they migrate to the air passages and grow to maturity.

CONDITION PRODUCED.—Wild as well as tame birds may become infested by the gape worm. Our trouble is usually with young chicks and turkeys. The small immature gape worms or eggs containing the embryos find their way to the intestinal tract of the young bird as indicated above, and finding their way to the trachea (wind pipe) and its branches, attach themselves, and by growing in size gradually obstruct the passage of air to the lungs. As a result, the bird finds breathing difficult, and after a while gasps for air, extending its head into the air, and finally dies. Usually a lump can be found by feeling along the trachea.

TREATMENT.—Hatch chicks by incubator and do not allow them to run out in the wet grass where they may find infested earth worms or contaminated water. Feed from clean containers, constructed for the purpose.

By grasping the bird in the left hand and forcing its mouth open, a doubled horse hair may be forced down the trachea. Twisting, and again withdrawing, usually dislodges the worms. Gentle pressure over the region of the mass may so injure the worms as to cause them to let loose their hold and be expelled by the chick sneezing. Care must be exercised lest the trachea be injured. A feather, from which all the barbs except the tip have been removed, dipped in turpentine, forced down the trachea and, when the tip is past the mass of worms, twisted as it is pulled out usually removes them. By referring to Fig. 1, No. 34, the location of the opening of the trachea through the larynx may be seen.

TAPE WORMS

DESCRIPTION.—So far, only round worms, possessing a complete digestive tract and distinct sex, male and female, have been discussed.

The tape worms differ from the round worms, in that they have no digestive tract, and both sexes are in the same individual. The tape worms all live in their adult state in the intestinal tract and absorb through their integument, nutrients taken in and digested by their host, thus robbing the host of food nutrients. The species studied in this laboratory was from chickens, and is the **Taenia infundibuliformis.** Its natural size is represented

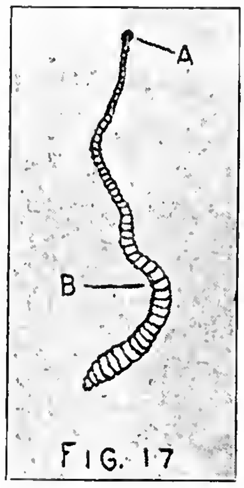


Figure 17.—**Taenia infundibuliformis** (tape worm) (from the intestines of a hen), natural size. a, head; b, the segments.

in Fig. 17. The worm is white; the head is scarcely as large as a pin head and is provided with four sucker discs and a circle of hooklets. By these means, the worm holds to the mucous membrane of the first portion of the intestines. Following the head, there is a short unsegmented neck, which is narrower than the head. From this there is gradually developed segments which become a trifle longer and wider as the distance from the head grows greater. A short distance from the neck the segments become mature, that is, provided with fully developed sexual organs ready for fertilization. Each segment is a hermaphrodite, being provided with both male and female generative organs. At the end of the chain of flat segments we find one or more ripe and filled with fully developed eggs. These segments as soon as ripe detach themselves and pass out to the ground with the feces, to contaminate water and feed and be again taken up by other birds. Other segments now develop in a like manner and the process goes on almost indefinitely.

CONDITION PRODUCED.—If a hen be infested with large numbers of this worm, it is robbed of much nutrient material and becomes unthrifty. As a result of their irritation, the worms cause a loss of appetite, derangement of digestion, catarrhal condition of the bowel and loss in egg production. In feces of birds infested by tape worms will be noted occasional segments of the worms. These will be upon fresh feces and if observed closely or placed in warm water will be seen to possess the power of contraction and expansion as they change their shape.

TREATMENT.—A few teaspoonfuls of a decoction of pumpkin seeds usually rids the intestinal tract of these worms. Powdered areca nut as prescribed for round worms may also be used.

NON-PARASITIC DISEASES

FOWL CHOLERA, OR CHICKEN CHOLERA

CAUSE.—Chicken cholera is caused by a germ (**B. avisepticus**) and is a blood disease (**septicaemia**). The germ is rather short and plump and, with aqueous fuchsin, stains at the poles or ends deeper than at the middle, hence it is called a polar staining bacillus. Figure 18 shows the germ magnified 1,000 times. This drawing was made from the blood smear from an outbreak among turkeys and chickens. The cells are varieties of blood cells. One of these, a white blood cell (a phagocyte) has apparently taken up one of the germs. See figure 18.

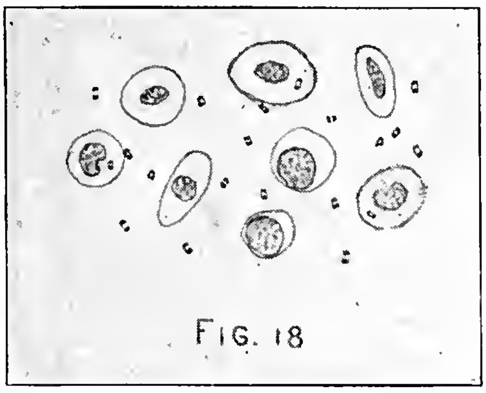


FIG. 18

Figure 18.—Blood smear from a case of fowl cholera, magnified 1,000 times. The germs, **B. avisepticus**, are scattered among the various blood cells. One white blood cell (**polymorphonuclear neutrophile**) has apparently taken up one of the germs.

MODE OF SPREAD.—Show birds often bring home the disease, or infected birds are introduced into the flock. Sometimes it is spread by eggs from an infected flock, by chicks recently hatched, or by infected droppings from infected hen houses tracked on the feet of men and animals, carried by streams or irrigation water, or dried and carried by dust or by wild birds.

The disease has been studied in this laboratory from one outbreak among turkeys and chickens, another among chickens, and still another among ducks. It may also infect pigeons, geese and wild birds. Buzzards are common carriers of the disease and insects have been known to carry the contagion. The germ retains its power to produce disease for weeks and even months. It resists, for a long time, both drying and severe cold weather. The period of incubation, that is from the time the germ enters the body until the disease symptoms appear, is given as from 12 to 48 hours. In our experimental work in which the virus (germs) was introduced into the peritoneal cavity, the period of incubation was 6 to 12 hours, and by the mouth 24 to 36 hours. The birds died 12 to 72 hours later.

SYMPTOMS.—The signs of the disease may be of so short duration that they will pass unobserved and the birds be found dead in the nests or under the roosts, or the birds may live 6 or 7 days. In these latter cases the bird mopes or sits around with tail and head down giving the so-called "ball" appearance. There is loss of appetite, great prostration, stairy feathers, dark comb, swaying gait, trembling, convulsions, thirst and intense diarrhoea. There is a high fever. The bird rapidly becomes emaciated. The disease spreads rapidly in the flock, and the percent of loss, if not treated, is very great. Pure breeds are more susceptible than scrubs. In the outbreak studied among ducks, the disease progressed very slowly, only from one to five or six dying in the course of a week. There were about 500 in the flock.

AUTOPSY.—Upon opening the abdominal cavity, one will first note the greatly enlarged liver, very dark in color, inflamed and easily torn, showing congestion and cloudy swelling. Sometimes the liver weighs 120 grams, or three times its normal weight. The intestines are congested and contain a frothy material, dark in color. There are occasional hemorrhages in the lining of the intestines. The spleen may be enlarged and its contents soft. Small hemorrhages may be found in the heart, its coverings and other parts. The kidneys are dark, enlarged and soft, indicating active and passive congestion and cloudy swelling. The blood does not coagulate readily and is found upon microscopic examination to be teeming with germs.

MODE OF PERFORMING AUTOPSY.—Lay the hen on her back. With a sharp knife open the abdominal wall, commencing close to the anus, passing the knife forward between the ribs and breast bone to a point just back of the "wish-bone." In like manner open the other side being careful not to injure any of the organs in the cavities. Now grasp the sternum or breast bone, forcing it forward so that it will break. It can then be removed easily. This will lay the cavities open so that all organs can be observed as illustrated and named in Fig. 1, to which the reader is referred.

TREATMENT.—Eradication.—The germs are found in the discharge from the bowels, and by the feet of other birds the infection is carried into feed and water troughs, or is picked up from the ground with food. Birds should be fed and watered in troughs frequently disinfected with five per cent carbolic acid. Sick birds should be immediately removed from the flock, and the dead ones should be cremated. The hen house and nests should be disinfected with formaldehyde as follows: Close tightly all doors, windows and other openings and for each 1,000 square feet of space in the building, use 20 ounces of formaldehyde (40 per cent) and 16⅔ ounces permanganate of potash. Place these two materials in a vessel and place in the middle of the room and leave for several hours. The yard should be cleaned every day. If the yard is small, it may be disinfected by covering with straw and burning. For the birds, intestinal antiseptics are indicated, the 30 grain veterinary sulphocarbolates compound giving us by far the best results. Other intestinal antiseptics are, hydrochloric acid, one teaspoonful to each quart of water; one percent copperas; one-half percent permanganate of potash. Vaccination with vaccine made from the germs has given excellent results.

BLACK HEAD (**Entero-hepatitis**)

CAUSE.—This disease is due to a protozoon, microscopic in size, which is found in the diseased areas of the caeca (blind pouches) and liver of turkeys, and rarely in chickens.

MODE OF SPREAD.—As will be seen later, the protozoon escapes from ulcers in the caeca and passes out with the feces. Foods or water contaminated with the excrements carry the disease germ to other birds. Chronic cases in older turkeys or chickens may keep the premises infected for a long time. These germs entering the liver and mucous membrane of the caeca cause inflammation and degeneration. Usually the caeca become infected first, and later the liver becomes invaded.

Fig. 19

Figure 19.—Liver from a case of Black-Head, **Entero hepatitis,** in a turkey. Photograph about ¾ natural size; weight is 452 grams (about one pound). a indicates the yellowish-white necrotic areas, lesions of the disease.

POST MORTEM.—Upon first opening the abdominal cavity, one's attention is attracted by the enlarged liver with areas of dead tissue. Figure 19 shows a liver about ¾ natural size, weighing nearly one pound. One or both of the caeca are enlarged. The enlargement is usually a short distance from the blind point and ulcerated areas are observed. There will also be noted a straw-colored fluid in the loose tissue about the heart. Figure 20 is from tissue taken from an area in the edge of the necrotic portion marked b in Figure 19. The liver cells, as they are first affected, are shown at A (cloudy swelling). At B the cells are farther along in the disease process and it will be noted that the nucleus has disappeared and the cell is disintegrating. At C are the congested vessels; and at D the white blood cells referred to above. There may also be noted in these areas some giant cells. At E are the protozoa causing the disease. A microscopic examination of sections from the kidneys, shows that poisonous products have been taken up by the blood. In these sections we found degenerative changes.

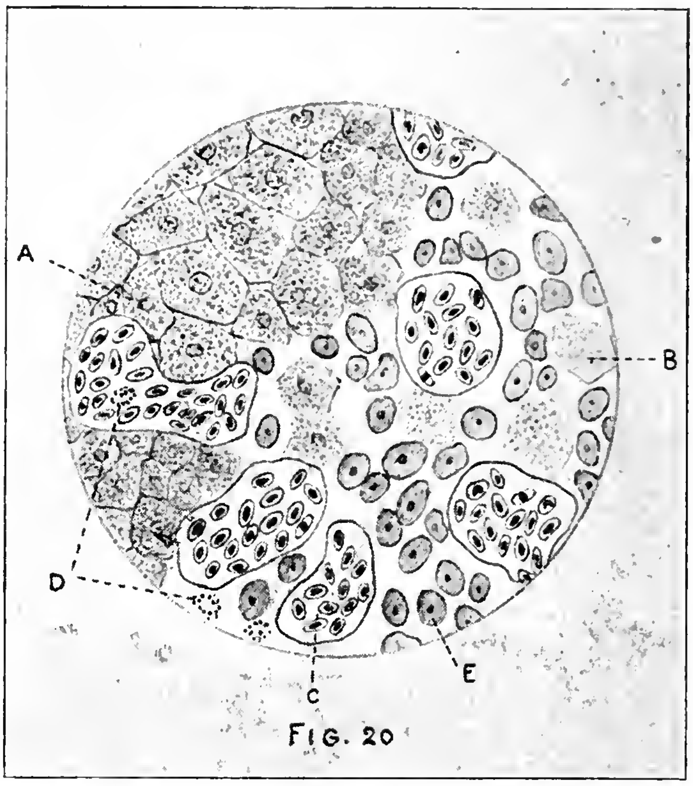


Figure 20.—A section of liver, No. 19, from the area marked by b, magnified 900 diameters; stained with **hematoxylon** and eosin. a, liver cells showing cloudy swelling; b, liver cells undergoing disintegration; c, congested blood vessels, passive congestion; d, white blood cells (eosinophiles) so abundant in the blood and diseased tissues in this disease; e, the protozoan causing the disease.

SYMPTOMS.—This disease is most common in turkeys of one month to a year old, although we have noticed it in birds much older. Only one case was found in the hen. The symptoms are not manifest till the disease in the organs has progressed to a considerable extent. The bird is at first dull, later the wings and tail may droop, feathers become ruffled and the bird sits around most of the time. Diarrhoea and loss of appetite is now noted, the discharge being of a greenish-yellow color. Gradually growing weaker, the bird usually dies in from three to ten days from the first signs of the disease. In the cases that live longer, the birds become emaciated. A blood study shows eosinophilia. The head may or may not turn purple, from which it gets its name—"black head."

TREATMENT.—Thorough cleansing of the hen house and yard, with disinfection; care as to feeding and watering, and intestinal antiseptics are indicated, as recommended for fowl cholera. The sulphocarbolates tablets as used in chicken cholera gave the best results in our experiments. It is best to secure these tablets from your veterinarian or druggist as they are on the market in 30 grain veterinary tablets. Dissolve one tablet in each quart of water. This solution can be given as a drink or used to mix soft feed. In one outbreak, a lady reports as follows: "Some turkeys were too sick to eat. In these cases a small piece of the tablet one-half the size of a sweet pea was dissolved and given twice a day. Nearly all these recovered."

WHITE DIARRHOEA

CAUSES.—There are two causes of white diarrhoea, one, a bacillary form due to a very short, plump, rod-shaped germ (**Bacterium pullorum**) with rounded ends; and one due to a protozon, (**Coccidium tenellum**). The germ of the bacillary form has been isolated at this station from the liver, spleen, kidneys, and other organs of chicks dead of the disease, and the protozoön of the coccidian form, from the ulcers of the caecum and intestines.

SYMPTOMS.—The bacillary form is accompanied by droopy wings, ruffled feathers, sleepiness, a tendency to huddle together, and little or no appetite. The abdominal yolk is not properly absorbed, and the whitish or whitish-brown, frothy discharge from the bowel adheres more or less to the vent fluff; the eyes are closed part of the time and there is apparently no interest in life. The appearance in many is stilty, with abdomen prominent behind, and they peep much of the time. In these cases, after death, one finds the yolk unabsorbed, or only partially so, and the intestines are more or less full. Chicks that hatch in late fall, winter or early spring are freer from this disease than summer hatched. This may be explained by the fact that hens with diseased ovaries gradually become poorer layers as the disease processes advance, and hence, only lay in late spring or early summer when nature intends reproduction of birds. Finally the hen may cease laying altogether.

In the coccidian form the symptoms as studied by the writer are similar to those of the bacillary form, except that, as a rule, the heavy death rate takes place later.

MODE OF SPREAD.—In the bacillary form the ovaries of laying hens, diseased but still functioning, may be infected by the germ. The germ can be isolated, particularly from the yolk, of at least some of the eggs formed in such an ovary. The chicks from infected eggs, as a result, have the disease more or less developed when hatched, as conditions which favor hatching also favor the multiplication of the germs to such an extent that sufficient toxic poisons have already been produced in the young to cause the disease, or at least manifest itself within a few hours after hatching. From these chicks the whitish, frothy, pasty bowel discharge, more or less sticky and with a tendency to paste up the vent, is laden with the germ, and others of the flock soon become infected from contaminated food picked up from the ground. In the bacillary form, chicks may begin to die soon after hatching; in the coccidian form in from three to ten days, a few dying each day.

The death rate is high, reaching in many cases, 75 per cent or more. Those that recover are stunted and do not make satisfactory growth. The greatest loss is from the first few days to two or three weeks. It is probable that the disease carriers are recovered chicks, which have established immunity, but still carry the organism, especially in the ovary, as typhoid carriers among people do in the infected kidneys or bowel ulcers.

Coccidian form.—The mode of spread of this form is at present problematical. It is possible that a chronic type occurs in some birds and thus perpetuates and scatters the organism.

POST MORTEM.—In the bacillary form the liver in general is usually pale, showing areas of active and passive congestion and cloudy swelling: The yolk is only partially absorbed and congestion of the intestines may or may not be present. The kidneys are normal size, but show congestion and cloudy swelling, and the carcass is more or less pale and emaciated.

Coccidian form.—Upon post mortem examination the conditions are found to be similar to the bacillary form, except that there will be noted more or less congestion of the intestinal lining with ulcers in the intestines, principally the caeca. The caeca appear to be interfered with functionally, containing considerable ingesta. Figure 21 shows a transverse section through an ulcerated area. In these areas we find cloudy swelling followed by retrogressive changes and death of the cells. The remains of the dead cells forms a cheesy mass. It will be noted in this drawing that only rem-

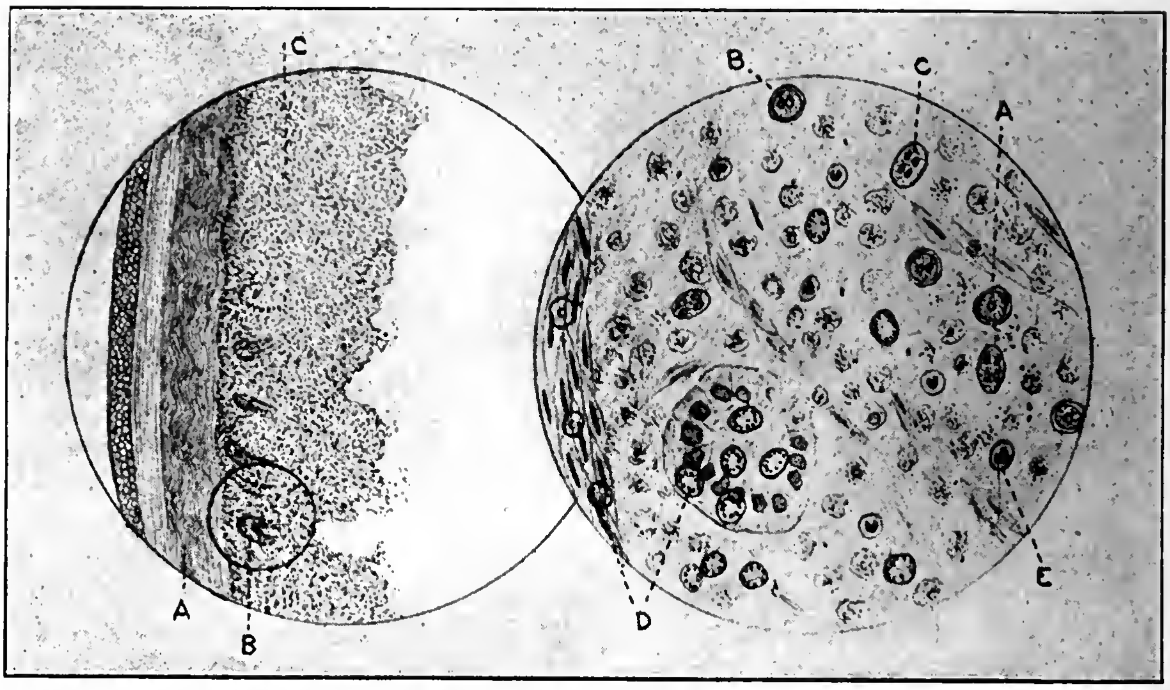


Fig. 21 Fig. 22

Figure 21.—A transverse section through the caecum of a chick that died of white diarrhoea; a, muscular layer which, at some points, is invaded by the protozoan, **Coccidium tenellum.** The glands of the mucous membrane have all disappeared except small remnants indicated by b; c, granular degenerated mass from dissolution of the mucous membrane, magnified 100 times.

Figure 22.—The area in the circle indicated by b in Fig. 21, magnified 900 times. The letters indicate the protozoon parasite in various stages of development; a, oocyst; b, first stage of sporoblast; c, first stage of sporozoit; d, the schizont showing within the merozoits. These are surrounded by a disintegrating cell mass; e, shows white blood cells (polymorphonuclear neutrophiles).

nants of a few glands normally present are yet intact, the balance of the mucous membrane, and in places the submucous layers, are invaded by the germ. In Fig. 22, section B has been magnified 900 times. As explained under the cut, all stages of the organism are observed in a mass of dying and disintegrating cells, the remains of the diseased mucous lining of the bowel. Repeated examinations have been made of healthy chicks killed for the purpose, and chicks dying from other causes and, thus far, no case has shown these conditions.

TREATMENT.—Unsanitary conditions, spoilt food, dirty stagnant water, improperly ventilated incubators, brooders and buildings, or badly regulated heat are factors in weakening the physical condition of chicks and favor ravages of disease.

Most of our experimental work with various remedies has been with the coccidian form. In one outbreak referred to above, 80 per cent of the first 2,000 chicks had died. We began trying to improve sanitary conditions, and administered various dilutions of permanganate of potash, copperas and carbolic acid. The loss was unaffected. By this time the writer had examined many dozen of birds in the laboratory, and in about 50 per cent of the cases the organism (**Bact. pullorum**) was isolated from the heart, blood, liver, spleen and kidneys, and in every case the coccidian ulcers described above were observed. These chicks began dying in numbers when about ten days old, very few dying before that time, and from this period to the end of the third week the great loss occurred. After this time but few died, but those having the disease in light form were stunted and did not make satisfactory growth.

With this data before me, I began on another line of treatment. For the past ten years I have used, to some extent, dilutions of bi-chloride of mercury as an intestinal antiseptic in chickens. This was used in this outbreak in a 1 to 10,000 dilution with sulphocarbolates of zinc, sodium and calcium. The latter had not given the satisfactory results when used alone that it gives in diarrhoea in colts and calves. Instructions were given to fumigate the incubators and the nursery trays with formaldehyde gas, as recommended under "chicken cholera," before filling with eggs.

After the chicks were hatched they were not to receive any feed for 48 to 72 hours as the yolk contained in their abdominal cavity will furnish food for that length of time, and an engorgement of the intestines might interfere with its absorption by pressing on the absorbing vessels. The following dilution was kept before them from the time of hatching to four weeks of age, and then given twice a week for the next few weeks: One of the 30 grain sulphocarbolates tablets as used for fowl cholera, and bichloride of mercury, 6 grains; and citric acid 3 grains. This quantity was dissolved in a gallon of water. The result was that 80 per cent of the next hatch was saved. The problem of obtaining the proper solution seemed a serious one. It was finally solved by the Abbott Alkaloidal Company, who kindly made up a quantity of the tablets, each containing the above proportions of ingredients for this experiment.

OTHER DISEASES OF THE INTESTINAL TRACT

ARSENICAL POISONING.—We have had cases brought to our attention in which birds became poisoned by eating poisoned grasshoppers. In these cases the grasshoppers were given arsenic in bran. The birds devouring large numbers of grasshoppers, became ill, and many died. The symptoms were dullness, loss of appetite, black comb, sitting, moping and unsteady gait. The birds must have been in considerable pain although they did not show it, but birds do not manifest pain as most other animals do. The autopsies showed the livers to be normal, except a trifle dark. There were no noticeable changes in the other abdominal organs except the intestinal tract. Upon opening the intestines there were noted patches of hemorrhage and areas of congestion and inflammation.

PTOMAIN POISONING.—In one flock there were 24 hens. A can of spoiled corn, that had been left sitting in the basement in a glass container with top removed, was given to the birds at 11 o'clock, and at 6 o'clock five were dead. At 2 p. m. next day, thirteen were dead and three more showing symptoms of poisoning. A flock of small chicks with the old hen, as well as three sitting hens that had not eaten any of the corn, were not in any way affected. There was no visible evidence of great pain, as spasms were absent. The birds had, at first, an unsteady gait with incoordination of movement. Prostration came quickly. The comb turned black. In some cases diarrhoea appeared with occasionally a small amount of blood. The birds lay on the ground in a relaxed condition, with head and neck curled over toward the breast, but not rigid. Whenever they were disturbed, they made a struggle. Death occurred in a few hours.

At post mortem the crop and gizzard contained some corn of a sour odor. The only tissue change noted was a congestion of the intestines, liver and kidneys (active and passive congestion and cloudy swelling). This condition is often due to rotten meat or other food stuffs and is called "limber neck."

As a remedy, give a tablespoonful of castor oil and one-fifth grain doses of sulphate of strychnine, the latter every 4 to 6 hours.

TYMPANY OF THE CROP.—Birds sometimes have enormously distended crops, which, upon examination, are found to be filled with gas. This condition often affects young chicks as well as older birds. It is due to a gas forming germ.

As a remedy, give intestinal antiseptics, such as 1 to 500 carbolic acid; 1 to 10,000 bichloride of mercury; or sulphocarbolates compound as recommended in diarrhoea.

CROP BOUND, OR OBSTRUCTION OF THE CROP.—This is due to foreign bodies, such as hog bristles, small feathers, straw, etc., closing the opening of the crop to the proventriculus, or stomach. A case came to the laboratory which may be of interest to the readers of this bulletin. Two incubator chicks, just old enough to begin to feather out, had been given potato parings. After death there was found in the crop of each chick, a potato paring extending from the crop through the second portion of the oesophagus into the stomach. Figure 1 shows these parts.

GANGRENE OF THE CROP has been observed several times in this laboratory. Upon opening the crop a very offensive odor is noted, and the lining is in a sloughing (necrotic) state. There may be given in these cases, in the earlier stages, salol, subnitrate of bismuth, or sulphocarbolates compound as recommended for diarrhoea.

INFLAMMATION of the various parts of the digestive tract has been included under diarrhoea.

DISEASES OF THE OVARY AND OVIDUCT

PROLAPSE OR EVERSION OF THE OVIDUCT.—This condition is often seen in hens that are heavy layers. It is perhaps most often found in old hens. Overfeeding and aggravated constipation have been found associated with this condition, and are, no doubt, some of the causes. Where the eggs are large, the straining that takes place, and inflammation of the oviduct are important factors. The upper portion of the oviduct, or that part that receives the yolk as soon as it is formed in the ovary and delivered, is lined with secreting cells. In this part the albumen which surrounds the yolk is formed. Farther along there are glands that secrete the shell that surrounds the outer surface of the albumen. It can be readily seen that all these cells require a rich or abundant blood supply. Any inflammation of the egg duct means an arrest of function of these glands and also others whose function it is to secrete a mucous which lubricates the passage and a stopping of the egg passage results. Inflammation of the oviduct is not an uncommon occurrence, and may be due to non-specific germs from the cloaca.

If the prolapsed or protruding mucous membrane is allowed to remain out, inflammation and swelling will soon result and the parts may become ulcerated later.

As a remedy, use a three per cent to five per cent carbolized vaseline and return the protruded part. Keep the hen on light diet for several days so that the parts may have a rest and the irritation causing the trouble will subside. Also give the hen a tablespoonful of castor oil and plenty of water.

EGG BOUND is the stopping or arresting of the passage of the egg at the time when it should be expelled from the oviduct. It is alluded to above, and in addition to those causes may be mentioned a weakness of the muscles whose duty it is to expel the egg.

SYMPTOMS.—The hen goes to the nest frequently and attempts to lay but is not successful. Lubricate the fore-finger with carbolized vaseline and insert it into the oviduct (Fig. 1 shows the relation of these organs) and remove the egg. In one case brought to the laboratory, the writer found inflammation of the oviduct, a lack of secretion and a very large egg which lay crosswise of the duct. It was necessary to break the egg shell to remove it. The hen was given a tablespoonful of olive oil, put on bran mash and sent home in three days.

TUMORS OF THE OVARY.—These often consist of yolks or ova which have formed but have failed to enter the oviduct. Later these masses become rather hard and yellowish in color, and are found to be made up of apparent concentric layers of cheesy matter. (Fig. 23 illustrates one of these grape-like masses.)

CYSTIC CONDITIONS are at times found. These cysts are imperfectly developed ova, which contain a colorous liquid. They appear like tumors and are attached by more or less long pedicles.

HEMATOMA or blood tumors, are sometimes found. Figure 24 illustrates one of these conditions.

SARCOMA was studied in the laboratory in two cases. They were generalized and affected other organs besides the ovary. Sarcomas are a variety of malignant tumors.

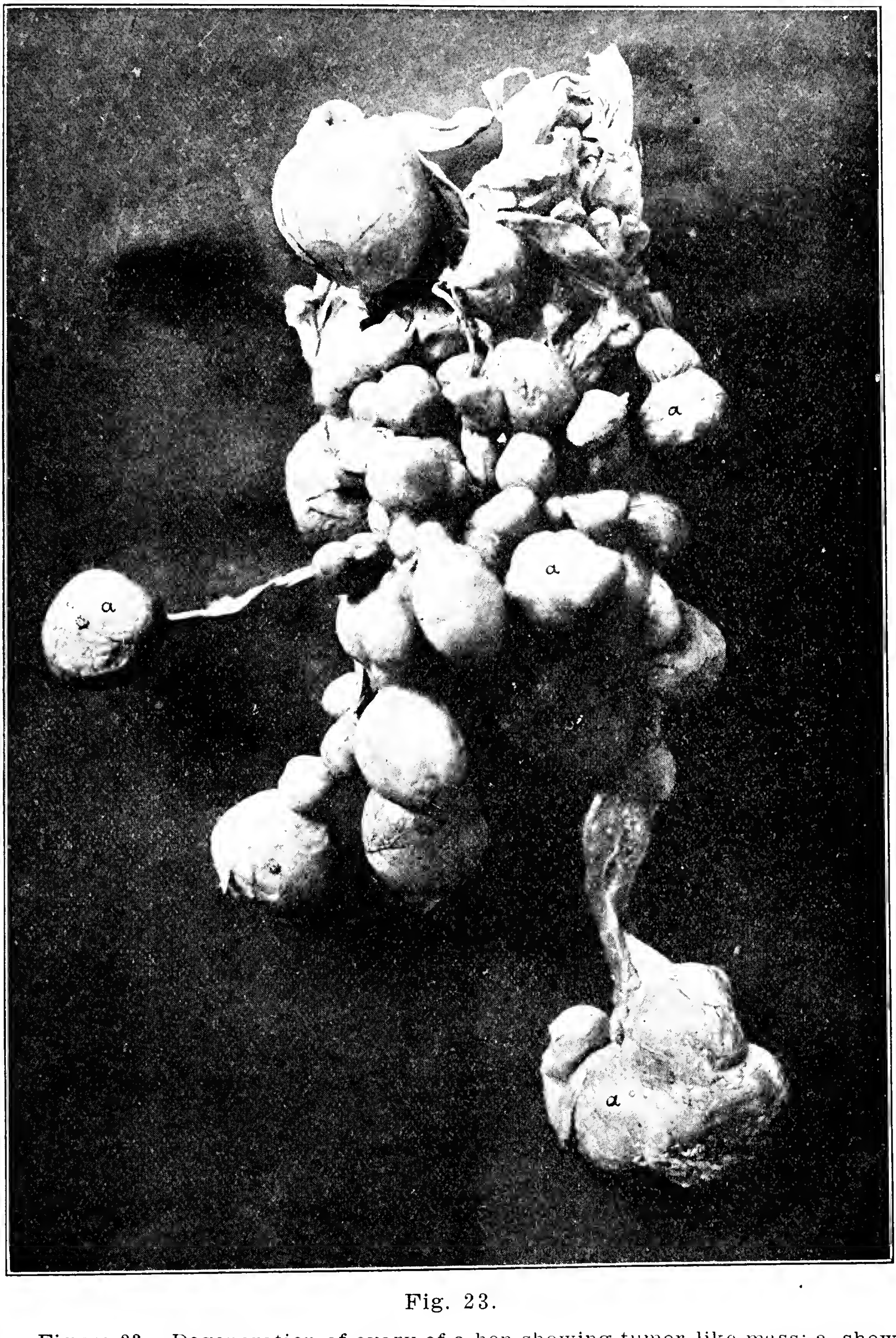


Fig. 23.

Figure 23.—Degeneration of ovary of a hen showing tumor-like mass; a, shows ova, which have undergone degeneration. Note the shrunken appearance and in some, shrivelled pedicle-like structures joining them to the ovary mass. The contents of these masses are cheesy (caseation necrosis). Natural size.

Fig. 24

Figure 24.—Hematoma or blood tumors of an ovary (of a hen), natural size; a. shows diseased ova. Note the shrunken atrophied condition; b, the sectioned surfaces of two of the tumors showing the coagulated blood.

BROKEN EGGS in the oviduct, as well as injury to those ova still undelivered, are often found and are the results of the hen being kicked or stepped upon by large animals. Death usually follows. We have also studied cases of ruptured ova due to heavy hens roosting on high perches and jumping upon the hard floor.

PROLAPSE OF THE CLOACA may occur in heavy laying hens that roost on high perches and fly a long distance to the ground, and especially when the wings are clipped. If these birds are allowed low roosts, and are put on a light diet, recovery takes place.

CLOACITIS.—The writer has observed one case in a cock in which there was inflammation of the cloaca with ulceration. The bird died later of inflammation extending the whole length of the rectum, infection having been progressive.

DISEASES OF THE LIVER

Reference has been made to diseases of the liver in conjunction with other conditions, as fowl cholera, entero-hepatitis, etc.

FATTY DEGENERATION is a condition in which the true liver tissue is replaced by fat. Such a liver may be smaller in size and rather hard in texture.

FATTY INFILTRATION may be healthy or not. In fattening animals there is always an excess of fat stored in the liver, which gives it a grayish-yellow color and makes it rather soft in texture. When such livers are cut through, the knife will have upon it some fatty material.

CONGESTION AND INFLAMMATION.—Congestion may be brought about by overfeeding and lack of exercise, or by a defective or weak heart. Active congestion and inflammation may be brought about also by tainted food or food that is mouldy or fermenting. In the latter case a toxic or poisonous substance is given off and on account of the liver being a destroyer of such poisons, they are taken there, and an excess amount overwhelms the cells and the irritation causes congestion and inflammation. The liver is enlarged and dark. The symptoms are not definite but the hen will be off feed and dull. The feathers will appear unkept and the hen will remain on the roost or in a corner. Give a tablespoonful of olive oil and soft feed.

RUPTURE of the liver may be caused by a kick or by being stepped upon by a large animal, or in case of congested livers, from concussion by the hens jumping from high places.

TUBERCULOSIS.—One case of tuberculosis has come to this laboratory. This bird had access to the sputum of a person suffering with the disease. The liver was slightly larger than normal and about natural in color. The surface was studded with pearl-like nodules from the size of a pin head to a millet seed. The tubercles were also scattered over the peritoneum. A microscopic examination showed the tubercle bacillus.

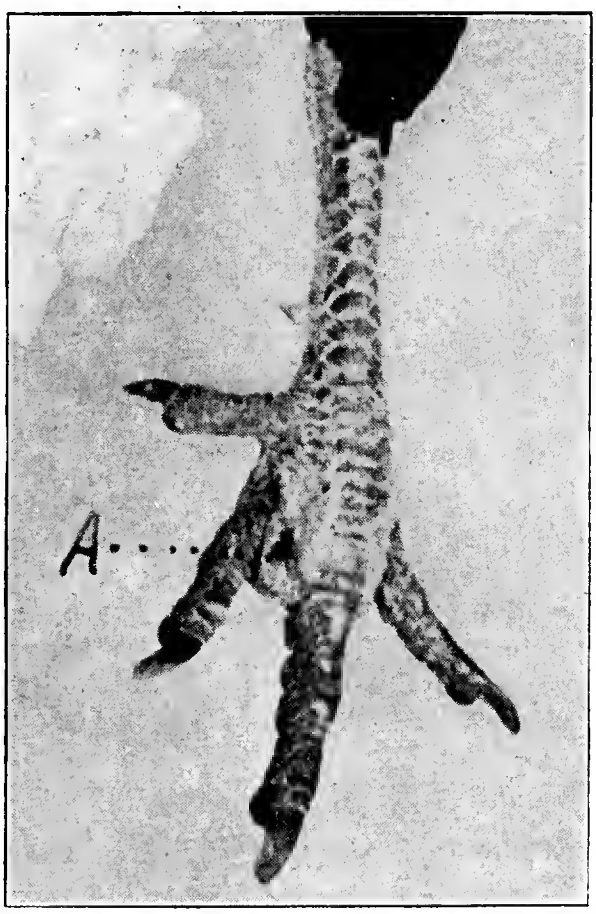


Fig. 25.

Figure 25.—Abscess in the soft structures between the toes of a hen; a, indicates the opening due to lancing, from which a cheesy-like pus was removed with a pus scoop (curette). This abscess was caused by a thorn of a Russian thistle penetrating the soft parts.

CATARRH OR COLD

Birds that roost in drafts, or are exposed to sudden changes in the weather, are liable to catarrh and colds. Exposure to cold rains is often a factor.

SYMPTOMS.—The appetite may be somewhat diminished. The bird sneezes, throws it head and may expel some mucous. The discharge is at first watery and later becomes more or less thick. The eyes may appear red and show more or less inflammation, and the lids may stick together. The characteristic offensive odor of roup is absent.

TREATMENT.—The same treatment as outlined for roup has given us uniformly good results.

BRONCHITIS.—We have noted in some cases that catarrh commencing in the head, principally the nasal chambers, extends down and involves the windpipe or trachea and even the branches of the trachea into the lung tissue. Sudden changes in the weather, dampness, roosting near a crack so that cold winds blow upon the birds, or any kind of a draft are the principal causes.

SYMPTOMS.—There is a rattling in the region of the trachea and the bird may gasp for air by extending the head upward. This is due to the fact that an accumulation of mucous in the air passage partially plugs the tubes and interferes with the passage of a normal amount of air to the lungs. As a result the bird will cough. There may be dullness and partial loss of appetite. The condition may pass off in a few days, respond to treatment, or it may last for several weeks and finally end in the death of the bird.

TREATMENT.—Give a tablespoonful of castor or olive oil. Also give one-grain doses of quinine three times a day, and place the bird in a warm, clean, comfortable quarter, free from drafts. Give plenty of clean water and soft food.

CONGESTION OF THE LUNGS

This is an engorgement of the blood vessels of the lungs. It has been observed in young birds and in birds during their moulting season, when they are poorly clad with feathers and exposed to inclement weather. The young chicks that are allowed to run out early in the mornings and become wet with the cold dew, or the chicks that are allowed to become wet and chilled with the cold spring rains are the ones that suffer from this condition. A contraction of the blood vessels of the skin and superficial parts, forces an abnormal amount of blood to the internal organs and congestion is the result. These birds appear sleepy, stupid, breathe rapidly, and in some cases with difficulty. The comb becomes bluish and the bird may die from a lack of sufficient air (asphyxiation). Upon opening the bird after death, the lungs will be found gorged with blood.

PNEUMONIA, OR INFLAMMATION OF THE LUNGS

Bronchitis, as described above, often terminates in pneumonia (broncho-pneumonia). It has been the experience of the writer that this form is the more common. Upon opening the bird the affected part of the lung will be found to be dark red, and when cut through it will appear liver-like. Serum and blood exude from the cut surface. The causes of pneumonia are exposure to cold and inclement weather as mentioned under catarrh.

SWELL HEAD IN YOUNG TURKEYS

The most characteristic symptoms are swellings of certain parts of the head, especially in the region of the maxillary sinus, which becomes filled with a gelatinous colorless substance. (For location of sinus, see Fig. 1, No. 31.)

These swellings may disappear in a few days or weeks, or may remain for several months. In the latter instance, the swelling may contain a cheesy material of foul odor, and in some cases death of the bird results.

CHICKEN POX

CAUSES.—This disease is called contagious epithelioma. It affects chickens, turkeys, pigeons and geese. Some investigators claim it is due to an ultramicroscopic germ, and that the germ is also the cause of avian diphtheria or roup. An ultramicroscopic germ is one that will pass the pores of the finest filters and which cannot be seen with the microscope nor grown in visible quantities upon culture media. There are just as many who are certain that their results show that the germs are not the same, and that the infection at one time will not produce roup and at another chicken pox. Our experiments do not lead us to the conclusion that they are the same disease caused by the same germ.

Chicken pox is contagious and can be transmitted from material of one bird to healthy birds by inoculation. Several germs have from time to time been isolated, among them protozoa, but none are constantly present in these cases.

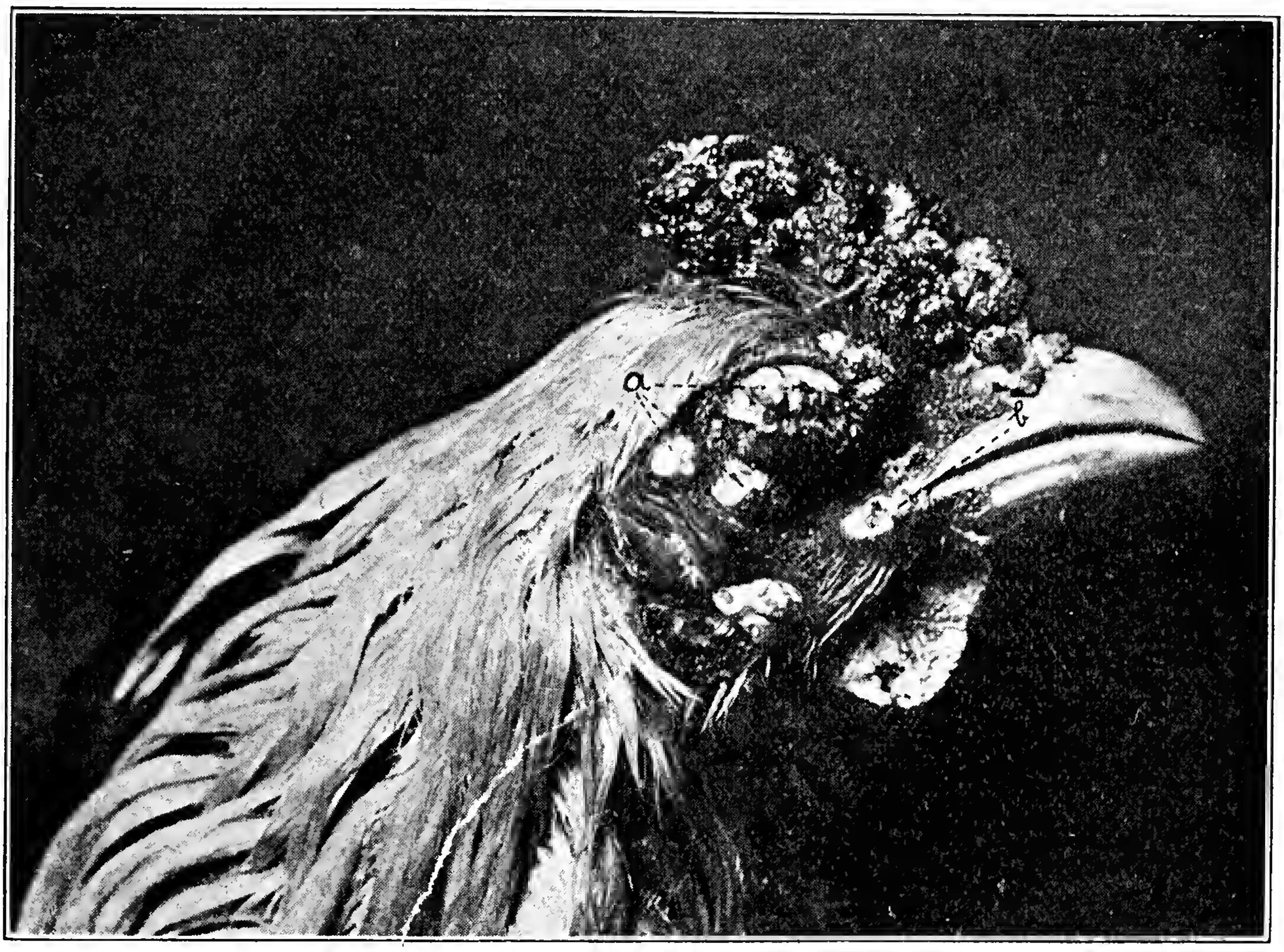


Fig. 26.

Figure 26.—Chicken pox (contagious epithelioma) slightly reduced; a, some well formed pock nodules consisting of masses of proliferated epithelium. It will be noted that some of these have obstructed the eye; b, shows some nodules at the base of the beak. This condition is sometimes found accompanying roup.

SYMPTOMS.—Figure 26 shows a photograph in which nodules of irregular size are seen over the comb, face and in the wattles. These nodules vary in size up to a pea and even larger. We have observed roup and chicken pox in the same flock.

ROUP OR AVIAN DIPHTHERIA

This condition is sometimes called swelled head, because usually there is swelling about the head.

CAUSE.—The cause appears to be far from settled. American and European investigators have from time to time isolated different germs, all of which perhaps contributed to the production of conditions found, but there are none of these germs that are constantly found by all. With the view of determining whether or not the type of roup existing in Colorado is due to an ultramicroscopic germ, two diseased hens were secured through the aid of Mr. Vaplon. These birds had swollen eyes, with an accumulation of catarrhal product in the maxillary sinuses (the bulging observed below and in front of the eye) and a discharge from the nostrils of an offensive odor. There were also characteristic yellowish-white diphtheritic patches in the mouth. Material from all these lesions from both birds was prepared in physiological salt solution (.85 per cent common table salt) and filtered through a Pasteur filter calculated to take out all germs that can be seen by aid of the microscope or that could be produced in visible growth upon artificial culture media. The fluid that passed through this filter was used in inoculating experimental birds. These birds were from flocks in which roup had not appeared. In all, fifteen inoculations were made. Tubes of media were inoculated with the filtrate and no visible growth of germs was seen after being incubated at 37 degrees C. for 72 hours.

Observations were continued on the inoculated birds for thirty days and roup did not appear in any of them. So far as this one experiment goes, it does not indicate that our type of roup is due to a filterable virus.

MODE OF SPREAD.—The disease is spread by the introduction of birds from infected premises, and by exposure of birds at poultry shows to the contagion. A chronic type of the disease in some birds of the flock may serve to infect others, when they are weakened by predisposing causes, as by exposure to cold, damp roosting places, drafts and badly ventilated buildings.

SYMPTOMS.—There are three forms of the disease. In the nasal form there it at first a thin watery discharge from the nostrils, with an offensive odor which is characteristic of roup. Later the catarrhal product becomes somewhat thicker and the nostrils become glued shut, and quite frequently there is a bulging of the maxillary sinus below and in front of the eye. This is due to an accumulation of the inflammatory products in this sinus, or cavity. Figure 27 illustrates this common swelling. The second part affected is the mouth. This affection often accompanies the nasal form. Figure 28 illustrates these diphtheritic ulcerations, which are covered with a yellowish-

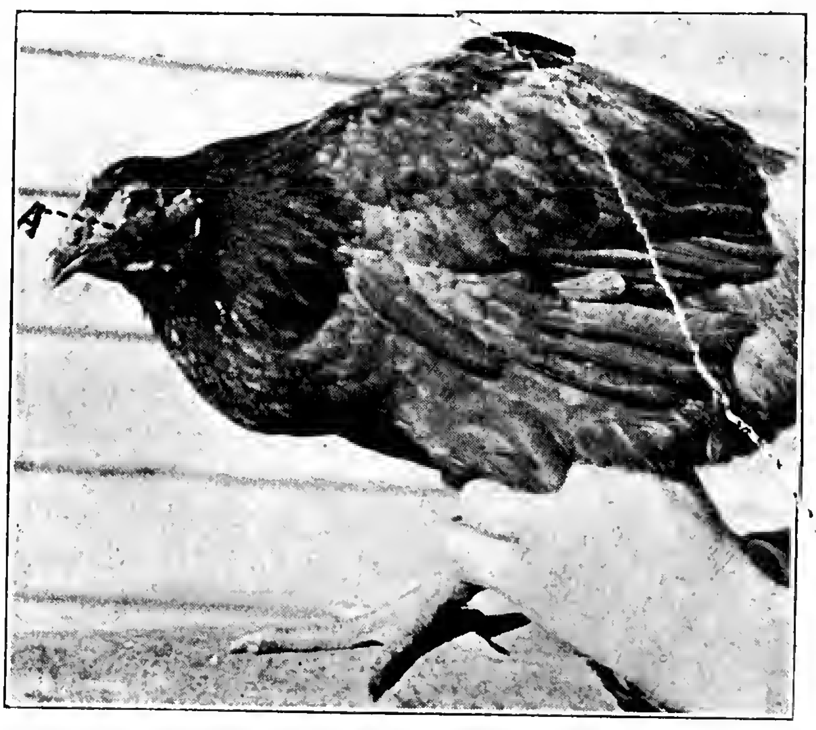


Fig. 27

Figure 27.—Hen afflicted with roup; a shows the swelling; the eye is swollen shut and the sinus beneath and in front of the eye is bulging as a result of the secretions from the inflammation caused by the germ of the disease. The mucous membrane surrounding the anterior portion of the eye ball is greatly inflamed (conjunctivitis) and is filled with a mucopurulent material.

white crust of coagulated exudate. From these necrosing patches the disease receives the name, avian diphtheria. The third location is the eye. There is at first an inflammation of the mucous membrane lining the anterior part of the eye-ball. As the disease progresses, the catarrhal product accumulates as a watery clot-like mass, whitish in color. The eyelids stick together and hold the material as it accumulates till the parts bulge outward. There is sneezing, shaking of the head and expulsion of mucous and loss of appetite; the bird appears weak, and has a tottery walk and becomes rapidly emaciated. Breathing is difficult at times, and often there is diarrhoea, and the bird dies in a few days.

TREATMENT.—Correct any condition which may be a predisposing cause. The hen house should be well ventilated, but without drafts on the birds, and it should be cleaned and disinfected daily. If the bird is not valuable, kill and burn it. Treatment with medicines differs with the location of the lesion. For the ulcers or diphtheritic patches in the mouth, nothing is better than burning with stick nitrate of silver (lunar caustic). For the

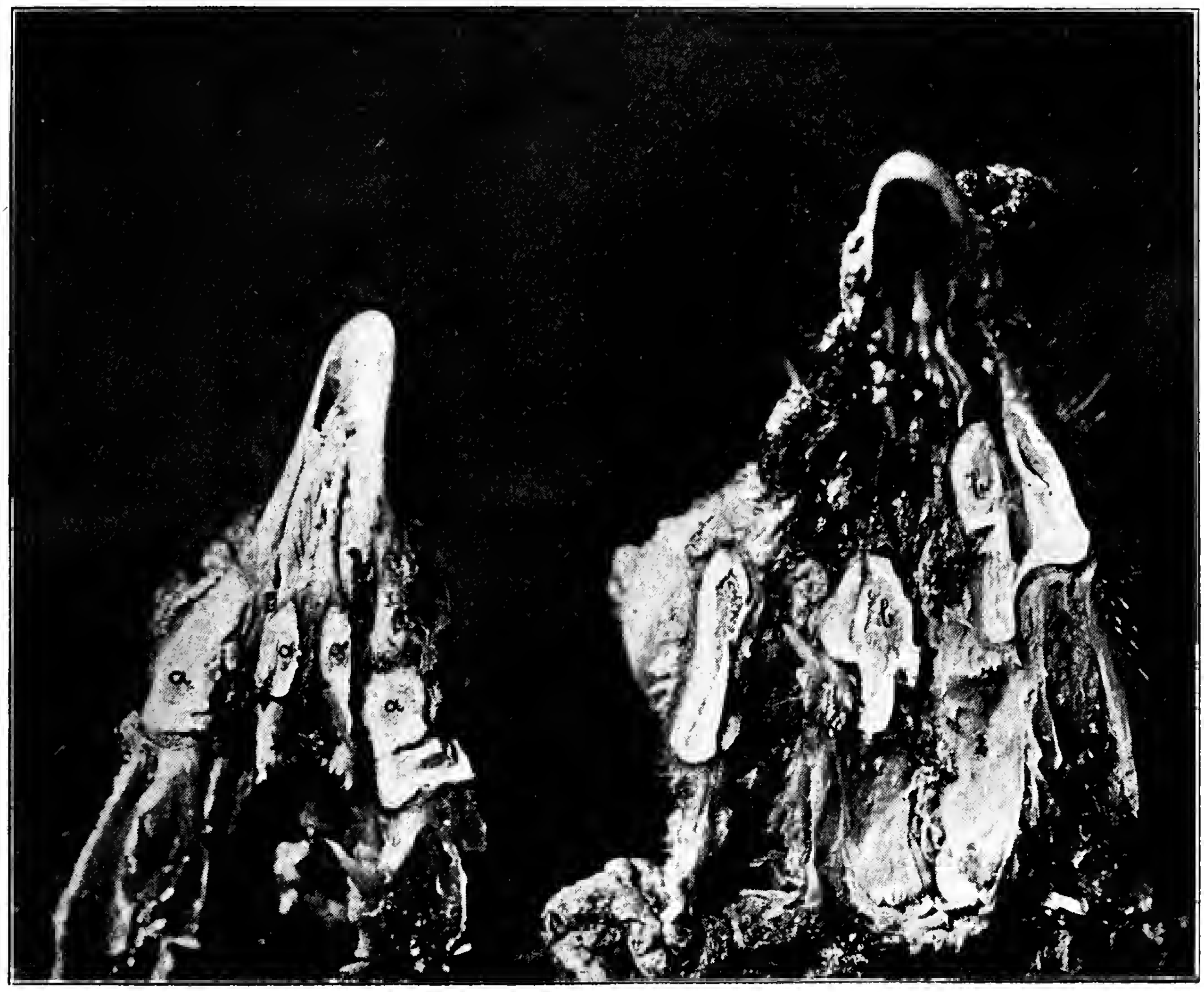


Fig. 28.

Figure 28.—Roup, **Avian diphtheria,** natural size, showing inner portion of upper and lower jaws; a, diphtheritic patches on edge of mouth and top portion of the tongue; b, same on roof of the mouth including hard palate.

eyes, press open the lids and remove the material with clean absorbant cotton; then apply the material as for injection into the nostrils. Wash out the nostrils with a 20 per cent solution of common baking soda, then with peroxide of hydrogen. With a medicine dropper or small syringe, inject some of the following; oil of thyme, 1 dram; oil of eucalyptus, 20 drops; oil of petrol, 2 ounces. Give plenty of clean water and soft feed. Give one grain of quinine three times a day, as well as a tablespoonful of castor oil.

Fig. 29

Figure 29.—A case of asphyxiation due to a small piece of corn grain lodging in the wind pipe.

Bulletin 186 May, 1913

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

The Fixation of Nitrogen in Colorado Soils

THE DISTRIBUTION OF THE NITRATES AND THEIR RELATION TO THE ALKALIS

By WM. P. HEADDEN

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1913

The Agricultural Experiment Station

FORT COLLINS, COLORADO

*Deceased.

THE FIXATION OF NITROGEN IN COLORADO SOILS

By WM. P. HEADDEN

Shortly after the publication of Bulletin 155, "The Fixation of Nitrogen in Some Colorado Soils," my attention was called to the question of the transportation of the nitrates from other sources to where we found these exceptional quantities and also to the question of their distribution both laterally and vertically in the soil. It was distinctly stated that the occurrences of these salts, the nitrates, were confined to certain characteristic "brown spots." The cause of the brown color was attributed to the Azotobacter films, i. e. pigmentation. The smallness of the areas when first observed, their erratic occurrence and wide distribution without regard to character of soil or geological horizon, practically precluded the idea of their being the products of any general concentration process. These questions, however, had already received consideration, especially in connection with the water which we found seeping from certain shale banks, in which connection we made this statement, "One question has undoubtedly suggested itself in regard to the origin of these nitrates, i. e., whether the popular idea that the irrigation water brings them to the surface, may not be correct. Some at least will deem this question as deserving a definite answer, especially as I have found that the waters issuing from the shales underlying the mesas carry significant quantities of nitrates. The shales themselves, when a sufficient quantity of them, 1,280 grams, was extracted with water, actually showed a trace of nitric acid. There are two samples of water and one of shale. They represent three different localities, two of them within three miles of one another, while the third is more than fifty miles from either of the other two." It might be argued "that the shale area is very large and though it contains but a trace of nitric acid, it might suffice to furnish all of the nitric acid which has been found, especially as the water has been issuing from these shales and filling up the lower portions of the country for a very long period."

"The occurrence of nitrates in the waters and apparently in the shale, is susceptible of an easy explanation, i. e., the nitre spots, which are only exaggerated instances of a general condition, occur in the lands above these shales. The water that falls or is put upon these lands, washes the nitrates down into the shales. The soil has no power, or but a very small one, to retain these salts and this seepage water is simply washing the nitrates out of the land." We considered the soil overlying these shales and not the shales themselves as the source of the nitrates. Those who believe in the leaching of these nitrates out of the shales will have to account for the fact that these overlying mesas are dotted with brown spots, rich in nitrates, while there are no shale banks above them from which the nitrates may have been leached.

If we are to consider seriously the shales as the source of these nitrates, we are compelled not only to consider them rich enough in nitrates to permit of capillarity carrying them to the surface and causing their deposition, but we must consider the shales as holding a very great store of them, so great that the time and the water necessary to erode our valleys has been insufficient to wash them out.

It is well known, that under certain conditions, nitrates may occur in soils in sufficient abundance to permit of their crystallization. These conditions are, however, by no means very common. Such occurrences of nitrates are given in our text books, particularly in our mineralogies, and are matters of common knowledge, so much so that some such origin would in all cases be the first one suggesting itself for consideration. Concerning the application of these facts to the shales as the origin of the nitrates it was plainly stated that we did not consider that they played this part for two reasons: First because many brown spots occur on the mesas above the shales; Second, because the brown spots occur in entirely different geological horizons where the shales do not occur, in alluvial deposits and under our ordinary prairie conditions; in other words the shales, provided that they contained nitre, could not be considered as the explanation for the greater number of the occurrences and independent of any other reason than their insufficiency, we must seek for a more general cause, one sufficient to account for all of the occurrences. This assumes that they have a common cause, which is a reasonable assumption so long, at least, as we are not sure that they actually have several different causes.

The origin of the alkalies in such countries as ours is beyond doubt correctly explained by attributing their formation largely to the various changes suffered by the felspars under the action of water, more or less strongly charged with carbonic acid, but in the absence of a sufficient supply of water to carry away the products of their decomposition. This appears to be an entirely adequate source to yield the chlorids, carbonates, sulfates, etc., which we find in our soils, or present as alkalis, but these are not the source of the nitrates.

I am fully aware that students of geology made record, more than twenty-five years ago, of the observation that the Cretaceous shales seem everywhere to be charged with alkalis. These alkalis are, in some cases, composed wholly of sulfates, in others they are mixtures of sulfates, carbonates and chlorids. Under special conditions, such as have been previously mentioned, small quantities of nitrates may be present. The amount of nitric nitrogen found in a shale underlying a cultivated mesa on which nitre spots occurred abundantly and from which the seepage passed into the shale, was 0.00399 percent, 40.0 p p m. This shale had, furthermore, been ground with the addition of this same seepage water and dried so that the amount given is, even for this condition, too high rather than too low.

The question whether the "black alkali" is not brought up by irrigating waters added, though a popular one, is perfectly proper, and is entitled to serious consideration, perhaps to more serious consideration than I gave it in either Bulletin 155 or 178, though I take cognizance of it in both of these bulletins.

Our Colorado alkalis consist essentially of sulfates, chlorids and carbonates. The sulfates are represented by calcic, magnesic and sodic sulfates. The ratio of these salts to one another varies exceedingly, but they are usually all present. In some cases one or the other may be wanting. The chlorids found are those of calcium, magnesium, sodium and small amounts of the chlorid of potassium. The carbonates are quite subordinate. Traces of nitrates are sometimes present, but they may be wholly absent.

Our study of a very alkaline soil, i. e. one which was strongly alkalized, will present the facts that we may expect to meet with under these conditions. This was a soil under cultivation for the purpose of studying, on the one hand, the effects of the alkalis on the crop, and on the other, the effect of cropping and cultivation upon this alkalized soil.

The alkali appeared on the surface of this soil as an incrustation, attaining, under favorable conditions, a thickness of one-half inch or more. These incrustations carried from two to five percent of chlorin and from none to a heavy trace of nitric nitrogen. The top two inches of portions of this plot yielded as much as three and nine-tenths percent of water-soluble material, of which five and one-half percent was chlorin. The second two inches of this soil yielded two and one-half percent of water-soluble of which only nine-tenths of one percent was chlorin. The nitric nitrogen was determined in these samples and we find the following results for these and other sections of the plot. The results are given in parts per million of the air-dried soil, in which there may have been a slight increase in the nitric nitrogen during drying.

This table shows what we found in four different sections of this plot on the date that the samples were taken. At the time these samples were taken I considered 36 p. p. m. nitric nitrogen in the air-dried soil, quite a notable quantity. The quantity varied in these samples apparently independently of the other factors, i. e. the amount of nitric nitrogen present bears no definite and direct relation to the amount of water-soluble, nor to the carbonates, nor to

	Total Water-Sol.	Sodic Carbonate	Chlorin	Nitric Nitrogen	Ratio N :Cl.
1............	39,314.0	779.8	2,145.0	7.08	1 :302.0
	25,500.0	1,060.0	229.5	Trace	tr. :229.0
2............	7,500.0	236.8	300.0	36.06	1 :8.3
	3,890.0	456.6	112.0	0.39	1 :330.0
3............	20,544.0	190.6	881.5	12.33	1 :72.0
	8,130.0	199.2	218.7	1.63	1 :173.0
4............	8,000.0	147.2	216.0	19.20	1 :11.3
	8,640.0	293.4	54.0	2.07	1 :27.0

the chlorid present. If there is any relation to the carbonates it would seem that the carbonates depress the nitrates. We have given the ratio of nitric nitrogen to the chlorin, but it is evidently of no value, varying from 1 :330 to 1 :8.3, and showing but very little or nothing.

At this time we paid much more attention to the ground-water and its composition than to the variation in the composition of the alkali on the surface of the soil. There is no doubt obtaining but that the alkalization of limited areas is due to the evaporation of water which finds its way into them, but which has no free underground outlet. We made no attempt to determine how much water was coming into this ground, but we did try to determine the composition of the water that came in and whether there was much, if any, lateral movement of the salts in the soil. The chief thing which interests us at this time is the variation in the substances held in solution both in regard to their quantity and composition. There were drains in some neighboring lands, supposed to cut off the water which would otherwise flow into this land. They were, however, not effective, and this water did flow into our plot. We made two analyses of these drain-waters with the following results given in parts per million:

	Total Solids	Chlorin	Nitric Nitrogen	Ratio N :Cl.
Drain No. 1....................	888.0	40.7	0.24	1 :170
Drain No. 2....................	1,047.0	44.3	0.48	1 :100

It is evident that such water, by its evaporation, might give rise to large quantities of mineral matter, but to only very moderate quantities of nitrates which, owing to their ready solubility, would probably not be deposited at all.

The study of the ground-waters within this alkalized area led to some interesting observations, for instance, they show that the character of the total solids contained in the water is not determined by the salts contained in the soil above the level of the water-plane, but represent much more nearly the salts held in the soil at this plane. This would of course be modified if there were a considerable volume of water moving freely downward through the soil, this, however, was not the case, and we found that there was an intimate relation between the height of the water-plane and the salts held in solution. In other words it was the salts in the soil and not those in the ground-water *per se* that determined the quantity and character of these salts in our case. We dug two holes at a period when the water was very high and, shutting out as best we could, by means of tiles, the water from the higher sections, we collected water representing three sections in one hole and four in another. The results are given in p. p. m. in the following statement:

	Total solids	Chlorin	Nitric Nitrogen
Hole No. 1—1st Sec.	2,842.8	232.9	1.28
2nd Sec.	2,450.0	177.9	0.76
3rd Sec.	1,938.5	117.9	0.36
Hole No. 2—1st Sec.	3,395.7	213.6	1.76
2nd Sec.	2,848.5	146.4	1.00
3rd Sec.	3,092.8	149.3	1.76
4th Sec.	2,985.7	156.4	1.68

The total solids in the water obtained from the first hole decreased rapidly with depth, but this decrease was not so marked in the second hole. The chlorin in the top sections of these holes is comparatively high and falls abruptly in the second section. The nitric nitrogen in these waters is very moderate in quantity, and in the first hole falls rapidly with depth, but the second section of the second hole alone shows any considerable variation. The ratio of nitric nitrogen to the chlorin in these cases is altogether erratic and bears no definite relation to the total solids or to the chlorin, even if the nitric nitrogen were present in quantities to be of any significance, which it is not. This relation between the depth of the water-plane and the total solids held in solution, was shown, too, in the variations in the waters of the permanent wells which we observed for more than three years. Each well had its own peculiarities, even when they were located close to each other. The following may illustrate this point. We will designate the wells as 1, 2 and 3.

Wells numbered 1 and 2 were close together, in fact were less than twelve feet apart, while number 3 was not more than 150 feet away. The results in the case of well number 3 are scarcely more striking than those obtained with the air-dried soil, but they are easily explained. When the water in the well was low, the salts in solution were also low, as the water-plane rose, in this case very nearly to the surface, the salts that went into solution increased. The nitrates were near or at the surface of the soil, as is clearly shown by the air-dried samples already given. The fact is that in this section of the land they were very abundant. The ratio of the nitric nitrogen to the chlorin in this water was 1 :3.63. The ground-water at the bottom of this well, that is the water underlying this section, contained an exceedingly small quantity of nitric nitrogen and the drain-waters, i. e. the ground-waters that were coming into this section, gave 0.24 and 0.48 parts per million for two different drains, and cannot justly be considered the source of the nitrates found at the surface. I have given the data for this case for the reason that the land was very rich in alkali, and affords us, I believe, reliable information relative to the probabilities that the nitrates discussed in Bulletin 155 and 178 may owe their origin to a process of concentration of ground-water rising through the soil, or filtering in from adjacent lands; in other words, of their having a common origin with the alkalis. We see in these samples of soil and ground-water only moderate quantities of nitrates, from a trace to thirty-six parts per million, in the soil, while in the well-waters it varies from a trace

THESE WELL-WATERS GAVE THE FOLLOWING RESULTS:

	Total Solids	Chlorin	Nitric Nitrogen
Well No. 1....................	10,357.0	971.4	3.6
	7,590.0	689.3	6.0
	8,387.0	792.9	3.4
	10,312.0	962.1	3.3
	9,831.4	895.4	3.1
	6,215.7	556.4	2.2
	6,461.4	525.0	1.9
	2,705.7	162.3	1.9
	2,388.5	165.0	1.7
	2,164.3	107.0	1.6
	1,990.0	105.0	1.9
	1,882.8	85.7	0.4
	1,752.8	80.5	0.4.
Well No. 2....................	7,297.0	578.0	28.0
	7,478.5	595.0	27.2
	6,821.4	522.9	26.0
	6,711.4	521.4	22.8
	6,717.1	571.0	9.2
	7,442.0	602.9	9.2
	7,561.3	610.0	8.2
	7,778.5	612.9	8.4
	5,564.3	503.6	28.0
	5,378.5	385.7	16.0
	8,492.8	397.1	16.0
	5,514.3	398.5	12.0
Well No. 3....................	1,600.0	68.0	Trace
	7,863.0	384.7	106.0
	5,385.7	240.8	54.0
	3,928.6	121.0	20.0

to 28 parts per million under ordinary conditions, and rises to 106 parts per million under special conditions, while the chlorin varies from 80 to 971 parts per million without any relation whatsoever to the amount of nitric nitrogen; the same is true, too, of the total solids, the sulfates and carbonates, so far as the latter have been given.

The accepted origin of the alkalis has already been indicated and is, I believe, of universal application. In regard to their presence in the shales perhaps the sulfids of iron ought to be considered as a possible agency contributing to their formation.

A question may be raised as to whether there are any occurrences of nitrates in the immediate vicinity. I think the nitrates appearing in well three owe their presence in such abundance to formation on the surface of the soil, but we will waive this point and give an analysis of a surface-soil from a typical "brown spot" where there is no unusual amount of alkali and whose limits are as distinctly marked as the margin of this printed page. The sample is a surface one, taken not more than one inch deep. The surface of this spot was moist due to the deliquescent character of the magnesic and calcic nitrates. The soil proper is a red, gypsiferous clay.

One of the effects of the presence of the nitrates in soil was set forth with emphasis in Bulletin 155, i. e. they brought about a muddy condition of the soil, a deflocculated condition which retained the water persistently. The statement was made, that while a certain soil was a veritable mud at two to two and one-half feet below the surface, no proper water-plane was met with at a depth of six feet; and in another which was muddy quite to the surface, we found no proper water-plane at six feet and had to wait nearly two hours to collect two gallons of water. It is easily conceivable that the presence of highly deliquescent salts, such as calcic and magnesic nitrates formed in the surface soil, should change the action of capillarity in the underlying soil and bring about excessive surface deposition of the salts already present in the mass of the soil. In the case here presented the surface-soil contained 11.56 percent of substances easily soluble in water, and the soil when dried in the air bath and exposed to the atmosphere, quickly becomes so moist that it forms a coherent mass when pressed between the thumb and finger. This spot occurs on the road side. The land here is not seeped and is not alkali land like the preceding. This sample is chosen because it is located in the same section of country as the land just discussed, and no explanation can be offered that the differences are due to location and general conditions and not to the causes that I have assigned, i. e. to excessive fixation of nitrogen and the formation of the nitrates *in situ*. I have already stated that the soil is a gypsiferous clay, and it follows that the amount of water-soluble found will depend almost altogether upon the amount of gypsum present and the persistency with which it is extracted with water.

ANALYSIS OF WATER-SOLUBLE FROM BROWN SPOT.

	Percent
Silicic acid	0.206
Calcic sulfate	80.440
Calcic chlorid	3.835
Magnesic chlorid	0.326
Magnesic nitrate	7.766
Potassic nitrate	0.093
Sodic nitrate	7.334
	100.000

The alkali incrustations, as well as the aqueous extracts of the surface soils, consist very largely of the sulfates of calcium, magnesium and sodium. The amount of the sodium sulfate varies exceedingly but in this case we find a small amount of sodic salts and a relatively small amount of chlorin. The soluble portion is 115,600.0 p. p. m., the chlorin is 3,112 and the nitric nitrogen is 3,120 p. p. m. It is evident in this case that the nitric acid must be combined with other bases than sodium, but to make our statements uniform we will give the nitric nitrogen and chlorin as the sodic salts corresponding to their respective quantities. The ratio of nitric nitrogen to chlorin in this case is 1 :1 and the corresponding amounts of sodic nitrate and chlorid are 18,720 and 4,979.2, or in the ratio of 1 :0.27.

The soil first given with its large quantity of alkalis and no unusual quantities of nitrates, and this sample of a "brown spot" with large amounts of nitrates and small amounts of alkali, gypsum excepted, which in this case is clearly a portion of the clay, illustrates the extreme difference between an alkali soil and a "brown spot" or nitre-area. I may add that I have seen a soil which is exceedingly rich in gypsum, so much so that it is ordinarily quite white, very strongly discolored with Azotobacter pigments and found it quite rich in nitric acid. This was in the immediate neighborhood of this "brown spot."

I answered this question of concentration fully in Bulletin 178 and showed that the nitrates could not have come from the adjacent lands. I presented the whole case, the favorable and unfavorable features, so fully that persons conversant with our conditions cannot doubt the competency of the data given to present the conditions really obtaining, and they gave no support to the concentration theory. Concerning this case I stated, "There is not another instance of the occurrence of nitre within this state which is so favorably located for justifying the theory of concentration from adjoining lands as this one, and it is for this reason that I have set forth these facts pertaining to the composition of the alkali, the soils to a depth of three feet, the aqueous extracts made from these soils, and the solids held in solution by the ground-waters." These facts were that there were no nitrates in the alkalis and none in the soils beyond such quantities as usually occur in soils. The aqueous extracts of these samples did not contain enough nitrates to give even a perceptible violet tinge when tested with ferrous sulfate and sulfuric acid in the usual way and the ground-waters were practically free from them. The soils yielded to water from 24,000 to 42,000 parts per million with from 5,000 to 7,000 p. p. m. of chlorin. The ground-waters carried from 12,600 to 15,400 parts of total solids per million, with from 3,100 to 4,600 parts of chlorin per million and only such traces of nitrates in the soils or the waters as it is usual to find under ordinary conditions. The alkali gathered from the surface of this soil carried 43.5 percent of sodic chlorid or 26.1 percent chlorin, but no nitrates. I stated that such alkalis, soils and waters could not be the source of nitrates found in neighboring lands even though these lands were lower and either the surface-water or the ground-water or both, flowed through and over this land. I think that this conclusion is fully justified. The facts in the case are that these waters do not find their way into the land discussed, at least, I could find no reason for thinking that they did then or do at the present time. The nitre spots presented in this connection were first observed in 1904. They were described as being sharply defined "brown spots on which nothing would grow." They have not yet become much better though the successive owners have combated this condition by fertilizing heavily, by continuous cultivation and by excessive irrigation. The general condition of this soil is represented by the following facts. The surface two inches carries 44,200 parts of water-soluble per million, of which about 30 percent is chlorin or 13,260 parts, and 1.6 percent is nitric nitrogen or 707.2 parts. The first foot of soil from the adjacent, we may say alkali field, gave 24,500 parts water-soluble per million with approximately 4,900 parts of chlorin and no nitric nitrogen beyond a trace. The alkali scraped off of the surface of this soil gave 27.6 percent soluble in water or 276,000 parts per million with 71,760 parts of chlorin and no nitric nitrogen. It is evident that the nitrates in the "brown spots" did not come from this source and that there is no relation beween any individual constituent of the alkali and the amount of nitric nitrogen which may be present.

We even went further in considering the part that the ground-water might play and presented the fact that the drain-water taken from a drain that runs east and west between the heavily alkalized land and some of these nitre-spots, so that the alkali land was north and the nitre-spots south of the drain with the fall of the land to the south. This drain-water carried one-tenth part nitric nitrogen per million and is the water which, if not intercepted by the drain, would flow beneath the nitre-areas. It carried 8,489 parts total solids in solution with 2,122 parts chlorin and one-tenth part of nitric nitrogen. The surface soil of the nitre-spots in this soil carried 98,820 parts water-soluble per million, 43,480 parts of chlorin and 494.0 parts of nitric nitrogen. Another sample from the area here considered gave 44,200 parts water-soluble, 13,260 of chlorin and 884 parts of nitric nitrogen. There is no relation between the alkalis of the neighboring lands, the solids held in solution by the ground-waters, or the water-soluble portion of the alkalized soil and the nitrates found in these nitre-spots. A similar soil in the same section of the country, perhaps seven miles distant from the preceding locality, gave the following results: 55,300 p. p. m. of water-soluble, 5,500 p. p. m. of chlorin and 4,203 p. p. m. of nitric nitrogen in which we have the ratio for nitric nitrogen to chlorin 1:1.33.

It may be convenient for some purposes to state our results in the form of this ratio, nitrogen to chlorin, but it means nothing and fails to convey an adequate idea of the relative quantities of the respective salts represented, especially to those who may be accustomed to think in terms of these salts, i. e. in terms of nitrates and chlorids instead of nitric nitrogen and chlorin. In the last sample for instance, we have the ratio of 1:1.33 for the nitric nitrogen to the chlorin, which tends to leave the impression upon the reader that the nitrates are subordinate in quantity because the value one and one-third is greater than one. The amounts of these salts present, calculated as sodic salts, were really 25,218 parts of sodic nitrate and 8,800 parts of sodic chlorid; in other words, instead of the chlorid predominating, the nitrates were present in three times as great a quantity as the chlorids. The actual ratio for these salts is 1:0.34. We will take another example from another section of the State, in which we have 33,200 p. p. m. of water-soluble, 658.4 p. p. m. chlorin, and 987.6 p. p. m. of nitric nitrogen. The ratio for the nitric nitrogen to the chlorin in this case is 1:0.66. To the person who knows the respective factors for converting this ratio into that of the nitrates and chlorids, it may convey a definite idea of their relative quantities, but even such a person is apt to overlook the great difference in the quantites of these salts actually present, which quantities, in this case are 5,926 parts of nitrates to 1,053 parts of chlorids, or in the ratio of 1:0.17, or stated differently, 0.6 per cent of the dry soil is composed of sodic nitrate and 0.1 percent of sodic chlorid.

We have now presented the details of two very distinct localities in which we find some lands seeped and strongly alkalized and in which also occur "brown spots on which nothing will grow," nitre-spots. These have been given to show that the nitre found in the "brown spots" does not owe its origin to the alkalis nor to the concentration of the ground-waters. We will briefly restate our results to show that there is no relation whatsoever between the alkalis and these nitre-spots which in any way justifies the view that the "brown spots" owe their origin to seepage, or have a common origin with the alkalis.

In the first case cited the alakalis were gathered and analyzed and while they always carried chlorin, some of them as much as five percent of their weight, none of them carried more than heavy traces of nitric nitrogen, and some of them carried none at all.

The soil samples taken from four different parts of this piece of land showed no unusual amounts of nitrates. These samples represent the first and second two inch sections of the soil and gave the following results in parts per million:

FIRST TWO INCHES.				SECOND TWO INCHES.			
Water-Sol.	Chlorin	Nitric Nitrogen	N:Cl.	Water-Sol.	Chlorin	Nitric Nitrogen	N:Cl.
39,314.0	2,145.0	7.1	1:302.0	25,500.0	229.0	Tr.	Tr:229.0
7,500.0	300.0	36.0	1: 8.3	3,890.0	112.0	0.3	1:130.0
20,544.0	881.5	12.3	1: 72.0	8,130.0	218.0	1.6	1:147.0
8,000.0	216.0	19.2	1: 11.0	8,640.0	54.0	2.1	1: 27.0

These samples were taken at the same time and show that in some sections of the land the alkali was very abundant but that there was no relation between the amount of alkali in the soil and the amount of nitric nitrogen present. Further they show that there is no relation between the chlorin in the soil and the nitric nitrogen. We find this true in both of the two-inch sections taken. The nitric nitrogen found in this strongly alkaline soil is by no means remarkably high unless the figure 36.0 p. p. m. nitric nitrogen be considered higher than usual which, I think, would in general be justified, but not in Colorado, for we often find much higher figures than these for ordinary, cultivated soils.

We also examined the ground-waters from this area and found them to contain total solids varying in quantity from 1,600 to 10,357 p. p. m., chlorin from 68 to 971.0 p. p. m., and nitric nitrogen from a trace to 106.0 p. p. m. There is no relation between the amounts of nitric nitrogen and those of chlorin. We have with

3.6 p. p. m. of nitric nitrogen 971.0 p. p. m. of chlorin with 106.0 p. p. m. nitric nitrogen 384.7 p. p. m. chlorin; with 3.3 p. p. m. nitric nitrogen 962.0 p. p. m. of chlorin, and with 54.0 p. p. m. of nitric nitrogen 240.8 p. p. m. of chlorin. These data, the favorable and unfavorable, have been given for a strongly alkalized piece of ground to show what the facts are which obtain under such conditions. The high nitric nitrogen in well No. 3 is easily explainable.

For the purpose of comparison we have also given the facts presented by a "brown spot" in the same section of the country. This "brown spot" occurs on a red, gypsiferous clay and is not on seeped land. The water-soluble was mostly gypsum, but the results were water-soluble 115,600 p. p. m., chlorin 3,112.0 p. p. m., and nitric nitrogen 3,120.0 p. p. m.

In the second case presented we have followed the same order of presentation and of course for the same purpose, and as this case has been previously published in its most essential points, I shall give it very briefly:

The alkali;	water-soluble	435,000.0 p.p.m.
	Chlorin	261,000.0 p.p.m.
	Nitric Nitrogen	None
The Soil;	water-soluble from	24,000.0 to 42,000.0 p.p.m.
	Chlorin	5,000.0 to 7,000.0 p.p.m.
	Nitric Nitrogen	Traces usually found in soils
Ground-Water;	Total Solids	12,600.0 to 15,400.0 p.p.m.
	Chlorin	3,100.0 to 4,600.0 p.p.m.
	Nitric Nitrogen	None or only traces
Drain-Water;	Total Solids	8,489.0 p.p.m.
	Chlorin	2,122.0 p.p.m.
	Nitric Nitrogen	0.1 p.p.m.

The "brown spots" in land immediately below this and through a part of which the drain-water just given had flowed:

Soil from "brown spot";	Water-soluble	98,820.0 p.p.m.
	Chlorin	43,480.0 p.p.m.
	Nitric Nitrogen	494.0 p.p.m.
Soil from another spot;	Water-soluble	44,200.0 p.p.m.
	Chlorin	13,260.0 p.p.m.
	Nitric Nitrogen	884.0 p.p.m
Soil from another "brown spot" on land in the same district. Soil;	Water-soluble	55,300.0 p.p.m.
	Chlorin	5,500.0 p.p.m.
	Nitric Nitrogen	4,203.0 p.p.m.
Soil from another "brown spot," not in the same district. Soil;	Water-soluble	83,200.0 p.p.m.
	Chlorin	658.4 p.p.m.
	Nitric Nitrogen	987.5 p.p.m.

The above drain-water contains 21,220 times as much chlorin as nitric nitrogen. But this is the water that underlaid the soil on which the "brown spots" showed only 87.6 times as much chlorin as nitric nitrogen in one case and 15 times as much in the other case. When one considers the fact that the sodic nitrate is more than twice as readily soluble as the chlorid and attracts moisture quite readily while the nitrates of calcium and magnesium are deliquescent, any concentration of these quantities of nitrates from such waters is wholly out of the question. Furthermore, these data show that any ratio given for the nitric nitrogen to the chlorin is utterly valueless.

The question of how much nitric nitrogen do ordinarily good, cultivated soils in Colorado contain, can properly be raised in this connection. I endeavored to answer this question in Bulletin 155, pages 33-35. I think that from 5 to 8 parts per million of the dry soil may be considered as maximum quantities under ordinary conditions. This is for samples taken to a depth of two inches and not after heavy rains or recent irrigation. If the samples be taken to greater depths it will usually be lower, provided the moisture conditions are the same. According to this the first alkaline soil given carried rather large amounts of nitric nitrogen in three out of four cases, 12, 19 and 36 p. p. m., but the second soil carried no unusual amounts. The brown spots from the respective sections, however, carried 3,462, 494.0, 884.0 and 4,203.0 p. p. m. of nitric nitrogen.

Apropos to the chlorin in ordinarily good, cultivated soils I have no data pertaining to samples taken to depths of only two or three inches, but I have quite a number of soil samples taken to depths of from one to three feet; these indicate that the chlorin in such soils under favorable conditions varies between 200 and 900 p. p. m., but in alkali soils whether nitrates be present or not the surface portions may be very rich in chlorin. I have a surface sample of soil from an orchard which was in fairly good condition but the trees, though apparently healthy, were small. The chlorin in this sample amounted to 1.5 percent of the dried soil or was 15,000 p. p. m. There was no incrustation on this soil, but it was dark, due to the large amount of chlorids present, among which was a large proportion of calcic chlorid. There was only a trace of nitric nitrogen in the aqueous extract of this soil, corresponding to such quantities of nitric nitrogen as we would expect to find in any ordinary soil. Further, the samples of alkali soils already given show that we may have very considerable amounts of chlorin occurring in the surface portions without any nitrates. In the case of the alkali previously given the chlorin amounted to 261,000 p. p. m. and there was no nitric nitrogen. It is often, but not always, the case, that we find large amounts of chlorin in such samples as are rich in nitrates and the same thing is true of the sulfates. That the chlorids are not always high when the nitric nitrogen is high is shown by the sample already given in which we have 987.6 p. p. m. nitric nitrogen and 658.4 p. p. m. chlorin, but the sulfates in this case were high.

OBSERVATIONS OF 1912.

The work done preparatory to writng up Bulletin 178 showed, when collected, that it would be desirable to follow the variations in the nitric nitrogen present in a definite locality and in these spots from time to time throughout several months. Accordingly we planned to make such observations but we have not been able to carry out these plans as we wished. Still we have gathered quite a mass of data. The fact that we have been prevented from carrying out our plans *in extenso* is not the only feature that contributes to making the data less valuable than they otherwise would have been, but other factors have also contributed to bring about these results. These nitrate conditions in general were much less severe in 1912 than they were in 1910 and 1911. There was, in some sections at least, a more general distribution of the trouble, but by far fewer cases of intense injury due to this cause, than in preceding years. In writing Bulletin 183 I had occasion to note that there was a general improvement in the quality of our sugar beets over that shown during the preceding four or five years. This was shown in a still greater measure in 1912. I do not doubt but that the intensity of this nitre trouble varies with different seasons though I have no definite figures to prove this assertion. Still it is true that in 1907, 1908, 1909 and 1910, the molasses in some factories gave a great deal of trouble in the crystallizers, whereas in 1911 they worked very easily. We had in certain sections other evidence of this change. The growth and physical properties of the beets were entirely different from those of the preceding years, the tops were small, prone, and of a yellowish green color. The beets were relatively large in comparison with the size of the tops, and their flesh had an opaque, yellowish white color and not the glassy, semi-transculent, watery white color of the previous years. In 1912 the crop was still better and the average precentage of sugar was two percent higher than it had been in some of the previous years. The nitric acid in the molasses of 1911 was less abundant than in 1909 and 1910. I have not analyzed the molasses of 1912. In addition to such general facts as these, there were fewer cases of intense injury to fruit trees in 1912 than in 1910 and 1911. This too is based upon general observation and not upon actual numbers. There were too many bad cases and too much general injury done in 1912, however, to escape notice or to be considered as a negligible factor in our fruit growing or in our general agriculture. We are simply giving the facts and not making any excuses for the data that we are about to present.

Our plan was to collect samples from certain measured areas at stated intervals and observe the variations in the amount of nitrates and chlorids present and also to note the appearance of any "brown spots" within these areas and the development of the nitrates in them. The lands chosen were supposed to be favorable for our purposes and were sufficiently varied in character to meet any objections which might be based upon the assumption of our being too strongly influenced in making the selection. Some of the land suffered a change in management during the period of our observations and we were deprived of intelligent cooperation, in fact of any kind of cooperation, and the land received no kind of care, which further changed the conditions. Our series of samples could not be made complete because of inopportune rains. This hindrance happened to me several times during the season.

THE FIRST PLACE CHOSEN.

The first place selected was a piece of land situated near the river and its drainage into the river was so free that the water backed up into the land when the water rose in the river and fell with it. This soil was sampled 20 Oct., 1911, to a depth of 60 inches, i. e. to the gravel which varies from 5 to 8½ feet from the surface. The results are given in parts per million.

ANALYSES OF SAMPLES FROM THE FIRST PLACE CHOSEN.

	Nitric Nitrogen	Total Nitrogen
1 to 6 inches	109.0	931.6
7 to 12 inches	14.0	768.4
13 to 22 inches	11.0	510.0
23 to 32 inches	6.0	469.2
33 to 42 inches	2.6	530.0
43 to 49 inches	2.0	312.8
50 to 60 inches	2.0	346.8

Another set of samples was collected 10 Dec., 1911. These samples are composite, each containing 22 subsamples.

	Nitric Nitrogen	Total Nitrogen
1 to 3 inches	50.0	972.4
4 to 6 inches	26.0	884.0
7 to 9 inches	8.4	884.0

Samples taken 15 April, 1912. Composite samples each containing 22 subsamples.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches	64.0	850.0	4,304.7
4 to 6 inches	40.0	816.0	2,366.6
Brown spot	1,722.0	2,148.8	19,832.0

Samples taken 10 July, 1912.

1 to 3 inches	486.9	1,196.8	12,344.0
4 to 7 inches	20.	748.0	1,443.0

No samples were taken at this place between the two last dates because it was too wet on the occasion of our visits either because it had just been irrigated or because it had just rained, or because the river was in flood.

THE SECOND PLACE CHOSEN.

The second place chosen was strongly alkalized and in part seeped. These are the factors that determined this selection. Some of this land is still under cultivation, but some of its has been abandoned for several years.

I will digress to state that many persons think that drainage would obviate the troubles met with in such land as this. I am sure that this is true, if we could drain it, but I hold it as entirely infeasible to drain this land, not because drains cannot be put through it, though this will be difficult on account of quaggy spots and quicksands, and cannot be done at any reasonable expense, but because the drains will be very difficult to keep open. The principal trouble, however, lies in the fact that this land will not drain. I have described such lands in previous bulletins and stated in one case that a hole made in such land held rain-water which flowed into it from the surface till it evaporated, and have further stated the necessity that I found myself under of letting a hole, sunk six feet in such muddy land, stand open over night in order to obtain a sample of water for analysis. I have also stated that I have seen some 7,000 feet of open trench in such land whose surface was muddy and yet there was not enough water in the bottom of the trench to form a flow. In this kind of land one may find water standing at the very surface and within a few feet of it find dry earth to a depth of from 6 to 16 feet or even more. The only way to drain this land would be to put a drain to every wet spot and I doubt whether this would be effective, even if the drain terminated in a well. *Drainage, where feasible, is undoubtedly the corrective measure to be taken in our alkali questions, but drainage is not always feasible.* Drainage often yields disappointing results. I recall having mentioned this in another bulletin and stating that I had opened a drain and found water enough flowing to show that this drain was not closed up, but that the land within a few feet of it was a perfect mudhole and partially covered with standing water. I recommend dranage for land that is wet, but I can see no use of with holding, what seems to me a patent fact, that it will cost more to effectively drain such land as this than the land will be worth for many years to come, if ever. The questions of drainage in some lands in Colorado are serious ones with which the alkali questions are intimately associated.

SAMPLES FROM THE SECOND PLACE CHOSEN.

The samples from this place are all surface-samples, namely none of them were taken to a greater depth than three inches. Other samples from this place, taken to a depth of three feet, have already been given. The samples here presented are composite, taken to represent a fairly large surface.

ANALYSES OF SAMPLES FROM SECOND PLACE CHOSEN.

	Nitric Nitrogen	Total Nitrogen	Chlorin
Samples taken April 4, 1912.			
1	8.0	1,196.8	18,273.0
2	16.0	992.8	19,180.6
3	30.0	1,312.4	19,560.0
Sample taken May 13, 1912.			
4	6.0	680.0	19,296.0
Samples taken July 10, 1912.			
5	29.0	1,312.0	19,560.0
6	20.0	1,047.0	33,920.0
7	30.0	1,142.4	17,960.0

These results are in perfect harmony with those obtained in previous years. There are, however, a few spots in which changes are taking place, which is rather surprising in consideration of the large amount of chlorin present in the surface portions. The amount of chlorin falls off rapidly with depth, for the first foot of soil, including the surface, carried only 3,870.0 p. p. m. of chlorin. The amount of chlorin is by no means constant. Samples of "brown spots" on this land, which were taken to see whether we were quite correct in our judgment, gave the following results:

Samples taken July 10, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
8	779.1	1,319.2	18,743.0
9	881.0	1,339.6	19,089.0

THE THIRD PLACE CHOSEN.

The third place selected was a larger area and was divided into equal sections, one-sixth-acre each. The surface-portion was sampled to a depth of seven inches, the top three inches was taken as one and the succeeding four inches as a second sample. Sixty samples were taken to these respective depths from each one-sixth-acre, united, thoroughly mixed and cut down to form a composite sample. We took, in sampling the whole acre, 720 individual samples. In the samples taken on April 15, 1912, only the surface-samples, i. e., the top three inches, were taken. This land was further sampled by taking vertical sections from the surface down to the water-plane. Three such sets of samples were taken during the period of observation. On one occasion seven such sections were made but on the other occasions we took only six sections. We did not use an auger in taking these samples, but opened a trench, prepared a clean vertical face, and took the samples from this. In order to exhibit still more fully the conditions in this ground, samples of surface-soil were taken from open spots in an adjoining alfalfa field similar in location and character to this land chosen for systematic sampling, and also samples of "brown spots" which occurred within this area. There were no "brown spots" in the alfalfa field. In addition to these soil samples, we also took three samples of ground-water obtained from the trenches dug for making the vertical sections. The acre of land chosen was located so that it gave us a variety of conditions and also included distinct cases of "brown spots." The samples from the open spots in the alfalfa field were taken because this land is as unfavorably situated as that chosen and is the continuation of it westward. This land, except for these spots, is occupied by a fairly good stand of alfalfa. To restate the matter of sampling: We have systematically taken composite samples each representing one-sixth of an acre. We have three series of vertical sections consisting of six members each, samples from "brown spots," surface-soil outside of the "brown spots," surface-soil from similar adjoining land, and samples of ground-water. I regret that this work could not have been done in 1910 and 1911 for the conditions were far less intense in 1912 and the land received much better care in these years than in 1912. The results are again given in parts per million. Each of the following sample, representing one-sixth of an acre, is a composite one containing 60 subsamples. The numbers 1, 2, 3, 4, 5 and 6 represent the same order of sections.

When I went in August to take my samples, I found this land so occupied by weeds, wild lettuce, Russian thistle, etc., that I considered it impossible to obtain satisfactory results and the sampling was given up and there are no general systematic samples subsequent to this date.

ANALYSES OF SAMPLES FROM THE THIRD PLACE CHOSEN.

Samples taken April 15, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1. 1 to 3 inches	276.0	1,115.2	2,696.9
2. 1 to 3 inches	387.5	1,142.4	1,139.7
3. 1 to 3 inches	367.0	1,074.4	1,542.0
4. 1 to 3 inches	70.0	816.0	412.3
5. 1 to 3 inches	8.0	625.6	66.0
6. 1 to 3 inches	4.0	639.2	156.7
Alfalfa field	40.0	1,353.2	7,693.4
"Brown spot," southwest corner	1,803.0	1,897.2	18,884.0
Brown top soil	10,000.5	14,920.0	14,464.0

Samples taken May 15, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1. 1 to 3 inches	190.0	992.8	1,797.7
4 to 7 inches	20.0	693.6	634.9
2. 1 to 3 inches	274.9	992.8	948.3
4 to 7 inches	74.8	666.4	659.7
3. 1 to 3 inches	253.1	965.6	329.8
4 to 7 inches	20.0	625.6	602.0
4. 1 to 3 inches	30.0	741.2	602.0
4 to 7 inches	15.0	625.6	371.1
5. 1 to 3 inches	5.0	639.2	140.2
4 to 7 inches	5.0	544.0	329.8
6. 1 to 3 inches	3.0	680.0	338.1
4 to 7 inches	1.5	557.6	359.8
Alfalfa field	80.0	1,761.2	18,554.0
Brown surface soil	3,814.0	5,412.8	12,493.0
12 feet from edge of "brown spot"	7.0	557.6	247.4
"Brown spot"	8,702.0	9,329.6	14,060.8
"Brown spot"	5,312.5	6,120.0	21,935.0

Samples taken June 12, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1. 1 to 3 inches	253.6	938.4	2,597.5
4 to 7 inches	16.0	673.2	676.1
2. 1 to 3 inches	289.3	1,156.0	8,106.0
4 to 7 inches	194.5	843.2	890.6
3. 1 to 3 inches	324.2	1,081.2	2,185.3
4 to 7 inches	16.0	683.4	593.7
4. 1 to 3 inches	117.1	701.6	808.1
4 to 7 inches	12.0	5,511.6	222.7
5. 1 to 3 inches	24.0	632.4	453.5
4 to 7 inches	4.0	516.8	329.8
*6. 1 to 3 inches	6.0	686.8	313.3
4 to 7 inches	8.0	584.8	907.1

	Nitric Nitrogen	Total Nitrogen	Chlorin
Alfalfa field	20.0	1,999.2	19,024.0
Brown surface soil	6,970.9	7,684.2	23,304.0
Brown soil tree holes	1,228.7	1,873.2	4,813.0
"Brown spot"	15,275.0	17,272.0	18,908.0
"Brown spot"	5,231.5	6,079.2	19,131.0
"Brown spot"	7,077.0	8,500.0	13,812.0
Surface-soil 16 feet from edge of last sample	16.0	591.6	273.9

Samples taken 13 July, 1912.

	Nitric Nitrogen	Total Nitrogen	Chlorin
1. 1 to 3 inches	261.4	952.0	2,482.0
4 to 7 inches	12.0	754.8	667.9
2. 1 to 3 inches	351.9	1,081.2	1,896.5
4 to 7 inches	57.2	686.8	658.2
3. 1 to 3 inches	266.0	897.7	1,467.8
4 to 7 inches	35.0	625.6	247.4
4. 1 to 3 inches	107.8	870.4	676.2
4 to 7 inches	42.2	646.0	272.1
5. 1 to 3 inches	12.0	652.8	247.4
4 to 7 inches	6.0	646.0	164.9
6. 1 to 3 inches	10.0	693.6	123.7
4 to 7 inches	0.5	476.0	206.2
Alfalfa field	25.0	1,788.4	18,743.0
"Brown spot"	11,287.5	13,804.0	15,733.0
"Brown spot"	4,356.5	5,562.4	17,993.0

*This section No. 6 had been irrigated quite recently.

The first set of samples taken for the purpose of determining the distribution of the nitrates in depth was taken 12 December, 1911. While the results are somewhat erratic, I think that this is in a measure, if not altogether, due to the effects of late irrigation. I have, unfortunately, no means of obtaining data pertaining to this feature of the question. These holes, or sections, are arranged in pairs 1 and 4, 2 and 5, 3 and 6. This is done because 1 and 4 are similarly located and are about 50 or 60 feet apart, one being immediately north of the other; 2 and 5 constitute another pair; and 3 and 6, another. This pair, 3 and 6, is located in the very outer edge of the bad territory of 1911, which was apparently quite good territory in 1912. The seventh section was taken in territory which has not, up to the present time, shown serious trouble, if it has shown any trouble at all. The chlorin was not determined in the first series.

ANALYSES OF SAMPLES OF VERTICAL SECTION.

Samples taken 12 December, 1911.

	Hole No. 1		Hole No. 4	
	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen
1 to 3 inches	422.7	1,128.3	3.0	992.8
4 to 6 inches	85.5	707.2	8.5	870.4
7 to 18 inches	26.0	516.8	20.0	501.4
19 to 31 inches	5.0	442.0	28.0	680.0
31 to 42 inches	0.2	442.0	48.0	469.2
43 to 54 inches	0.1	346.8	50.0	380.8

	Hole No. 2		Hole No. 5	
	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen
1 to 3 inches	2.8	639.2	18.1	639.2
4 to 6 inches	6.0	605.2	18.5	530.4
7 to 18 inches	2.4	578.0	13.0	578.0
19 to 30 inches	24.0	455.6	28.0	487.8
31 to 42 inches	52.0	448.8	56.0	639.2
43 to 54 inches	80.0	537.2	32.0	516.8

	Hole No. 3		Hole No. 6		Hole No. 7	
	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen	Nitric Nitrogen	Total Nitrogen
1 to 3 inches	0.8	652.8	24.6	904.4	1.2	829.6
4 to 6 inches	2.4	516.8	12.2	564.4	0.5	639.2
7 to 18 inches	1.6	374.0	9.6	564.4	0.6	401.2
19 to 30 inches	1.2	272.0	2.4	394.4	1.0	306.2
31 to 42 inches	1.2	244.8	2.4	435.2	1.2	326.4
43 to 54 inches	0.8	285.6	2.0	503.2	0.7	306.0

Samples taken 15 May, 1912.

	Hole No. 1.				Hole No. 4.			
	Water-Soluble	Nitric Nitrogen	Total Nitrogen	Chlorin	Water-Soluble	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches	13,475.0	237.4	918.0	3,158.4	3,925.0	52.9	1,020.0	387.6
4 to 7 inches	5,425.0	15.0	664.4	940.0	4,326.0	3.5	700.0	197.9
8 to 19 inches	9,000.0	6.0	530.4	560.7	3,215.0	12.0	556.7	577.2
20 to 31 inches	6,550.0	10.0	489.6	470.0	7,375.0	32.0	605.2	593.7
32 to 43 inches	10,625.0	6.0	448.8	494.8	8,600.0	57.0	503.2	634.9
44 to 55 inches	17,925.0	6.0	462.4	354.6	......	...	......	....

	Hole No. 2.			Hole No. 5.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	4.5	693.2	206.1	28.0	632.4	123.7
4 to 7 inches....	1.5	401.2	206.1	24.0	508.2	1,154.5
8 to 19 inches....	0.5	435.2	313.3	2.5	557.6	395.1
20 to 31 inches....	16.0	326.4	387.6	Trace	476.0	296.8
32 to 43 inches....	20.0	312.8	321.6	2.0	448.8	123.7
44 to 55 inches....	24.0	244.8	123.7	2.5	455.6	230.9

	Hole No. 3.			Hole No. 6.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	3.0	693.6	123.7	18.0	843.2	371.1
4 to 7 inches....	2.0	442.0	346.3	10.0	530.4	272.1
8 to 19 inches....	1.0	394.4	164.9	5.0	462.4	288.6
20 to 31 inches....	Trace	285.6	181.4	2.0	367.2	222.6
32 to 43 inches....	None	231.2	296.9	2.0	346.8	222.6
44 to 55 inches....	0.5	387.6	272.1	1.5	367.2	206.1

Samples taken 13 July, 1912.

	Hole No. 1.			Hole No. 4.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	24.0	680.0	3,474.0	222.7	1,094.8	3,051.0
4 to 7 inches....	2.0	455.6	478.3	20.0	646.0	494.8
8 to 19 inches....	0.5	258.4	371.1	30.0	578.0	907.1
2 0to 31 inches....	24.0	278.8	395.8	12.0	469.2	511.2
32 to 43 inches....	5.0	380.8	494.8	16.0	340.0	288.6
44 to 55 inches....	Trace	350.0	313.3	20.0	530.0	395.8

	Hole No. 2.			Hole No. 5.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	20.0	625.6	164.9	340.1	1,033.6	1,937.8
4 to 7 inches....	1.0	625.6	82.4	34.5	571.2	453.5
8 to 19 inches....	2.0	455.6	247.4	79.2	591.6	618.3
20 to 31 inches....	32.0	408.0	437.0	36.3	578.0	453.5
32 to 43 inches....	30.0	380.8	371.1	83.7	501.4	395.8
44 to 55 inches....	Water	....	....	71.5	508.2	445.3

	Hole No. 3.			Hole No. 6.		
	Nitric Nitrogen	Total Nitrogen	Chlorin	Nitric Nitrogen	Total Nitrogen	Chlorin
1 to 3 inches....	2.0	571.2	82.4	24.0	734.4	329.8
4 to 7 inches....	Trace	285.6	41.2	3.0	516.8	329.8
8 to 19 inches....	None	326.4	123.6	2.0	448.8	247.4
20 to 31 inches....	Trace	333.2	181.4	8.0	360.4	164.9
32 to 43 inches....	None	190.4	206.2	5.0	326.4	164.9
44 to 55 inches....	None	217.6	329.8	3.0	401.2	288.6
56 to 67 inches....	....	....	....	1.5	319.6	329.8

There were three samples of ground-water taken from this area, one on 12 December, 1911, and two 15 May, 1912. The sample taken 12 December, 1911, was taken from Hole No. 1. The sample of soil representing the top three inches of this section, carried 422.7 p. p. m. of nitric nitrogen, as is shown by the previous statement of results, and the nitrates diminished very rapidly with depth. The other two samples were taken 15 May, 1912, one from Hole No. 4 and the other from Hole No. 6. One of these samples would have been taken from Hole No. 1, because the preceding sample of water was taken from this hole, but under the conditions I would have had to dig another hole to do so, and as number 4 was only 50 to 60 feet north of it,I took this instead. It would have been better to have taken the sample at the first place instead of at the second, for a few feet, say 50, as in this case, may make too much difference in the composition of the ground-waters to permit of their comparison. This fact is shown by wells one and two given on page 8. These wells were sunk to different depths, but both entered the ground-water. Though these wells were only about twelve feet apart and the corresponding samples were taken on the same dates, the waters are scarcely comparable in any respect. The value of three isolated samples of water is but small in representing the underground conditions in an acre of land, especially as only two of them were taken on the same date. The study of ground-waters presents more difficulties than any subject that I know of and to interpret the results obtained is a very unsatisfactory task. We will give the analyses of these ground-waters for just what they may be worth. We do this, in fact we hold it as indispensable to give them, in order to complete our data regarding this land. This water was met with at different depths from the surface. I assumed that this land was so open and uniform in structure that the water-plane at least would be the same when the holes were dug in level land and only about 50 feet apart. I am not sure that this was true, still in spite of our doubts, we may assume it to have been so. The difference in the water-planes found in December and May was one foot and seven inches. The analytical results were as follows:

ANALYSES OF GROUND WATERS.

	Hole No. 1.	Hole No. 4.	Hole No. 6.
Depth of water-plane	4′ 9″	4′ 2″	8′ 7″
	Water-residue Percent.	Water-residue Percent.	Water-residue Percent.
Calcic Sulfate	20.286	10.174	20.593
Magnesic sulfate	41.753	40.947	32.658
Magnesic chlorid	....	....	7.169
Potassic sulfate	4.027	3.484	....
Potassic chlorid	....	....	3.120
Sodic sulfate	5.042	11.625	....
Sodic carbonate	14.763	8.670	7.129
Sodic chlorid	13.010	13.305	11.495
Sodic nitrate	0.164	11.343	17.528
Manganic oxid.	0.226	....	....
Sodic silicate	0.729	0.479	0.398
Total	100.000	100.000	100.000

Sanitary Analyses in Parts per Million.

Total solids	9,788.000	18,557.000	13,258.000
Free ammonia	0.170	0.310	
Alb. ammonia	0.128	0.525	
Nitrous nitrogen	Trace	Not determined	
Nitric nitrogen	4.000	318.800	441.500
Chlorin	760.000	1,390.300	1,567.000

We have given the results of the examination of thirty-six samples of ground-water which show from no nitric nitrogen up to 441 parts per million. In several cases we find very small amounts in the surface-soil at the time the samples were taken and find that this increased as we gained depth till we encountered the ground-water which was richer in nitrates than any section of the soil. There can scarcely be any doubt but that this was due to the washing of the nitrates down into the soil, which is the direction in which the nitrates are usually found to move. In one case we found that the ground-water before irrigation carried only traces of nitric nitrogen, but after a copious irrigation, whereby the ground-water was raised to within a few inches of the surface, we found 106 parts per million. The evident explanation of this is that the nitrates were dissolved out of the surface-soil and transferred to the ground-water. Three months later when this irrigating water had drained out of the soil, the nitric nitrogen had fallen to less than one-tenth-part per million. I have already stated that the total solids in these ground-waters decreased as the water-plane fell, this was the case in these samples. In July, immediately after irrigation when the water-plane was near to the surface, the total solids carried by the water amounted to 7,862 p. p. m. and the nitric nitrogen to 106 p. p. m. In October, when the water-plane had fallen, the total solids amounted to 1,201 p. p. m. and the nitric nitrogen to 0.04 p. p. m. This water carried, in July just before the ground was irrigated, only a trace of nitric nitrogen. We have here clear proof that the nitric nitrogen was not deposited by the evaporation of ground-water and was not brought into this area from adjoining land by ground-waters.

We have in another case, not referred to in the previous paragraphs, a demonstration of the same facts, i. e. that the nitrates do not come from below and are not deposited on the surface by evaporation of the water. In this case the land was in bad condition, the details of which we will not give. I made persistent inquiry regarding the underground-water conditions and dug a hole to a depth of about four feet, but could not find that the water-plane was very near the surface. The property changed owners and the new owner started to investigate these conditions by having holes dug in order to ascertain the depth of the water-plane. He obtained a small amount of water at about five and one-half or six feet, but there was much less water below this until he reached a depth of sixteen feet, at which depth he found water which was under some hydrostatic pressure. It rose to about five and one-half feet. The water found at about five feet, and that which had accumulated in the cellar under the house, was evidently surface-water which had accumulated at these depths. The surface-water was rich in nitrates, but this water that came from the greater depth contained none, though it was very heavily charged with alkalis; the total solids amounted to 22,104. p. p. m. This water which had percolated through the shales and formed the ground-water at this place, though heavily charged with the ordinary alkalis of the section, which were in no way abnormal in their composition, contained no nitrates and could not have been the source of the nitrates found in the surface-soil. On the other hand, the water that had percolated from the surface and was met with a depth of between five and six feet, was quite rich in nitrates. These nitrates had not been collected by the underground-waters at some distant locality and brought by them to this place and deposited here by their evaporation from the surface of the soil. This was not a newly irrigated district. These under-ground waters had been there for many years and the orchard had grown healthily for thirteen years. The land was alkalized but not worse than the land presented as the first case given in this bulletin. As the ground-water proper contained no nitrates, though heavily charged with alkalis, it was undoubtedly the source of the latter present in the soil, but could not be the source of the former. The nitrates found in the water met with at a depth of between five and six feet had been washed down from the surface and had not been brought up from below, that is they had not been gathered from the rocks of the country nor from other lands affected with this trouble.

There is a practical and suggestive question in this connection which has been raised by intelligent orchardists, i. e. is there danger of spreading the trouble by the inoculation of one soil from another, and by the use of drainage water for irrigation, and further, is there any danger of injury from the use of such water due to the presence of nitrates already formed? I do not believe that there is danger from the latter source, at least, not in general.

THE FOURTH PLACE CHOSEN.

The fourth place selected was a section of country on a mesa where a few years ago no "brown spots" were recognizable, but where they have made their appearance since our earlier observations of this section. The inconveniences and mishaps in collecting our samples at stated times at this place were so great that we succeeded in collecting only a few samples, which we will give as miscellaneous ones. They will be none the less interesting on this account. Perhaps they may be even more instructive. As just stated, a few years ago there were no pronounced, characteristic "brown spots" noticeable. There probably was, in many places, an abundance, perhaps an excess of nitrates, but for the past four or it may be five years there has been no doubt about their presence. The first sample that I will give was taken from a wheat field 4 May, 1912. The soil was a red, mesa clay. The surface was quite white. We judged this to be a case of ordinary alkali. In sampling, only the surface soil was taken, and we obtained the following results in parts per million:

ANALYSES OF SAMPLES FROM THE FOURTH PLACE CHOSEN.

	Nitric Nitrogen	Total Nitrogen	Chlorin
Ordinary alkali soil	14.0	516.8	6,031.8
Ordinary alkali surface soil	80.0	693.6	6,922.0
Brown surface soil	921.5	1,360.0	11,416.0
Very brown spot	5,498.0	5,548.8	17,016.0
Ordinary soil 50 feet away	12.0	612.0	45.3
White alkali soil	40.0	1,319.2	23,584.0
Brown spot	2,962.5	3,631.2	24,038.0
Brown spot	1,044.5	1,672.8	18,678.0
Very brown spot	6,444.5	6,629.6	19,692.0
Twenty feet outside of spot	2.0	435.2	206.2
White alkali soil	24.0	1,210.4	18,117.0

This whole group that we have given as miscellaneous samples was collected within an area of less than five miles in length by one-half mile in width. Some of the spots are small but the last white alkali soil given was from a field of probably forty acres.

An important question suggests itself in connection with the fact that the surface portions of these spots are often, but not always, rich in chlorin. The same thing is true of the surface portions of some other lands where there are no nitrates. There seems to be no general rule which holds good for all soils in regard to the concentration of the chlorin near or at the surface of the soil. We have given cases in which the surface salts were very rich in chlorin and the nitrates were practically absent, and we have also given samples in which the nitrates were very abundant and the chlorin, or the equivalent chlorids, were subordinate in quantity. We have further seen that the ground-water at a depth of about four and one-sixth feet, may be quite rich in nitrates and the surface soil be very poor in them. The water here referred to carries 318.8 p. p. m. while the surface soil carried 53.0 p. p. m., and the second section, 4 to 7 inches inclusive, carried 3.5 p. p. m. of nitric nitrogen.

On the other hand, a sample of ground-water taken only fifty to sixty feet from where this sample was taken, carried only 4.0 p. p. m., while the surface three inches of soil contained 422.7 p. p. m. of nitric nitrogen. In this case nearly all of the nitric acid was within 18 inches of the surface; from the 19th to the 31st inch inclusive, the soil contained only 5.0 p. p. m., and from the 43rd to the 54th inch it contained only 0.1 p. p. m. and the ground-water as stated 4.0 p. p. m. The former ground had been irrigated and the latter probably not.

We regret that we cannot give the results of more extended experiments to determine how the movement of the salts in the soil is influenced by the capillary movement of water in the same, and how the movement of one salt may be influenced by the presence of other salts. If others have studied these problems their work has not come to my knowledge. The work done in connection with this bulletin was too far advanced when the desirability of such a study in this connection became evident to us. We made an attempt to carry out three experiments but this is too small a number of experiments, and the time at our command was too short to arrive at more than tentative results. In these experiments we took a fine, sandy to silty loam which we had previously analyzed. We re-determined the total nitrogen, nitric nitrogen and chlorin. We brought this soil into tubes 1½ inches in diameter and 50 inches long. The tubes were cut into sections, 10 inches long, and united by rubber bands. In one case we brought the lower end of the soil column just below the surface of distilled water contained in an appropriate vessel. The lower end of the second tube was brought below the surface of an eight percent solution of calcic nitrate and sodic chlorid. In the third tube we mixed the calcic nitrate with soil and filled the top three inches of the tube with the mixture. This tube caused us trouble and as we had to try to manipulate the soil in the tube, finally taking out a portion of it and filling up one ten-inch section, there is too great a degree of uncertainty attaching to the results to justify us in giving them. We will give the other two only, i. e. the soil columns in which the distilled water alone or the solution of nitrates and chlorids were used and in which the water rose to a height of thirty-five inches.

DISTRIBUTION OF SALTS IN 40-INCH COLUMN OF SOIL BY THE ASCENTION OF DISTILLED WATER DUE TO CAPILLARITY.

	Nitrogen as Nitrates Percent	Chlorin Percent	Total Nitrogen Percent
Top 5 inches	0.0012	0.170	0.06120
Second 5 inches	0.0024	0.573	0.06528
Third 5 inches	0.0020	0.354	0.05848
Fourth 5 inches	0.0006	0.061	0.05644
Fifth 5 inches	0.0005	0.034	0.05508
Sixth 5 inches	0.0001	0.029	0.05508
Seventh 5 inches	None	0.043	0.05644
Eighth 5 inches	None	0.028	0.05780

The distilled water in the vessel was about a litre in volume, and it contained small amounts of nitrates and chlorids at the end of the experiment. The amounts of chlorin and nitric nitrogen in the soil, as put into the tube, were respectively 0.1578 and 0.00164 percent, and the total nitrogen 0.05168 percent. The soil was thoroughly mixed so that it was perfectly uniform in composition when put into the tubes. The lower portion of the soil column, i. e. the bottom ten inches, was entirely freed from its nitrates; this may have been due to washing out of the nitrates as well as due to upward movement in obedience to capillarity. The presence of nitrates in the distilled water at the end of the experiment indicates that there was an actual passage of the nitrates from the soil into the water. A third possible explanation for the disappearance of the nitrates might be their reduction, we have not considered this at all, and have paid no attention to the nitrites nor to the ammonia present in either the water or the soil. The duration of these experiments was only thirty days, too short a time, but it was not practical to continue them longer. The water attained a height of thirty-five inches in the case given. We observe that the five inches of soil marking the upper limit of moisture, shows an increase of nitrates, but this increase is insignificant compared with the increase of the chlorin. The original soil carried 16.4 p. p. m., this five-inch section carried 24 p. p. m., but the next five-inch section above this, carried only 12.0 p. p. m. As our results stand they indicate that the movement of the nitrates is probably very far from simple, and where the differences, i. e. gains over the amounts originally present, are so small that they fall below the values found for the nitrifying efficiency of our soils in the same time, it is wholly unsafe to draw even tentative conclusions. These statements are not to be applied to the chlorin for we find a very decided upward movement of this element. In the original soil as placed in the tube we find 1,578 p. p. m. but in the five inches of the column, containing the limit to which the moisture rose, we find 5,730 or 3.6 times as much as in the soil as put into the tube, we find too, that the next five inch section of soil above this shows an increase from 1,578 to 1,600. In regard to the total nitrogen there seems to be an increase as we approach the upper portion of the tube, and in fact throughout the whole soil column.

In the second case that we will give the conditions were different, and had been made so to see what the distribution of these salts would probably be if they were being brought up to the surface from the ground-water which had brought them into solution. For this purpose we made a solution containing eight percent of a mixture of equal parts of calcic nitrate and sodic chlorid.

DISTRIBUTION OF SALTS IN A 40-INCH COLUMN OF SOIL BY THE ASCENTION OF THEIR SOLUTION DUE TO CAPILLARITY.

	Nitrogen as Nitrates	Chlorin	Total Nitrogen
	Percent	Percent	Percent
Top 5 inches	0.0010	0.242	0.06120
Second 5 inches	0.0016	0.475	0.06460
Third 5 inches	0.0100	0.748	0.09316
Fourth 5 inches	0.0250	0.604	0.12308
Fifth 5 inches	0.0400	0.481	0.14280
Sixth 5 inches	0.0500	0.459	0.15504
Seventh 5 inches	0.0350	0.601	0.16116
Eighth 5 inches	0.0500	0.703	0.17408

The nitrates did not attain a greater height than thirty inches, while the chlorin reached the limit, forty inches. The quantity of nitrate decreased with the height of the column, the chlorid varied, but showed a maximum in the sixth five-inch section from the bottom. The nitric nitrogen in the seventh and eighth five-inch sections from the bottom contained no more or even less than the soil contained when introduced into the tube. Again the question is evidently less simple than it might at first appear, but it seems very probable that the distribution of the nitric nitrogen is the same that we would find in a soil in which the nitrates had been washed from the surface into the ground-water by a moderate application of water to the surface. The section of this soil as it was taken from the field showed the following distribution of nitric nitrogen down to the depth of 60 inches: one to six inches 109.0 p. p. m.; seven to twelve inches 14.0 p. p. m.; thirteen to twenty-two inches 11.0 p. p. m.; twenty-three to thirty-two inches 6.0 p. p. m.; thirty-three to forty-two inches 2.6 p. p. m.; from this point downward to a depth of sixty inches the nitric nitrogen was constant at 2.0 p. p. m. It does not seem probable that this nitric nitrogen was involved in an upward movement.

DISCUSSION.

We have given the results obtained with the samples as taken without comment, in order that the reader may consider them in detail for himself, but even so it is quite impossible for him to make any reliable interpretation without a knowledge of the varied conditions that obtained at the different places, and at the same place from time to time, and particularly of the conditions which obtained at the time the samples were taken. I have already stated that these conditions in 1912 were decidedly less intense than in the years of 1910 and 1911. While this staement is intended as a general one, it applies specifically to three out of the four places given and to the fourth place, too, with the important modification that in preceding years no nitre spots could be recognized by us, but one spot was definitely located in this year. While this general statement is true, there were a number of places where this condition was much worse than in former years. In fact, it appeared in this year, 1912, in places where it had not previously appeared, or if previously present it had not become sufficiently intense to produce noticeable injury. In one section of the State the trouble etxended very greatly, I call to mind one piece of land which in 1911 showed very little of this trouble, but the conditions in 1912 were very bad. In fact, the garden stuff planted on it was, to a large extent, a failure. The water-plane in this land was from 5 to 8 feet below the surface. The soil was a fine, sandy loam.

The first place chosen was, prior to 1909, an apple orchard. The trees had attained the age of 27 or 28 years, were large, and apparently healthy. There was but little premonitory burning which was not recognized as such until after the fatal attack which destroyed the orchard, that is, killed the trees in a few weeks. The following year it was planted to corn, the next year to cantaloupes, and last year, 1912, to oats. These crops have all been failures. The character of this soil, the location of the land, and its drainage, are all that can possibly be desired. The development of this trouble has ruined it, for the present at least. Samples taken from the surface of this land have shown the presence of from 864 to 3,861 p. p. m. nitric nitrogen. These samples were not taken immediately after irrigation, and were taken in the summer season. The samples of soils presented were taken, those of the vertical section in October, and show that the top six inches of soil contain approximately 218 parts of nitric nitrogen, while the remaining fifty-four-inches sampled contained 106 parts. The surface portion is rich in chlorin. The surface six inches carry 1,863 parts of chlorin, the remaining fifty-four inches carry 8,749 parts. The surface section of soil was taken to a depth of six inches. This is too deep to get the highest amounts of nitric nitrogen and chlorin in parts per million. This would undoubtedly have been found within an inch, perhaps within the surface one-half-inch, still we find that there is a little more than twice as much nitric nitrogen in the top six inches of soil as there is in the succeeding 54 inches. The ratio of nitric nitrogen to chlorin in the surface six inches of soil is 1:8.5; in the remaining 54 inches it is 1:82.5. In the bottom 28 inches of this section we find that the soil carries only two parts per million of nitric nitrogen and an average of 396.5 p. p. m. of chlorin. The ratio of nitric nitrogen to chlorin in this section of the soil, i. e. for the bottom 28 inches, is practically 1:188. On 10 December, 1911, three sets of samples, each representing the surface nine inches, were taken. There were twenty-two samples in each set and these were united to form a composite sample. These composite samples show that the surface three inches contained one and one-half times as much nitric nitrogen as the succeeding six inches and the second three inches contained three times as much nitric nitrogen as the third three inches, but the chlorin in the second and third three inches was exactly the same. It is in this connection that the interesting question of the movement of salts in the soil, and to what extent their movement may be affected by the capillary movement of the water on the one hand and the power of the soil particles to retain the salts on the other hand, has presented itself. This soil is a fine, sandy loam underlaid by gravel which gives free drainage to the river and is so open that the water-plane under this land rises and falls with the rise and fall of the river, so that any nitrates that may find their way into the ground-water have direct drainage into the river.

I have pointed out that in studying the composition of the ground-waters we found this to depend quite directly upon the height of the water-plane and that we had been convinced that this composition came very nearly to representing the soil solutions at that level. This statement pertained only to narrow wells. We found the waters obtained from newly opened wells growing decidedly poorer in dissolved mineral matter as we attained more depth, but I have found no record of any attempt to determine the movement of different classes of salts under these conditions nor how they mutually modify one another's movements.

The soil here considered was all in bad condition; in fact, the nitrates had become so abundant as to make the land for the present time, at least, useless. There were spots in which this action was intense and we find a maximum for the samples given of 1,722

p. p. m. nitric nitrogen and 19,832 p. p. m. chlorin. There was no sample taken below the surface in this case, but the next set of general samples serves to indicate the condition in such intense cases, for they approach the preceding conditions in spite of the irrigations and rains that we happened to find in progress, or which had recently taken place. We found in these general samples 487 p. p. m. nitric nitrogen in the surface three inches with more than 12,000 p. p. m. chlorin; in the next four inches only 20 p. p. m. nitric nitrogen and 1,443 p. p. m. chlorin. There is an abundance of chlorin in the underlying soil to permit of an explanation for the large amounts of it found on the surface by a process of concentration; not so with the nitrates. In what way and to what extent the presence of calcic and magnesic nitrates or their chlorids formed at or near the surface, would affect the movement of the other salts in the soil is not clear and would probably depend upon moisture conditions. In this case we have the rainfalls, the irrigations and even the backing up of the river water in the field, perhaps we should say damming back of the ground-waters, as disturbing factors.

The second place chosen has not been in a desirable condition for more than six years. Some persons think that drainage would reclaim this land. I think that drainage might benefit it, but I doubt most seriously whether this land can now be profitably reclaimed. I have already given my reasons with the full knowledge that some, perhaps many, will call my conclusions into question. My conclusions are based upon somewhat extended observations and, while I wish that I could truthfully state an opposite opinion, I am convinced that drainage is in the first place so difficult as to be infeasible, and, in the second place, I am convinced that the results obtained would be very disappointing. This place is strongly alkalized and in part seeped. We have in this land, both on the surface and in deeper sections, comparatively small amounts of nitric nitrogen and large amounts of chlorin. The ratio of nitric nitrogen to chlorin varies from 1:598 to 1:3,216. In six years' observation of this place, we have never been able to locate but one nitre-spot and that was in 1912. In this case we have a very strongly alkalized area and no nitre. A part of this area is badly seeped in other parts this is not the case; on the contrary, water may not be met with until one attains a depth of nine feet or more. The alkalization and seepage of this land is not something of recent date, but is of long standing, more than six years, at least, and a part of this tract was entirely barren at the beginning of this period. If the nitre and the alkali had a common origin, as a somewhat current, popular view would assert, we should, at all times within the six years during which we have had this land under observation, have found excessive quantities of nitrates. This has not been the case and is not now the case. I have in previous publications stated that land may be so wet as to preclude the occurrence of nitrates, at least such occurences as we have made the subjects of our study. This statement does not apply to the greater part of this land, if it does to any of it. A portion, that is spots here and there in this land, is certainly in bad condiion at the present time. This is not due to nitrates but to water. Within half a mile of this land, however, occur some bad and persistent nitre-spots where there is no excess of water or alkali. Alkalied land and nitre-spots are not synonomous terms, a fact which I have frequently stated. One might think that the surface portion of this soil is the portion richest in soluble salts; this is not the case, at least not necessarily so, for we have found the soil at a depth of two and three feet, richer in soluble matter than the first foot, but so good as free from nitrates. In this land we have a very great concentration of the chlorids in the surface-soil without nitrates, showing that this concentration may be entirely independent of the nitrates. In other cases, we have the nitric nitrogen present in excess of the chlorin. Large amounts of chlorin occur generally with excessive nitrates. This seems accidental and not necessary.

The third place selected was land in a portion of which the nitrates had quite recently developed in very deleterious quantities. In 1909 there was some burning, in 1910 a few trees died, in 1911 a portion of the orchard was destroyed. I counted at one time thirty-five successive trees in a row that had died within two weeks. These were not small, weak trees, but well grown, and previous to this time, healthy appearing trees. "Brown spots" were very marked in portions of this third piece of land selected; in others there was nothing noticeable, but in the greater portion, the whole surface showed by its general color the presence and activity of the Azotobacter. This section of the land, particularly in 1911, was puffed up and oily looking. I do not recall having at any time seen an incrustation of alkali on it. This may have been due to the careful cultivation that it received. I think that this is probable, for adjoining land, similarly located and separated from this by a wire fence, did show such incrustation where it was not occupied by a good stand of alfalfa. We took a large number of samples from this third place, representing the alkali ground in the alfalfa field, the surface soil of one acre of the orchard land to a depth of seven inches, the top three inches being taken as one sample and the succeeding four inches being taken as a second sample. We also made in all nineteen sections of this acre of land, digging in each till we encountered water. From these sections samples were taken forming a continuous section, usually to a depth of fifty-five inches, but the maximum depth to which any set of samples was taken was sixty-seven inches. There were also other samples taken. especially samples within the "brown spots" mentioned as occurring as distinct spots in some portions of this land; and others taken just outside of these spots; also some of the ground-water. The conditions in 1912 were better than in 1911, and we found only moderate quantities of nitrates in 1912 in sections of this land in which they were very evident in 1911.

I raised the question in Bulletin 155 in regard to the amount of nitric nitrogen that we may expect to meet with in good, cultivated soils. especially in the surface portions. We concluded that in general from five to eight parts per million would be found to be a usual maximum, but that 30, 40, and 50 are not unusual amounts to find in our lands, particularly if fallow. We also found like quantities in cropped land absolutely free from seepage. In cultivated fields we have found 120 to 160 and 200, and have shown that the amount may vary in a cultivated field up to 330 p. p. m. I do not think that the finding of from 30 to 50 or more p. p. m. of nitric nitrogen in alkali incrustations, which usually means the soil and effloresced alkali scraped up together off of the surface of the land, is at all significant of the association of the nitric nitrogen and alkali, for we find such amounts in land which we would consider entirely free from alkali.

The distribution of the nitre in the surface-portions of the land is set forth by series of composite samples, each composite sample consisting of 60 sub-samples. The sample from the alfalfa field was likewise a composite sample of about 20 sub-samples, but these were taken from the surface with a shovel and not with a soil tube. These samples give a section of the land selected beginning with the alfalfa field and crossing the area of active fixation and nitrification, to a section where. in 1912, it was very moderate, perhaps no more than normal, for our lands.

This section, beginning with the alfalfa field, shows 20 to 8c p. p. m. of nitric nitrogen. reaches a maximum of 367 p. p. m., and then passes to a minimum of 3 p. p. m. We find that the surface three inches carry by far the larger part of these nitrates. The alfalfa land sampled was free from vegetation, but was quite strongly alkalized. The orchard land was not strongly alkalized, but the brown color, due to the Azotobacter pigmentation, could be traced with the greatest ease and detail in 1911 throughout this land. In 1912 this was the case only in portions of it, and these portions are as clearly designated by the analytical results as the brown areas were distinct to the eye. I have no doubt that I could have collected samples, taken to a depth of three inches, in any one of these six sections, which would have shown either very low or very high results. and if I had sampled the acre of land in the direction at right angles to that in which I did sample it, I could have shown that the whole acre of land was exceedingly uniform in its content of nitric nitrogen. and all very rich or moderately poor. according to what state of things I wished to prove. We will illustrate this in later paragraphs. We content ourselves. for the present, with showing that the distribution of the nitric nitrogen in the surface-soil is exceedingly irregular and is independent of the distribution of the alkali, and with the observation that portions of this land which were very bad in 1911 were by no means bad in 1912.

In regard to the vertical distribution of the nitrates. the samples taken in December, 1911, a few weeks, six to eight weeks, after the fall irrigation, indicate, in the main. that the nitrates had been washed down into the soil and the ground-water.

This land is not drained. It has never been considered wet enough to require draining. An important question in this connection, is that regarding the lateral movement of the ground-water, if there be any. I think that any lateral movement that there may be is comparatively slow. This. however, is merely an opinion at which I have arrived from observation and is not proven by direct experiment. I do not think that I have at any time found the water-plane, even in the lowest-lying hole that we dug, less than four feet, six inches below the surface. In a hole dug at another point I found water near the surface. but at this particular point the trees were still in good condition. It is just to state in this connection that I thought, at the time that the water-plane in this instance was temporarily higher than usual. Be that as it may, the water was high and the trees were well grown and healthy. I am strongly of the opinion that the ground-water found in any given hole in this land, belongs, for the most part, just where we find it. That there may be some lateral movement is possible. but I think that this is very small, if it exists at all.

We find that in holes 2, 4 and 5, opened in December, 1911, that the nitrates increase with depth till we reach the water-plane, but that the amounts, compared with some of our results, are not very remarkable, the maximum being 80 p. p. m. I believe that this is due to the fact that the nitrates were washed from the surface into the soil, and had these localities had a little more water applied, we would have found the surface and succeeding portions still poorer, but possibly in the same order that we now find them. In holes 1 and 6 we find the reverse to be the case. This is shown very markedly in the results obtained with the samples taken in Hole No. 1. in which we have 422.7 p. p. m. in the top three inches and only 0.1 p. p. m. at a depth of 4½ feet. Hole No. 6 shows the same facts. but the amounts of nitric nitrogen involved are so small, 24 p. p. m., being the maximum, that it, for our present purposes, may be neglected. The spot where Hole No. 1 was dug, had probably failed to receive any considerable irrigation and the whole summer's formation had probably remained at the surface. This is suggested by the fact that the sample of ground-water taken from this hole at this time, contained only 4 p. p. m. nitric nitrogen, a quantity less than is found in some deep wells. The total solids in this water, however. was nearly 10.000 p. p. m. The hole dug close to this at the next sampling showed the same facts quite as strikingly as this one. In these samples we determined the water-soluble to see if there could be discovered any relation between this factor and the nitrates. We obtained for the surface three inches of soil the following results: Water-soluble. 13.475 p. p. m.; nitric nitrogen, 237.4 p. p. m.; for the twelve inches from 44 to 55 inches inclusive, water-soluble 17,925 p. p. m.; nitric nitrogen 6.0 p. p. m. We find the nitric nitrogen to diminish very rapidly with even slight depths, unless it has been carried down by rain or irrigating water, and in this land we nowhere find excessive quantities of nitrates. except where we can readily and with certainty recognize the brown pigmentation of the Azotobacter. The nitric nitrogen found in the surface section, three inches, is less than is found for the composite sample made up of 60 samples representing a sixth of an acre.

The extremely variable results obtained by taking such sections of soil is well shown by these 19 sections, as the numbers in each set have the same significance. The three sections numbered 1 were taken as close together as I deemed advisable, so of number 2 and the succeeding ones. I fear lest I erred in taking them a little too close together. Holes 1 and 4 were only about 55 feet from one another and yet we find altogether different conditions, and the same is true of holes 2 and 5, which were the same distance apart. The same may be said of these taken in pairs the other way, i. e., 1 and 2, 4 and 5. We observe the same irregularity on the surface of the soil and we can, using the brown color as a guide, pick out these irregularities with all certainty. Hole No. 6 was located in ground that was bad in 1911 but showed no injury in 1912, while the Hole No. 7 was located in territory that has never shown any trouble. We find the nitric nitrogen in the samples taken from these vertical sections, decreasing rapidly with depth, and in case of number 7, surprisingly low for our soils.

In regard to the ground-waters collected from these various holes, we find a very great variation, indeed, just as great as we find in the vertical or lateral distribution of the nitrates and other salts. I have already stated the chief features of the ground-water obtained from Hole No. 1. The second sample of ground-water taken from this sixth of an acre was taken from Hole No. 4. The water-plane was 4 feet 2 inches below the surface. The three-inch-sample of surface-soil contained 52.9 p. p. m. nitric nitrogen. The foot terminating at the water-plane, contained 57.0 p. p. m., while the intervening sections varied 3.5, 12 and 32 p. p. m. The total solids in this ground-water were 18,557 p. p. m. and the nitric nitrogen 318.8 p. p. m. The other sample of ground-water carried 13,-258.0 p. p. m. water-soluble with 441.5 p. p. m. nitric nitrogen, while the surface-three-inches of soil carried 18.0 p. p. m. nitric nitrogen, which at a depth of 55 inches had fallen to 1.5 p. p. m. The water-plane at this time was 8 feet 7 inches below the surface. This same land was brown in 1911 and the trees died. These facts even do not convey a full idea of the uneven distribution of the nitrates in this soil. We have seen that we can pick areas of one sixth of an acre, so that they will show wide variations. We have further shown in this single piece of land the same thing that we have used other individual pieces to show, i. e., that there is no connection between the ordinary alkali and the nitrates. The vertical distribution of the nitrates, as exhibited by the nineteen vertical sections made of this land, is certainly perplexing. We find a large amount in the surface-soil of one section with the water-plane four feet nine inches below the surface. The nitric nitrogen decreases rapidly in this section from 423 p. p. m. of the air-dried soil to less than one part. This difference is very great as becomes more apparent on calculating this nitric nitrogen to the sodic salt. When we find 2,538 p. p. m. in the surface three inches and less than one part in the lowest foot taken. The ground-water taken 12 hours after the trench was dug contained only 4 p. p. m. of nitric nitrogen or as sodic nitrate 24 p. p. m. This sample of water should have been taken when the hole was first opened and should not have been allowed to stand. We have in the surface-portions of this soil large amounts of nitrates and in the ground-waters only small amounts and in the intervening soil still less, in fact, as good as none. These facts may be remarkable, but this is the way we found them. There was no incrustation on this soil. The ground-water carried 9,788 p. p. m. of total solids. If we assume that these 2,538 parts of nitrates, calculated as sodic nitrate for convenience, owe their origin to the evaporation of this ground-water brought to the surface by capillarity, we have to answer the following questions: How long has it taken to do this? What has become of the associated salts which we know are readily moved through the soil by capillarity? In regard to the first question, we have only the testimony of the trees. They lived and grew healthily till the season of 1911. A few of them showed distress in 1910. These nitrates were not present in deleterious quantities at this place till the season of 1911, so the concentration must have taken place very rapidly. To furnish the amount of nitrates in the surface three inches of this land per acre would require the evaporation of 40.4 acre feet of water, which we found four feet nine inches below the surface. Can this be done in this time? Our actual evaporation is less than 60 inches *per annum* from a free water surface (it is 41 inches at Fort Collins) and the evaporation of 40 acre feet of water from the surface of this land would require about eight years, provided it presented a free water surface, but we found this free water 4¾ feet below the surface. Further, what has become of the million pounds of other salts which this water holds in solution? This is not the only trouble. We find within 60 feet of this, entirely different conditions. The ground-water is practically the same distance below the surface, if there be any difference the water is a little nearer the surface in the second case; but there on the same date, so that there is no question of weather conditions, we find 2 p. p. m. in the surface three inches which at a depth of 54 inches reaches 80 p. p. m. and the ground-water contains 318 p. p. m. of nitric nitrogen and 18,557 p. p. m. of total solids. Why is the surface portion so poor in nitric nitrogen and why do the nitrates increase with depth till we find the ground-water much richer than the soil? The answer that I offer is that the late irrigation had washed these nitrates into the deeper portions of the soil and into the ground-water. While our conditions are involved and our data difficult to interpret, there is nothing to indicate that, in fact, these nitrates ever moved back to the surface. My conviction is that in the case of the first hole dug we selected a spot which had escaped with a light irrigation or without any. There was no reason why the people should be careful about the distribution of the water, as the trees were already dead. The nitrates found were those that had been formed there during the preceding season. The fact that these trenches had to be dug in slightly different places for the different sectional samples is unfortunate because a difference of two or four feet may make every difference as our surface samples, taken only a few feet part, fully demonstrate.

We have given samples taken from alkalized land showing respectively 0, 40, 80, 20 and 25 p. p. m. nitric nitrogen associated with 7,693.4; 18,554.0; 19,024.0; 18,743.0 and even 261,000.0 p. p. m. of chlorin. We also selected surface samples from brown spots which showed but slight or no incrustations of white lakali. Very pronounced brown spots gave 8,970.9; 1,229.7; 15,275.0 and 5,231.5 p. p. m. nitric nitrogen. The chlorin in these cases was high, but without any definite relation to the amount of nitric nitrogen. We have for instance in the white alkali 20 p. p. m. nitric nitrogen with 19,024 p. p. m. of chlorin. In a very extreme brown spot we have 15,275.0 p. p. m. nitric nitrogen and 18,908 p. p. m. chlorin. We have before now tested such spots and found no living bacteria in the surface, but they were alive a few inches below it and at the edges.

The surface soils of sections 4 and 5 gave respectively 117.0 and 24.0 p. p. m. nitric nitrogen. A brown spot lying just between these sections gave 7,076.0 p. p. m., while a sample taken just outside of the brown spot showed only 16.0 p. p. m. of nitric nitrogen. At another time the inner portion of this spot gave 10,000.5 p. p. m. nitric nitrogen This ground is about equidistant from holes No. 1 and 2, probably a little nearer to hole No. 2. These facts are general. I have elsewhere stated that the Azotobacter pigments are not the cause of all brown spots any more than nitre is the cause of the death of all trees. I recall stating that one dark colored piece of land owed its color to the presence of calcic chlorid and others to the presence of salt, and others simply to organic matter. But usually we can recognize the brown spots due to the Azotobacter pigments. I selected another place to make observations similar to those just recorded, but we were so unfortunate in taking our samples, mostly due to the weather, that I have given the samples taken the weight of miscellaneous samples, though they are really members of a sadly broken series. The nitrates developed for the first time in this section of the country about 1909. Previous to that if present, as I suppose they really were, their development was not prominent enough to attract attention. There is an abundance of alkali all over this mesa, which was apparent the first time that I saw the section. Samples of soil rich in alkali gave 14 p. p. m. nitric nitrogen, ordinary white alkali soil, surface, 40 p. p. m. nitric nitrogen, and 235,584 p. p. m. chlorin, while a very brown spot showed 5,498.0 p. p. m. nitric nitrogen with 17,016.0 p. p. m. chlorin. This spot was exceedingly sharply defined. A sample taken almost at the edge of this carried 12 p. p. m. Some spots at this place that were very bad in 1911 had entirely disappeared in 1912. These spots do not by any means always occur in unfavorably located land.

The only condition that seems indispensible to their development is a constant and fairly abundant supply of moisture and a chemically alkaline soil. We have recorded samples taken from a cultivated field on the same date which showed the presence of from 5.0 to 150 p. p. m., and again samples taken from the same field on different dates which gave from 65 to 100 and even 333 p. p. m. of nitric nitrogen.

RÉSUMÉ

The occurrence of "brown spots" has been complained of from time to time for years past. The first ones that I saw, to recognize as being rich in nitrates, were in uncultivated land in the extreme southern part of the state. These were round or eliptical spots, smooth and shining on the surface, and had an almost black color. They were wholly destitute of vegetation. The rocks forming the neighboring mountains were granites and schists. The strata underlying this soil were sands and clays of lacustrine origin. The waters of this section are exceptionally pure and are acid in character, i. e. the most of them, surface waters excepted, contain more acids than are necessary to combine with the bases; silicic acid is usually in marked excess. Other occurrences are in Cretaceous and still others in Triassic areas. Some of these brown spots are small and isolated, in other cases they have coalesced and cover comparatively large areas—twenty, thirty or more acres from which the vegetation has, in many cases, been exterminated. The barrenness of these spots has not in all cases been permanent, in other cases it has been very persistent. These spots in 1910 and 1911 were very common in some sections of the state, and but few cultivated sections in the state, with which I am familiar, are entirely free from them. We have some marked cases of their occurrence in this immediate neighborhood which is within forty miles of the northern boundary of the state, and I have seen them almost on the southern boundary line. They also occur in the extreme eastern and western parts and at various altitudes up to 7500 feet.

Their appearance is peculiar, usually the soil is mealy and from a light brown to almost black in color, varying somewhat with the soil. That they have spread during the past seven years is evident from the statements made concerning the damage done. Lands that were considered desirable five years ago are now of little value and where four years ago, only an acre or two was known to be affected, many acres are now involved. These spots are not confined to any particular variety of soil or to any particular geological horizon. They occur on well drained land as well as on land that contains an abundance of water. In some cases the muddy condition of the land seems to be a result rather than the cause of this condition.

These spots are characterized by their brown color. In some instances they appear smooth and shining, but usually they are soft under the foot, mealy, and at a little distance give the impression that they are moist. In orchards where oil has been used for heating one might readily take small spots as due to spilled oil or contrariwise, an oil spot for a nitre spot. The amount of water-soluble salts in the surface portions of these spots, varies exceedingly. By surface portion, I mean all depths up to three inches. These spots do not, as a rule, show efflorescences which is characteristic of alkali spots. There is sometimes an incrustation. The maximum amount of water-soluble found in a selected sample of this brown surface incrustation amounted to 22.5 percent, of which 29.1

percent was sodic nitrate, 12.0 percent was sodic chlorid and the other salts were sulfates. Another exceedingly rich sample yielded 13.4 percent of water-soluble, of which 41.86 percent was nitrates, 10.0 percent chlorids and the rest sulfates. The occurrence of very small amounts of sodic carbonate in the aqueous extracts of soils from these spots is noticeable, in fact the carbonates are more frequently absent than present. Calcic carbonate, however, is always present, and usually abundantly so, in these soils. It should also be stated that our common alkalis seldom contain large amounts of carbonates. There does not appear to be any relation between the amount of nitrates and that of any other class of salts present. Our alkalis consist of sulfates and chlorids, the carbonates being very subordinate in quantity. Sometimes the sulfates, sometimes the chlorids, and at other times the nitrates are the predominating salts in the water-soluble portions of these brown spots. For example we have sulfates 90.0, nitrates 8.2 and chlorids 1.5 percent; again nitrates 50.2, chlorids 38.2, and sulfates 9.9 percent; again nitrates 35.6, chlorids 33.6, sulfates 28.3 percent; again chlorids 67.4, nitrates 15.4, sulfates 15.1 percent; again sulfates 46.9, nitrates 41.9, chlorids 10.0 percent; again sulfates 80.4, nitrates 15.1 and chlorids 4.1 percent. The last sample given is the extract from a gypsiferous, clay soil, and calcic sufate was the only sulfate present. Our ordinary white alkali is essentially a mixture of sulfates, but occasionally is very rich in chlorin. It seldom carries more than a trace of nitric acid and is often entirely free from it. I have, when possible, given the nitric acid as sodic nitrate. This, as elsewhere stated, has been done as a matter of convenience. The nitrates present in some cases are certainly those of calcium and magnesium and these salts are probably always present but not necessarily to the exclusion of other nitrates.

The fact of the existence of these spots is no longer in question, nor are the results due to their formation. The extermination of vegetation in these areas, involving the killing of many acres of old, well established apple orchards, has been observed in many places, and there is no question but that the nitrates are the cause of this. This question was naturally the first one suggesting itself. Neither the sulfates nor the chlorids produce the changes in the trees observed in these cases and nitrates do. The trouble complained of is characteristic and is common to all the cases that we have observed.

The origin of these nitrates, however, may be questioned. The first explanation offering itself was that of concentration. In this event water seemed to be the only possible carrier. Our irrigating waters do not carry nitrates, for the most part they are snow-waters; our ground-waters do not carry greater quantities of nitrates than may be found in drain-waters from other lands, the same is true of our drain-waters unless they be from badly affected areas. Our well waters are not richer in nitrates than it is usual to find such waters. I have given in Bulletin 178 analyses of two most extraordinary well waters which contain nitrates. Our soils are not rich in organic matter or as a rule in nitrogen so that ordinary nitrification and leaching cannot account for it. Seepage and ground-waters may be very heavily charged with alkalis but ordinarily contain only small amounts of, or no, nitrates. We mentioned nitrate areas in locations surrounded on three sides by alkali and seeped lands, but these locations themselves are well drained. The nitrates in these locations are not derived from the alkalis and seepage water from these adjacent lands for the following reasons: These adjacent lands contain only such quantities of nitric nitrogen as soils in general may contain. The alkalis, even the efflorescent ones, taken together with the surface portion of the soil, contain no nitrates; the ground-water underlying this seeped section contained no nitrates, therefore this land, though rich in alkalis and seeped, could not be the source of the nitrates found in the nitre areas. Further the drain-waters flowing from a drain laid through a portion of this land, but not under a nitre area, while comparatively rich in alkalis, carrying some 9,000 parts total solids per million, carried only 0.1 p. p. m. of nitric nitrogen. The nitrates found in these spots could not have been derived ready formed from these outside sources. The land was well drained; three out of five drains laid in this land drew no water except after irrigation. There is no unusual amount of the ordinary alkalis in this soil. Vegetation does well in this land except in these spots. The soil itself, except in these spots, is not rich in nitrogen and here it seems to be largely in the form of nitrates. The evaporation of the ground-water that underlies this land would yield large amounts of the ordinary alkalis but no nitrates, or very small amounts, and as the land is level and uniform in character and texture, there is no reason why the deposition should not be general over the surface and not confined to spots. The fact is that the nitrates are confined to the brown spots. All of these considerations were weighed before Bulletin 155 was written, and the question asked, whence comes the nitrogen. Our investigations had shown that it did not come from the adjoining lands, nor from below and the land itself does not ordinarily contain it, but still there is no question of its presence. It was not always there, for the beginning and cause of this trouble had been observed and unsuccessfully combated. In 1904 this land was free from this trouble, in 1909 apple trees and garden vegetables could not maintain themselves against its influence. Besides, the spots were extending their boundaries. It was not a stationary thing, but was growing. The adjacent land had in the meantime not changed materially; it continued to be barren of nitrates, but the seepage condition was growing worse; this, however, did not, and does not now affect this land. Between 1906 and 1908 the trouble began to be recognized here and there without knowledge of its cause, but in 1909 it began to destroy orchards over larger areas, and the nitrates were recognized as the direct cause of this. From 1909 on, the annual loss of trees due to this cause, has been great. This trouble has varied in intensity, having been apparently most sever in 1910 and 1911. The distribution of these "brown spots" in any given piece of land is very erratic and the "brown spots" are often, one may say usually, sharply defined. Such considerations eliminate the waters, the alkalis and the neighboring lands as sources of the nitrates or of the nitrogen contained therein. In Bulletin 155 of this Station, I suggested the atmosphere as the source of this nitrogen and fixation as the means of transferring it from the atmosphere to the soil. The most probable agency having the power to accomplish this seemed to be the Azotobacter. Examination of these soils proved these organisms to be present in great abundance, except in areas too rich in soluble salts, but they were abundant at the edges of such areas, and below the surface. The Azotobacter form a brown to an almost black pigment. The formation of this pigment has been shown by Professor Sackett to be conditioned by the presence of the nitrates. The "brown spots" are rich in Azotobacter, either throughout or at their edges and below the surface, the nitrates are present in exceptional quantities and the spots are recognized by their brown color. Our soils when incubated without the addition of any carbohydrate, show a marked fixation of nitrogen. My own results showed a fixation of 10.54 milligrams for each 100 grams of soil in 27 days and the moist soil kept at the room temperature showed an increase of 4.82 milligrams in the same time for each 100 grams of soil. It is usual to add glucose or mannite to furnish energy but an ordinary cultivated soil fixed these quantities without any addition of any kind except boiled, distilled water. That energy was necessary there can be no doubt, that it was not added in the form of glucose or mannite is also certain. If it was used, as we agree it must have been, it must have been derived from the soil itself, but our soils are not remarkably rich in organic matter. The total nitrogen was found to be 0.1075 percent at the beginning of the experiment. Other analyses of this soil gave the total nitrogen as 0.147, humus 0.426 and ignition 5.072 percent. These are facts which we have recorded in Bulletin 178. My experiments do not stand uncorroborated. Professor Sackett obtained very similar results with other soils. I do not know the conditions in our soils which may possibly limit this ability to fix the atmospheric nitrogen. The conditions of my experiments seem to give rise to a strong development of Azotobacter. This soil at the beginning of the experiment gave a very moderate culture of Azotobacter, but after thirteen days another sample gave a remarkably strong one which developed the brown pigment within nine days. This soil, as are all of our soils, with almost no exceptions, is alkaline in reaction. The nitrification, too, in these samples without the addition of anything except distilled water which had been boiled to expel any traces of ammonia that might be present, was very marked. We found a maximum gain equal to 138 percent of the nitric nitrogen present at the beginning of the experiment which was 35.0 p. p. m. Professor Sackett has studied this subject more thoroughly and systematcally with interesting results, one of which, with his permission, I use, i. e. some of our soils show a nitrifying efficiency 173 times greater than an Iowa soil which I understand was a typical one. The increase in the nitric nitrogen present in this soil in six weeks was 1040 fold. I have personally done nothing with the ammonifying efficiency of our soils, but Professor Sackett has presented the results of his investigations of this subject in Bulletin 184 of this Station, from which it appears that the ammonifying efficiency of our soils is from two to three times greater than average soils from other localities for which we have comparable data. Two of Professor Sackett's conclusions are as follows:

"Soils in the incipient stage of the nitre trouble appear to surpass our normal soils in ammonifying efficiency." "Compared with soils from other localities, our nitre soils excel in ammonifying efficiency."

It has been stated and emphasized that our soil conditions seem exceedingly favorable to the development of bacteria, especially such as require an alkaline medium for their development.

It is stated in Bulletin 178, p. 90, that quite a vigorous development of algae and diatoms took place on the soil that I used in my incubation experiments when it was exposed to the light in a culture dish. I have since that tested other samples of soil and found that they all yielded an abundant growth of algae. Mr. W. W. Robbins has taken up the subject systematically and has published some of his observations in Bulletin 184. Out of twenty-two samples of soil taken for experiment, only two failed to give a growth of algae, and one of these was a sample of raw, uncultivated, adobe soil. This abundant presence of algae has been mentioned as a possible source of energy.

SUMMARY AND CONCLUSIONS.

Our soils, as is shown by numerous analyses, are not unusually rich in nitrogen. They are only moderately well supplied with it and the unusual amounts of nitrates found cannot be produced by the nitrification of the supply already in the soil, but this supply must be supplemented by nitrogen from some other source, we believe that this other source is the atmosphere.

The nitric-nitrogen does not owe its origin to the same sources that furnish our ordinary white alkalis which, beyond question are decomposition products of our common minerals, but principally of the feldspars, by agencies now at work.

The distribution of the nitrates in our soils cannot be consistently accounted for by any theory of concentration of pre-existing nitrates. Their distribution is wholly independent of that of the alkalis—the latter being practically free from nitrates, as much so as a great many of our soils, while the aqueous extract of our soils, especially those showing the brown color due to Azotobacter, are extremely rich in calcic and magnesic nitrates.

The ratio of the nitric to the total nitrogen in many of our soils, particularly in the surface portion of the brown spots, is very high due to fixation and nitrifcation.

The deeper portions of the soil under these brown spots are usually poor in nitrates, but irrigation or rainfall may carry the nitrates on the surface downward, even into the ground water. While the solutions of potassic and sodic nitrates show capillary action, it is doubtful whether the calcic and magnesic nitrates do not move downward, especially in soils that are quite moist, rather than upward. The calcic and magnesic nitrates do not show capillary movement exposed in glass vessels, as do sodic chlorid and nitrate, ammonic chlorid and many other salts.

The solubility of the nitrates contributes to their easy and rapid removal by downward moving waters. The soil seems to have but little or no power to retain these salts, nitrates, so they pass readily into the drainage waters of the country, but our ground and drainage waters are rich in nitrates only when they come from nitre areas. Of the many ordinary and artesian well waters that I have examined, I have found but two that contain unusual quantities of nitrates. I have described these in Bulletin 178.

The shales and sandstone do not furnish these nitrates or else all of our well waters would be rich in nitrates, but they are not richer in nitrates than well waters usually are. These well waters, both from ordinary and artesian wells, are usually quite rich in the so-called alkali salts, but not in nitrates.

These nitre spots occur in sections where these shales and sandstones do not occur, and consequently cannot be derived from them. These facts were known to us before we published anything upon the subject, and this process of elimination led us to the views adopted before we had any results of bacteriological experimentation at our disposal. If the alkalis and nitrates have a common origin they should have a common distribution, but this is not the case even for very limited areas. If they owed their origin to leaching then the ground-waters found beneath these lands should contain notable quantities of nitrates, but this is not true and the nitrates are localized in the brown spots to such an extent that the people have made this characteristic the distinguishing one in their complaints.

The nitrates might make the soil more hygroscopic but there is nothing in them *per se* to produce a color, but Azotobacter in the presence of nitrates, do produce a brown, almost black, color. The brown, often almost black, color is characteristic of these spots and samples of soil taken only a little way, a few feet, from these brown spots, contain no unusual amounts of nitrates. This is true to such an extent that I believe it quite possible to collect samples within a few inches of one another, one of which may show only ordinary amounts of nitric nitrogen and the other from hundreds to thousands of parts per million.

The burden of the complaints made is of "brown spots on which nothing will grow." These spots have appeared in cultivated land, much of it otherwise very good land, not seeped nor saturated with alkali and not deficient in drainage.

Bulletin 187 June, 1913

The Agricultural Experiment Station

of the

Colorado Agricultural College

Feeding Experiments With Lambs

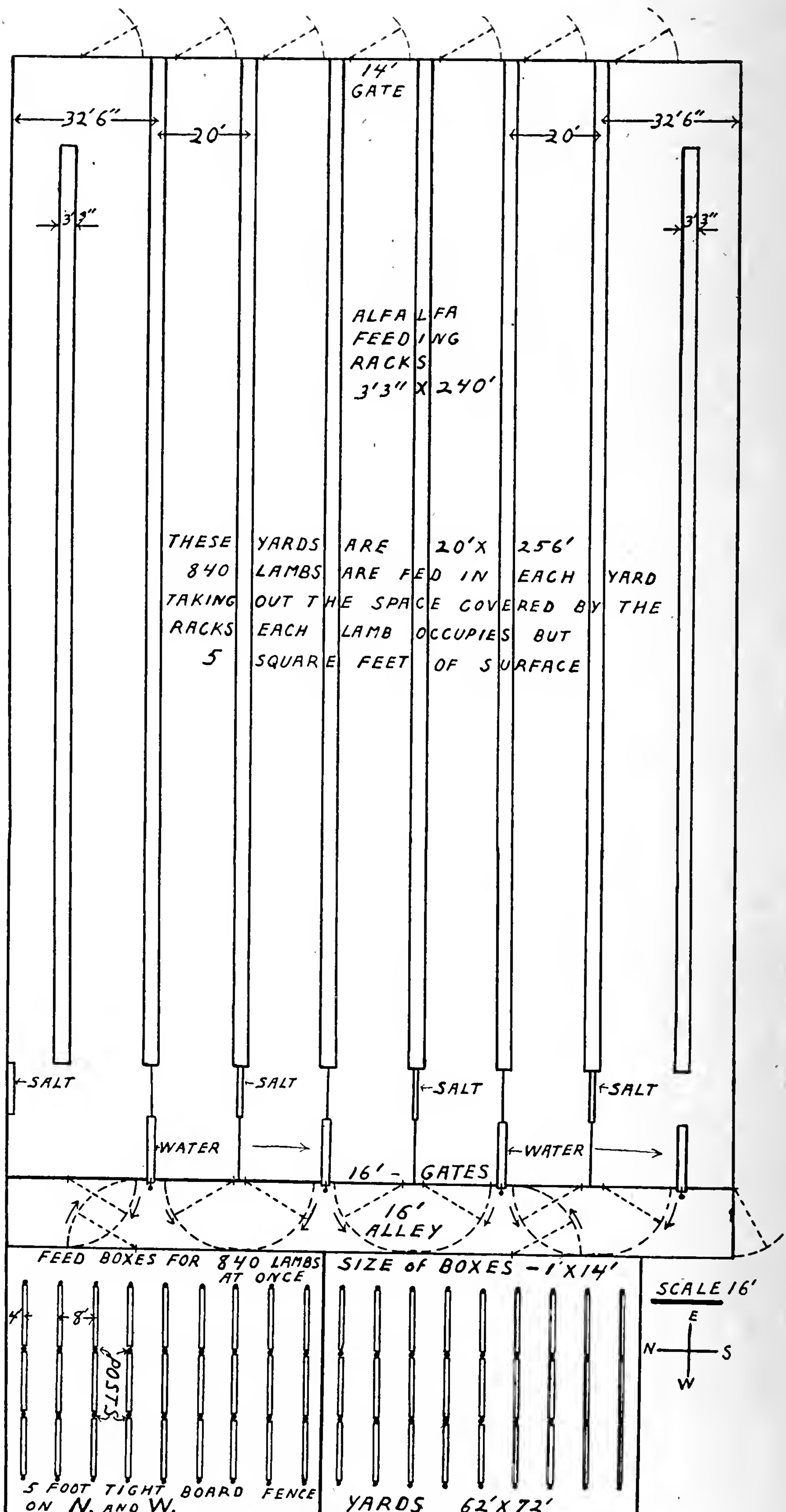
1908-9, 1909-10, 1910-11

G. E. MORTON

Alfalfa Meal for Feeding Lambs
Ration Experiments With Lambs
Loss Caused by Dogs Among Lambs

WHOLE HAY, CUT HAY, AND ALFALFA CUTTER USED.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1913



MODEL SHEEP FEEDING YARDS FOR FURTHER INFORMATION WRITE THE ANIMAL HUSBANDRY DEPT. FT. COLLINS COLO. C.A.C.

Feeding Experiments with Lambs

1908-09, 1909-10, 1910-11.

G. E. Morton*

INTRODUCTION

This bullletin includes three winters' work with lambs, covering the following points:

1. Alfalfa hay, whole, compared with alfalfa hay, cut, using corn as the grain ration.
2. Scotch (hulled, or brewing) barley compared with corn, using alfalfa as the hay ration.
3. The self feeder for alfalfa hay compared with the panel method of feeding, using alfalfa hay and corn for the ration.
4. Scotch barley, California feed barley, and corn compared, using alfalfa as the hay ration.
5. Cut alfalfa hay, and fine alfalfa meal compared with each other and with whole hay, using corn as the grain ration.
6. Loss caused by dogs gaining entrance to corrals and worrying fattening lambs.

Alfalfa Hay or Reduced Hay

In Bulletin 151 of this Station, I reported two trials of cut alfalfa hay in comparison with whole alfalfa hay. The term "cut hay" is used in these bulletins to designate hay run through a fodder cutter but not reduced to the fineness of typical commercial alfalfa meal. In our experiments we used a three-quarter inch cut. Much of the alfalfa meal on the market has the stems reduced to about one-half inch in length, and usually they are somewhat shredded. There are a number of mills on the market especially designed for the reduction of alfalfa hay to a so-called meal, but there is only one, so far as I know, that reduces the hay to a meal comparable with fine corn meal or reground bran. Most mills produce a shredded alfalfa, which has earned the well-established commercial term, "alfalfa meal."

Reducing alfalfa to three-quarter inch lengths, secures, according to the observation of the writer, practically all advantages to be obtained from the use of reduced hay or alfalfa meal for fattening animals, cost considered. The finer the reduction is made, the greater the cost of reduction becomes, as a rule. Consequntly we used the cut hay in all experiments here reported. In the 1910-1911 experiment we also tried the finest grade of meal produced in a commercial way. Consequently, these experiments give data as to the value of reduced hay, both fine and coarse.

---

* With the assistance of G. A. Gilbert and H. E. Dvorachek in working up data.

The question of the feeding value of alfalfa meal is one of much importance to farmer feeders, both those located close to established alfalfa mills and those contemplating the installment of reducing machinery upon their own farms or the use of portable mills, some being manufactured which are capable of doing custom work from farm to farm in the same way as a threshing outfit. As a result, inquiries have come, both from farmers and from manufacturers, as to the merit of reducing alfalfa for use in feeding operations upon the farm where grown. The problem resolves itself into two questions: First, does the reduction of the hay result in a greater gain in live weight per ton of hay fed? Second, if so, does the extra gain more than offset the cost of reduction? Both of these questions should be kept clearly in mind in scrutinizing the experimental data.

LAMBS USED

All lambs used in these experiments were range bred. In the 1908-09 experiments, they were Hampshire-cross, Wyoming lambs. Lambs from the same flock were used in 1910-11. In 1909-10, southern lambs (Mexicans) from New Mexico were used.

METHODS

The experimental work was started within a few days of the arrival of the lambs both the first and second winters. The third winter the lambs were brought up to one pound of grain per head per day before being divided up for experiment. In all three seasons the lambs were kept on feed until finished, giving data for a sufficient length of time to gauge the merits of the rations used.

The lambs were weighed every second week. The grain was fed whole and was weighed at every feeding, being fed twice a day. The hay was fed in self feeders, except where specified as fed on the ground. When a lamb died, one of approximately equal weight was put in to take its place, if available. Otherwise the weight and gain were figured on the basis of one less lamb. The character of the hay used will be noted under each experiment.

FIRST SERIES, 1908-09.

LOSS CAUSED BY DOGS.

The lambs in this experiment were started November 14th. During the seventh week of the experiment, dogs dug under the supposedly dog-proof fence and worried the lambs. The dogs were discovered at daylight and were then worrying the lambs in Lot II. Some of the lambs in Lot I were torn about the thighs and ears and a smaller number in Lot II were in the same condition. The lambs in Lot III were frightened but none were torn. This showed that the dogs attacked Lot I first and then passed into Lot II, and it is interesting to note in the following tables the loss in weight caused in the various lots. Observe the loss in weight for Lots I and II at the end of the eighth week

LOT I.—BI-WEEKLY DATA. ALFALFA HAY (WHOLE), SCOTCH BARLEY.

November 14, 1908—February 20, 1909. (90 Lambs in Lot)

Period	Weight	Gain	Average Gain Per head	FEED Alfalfa Whole	FEED Barley (Scotch)
Beginning	6370				
2nd week	6915	545	6.06		581
4th "	7140	225	2.50		1132
6th "	7380	240	2.67		1260
8th "	7036	—344	—3.82		1260
10th "	7633	597	6.63		1260
12th "	8210	577	6.41		1500
14th "	8460	250	2.78		1869
		2090	23.22	23234	8862

LOT II.—BI-WEEKLY DATA ALFALFA HAY (WHOLE), CORN

November 14, 1908—February 20, 1909. (90 Lambs in Lot)

Period	Weight	Gain	Average Gain Per head	FEED Alfalfa Hay	FEED Corn
Beginning	6345				
2nd week	6970	625	6.94		581
4th "	7315	345	3.83		1132
6th "	7740	425	4.72		1260
8th "	7160	—580	—6.44		1260
10th "	7840	680	7.56		1260
12th "	8545	705	7.83		1500
14th "	8900	355	3.94		1823
		2555	28.38	22982	8816

LOT III.—BI-WEEKLY DATA. ALFALFA HAY (CUT), CORN

November 14, 1908—February 20, 1909. (90 Lambs in Lot)

Period	Weight	Gain	Average Gain Per head	FEED Chopped Alfalfa Hay	FEED Corn
Beginning	6295				
2nd week	6860	565	6.28		581
4th "	7073	213	2.37		1132
6th "	7230	157	1.74		1260
8th "	7530	300	3.33		1260
10th "	7980	450	5.00		1260
12th "	8620	640	7.11		1500
14th "	8860	240	2.67		1822
		2565	28.50	20120	8815

TOTAL WEIGHTS AND GAINS—14 WEEKS

November 14, 1908—February 20, 1909. (90 Lambs in Each Lot)

Lot No.	Ration	Weight at Beginning	Weight at Close	Gain in Weight	Total Feed Consumed (lbs.) Corn	Barley (Scotch)	Alfalfa Hay
I	Barley, Alfalfa Hay (whole)..	6370	8460	2090		8862	23234
II	Corn, Alfalfa Hay (whole)..	6345	8900	2555	8816		22982
III	Corn, Alfalfa Hay (chopped)	6295	8860	2565	8815		20120

Lot III showed no loss in weight. The others showed a very heavy loss in weight especially in view of the fact that they had several days in which to make up the shrink before weighing time came. The lambs in these two lots made a loss of 924 pounds when they should have made a gain of about 720 pounds thus losing 1644 pounds of gain on 180 lambs, or a trifle over 9 pounds per head. Some of this shrink undoubtedly was made up later as the bi-weekly gains for Lots I and II are larger during the succeeding weeks than the gains for Lot III, in spite of the fact that at the end of the experiment Lot III had the greatest average gain per head.

CUT HAY VS. WHOLE HAY.

The entrance of the dogs of course invalidated the results of the ration experiments, but at least one interesting point can be gained, so the final result for these three lots are given here.

FEED FOR GAIN AND COST OF GAIN, 1908-09

(90 Lambs in Lot)

	Ration	Average Gain per head 14 weeks (lbs.)	Lbs. feed for 100 lbs. gain			Cost of feed per 100 lbs. gain	
			Alfalfa hay	Corn	Barley	A	B
Lot I	Barley, Alfalfa Hay (chopped)	*23.22	1112		424	$7.02	$8.13
Lot II	Corn, Alfalfa Hay (whole)	*28.38	866	345		5.70	6.60
Lot III	Corn, Alfalfa Hay (chopped)	28.50	784	347		5.82	6.61

A.—Grain at 1c per lb.; Alfalfa Hay (whole) $5.00 per ton; Alfalfa Hay (cut) $6.00 per ton.
B.—Grain at 1c per lb.; Alfalfa Hay (whole) $7.00 per ton; Alfalfa Hay (cut) $8.00 per ton.
* —Dogs entered pen causing loss in weight.

You will note in the table given above that Lot II made practically the same average gain per head that Lot III made, in spite of the fact that the dogs caused a loss in weight for Lot II and did not cause a loss in Lot III. 113 pounds more hay were required to produce each 100 pounds of gain in Lot II, the whole hay lot, but this is offset by the extra cost of the cut hay for Lot III at $1 per ton additional, making the cost of 100 pounds gain in live weight stand at $5.70 for the whole hay lot and $5.83 for the cut hay lot.

Figuring hay at $7 per ton, instead of $5, brings the whole hay and cut hay lots together at $6.60 and $6.61. And it should be noted that the higher the price of hay, the greater the benefit secured from cutting the hay. It costs no more to cut a high priced ton of hay than a low priced ton, but the saving is correspondingly greater.

SECOND SERIES, 1909-10

The following table gives the necessary data:

FEED FOR GAIN AND COST OF GAIN. 1909-10

(125 Lambs in Lot)

Ration	Average Gain per head 14 weeks (lbs.)	Lbs. feed for 100 lbs. gain: Alfalfa hay	Corn	Barley	Cost of feed per 100 lbs. gain: A	B
Lot I Barley, Alfalfa Hay (whole in self feeder)..........	29.32	859		307	$5.22	$6.08
Lot II Corn, Alfalfa Hay (cut in in self feeder)..........	30.12	908	299		5.71	6.62
Lot III Corn, Alfalfa Hay (whole in self feeder)..........	30.80	905	293		5.19	6.10
Lot IV Corn, Alfalfa Hay (whole on ground)	30.96	955	291		5.30	6.25

A.—Grain 1c per lb.; Alfalfa Hay (whole) $5.00 per ton; Ailfalfa Hay (cut) $6.00 per ton.
B.—Grain 1c per lb.; Alfalfa Hay (whole) $7.00 per ton; Alfalfa Hay (cut) $8.00 per ton.

CUT HAY VS. WHOLE HAY

This experimental series gives a clean cut comparison of the merits of reduced hay. In this trial as in the previous winter's trial, the openings of the self feeders were narrowed so that there was no unnecessary waste of the alfalfa meal. The hay used throughout the experiment was first and second cutting, fairly typical of hay as cured in this section from season to season. The hay was bought from farmers near Fort Collins.

Comparing Lots II and III, we see that the average gain per head was 30.1 lbs. for the cut hay lot, and 30.8 lbs. for the whole hay lot. The amount of hay used per hundred pounds gain in live weight produced was 908 lbs. for the cut hay and 905 lbs. for the whole hay. The amount of corn used on the same basis was 299 lbs. for the cut hay lot and 293 lbs. for the whole hay lot. In every item, the advantage, though slight, is in favor of the whole hay. This of course results in a higher cost of production for the cut hay lot, $5.71 as against $5.19 for the whole hay lot.

The question at once arises whether there is no benefit at all in reducing hay. Such benefit has been found in other cases and why not here? The answer probably is found in the fact that good alfalfa hay was used. Alfalfa hay of good quality is very palatable to live stock, and when fed in properly constructed self-feeder racks, not a great deal of waste occurs. If the hay is coarse stemmed, over ripe, or weathered, a much greater proporton of the stems will be rejected.

SELF FEEDERS FOR HAY

Comparing lots III and IV, we find, as in our previous experiments reported in Bulletin 151, a saving in hay resulting from the use of the self feeder,—in this case 50 pounds of hay for each hundred pounds gain. With hay at $5.00 per ton, the saving on one hundred pounds of gain is shown to be 11 cents, or about 3½ cents per lamb. With four lambs per running foot this amounts to 14 cents saving in hay each season per running foot of rack. As stated in Bulletin 151, the cost of material for the rack is $1 per running foot. In the former experiment a saving of 56 cents per running foot was secured. The combined evidence of the two experiments gives an average saving of 35 cents per running foot of rack each season when hay is at $5.00, a sufficient return to warrant the use of the racks. Of course as hay goes higher in price the saving is greater. The neatness of the feeding premises is an argument in itself for the self feeder, regardless of the saving in hay.

SCOTCH BARLEY COMPARED WITH CORN

Aside from the fact that barley is a large yielding crop in Colorado, it is a crop that ripens early in the season, and it can often be bought for a lower price than old corn, prior to the appearance of a good quality new-crop corn on the market. During this last season (Fall 1912) new corn made a late appearance and was of poor quality because of early fall snows in the western section of the corn belt. As a result more barley was used for sheep feeding in the eastern Colorado feeding districts than ever before. Many feeders seem to have a prejudice against barley as a stock feed. Possibly this is because most experimental data with regard to the feeding of barley to hogs and to cattle shows a feeding value for barley of about one-tenth less than corn. My own observations with regard to barley for sheep indicated that barley was equally as good a feed as corn. This led to the experiments; and comparing Lots I and III in the last table above, we see that a trifle less hay and more grain was used by the barley lot than by the corn lot, resulting in a cost of $5.22 per hundred pounds gain for the barley-fed lot and $5.19 for the corn-fed lot, when hay is $5.00 per ton and both barley and corn $1 per cwt. This gives it an equal value with corn when fed with alfalfa hay.

THIRD SERIES, 1910-11

This series included barley experiments as follows:

FEED FOR GAIN AND COST OF GAIN. 1910-11.
(100 lambs in lot)

Ration	Average Gain per head 14 weeks Lbs.	Lbs. feed for 100 lbs. gain: Alfalfa	Calif. feed barley	Scotch barley	Corn	Cost of feed per 100 lbs. gain: A	B
Lot II Alfalfa Hay and California Feed Barley	30.14	670	377			$5.45	$6.12
Lot III Alfalfa Hay and Scotch Barley....	33.52	647		339		5.01	5.65
Lot IV Alfalfa Hay, whole, and Corn........	31.86	579			357	5.02	5.60

A.—Grain at 1c per lb.; Alfalfa Hay (whole) at $5.00 per ton.
B.—Grain at 1c per lb.; Alfalfa Hay (whole) at $7.00 per ton.

SCOTCH BARLEY, CALIFORNIA FEED BARLEY, AND CORN COMPARED

California feed barley was included in this trial because it is a heavy yielding barley, and is extensively grown in this state. It is a six-row barley, and the kernels are much lighter and have more hull than a good, Scotch brewing barley, California feed barley can be brewed, but is not taken for that purpose in this state unless there is a scarcity of barley. As a result there is little competition between brewer and feeder for this variety.

Comparing Lots II and III, we find that the California feed barley lot made an average gain of 30.1 pounds per head while the Scotch barley lot made a gain of 33.5 pounds per head. The feed barley lot required 24 pounds more of alfalfa hay and 28 pounds more of grain for each hundred pounds gain in live weight. This throws the cost of 100 pounds gain to $5.45 for the feed barley lot and $5.01 for the Scotch barley lot,—a material difference in favor of the Scotch barley.

Comparing lots III and IV, we find that the Scotch barley lot made an average gain per head of 1.6 pounds more than the corn lot, and required 68 pounds more hay and eighteen pounds less grain than the corn lot, resulting in a cost of $5.01 for each hundred pounds gain in live weight made by the Scotch barley lot, and $5.02 for the corn lot,—an immaterial difference. Figuring hay at $7.00 per ton, it makes a difference of only 5 cents in cost of gain against the barley fed lot.

FINE ALFALFA MEAL COMPARED WITH CUT HAY

FEED FOR GAIN AND COST OF GAIN. 1910-11.

(100 lambs in lot)

	Ration	Average Gain per head 10 weeks Lbs.	Lbs. feed for 100 lbs. gain. Alfalfa Meal	Alfalfa Cut	Corn	Cost of feed for 100 lbs. gain. A	B
Lot V	Alfalfa Meal and Corn	28.54	406		300	$5.03	$5.44
Lot VI	Alfalfa, cut, and Corn	23.93		552	358	5.24	5.79

A.—Corn at 1c per pound; Alfalfa Hay, cut, at $6.00 per ton; Alfalfa Meal $10.00 per ton.
B.—Corn at 1c per pound; Alfalfa Hay, cut, at $8.00 per ton; Alfalfa Meal $12.00 per ton.

The cost of reducing alfalfa hay to a fine meal is rather heavy and the prices taken in the above table are none too high.

We find here a marked saving in the amount of hay used per hundred pounds gain in live weight, the fine meal lot using 46 pounds less hay than the cut hay lot. The fine meal lot also used 12 pounds less corn per hundred pounds gain in live weight.

The meal used was as fine as a finely ground corn meal. Its cost was high because the capacity of the machine producing it was very low. To produce two tons of this meal per day required two men and a team besides the power cost, and if the hay were in the slightest degree damp two tons a day could not be put through.

The alfalfa cutter used for producing the cut hay would run through two tons per hour. Figuring the cost of cut hay at $1 per ton greater than whole hay, and of fine meal at $5 per ton greater than whole hay, with whole hay at $5 per ton, we have a cost for producing 100 pounds gain in live weight of $5.24 for cut hay and $5.03 for fine meal.

We may also compare Lot VI, the cut hay lot, with Lot IV of the previous table. The lambs used in Lots II to IV inclusive were all divided up for experiment at the same time, were put into the feed lot at the same time, and were all on a pound of grain per head per day at the time of starting the experiment. Lots V and VI were redivided a month later because of an accident, and so the data for them covers only ten weeks instead of fourteen weeks as in the case of Lot IV. The lots may fairly be compared, however, on the basis of feed required for gain in live weight, as all lots had passed the preliminary period during which grain feed was being increased to one pound.

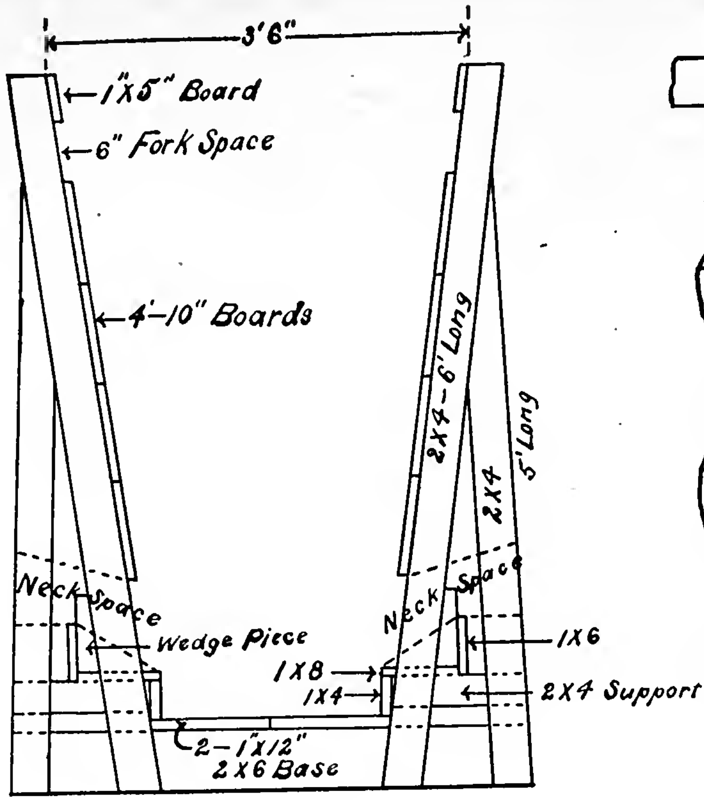
Comparing Lots IV and VI, we find that the whole hay lot required 27 pounds more hay and 1 pound less corn for each hundred pounds gain in live weight produced, resulting in a cost for the whole hay lot of $5.02, while the cut hay lot cost $5.24. We see here no saving in cost of gain, but with lot V, the alfalfa meal lot, we see a slight saving when whole hay is $7 per ton, but none when whole hay is $5 per ton. The hay used was poor quality chiefly because grasshoppers had worked upon it in the field. Good alfalfa hay is eaten quite closely without being cut or ground, so that cutting or grinding good hay does not cause closer consumption in the same degree as with poor hay. Even a good quality hay has more or less poor hay mixed with it because stack tops and bottoms are necessarily of poor quality, so that cutting the hay usually results in closer consumption of these parts. When all the hay is poor quality, the cutting apparently results in much closer eating of the stems, and a correspondingly greater saving.

CONCLUSIONS

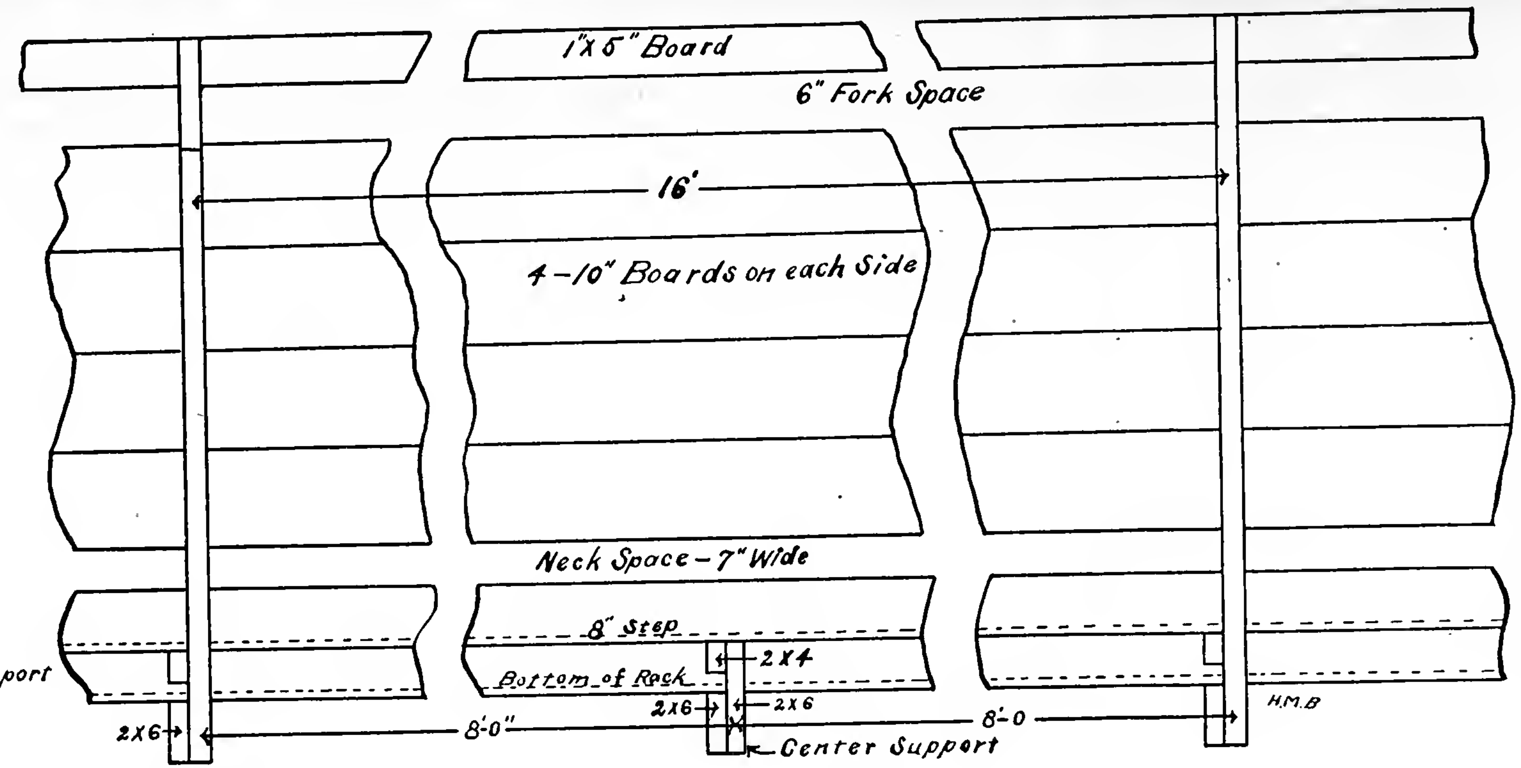
Self Feeders for Hay

We may safely conclude as the result of two years' work that there is a material saving in cost of production where self feeders are used. The figures for these two years show a saving of 35 cents per running foot, which would repay the cost of the racks in three seasons.

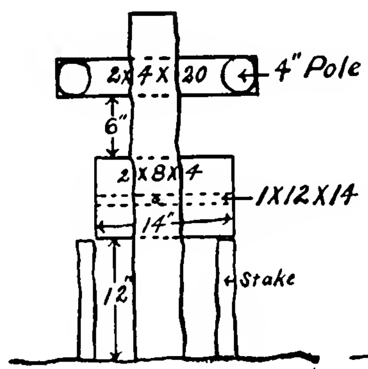
There are a number of facts to be noted concerning the self feeders, which have been observed in the course of their use. The distance between rack openings on opposite sides of the rack must not be too great, or a pillar of uneaten hay will remain, preventing the main body of hay in the rack from slipping down to where the sheep can reach it.



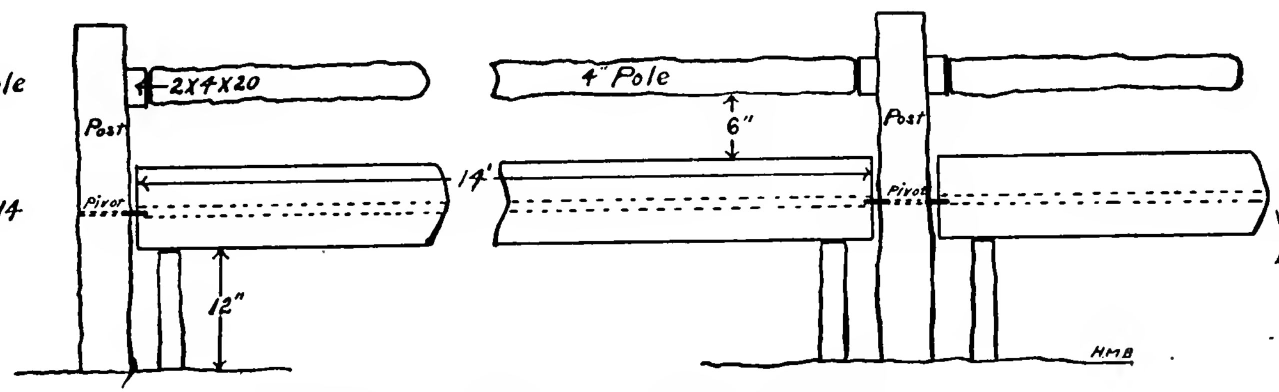
End View



Side View of Self Feeding Hay Rack for Sheep



End View



Side View of Invertible Sheep Feeding Trough

THESE PLANS ARE TAKEN FROM RACKS AND TROUGHS NOW IN USE ON THE STATE AGRICULTURAL COLLEGE FARM
FOR FURTHER INFORMATION WRITE THE ANIMAL HUSBANDRY DEPT. C.A.C

FORT COLLINS
COLO.

SCALE 1 FOOT

AGJ

The slope of sides must not be too great or the hay will jam in the narrowest part at the bottom.

If alfalfa meal is fed in self feeders, covers should be provided, as snow incorporates itself so thoroughly with the meal that much waste will result. On the preceding page is given a plan of the self feeder. When alfalfa meal is used, put a 1x4 piece on each side below the lowest 10 inch board, thus reducing the neck space. Also put in a false floor made by two 12 inch boards in the shape of an inverted V-shaped hog trough. This directs the meal to each opening and the sheep are not forced to stretch in order to get at the meal. The use of the self feeder has become general in the Fort Collins lamb-feeding district, and its use will be found advantageous in all Colorado feeding districts.

BARLEY FOR FATTENING LAMBS

A plump, full kerneled barley is as good as corn, pound for pound, for fattening lambs, when it is used with alfalfa hay as a roughage. A light kerneled, heavy hulled barley such as California feed barley (a six rowed barley) is not as valuable as the two or four rowed barleys, although it yields somewhat more per acre than the two or four rowed barleys. The one trial thus far made indicates a feeding value about ten per cent less than the heavier barleys.

ALFALFA MEAL

Most of our experiments were with a coarse meal, or cut hay. Four years' work shows that a saving results from the use of cut hay, but that with good hay the saving is fully offset by the cost of cutting the hay where the cost of such cutting amounted to $1 per ton. In one instance, where poor quality of hay was used, a money saving was effected by its use when the cost of cutting was $1 per ton. I believe we may safely sum up the situation as follows: In any section where one or more cuttings of hay are usually badly weathered because of rains, it will pay the feeder to reduce his hay, provided the cost of the meal delivered at his farm, in excess of the cost of whole hay, is not more than $1 per ton for the coarser grades, or $3 to $4 for the finely floured meal. We as yet have no evidence that it will pay to reduce a good quality of hay.

Where one is installing his own machinery, he should figure power cost, depreciation and interest, as well as labor cost; and he should also realize that having the machine upon the place will enable him to secure much closer consumption of coarse, poor quality products, such as straw, corn stalks, and tops and bottoms of alfalfa stacks especially if he is in a position to mix a more palatable feed, such as beet syrup, with the cut product. Where one hauls his hay to a mill to be cut, he should figure the cost of such hauling as well as the price for cutting the hay.

The fodder cutter and alfalfa mill have a legitimate place upon many farms, and the publication of our experimental results is not meant to discourage their use where needed. But statements to the effect that there is a 50% greater feeding value in alfalfa meal than in the hay from which the meal was made are not well founded. Experiments at this Station in 1902 (Bulletin 75, p. 9) show that 28 per cent of alfalfa hay fed to lambs was uneaten. This means that if the rejected stems were of the same value as the rest of the hay, not more than one-third greater feeding value could be secured by their consumption; while because of the large amount of crude fiber in the coarser stems, they do not possess nearly the feeding value of the rest of the hay. In addition to the closer consumption of the coarse parts of hay, something is gained in saving the energy used in mastication of uncut hay. Reducing the hay undoubtedly adds to its value, the increased value being somewhat proportionate to the fineness of reduction; but the greatest possible increase in value, with finest reduction probably is not over 40 per cent of the value of the whole hay. With ordinary grades of hay, and typical fineness of reduction, the feeder may ordinarily figure on 15 to 25 percent increase in value.

APPENDIX

BI-WEEKLY DATA. ALFALFA HAY (WHOLE), SCOTCH BARLEY

December 18, 1909—March 26, 1910

LOT I. (125 Lambs in Lot)

Period	Weight	Gain	Average gain per head	FEED: Alfalfa Hay (whole)	FEED: Barley
Beginning	8765				
2nd Week	8970	205	1.64		880
4th "	8890	—80	—.64		980
6th "	9750	860	6.88		1568
8th "	10355	605	4.84		1960
10th "	11015	660	5.28		1960
12th "	11605	590	4.72		1960
14th "	12430	825	6.60		1960
Total		3665	29.32	31498	11268

BI-WEEKLY DATA, ALFALFA HAY (CHOPPED), CORN

December 18, 1909—March 26, 1910

LOT II. (125 Lambs in Lot)

Period	Weight	Gain	Average Gain per head	FEED: Alfalfa Hay (chopped)	FEED: Corn
Beginning	8765				
2nd Week	9260	495	3.96		880
4th "	9395	135	1.08		980
6th "	10015	620	4.96		1568
8th "	10655	640	5.12		1960
10th "	11275	620	4.96		1960
12th "	12175	900	7.20		1960
14th "	12530	355	2.84		1960
Total		3765	30.12	34175	11268

BI-WEEKLY DATA, ALFALFA HAY (WHOLE), CORN

December 18, 1909—March 26, 1910

LOT III. (125 Lambs in Lot)

Period	Weight	Gain	Average Gain per head	FEED: Alfalfa Hay (whole)	FEED: Corn
Beginning	8890				
2nd Week	6365	505	4.04		880
4th "	6375	—20	—.16		980
6th "	10110	735	5.88		1568
8th "	10690	580	4.64		1960
10th "	11425	735	5.88		1960
12th "	12045	620	4.96		1960
14th "	12740	695	5.56		1960
Total		3850	30.80	34857	11268

BI-WEEKLY DATA, ALFALFA HAY (WHOLE ON GROUND), CORN

December 18, 1909—March 26, 1910

LOT IV. (125 Lambs in Lot)

Period	Weight	Gain	Average Gain per head	FEED: Alfalfa Hay (on ground)	FEED: Corn
Beginning	8910				
2nd week	9425	515	4.12		880
4th "	9125	—300	—2.40		980
6th "	10000	875	7.00		1568
8th "	10725	725	5.80		1960
10th "	11440	715	5.72		1960
12th "	12200	760	6.08		1960
14th "	12780	580	4.64		1960
Total		3870	30.96	36977	11268

TOTAL WEIGHTS AND GAINS.—14 WEEKS

December 18, 1909—March 26, 1910

(125 Lambs in Lot)

Lot	Ration	Weight at Beginning	Weight at Close	Gain in Weight	TOTAL FEED CONSUMED (lbs.): Corn	Barley	Whole Hay on Ground	Whole Hay	Chopped Hay
1	Barley and Whole Alfalfa	8765	12430	3665	.....	11268	.....	31498	.....
2	Corn and Chopped Alfalfa	8765	12530	3765	11268	.....	.....	.....	34175
3	Corn and Whole Alfalfa	8890	12740	3850	11268	.....	.....	34857	.....
4	Corn and whole Alfalfa on Ground	8910	12780	3870	11268	.....	36977	......	.....

BI-WEEKLY DATA, ALFALFA HAY (WHOLE), CALIFORNIA FEED BARLEY

December 17, 1910—March 25, 1911—14 Weeks

(100 Head in Lot)

LOT II.

Period	Weight	Gain	Average Gain per head (lbs.)	FEED Alfalfa	FEED Barley
December 17, 1910	7113				
December 31, 1910	7220	107	1.07		1400
January 14, 1911	7775	567*	5.67		1400
January 28, 1911	8101	326	3.26		1400
February 11, 1911	8660	559	5.59		1400
February 25, 1911	8940	280	2.80		1575
March 11, 1911	9695	755	7.55		2100
March 25, 1911	10115	420	4.20		2100
Total		3014	30.14	20199	11375

* One died, weight 70 pounds. One put in, weight 58 pounds.

BI-WEEKLY DATA, ALFALFA HAY (WHOLE), SCOTCH BARLEY

December 17, 1910—March 25, 1911,—14 Weeks

(100 Head in Lot)

LOT III.

Period	Weight	Gain	Average Gain per head (lbs.)	FEED Alfalfa	FEED Barley
December 17, 1910	7103				
December 31, 1910	7520	417	4.17		1400
January 14, 1911	7847	327	3.72		1400
January 28, 1911	8330	483	4.83		1400
February 11, 1911	8890	560	5.60		1400
February, 25 1911	9175	285	2.85		1575
March 11, 1911	9710	535	5.35		2100
March 25, 1911	10455	745	7.45		2100
Total		3352	33.52	21678	11375

BI-WEEKLY DATA, ALFALFA HAY (WHOLE), CORN

December 17, 1910—March 25, 1911.—14 Weeks

LOT IV. **(100 Lambs in Lot)**

Period	Weight	Gain	Average Gain per head (lbs.)	FEED Alfalfa	FEED Corn
December 17, 1910	7183				
December 31, 1910	7365	201*	2.01		1400
January 14, 1911	7667	302	3.02		1400
January 28, 1911	8140	473	4.73		1400
February 11, 1911	8645	505	5.05		1400
February 25, 1911	9150	505	5.05		1575
March 11, 1911	9875	725	7.25		2100
March 25, 1911	10350	475	4.75		2100
Total		3186	31.86	18462	11375

* One died, weight 75 pounds. One put in, weight 56 pounds.

BI-WEEKLY DATA, FINE ALFALFA MEAL, CORN

January 14, 1911—March 25, 1911—10 Weeks

LOT V. (100 Lambs in Lot)

Period	Weight	Gain	Average Gain per head (lbs.)	FEED Alfalfa	FEED Corn
January 14, 1911	7893				
January 28, 1911	8474	599*	5.99		1400
February 11, 1911	8910	460**	4.60		1400
February 25, 1911	9500	590	5.90		1575
March 11, 1911	9945	445	4.45		2100
March 25, 1911	10705	760	7.60		2100
Total		2854	28.54	11580	8575

* One missing, average weight 85 pounds. One put in, weight 67 pounds.
** One missing, average weight 89 pounds. One put in, weight 65 pounds.

BI-WEEKLY DATA, ALFALFA HAY (CUT), CORN

January 14, 1911—March 25, 1911—10 Weeks

LOT VI. (100 Lambs in Lot)

Period	Weight	Gain	Average Gain per head (lbs.)	FEED Alfalfa	FEED Corn
January 14, 1911	7897				
January 28, 1911	8115	228*	2.28	5759	1400
February 11, 1911	8585	470	4.70	860	1400
February 25, 1911	9055	470	4.70	2248	1575
March 11, 1911	9760	705	7.05	3590	2100
March 25, 1911	10280	520	5.20	750	2100
Total		2393	23.93	13207	8575

* One died, weight 75 pounds. One put in, weight 65 pounds.

TOTAL WEIGHTS AND GAINS—14 WEEKS

December 17, 1910—March 25, 1911

(100 Lambs in Lot)

Lot No.	Ration	Weight at Beginning	Weight at close	Gain in Weight (lbs.)	TOTAL FEED CONSUMED Calif Feed Barley	Scotch Barley	Corn	Alfalfa Hay (whole)
II	Alfalfa Hay and California Feed Barley	7113	10115	3014	11375	.....	.....	20199
III	Alfalfa Hay and Scotch Barley.....	7103	10455	3352	.....	11375	.....	21678
IV	Alfalfa Hay, whole, and Corn	7183	10350	3186	.....	.....	11375	18462

TOTAL WEIGHTS AND GAINS—10 WEEKS

January 14, 1911 to March 25, 1911

(100 Lambs in Lot)

Lot No.	Ration	Weight at Beginning	Weight at Close	Gain in Weight (lbs.)	TOTAL FEED CONSUMED Alfalfa Meal	Alfalfa Hay (cut)	Corn
V.	Alfalfa Meal and Corn	7893	10705	2854	11580	.....	8575
VI.	AlfalfaHay(cut) and Corn	7897	10280	2393	.....	13207	8575

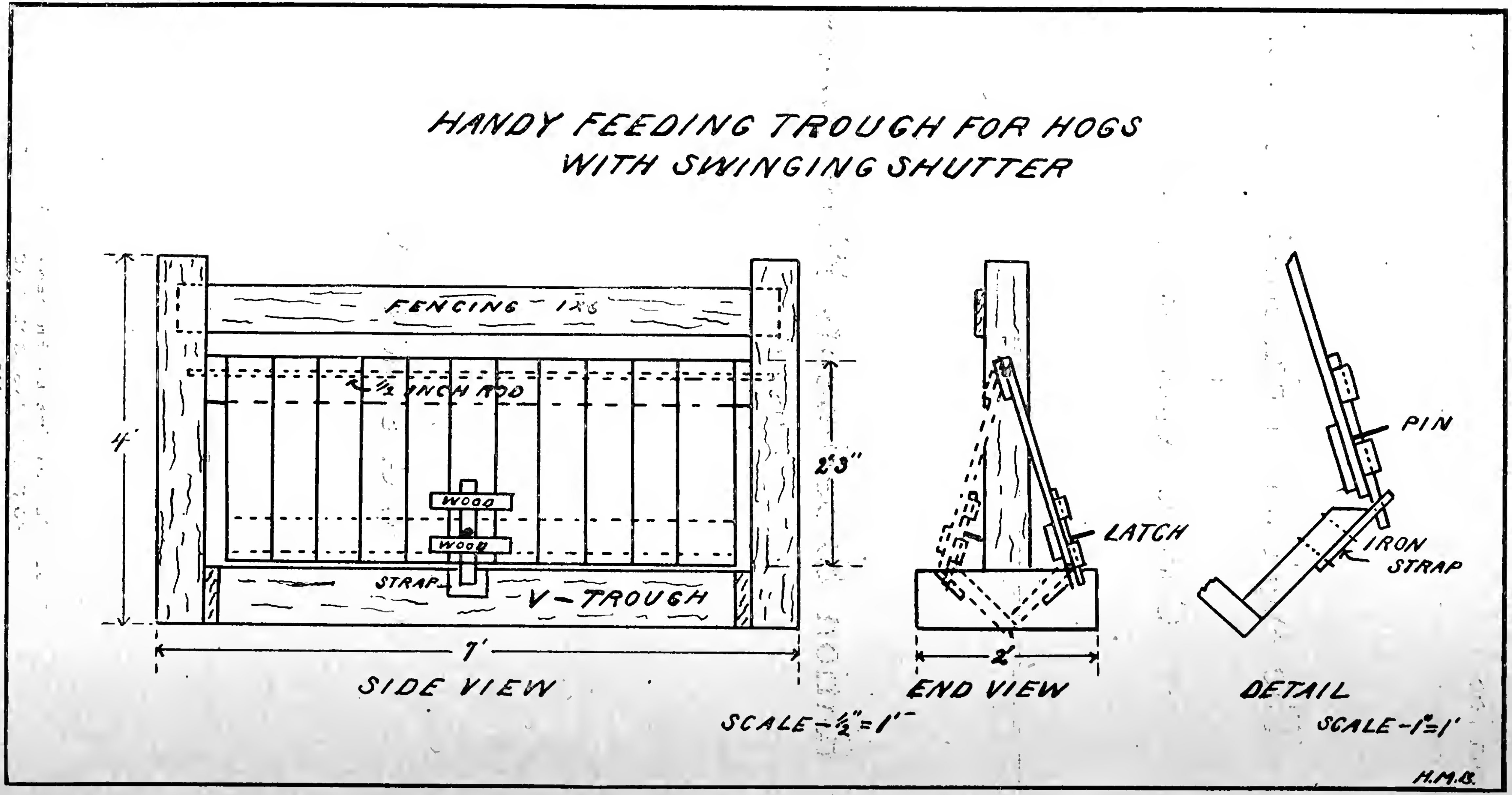
Bulletin 188 June, 1913

The Agricultural Experiment Station
of the
Colorado Agricultural College

Ration Experiments With Swine
1908-1911

By G. E. MORTON

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1913


HANDY FEEDING TROUGH FOR HOGS
WITH SWINGING SHUTTER
FENCING 1x6
½ INCH ROD
WOOD
WOOD
STRAP
V-TROUGH
4'
7'
2'3"
SIDE VIEW
LATCH
2'
END VIEW
PIN
IRON
STRAP
DETAIL
SCALE-½"=1'
SCALE-1"=1'
H.M.B.

Ration Experiments With Swine, 1908-1911

G. E. MORTON*

INTRODUCTION

Three series of experiments are reported in this bulletin. All were designed to continue the work of determining or demonstrating the most economical protein supplements for grain, particularly barley and corn. The experiments include no new combinations of feeds, and results with similar rations have been reported from a number of experiment stations, but each state finds it quite needful to rework many problems in order to be able to state at first hand that certain definite results have been secured from given feeds.

The work with fertilizer tankage is new work so far as the writer knows, and the sole object of the experiments with fertilizer tankage was to find whether the cheaper product could be used to replace selected tankage.

The experimental work with alfalfa done at the Station has been chiefly with whole hay in racks. The third series of experiments here reported shows results obtained from the use of alfalfa meal fed with the grain in slop.

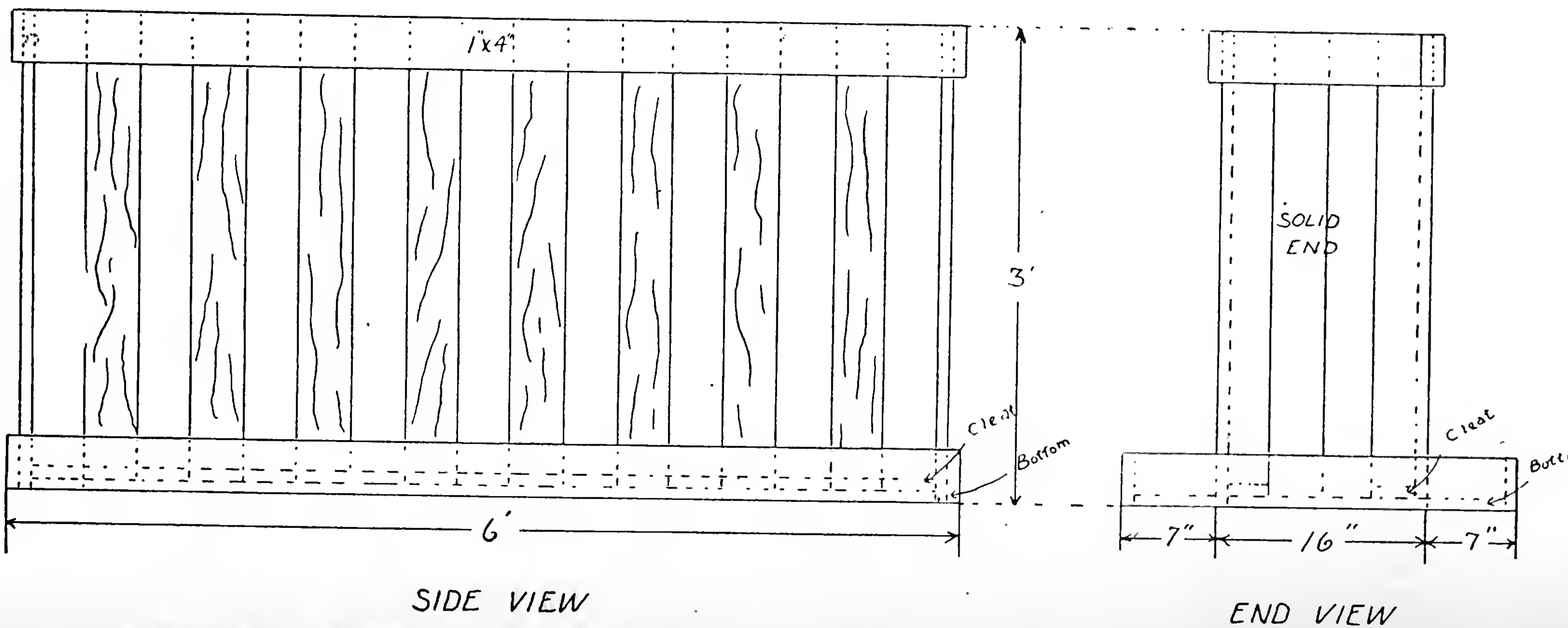
It has been very difficult to secure for experimental feeding purposes, shoats properly grown and even in size. Not many hogs are produced in the territory tributary to Fort Collins, because of specialized crop farming, and for experimental purposes it is desirable to have the entire group of shoats used in one series of experiments come from the same farm in order to insure uniformity of breeding, thrift and development. The shoats used in these experiments were in each case from one farm and were reasonably even in weight and development. Because of limited numbers from which to select, sows were used as well as barrows; and in dividing into experimental lots, equal numbers of sows were placed in each pen.

One series of experiments carried out with alfalfa meal is not reported, because the shoats secured had not been properly developed, and instead of growing frame as they fed out, became overfat near the beginning of the experiment and caused too high a cost for production of gain. This of course would not invalidate comparisons between rations, but might discredit the use of alfalfa meal as being too expensive a ration. Consequently, this series is omitted.

*With assistance of H. E. Dvorachek and G. A. Gilbert in preparing data.

ALFALFA FEEDING RACK FOR HOGS

THIS RACK IS CONSTRUCTED ENTIRELY OF 1"X4" STUFF. THE SIDES ARE MADE OF 1X4'S PLACED 4" APART, THE ENDS BEING MADE SOLID. IT REQUIRES 14 - 1X4'S TO BUILD IT



THESE PLANS ARE TAKEN FROM RACKS USED ON THE STATE AGRICULTURAL COLLEGE FARM
FOR FURTHER INFORMATION WRITE THE ANIMAL HUSBANDRY DEPT FT. COLLINS COLO. CAC

AGJ

1908-1909 EXPERIMENTS

Six lots of ten head each were fed. The pens averaged 47 to 48 pounds per pig when put on feed. They were uniform in breeding, age, and condition. At the close of fourteen weeks feeding, the lots ranged from an average weight of 109 pounds per head to 143 pounds per head. No attempt was made to finish the pigs out to a two hundred pound weight or heavier, as the fourteen weeks feeding period shows comparative results just as well as feeding for a longer period.

The following table gives the results:

FEED FOR GAIN AND COST OF GAIN. 1908-1909.
(Ten Pigs in Each Pen)

Pen No.	Ration	Av. Gain per head 14 weeks (lbs.)	Pounds of Feed for 100 Lbs. Gain: Corn	Barley	Shorts	Tankage	Cost of Feed for 100 lbs. Gain*	Standing of Lots
1	Corn (3); Barley (3); Selected Tankage (1)	143.1	191	191	....	64	5.10	3
2	Corn (6); Fertilizer Tankage (1)	109.0	400	....	....	67	4.84	1
3	Corn (6); Selected Tankage (1)	128.2	379	....	....	63	5.05	2
4	Corn (3); Selected Tankage (1)	117.0	345	....	....	115	5.75	6
5	First 4 weeks, Corn (3); Selected Tankage (1)	.....	...	....	....	...	....	
	Next 4 weeks, Corn (4) Selected Tankage (1)	125.9	352	....	....	84	5.20	4
	Last 6 weeks, Corn (5); Selected Tankage (1)	.....	...	....	....	...	....	
6	Corn (2); Shorts (1)..	91.3	327	....	....	163	5.31	5

* Note—Corn at 1c per lb.; Barley at 1c per lb; Selected Tankage at 2c per lb. ($40 per ton); Fertilizer Tankage at 1¼c per lb. ($25 per ton); Wheat Shorts at 1¼c per lb.; ($25 per ton).

Fertilizer Tankage With Corn

This was our first trial of fertilizer tankage, and we were led to it by the close similarity of appearance between the two grades of tankage, which made it difficult to distinguish between them by cursory examination. The tankage used in this trial was some that had become wet and developed a stronger odor than selected tankage, and as a result the pigs did not eat quite so much corn and tankage as the lot on corn and selected tankage. The result is shown in a smaller gain. In spite of this, the cheaper cost of fertilizer tankage gave this lot first rank in producing cheap gain in live weight. Fertilizer tankage at this time was $21 per ton, while selected tankage was $35 per ton, f. o. b. Denver. The prices used in the table were round numbers approximating the cost of the tankage delivered at Fort Collins, 75 miles from Denver.

While the cost of gain with the fertilizer tankage was less than for the other lots, it was not enough less to mark the fertilizer tankage as a superior feed, for the finish of the pigs in this lot was not so good as in the others because of the smaller gain in weight. The results were striking enough, however, to warrant further investigation of the fertilizer tankage as a hog feed.

Because of certain processes sometimes used in making fertilizer tankage, the product from some packing houses is not a safe hog feed. A discussion of the merits and dangers will be found in the final discussion of results farther on in this bulletin.

SELECTED TANKAGE WITH CORN.

There were three lots of hogs upon selected tankage and corn, Pen 3 receiving 1 part of tankage to 6 parts of corn, Pen 4 receiving 1 part of tankage to 3 parts of corn, and Pen 5 receiving during the first four weeks 1 part of tankage to 3 parts of corn, during the second four weeks 1 part to 4, and during the last six weeks 1 part tankage to 6 parts corn. Thus the shoats in this lot received a ration with less protein and more carbohydrates towards the close.

Pen 3, receiving 1 part selected tankage to 6 parts corn, gave the largest gain of the three, and this gain was produced more economically than that of any other pen fed selected tankage and corn. The proportion of tankage fed Pen 4, one part to three of corn, caused a heavy expense for gain. No advantage was found from feeding one part tankage to three of corn at the start and decreasing until the proportion was 1 to 6. It seems better to feed 1 part tankage to 6 parts corn from start to finish.

SELECTED TANKAGE, CORN, AND BARLEY

The highest gain made by any pen in the series was that made by Pen 1, fed 3 parts corn, 3 parts barley, and 1 part selected tankage Compared with the ration of 6 parts corn and 1 part tankage (Pen 3) the cost of gain was practically the same, and the finish of the hogs higher, making this ration a very satisfactory one.

CORN AND WHEAT SHORTS.

This ration was used as a comparison or check ration for all the others, as most hog feeders know about what this ration will do. It will be seen that out of six pens, the pen on this ration made the poorest gains of any, and the gain made was the most expensive excepting that made by lot 4. This means that all of the other rations except the one where selected tankage was fed too heavily, proved superior to a ration that is considered a very good one by practical feeders in the corn belt.

FEED FOR GAIN AND COST OF GAIN, 1909-1910
(10 Pigs in Each Pen)

No. of Pen	Ration	Average Gain per Head in 8 Weeks.	Pounds of Feed for 100 Pounds of Gain in Live Weight: C. F. Barley	Corn	Selected Tankage	Fertilizer Tankage	Shorts	Winter Rye	Alfalfa Hay	Sugar Beets	Cost of 100 Lbs. Gain	Standing * of pens
1	C. F. Barley, Alfalfa Hay	92.9	498	..	..	..	..	..	27	..	$5.06	3
2	C. F. Barley 1 part; Corn 1 part; Alfalfa Hay	97.4	238	238	..	..	..	..	29	..	4.83	1
3	C. F. Barley 9 parts; Selected Tankage 1 part	87.5	476	...	53	..	..	..	..	..	5.82	9
4	C. F. Barley 7 parts; Selected Tankage 1 part	92.0	440	...	63	..	..	..	..	..	5.66	6 & 7
5	C. F. Barley 5 parts; Selected Tankage 1 part	85.1	454	...	91	..	..	..	..	..	6.36	11
6	C. F. Barley 9 parts; Fertilizer Tankage 1 part	94.1	444	...	..	49	..	..	..	..	5.05	2
7	C. F. Barley 7 parts; Fertilizer Tankage 1 part	84.6	481	...	..	69	..	..	..	..	5.67	8
8	C. F. Barley 5 parts; Fertilizer Tankage 1 part	93.0	416	...	..	84	..	..	..	..	5.21	4
9	C. F. Barley 4 parts; Sugar Beets 1 part	77.1	505	...	..	..	..	..	..	126	5.37	5
10	C. F. Barley 2 parts; Shorts 1 part..	88.9	348	...	..	..	174	..	..	...	5.66	6 & 7
11	Winter Rye	65.5	...	...	..	..	...	628	..	...	6.28	10

* Note.—C. F. Barley at 1c per lb.; Corn at 1c per lb.; Winter Rye at 1c per lb.; Selected Tankage at 2c per lb., $40 per ton.

Fertilizer Tankage at 1¼c per lb., $25 per ton.; Wheat Shorts at 1¼c per lb., $25 per ton; Sugar Beets at $5 per ton; Alfalfa Hay at $5 per ton.

1909-1910 EXPERIMENTS

Eleven lots of ten head each were fed. The pens averaged from 173 to 178 pounds per pig at the beginning of the experiment, and 241 to 271 at the close. The pigs used were uniform in breeding, age and condition.

The preceding table gives the results.

California Feed Barley with Wheat Shorts or Alfalfa Hay.

The check ration used in this series was California feed barley 2 parts and wheat shorts 1 part. The ration stands about midway of the various rations used, both in gain in live weight produced and in cost of gain. Most of the other rations were combinations of various feeds with California feed barley, made with a view to find the proper proportions with protein supplements to secure cheapest results.

The best ration in the series was California feed barley 1 part and corn 1 part, with alfalfa hay according to appetite. The hay was fed whole in racks. This is a ration that is available to many Colorado hog feeders, and because of its economy should be widely used. Where the barley was used with alfalfa hay alone, no corn being used, gains were not quite so cheaply secured, yet this ration was third in economy among the entire eleven rations, and at present prices of fertilizer tankage, would rank second in economy in producing gain, displacing the pen which gave best results from the use of fertilizer tankage.

California Feed Barley and Fertilizer Tankage

The ration which was second in point of cheapness of production was that fed Pen 6, California feed barley 9 parts, fertilizer tankage 1 part; and that fed Pen 8 was close to it in economy, the ration being 5 parts California feed barley to 1 part fertilizer tankage. The difference in cost of production between these two was 16 cents per hundred pounds gain in live weight. Why Pen 7, fed 7 parts barley to 1 part of fertilizer tankage should not have done as well as the other two cannot be explained by the character of the ration as it is a mixture standing between the two in amount of tankage used.

Sugar Beets with California Feed Barley.

This ration was fed Pen 9, using 4 parts of barley to 1 of sugar beets. The cost of producing gain was $5.37 per hundred pounds gain, which is a reasonable cost compared with that of other rations.

Winter Rye.

Because of special requests from mountain districts where winter rye is a useful grain crop, one pen was given rye without any supplementary feed. The feed did not prove satisfactory chiefly because of lack of palatability. The hogs would not eat it well and consequently made very small gains.—8½ pounds per head per week as compared with 11½ pounds per head per week made by the barley and alfalfa hay lot.

1911 EXPERIMENTS

Four lots containing 8 pigs each were fed. The pens averaged 116 and 117 pounds per pig at the start, and 163 to 178 pounds at the close of 8 weeks' feeding. The pigs were uniform in breeding, age, and condition. The following table gives results:

FEED FOR GAIN AND COST OF GAIN, 1911
(8 Pigs in Each Pen)

Pen No.	Ration	Av. Gain per head in 8 wks	Pounds of Feed for 100 lbs. Gain: Corn	Shorts	Alfalfa	Cost of 100 lbs. Gain*	Standing of Pens	Lbs. of Grain replaced by 100 lbs Alfalfa Meal
1	Corn and Shorts equal parts	76.5	254	254	....	5.72	4	..
2	Corn 4 parts: Alfalfa Meal 1 part	63.5	430	...	107	4.84	1	73
3	Corn 5 parts; Alfalfa Meal 1 part	58.6	486	...	98	5.35	3	22
4	Corn 6 parts; Alfalfa Meal 1 part	62.3	469	...	78	5.08	2	50

*Corn at 1c per lb.; Wheat Shorts at 1¼c per lb. ($25 per ton); Alfalfa Meal at $10 per ton.

CORN AND WHEAT SHORTS

This ration was again used as a check ration, but in this series equal parts of corn and shorts were used. This ration was the least economical of any used in the series, costing $5.72 for 100 pounds of gain in live weight.

CORN AND ALFALFA MEAL

Three lots were fed upon corn and alfalfa meal, Pen 2 getting 4 parts of corn to one of alfalfa meal, Pen 3 getting 5 parts of corn to 1 of alfalfa meal, and Pen 4 getting 6 parts of corn to 1 of alfalfa meal. The 4 to 1 lot made the best gains of the three,—and the cheapest gains, with corn at 1c per lb. and alfalfa meal at $10 per ton, the cost of gain being $4.84 per hundred pounds. With corn higher or alfalfa meal lower in price, this ration would appear still better, as in this ration more grain was replaced by 100 pounds of alfalfa meal than in any of the other corn-alfalfa meal rations.

The lots on corn and alfalfa meal did not make as large gains in the eight week period as the corn and shorts lot, falling 13 to 18 pounds short on the average. But the gain was put on so much more economically that one could afford to feed somewhat longer to get the same finish.

CONCLUSIONS FROM ALL EXPERIMENTS

Selected Tankage

Selected tankage is a valuable feed, as evidenced by many experiments in the corn belt states. It is hoped that the economical showing of rations containing from 6 to 9 parts barley or corn and 1 part of tankage, as compared with corn and wheat shorts, will overcome in the minds of Colorado farmers the still prevalent idea that hogs cannot be finished as economically here as in the corn belt. Selected tankage can be advocated without qualification as an excellent supplement to starchy grains in this region. We find that hogs do not as a rule relish it until they become used to its flavor, but after that no dificulty is found in getting them to eat heartily.

Fertilizer Tankage

In the process of manufacturing tankage, either for fertilier purposes or for feeding, the meat scraps are cooked with live steam at high pressure. Such cooking is sufficient to destroy disease germs, so no one need fear disease from either form of tankage, if the tankage after being sacked is stored where there is no danger of contamination from hog cholera. The chances of such contamination are so slight that they may be considered negligible, since tankage has been used extensively for years and has proven satisfactory. In the making of selected tankage, diseased carcasses as a rule are not used, heads and other bony parts and scrap meats being used. The bones themselves are removed before the product is dried and ground. In the cooking process a liquid portion evaporates with the steam and condenses on the inside of the boilers. This liquid is a very concentrated beef essence and is difficult to reduce to solid form, such reduction being brought about by treating with acid or running over hot rolls. This product, called "stick," is usually put in with the fertilizer tankage, and fertilizer tankage also contains more hair and charred bone. The bone is probably a benefit rather than otherwise, and in our experiments the hair did not prove to be a detriment. There was no stick in the tankage used in these experiments, as the Denver packing houses were not putting the stick in at that time. But even when stick is put in fertilizer tankage, I can see no objection to its use for feeding, provided the stick is dried over hot rolls. The advantage of using the fertilizer tankage is its lower price. At the time of these experiments selected tankage was $35 and fertilizer tankage was $21. Fertilizer tankage has risen in price to $25 and $30 now, but there is still considerable saving in its use.

The following quotation from a letter to the writer by J. J. Ferguson of Swift & Company, will explain further the difference between selected and fertilizer tankage. This letter was in response to an inquiry as to the possible dangers of feeding fertilizer tankage to hogs:

"Product from slime tanks and offal tanks goes to fertilizer. These materials in themselves are highly undesirable, but in addition they are usually allowed to lie around and undergo fermentation, which produces division products which may be highly dangerous from a feeding standpoint.

"On the contrary in the manufacture of feeding tankage we use only select material from U. S. Inspected and Passed animals and handle it promptly all along the line so that there is no possibility of its undergoing fermentation or decomposition."

During the two years feeding at the station no ill effects upon hogs was caused by fertilizer tankage, but in view of the facts given above, while feeders, particularly those operating upon a large scale, may save considerable money by the use of fertilizer tankage, they should make sure of the process of preparation of the product before using it.

CALIFORNIA FEED BARLEY

This barley is not quite so satisfactory a feed as a good, plump brewing barley, but yet gives good results with alfalfa hay, alfalfa meal, or tankage. Use about nine parts of barley to one of tankage, or four parts to one of alfalfa meal. When fed with alfalfa hay put the hay in the racks letting them eat what they will and feed all the barley slop they will clean up.

BARLEY AND SUGAR BEETS

The rations named above are ordinarily more economical than this, but if one has sugar beets to feed, use 1 part to 4 of grain and good results will be obtained from pigs of 150 pounds weight or over. They should not be used for pigs of light weight, as they are too bulky a feed.

RYE

Rye alone is not palatable and should be fed with other feeds.

ALFALFA MEAL

In using alfalfa meal in slop with grain, it should be as finely ground as possible, and about four parts of grain used to each part of alfalfa meal. This is a ration that should not be fed to pigs weighing less than 100 pounds, as it is too bulky.

Grain and alfalfa meal make a very economical ration as compared with grain and shorts.

APPENDIX

WEEKLY DATA: RATION, CORN 3 PARTS, BARLEY 3 PARTS, SELECTED TANKAGE 1 PART.
October 31, 1908—February 6, 1909
Pen 1. (10 pigs in pen)

Period	Weight	Gain	Av. Gain	FEED: Corn	FEED: Barley	FEED: Selected Tankage
Beginning	480					
1st Week	565	85	8.5	96	96	32
2d Week	632	67	6.7	114	114	38
3d Week	707	75	7.5	136	136	45
4th Week	839	132	13.2	150	150	50
5th Week	948	109	10.9	186	186	62
6th Week	1070	122	12.2	207	207	69
7th Week	1146	76	7.6	192	192	64
8th Week	1257	111	11.1	210	210	70
9th Week	1377	120	12.0	252	252	84
10th Week	1477	100	10.0	237	237	79
11th Week	1578	101	10.1	210	210	70
12th Week	1672	94	9.4	231	231	77
13th Week	1772	100	10.0	255	255	85
14th Week	1911	139	13.9	252	252	84
		1431	143.1	2728	2728	909

WEEKLY DATA: RATION; CORN 6 PARTS, FERTILIZER TANKAGE 1 PART.
October 31, 1908, to February 6, 1909
Pen 2. (10 pigs in pen)

Period	Weight	Gain	Av. Gain	FEED: Corn	FEED: Fertilizer Tankage
Beginning	475				
1st Week	555	80	8.0	185	31
2d Week	597	42	4.2	235	39
3d Week	642	45	4.5	246	41
4th Week	712	70	7.0	270	45
5th Week	771	59	5.9	303	50.5
6th Week	849	78	7.8	309	51.5
7th Week	923	74	7.4	306	51.0
8th Week	991	68	6.8	306	51.0
9th Week	1058	67	6.7	246	41.0
10th Week	1158	100	10.0	354	59
11th Week	1214	56	5.6	339	56.5
12th Week	1324	110	11.0	324	54.0
13th Week	1480	156	15.6	480	80
14th Week	1565	85	8.5	468	78
		1090	109.0	4371	728.5

WEEKLY DATA. RATIONS; CORN 6 PARTS, SELECTED TANKAGE 1 PART.
October 31, 1908, to February 6, 1909.
Pen 3 (10 pigs in pen)

Period	Weight	Gain	Av. Gain	FEED: Corn	FEED: Selected Tankage
Beginning	475				
1st Week	580	105	10.5	186	31
2d Week	640	60	6.0	234	39
3d Week	700	60	6.0	240	40
4th Week	800	100	10.0	288	48
5th Week	884	84	8.4	318	53
6th Week	994	110	11.0	324	54
7th Week	1076	82	8.2	330	55
8th Week	1169	93	9.3	336	56
9th Week	1258	89	8.9	342	57
10th Week	1313	55	5.5	432	72
11th Week	1407	94	9.4	348	58
12th Week	1512	105	10.5	480	80
13th Week	1645	133	13.3	528	88
14th Week	1757	112	11.2	468	78
		1282	128.2	4854	809

WEEKLY DATA. RATIONS; CORN 3 PARTS, SELECTED TANKAGE 1 PART.
October 31, 1908, to February 6, 1909.

Pen 4. (10 pigs in pen)

Period	Weight	Gain	Av. Gain	FEED Corn	FEED Selected Tankage
Beginning	467				
1st Week	575	108	10.8	159	53
2d Week	632	57	5.7	210	70
3d Week	702	70	7.0	225	75
4th Week	803	101	10.1	252	84
5th Week	873	70	7.0	276	92
6th Week	973	100	10.0	288	96
7th Week	1057	84	8.4	270	90
8th Week	1139	82	8.2	291	97
9th Week	1214	75	7.5	309	103
10th Week	1272	58	5.8	303	101
11th Week	1358	86	8.6	327	109
12th Week	1439	81	8.1	339	113
13th Week	1570	131	13.1	357	119
14th Week	1637	67	6.7	432	144
		1170	117.0	4038	1346

WEEKLY DATA. RATIONS; FIRST FOUR WEEKS, CORN 4, TANKAGE 1;
NEXT FOUR WEEKS, CORN 4, TANKAGE 1;
LAST SIX WEEKS, CORN 5, TANKAGE 1.
October 31, 1908, to February 6, 1909.

Pen No. 5. (10 pigs in pen)

Period	Weight	Gain	Av. Gain	FEED Corn	FEED Selected Tankage
Beginning	468				
1st Week	558	90	9.0	168	56
2d Week	628	70	7.0	213	71
3d Week	707	79	7.9	228	76
4th Week	795	88	8.8	252	84
5th Week	884	89	8.9	303	79
6th Week	979	95	9.5	300	75
7th Week	1055	76	7.6	292	73
8th Week	1148	93	9.3	304	76
9th Week	1242	94	9.4	340	68
10th Week	1337	95	9.5	350	70
11th Week	1414	77	7.7	370	74
12th Week	1514	100	10.0	390	78
13th Week	1636	122	12.2	460	92
14th Week	1727	91	9.1	460	92
Total		1259	125.9	4430	1064

WEEKLY DATA. RATION; CORN 2 PARTS, SHORTS 1 PART.
October 31, 1908, to February 6, 1909.

Pen 6 (10 pigs in pen)

Period	Weight	Gain	Av. Gain	FEED Corn	FEED Shorts
Beginning	481				
1st Week	564	83	8.3	133	67
2d Week	583	19	1.9	167	83
3d Week	648	65	6.5	168	84
4th Week	754	106	10.6	206	103
5th Week	815	61	6.1	232	116
6th Week	863	48	4.8	216	108
7th Week	931	68	6.8	208	104
8th Week	954	23	2.3	236	118
9th Week	1023	69	6.9	221	110.5
10th Week	1116	93	9.3	252	126
11th Week	1177	61	6.1	216	108
12th Week	1244	67	6.7	236	118
13th Week	1341	97	9.7	260	130
14th Week	1394	53	5.3	236	118
Total		913	91.3	2987	1493.5

TOTAL WEIGHTS, GAINS AND FEED CONSUMED

November 27, 1909 - January 22, 1910

(10 pigs in pen)

Feeding Period 8 Weeks

No. of Pen	Ration	Weight Beginning lbs.	Weight Close lbs.	Gain lbs.	TOTAL FEED CONSUMED							
					C. F. Barley	Corn	Seleeted Tankage	Fertilizer Tankage	Shorts	Winter Rye	Alfalfa Hay	Sugar Beets
1	C. F. Barley; Alfalfa Hay	1735	2664	929	4625	...	...	...	...	...	285	...
2	C. F. Barley and Corn equal parts; Alfalfa Hay	1736	2710	974	2315	2315	...	...	...	...	286	...
3	C. F. Barley 9 parts; Selected Tankage 1 part	1748	2623	875	4167	...	463	...	...	...	...	...
4	C. F. Barley 7 parts; Seleeted Tankage 1 part	1740	2660	920	4052	...	582	...	...	...	...	...
5	C. F. Barley 5 parts; Seleeted Tankage 1 part	1748	2599	851	3863	...	775	...	...	...	...	...
6	C. F. Barley 9 parts; Fertilize Tankage 1 pat	1753	2694	941	4175	...	...	464	...	...	...	...
7	C. F. Barley 7 parts; Fertilizer Tankage 1 part	1747	2593	846	4066	...	...	584	...	...	...	...
8	C. F. Barley 5 parts; Fertilizer Tankage 1 part	1741	2671	930	3873	...	...	777	...	...	...	...
9	C. F. Barley 4 parts; Sugar Beets 1 part	1745	2516	771	3895	...	...	...	...	...	...	973
10	C. F. Barley 2 parts; Shorts 1 part........	1748	2637	889	3090	...	...	...	1545	...	...	...
11	Winter Rye	1755	2410	655	...	...	...	...	...	4116	...	...

PEN 1—WEEKLY DATA, 1909-1910
California Feed Barley, Alfalfa Hay in Rack, according to Appetite

Date	Weight	Gain	FEED: C. F. Barley	Alfalfa Hay
Nov. 27	1735	...	....	..
Dec. 4	1837	102	450	35
Dec. 11	1988	151	500	33
Dec. 18	2100	112	550	53
Dec. 25	2159	59	600	65
Jan. 1	2335	176	600	34
Jan. 8	2497	162	650	32
Jan. 15	2513	16	625	11
Jan. 22	2664	151	650	22
Total		929	4625	285

PEN 2—WEEKLY DATA, 1909-1910
California Feed Barley and Corn, equal parts; Alfalfa Hay in Rack, according to appetite (10 pigs in pen)

Date	Weight	Gain	FEED: Corn	C. F. Barley	Alfalfa Hay
Nov. 27	1736				
Dec. 4	1888	152	225	225	40
Dec. 11	1980	92	250	250	33
Dec. 18	2102	122	275	275	51
Dec. 25	2231	129	300	300	62
Jan. 1	2372	141	300	300	34
Jan. 8	2470	98	325	325	33
Jan. 15	2592	122	315	315	11
Jan. 22	2710	118	325	325	22
Total		974	2315	2315	286

PEN 3—WEEKLY DATA, 1909-1910
California Feed Barley 9 Parts, Selected Tankage 1 Part
(10 pigs in pen)

Date	Weight	Gain	FEED: C. Feed Barley	Selected Tankage
Nov. 27	1748			
Dec. 4	1876	128	396	44
Dec. 11	2000	124	459	51
Dec. 18	2100	100	495	55
Dec. 25	2188	88	540	60
Jan. 1	2326	138	540	60
Jan. 8	2478	152	585	65
Jan. 15	2508	30	567	63
Jan. 22	2623	115	585	65
Total		875	4167	463

PEN 4—WEEKLY DATA, 1909-1910
California Feed Barley 7 parts; Selected Tankage 1 part
(10 pigs in pen)

Date	Weight	Gain	FEED: C. F. Barley	Selected Tankage
Nov. 27	1740			
Dec. 4	1897	157	387	55
Dec. 11	2042	145	445	63
Dec. 18	2136	94	480	70
Dec. 25	2228	92	525	75
Jan. 1	2377	149	525	75
Jan. 8	2508	131	568	82
Jan. 15	2531	23	554	80
Jan. 22	2660	129	568	82
Total		920	4052	582

PEN 5—WEEKLY DATA, 1909-1910

California Feed Barley 5 Parts; Selected Tankage 1 Part

(10 pigs in pen)

Date	Weight	Gain	FEED C. F. Barley	FEED Selected Tankage
Nov. 27	1748			
Dec. 4	1847	99	365	73
Dec. 11	1947	100	427	85
Dec. 18	2073	126	458	92
Dec. 25	2178	105	500	100
Jan. 1	2322	144	500	100
Jan. 8	2424	102	541	109
Jan. 15	2505	81	531	107
Jan. 22	2599	94	541	109
Total		851	3863	775

PEN 6—WEEKLY DATA, 1909-1910

California Feed Barley 9 Parts; Fertilizer Tankage 1 Part

(10 pigs in pen)

Date	Weight	Gain	FEED C. F. Barley	FEED Fertilizer Tankage
Nov. 27	1753			
Dec. 4	1865	112	396	44
Dec. 11	2006	141	459	51
Dec. 18	2107	101	495	55
Dec. 25	2220	113	540	60
Jan. 1	2355	135	540	60
Jan. 8	2435	80	585	65
Jan. 15	2520	85	575	64
Jan. 22	2694	174	585	65
Total		941	4175	464

PEN 7—WEEKLY DATA, 1909-1910

California Feed Barley 7 Parts, Fertilizer Tankage 1 Part

(10 pigs in pen)

Date	Weight	Gain	FEED C. F. Barley	FEED Fertilizer Tankage
Nov. 27	1747			
Dec. 4	1880	133	387	55
Dec. 11	1970	90	445	63
Dec. 18	2064	94	480	70
Dec. 25	2181	117	525	75
Jan. 1	2497	107	568	82
Jan. 8	2302	121	525	75
Jan. 15	2390	88	568	82
Jan. 22	2593	96	568	82
Total		846	4066	584

PEN 8—WEEKLY DATA, 1909-1910

California Feed Barley 5 Parts, Fertilizer Tankage 1 Part

(10 pigs in pen)

Date	Weight	Gain	FEED C. F. Barley	FEED Fertilizer Tankage
Nov. 27	1741			
Dec. 4	1875	134	370	74
Dec. 11	2026	151	422	84
Dec. 18	2158	132	458	92
Dec. 25	2239	81	500	100
Jan. 1	2339	100	500	100
Jan. 8	2460	121	541	109
Jan. 15	2563	103	541	109
Jan. 22	2671	108	541	109
Total		930	3873	777

PEN 9—WEEKLY DATA, 1909-1910

California Feed Barley 4 Parts, Sugar Beets 1 Part

(10 pigs in pen)

Date	Weight	Gain	FEED: C. F. Barley	FEED: Sugar Beets
Nov. 27	1745			
Dec. 4	1763	18	360	90
Dec. 11	1854	91	435	109
Dec. 18	1976	122	500	125
Dec. 25	2079	103	500	125
Jan. 1	2236	157	500	125
Jan. 8	2310	74	550	138
Jan. 15	2408	98	525	131
Jan. 22	2516	108	525	130
Total		771	3895	973

PEN 10—WEEKLY DATA, 1909-1910

California Feed Barley 2 Parts, Wheat Shorts 1 Part

(10 pigs in pen)

Date	Weight	Gain	FEED: C. F. Barley	FEED: Shorts
Nov. 27	1748			
Dec. 4	1784	36	300	150
Dec. 11	1944	160	334	166
Dec. 18	2080	136	367	183
Dec. 25	2176	96	400	200
Jan. 1	2241	65	400	200
Jan. 8	2376	135	433	217
Jan. 15	2512	136	433	217
Jan. 22	2637	125	423	212
Total		889	3090	1545

PEN 11—WEEKLY DATA, 1909-1910

Winter Rye

(10 pigs in pen)

Date	Weight	Gain	FEED: Winter Rye
Nov. 27	1755		
Dec. 4	1807	52	448
Dec. 11	1884	77	418
Dec. 18	2046	162	530
Dec. 25	2082	36	565
Jan. 1	2224	142	555
Jan. 8	2244	20	550
Jan. 15	2351	107	525
Jan. 22	2410	59	525
Total		655	4116

TOTAL WEIGHTS, GAINS AND FEED EATEN

(8 pigs in pen)

(Feeding Period Eight Weeks)

No. of Pen	Ration	Weight Beginning lbs.	Weight Close lbs.	Gain lbs.	Total Feed Consumed lbs.: Corn	Shorts	Alfalfa Meal
1	Corn 1 part; Shorts 1 Part......	1171	1783	612	1555	1555	...
2	Corn 4 parts; Alfalfa Meal 1 part	1161	1669	508	2184	....	546
3	Corn 5 parts; Alfalfa Meal 1 part	1158	1627	469	2278	....	462
4	Corn 6 parts; Alfalfa Meal 1 part	1155	1654	499	2340	....	390

PEN 1—WEEKLY DATA, 1911
Corn and Wheat Shorts, Equal Parts

(8 pigs in pen)

	Weight	Gain	FEED Corn	FEED Shorts
Oct. 19	1158	...	...	...
Oct. 20	1176	...	...	...
Oct. 21	1178	...	...	...
Average at Beginning	1171			
Oct. 27	1274	103	155	155
Nov. 3	1354	80	200	200
Nov. 10	1431	77	200	200
Nov. 17	1486	55	200	200
Nov. 24	1590	104	200	200
Dec. 1	1647	57	200	200
Dec. 8	1713	66	200	200
Dec. 14	1772	...	...	...
Dec. 15	1785	...	...	...
Dec. 16	1793	...	...	...
Average at End	1783	70	200	200
Total		612	1555	1555

PEN 2—WEEKLY DATA, 1911
Corn 4 Parts; Alfalfa Meal 1 Part (Meal fed in Swill)

(8 pigs in pen)

	Weight	Gain	FEED Corn	FEED Ground Alfalfa
Oct. 19	1149	...	...	...
Oct. 20	1166	...	...	...
Oct. 21	1169	...	...	...
Average at Beginning	1161	...	...	..
Oct. 27	1270	109	224	56
Nov. 3	1315	45	280	70
Nov. 10	1365	50	280	70
Nov. 17	1440	75	280	70
Nov. 24	1507	67	280	70
Dec. 1	1552	45	280	70
Dec. 8	1616	..	...	..
Dec. 14	1652	..	...	..
Dec. 15	1672	..	...	..
Dec. 16	1669	53	280	70
Average at End	1682	64	280	70
Total		508	2184	546

PEN 3—WEEKLY DATA, 1911
Corn 5 parts; Alfalfa Meal 1 Part (Meal fed with Swill)

(8 pigs in pen)

	Weight	Gain	FEED Corn	FEED Ground Alfalfa
Oct. 19	1147	..	...	..
Oct. 20	1158	..	...	..
Oct. 21	1170	..	...	..
Average at Beginning	1158		...	..
Oct. 27	1217	59	234	56
Nov. 3	1297	80	292	58
Nov. 10	1356	59	292	58
Nov. 17	1408	52	292	58
Nov. 24	1471	63	292	58
Dec. 1	1526	55	292	58
Dec. 8	1581	55	292	58
Dec. 14	1620	..	...	..
Dec. 15	1620	..	...	..
Dec. 16	1640	..	...	..
Average at End	1627	46	292	58
Total		469	2278	462

PEN 4—WEEKLY DATA, 1911
Corn 6 Parts; Alfalfa Meal 1 Part (Meal fed in Swill)

(8 pigs in pen)

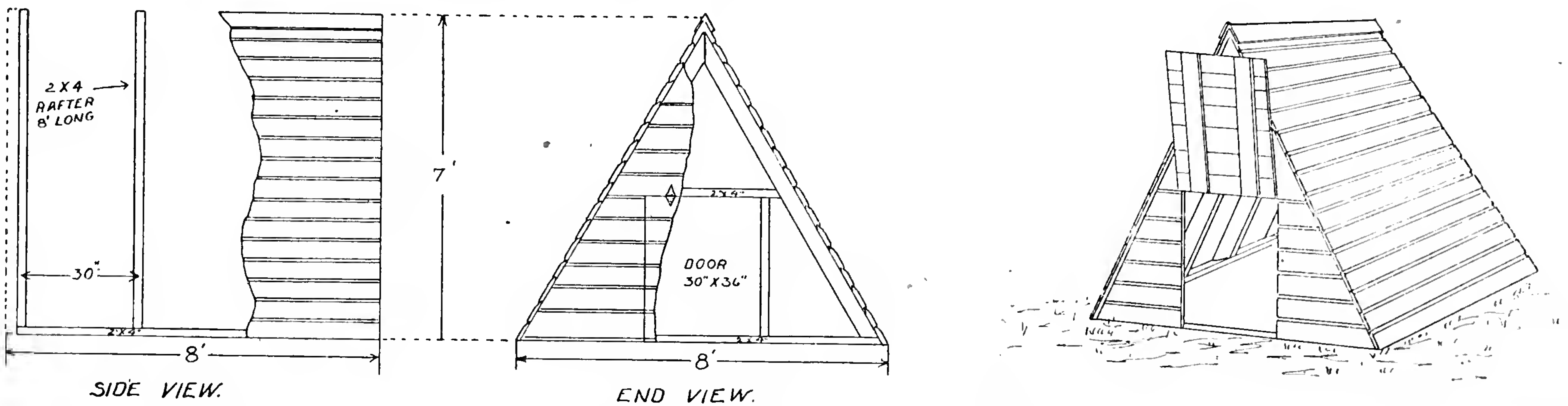
	Weight	Gain	FEED Corn	FEED Ground Alfalfa
Oct. 20	1145	..	...	..
Oct. 19	1153	..	...	..
Oct. 21	1166	..	...	..
Average at Beginning	1155	..	...	..
Oct. 27	1241	86	240	40
Nov. 3	1306	65	300	50
Nov. 10	1364	58	300	50
Nov. 17	1427	63	300	50
Nov. 24	1498	71	300	50
Dec. 1	1541	43	300	50
Dec. 8	1607	66	300	50
Dec. 14	1644	..	...	..
Dec. 15	1643	..	...	..
Dec. 16	1654	47	300	50
Average at End	1675	..	...	..
Total		499	2340	390

TOTAL WEIGHTS, GAINS, AND FEED EATEN—14 WEEKS
October 31, to February 6, 1909

(10 pigs in pen)

No.	Ration	Weight at Beginning, lbs.	Weight Close lbs.	Gain in Weight Lbs.	TOTAL FEED CONSUMED (Lbs.) Corn	Barley	Shorts	Tankage
1	Corn 3 parts; Barley 3 parts; Selected Tankage 1 part	480	1911	1431	2728	2728	......	909
2	Corn 6 parts; Fertilizer Tankage 1 part	475	1565	1090	4371	....	......	728.5
3	Corn 6 parts; Selected Tankage 1 part	475	1757	1282	4854	....	......	809
4	Corn 3 parts; Selected Tankage 1 part	467	1637	1170	4038	....	......	1346
5	First 4 weeks, Corn 3 parts; Selected Tankage 1 part Next 4 weeks, Corn 4 parts; Selected Tankage 1 part Last 6 weeks, Corn 5 parts; Selected Tankage 1 part	468	1727	1259	4430	....	......	1064
6	Corn 2 parts; Shorts 1 part	481	1394	913	2987	....	1493.5	......

INDIVIDUAL HOG HOUSES.



A DURABLE AND WARM HOG HOUSE COVERED WITH DROP SIDING. IT HAS A VENTILATOR WINDOW 12" X 18" IN THE REAR, NEAR THE TOP, WHICH MAY BE OPENED OR CLOSED AS DESIRED.

Bulletin 189 June, 1913

The Agricultural Experiment Station OF THE Colorado Agricultural College

COST OF BEEF PRODUCTION UNDER SEMI-RANGE CONDITIONS

BY

G. E. MORTON.

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1914

The tables below show the selling price per cwt., at feeding pens, needed to break even on cost of feed, when feeders cost $4, $4.50, and $5 per cwt.; provided gains are made as in this experiment; viz. 100 lbs. gain on 5.1 cwt. barley and .349 ton alfalfa hay.

SELLING PRICE PER CWT., AT FEEDING PENS, NEEDED TO BREAK EVEN ON COST OF FEED, WHEN FEEDERS COST $4 PER CWT.*

	California Feed Barley Per Cwt.						
Alfalfa per ton	$ .90	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50
$4.00	4.72	4.91	5.09	5.28	5.46	5.65	5.83
5.00	4.85	5.04	5.22	5.41	5.59	5.78	5.96
6.00	4.97	5.16	5.34	5.53	5.71	5.90	6.08
7.00	5.10	5.29	5.47	5.66	5.84	6.03	6.21
8.00	5.22	5.41	5.59	5.78	5.96	6.15	6.33
9.00	5.35	5.54	5.72	5.91	6.09	6.28	6.46
10.00	5.48	5.67	5.85	6.04	6.22	6.41	6.59
11.00	5.60	5.79	5.97	6.16	6.34	6.53	6.71
12.00	5.73	5.92	6.10	6.29	6.47	6.66	6.84
13.00	5.85	6.04	6.22	6.41	6.59	6.78	6.96
14.00	5.98	6.17	6.35	6.54	6.72	6.91	7.09
15.00	6.11	6.30	6.48	6.67	6.85	7.04	7.22

*Table made by adding cost of 658 lb. steer at 4c per lb. to cost of 373 lbs. gain in live weight, and dividing by 1031 lbs., selling weight.

SELLING PRICE PER CWT., AT FEEDING PENS, NEEDED TO BREAK EVEN ON COST OF FEED, WHEN FEEDERS COST $4.50 PER CWT.*

	Barley Per Cwt.						
Alfalfa Hay per ton	$ .90	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50
$4.00	5.04	5.23	5.41	5.60	5.78	5.97	6.15
5.00	5.17	5.36	5.54	5.73	5.91	6.10	6.28
6.00	5.29	5.48	5.66	5.85	6.03	6.22	6.40
7.00	5.42	5.61	5.79	5.98	6.16	6.35	6.53
8.00	5.54	5.73	5.91	6.10	6.28	6.41	6.65
9.00	5.67	5.86	6.04	6.23	6.41	6.60	6.78
10.00	5.80	5.99	6.17	6.36	6.54	6.73	6.91
11.00	5.92	6.11	6.29	6.48	6.66	6.85	7.03
12.00	6.05	6.24	6.42	6.61	6.79	6.98	7.16
13.00	6.17	6.36	6.54	6.73	6.91	7.10	7.28
14.00	6.30	6.49	6.67	6.86	7.04	7.23	7.41
15.00	6.43	6.62	6.80	6.99	7.17	7.36	7.54

*Table made by adding cost of 658 lb. steer at 4½c per lb. to cost of 373 lbs. gain in live weight, and dividing by 1031 lbs., selling weight.

SELLING PRICE PER CWT. AT FEEDING PENS, NEEDED TO BREAK EVEN ON COST OF FEED WHEN FEEDERS COST $5 PER CWT.*

	Barley Per Cwt.						
Alfalfa Hay per cwt	$ .90	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50
$4.00	5.35	5.54	5.72	5.91	6.09	6.28	6.46
5.00	5.48	5.67	5.85	6.04	6.22	6.41	6.59
6.00	5.60	5.79	5.97	6.16	6.34	6.53	6.71
7.00	5.73	5.92	6.10	6.29	6.47	6.66	6.84
8.00	5.85	6.04	6.22	6.41	6.59	6.78	6.96
9.00	5.98	6.17	6.35	6.54	6.72	6.91	7.09
10.00	6.11	6.30	6.48	6.67	6.85	7.04	7.22
11.00	6.23	6.42	6.60	6.79	6.97	7.16	7.34
12.00	6.36	6.55	6.73	6.92	7.10	7.29	7.47
13.00	6.48	6.67	6.85	7.04	7.22	7.41	7.59
14.00	6.61	6.80	6.98	7.17	7.35	7.54	7.72
15.00	6.74	6.93	7.11	7.30	7.48	7.67	7.85

*Table made by adding cost of 658 lb. steer at 5c per lb. to cost of 373 lbs. gain in live weight, and dividing by 1031. lbs., selling weight.

COST OF BEEF PRODUCTION UNDER SEMI-RANGE CONDITIONS.

G. E. MORTON*

Yearling range-bred steers can be put on the market the spring that they are coming two years old, at a weight of from 1000 to 1150 pounds. The object of this experiment was to secure some information concerning the cost of producing fat cattle of that age and weight, under modified range conditions, the cattle to be run on native grass within fences in summer, and to be winter fed. The writer realizes fully the difficulty of securing typical conditions for such an experiment, and does not claim that in this instance either the conditions of summer range or the results are typical, but they do furnish actual figures showing the cost of winter feeding calves and fattening yearlings, and showing weights and gains made by calves and yearlings both summer and winter during two years that were very hard on stock because of lack of rainfall.

The inclosed range, or native grass, upon which the cattle in this experiment were run, lies just east of the first range of foothills west of Fort Collins, and is occupied mostly by buffalo and gamma grasses. These grasses make quite a luxuriant growth in some sections, but on this range are very short. In the spring they take a much longer time than western wheat grass (blue-stem) to get to a length that furnishes grazing for cattle, and they dry up very quickly in midsummer under adverse weather conditions.

On this range about 20 acres per head is needed, with ordinary weather conditions, for the summer ranging from May 15th to October 15th, and if grass is late in the spring, or the summer is unusually dry, the stock cannot be run five months on it. As the amount of open range needed for cattle in different parts of Coloraodo varies from 10 acres to 50 acres per head for all-year grazing, with hay feeding on most ranges in case of winter storms, it will be seen that the range on which these cattle were run is considerably below the average in beef carrying capacity.

The experiment was carried out as follows: Fifteen head of range bred, 3 year old, Hereford cows, showing some Shorthorn blood, were purchased from Schaefer Bros., of Orchard, Colorado, in April, 1910, and were put out upon inclosed range on May 6, 1910. All the cows were with calf to a Hereford bull, and the bulk of the calves were dropped from May to July, a few late ones being born in July.

September 1st, the bull calves were castrated.

October 20th, the cows and calves were brought in, the calves to be winter fed, and the cows to be fattened and sold. This experiment does not follow the cows further. The weight of the calves on October 20th was 4320 pounds for fifteen head, or an average of 288 pounds per head, a very light weight. October 20th is about a month earlier than the time at which stock is brought in from most summer ranges, except high mountain ranges; but the dry season resulted in such scant feed, that heavy loss would have resulted from leaving them out longer.

---

* Assisted in preparation of data by J. B. McNulty and G. A. Gilbert.

Address	Nature of Range	OPINIONS FURNISHED BY ME[...] Cost per head for ranging from Apr. 1st to Nov. 1st			Cost per head for Ranging from Nov. 1st to Apr. 1st			
		Cows and calves	Year-lings	2-yr.-olds	Cows and calves	Year-lings	2-yr.-olds	
E. L. M., Longm'nt	Inclosed	$5.25	$2.80	$4.20	$7.50	$5.00	$6.25	
A. A. N., Montrose	Open forest (with drift fences)	1.00	1.46	1.46	...	...	...	V
J. H. D., Spicer..	Open	1.75	1.75	1.75	11.00	5.50	8.00	N
— — — Walden..	Open	3.50	2.00	3.00	8.00	6.00	7.00	$
J. E. W., Gill.....	Open	2.00	1.00	1.00	3.00	2.00	2.00	$2
H. H., Romeo....	Open	1.00	1.00	1.00	...	...	...	
— — Calhan....	Open and Inclosed	5.00	4.00	5.00	8.00	6.00	7.00	
C. L. G., Sheephorn	Open	2.00	2.00	2.00	8.00	8.00	8.00	$2

The following table shows the precipitation for the months March to August during the two years of the experiment, and compares it with the normal precipitation:

MONTHLY PRECIPITATION IN INCHES AT THE COLORADO EXPERIMENT STATION, FORT COLLINS*

Date	Mar.	Apr.	May	June	July	Aug.
1910	0.06	0.42	4.75	1.04	0.87	1.92
1911	0.05	1.89	0.72	1.78	1.47	0.59
Normal	0.99	2.14	2.96	1.60	1.83	1.20

From this bulletin it will be seen how much below normal the precipitation was during the growing season both years, except for very heavy rains during May, 1910, from which there was necessarily a heavy run off.

The lateness of calving contributed to the lack of weight in the calves when brought in.

November 5th the calves were separated from the cows, after having become accustomed to hay, and were fed hay and a small amount of barley until June 3, 1911. The following summary shows results.

SUMMARY OF COST OF WINTERING CALVES

Average weight per head, November 5, 1910	288	lbs.
Average weight per head, June 3, 1911	632	lbs.
Average gain in weight per head, ...	339**	lbs.
Average daily gain per head, ...	1.63	lbs.
Amount of feed consumed per head:		
Alfalfa hay, ...	2200	lbs.
Feed barley, ...	788	lbs.
Value of feed consumed per head:		
Alfalfa hay, at $5 per ton, ...	$ 5.50	
Feed barley at $1.00 per cwt., ...	7.88	
Total	$13.38	
Feed consumed for 100 pounds gain in live weight:		
Alfalfa hay, ...	632	lbs.
Feed barley, ...	227	lbs.
Cost of 100 pounds gain in live weight, ...	$ 3.85	
Average amount of feed consumed daily:		
Alfalfa hay, ...	10.47	lbs.
Feed barley, ...	3.77	lbs.

* Bulletin 182, Colo. Exp. Sta.

**Gain of 15 head for 16 weeks, and 14 head for 14 weeks.

VARIOUS PARTS OF THE STATE.

..rs of ..lness .. cow ..ange	Percentage of calves secured	Market price of: Alfalfa hay in stack	Market price of: Native hay in stack	Market price of: Barley per cwt	Average price secured for feeders in the neighborhood: Calves	Yearlings	Two's	Weight November 1st: Calves	Yearlings	Two's
	..	$ 5.00	$10.00	$1.10	$18.00	$25.00	$40.00	......	......	......
.. yrs.	80	6.00	9.00	...	22.00	35 to 38	45 to 55	550 ...	780 ...	1000
.. yrs.	80	...	4 to 6	...	20 to 22	28 to 32	42 to 50	450 ...	650 ...	900
.. yrs.	75	...	5.00	...	20.00	30.00	40.00	450 ...	675 ...	850
.. yrs.	60	10.00	16.00	1.40	Seldom	sold at	these ages	300-400	400-600	600-800
.. yrs.	80	...	8.00	1.50	12 to 18	15 to 20	15 to 25	200 ...	300-500	500-1000
.. yrs.	..	...	12.00	...	12.00	20.00	28.00	200-300	400-600	600-800
.. yrs.	60	...	8.00	1.50	20.00	30.00	42.50	450 ...	750 ...	1000

The weight of the calves, June 3d, was 632 pounds per head, which is good, as only 3¾ pounds of barley per head were fed. The average daily gain was 1.6 lbs., and the cost of 100 pounds gain was $3.85 with alfalfa hay @ $5 per ton and barley @ $1 per cwt. This encourages the liberal winter feeding of range calves.

The usual winter feed for calves in a good range section is from November 15th or December 1st to March 15th or April 1st, a period of four months, with a consumption of 20 pounds of hay per head per day, or 1¼ tons in the four months. The consumption of hay with our calves was 10.47 lbs. per head per day, and in addition they ate 3.77 lbs. barley per day.

The calves, now one year old, were run on the range during the summer of 1911 from June 3d to September 18th. This summer's grazing season was even shorter than the last, as there was less precipitation than in 1910, and grass suffered more in proportion because of its being the second dry year. The disastrous result in the growth of the yearlings is seen in their gain as shown by the following table.

Twenty-six pounds gain in three and one-half months is so little as hardly to be counted. The steers of course gained in frame, but lost their baby flesh in corresponding degree.

SUMMARY OF COST OF FATTENING YEARLINGS

Average weight per head June 3, 1911	632	lbs.
Average gain per head, June 3 to September 18, on range	26	lbs.
Average weight per head, Sept. 18, 1911,	658	lbs.
Average weight per head, April 6, 1912, (Out of feed lot)	1031	lbs.
Average gain in weight per head (30 weeks)	373	lbs.
Average daily gain per head,	1.78	lbs.
Amount of feed consumed per head:		
Alfalfa hay	2605	lbs.
Feed Barley,	1903	lbs.
Value of feed consumed per head:		
Alfalfa hay at $5 per ton,	$ 6.51	
Feed barley at $1 per cwt.,	19.03	
Total	$25.54	
Feed consumed for 100 lbs. gain in weight:		
Alfalfa hay	698	lbs.
Feed barley	510	lbs.
Cost of 100 lbs. gain in live weight: (Alfalfa hay at $5 per ton, barley at $1 per cwt,)	$ 6.85	
Average amount of feed consumed daily:		
Alfalfa hay	16.1	lbs.
Feed Barley	11.8	lbs.

The table above gives also the summary of the second winter's feeding, which finished the steers and heifers for market. They were fed from September 18, 1911, to April 6, 1912, going in at 658 pounds, and coming out at 1031 pounds, a gain of 373 pounds per head in seven months,—an average gain of 1.78 pounds per day. They were fed 16.1 pounds of alfalfa hay and 11.8 pounds of California feed barley per day on the average, and the cost of gain was $6.85 per hundred pounds; a figure at which a very good profit can be made.

The following summary gives a complete statement of the entire experiment:

SUMMARY OF BEEF PRODUCTION COST

Cost of cows per head	$ 35.00
Cost of pasturing cows and calves, first summer, per head (Equivalent to 5 per cent. interest on 10 a. of $10 fenced land)	5.00
Depreciation in value of cows from spring to fall	5.00
Net cost of calves per head at beginning of first winter, average weight 288 lbs.	10.00
Cost of feeding calves first winter per head, average gain in weight 346.5 lbs., (Alfalfa hay at $5 per ton, barley at $1 per cwt.)	13.38
Cost of pasturing yearlings per head	5.00
Net cost of feeder yearlings per head in fall, average weight 658 lbs.	28.38
Market value of yearlings as feeders at 4½c per lb.	29.61
Cost of fattening yearlings, per head, average gain in weight 373 pounds without shrink (Hay at $5 per ton, barley at $1 per cwt.)	25.54
Total cost of fat steers and heifers, at two years, per head, (Average weight 1031 lbs. out of feed lot)	53.92
Sales, (net in Denver) per head, average weight 967 lbs., to packers, (5 steers at $7.50, and 8 heifers at $7)	67.39
Profit per head, over cost of feed and shrink	13.47

These figures do not include the cost of labor in winter feeding.

The figures given above are open to many exceptions, as conditions vary greatly with regard to the cost of summer pasturage, depreciation of cows and so on. This summary aims to give a typical cost for the production of beef *with the weights and gains actually obtained in this experiment during the two unusually dry years.* (1911 was the driest year since 1893, 18 years). Taking these weights as indicative of about the worst to be expected, the summary shows what profit, if any, may be expected from the production of beef under such conditions. The best that we can do is to admit that, from the standpoint of showing a typical cost of production, the experiment is a failure, and we can use the figures of summer gains only as a basis around which to group other facts.

In the table I have shown the cost of pasturing cows and calves at $5 per head for the cows. On free range, or on forest reserve, where the charge for grazing is 25 cents per head, the summer cost, including round up and branding, is probably not over $1 per head. There are extensive sections in the eastern part of the State where the range is like that these cattle were run on, and 20 acres per cow is needed for summer pasture. When this land is held at $10 per acre, the cost of pasturing would be $10 for the summer.

While I have given $5 per head to cover depreciation in value of cows, and interest on investment, some cattlemen do not figure depreciation on cows, as they expect to sell their cows for beef in the fall when their usefulness is nearly over, and realize as much for them as they cost as two-year-olds.

I have not figured loss of mature cattle in the summary, nor charged the extra cost due to a percentage of calves less than 100%.

On various ranges the percentage of calves raised runs from 50% to 80%, the average for Colorado ranges probably being 65%.

The cost of feeder yearlings as shown by the table is $28.38, which is only $1.23 less than their value delivered at a market. There was evidently no profit in raising them to this point, and the profit of $13.47 finally shown is practically all to be credited to the fattening of the steers as yearlings. The results of the winter feeding both of the calves and yearlings may be taken as reasonably typical, and it is evident that the winter feeding of the calves was a paying proposition. This bears out the results published in Bulletin 149 of this Station. It is also evident that the fattening of the steers as yearlings was a profitable operation, and with reasonable growth on range there is every encouragement for the production of beef in valleys of the State where alfalfa and barley can be grown, and there is outside range for the cattle. In this way steers can be put on the market as yearlings at a weight which makes for the grower all the profit that can be made out of them. The grower who feeds out his own stuff is in shape to transfer his steers from range to feed lot without shrinkage, and he is also in a position to take advantage of the high market usually found from June to September. In sections a considerable distance from the railroad, when specialized crops cannot be grown because of impracticability of transportation, there is not quite the rush of spring work which occurs in our developed feeding sections, and fattening steers can be held in the feed lot well into the summer without seriously disorganizing the farm work. And because of cool weather well into the summer, practically all sections of the State will find little trouble from flies until well into July. From July to September, there is a dearth of fat cattle on the market, most feed lots being empty and the main supply of the killers being found in Texas grassers.

This experiment, and the other experiments reported in this bulletin, show the possibility of feeding at a profit in any section of the State with the feeds that can be grown there. Undoubtedly there may be rations which would secure better results than straight alfalfa and barley, but the knowledge that these will fatten stock profitably should encourage a beginning of the industry, and by the use of roots or silage in connection with alfalfa and barley, we should see the fattening of cattle carried on in every section of the State, instead of being confined to the localities where there are sugar factories furnishing a cheap feed in beet pulp.

I give in the following table * information gathered from a selected lot of men running range cattle in different sections of the State. The figures given by them will serve to show normal cost of ranging cattle, and this data together with that given in the foregoing tables should enable one to work out within reasonable limits the variable cost of producing beef from range cattle. No set of figures worked out in any one locality and season can possibly give one a figure that may be used under other conditions. All that can be shown is what may be accomplished under similar conditions.

*Table on top of pages 4 and 5.

COST OF FEEDING UNDER OTHER CONDITIONS

The market price of barley, or the cost of growing it on the farm, varies with the locality, so the following table is given, showing the cost of gain with alfalfa and barley at a given price *when gain is made at the same rate as made by the yearling steers fattened in this experiment,—namely, 1.78 pounds per head per day, and with the same consumption of alfalfa and barley, which was 16.1 pounds alfalfa and 11.8 pounds barley per head per day.*

COST OF 100 POUNDS GAIN WITH YEARLING STEERS

Alfalfa per ton	California Feed Barley Per Cwt. $ .90	$1.00	$1.10	$1.20	$1.30	$1.40	$1.50
$4.00	5.98	6.49	7.00	7.51	8.02	8.53	9.04
5.00	6.38	6.84	7.35	7.86	8.37	8.88	9.39
6.00	6.68	7.19	7.70	8.21	8.72	9.23	9.74
7.00	7.03	7.54	8.05	8.56	9.07	9.58	10.09
8.00	7.38	7.89	8.40	8.91	9.42	9.93	10.44
9.00	7.73	8.24	8.75	9.26	9.77	10.28	10.79
10.00	8.08	8.59	9.10	9.61	10.12	10.63	11.14
11.00	8.43	8.94	9.45	9.96	10.47	10.98	11.49
12.00	8.78	9.29	9.80	10.31	10.82	11.33	11.84
13.00	9.13	9.64	10.15	10.66	11.17	11.68	12.19
14.00	9.48	9.99	10.50	11.01	11.52	12.03	12.54
15.00	9.83	10.34	10.85	11.36	11.87	12.38	12.89

Feed for 100 lbs. Gain, 5.1 cwt. barley, and .349 ton alfalfa, 51c increase in the cost of 100 lbs. gain, for each 10c increase in price of barley.

35c increase in cost of 100 lbs. gain for each $1 increase in price of hay.

BI-WEEKLY RECORD OF FATTENING YEARLINGS

13 head, (5 steers and 8 heifers), from Oct. 21, 1911, to April 6, 1912.

Period	Total weight	Average weight per head	Average gain in weight per head	Average gain in weight per head per day	Total Feed Eaten: Alfalfa hay	Total Feed Eaten: Barley	Average daily Consumption of Barley lbs.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	
Beginning * Sep. 18, 1911	8,557	658	..	....			
6th Week	9,370	721	63	1.49	......	......	......
8th "	9,960	766	45	3.24	......	......	......
10th "	10,425	802	34	2.55	......	455	2.5
12th "	10,650	819	17	1.23	......	819	4.5
14th "	10,890	838	19	1.31	......	1092	6.0
16th "	11,060	851	13	.93	......	1397	7.6
18th "	11,240	865	14	.98	......	2054	11.2
20th "	11,605	893	28	2.00	......	2457	13.5
22nd "	12,145	934	41	2.96	......	2639	14.5
24th "	12,550	966	32	2.22	......	2730	15.0
26th "	12,825	987	21	1.51	......	2821	15.5
28th "	13,100	1008	21	1.51	......	2863	15.7
30th "	13,410	1031	24	1.70	......	2814	15.4
					......	2603	14.3
			373	1.78	33,865	24,744	

*·Cattle were dehorned during first period.

(See other tables on Page 2.)

Bulletin 190 June, 1913

The Agricultural Experiment Station
of the
Colorado Agricultural College

Variation Studies in Brome Grass

(*A Preliminary Report*)

By ALVIN KEYSER

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1913

Station Staff

C. P. GILLETTE, M. S. Entomologist........................Director
W. P. HEADDEN, A. M. Ph. D. ....Chemist
G. H. GLOVER, M. S., D. V. M. ....Veterinarian
W. G. SACKETT, B. S. ....Bacteriologist
ALVIN KEYSER, A. M. ....Agronomist
J. O. WILLIAMS, B. S. A., U. S. Expert-in-charge......Horse Breeding
B. O. LONGYEAR, B. S.,..................................Botanist
G. E. MORTON, M. L., B. S. A...................Animal Husbandman
E. B. HOUSE, B. S. (E. E.), M. S................Irrigation Engineer
V. M. CONE, B. S...........................Irrigation Investigations
R. E. TRIMBLE, B. S. ....Assistant Irrigation Investigations
P. K. BLINN, B. S., Rocky Ford..................Alfalfa Investigations
EARL DOUGLASS, M. S.,.........................Assistant Chemist
S. ARTHUR JOHNSON, M. S................Assistant Entomologist
GEORGE P. WELDON, B. S................Assistant in Entomology
L. C. BRAGG ....Assistant in Entomology
W. E. VAPLON............................Poultry Investigations
J. W. ADAMS, B. S., Cheyenne Wells........................
............................Agronomy Assistant, Dry Farming
ELLWOOD D. ROOD, A. B. ....Assistant Chemist
W. W. ROBBINS, M. A. ....Assistant Botanist
PAUL S. JONES, B. S. ....Assistant Irrigation Investigations

OFFICERS

CHARLES A. LORY, LL. D ....President
C. P. GILLETTE, M. S................................Director
L. M. TAYLOR...Secretary
MARGARET MURRAY ....Executive Clerk

Variation Studies in Brome Grass

(A Preliminary Report.)

By ALVIN KEYSER

In 1909 studies were commenced with the prime object in view of discovering the best types of grasses for pasture and meadow purposes in the various sections of Colorado. It was realized that

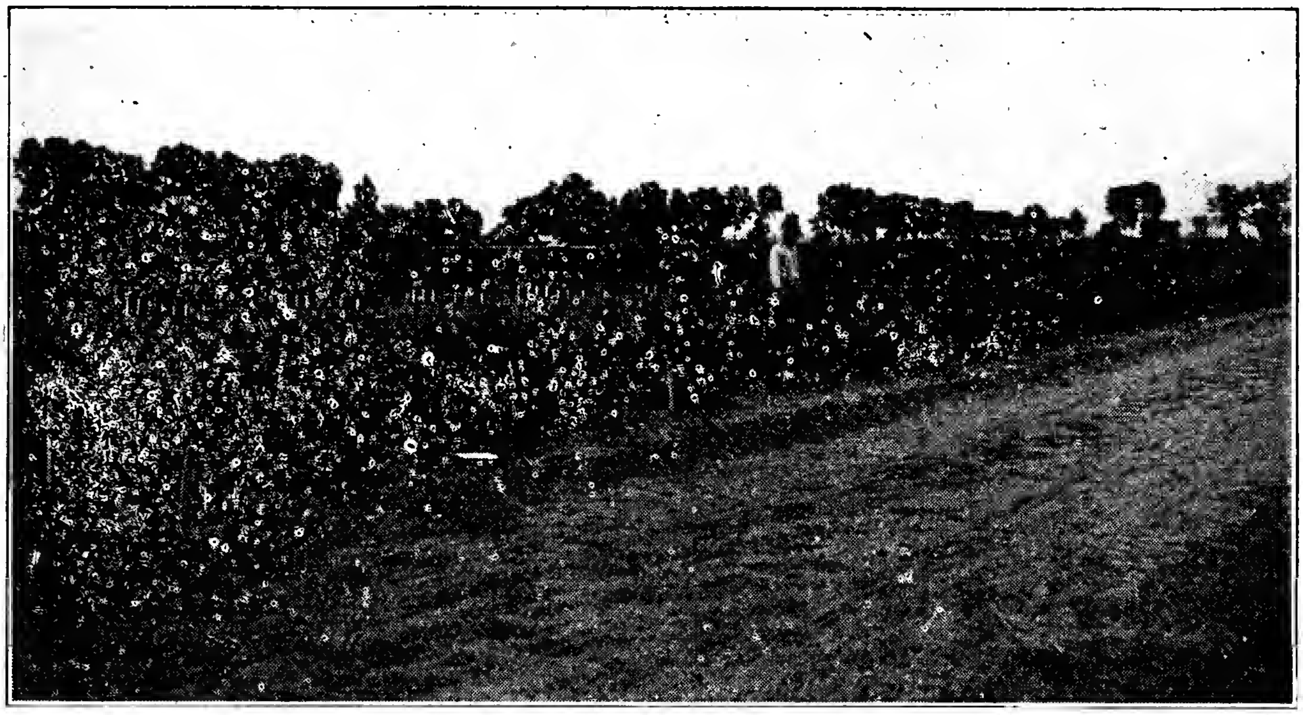


Plate No. 1.

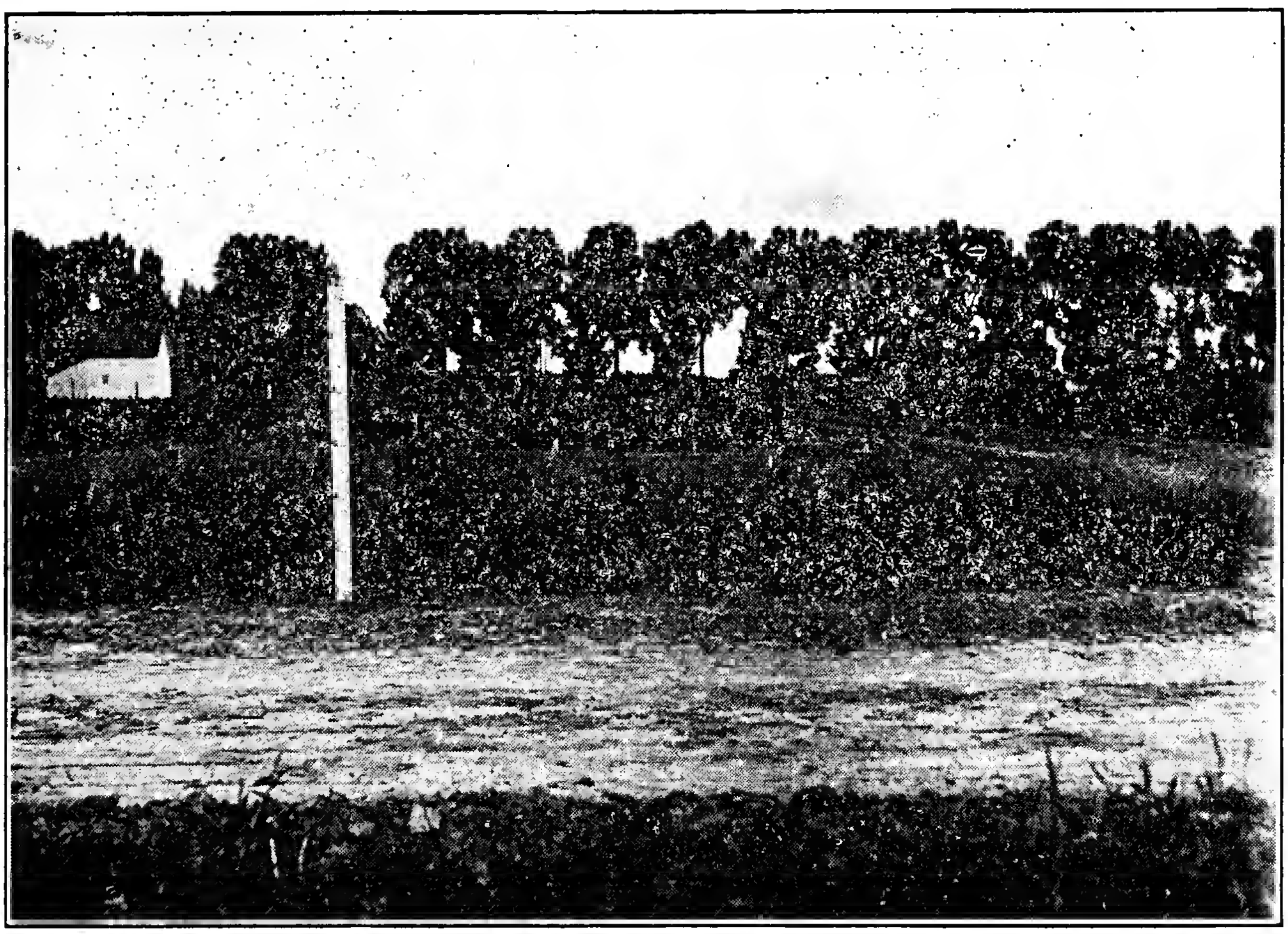


Plate No. 2.

this was not a simple problem because Colorado presents all possible conditions of altitude variation, between an altitude of approximately 3,500 feet and over 14,400 feet. These variations in altitude alone bring forth conditions varying from a temperate to an arctic climate. The climatic variations due to altitude are not the sole climatic variations to be met in a study of this kind. The rainfall varies from a minimum of less than ten inches to a maximum of over 30 inches in some localities. We have dry land agriculture and irrigated agriculture represented in practically every section under these various conditions of altitude and rainfall.

Plate No. 3.

Manifestly, no one grass or combination of grasses is best adapted for all of these conditions. It so happened that among the grasses giving considerable promise for pasture purposes, especially in the higher altitudes, both under the dry land and irrigated conditions, what is commonly known as the awnless brome grass (Bromus inermis) was one of the most promising. When the experiment had gone far enough to demonstrate the advisability of pushing this grass for certain sections, studies were commenced to see if there were different types or strains of Bromus inermis which might have peculiar advantages for specific definite conditions. With this idea in view, seed was obtained from a number of different sources and planted in our grass gardens upon the experimental grounds at Fort Collins. The particular line of studies here reported are the outgowth of a portion of the studies thus started.

It was early observed that we possessed a large number of

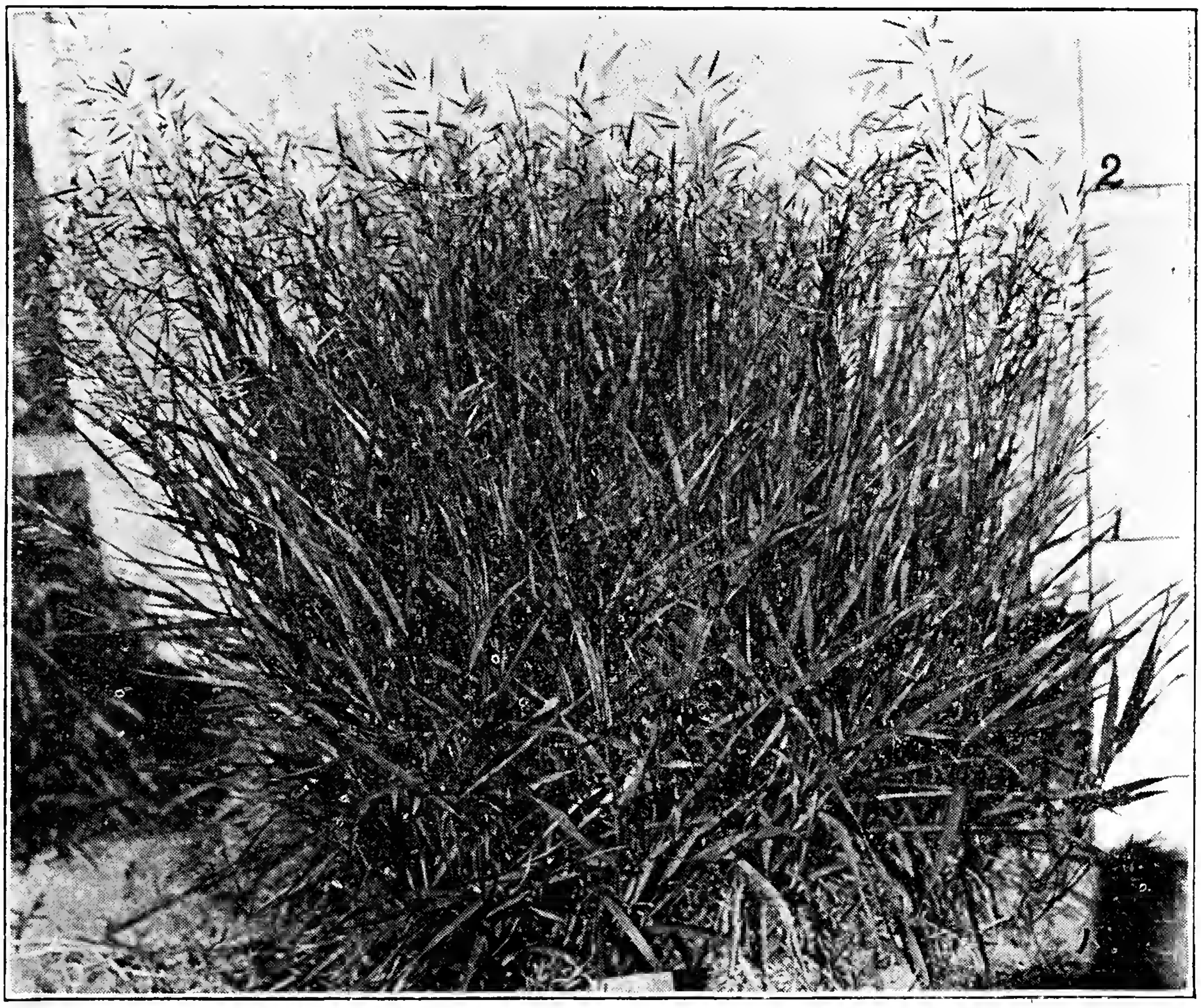


Plate No. 4.

strains and apparently different types in the plantings. These strains were then selected and seed from each strain was planted in rows three feet apart. The plantings in the rows themselves were made two feet apart. After the young plants had started they were thinned to one plant in the hill. This was done in order to have each hill represent not only an individual plant, but as far as possible, a distinct individual type or strain for future study. At the present time there remain under observation, 121 distinct strains or types which have survived the conditions of winter and the vicissitudes attendant upon their growth and development.

One of the next steps to be taken up in this work was to determine if these different strains appearing were *pure line* strains or whether they

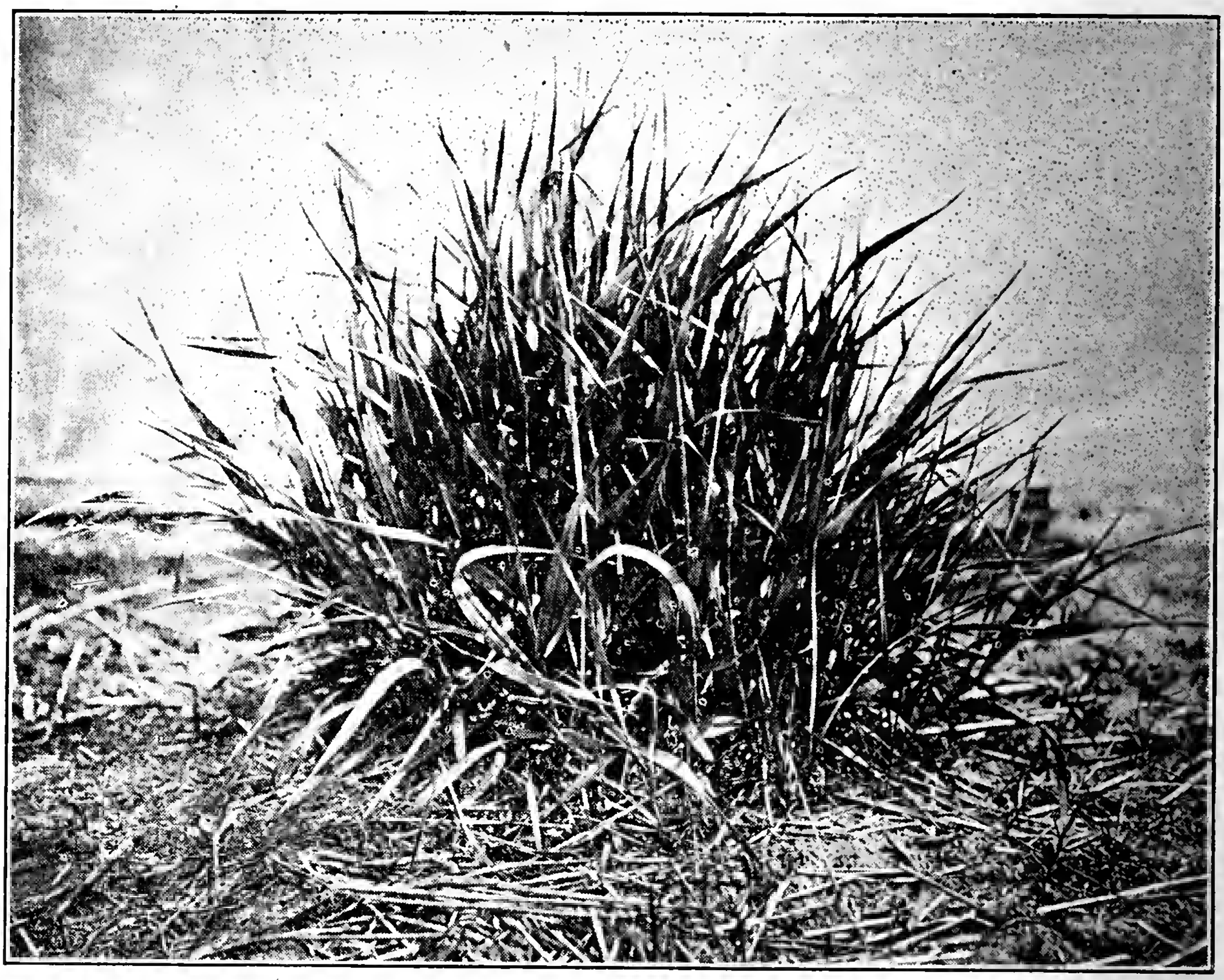


Plate No. 5.

would break up into mixed strains when the seed was planted for the next generation. Accordingly, three different plantings of each of these types have been made for progeny studies. This work is not yet ready for complete report, but has progressed far enough so that we can say that in the large majority of cases it has been found that each one of these strains was a pure line strain and bred true when the seed was planted, giving rise to a generation resembling the parent plant in habits of growth, color, size, root development and other observable physical characteristics.

In a few cases it was found that the progeny of an individual strain broke up into different forms. The supposition or the hypothesis upon which we are working is that these forms which show splitting are crosses. The evidence is very strong in favor of this fact, altho it has not been carried far enough to permit of positive statements. If this splitting should continue to occur in succeeding generations, we would consider the evidence sufficiently conclusive to call such splitting strains crosses or hybrids. Up to this point of our investigation, however, these splitting strains have not been propagated by seed to determine this point, as other factors under observation have occupied the time at present available for this experiment. We have the seed of the splitting strains and when some other portions of

Plate No. 6.

the experiment are completed we expect to make plantings of these strains for genetic studies on these points. Until other work is completed we will not be able to do this because time and land are both occupied with other phases of the subject. Suffice it to say that three crops of seed from the parent strains have been planted in progeny rows and that the progeny, with the exception of the splitting strains above noted, have bred true, indicating pure types. This phase of the work has gone far enough so that we feel justified in saying that it would be possible for us to successfully propagate by seed the most of the highly variable strains which occur in our work. From a practical standpoint this phase is extremely important, because if we work out a type of brome grass plant that is peculiarly adapted for pasture or

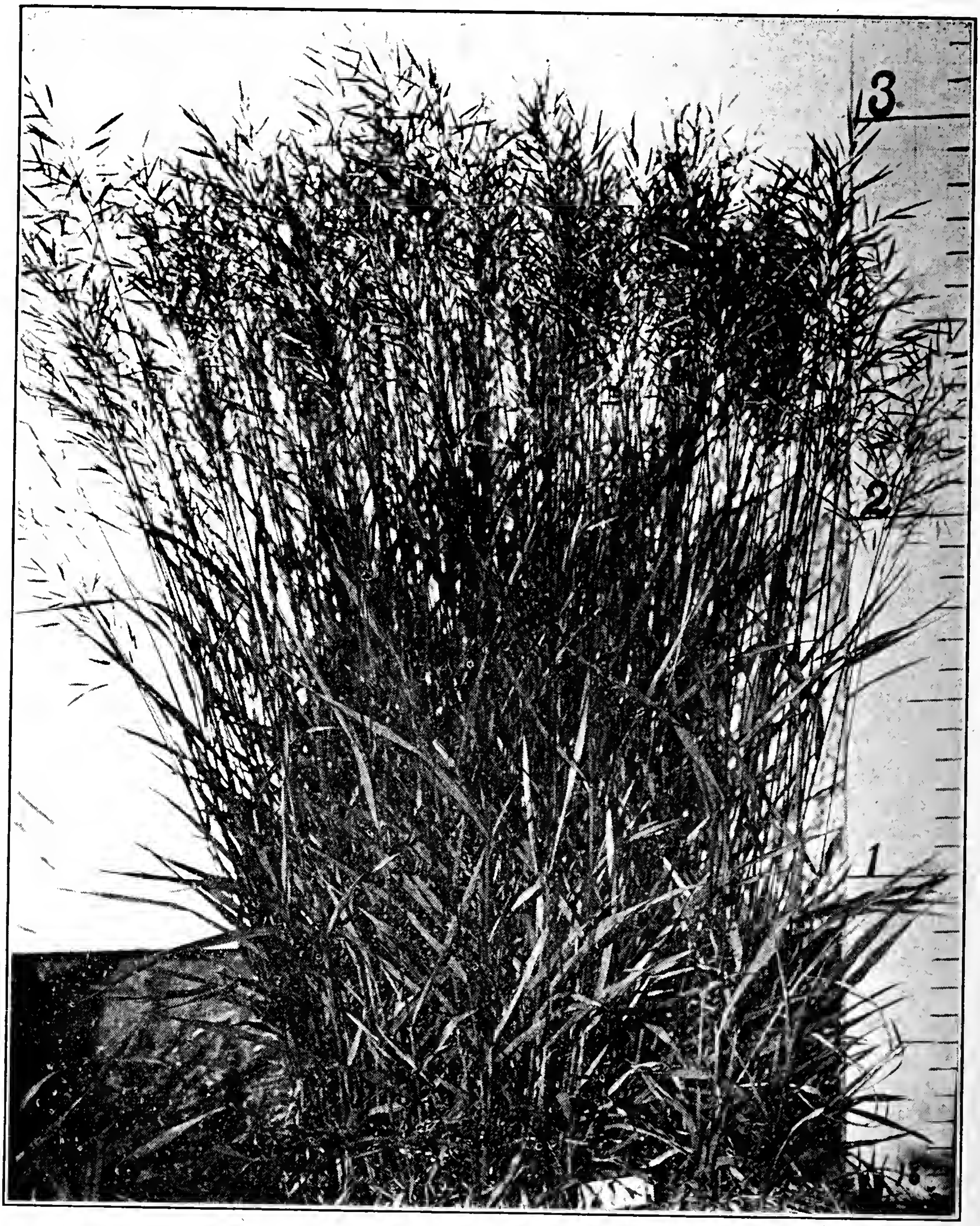


Plate No. 7.

hay purposes in any locality, it is absolutely essential that the characters which make it valuable must be susceptible of successful seed propagation in order to be able to establish the type in any community to which it is adapted.

A few of these types which have proved themselves to be pure line types are being grown in small fields in some of our high altitude locations. They are thus being observed under actual farming conditions. This part of the work of necessity progresses slowly at first, until a strain proves itself in a locality and people commence to desire the seed in order to get the same desirable strain.

While these phases of the subject are being studied, studies upon the variations occurring in the different strains are being made. It may be interesting to call attention to some of these variations at the present time, altho the studies are not completed and will not be for some little time in the future. In the illustrations which follow, pictures are shown of some of these types, selected to illustrate variations which occur. These pictures illustrate differences to be noted both in the mature or seed stage of the crop and in the spring condition of the crop. A comparison will show that these differences are maintained thruout the growing period.

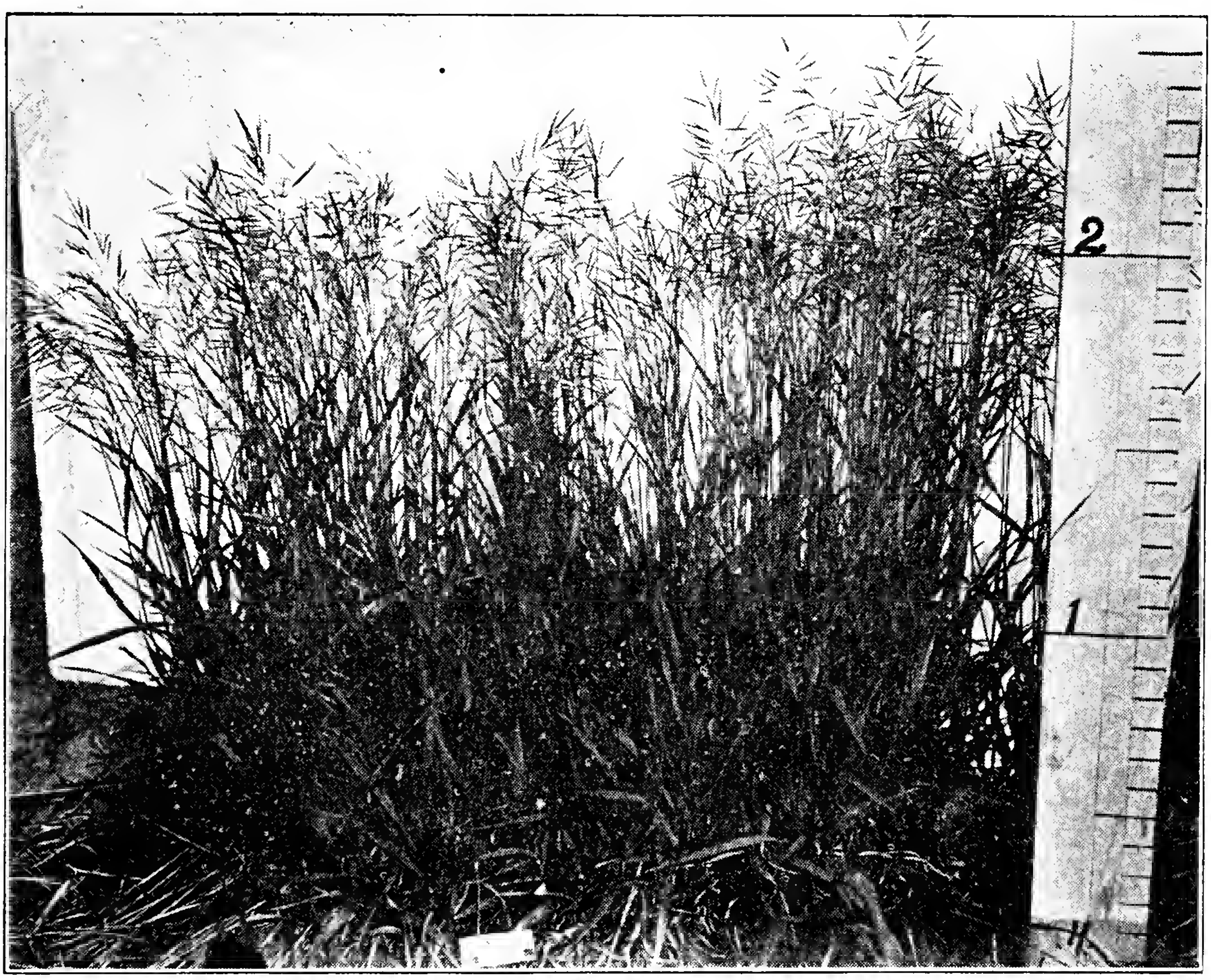


Plate No. 8

Plate No. 1 shows a general view of some of these strains taken at the time of greatest growth when the seed was about in the milk stage.

Plant No. 6 and plant No. 42 (Plates 3 and 4), illustrate one set of differences which occur. Plant No. 6 represents a type of variation having a very sparse number of stools or tillers. Plant No. 42 on the other hand, illustrates one very profusely stooled. These pictures were taken upon the same day at a time representing practically the same state of development. Altho plant No. 6 has an average height of 29 inches, the average height of the leaf mass is only 19 inches. The leaf mass is very sparse. The leaves present a medium broad appearance of natural length. The color is a very yellow green. In describing the plant this was described as sparingly leafy. Notes were taken upon the date of ripening, showing that these plants were both considered ripe July 7, 1912.

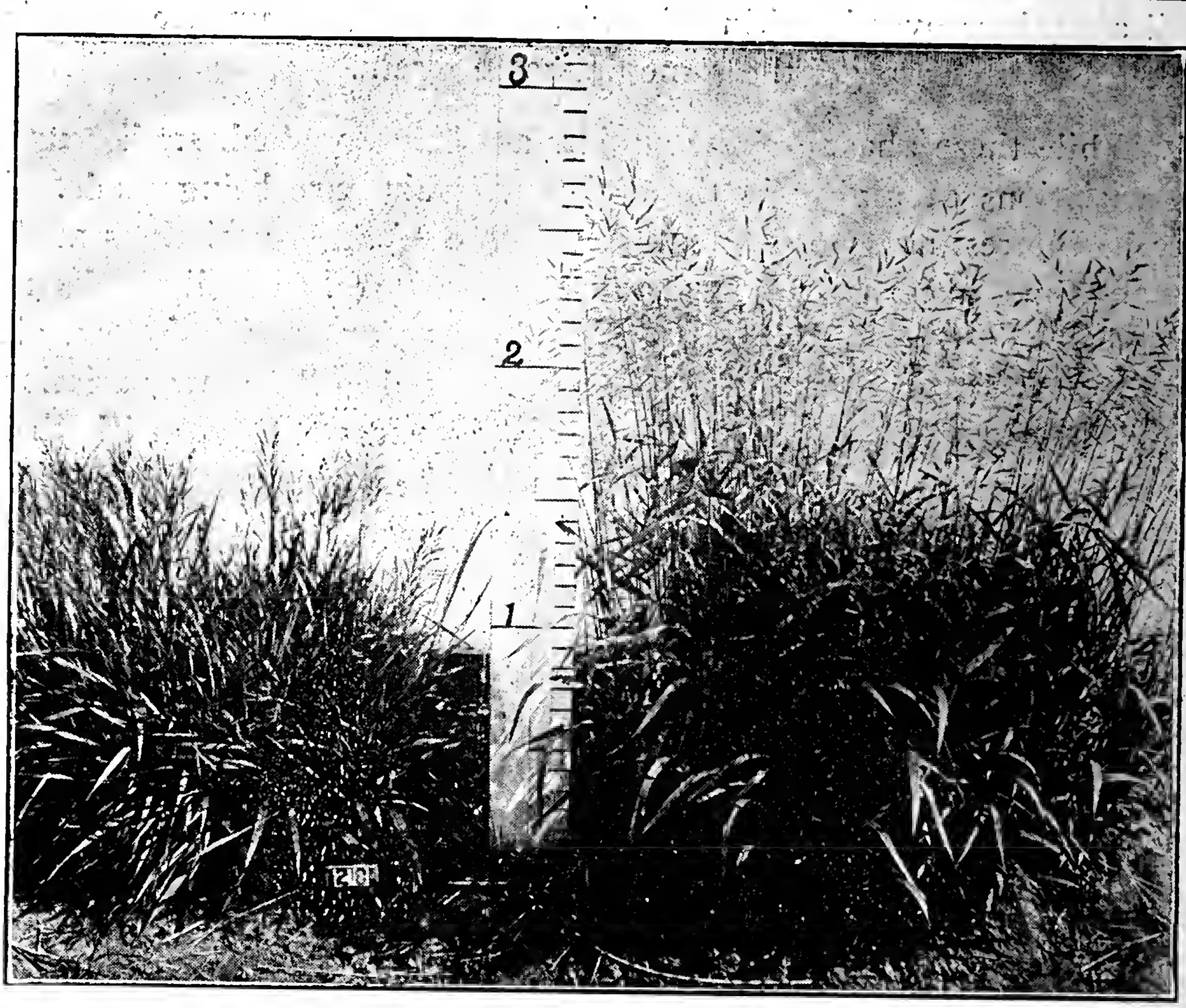


Plate No. 9.

Plant No. 42 Plate No. 4), on the other hand, has a total height somewhat less than plant No. 6. The leaf type is what we describe as very narrow. The leaves, altho short, are exceedingly abundant, so that a very felty tuft or sod is produced. The stools are exceedingly abundant and artificial means have to be resorted to to keep

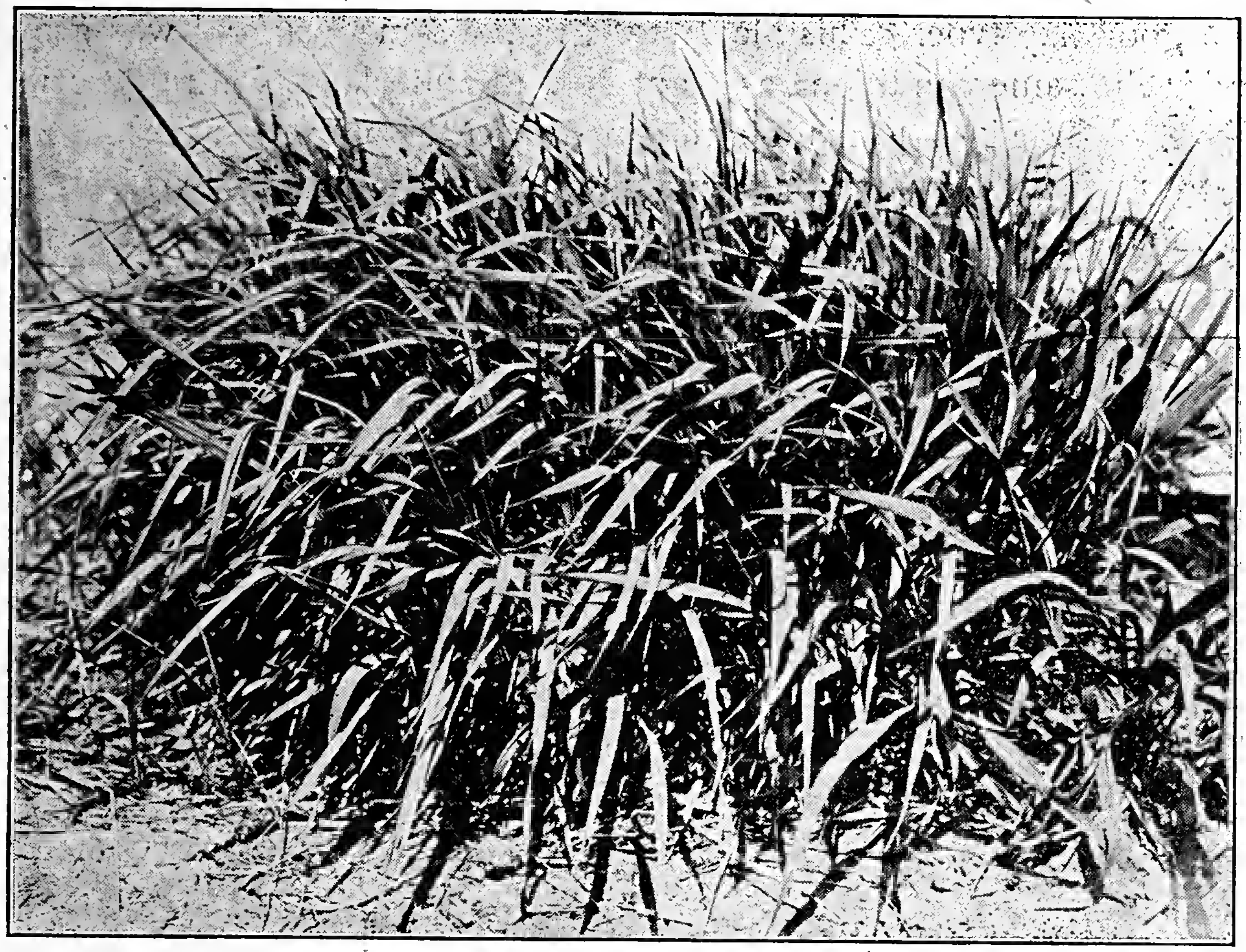


Plate No. 10.

the stools from tillering by the underground root stalks so abundantly as to mix this strain with the adjacent plants in the same rows and even with adjacent rows. The color is a very dark green. Altho this plant is shorter in height than plant No. 6, the leaf mass has an average height of 21 inches as compared with 19 inches in the case of plant No. 6.

Plant No. 6 (Plate No. 5) is also shown as it appeared in the spring of 1913.

Plant No. 40 (Plate No. 6) illustrates another type of variation which takes place. In this plant, the leaf mass is only 10 inches high, altho the leaves are exceedingly abundant. The seed heads are also short, attaining an average height of only 18 inches in 1912. This is a type of plant that we have designated as a purely pasture type. It does not make growth enough even under good irrigation conditions to warrant mowing for meadow purposes. It is a type that will endure a great deal of grazing and tramping, as it makes a very heavy underground root development, springs up strong and quickly, yet never grows to a very great height.

Plant No. 43 (Plate No. 7) illustrates what we have designated as a good hay type. This plant stood in the same row and was grown under the same conditions as plant No. 40 and plant No. 42 described above. While No. 40 made a height growth of only 18 inches, No. 43 stood 35 inches, and the leaf mass which is the valuable part of the hay, made a height growth of 22 inches. This is a very desirable type

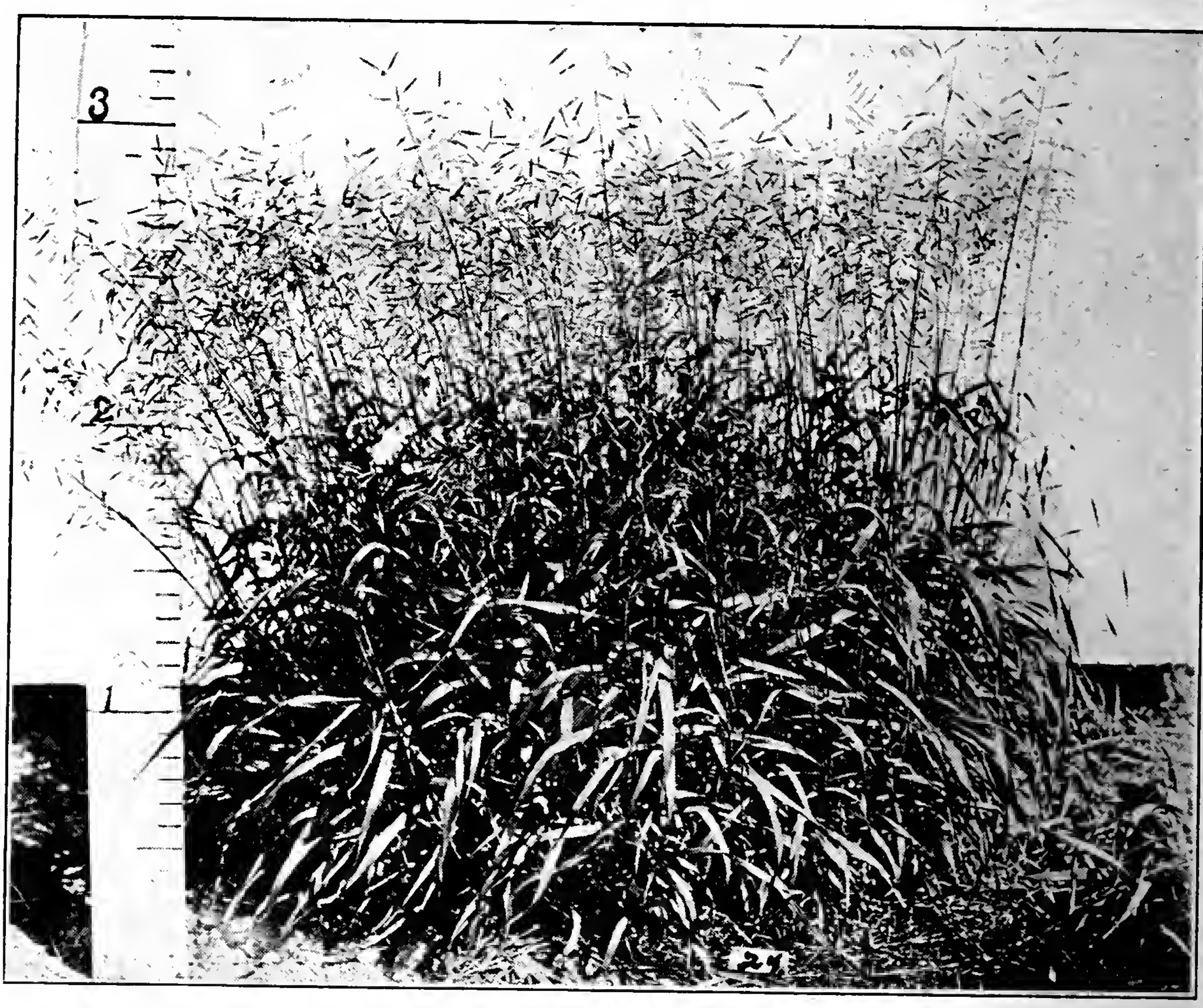


Plate No. 11.

of hay plant as the plant is not only of the very desirable leafy type, but also stools quite abundantly. It is also an exceedingly heavy seed producer so that this characteristic can be propagated.

Plant No. 67 (Plate No. 8) illustrates the same desirable hay characteristics. Plant No. 67 is a more vigorous stooler than plant No. 43, but is not quite as desirable in leaf characters. Plant No. 67

is a very bright yellow-green, while No. 43 is a very dark green, having a brownish tinge to the infloresence.

Plate No. 9 illustrates plants Nos. 40 and 41, No. 41 being the plant on the right. These two plants grew in the same row and under

Plate No. 12.

the same conditions. Plant No. 40 attained a total height growth of 18 inches, No. 41, 29 inches in 1912. No. 41 is a very heavy stooler; No. 40 was rather sparse in this characteristic. No. 41 produced an abundant supply of seed. No. 40 produced seed heads very sparsely.

The progenies of these plants exhibited the same characteristic.

Plate No. 10 illustrates the appearance of plant No. 41 in the spring of 1913.

Plant No. 107 and Plant No. 18 (Plates Nos. 11 and 12) illustrate some other interesting variations. These two plants have made practically identical height growth. It so happened that both of these plants exhibited the same general color appearances and almost identically the same type of leaf growth. The shape and general appearance of the leaf is so much alike that they can scarcely be distinguished. The chief differences to be observed in these two plants are that of

Plate No. 13.

tillering. Plant No. 107 is an exceedingly abundant stooler. The stolons put out from the roots are so abundant and vigorous that it is necessary to prume them back several times during the summer in order to keep this plant separated from the individual plants each side of it in the rows and in adjacent rows. Plant No. 18 on the other hand, puts out almost no stools. The plant at the time this picture was taken was three years old and yet the stool was practically of identical size as shown by measurements and counts, that it was during the latter part of its first season of growth. Our present experience with this characteristic is such that for pasture purposes especially, a type of plant similar to No. 107 would be selected always, because it is very much hardier, and stands tramping very much better because of its stoloniferous habit. For hay making purposes, the question is still in doubt, because meadows are not subjected to some of the conditions which surround pastures, so that it is not yet wise to pass an opinion. We do know that a type of plant like No. 107 has a

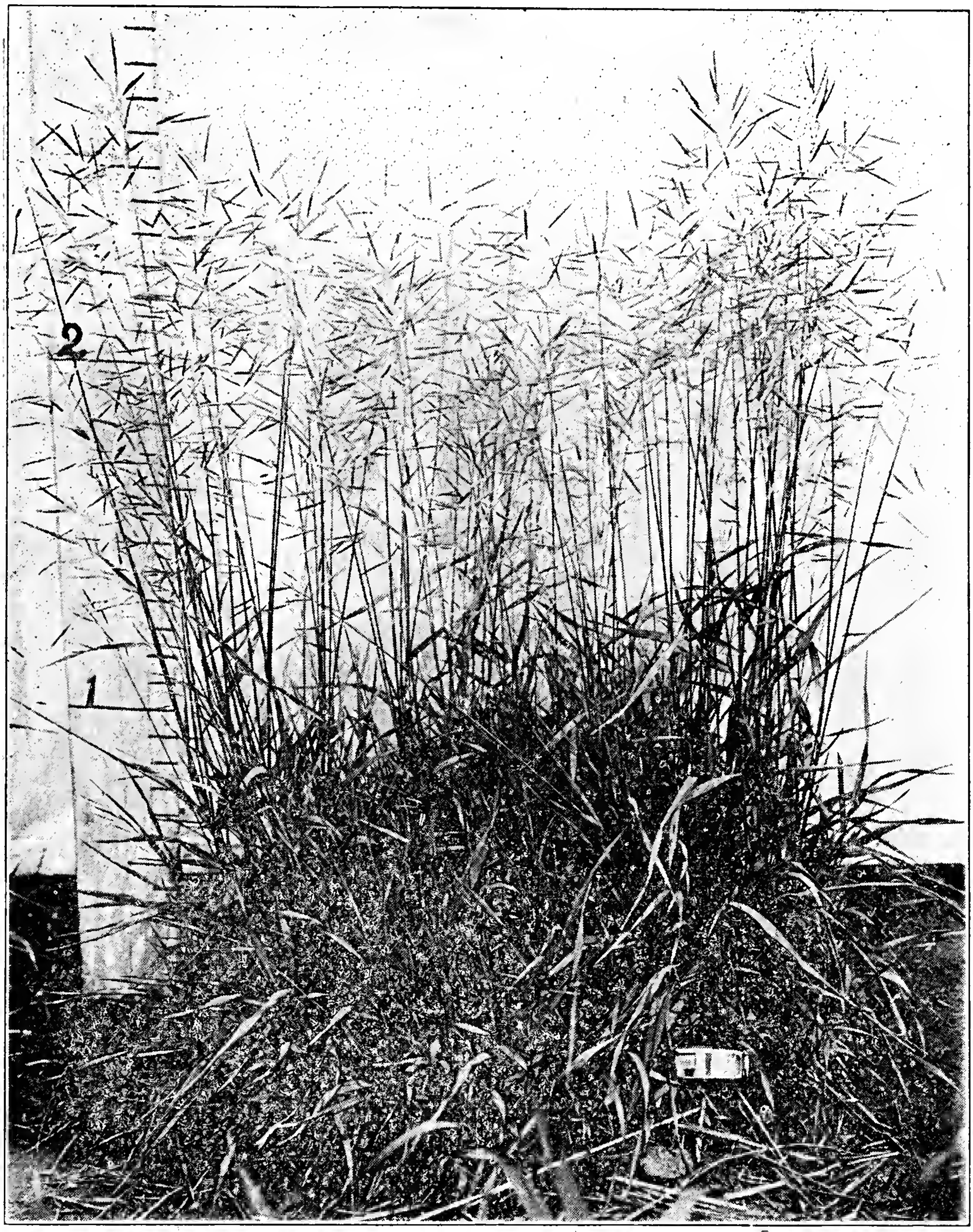


Plate No. 14.

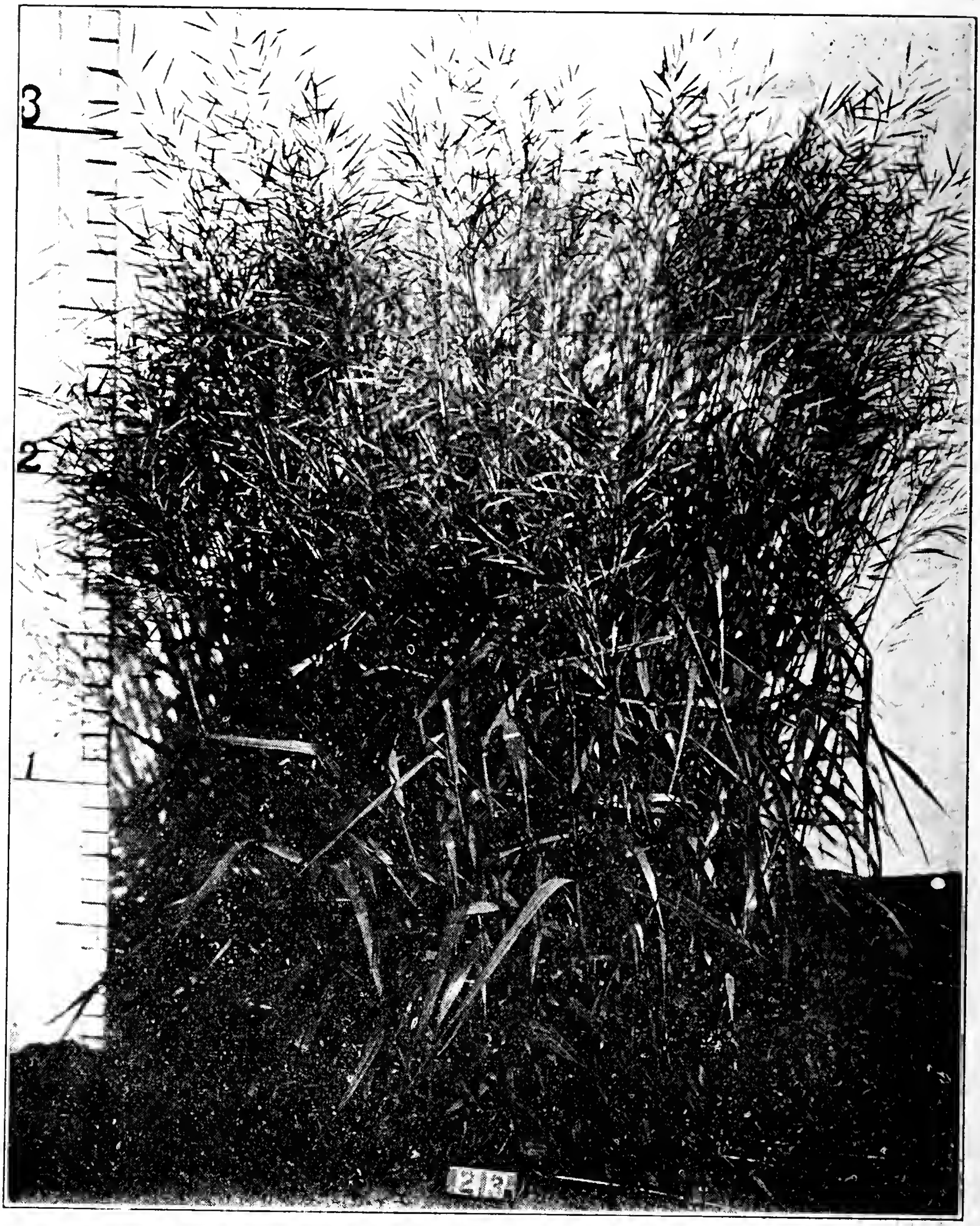


Plate No. 15.

tendency under meadow conditions, to a reduced length of leaf and stem growth because of the very great abundance of stolons put out and the tillers produced, while seemingly, there is a tendency of plants of the type of No. 18 to maintain under meadow conditions, a sufficiently high growth to permit continuous mowing for a longer period without some special treatment to increase development.

Plate No. 13 illustrates plants Nos. 116, 117 and 118, also three distinct types of variation which occur. Plant No. 116 made an average height growth in 1912 of nearly three feet. The plant was evidently possessed of a very great amount of vigor because in spite of the very much larger number of tillers it made a higher stem growth, a heavier infloresence and a higher, denser leaf growth than either plant No. 117 or No. 118 growing in the same row and immediately adjacent in the order given.

Plant No. 78 (Plate No. 14) and Plant No. 105 (Plate No. 15) illustrate two contrasting growth habits. These two plants are practically equal in stooling habit in so far as the lateral extent of the stooling area is concerned. Each has covered in three years' time practically the same area of ground. It will be noticed that the leaf height in plant No. 78 is low, while the leaf height in plant No. 105 extends

Plate No. 16.

well up into the infloresence. Altho the ground covered by these two plants was almost identical there was over three times the amount of weight of foliage produced at the time of cutting in the case of plant No. 105, indicating a very much better habit of plant for hay making purposes in the case of No. 105. It is interesting to note that the progeny rows from these individuals exhibited exactly the same characteristics, showing that in these speecific instances, pure lines were attained. The variations in spring starting of these different strains are nearly as striking as the variations in their later development.

Plate No. 16 shows early sprng development of plants No. 105 and 106, in the spring of 1913 Plant No. 105 on the left, started very much earlier and more vigorously than plant No. 106 on the right. These two plants exhibited a striking contrast not only in the shape of the growing mass produced but in the character of their foliage. Plant No. 105 is a broad leaved, vigorous grower, and starts very early in the spring, and continues growing late in the fall. Plant No. 106 starts slowly in the spring, has narrow, short leaves, and a very dark green color. By the first of June plant No. 105 had attained a height of 30 inches in 1913, and plant No. 106 a height of only 18 inches. Fom previous experience with this plant we would be warranted in concluding that it has practically reached as much development in the way of leaf growth as it will make during the season, while we can expect plant No. 105 to make a considerable further growth before it reaches seed maturity.

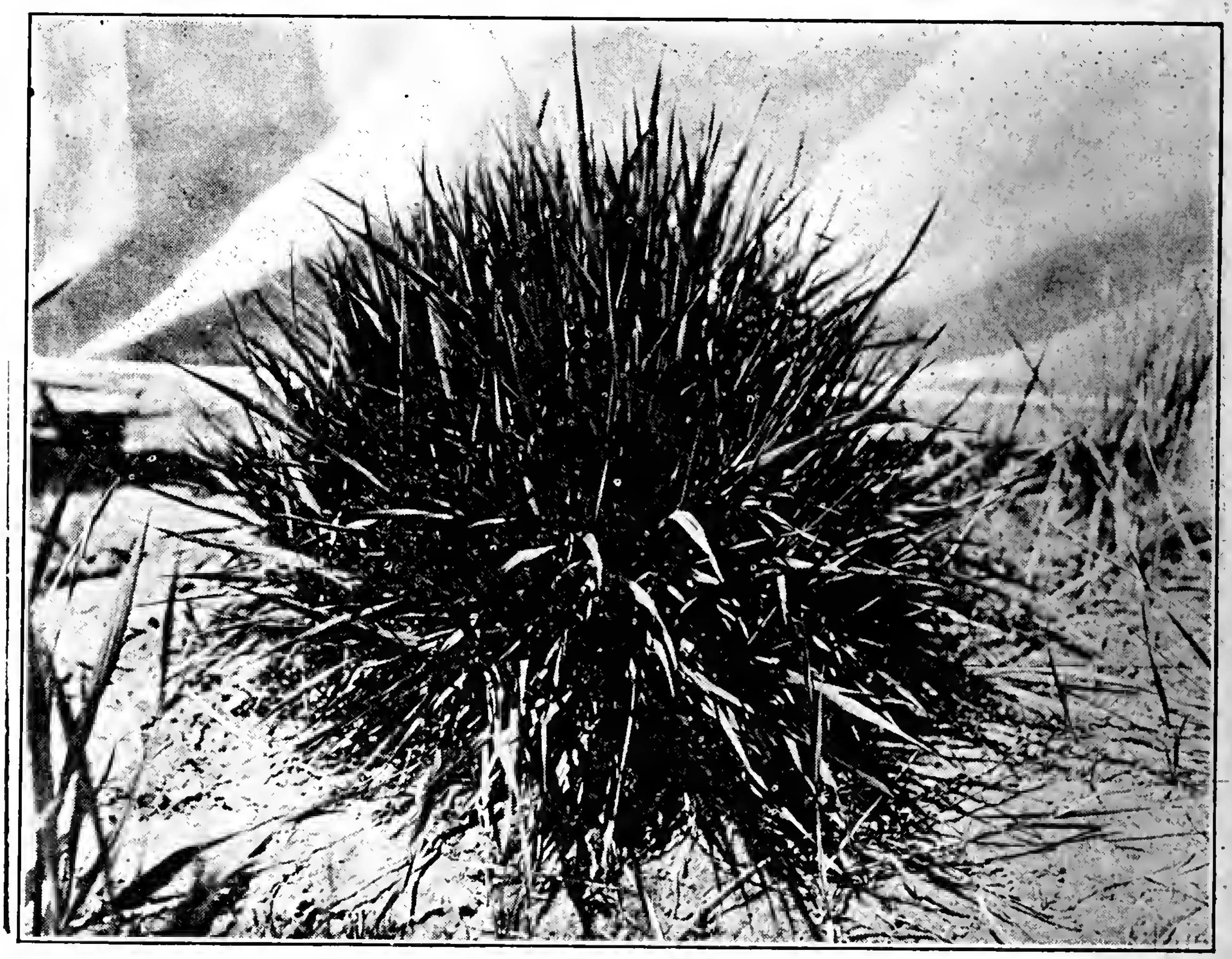


Plate No. 17.

Plant No. 24 (Plate No. 17) and Plant No. 25 (Plate No. 18) illustrate another set of contrasts Plant No. 24 in a very sparse stooler.

Plant No. 25 is an exceedingly abundant stooler. These two plants in the past have been practically identical in height growth Plant No. 24 is a very bright yellow green. Plant No. 25 is a very dark green or blue green. Plant No. 24 has very fine leaves and stems, while plant No. 25 is rather coarse. These two plants exhibited about the same characteristics in starting in the spring.

A further contrast is shown in Plate No. 19, between plant No. 24 shown on the left, and plant No. 63 shown on the right. While plant No. 24 is a sparse stooler, it is a vigorous grower, attaining a good height and continues vigorous. Plant No. 63 on the other hand, appears to be of very low vigor. It stools very sparsely, starts very late

Plate No. 18.

in the spring. The progeny rows obtained by planting seed from plant No. 63 have this same slow, sickly development shown by the parent.

Notes are being taken and studies made to determine if any of these various physical characters as exhibited in these original plantings or their progeny are correlated with specific performances. While correlation tables might be constructed from the data at hand, this will not be done until more data is accumulated. From a cursory eximination there would seem to be very little correlation between color and leaf habits and ability of the plants to perform. Preliminary counts and preliminary computations, however, seem to indicate that there may be a relation between the tillering habit and the development which actually takes place in the strains and their progeny, when these strains prove themselves to be pure lines.

Some studies have been made on propagating some of these strains vegetatively. While we have none of these vegetatively propagated strains in the nursery at the present time, we have had clonal varieties which were destroyed as soon as it was shown by experiment that this method of propagation was favorable for increased seed production of desirable strains and that true clonal varieties could be made by such a method. In the case of desirable strains this method of propagating may enable us to very quickly increase a desirable strain for seed increase. Of course, if a strain should happen to be a hybrid so that splitting occurred in the F_2 generation, the vegetative method of propagation would be of no use, but in the case of pure lines it can be utilized to get a larger seed producing capacity of some of the pure strains.

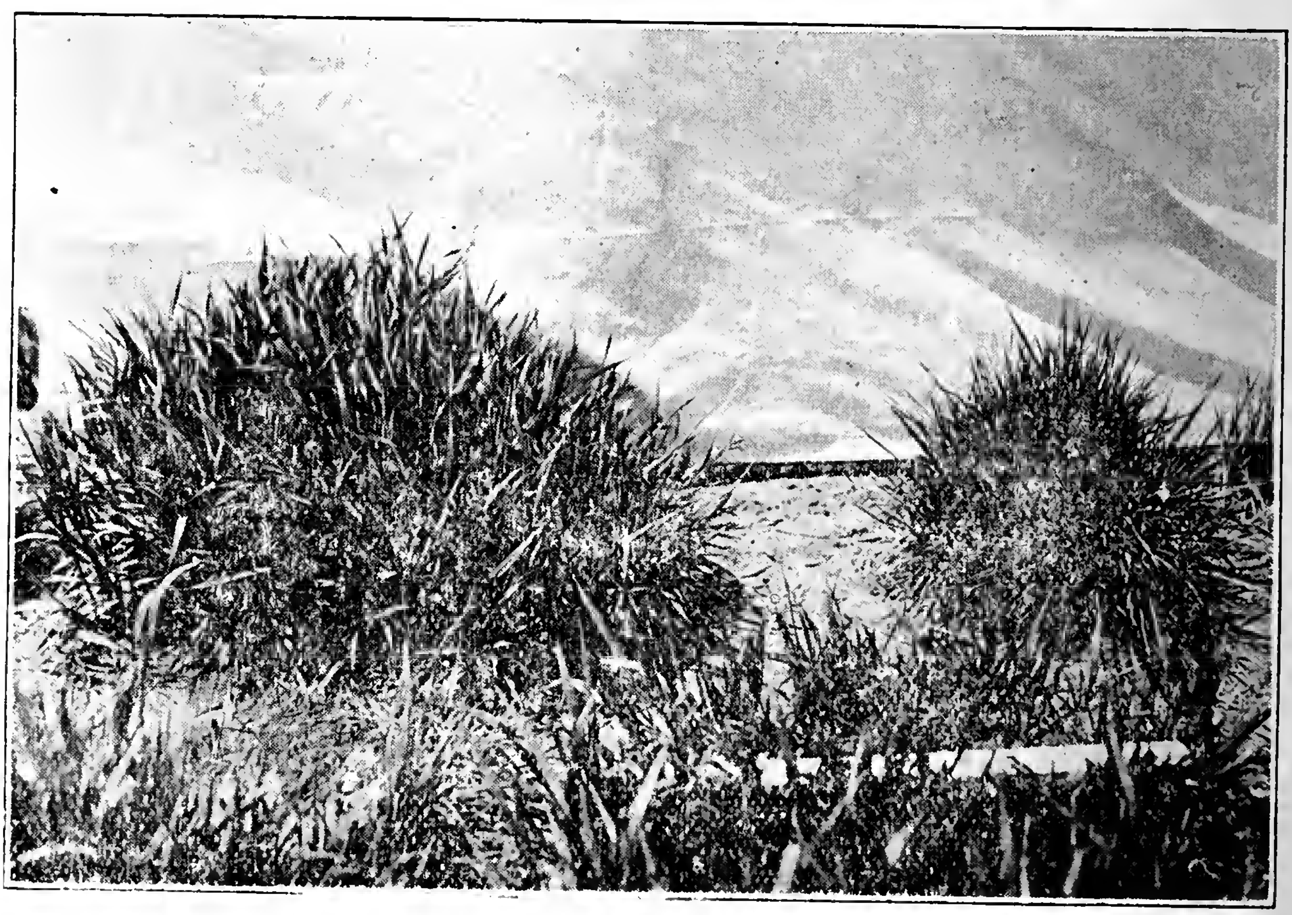


Plate No. 19.

Bulletin 191 June, 1913

The Agricultural Experiment Station
of the
Colorado Agricultural College

Alfalfa Seed Production

(A Progress Report)

By PHILO K. BLINN

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1913

Station Staff

C. P. GILLETTE, M. S. Entomologist	Director
W. P. HEADDEN, A. M. Ph. D.	Chemist
G. H. GLOVER, M. S., D. V. M.	Veterinarian
W. G. SACKETT, B. S.	Bacteriologist
ALVIN KEYSER, A. M.	Agronomist
J. O. WILLIAMS, B. S. A., U. S. Expert-in-charge	Horse Breedin
E. R. BENNETT, B. S.	Horticulturis
B. O. LONGYEAR, B. S.,	Botanist
G. E. MORTON, M. L., B. S. A.	Animal Husbandman
E. B. HOUSE, B. S. (E. E.), M. S.	Irrigation Engineer
V. M. CONE, B. S.	Irrigation Investigations
R. E. TRIMBLE, B. S.	Assistant Irrigation Investigations
P. K. BLINN, B. S., Rocky Ford	Alfalfa Investigations
EARL DOUGLASS, M. S.,	Assistant Chemist
S. ARTHUR JOHNSON, M. S.	Assistant Entomologist
[1]B. F. KAUPP, M. S., D. V. S.	Veterinary Pathologist
GEORGE P. WELDON, B. S.	Assistant in Entomology
L. C. BRAGG	Assistant in Entomology
[2]R. S. HERRICK, B. S., Grand Junction	Field Horticulturist
C. L. FITCH	Potato Investigations
W. E. VAPLON	Poultry Investigations
J. W. ADAMS, B. S., Cheyenne Wells	Agronomy Assistant, Dry Farming
[3]G. D. WALTERS, B. S.,	Assistant Irrigation Investigations
ELLWOOD D. ROOD, A. B.	Assistant Chemist
W. W. ROBBINS, M. A.	Assistant Botanist
[4]PAUL S. JONES, B. S.	Assistant Irrigation Investigations

OFFICERS

CHARLES A. LORY, LL. D	President
C. P. GILLETTE, M. S.	Director
L. M. TAYLOR	Secretary
MARGARET MURRAY	Executive Clerk

[1]—Resigned November 1, 1912.
[2]—Resigned July 31, 1912
[3]—Resigned May 1, 1912.
[4]—Appointed May 15, 1912.

Alfalfa Seed Production.

(A Progress Report)

Philo K. Blinn

Alfalfa is indispensable to the farmers of the western states for hay production and for keeping up soil fertility in their crop rotations. The area in alfalfa is rapidly increasing in many of the eastern states. Consequently, there is a large demand for alfalfa seed for sowing new fields, and each year the supply of desirable seed seems to be more limited.

Considerable imported seed has been used in recent years, but with rather irregular success. Some lots of seed proved to be good, while others seemingly of different strains have not given satisfaction. In the absence of any pure seed regulations there seems to be no way of identifying the best strains of alfalfa seed on the open markets. Consequently, many of the farmers are preferring to sow home grown seed when it is possible to secure it, claiming better and more uniform results.

It has become well established that some strains of alfalfa are superior to others, especially for some localities. It seems important that there should be developed an alfalfa seed growing industry to furnish a more dependable "home grown" supply of the best strains of alfalfa seed.

Fifteen or twenty years ago, certain districts in Colorado were producing considerable alfalfa seed, even exporting some. Recently the same sections are growing barely enough seed for local demands.

During the early years of alfalfa seed growing in these districts, yields of seed varying from five to ten bushels per acre were quite common. Now it is seldom that a grower can secure a yield of more than three to four bushels of seed per acre. This is especially true on some of the best irrigated land. Such yields are not inducement enough for a farmer on high priced land to leave a crop of alfalfa to mature for seed.

The question as to why alfalfa is failing to produce seed as abundantly as it did in former years, has caused the Experiment Station to devote special attention to the problem. The solution has not been fully reached. But some results of value may be reported at this time.

Factors That Influence Seed Production

Influence of Vegetative Growth.—It is a recognized law of plant life that where plants are forced for vegetative growth, there is a tendency to weaken seed production. Many of our cultivated flowering plants are notable examples where the continued forcing for flowers and foliage, without regard to seed production, has resulted in the total loss of the power of such plants to produce seed. This is not only true of our cultivated flowering plants, but our field crops will act in the same way if handled in the same manner. For instance, the potato, which has been grown for tubers almost indefinitely, produces varieties that fail to set seed balls, which are the true seed of the potato. We have varieties of alfalfa that are non-seed-producing. In fact, many plants have been found in our investigations that even fail to produce flowers, simply forming a modified growth without the functional organs of reproduction where the flowers should develop. Of course such variations disappear sooner or later unless propagated by vegetative cuttings. Since alfalfa is commercially propagated by seed, sterile plants do not originate seedless varieties. Only seed bearing plants are propagated.

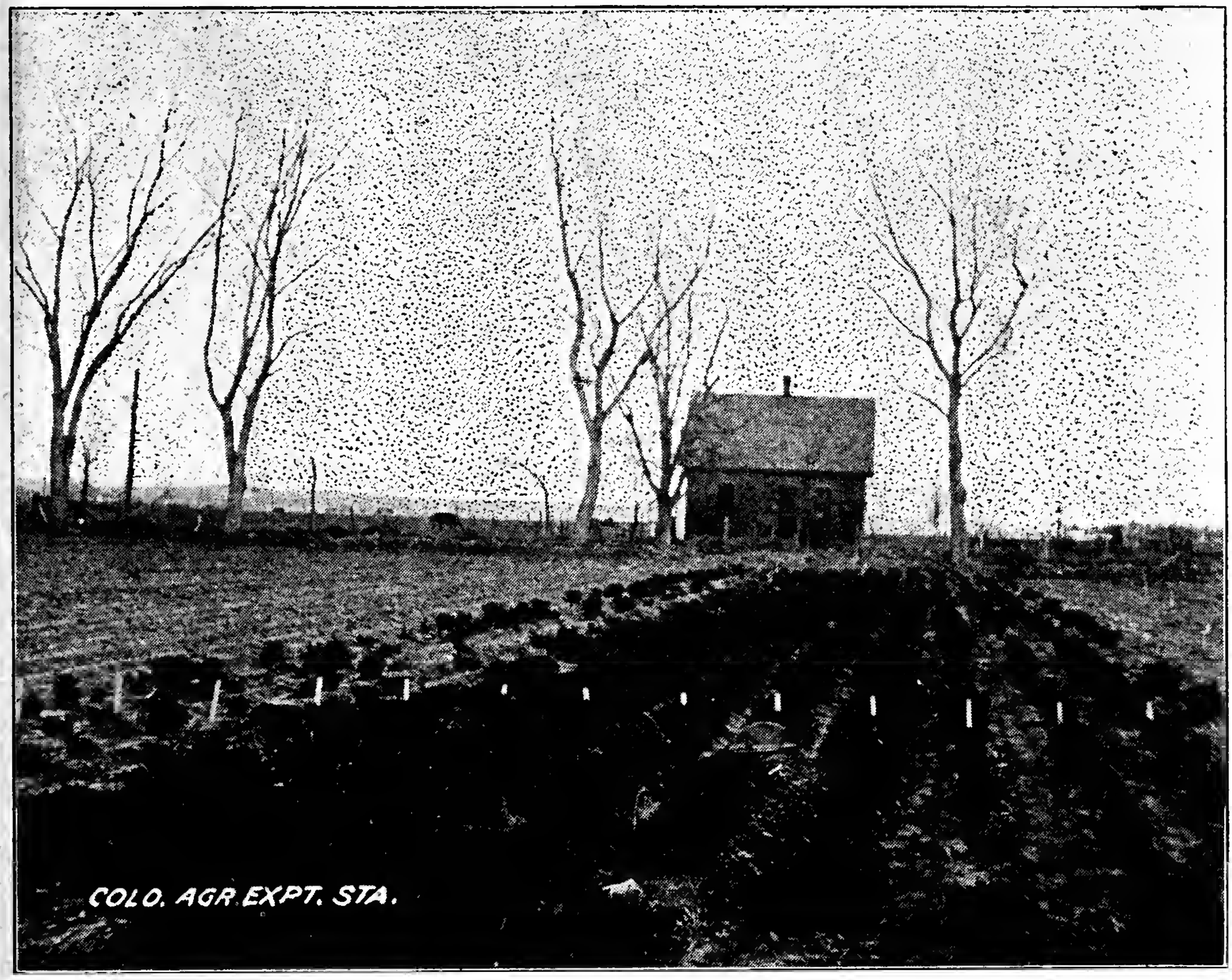
Influence of Moisture Supply.—It is the common experience of every farmer who grows alfalfa, that the conditions which make for the best yields of hay, are not conducive to seed production. The heaviest yields of seed have been secured where the plants have seemed to make a rather dwarfed growth, due to the lack of moisture or some other condition adverse to the rapid development of forage. These plants evidently had sufficient moisture at the right time to set and fill the seed, for without any moisture the seed will "blast" and fail to fill. If too much water is applied the seed fails to set apparently due to the luxuriant growth of forage that follows. It seems fair to conclude that the regulation of moisture at the right time and in the right amount is one of the important factors that influences the production of alfalfa seed. It seems almost impossible to formulate a rule to fit all conditions of farms, subsoils and seasons. In one case, three to four irrgations were found necessary to produce seed on a field of heavy adobe that would not absorb moisture easily. While on a lighter loamy soil, one irrigation would induce so rank a growth of hay that the crop was a failure.

Climatic Conditions and Other Influences.—Aside from the influence of vegetative growth and the moisture supply, there are the effects of climatic conditions and seasonal changes. Injurious insects sects and plant diseases greatly modify the results in alfalfa seed production. But these do not seem to explain why the yields of seed have decreased from former times. There is no perceptible climatic change, nor direct evidence to show that insects or diseases are responsible as a general cause.

CONDITIONS THAT HAVE CHANGED

In canvassing the conditions that may have influenced alfalfa seed production, we find that the question of subsoil moisture is decidedly changed to what it was in the early days of alfalfa seed growing.

Most of the land in Colorado, before being irrigated, had dry subsoil to almost indefinite depths, but after the land had been irrigated for a number of years, an underground water table was established at varying depths from the surface according to the character of the soil formation. When alfalfa was first sown on land that had never been irrigated it required considerable water to produce a maximum crop of hay. It was principally during this period of time before the subsoil became filled with moisture, that the good yields of alfalfa seed were secured. When the subsoil was dry the growth of alfalfa was retarded and the conditions were more favorable for seed production. Numbers of farmers have related practically the same experience,—where certain fields had produced alfalfa seed very successfully, until a ditch or irrigation on higher ground caused a water table to form under the land, after which the fields no longer produced seed satisfactorily, but they continued to grow forage more luxuriantly than ever. The conclusion seems evident, that too much moisture in the subsoil or con-



No. 1.—The first selections of alfalfa to increase seed production one year from date of seeding; four rows to the left, grown from seed selected from heavy seed producing plants; the six rows in the center sown at the same time, Turkestan alfalfa, commercial seed.

ditions resulting from long continued irrigation are the causes of the decreased yields of alfalfa seed on the well irrigated land. The attempt to regulate moisture supply for seed production on such land has become fruitless because of the lost control in an over supply of subsoil moisture. The uncertain elements of drainage and capillary action in different soils under different conditions make it impossible to depend on results.

TESTS AND EXPERIMENTS

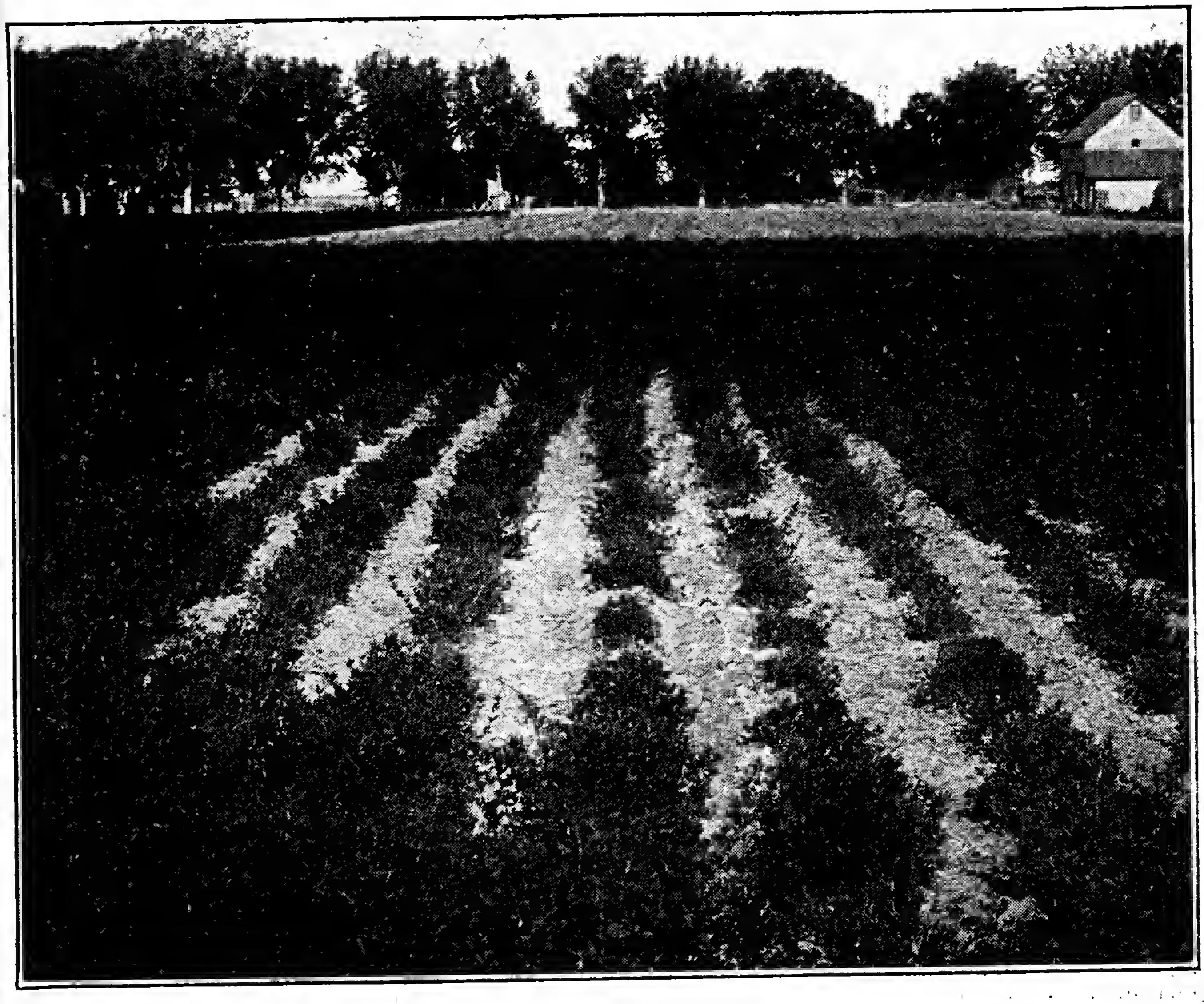
Seed Selection.—One of the first points to attract attention on investigating alfalfa seed production was the fact that there were individual plants that bore seed heavily in fields where most of the plants were failing to form seed. It seemed that if selections of seed from these well filled plants were made, that immediate results would follow by establishing a new strain of seed-producing alfalfa.

Selections of this kind were made in 1904. The results, however, were disappointing, owing to the fact that the selections were made from some ordinary alfalfa which afterwards proved to be much inferior in point of forage production as compared to other strains which were tested with these selections. Plate No. 1, is a view of this first test. The four rows to the left in the picture are the progenies of these first selections; the six rows in the center were Choice Turkestan plants. Owing to this unfavorable comparison the selections were abandoned for more promising ones that were subsequently made from a larger comparative test of sixty-four different strains of alfalfa from the different sections of the world secured from the U. S. Department of Agriculture. These varieties were sown in adjacent plats and all received the same care and were under the same conditions as nearly as possible. Each plat was thinned to single plants in order to observe the characteristic traits of the different individual plants and types.

The results of this comparative test have been interesting and valuable. It was shown that there are other contrasts of qualities in alfalfa that are more valuable than mere seed production. For instance, the important questions of hardiness, disease-resistance, and the quality and quantity of forage produced, are points that are fundamentally important in seed selection. Hence our efforts have since been directed towards developing and establishing a type of alfalfa that will combine all the desirable traits as far as possible. The results have been encouraging. Plants have been found among the best hay types that produced as high as two ounces of seed per plant.

Systematic seed selection has proved to be efficient in establishing greater uniformity in the types and qualities desired in alfalfa. The leaf characters, the stooling habits, and the flower colors have been reproduced true to type in the progenies of many of our selections. The seed producing traits of different plants in almost every strain tested, have shown inherent tendencies, which clearly indicate that seed selection will be one of the important factors in improving the production of alfalfa seed. It has been found possible to produce seed from good hay types if the proper cultural conditions are supplied. The results of a great number of selections that have been made during the past eight years have demonstrated that under favorable conditions of growth, the best types of alfalfa for forage are not inclined to produce much seed, and that the best seed yielding plants are not as a rule the best types for hay production. In other words, a strong inherent forage producing tendency in alfalfa has much the same relation to seed yields as an exceptionally favorable growing condition. Thus it is thought that the best types of alfalfa should be developed by systematic selection and breeding. Then, the seed for commercial seeding should be produced where the conditions of growth can be regulated to some extent, either by natural conditions favoring the production of seed, or by artificial methods of controlling the growth of the forage.

Moisture Requirements for Seed Production.—The amount of moisture in the soil best suited to seed yields has not been determined in unit terms of any kind. In fact the results of observations on this point are rather conflicting.



No. 2.—A dry spot in an alfalfa field where irrigation was witheheld two seasons, to test seed production. The dry spot was caused by a gravel layer eight feet below the surface; balance of field growing rank with the subsoil moisture.

It is usually conceded that a heavy, dashing rain when the alfalfa is in full bloom is injurious to the seed prospects, as the flowers that are out at the time usually fail to form seed. Yet there are numerous experiences which seem to indicate that a light irrigation when the field is just passing out of full bloom is often beneficial to the seed crop. Again it has been noted that alfalfa on ditch banks, where there is a continual supply of moisture, has some times set well with seed; while in fields that have plenty of subsoil moisture, growing good crops without irrigation, will not form seed satisfactorily. Hence it is difficult to draw conclusions. But there is ample evidence to show that *how, when,* and *where* moisture is supplied has something to do with the question as well as the *amount* of water.

Plate No. 2, is a view of a dry spot in a field of alfalfa planted in rows where irrigation has been withheld for two years to test seed production. The soil is a deep sandy loam, sixteen feet to the water table, and the alfalfa in this field grew rank with no apparent need of irrigation except in some dry spots. Here it seemed possible for one to find the proper amount of moisture required to form seed, for somewhere between the dried up center of this spot and the rank growing portion of the field there should have been a point that had the proper moisture to set seed. Such was not the case as there was practically no difference in the seed yield. The whole field failed to set seed satisfactorily.

No. 3.—An alfalfa nursery, each row a different strain, irrigation withheld for over a year; in the forground, plants showing need of moisture, distant ends of the rows not needing moisture owing to the capillary moisture in the subsoil; water being applied to the dry portion in every other row to test results of light surface irrigations.

A test hole with a soil auger proved that the cause of the dry spots was due to a gravel stratum eight feet below the surface which cut off capillary moisture. The rest of the field had twelve feet of moist soil.

Plate No. 3, is a view of one of the nursery plats at Rocky Ford which has been held without irrigation for over a year. The lower half of the rows are suffering for the need of moisture, while in the upper half the rows can hardly be distinguished, due to the rank growth resulting from the subsoil moisture.

The dry portion of this nursery has been divided into three different parts, each portion to be irrigated with a different amount of moisture.

Before irrigating, moisture determinations were made for each foot in depth in the moist, and dry portions of the plat, with the following results of moisture percentages based on the dried soil samples:

AMOUNTS OF MOISTURE IN MOIST AND DRY PARTS OF ALFALFA PLAT.

	1 ft.	2 ft.	3 ft.	4 ft.	5 ft.	6 ft.	7 ft.	8 ft.	9 ft.	10 ft.
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
Moist part....	7.9	7.5	6.1	5.1	5.3	6.0	7.0	7.6	10.3	11.8
Dry part.....	5.3	4.5	3.9	3.8	4.1	5.0	5.5	5.6	5.1	7.7

Gravel was encountered at ten feet under the dry portion, and was not encountered under the moist part of the plat.

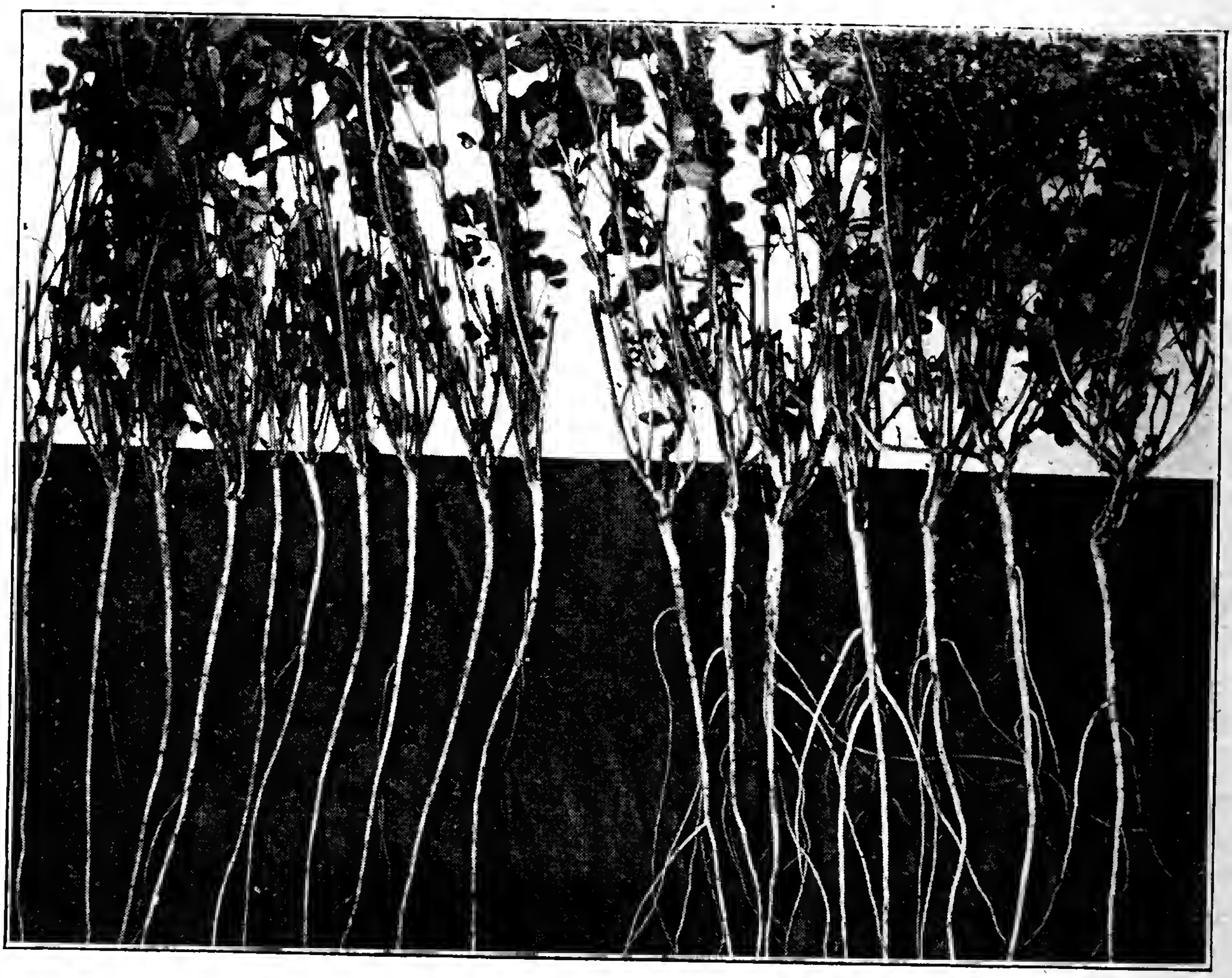
It will be observed that in both portions of this plat the soil is driest from three to six feet in depth. It is evident that the plants have made their growth from the precipitation at the surface, and from the deep subsoil moisture through their long roots that were developed when irrigation kept the whole subsoil moist, as rootlets were encountered to the depth of ten feet. More extended investigations will be necessary before drawing definite conclusions. But these tests suggest two reasons why alfalfa growing on deep subsoil moisture might fail to set seed well. First, when the plants are in full bloom and forming seed there is an extra demand for moisture that may not be supplied fast enough through the long roots passing through the dry surface soil, consequently the flowers "blast". Second, owing to the fact that the plants are deriving most of their nourishment from the deep soil areas, it may be that the failure to set seed is due to the availability of food constituents in the subsoil or to the absence of some constituent.

CONTROLLING MOISTURE FOR SEED PRODUCTION.

The usual attempts to regulate moisture for seed production are fruitless of results because the ordinary methods of growing alfalfa for hay are inadequate for the purpose of seed production.

Thick Seeding.—The method of seeding alfalfa thickly, either by drilling or broadcasting, is admirably suited to the production of fine hay, but is not suitable for the production of seed. The stems growing thickly, fine and succulent are more likely to "lodge" with wind or rain, and the flowers are borne principally on the tips of the plants due to the overcrowding. In a very thin stand of alfalfa the stems grow more branched and stocky, the flowers are produced in greater profusion over the whole plant and are more inclined to set seed.

Irrigation by Flooding.—The general practice of irrigating alfalfa by surface flooding, has succeeded well in growing hay, but the tendency is generally towards getting the soil too wet for good results for seed production. Where land has been flooded for a number of years the soil becomes compacted, and will crack, and dry very rapidly. If irrigated it easily becomes too wet, making it next to impossible to regulate the moisture conditions suitably for seed production where land is flooded.



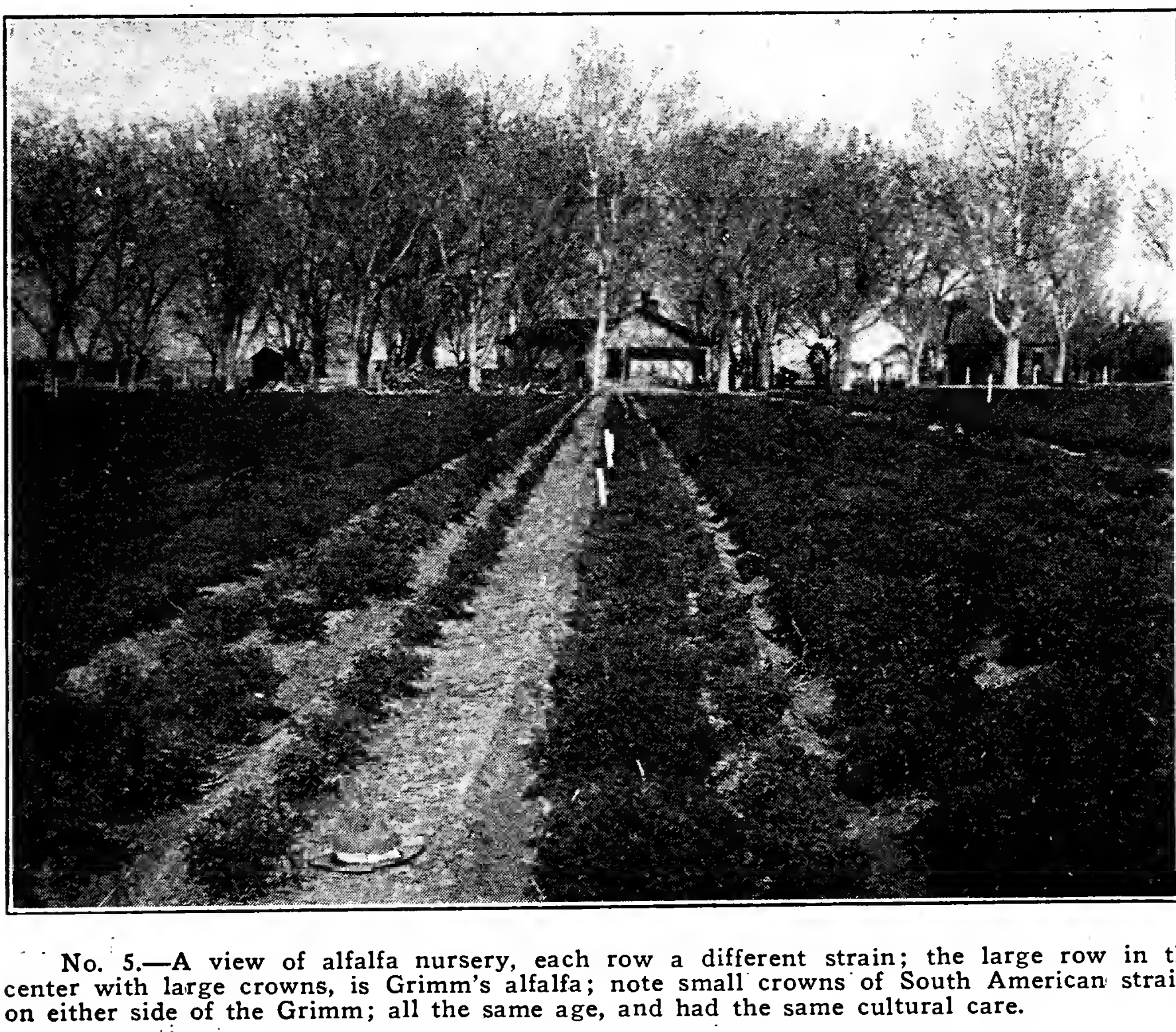
No. 4.—A contrast between the root development of alfalfa in a thick stand irrigated by surface flooding shown in the left; and plants of the same variety sown the same time in rows twenty inches apart, cultivated and irrigated in furrows, as shown in the plants on the right.

Combining Hay and Seed Production.—Experience has shown that it is not practical to combine the production of hay and seed from the same field, because of the different moisture requirements for each. The success of the hay crop almost precludes the chance of the success of the other. Yet, there is usually a light growth of hay in connection with alfalfa seed growing, as the season in Colorado is not long enough to mature two crops of seed in one year.

ALFALFA IN ROWS FOR SEED PRODUCTION

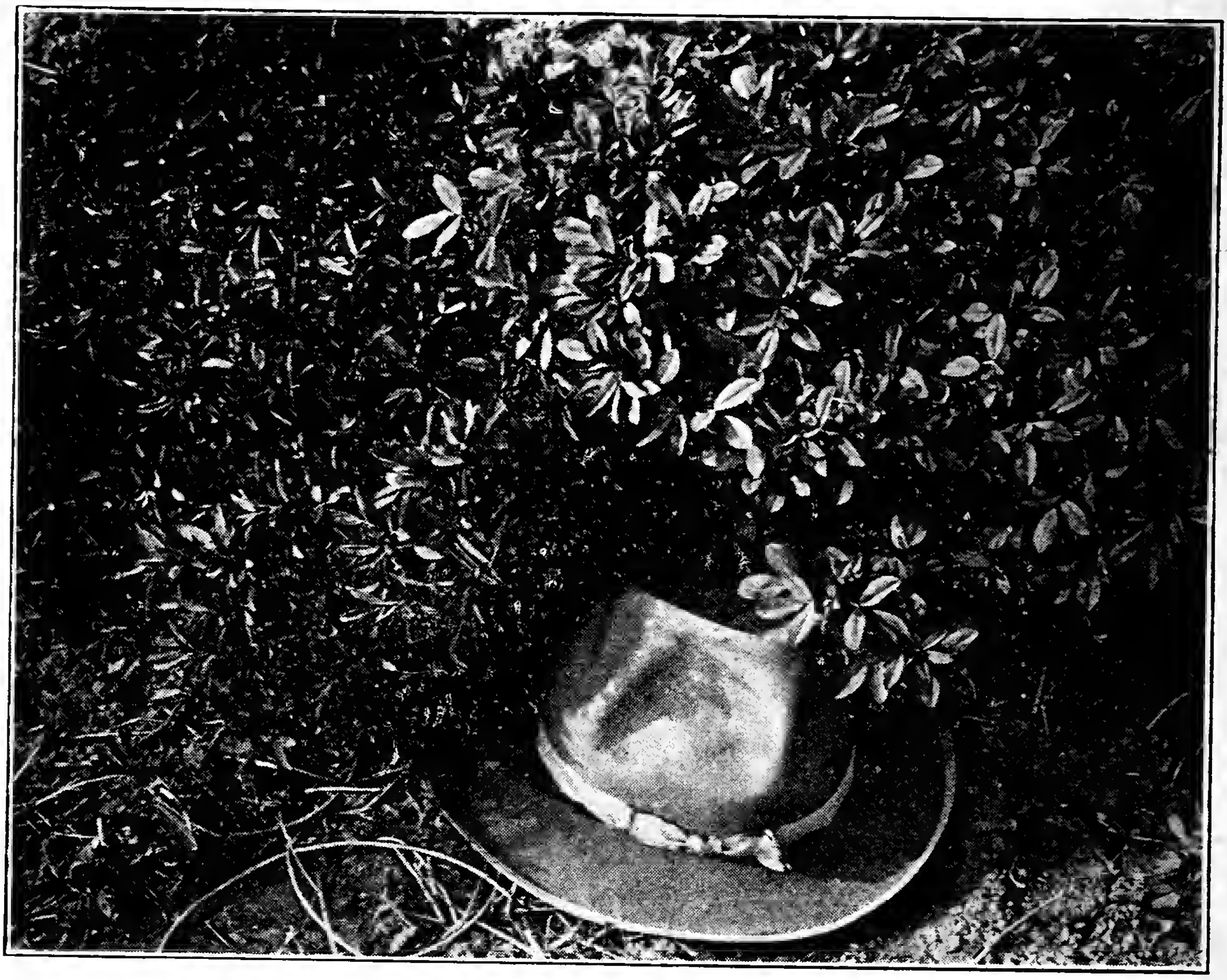
Growing alfalfa in rows with intertillage, for seed production, is not a new idea, but it is practically new in Colorado. Until the Experiment Station advocated the method as a means of regulating the moisture supply for seed production, there was little sown in rows outside of the experimental plats. The advantages of this method for conserving moisture, and controlling the application of light irrigations are obvious. Many farmers who are interested in alfalfa seed growing have seeded large fields in rows during the past two years, with a view of producing seed.

It is too early yet, to make reports of results, for it is very evident that there will be much to be learned, in regard to the cultural care, the amount of irrigation, how, and when to apply the water for the best results. The application of this information to the different soils on different farms in different seasons, will need to be worked out more fully.



No. 5.—A view of alfalfa nursery, each row a different strain; the large row in the center with large crowns, is Grimm's alfalfa; note small crowns of South American strains on either side of the Grimm; all the same age, and had the same cultural care.

The Advantages of Alfalfa in Rows.—Having alfalfa in rows, permits thoro cultivation to kill weeds, destroy grasshoppers' eggs, and conserves monsture. It makes it possible to control light applications of water by irrigating in furrows. These can be made in every row, or every other row as is found necessary. By having these furrows "logged out" smoothly, a very light irrigation can be applied with little flooding or over soaking of the soil. By varying the distance between the rows, and the rate of seeding in the rows, it is possible to establish a uniform, thin stand, which is essential to securing the stocky growth that is neccessary for good seed production. Growing alfalfa in rows with intertillage, induces more surface branching of the roots, which is desirable in dry land conditions, or where it is desirable to regulate the growth with surface moisture. Plate No. 4, shows the relative growth of side roots in alfalfa flooded, and that grown in cultivated rows.



No. 6.—A contrast in leaf color and size of two choice forage types from the Grimm row shown in Plate No. 5.

Objections to Alfalfa in Rows.—The difficulties in handling hay machinery on the rough furrows is the principle objection urged against alfalfa in rows, but by running the mower with the rows, or diagonally across the rows, this objection can be overcome. There is also a tendency for the loose soil in rowed alfalfa to wash out with heavy rains, but by selecting the proper field and running the rows on a slower grade, this difficulty can be obviated. If alfalfa in wide rows is left neglected it will become a veritable weed patch.

Distance Between Rows.—The proper distance to seed alfalfa in rows for seed production has not been fully established. In fact there will probably be no set rule, as the distance will vary according to the location, the supply of moisture, and the nature of the soil.

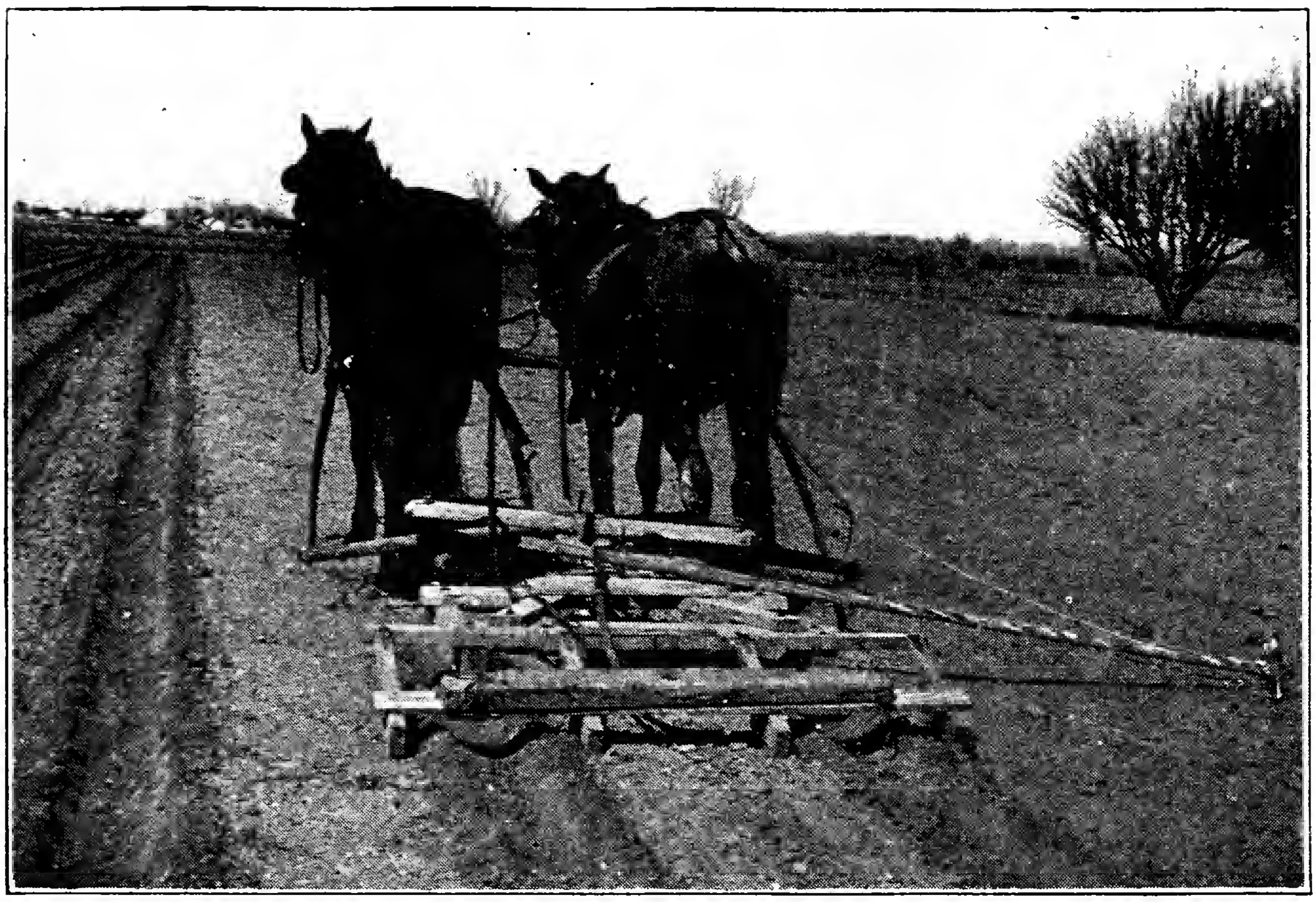
No. 7.—A contrast of inherent seed setting traits of two adjacent plants.

No. 10.—A field of Grimm alfalfa sown in twenty-inch rows. under irrigated conditions, seeded at rate of four pounds per acre. Photo taken May 8, 1912.

No. 8.—A contrast, in time of blooming, a trait valuable for early honey flow, and possibly in seed production.

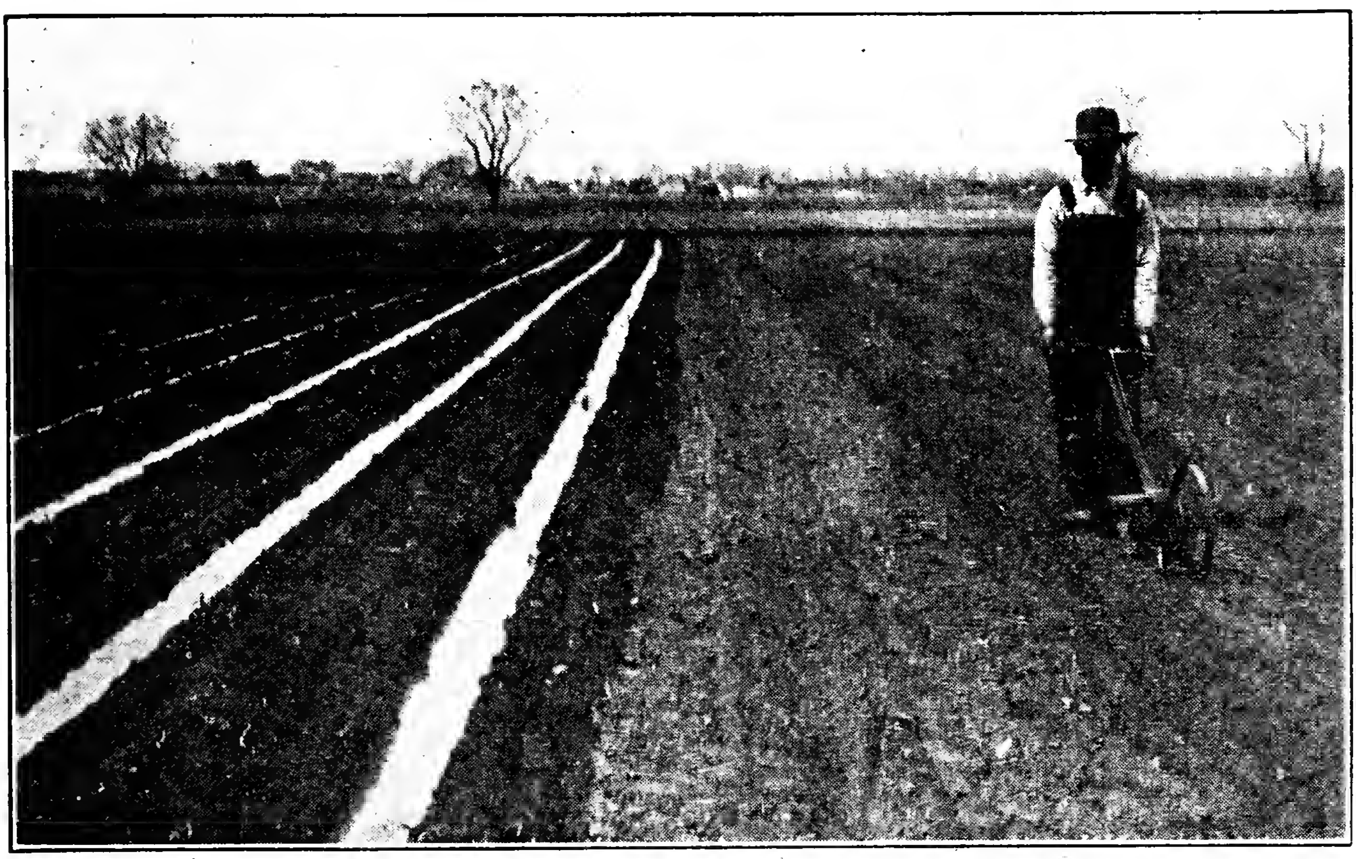
Under Irrigation.—The twenty inch rows have been used because the same tools used in sugar beet culture, were convenient to use in alfalfa. It has become evident that even at twenty inches apart in rows,

No. 9.—A view of the poorest portion of twelve acres of Grimm alfalfa sown in forty-two inch rows at Eastonville, Colo., under dry-land conditions, altitude 7200 feet, taken June 13, 1912, one year after seeding, rate of seeding two pounds per acre.



No. 11.—A marking and logging out device for seeding and irrigating alfalfa in rows, to prevent surface flooding of the soil.

alfalfa should be seeded very thinly, for the best results in seed production. It is difficult to seed uniformly in rows with much less than two pounds of seed per acre for rows 20 inches apart.



No. 12.—Drilling alfalfa nursery in twenty inch rows, and irrigating in logged out furrows, between every other row; note moisture "subbing" entirely across the space between the forty inch furrows without any flooding.

Alfalfa on Dry Land.—Under dry land conditions experience has shown that thirty-six to forty-two inches apart is required for alfalfa in rows, for in this case, it is a question of a limited moisture supply, where the success of the crop will depend on conserving the moisture by cultivation and limitating the number of plants to draw upon it.

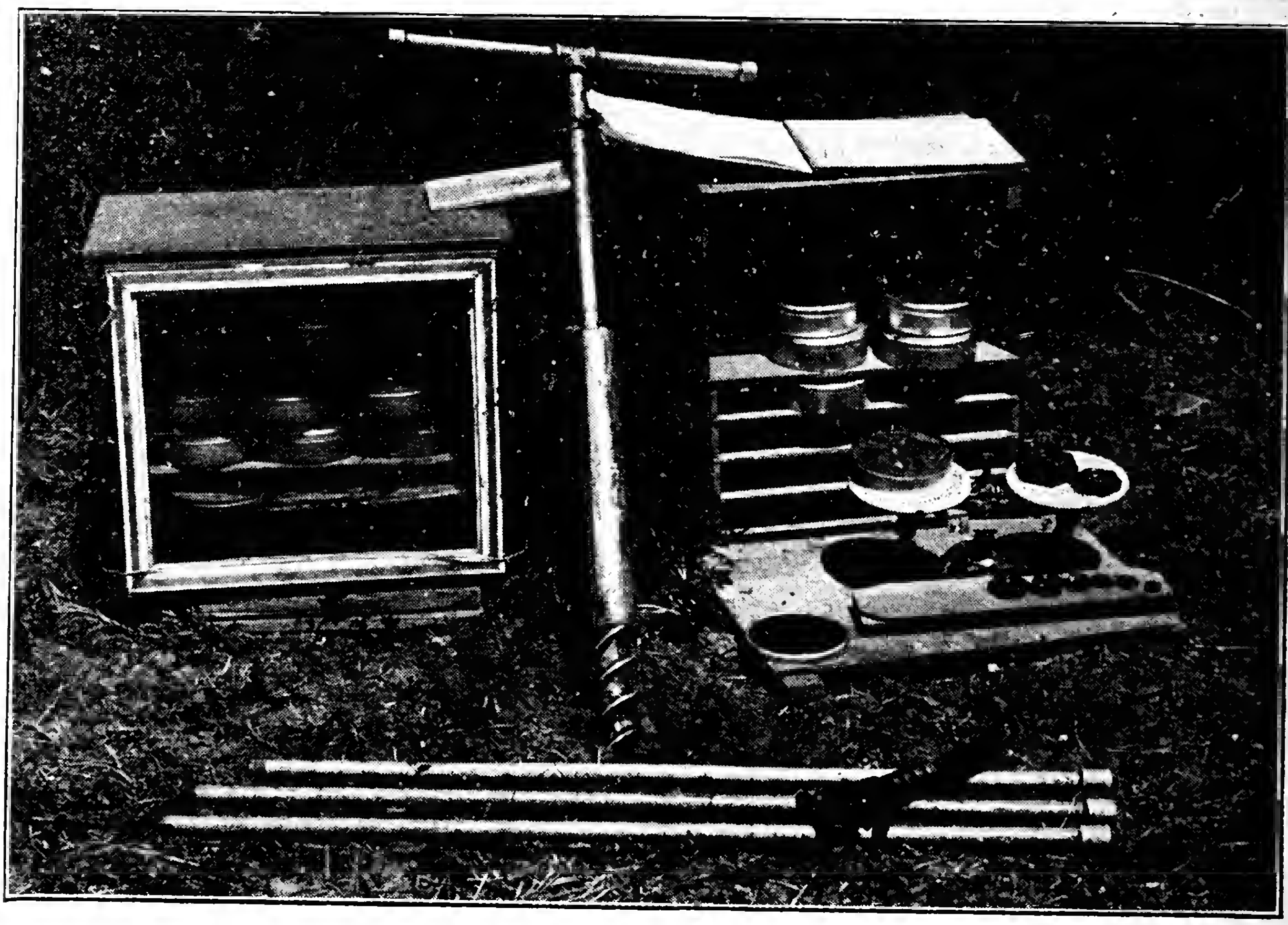
A thoro preparation of the soil by deep tillage for one or two years previous to starting alfalfa on dry land is necessary to establish moisture in the subsoil. Then it is essential to start with a thin stand of plants, keep these clean of weeds, and hold all moisture possible by cultivation to insure the alfalfa living over the dry seasons.

Alfalfa seed growing on dry land is partly in the experimental stage. Results have been secured that will warrant the prediction that some of the dry land sections will be devoted to alfalfa seed growing, when the different soil conditions are understood, and the cultural requirements are carried out.

CONCLUSIONS.

The results of the investigation in alfalfa seed production indicate that alfalfa seed yields can be improved by systematic seed selection to develop the inherent traits of seed production in the desirable types; by selecting fields that are adapted to growing alfalfa seed which are not over soaked with subsoil moisture; by seeding thinly in rows to secure a stocky growth and permit intertillage; and by regulating the moisture supply with cultivation and light furrow irrigation to control vegetative growth.

May 29, 1913.



No. 14.—Apparatus for determining soil moisture; a 12 foot jointed soil auger with sleeve to follow the auger bit to remove soil easily; a set of trip scales with tin boxes for samples; a sheet-iron stove-oven for drying samples; a glass door for the oven when set in strong sunshine will heat soil samples 110 to 125 degrees; sufficient to dry samples in three days to air dry samples.

Bulletin 192 November, 1913

The Agricultural Experiment Station

OF THE

Colorado Agricultural College

HOME-MADE CIDER VINEGAR

By WALTER G. SACKETT

PUBLISHED BY THE EXPERIMENT STATION
FORT COLLINS, COLORADO
1913

The Agricultural Experiment Station

FORT COLLINS, COLORADO

THE STATE BOARD OF AGRICULTURE.

		Term Expires
HON. F. E. BROOKS	Colorado Springs,	1915
HON. J. S. CALKINS	Westminster,	1915
HON. J. C. BELL	Montrose,	1917
HON. WILLIAM HARRISON	Clifton,	1917
HON. CHAS. PEARSON	Durango,	1919
HON. R. W. CORWIN	Pueblo,	1919
MRS. J. B. BELFORD	Denver,	1921
HON. A. A. EDWARDS	Fort Collins,	1921

GOVERNOR E. M. AMMONS,
PRESIDENT CHAS. A. LORY, } *Ex-Officio*

L. M. TAYLOR, Secretary J. S. JONES, Treasurer

EXECUTIVE COMMITEEE IN CHARGE

A. A. EDWARDS, *Chairman*

J. S. CALKINS E. M. AMMONS

STATION STAFF

W. P. HEADDEN, A. M., Ph.D.	Chemist
C. P. GILLETTE, M. S., *Entomologist*	Director
G. H. GLOVER, M.S., D.V.M.	Veterinarian
W. G. SACKETT, B.S.	Bacteriologist
ALVIN KEYSER A.M.	Agronomist
J. O. WILLIAMS, B.S.A., *U. S. expert-in-charge*	Horse Breeding
E. P. SANDSTEN, Ph.D.	Horticulturist
B. O. LONGYEAR, B.S.	Botanist
G. E. MORTON, M.L., B.S.A.	Animal Husbandman
E. B. HOUSE, B.S., (E.E.), M.S.	Irrigation Engineer
V. M. CONE, B.S.	Irrigation Investigations
R. E. TRIMBLE B.S.	Assistant Irrigation Investigations
P. K. BLINN, B.S., Rocky Ford	Alfalfa Investigations
EARL DOUGLASS, M.S.	Assistant Chemist
S. ARTHUR JOHNSON, M.S.	Assistant Entomologist
L. C. BRAGG	Assistant in Entomology
J. W. ADAMS, B. S., *Cheyenne Wells*	Agronomy Assistant, Dry Farming
ELWOOD D. ROOD, A.B.	Assistant Chemist
W. W. ROBBINS, M.A.	Assistant Botanist
PAUL S. JONES, B.S.	Assistant Irrigation Investigations
RALPH L. PARSHALL, B.S.	Assistant Irrigation Investigations
JAMES D. BELL, B.S.	Assistant Irrigation Investigations

OFFICERS

CHAS. A. LORY, LL.D.	*President*
C. P. GILLETTE, M.S.	*Director*
L. M. TAYLOR	*Secretary*
MARGARET MURRAY	*Executive Clerk*

HOME-MADE CIDER VINEGAR

By Walter G. Sackett.

In driving through the fruit-growing sections of the United States, one cannot fail to be impressed with the fact that thousands of bushels of apples and other fruit are allowed to go to waste annually just because it is too much trouble to gather it up and make some use of it. This is particularly true during a season when prices are low owing to an overproduction. Such a practice would be condemned, most certainly, by any commercial firm, and rightfully so, as a most extravagant waste and far removed from any principle of scientific management. Talk with any captain of industry, and he will invariably tell you that the largest profits in his business accrue from the complete utilization of the waste products.

Indifference to the needs of others and ignorance of the latent possibilities in this second grade fruit are largely responsible for the fruit grower's short-sightedness. He is apt to forget that there are a few more than ninety-three million others in this country who are dependent upon him for orchard products such as cider, apple butter, jelly and vinegar, all of which could be made from this fruit which he permits to rot unnoticed under the trees. Could he only be shown the roll of greenbacks or catch the glitter of the gold which would represent his actual net return from the complete utilization of this unnecessary waste, rotten apples, wormy apples, green apples and everything would be cleaned up the next time we should pass by his orchard.

In spite of the fact that thousands of gallons of white wine vinegar, which has never been near a wine press, are produced yearly by a purely chemical process from alcohol, there is still a market for good, old-fashioned, apple cider vinegar. The genuine article will never be entirely replaced by the artificial product. But where is the public to obtain pure apple vinegar of acceptable quality? It is not for sale at the local groceries except in sealed bottles at twenty-five cents a quart. Beside it on the shelf may be found the distilled vinegar, artificially colored with caramel, and the white pickling vinegar at fifteen cents a bottle. In bulk the distilled vinegar can be bought for forty cents the gallon with a reliable guarantee behind it for strength and quality. But you say, "Surely you must be mistaken about not being able to get cider vinegar from your grocer in bulk." No, gentle reader, do not be deceived by the stencil mark on the end of the barrel. If, perchance, this particular lot came from a nearby ranch, the odds are in favor of its not being worth carrying home. Do not understand me to speak thus lightly of all home-made vinegar for there is some to be found of splendid quality, but it is the exception. As a rule the storekeeper will apologize to the customer for his farm vinegar, but with that which comes from the wholesale dealer it is different. Most certainly a sad condition, when the first and best vinegar that was ever made came from the farm home! What is more, it cannot be obtained from the farmer or apple grower today for most of them are buying all of the vinegar they use.

What has become of our apple vinegar industry, and why have the merchants turned their attention to the distilled article? The answer to this can be had without pursuing an extensive investigation into the economics of the question. It is simply this—the average run of farm vinegar is so inferior to the distilled product that the merchants cannot afford to handle it. The quality is so variable and the strength is so unreliable that the good housewife has learned through the repeated experience of having her pickles spoil not to ask for cider vinegar.

There is no good reason why this condition of affairs should exist which has resulted in placing a boycott on the farm product, but in the light of the facts as they actually exist, is not the consumer justified in taking this stand? There is no doubt that the synthetic article has come to stay, but this does not mean that genuine apple vinegar is a thing of the past. However, until we are able to produce as good or better vinegar on the farm and in the orchard and can guarantee its quality and strength to be reasonably constant, we have no right to ask or to expect the public to buy an inferior product or to help build up the industry by its patronage.

It is just as easy to make high-grade apple vinegar at home when one understands the different operations and principles involved as it is to make good butter or good bread. If the housewife knew as little about making butter and baking bread as the average farmer or orchardist knows about making vinegar, we should all forsake the staff of life and take refuge in the nearest sanitarium.

Selection of the Apples.

What has been said above concerning second grade fruit for cider and vinegar is not to be construed as meaning rotten, wormy, dirty, or unripe fruit. Nothing is gained by such a practice and often all is lost. In the first place, it is impossible to cover up the flavor of the spoiled apples in the vinegar, and in the second place, when decayed and dirty fruit is employed, it is practically out of the question to control the fermentations in the cider upon which the quality of the finished product depends almost entirely.

There is no reason why apples which have merely been bruised should not be used, and where they are not too badly rotted, the soft portion can be cut out. Children are always glad to have a hand in cider making and this is just where their services will fit in nicely. Remember that many hands make light work and likewise clean, acceptable cider, and you will be surprised to see in how short a time the spoiled parts can be removed from the bushels of otherwise worthless apples.

The importance of washing the apples thoroughly with clean water before they go to the mill to be ground cannot be overestimated. There is bound to be a quantity of soil and dust clinging to the outside, particularly where the orchards lie along a public road and are clean cultivated so that the apples fall on plowed ground. This can be carried out very conveniently in an ordinary washtub, after which the apples should be allowed to drain before they are ground. One is always astonished at the amount of mud in the water after such an operation, even when relatively clean, hand-picked fruit is employed.

Let us see next whether all varieties of apples are equally well suited to cider vinegar making; whether a good cider apple is necessarily a good vinegar apple; and what constituent or constituents of the apple determine its usefulness for these different purposes.

In answer to the first question, it may be said that apples differ very widely in their adaptability to cider and vinegar making; some appear to have been created for this very purpose, while others would not do at all.

Concerning the second point, we find it is quite often the case that an apple which makes an excellent cider to drink would not make good vinegar. This is due to the fact that most tastes demand a cider that is not too sweet and with a slight acidity. Such apple juice would be very apt to make weak vinegar because of the relatively small amount of sugar present.

This reference to sugar brings us to the third item, namely, the important constituents of the apple so far as cider and vinegar are concerned. Several years ago, Dr. Van Slyke of the Geneva, N. Y., Experiment Station, reported a series of analyses of apple juices representing eighty-three different American-grown varieties. He gives the average composition of these juices as follows:

Solids	13.52 per cent
Total sugar as invert sugar	10.91 per cent
Ash	.29 per cent
Fixed acid (malic)	.52 per cent

The sugar is unquestionably the most important of these substances so far as the part which it plays in the making of cider vinegar since the degree of sourness due to the vinegar acid (acetic) is directly proportional to the fermentable sugar present; in other words, all of the acid which was not originally present in the cider as natural apple acid, or malic acid, is produced from the sugar by processes which are soon to be described. Therefore, since from a given amount of sugar just so much acid and no more can be made, we can understand quite readily that for a high grade vinegar of maximum acidity the apple juice containing the most sugar will be the most desirable. The amount of natural acid present in the juice plays an insignificant part in the final acidity of the vinegar, since the small quantity that is present in the apple juice practically all disappears during the change into vinegar. From this it is clear that it is the sugar and not the natural apple acid that is to be considered in cider for vinegar.

Now, as has been stated above, cider for table use is usually more pleasant to drink when it is not too heavy and when the sugar is lower and the acid somewhat higher than the standard for vinegar cider requires.

The composition of the juice of some of our common commercial varieties, especially the sugar content, may be of interest at this time in connection with what has been said with reference to the suitability of different ciders for vinegar making. The analyses which I am submitting are those given by Dr. Van Slyke* for eastern apples.

Table I—Analyses of Apple Juice of Different Varieties of American Apples.

Variety of Apple.	Specific Gravity.	Solids. Per cent.	Equivalent of total sugar in form of invert sugar. Per cent.	Fixed acid as malic. Per cent.
Baldwin	1.072	16.82	15.39	.67
Belleflower	1,061	14.09	12.82	.58
Ben Davis	1.052	12.77	10.60	.46
Ben Davis	1.046	10.69	6.74	.44
Gano	1.046	10.16	8.61	.41
Gano	1.056	13.92	11.32	.41
Grimes Golden	1.070	18.18	14.05	.74
Jonathan	1.056	14.62	11.60	.32
Maiden Blush	1.051	12.70	9.99	.67
Northern Spy	1.052	13.77	9.77	.69
Red Siberian Crab	1.070	17.34	11.83	.97
Rome Beauty	1.048	11.37	8.70	.37
Wealthy	1.057	15.26	11.64	.66
Whitney	1.060	14.16	11.39	.40
Winesap	1.065	16.45	13.34	.58
Yellow Transparent	1.049	11.71	9.76	.87

An examination of the above table shows us that there is a wide variation in the percentage of sugar in the apple juice of different varieties, varying from 6.74 per cent. in one sample of Ben Davis to 15.39 per cent. in the Baldwin; that the quantity of sugar in any given variety may vary as much as 4 per cent. (Ben Davis 6.74-10.60).

The amount of sugar depends upon a number of factors such as soil, climate, culture, variety, and ripeness, unripe and over-ripe apples containing less sugar than ripe ones.

†Browne has shown very clearly the changes that take place in the sugar content of apples at different periods of ripeness:

Table II—Sugar in Baldwin Apple at Different Periods.

Date	Condition.	Equivalent of Total Sugar in Form of Invert Sugar.
Aug. 7, 1899	Very green	8.11
Sept. 13, 1899	Green	10.72
Nov. 15, 1899	Ripe	14.87
Dec. 15, 1899	Over-ripe	14.85

The question is sometimes asked whether the so-called "sweet apples" will make as good vinegar as the tarter varieties. All things being equal, there is no reason why they should not, provided they contain as much sugar as the more acid kinds. This statement may seem somewhat paradoxical, but it should be remembered that

*Van Slyke, L. L., Bulletin 258, Geneva, N. Y., Exp. Sta. "A Study of the Chemistry of Home-Made Cider Vinegar," 1904.

† Browne. Annual Rept. Penn. Dept. Agr. 1899, p. 541.

it is the presence of acid rather than the absence of sugar that makes an apple taste sour. As a matter of fact, some of our very sourest sorts contain as much and more sugar than the sweetest sweet apples. Cider for vinegar should not contain less than 8.5 per cent. of sugar.

Storage of the Cider.

The most satisfactory containers for both cider and vinegar are whisky and brandy barrels. Molasses barrels and old vinegar barrels should be used only when no others are available, and then not until they have been very carefully and thoroughly cleaned. Too much stress cannot be laid upon the necessity of scalding old vinegar barrels with either live steam or boiling water to remove the last trace of the old vinegar. There is, perhaps, no one factor which is responsible for more failures in farm vinegar making than the time-honored but pernicious custom of using old vinegar barrels for sweet cider without even rinsing out the dregs of former years. Mere rinsing is not sufficient. They must be scalded to make them fit for use. If this is not done in such a manner as to kill all of the organisms in the barrel, the probability is that the sweet cider which is put in them subsequently will never make vinegar. The reason for this will be given a little later. In a recent number of a certain farm journal, the following is given under directions for making apple vinegar:

"Get a barrel in which good vinegar has been made and use it, or get some of the scum off of the top of good vinegar and rinse out the new barrels with this as soon as they cool after having been thoroughly washed out with boiling water. Put fresh cider into these barrels."

No procedure more absurd and dangerous to the success of apple vinegar could possibly be undertaken than is contained in this recommendation. In fact, it would be difficult to find a better recipe for vinegar failures than this. Never, under any consideration, put either "mother" or old vinegar into sweet cider. It is never safe to use metallic containers for holding cider even for an interval of a few hours, since the acid of the juice attacks the metal, dissolving a portion of it. Such cider, because of the metal in solution, might produce metallic poisoning in the person drinking it.

The sweet cider as it comes from the press may either be placed at once in barrels, which should not be filled more than two-thirds to three-fourths full, or if one has suitable wooden tubs or vats in a clean, cool place, it may be stored there for twelve to twenty-four hours to permit settling, after which it should be transferred to barrels. The bung should be left out and a loose stopper of cotton batting inserted in the hole to decrease evaporation and prevent dirt from falling in. The barrels should not be tightly stoppered until the vinegar contains at least 4.5 to 5.0 per cent. of acetic acid, at which time they should be filled entirely full and securely bunged. Throughout the entire period of vinegar making, the casks should be placed on their side and not on the end. This gives the cider a larger free surface exposed to the air, which is quite essential to rapid vinegar formation. It may be of some advantage in admitting air to bore a one and one-half inch hole in each end of the barrel along the upper edge. If this is done, the holes should be covered with fine wire gauze or two thicknesses of cheese cloth to exclude small vinegar flies.

The Alcoholic Fermentation.

A few days after the cider is put into the barrels, the characteristic frothing appears at the bung-hole. To use a common expression, "It is beginning to work." This indicates that the alcoholic fermentation, the first step in the vinegar making process, has begun, and the sugar of the apple juice is being converted into alcohol and carbon dioxide gas.

The first of these substances is too well known to need any further comment other than to state that it is this element of "hard" cider that gives it its intoxicating property. With carbon dioxide, many of us are not as well acquainted. It is this gas escaping from the fermenting cider that causes the frothing and likewise the foamy appearance of the bread sponge. It is this gas dissolved in the cider or in the carbonated drinks at the soda-water fountains that imparts to them the characteristic bite or tingle, and upon escaping from the stomach produces that peculiar sensation in the head and nose. Strangely enough, this same gas is the active principle of practically all chemical fire extinguishers.

Now, what is the exciting agent which starts up the fermentation in the bread sponge and in the sweet cider? In both cases it is the same: a microscopic organism, the yeast plant. In the one instance we add a yeast cake to the bread mixture; in the other we either trust to the wild yeasts of the air and the skin of the apples or following the more recent, approved method, we add a yeast cake or a pure culture of a yeast selected especially for this purpose.

To depend upon the wild yeasts of the air to accomplish the fermentation is too uncertain since many of them are able to convert only a small part of the sugar into alcohol, while others act so slowly that they are impracticable. Inasmuch as the percentage of acetic acid in the vinegar depends directly upon the amount of alcohol produced, it is very essential to secure as large a yield of alcohol as possible from the sugar present. This means converting all of the sugar into alcohol in the shortest time possible. The most satisfactory way of doing this is to add one cake of compressed yeast, stirred up in a little cooled, boiled water, to each five gallons of sweet cider. In place of this, one quart of liquid wine yeast, propagated from a pure culture, may be used for each thirty gallons of cider.

During the alcoholic fermentation, the cider should be kept at a temperature of 65 to 80 degrees F. Here is where many make the very serious mistake of putting their fresh cider into a cool cellar where the fermentation takes place entirely too slowly. If the cider is made in the fall, the barrels should be left out of doors for a while on the protected, sunny side of a building and kept warm, unless a regular vinegar-cellar, artificially heated, is at hand.

If yeast is added and the proper temperature is maintained, the alcoholic fermentation should be completed in six weeks to three months in place of seven to ten months as in the old-fashioned way. Experiments along this line have shown that when yeast is added and a temperature of 70 degrees F. is held, the cider at the end of one month contained 7.25 per cent. of alcohol as against .11 per cent. when no yeast was used and the temperature was between 45 and 55 degrees F. Cider kept in a cellar at 45 to 55 degrees with no yeast added required seven months to make 6.79 per cent. of alcohol.

Temperature, alone, is an important factor as shown by an experiment wherein cider to which no yeast was added was held for three months at 70 degrees F. and yielded 6.41 per cent. of alcohol.

There is no question but that the time required for completing the alcoholic fermentation can be reduced at least one-half by adding yeast and by maintaining the proper temperatures. By hastening this operation, the loss of alcohol by evaporation is reduced, and the acetic fermentation can be started that much sooner.

Theoretically, 100 parts of sugar should give 51 parts of alcohol and 49 parts of carbon dioxide gas. This figure has been shown by Browne to be a little high. In actual practice, 45-47 parts of alcohol from 100 parts of sugar is a fair average.

But why not add "mother" or vinegar to sweet cider or put sweet cider into an old vinegar barrel? Here is the reason: We have seen from what has gone before that alcohol is produced from the fermentation of the sugar. We shall soon learn that the acetic acid of the vinegar is formed from this alcohol. Now, in order to obtain the maximum amount of acetic acid, it is necessary to have as much alcohol as possible in the hard cider, and this can be obtained only by the complete conversion of all the sugar into alcohol and carbon dioxide gas. The complete destruction of the sugar can be accomplished only by the uninterrupted action of the yeast, and the presence of "mother" of vinegar by producing acetic acid interferes seriously with this fermentation. The yeast cells are either killed or their useful activity is checked long before all of the sugar has been changed into alcohol. This is the condition of a very large percentage of farm vinegar—just hard cider that will not and never will make vinegar. It means just this:

A small part of the sugar was made into alcohol and this alcohol was at once changed to acetic acid by the "mother" present; this acetic acid killed the yeast so that no more sugar could be changed to alcohol and no more alcohol being found, no more acetic acid could be made by the "mother." We have a weak, worthless something neither vinegar nor hard cider with considerable unfermented sugar still present and incapable of further fermentation because no yeast can develop in the weak acetic acid solution.

The Acetic Acid Fermentation.

The second step in vinegar making is the change of the alcohol of the hard cider into the acetic acid of the finished product. This is accomplished by the acetic acid germ, another microscopic plant still smaller than the yeast. In some peculiar way it is able to bring about a union between the alcohol of the hard cider and the oxygen of the air so that the alcohol is transformed into acetic acid and water.

As soon as the alcoholic fermentation, described in the preceding section, is completed, draw off the clear liquid, being very careful not to disturb the sediment in the barrel. Wash out the barrel thoroughly and replace the hard cider. It is believed that removing this sediment permits the acetic acid to form somewhat more quickly, and furthermore, the sediment may undergo decomposition and impart a disagreeable flavor to the cider. Again, these dregs may harbor living bacteria which either destroy acetic acid or interfere with its formation.

This done, we are now ready to introduce the acetic acid germs. This may be carried out in a number of different ways, but preferably by means of a pure culture of a desirable organism which has been selected because of its ability to produce strong acetic acid and to impart an agreeable flavor to the vinegar. In place of the pure culture starter, one may add two to four quarts of good cider vinegar containing more or less "mother" for each barrel. The introduction of a desirable organism is left to chance in this case. A serious objection to this latter method is that sometimes one introduces foreign organisms with the "mother" which may prove detrimental to the vinegar. The pure culture starter is free from this objection. On the whole, the indiscriminate use of "mother" alone is to be discouraged, since the popular idea of what constitutes "mother" is apt to be wrong. Pure "mother" is made up exclusively of acetic acid bacteria and is recognized as the thin, white, glistening, gelatinous membrane that forms on the surface of vinegar. It seldom becomes one sixteenth of an inch in thickness and should be translucent or white in color. It is entirely distinct from the thick, tough, dark brown, slipping, leathery masses which form in vinegar and are usually regarded as "mothy of vinegar." Such accumulations contain the acetic acid germ, in all probability, but in an impure state. In addition to this organism there may be present yeast cells and numerous bacteria which are positively harmful to the vinegar. Often these growths undergo decomposition and give the vinegar a flavor of rotten oranges. Again the germs present may cause the partial or complete loss of the acid, particularly if the barrels are not full and tightly stoppered. All things taken into consideration, the use of this sort of "mother" is a rather dangerous procedure.

With the acetic fermentation, as with the alcoholic, the higher temperatures favor the changes. Experimental work shows that hard cider to which no acetic acid bacteria were added other than those that came from the air, and kept at 65 degrees F., when six months old, contained 7.03 per cent. of acetic acid, while that held at 55 degrees F. showed only 3.63 per cent.

The addition of some kind of an acetic acid starter, either as a pure culture of the acetic organism or as good vinegar, hastens the fermentation and reduces appreciably the time required for making marketable vinegar.

For most satisfactory results we would recommend using the pure cultures and holding the vinegar at a temperature of 65 to 75 degrees F. Under these conditions, salable vinegar can be obtained in three to six months in place of two to three years, as is often the case. Theoretically, 100 parts of alcohol should give about 130 parts of acetic acid, but in actual practice this will probably fall below 120.

When the acetic acid has reached 4.5 to 5 per cent., fill the barrels as full as possible and cork tightly. In this way, contact of the air with the vinegar is cut off and the acetic acid organisms soon cease their activity. If this is not done and the acetic and other bacteria are allowed to develop indefinitely, there is apt to be a reverse reaction resulting in a partial or complete loss of the acetic acid. Such vinegar is, of course, worthless.

Clarification of Vinegar.

For those who desire an extra fancy product of extraordinary brightness, suitable for bottling, it will be necessary to subject the vinegar to a special process of clarification known as fining. According to Bioletti*, the best results are obtained by using isinglass. This is employed at the rate of from one-half to three-fourths of an ounce of isinglass to each one hundred gallons of vinegar.

"The isinglass is cut into small pieces and soaked for twelve to twenty-four hours in a little water containing acetic or tartaric acid equal in weight to the isinglass used. When thoroughly soft it is then rubbed several times through a fine sieve, gradually adding a little more water until a perfectly fluid liquid is obtained. This fluid is then well mixed with a little vinegar and thoroughly stirred into the cask. With some vinegars it is necessary to add a little tannin, from one-half to one-seventh the amount of the isinglass used. This tannin should be added at least twenty-four hours before the finings.

When the finings have settled and the vinegar is perfectly bright it is ready for bottling."

Pure Cultures for Vinegar Making.

Reference has been made above to the use of pure cultures, both yeast and acetic acid bacteria, for vinegar making. For a little more than one year, the Bacteriological Laboratory of the Colorado Experiment Station has been supplying these at fifty cents (50c) per set, post paid, sufficient for one barrel, to those who care to give them a trial. Full printed directions for their use are included. These cultures have been selected because of certain properties which they possess which make them especially suited to the vinegar industry. No guarantee, either expressed or

* Bioletti, Frederic T., Grape Vinegar, Bull. 227, California Exp. Sta., 1912.

implied, goes with the cultures, since it is not the purpose of the Experiment Station to exploit these products, but rather to distribute them at the cost of production for experimental purposes. Inasmuch as one of the cultures is to be added to the sweet cider, the set should be obtained a few days, not longer, before the cider is to be made.

Requests for cultures should be addressed to the Bacteriological Laboratory, Colorado Experiment Station, Fort Collins, Colorado, and should be accompanied by a remittance of fifty cents (50c).

Directions For Using Pure Cultures in Making Vinegar

Preparation of Yeast Culture.

1. For each barrel of sweet cider, sterilize one two-quart Mason jar by washing thoroughly and boiling for five minutes in clean water.
2. Cover the top of the jar with a single layer of clean muslin or cheese cloth just removed from boiling water and secure it in place by a string tied about the neck of the can.
3. Select 6 or 8 medium sized *ripe* apples; pare and quarter or slice them; add one quart of water and boil till soft; strain liquid through clean cloth while hot into Mason jar, first removing the cloth covering from the top.
4. Make up the volume of liquid to approximately one quart with boiling water; add 4 tablespoonfuls of sugar and replace the cloth immediately.
5. When the liquid has cooled thoroughly, partly remove the cloth covering and add the contents of the culture bottle marked "Yeast." Replace the cloth. Just previous to opening the culture bottle, shake thoroughly and immerse the lip and cork only, ten second in boiling water. Do not touch the lip while removing cork.
6. Keep the jar in subdued light at a temperature of 75 degrees F. to 90 degrees F. After two to four days the foaming characteristic of alcoholic fermentation should appear.
7. After four to six days, add the entire contents of the *yeast* jar to the barrel of freshly made *sweet* cider. *The barrel must not be more than two-thirds full;* it should be placed on its side, and the bung-hole be left open, or, better, plugged loosely with a tuft of clean cotton batting.
8. Keep the barrel at 75 degrees F. to 85 degrees F.

Preparation of Acetic Culture.

1. Three to four weeks after the yeast culture has been added to the cider prepare the Acetic Culture in precisely the same manner as described for the yeast in paragraphs 1 to 6 above. See that all of the culture is removed from the bottle; rinse with a little cooled boiled water if necessary. Do not shake the jar while the culture is developing.
2. By the end of one to two weeks, a white, gelatinous film or membrane should be visible on the surface of the liquid. This is a growth of acetic acid bacteria and constitutes the "Mother of Vinegar."
3. When this acetic membrane is well formed, which will require about two weeks, with a clean sliver of wood, previously dipped into boiling water, remove the membrane from the jar, but do not lay it down; pour the contents of the jar into the barrel of cider, now fermented, to which the yeast was added some five or six weeks before; next drop the sliver with the attached acetic film into the barrel through the bung-hole. The wood will serve to float the acetic membrane on the surface of the hard cider and thereby hasten its development by keeping it in contact with the air.
4. Keep the barrel at 65 degrees F. to 75 degrees F. till the vinegar has formed.
5. When vinegar of satisfactory quality has been obtained, in three to six months, draw off and store at a cool, even temperature in casks which are kept full and tightly bunged.
6. Both of these cultures can be propagated indefinitely by employing a small portion of the jar cultures in the same manner as the original bottle starters.