Issued April 20, 1910.

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF CHEMISTRY—BULLETIN No. 128.
H. W. WILEY, Chief of Bureau.

TRI-LOCAL EXPERIMENTS ON THE INFLUENCE OF ENVIRONMENT ON THE COMPOSITION OF WHEAT.

By

J. A. LE CLERC,
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WITH THE COLLABORATION OF
SHERMAN LEAVITT,
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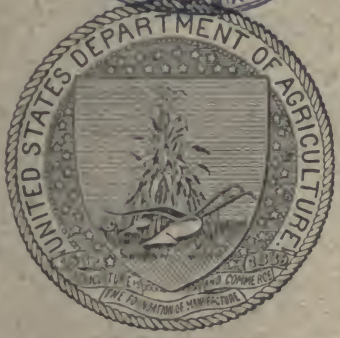

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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF CHEMISTRY,
Washington, D. C., February 1, 1910.

SIR: I have the honor to submit for your approval a manuscript containing the results of an investigation made in this bureau on the influence of environment on the composition of wheat. These trilocal experiments were instituted in 1905 as a special feature of the environmental investigations of cereals, conducted in collaboration with the Office of Grain Investigations, Bureau of Plant Industry, the part taken by the Bureau of Chemistry being in charge of the laboratory of Vegetable-Physiological Chemistry. Definite and important results have been obtained. I recommend that this report of progress be published as Bulletin No. 128 of the Bureau of Chemistry.

Respectfully,

H. W. WILEY,
Chief of Bureau.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

TRI-LOCAL EXPERIMENTS ON THE INFLUENCE OF ENVIRONMENT ON THE COMPOSITION OF WHEAT.

INTRODUCTION.

The variation in the composition of plants of the same species when grown under different conditions has been the subject of much study during the past half century. The term environment as here used includes all the factors of any locality which might tend to influence the growth of the plants, as, for instance, climatic conditions, soil, time of planting and harvesting, method of cultivation and manuring, previous crop and rotation, thickness of seeding, etc. By climatic conditions rain, sunshine, humidity of the atmosphere, temperature, winds, elevation, etc., are meant.

The experiments here recorded were begun in 1905 with the collaboration of the Office of Grain Investigations of the Bureau of Plant Industry, and consisted in growing wheat from the same original seed continuously in each of the three apices of a triangle, for example, (1) in Kansas, Texas, and California, (2) in South Dakota, Kansas, and California. The crop from each apex was then sent to the other two stations and there grown under the same conditions as the continuously grown seed. There were thus three plots at each apex, or station, all from the same original seed; one plot grown continuously at that point, the seed of the other two plots coming from the other points of the triangle. By this interchange of seed it was possible to determine the influence of climate and soil and of the kind of seed on the composition of the crop.

PREVIOUS ENVIRONMENT EXPERIMENTS.

Experiments to test the influence of environment on the composition of cereals were started some twenty or more years ago by Clifford Richardson, under the direction of H. W. Wiley, Chief of the Bureau of Chemistry. These consisted in growing the same varieties of wheat, etc., in different localities, and Richardson concluded from the data obtained that the soil exerted the greatest influence on the composition, that is, that wheat grown in Colorado would have approximately a constant percentage of gluten. In an article

on this subject published in the Yearbook of this Department for 1901, Wiley concluded from a further series of experiments that the length of the growing period was the determining factor in influencing the composition of wheat, a short period of growth and a cool climate producing a high protein content, and vice versa.

As far back as 1857 Laws and Gilbert [a] concluded from their experiments at Rothamsted that the length of the growing period after heading influenced the plumpness and the nitrogen content of the grain; that is, a long period gives a plump grain with a low percentage of nitrogen.

In 1893 Schindler [b] attributed the low percentage of nitrogen in wheat to the long growing period from the time of bloom to ripeness.

Climatic conditions have thus been given the most credit for influencing the composition of plants. Jensen [c] pointed out that the size of the grain decreased as the climate became more "continental" in character, and with the decrease in size the percentage of nitrogen increased. This is shown by the fact that wheats grown in the northwestern part of the United States and in Manitoba, Russia, and Hungary (all having a continental climate, that is, cold and dry winters, rain in late spring and early summer, and high temperature at harvest) contain a high percentage of nitrogen and are hard and almost flinty in character; whereas insular or coast climates produce wheats high in starch, low in gluten, but plump and soft.

In an article on agricultural research, A. D. Hall [d] calls attention to the fact that climate produces greater changes in composition than do fertilizers, soil, date of seeding, etc.

Eckenbrecher [e] grew six varieties of barley in twelve different localities and found that the same variety showed a much larger variation in nitrogen content and in weight per 1,000 grains when grown in the twelve localities than the six varieties did when grown in any one locality; that is, that climatic conditions, or environment, exerted a greater influence than did the seed or even the variety. Yet Hall, in the article just quoted, makes the statement that variety is the chief factor in affecting the composition of plants; that each race or variety possesses characteristics which are modified only to a relatively slight extent by soil, seed, or climate.

Von Seelhorst [f] showed that the more space there was between plants the higher was the percentage of nitrogen and of ash ingredi-

[a] Some Points on the Composition of Wheat, London.
[b] Der Weizen, Berlin.
[c] Exper. Sta. Rec., 1900–1901, **12**: 737.
[d] Science, 1905, **22**: 461.
[e] Wochenschr. Brau., 1907, **24**: 491.
[f] J. Landw., 1899, **47**: 379.

ents generally in cereals. The same author in collaboration with Fresenius [a] showed that increasing moisture, for example, rainfall or irrigation, decreased the nitrogen percentage of oat straw. This is in line with the results of wheat analyses published by Le Clerc in the Yearbook of the U. S. Department of Agriculture for 1906, in which it was shown that a sample of wheat grown on irrigated land gave 11.1 per cent of protein, while the same seed sown on adjoining nonirrigated land produced a crop containing 17.7 per cent of protein. It was also shown that many samples of wheat grown on so-called arid land contained over 3 per cent more protein than the same kind of wheat grown in the more humid regions or under irrigation.

Wohltmann [b] carried on experiments extending over several years on the influence of weather conditions on the composition of cereals and found that rainy, cloudy summers decreased the percentage of nitrogen and that dry, sunny, and warm summers increased the protein content.

Bogdan [c] found that the increase of salt content of alkali soils produced an increase in the nitrogen and the ash of wheat, though the absolute amount of these constituents decreased, due to the fact that the grains were smaller. This, in a certain way, explains the good quality of the rather small grains of wheat grown in southeastern Russia, northwestern America, Hungary, etc., where the soil is rich in soluble salts, especially nitrates. It has, however, generally been assumed that fertilizers influence the yield considerably and to a smaller extent the composition. In like manner, soil is one of the lesser factors affecting the composition of wheat. This is the opinion of Laws and Gilbert, Hall, Wiley, and others; though, of course, a nitrogen-rich soil will yield a crop of a somewhat greater nitrogen content than will a nitrogen-poor soil.

CONDUCT OF THE EXPERIMENTS.

Two samples of wheat were used in the experiments: (a) Kubanka, a durum wheat of the spring variety grown in South Dakota, Kansas, and California; (b) Crimean, a common wheat of the winter variety, grown in Texas, Kansas, and California. The original Kubanka seed used for the South Dakota, Kansas, and California triangle was grown in South Dakota in 1905 and sent to Kansas and California for the 1906 sowing, a sample likewise being grown in South Dakota in 1906. The crop thus obtained at each point in 1906 formed the real starting point of the tri-local experiment. The South Dakota seed of

[a] J. Landw., 1905, **53**: 27.
[b] Centrbl. Agr. Chem., 1906, **35**: 41.
[c] Exper. Sta. Rec., 1901–2, **13**: 329.

1906 was then sown in South Dakota in the spring of 1907, and a sample was sent to Kansas and one to California for the 1907 seeding. Likewise the 1906 Kansas crop was planted again in Kansas and was also sent to South Dakota and California for 1907 seeding. The same course was followed with the California seed. For the 1908 crop, the seed used was that which had been obtained from the continuously grown plot at each station. In exactly the same way a sample of Crimean was grown in Texas, Kansas, and California, the original seed having been grown in Kansas in 1905. Samples of each crop were collected and analyzed for water, ash, phosphoric acid, total nitrogen,[a] alcohol-soluble nitrogen, salt-soluble nitrogen, fat, fiber, pentosans, invert sugar, and cane sugar. In addition to this, the weights per bushel and per 1,000 grains were taken and the character, including the flinty or starchy condition of the grain, observed. The results obtained on the Crimean and Kubanka wheat during the successive years are given in the following table:

Composition of wheat when grown continuously in one locality and when grown in different localities.

CRIMEAN.

Original seed, Kansas, 1905.

Determinations.	Grown in Kansas.	Grown in California.	Grown in Texas.
Protein (per cent)	16.22	.....	.....
Ash (per cent)	2.41	.....	.....
Phosphoric acid (per cent)	1.07	.....	.....
Fat (per cent)	2.23	.....	.....
Fiber (per cent)	2.51	.....	.....
Pentosans (per cent)	8.27	.....	.....
Sugars (per cent)	2.63	.....	.....
Alcohol-soluble nitrogen (per cent)	1.55	.....	.....
Salt-soluble nitrogen (per cent)	.60	.....	.....
Weight per 1,000 grains (grams)	21.05	.....	.....
Weight per bushel (pounds)	56.50	.....	.....
Flinty (per cent)	98.00	.....	.....
1906 crop from Kansas seed of 1905.			
Protein (per cent)	19.13	10.38	12.18
Ash (per cent)	2.05	1.81	1.80
Phosphoric acid (per cent)	1.02	1.05	1.01
Fat (per cent)	1.86	1.94	1.92
Fiber (per cent)	2.50	2.36	1.89
Pentosans (per cent)	8.88	8.07	7.89
Sugars (per cent)	2.35	2.98	2.60
Alcohol-soluble nitrogen (per cent)	1.45	.75	.91
Salt-soluble nitrogen (per cent)	.61	.40	.40
Weight per 1,000 grains (grams)	22.7	34.0	30.8
Weight per bushel (pounds)	58.8	59.4	58.9
Flinty (per cent)	100	36	.....

[a] The nitrogen determinations were made by T. C. Trescot, in charge Nitrogen Section.

Composition of wheat when grown continuously in one locality and when grown in different localities—Continued.

CRIMEAN—Continued.

1907 crop from seed of 1906.

Determinations.	Grown in Kansas.			Grown in California.			Grown in Texas.		
	From Kansas seed.	From California seed.	From Texas seed.	From Kansas seed.	From California seed.	From Texas seed.	From Kansas seed.	From California seed.	From Texas seed.
Protein (per cent)	22.23	22.23	22.81	11.00	11.33	11.37	16.97	18.22	18.21
Ash (per cent)	2.22	2.28	2.21	2.21	2.21	2.26	2.46	2.45	2.46
Phosphoric acid (per cent)	.98	1.01	.99	1.11	1.11	1.11	1.15	1.21	1.13
Fat (per cent)	2.21	2.16	1.92	2.04	2.07	2.08	1.91	1.94	2.05
Fiber (per cent)	2.48	2.46	2.6	2.34	2.25	2.28	1.98	2.36	2.07
Pentosans (per cent)	8.22	8.14	8.23	7.76	7.87	8.09	8.43	8.45	9.00
Sugars (per cent)	2.99	2.9	2.91	4.01	3.88	3.91	2.81	2.17	2.20
Alcohol-soluble nitrogen (per cent)	1.55	1.61	1.45	.77	.78	.77	1.31	1.27	1.46
Salt-soluble nitrogen (per cent)	.79	.79	.82	.49	.53	.51	.68	.67	.63
Weight per 1,000 grains (grams)	20.5	21.3	20.4	33.8	33.3	33	23.6	22.7	23.6
Weight per bushel (pounds)	51.3	51.3	50.7	61.3	61.8	62.3	58.5	57.3	58.6
Flinty (per cent)	100	100	100	50	60	50	98	100	95

1908 crop from seed of 1907.

Protein (per cent)	14.70	Lost.	14.77	11.52	11.75	12.44	Crop failed.
Ash (per cent)	1.84		1.95	1.77	1.65	1.75	
Phosphoric acid (per cent)	1.11		.98	.95	.77	.86	
Fat (per cent)	1.85		2.22	1.80	2.11	2.00	
Fiber (per cent)	3.58		2.36	2.40	2.70	2.92	
Pentosans (per cent)			8.73	8.87	8.65	8.61	
Sugars (per cent)	2.78		2.72	3.87	3.80	3.71	
Alcohol-soluble nitrogen (per cent)	1.05		1.14	.81	.84	.91	
Salt-soluble nitrogen (per cent)	.63		.65	.54	.56	.57	
Weight per 1,000 grains (grams)	28.8		28.4	33	32.8	33.6	
Weight per bushel (pounds)	58.2		58.1	61.7	61.4	60.2	
Flinty (per cent)	99		99	95	95	95	

1909 crop[a] from seed of 1908.

Protein (per cent)				12.11	13.27		
Fat (per cent)				1.92	2.10		
Fiber (per cent)				2.39	2.47		
Pentosans (per cent)				8.67	8.85		
Alcohol-soluble nitrogen (per cent)				.99	.90		
Salt-soluble nitrogen (per cent)				.52	.50		
Weight per 1,000 grains (grams)				33.7	33.2		
Weight per bushel (pounds)				62.7	63.1		
Flinty (per cent)				80	90		

[a] Other 1909 crops not yet received and analytical data incomplete. These few figures are submitted to show the continuation of the same tendencies observed in previous years.

Composition of wheat when grown continuously in one locality and when grown in different localities—Continued.

KUBANKA.

Original seed, South Dakota, 1905.

Determinations.	Grown in Kansas.	Grown in California.	Grown in South Dakota.
Protein (per cent)			13.63
Ash (per cent)			2.11
Phosphoric acid (per cent)			1.05
Fat (per cent)			2.41
Fiber (per cent)			2.24
Pentosans (per cent)			7.80
Sugars (per cent)			2.95
Alcohol-soluble nitrogen (per cent)			.92
Salt-soluble nitrogen (per cent)			.52
Weight per 1,000 grains (grams)			37.2
Weight per bushel (pounds)			62.8
Flinty (per cent)			70

1906 crop from 1905 seed.

Protein (per cent)	19.85	9.68	14.24
Ash (per cent)	1.85	2.12	1.85
Phosphoric acid (per cent)	.93	1.10	1.06
Fat (per cent)	1.97	2.16	2.27
Fiber (per cent)	2.53	2.59	2.60
Pentosans (per cent)	7.61	7.37	6.87
Sugars (per cent)	2.47	2.91	3.53
Alcohol-soluble nitrogen (per cent)	1.47	.69	1.15
Salt-soluble nitrogen (per cent)	.68	.37	.58
Weight per 1,000 grains (grams)	30.4	41.7	35.7
Weight per bushel (pounds)	56.8	60.0	61.3
Flinty (per cent)	100	13	70

1907 crop from 1906 seed.

Determinations.	Grown in Kansas.			Grown in California.			Grown in South Dakota.		
	From Kansas seed.[a]	From California seed.[a]	From South Dakota seed.[a]	From Kansas seed.	From California seed.	From South Dakota seed.	From Kansas seed.	From California seed.	From South Dakota seed.
Protein (per cent)				9.70	9.90	9.05	14.24	13.89	12.87
Ash (per cent)				2.22	2.08	2.11	2.10	2.19	2.09
Phosphoric acid (per cent)				1.06	1.03	1.02	1.03	1.07	1.06
Fat (per cent)				2.69	2.58	2.49	2.73	2.72	2.48
Fiber (per cent)				2.36	2.59	2.24	2.45	2.50	2.29
Pentosans (per cent)				8.51	6.89	6.97	6.86	7.20	6.35
Sugars (per cent)				4.81	4.83	4.34	3.63	3.73	3.63
Alcohol-soluble nitrogen (per cent)				.62	.67	.54	1.05	.99	.88
Salt-soluble nitrogen (per cent)				.43	.49	.43	.50	.49	.42
Weight per 1,000 grains (grams)				43.8	41.4	39.1	38.7	37.9	39.4
Weight per bushel (pounds)				61.8	62.0	61.5	62.2	63.0	63.7
Flinty (per cent)				22	29	12	99	93	88

[a] Crop failed.

Composition of wheat when grown continuously in one locality and when grown in different localities—Continued.

KUBANKA—Continued.

1908 crop from 1907 seed.

Determinations.	Grown in Kansas.			Grown in California.			Grown in South Dakota.		
	From Kansas seed.	From California seed.	From South Dakota seed.	From Kansas seed.	From California seed.	From South Dakota seed.	From Kansas seed.	From California seed.	From South Dakota seed.
Protein (per cent)	14.88	14.56	15.01	15.93	14.71	15.25	17.10	16.60	16.53
Ash (per cent)	1.97	2.05	1.97	1.65	1.61	1.73	2.28	2.19	2.03
Phosphoric acid (per cent)	1.03	1.03	1.00	.79	.70	.81	1.26	1.16	1.16
Fat (per cent)	2.44	2.23	1.94	2.75	2.47	2.66	1.97	2.03	2.28
Fiber (per cent)	2.45	2.70	2.61	3.19	2.50	3.34	2.53	2.57	2.61
Pentosans (per cent)	8.26	8.00	7.99	8.14	7.47	7.65	8.31	8.53	7.15
Sugars (per cent)	3.35	3.43	3.28	5.01	4.81	4.86	4.20	4.03	4.32
Alcohol-soluble nitrogen (per cent)	.92	.86	.86	1.20	.....	1.20	1.20	1.11	1.13
Salt-soluble nitrogen (per cent)	.66	.62	.58	.63	.63	.61	.69	.58	.61
Weight per 1,000 grains (grams)	30.8	30.5	31.8	37.7	44.8	36.3	25.8	24.9	29.8
Weight per bushel (pounds)	57.8	55.2	53.8	60.0	61.2	59.4	59.0	57.8	60.2
Flinty (per cent)	100	96	98	100	100	100	100	100	100

1909 crop[a] from 1908 seed.

Protein (per cent)	.....	.....	.....	14.90	14.30	14.35	.....	.....	.....
Fat (per cent)	.....	.....	.....	2.41	2.13	2.43	.....	.....	.....
Fiber (per cent)	.....	.....	.....	2.35	2.38	2.24	.....	.....	.....
Pentosans (per cent)	.....	.....	.....	7.53	7.63	7.28	.....	.....	.....
Alcohol-soluble nitrogen (per cent)	.....	.....	.....	1.15	1.09	1.10	.....	.....	.....
Salt-soluble nitrogen (per cent)	.....	.....	.....	.63	.58	.59	.....	.....	.....
Weight per 1,000 grains (grams)	.....	.....	.....	46.5	45.4	46.0	.....	.....	.....
Weight per bushel (pounds)	.....	.....	.....	64.1	64.3	65.0	.....	.....	.....
Flinty (per cent)	.....	.....	.....	99	98	98	.....	.....	.....

[a] Other 1909 crops not yet received and analytical data are incomplete. These figures are submitted to show the continuation of the same tendencies observed in previous years.

VARIATIONS IN NITROGEN CONTENT.

The greatest variations shown by the tabulated data are in the percentage of nitrogen, the weight per 1,000 grains and per bushel, the percentage of starchy grains, and possibly the percentage of sugar, though all constituents varied appreciably. As protein is the most important constituent of wheat, its variation will be discussed.

In the case of the Crimean wheat, the percentage of protein in the original Kansas seed grown in 1905 was 16.2; in 1906 the percentage of protein at Kansas was 19.1; at California, 10.4; and at Texas, 12.2, a difference of over 8 per cent due entirely to the change of environment. In 1907 all three plots of wheat grown in Kansas from Kansas 1906 seed, California 1906 seed, and Texas 1906 seed gave the following percentages of protein—22.2, 22.2, 22.8, respectively; those grown in Texas, 1907, from Texas 1906 seed, Kansas 1906 seed, and California 1906 seed gave 18.2 per cent, 17 per cent, and 18.2 per cent,

respectively; and those grown in California in 1907 from California 1906 seed, Kansas 1906 seed, and Texas 1906 seed gave 11.3 per cent, 11 per cent, and 11.4 per cent, respectively. It will thus be seen that apparently the crop is not at all influenced by the composition of the seed nor by the origin of the same; that is, California seed of 1906 with 10.4 per cent of protein gave a crop containing 22.2 per cent in Kansas in 1907, an increase of 120 per cent; moreover, Texas seed with 12.2 per cent of protein gave a crop containing 22.8 per cent in Kansas; and Kansas 1906 seed with 19.1 per cent of protein yielded a crop with 22.2 per cent when again grown in Kansas in 1907. In other words, all the grain grown in the three plots in Kansas from California, from Texas, and from Kansas seed, whose protein content varied from 10.4 to 19.1 per cent, produced a crop of identical protein content and of practically the same composition generally, the weight per 1,000 grains, the weight per bushel, and the character of the grain being the same. In the same way when the Kansas seed with 19.1 per cent of protein, the Texas seed with 12.2 per cent of protein, and the California seed with 10.4 per cent of protein were all grown in California, the composition of the grain from the three plots was almost identical, namely, 11 per cent, 11.4 per cent, and 11.3 per cent of protein. The other constituents and the physical characteristics were likewise practically identical in all three samples. The three samples grown in Texas from Kansas seed, from California seed, and from Texas seed also showed the same composition and physical appearance, although, as previously shown, the seed producing them varied widely both physically and chemically. Similar results were obtained from Kubanka wheat grown in South Dakota, Kansas, and California, and such was also the case for both Crimean and Kubanka seed at the several stations during 1908.

Wheats of the same variety when grown in the same locality and under the same conditions are, therefore, seen to vary but little in composition, although coming from seed differing widely in physical and chemical characteristics. These results are corroborative of Eckenbrecher's work with barley and are entirely at variance with Hall's statement, previously quoted, namely, that "each race or variety possesses qualities which are modified only to a slight degree by seed, soil, or climate."

EFFECT OF ACCLIMATION.

Inasmuch as the percentage of protein is somewhat higher in the crop grown in Kansas or South Dakota from California seed than the crop grown continuously in Kansas or South Dakota, it may possibly be claimed that in general seed, taken from a locality with a long period of growth, such as California, to a locality with a shorter

growing period, such as South Dakota, will be higher in protein than the acclimated seed, or vice versa, as has been suggested by Thatcher, of the Washington Agricultural Experiment Station. For example, the California seed when taken to South Dakota gives a crop with 13.9 per cent of protein, while the acclimated South Dakota seed gives one with 12.9. On the other hand, South Dakota seed taken to California yielded a grain with 9.1 per cent of protein, whereas the acclimated California seed gave 9.9 per cent. These results show a slight difference, thus corroborating this theory to a certain extent. The differences are, however, so small and the experiment has been of such short duration that this theory needs still further corroboration before it can be accepted absolutely.

Following is the comparative composition of the California seed taken to South Dakota and Kansas, and the South Dakota and Kansas acclimated seed, and vice versa:

Composition of acclimated and nonacclimated seed from the same source.

KUBANKA.

Source of seed.	Place of growth.	Year of growth.	Protein.	Sugars.	Weight per 1,000 grains.	Weight per bushel.	Flinty.
			Per ct.	*Per ct.*	*Grams.*	*Pounds.*	*Per ct.*
South Dakota, 1906	California [a]	1907	9.1	4.4	39.1	61.5	12
California, 1906	do. [a]	1907	9.9	4.9	41.4	62.0	29
South Dakota, 1907	do. [b]	1908	15.2	4.9	36.3	59.4	100
California, 1907	do. [b]	1908	14.7	4.8	44.8	61.2	100
California, 1906	South Dakota	1907	13.9	3.8	37.9	63.0	98
South Dakota, 1906	do	1907	12.9	3.7	39.4	63.7	88
California, 1907	do	1908	16.6	4.0	24.9	57.8	100
South Dakota, 1907	do	1908	16.5	4.3	29.8	60.2	100

CRIMEAN.

Kansas, 1906	California [a]	1907	11.0	4.0	33.8	61.3	50
California, 1906	do. [a]	1907	11.3	3.9	33.3	61.8	60
Kansas, 1907	do. [b]	1908	11.5	3.9	33.0	61.7	95
California, 1907	do. [b]	1908	11.8	3.8	32.8	61.4	95
California, 1906	Kansas	1907	22.2	2.9	21.3	51.3	100
Kansas, 1906	do	1907	22.2	3.0	20.5	51.3	100
Texas, 1907 [c]	do	1908	14.8	2.7	28.4	58.1	99
Kansas, 1907	do	1908	14.7	2.8	28.8	58.2	99

[a] Grown at Yuba, Cal. [b] Grown at Davis, Cal. [c] Crop from California seed list.

It will thus be seen that in each case when California seed is sent either to South Dakota or to Kansas the percentage of protein is somewhat (though very little) increased over that grown continuously in South Dakota or Kansas. On the other hand, when wheats grown in South Dakota or Kansas are sent to California the reverse is true.

INFLUENCE OF HEREDITY.

Too much has been taken for granted regarding the influence of heredity in plants. Without detracting from the power which heredity may exert in the progeny of seed, the results here produced

show that plants are to a very large extent influenced by their environment. Seeds grown in Kansas are quite different in chemical composition and in physical appearance from the same variety grown in another locality having different climatic conditions. That the composition of the seed has very little to do with the composition of the crop, especially when that seed has been sown in another locality having different climatic conditions, is fully demonstrated by the data given in the tables where it is shown, for example, that the California and Kansas grown wheats give crops of practically the same composition when grown side by side in California or when grown side by side in Kansas. It is seen that, notwithstanding the fact that three plots were grown in Kansas, California, and Texas or South Dakota from seed of the same variety which, because it had been grown in different environments, had acquired widely different chemical and physical characteristics, the resulting crops from the three plots in each station were identical.

SLIGHT INFLUENCE OF THE SOIL.

That the soil has also only a relatively small influence is shown in the table below:

Effect of the soil on the composition of wheat.

Determinations.	Kubanka wheat. Grown in South Dakota continuously.				Crimean wheat. Grown in Kansas continuously.			
	1905.	1906.	1907.	1908.	1905.	1906.	1907.	1908.
Protein.....per cent..	13.1	14.2	12.9	14.8	16.2	19.2	22.2	14.5
Weight per 1,000 grains.....grams..	37.2	35.7	39.4	29.8	21.1	22.7	20.5	28.4
Weight per bushel.....pounds..	62.8	61.3	63.7	60.2	56.5	58.8	51.3	58.1
Flinty.....per cent..	70.0	70.0	88.0	100.0	98.0	100.0	100.0	99.0

When it is considered that the Crimean wheat was grown on the same piece of land in Hays, Kans., in 1905, 1906, 1907, and 1908, and that the percentage of protein varied from 22.2 to 14.5 during those years, it becomes apparent that it is not so much the soil as it is the climatic conditions in general which affect the composition and physical appearance of such a crop. This is further illustrated by the fact that the year of extreme high protein content (1907) was a very dry one, while during the year of low protein (1908) a relatively large amount of rain fell.

VARIATIONS IN PHYSICAL APPEARANCE.

The next most notable difference is rather a physical one; that is, the appearance of the grain. Seed grown in Kansas or South Dakota show either no starchy grains or not more than 12 per cent at most; yet when they are transported to California and grown there the following year, the percentage of starchy grains increases to 50 and 88

per cent, respectively. Such wheat grown in California the previous year, and already somewhat acclimated, gave only 40 and 71 per cent of starchy grains, respectively, thus possibly showing in another way that wheats taken from a continental climate to a coast climate will show a lower value or greater deterioration the first year than seed acclimated to a coast climate. That the reverse is just as true when wheat grown in a coast climate is transported to a continental climate is shown by the following illustration: The California seed with 87 per cent of starchy grains gave a crop in South Dakota with only 2 per cent of starchy grains, whereas the seed grown continuously in South Dakota had 12 per cent. The California Crimean wheat of 1906, with 64 per cent of starchy grains, gave a crop in Kansas with absolutely no appearance of starchy grains. It was, in fact, identical with the seed grown continuously in Kansas. These figures again show what a tremendous factor climate is. The results further show that the white spots on grains are not necessarily hereditary nor, in fact, are any of the characteristics mentioned. They appear rather to be influenced almost altogether by climatic conditions prevailing during the growing period or even previous to the planting of the crop. In California the weights per 1,000 grains and per bushel are much larger than in Kansas, but the percentages of protein and of flinty kernels are much less. The percentage of sugars seems to increase slightly when Kansas and South Dakota seed are grown in California. There is not much, if any, difference, however, in the percentage of fat, fiber, pentosans, and ash. Similar differences are observed between California and Texas, and Kansas and Texas, though in these cases the differences are not so large, Texas being somewhat intermediate.

RELATION BETWEEN ABSOLUTE WEIGHT AND PERCENTAGE OF PROTEIN IN THE GRAIN.

Regarding the relative amount of protein in large and small grains, it is sometimes assumed that the large berries though low in percentage of nitrogen yet contain as much nitrogen per berry as do the smaller grains, which have a higher percentage of nitrogen. That such is not always the case will be seen when these data are carefully examined. In the table showing the results on Crimean wheat it is seen that the Kansas 1907 crop contained 22.2 per cent of protein, with a weight per 1,000 grains of 20.5 grams and per bushel of 51.3 pounds, whereas the California 1907 crop had 11.3 per cent of protein and weighed 33.3 grams per 1,000 grains and 61.8 pounds per bushel. From this it is seen that 1,000 grains of Kansas grown wheat contained 4.6 grams of protein compared to 3.7 grams of protein for 1,000 grains of California wheat; 1,000 of the smaller Kansas grains contained 20 per cent more protein than 1,000 large California

grains. In the same way, 1 bushel of Kansas 1907 wheat contained 11.3 pounds of protein while 1 bushel of the California grain contained 6.9 pounds of protein.

INFLUENCE OF LOCAL WEATHER CONDITIONS.

When wheats are grown continuously in any locality the percentage composition and the physical appearance and characteristics are very similar, the only differences being those due to varying weather conditions from year to year. These differences in composition are, however, never so large as those found between two localities, such as Kansas and California. In Kansas the percentage of protein varied from 16.2 in 1905 to 22.2 in 1907, due to the excessive drought in 1907, falling to 14.7 in 1908, which was a comparatively wet year. The drought of 1907 caused the crop to shrivel, the weight per bushel decreasing from 58.8 pounds in 1906 to 51.3 in 1907. Moreover, the same change took place in every sample of wheat grown in Kansas, whether from Kansas, from California, or from Texas seed. The difference in composition, especially in protein content, between crops of the same variety grown in different localities showed greater variations than those just discussed, as will be seen from the table, where it is shown that Kansas wheat contained as much as 22.8 per cent of protein while the California wheat contained only 11.7 per cent.

CONCLUSIONS.

From the data obtained, therefore, the following conclusions may be drawn:

Wheat of the same variety obtained from different sources and possessing widely different chemical and physical characteristics, when grown side by side in one locality, yields crops which are almost the same in appearance and in composition. Wheat of any one variety, from any one source, and absolutely alike in chemical and physical characteristics, when grown in different localities, possessing different climatic conditions, yields crops of very widely different appearance and very different in chemical composition. These differences are due for the most part to climatic conditions prevailing at the time of growth. The results so far obtained would seem to indicate that the soil and seed play a relatively small part in influencing the composition of crops. The practice of trying to improve crops in one locality, which crops are to be grown in another locality of widely different climatic conditions, should be discouraged. Crops should be improved in the locality in which they are intended to be grown, or the seed should be selected from a region which has similar climatic conditions.