U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 187.

B. T. GALLOWAY, *Chief of Bureau.*

A STUDY OF CULTIVATION METHODS AND CROP ROTATIONS FOR THE GREAT PLAINS AREA.

BY

E. C. CHILCOTT,

AGRICULTURIST IN CHARGE, ASSISTED BY MEMBERS OF THE FIELD STAFF OF THE OFFICE OF DRY-LAND AGRICULTURE INVESTIGATIONS.

ISSUED NOVEMBER 5, 1910.

WASHINGTON:
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1910.

A TYPICAL VIEW OF EXPERIMENTAL FIELD PLATS.

(Photographed at the Substation at Edgeley, N. Dak., August 1, 1908, by Dr. H. L. Shantz.)

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., June 11, 1910.

Sir: I have the honor to transmit herewith a paper entitled "A Study of Cultivation Methods and Crop Rotations for the Great Plains Area," by Prof. E. C. Chilcott, Agriculturist in Charge of Dry-Land Agriculture Investigations, assisted by the members of his field staff. These men have not only attended to the details of the field experiments and prepared the notes for the permanent records, but they have also assisted in the preparation of these data for publication.

The paper embodies the results of four years' experiments in crop rotation and cultivation methods conducted at eleven stations in the Great Plains area. These investigations are of such a nature as to require a long term of years before final conclusions can be reached. It is believed, however, that in view of the urgent demand for information concerning these problems which is constantly being made upon this Bureau, these results and tentative conclusions and suggestions should be made public at this time.

I recommend that this paper be published as Bulletin No. 187 of the special series of this Bureau.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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Fig. 1. Map of the Great Plains area, showing the location of the experiment stations and the annual and seasonal rainfall 11

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A STUDY OF CULTIVATION METHODS AND CROP ROTATIONS FOR THE GREAT PLAINS AREA.

INTRODUCTION.

The Office of Dry-Land Agriculture Investigations of the Bureau of Plant Industry has been carrying on investigations in dry-land agriculture in the Great Plains area since the spring of 1906. A large amount of data has accumulated. Urgent demands are being made by settlers, actual and prospective, for information concerning the best methods of farming in the Great Plains. It therefore seems desirable at this time to give publicity to such of these facts and figures as have a direct bearing upon this subject. It is not claimed that sufficient data have yet been accumulated to form the basis for final conclusions. It is believed, however, that these results are of sufficient importance to deserve careful consideration and that they throw some strong light upon the much controverted questions of summer tillage, continuous cropping, and crop rotation. It is hoped that the tentative conclusions drawn and the suggestions made may be useful.

QUESTIONS ASKED.

These investigations were undertaken to answer the following main questions, besides many subsidiary ones:

(1) How can the largest average yields of four staple crops—corn, spring wheat, oats, and barley—through a long series of years be obtained: (*a*) By raising the same crop continuously by ordinary methods of culture now in practice; (*b*) by continuous cropping with the same crop, using the most approved methods of cultivation for moisture conservation; or (*c*) by alternate cropping and summer tillage by the most approved methods?

(2) Do moisture conservation methods pay where continuous cropping to the same crop is practiced?

(3) Do alternate cropping and summer tillage pay where the same crop is raised each alternate year?

(4) How do simple 3-year crop rotations compare with continuous cropping, both with and without conservation methods, and with alternate cropping and summer tillage in the profitable production of crops?

(5) What 3-year rotation has given the best results?

(6) Which gives the best results, fall plowing or spring plowing?

(7) Should corn stubble be plowed or disked without plowing as a preparation for spring wheat?

(8) Can summer tillage be profitably introduced into a rotation system?

(9) Can any system of crop rotation be devised, involving the use of perennial grasses or legumes, or biennial legumes, which will be adapted to conditions in the Great Plains area?

(10) Can green manuring be profitably substituted for summer tillage, thereby conserving both the moisture and the organic matter of the soil?

(11) What is the best method of introducing winter wheat into a rotation?

ANSWERS OBTAINED.

The following tentative answers have been obtained from the investigations. They are likely to be modified by future results. They are, however, based upon the best evidence obtainable in the present state of our knowledge:

(1) The average yields in bushels per acre from the three methods of tillage have been as follows:

Average production per acre of wheat, oats, and barley.

Methods of tillage.	Wheat.	Oats.	Barley.
Continuous cropping, ordinary methods	17.4	30.2	21.1
Continuous cropping, moisture conservation	16.5	30.5	22.9
Alternate cropping and summer tillage	22.5	44.1	30.7

(See Tables I, II, and III, pp. 16 and 17.)

(2) The average results of moisture conservation methods have not proved profitable as compared with ordinary methods where continuous cropping has been practiced. (See paragraph 2 of Conclusions, p. 68.)

(3) The average results of alternate cropping and summer tillage have not proved profitable, as compared with continuous cropping with ordinary methods. (See paragraph 1 of Conclusions, p. 67.)

(4) Simple 3-year rotations of corn, wheat, and oats, or corn, barley, and oats have proved more profitable than continuous cropping or alternate cropping with any one of these four crops. (See paragraph 3 of Conclusions, p. 68.)

(5) Corn on either fall or spring plowing, followed by either wheat or barley on disked corn stubble, followed by oats on early fall plowing has given best average results. (See paragraph 4 of Conclusions, p. 68.)

(6) Fall plowing has given slightly better average results than spring plowing. (See paragraph 11 of Conclusions, p. 69.)

(7) Disking corn stubble, without plowing, has given better results than plowing as a preparation for spring wheat. (See paragraph 10 of Conclusions, p. 69.)

(8) Summer tillage has not given as good average results when used in a rotation as a preparation for spring wheat or oats as has a properly cultivated corn crop. It seems probable that it will be found advisable to occasionally introduce summer tillage into a rotation as a preparation for winter wheat. (See paragraph 9 of Conclusions, p. 68.)

(9) The evidence so far obtained leads to the conclusion that a 5 or 6 year rotation of corn, winter or spring wheat, brome-grass (three years), oats, barley, emmer, or

wheat will give better average results than any other system so far tried. There are, however, undoubtedly many localities where the growing of perennial grasses is so uncertain as to make the adoption of this rotation inadvisable. It is possible that it may be found practicable to substitute alfalfa for brome-grass in some localities. Some other perennial grass or legume may be found that will prove adapted to the conditions in some parts of the Great Plains. In some localities it may be found practicable to shorten the rotation to four years and substitute red clover for the brome-grass. (See paragraphs 14, 15, and 16 of Conclusions, p. 70.)

(10) Where perennial grass or legumes can not be successfully grown, it will undoubtedly be found profitable to resort to green manuring. Winter rye has so far given the best results. Canada field peas and common sweet clover (*Melilotus alba*) have also given good results, but the fact that they do not reach a sufficient stage of growth to plow under before the end of the June rains is against them. On the other hand, being nitrogen gatherers they will undoubtedly produce a higher quality of organic matter in the soil than rye, although the quantity may be less. (See paragraph 18 of Conclusions, p. 70.)

(11) Winter wheat should be grown to a greater or less extent wherever it is found possible to do so, as it possesses some great advantages over spring wheat. It can be fitted into any rotation adapted to the Great Plains. In some localities it may prove profitable to summer till the land as a preparation for winter wheat, as it undoubtedly responds to this preparation to a much greater extent than do spring-sown grains. Green manuring may, however, be used instead of summer tillage. (See paragraph 10 of Conclusions, p. 69.)

As will be seen from the foregoing answers, our investigations lead strongly to the conclusion that the devising of systems of rotation adapted to local conditions is of greater importance than tillage methods. It is not to be inferred, however, that the subject of proper tillage can be safely neglected. Such is far from being the case. Tillage methods must be carefully studied and intelligently practiced. But both the study and the practice must be carried on in connection with crop rotation and with a view to bringing about the best possible physical and biological condition of the soil. In order to do this intelligently, the requirements of the crops to be grown, the local peculiarities of the soil, and the climate must be the main factors considered. No hard and fast rules can be established. Each farmer must study his soil, his climate, and his crop requirements, and must adopt such systems of tillage as experience and observation have shown to bring the desired results under the peculiar combinations of conditions which prevail at the time and place and are most likely to exist during the growing period of the crop. Nor should the ultimate effect upon the soil of any system of tillage be neglected. Favorable physical, chemical, and biological conditions of the soil should at least be maintained and, if possible, improved from year to year.

The establishment of a system of crop rotations presents many difficulties, particularly in a new country. Among these difficulties is the need of immediate cash returns from the crops grown. Wheat is not only the most staple cash crop, but on the basis of the prices which have prevailed for the last ten years and the average yields obtained in the Great Plains it has also been the most profitable when immediate cash returns alone have been considered. This has been a strong incentive to adopting a one-crop system of wheat grown continuously on the same land, year after year, with sometimes an occasional summer fallow to clean the land of weeds.

It must be admitted that this system has often brought in larger immediate cash returns than could be obtained from a simple diversification of crops. Mere diversification without any systematic rotation often means simply devoting a portion of the farm to the growing of some less profitable crop in the place of wheat. There is an advantage in growing several different kinds of crops, all of which are not as likely to suffer loss from either poor yields or low prices as would a single crop of any one kind. Such a system can not, however, be defended unless these substituted crops can be fed or otherwise disposed of in such a way as to bring more than the relative market prices, as compared with wheat, which have prevailed in the Great Plains for the last ten years. But our investigations have shown that with a properly planned rotation of corn, wheat, oats, and barley the average farm value per acre for all the crops will be greater than that obtained from growing wheat continuously. Such a system must, of course, involve proper methods of soil preparation, as well as rotation of crops. If in addition to the increased yields obtainable under a rotation system the coarse grains can be fed on the farm, the net profits from this system will be further increased. If by returning the manure produced from the coarse grain, fodder, and hay crops to the land the soil can be maintained in better chemical, physical, and biological condition, it will not only further increase the yields in favorable years, but will also decrease the danger from drought in unfavorable ones. Nor is this all the advantage to be gained from crop rotation and its concomitant feature of stock raising. Under such a system the labor of the farm is more evenly distributed throughout the year, thus requiring less expense for extra laborers at harvest time and better utilization of teams and tools. And last, and perhaps most important of all, is the fact that a farm operated on such a system affords greater incentives and opportunities for true home building. It is believed that all of these desirable objects can be attained by adopting systems of rotation adapted to local conditions. It can, therefore, be stated with a reasonable degree of certainty that crop rotation is the major factor in the great problem of dry-land agriculture in the Great Plains area, with cultivation methods as an important minor factor.

These investigations have been carried on at Judith Basin, Mont.; Dickinson and Edgeley, N. Dak.; Highmore and Bellefourche, S.

Dak.; North Platte, Nebr.; Akron, Colo.; Hays and Garden City, Kans.; Amarillo and Dalhart, Tex. The locations of these stations are shown on the accompanying map, figure 1. Results have been obtained for three years from Edgeley and North Platte; for two years from Amarillo, Highmore, and Dickinson; and for one year

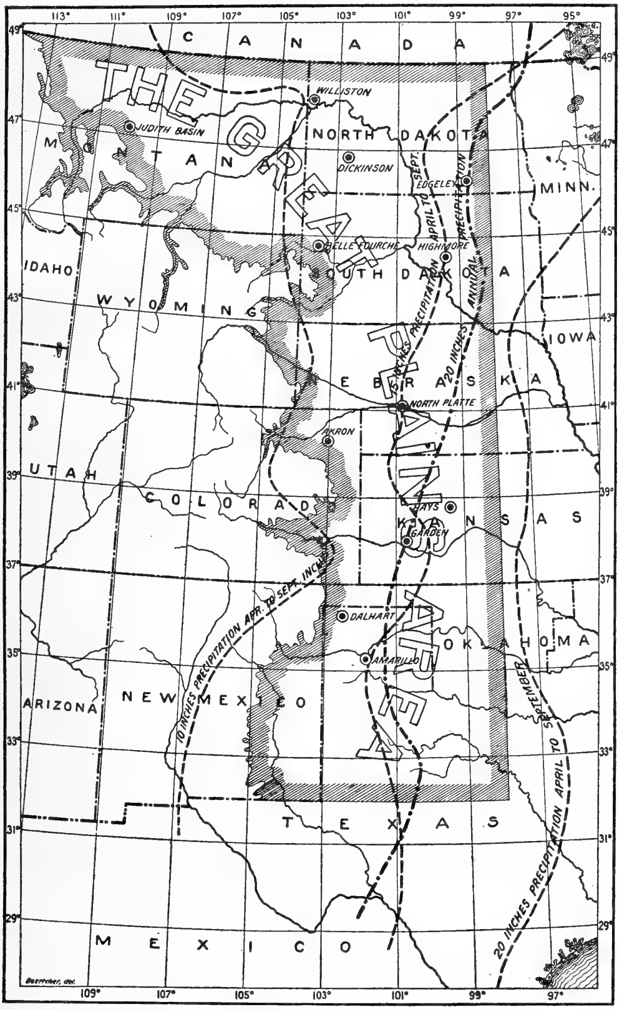

FIG. 1.—Map of the Great Plains area, showing the location of the experiment stations and the annual and seasonal rainfall.

each from the remaining stations. They show, therefore, the results of eighteen comparative tests, involving more than a thousand plats located at eleven stations widely distributed throughout the Great Plains area, and should be fairly representative of the area.

The view of field plats at the substation at Edgeley, N. Dak. (see frontispiece), where these investigations are carried on in cooperation with the North Dakota Agricultural Experiment Station, is typical of all the field stations. From 120 to 150 one-tenth acre plats are used at each station. These plats are accurately and permanently laid out and marked and great care is exercised to obtain exact yields, comparable to common field conditions.

It would be practically impossible to carry on these investigations without the hearty cooperation of the state experiment stations of Montana, North Dakota, Nebraska, and Kansas.

The Physical Laboratory and the Offices of Western Agricultural Extension, Alkali and Drought Resistant Plant-Breeding Investigations, Grain Investigations, Forage-Crop Investigations, and Soil-Bacteriology Investigations, all of the Bureau of Plant Industry, have cooperated and rendered valuable assistance along their respective lines. None of the results of their investigations have, however, been incorporated in this publication. The interrelation of these several lines of investigations with those of dry-land agriculture will be discussed in future publications.

THE SUFFICIENCY OF THE DATA SUBMITTED.

As the general plans of the investigations in dry-land agriculture, of which those herein described are a part, have been fully set forth in a previous publication,[a] no detailed description will here be attempted. Suffice it to say that a member of the scientific staff of this office is in constant attendance at each of the several stations mentioned during the entire growing and harvesting season. He attends personally to all the field operations, the measuring and weighing of products, etc., and keeps accurate notes of the work.[b] The work is in close cooperation with the Physical Laboratory of this

[a] Yearbook of the Department of Agriculture for 1907, pp. 451–468.

[b] The field work at the several stations is under the immediate supervision, respectively, of the following-named members of the scientific staff of this office:

John S. Cole, Traveling Field Assistant.

J. E. Payne, Superintendent Akron, Colo., station.

F. L. Kennard, Superintendent Dalhart, Tex., station.

J. M. Stephens, Superintendent Judith Basin, Mont., station.

O. J. Grace, Acting Superintendent Dickinson, N. Dak., station.

W. W. Burr, detailed to North Platte, Nebr., station.

E. F. Chilcott, detailed to Amarillo, Tex., station.

A. L. Hallsted, detailed to Hays, Kans., station.

H. R. Reed, detailed to Garden City, Kans., station.

O. R. Mathews, detailed from the Office of Western Agricultural Extension, Bureau of Plant Industry, to Bellefourche, S. Dak., station.

C. H. Plath, detailed to Edgeley, N. Dak., station.

J. C. Thysell, detailed to Dickinson, N. Dak., station.

W. O. Whitcomb, detailed from the Office of Western Agricultural Extension, Bureau of Plant Industry, to Williston, N. Dak., station.

Bureau, which keeps a record of the physical and meteorological conditions at each station. Several other offices of this Bureau are also in cooperation at most of the stations. The Agriculturist in Charge of Dry-Land Agriculture Investigations and his traveling field assistant make frequent visits to the field stations during the growing season for the purpose of inspecting the work. Other cooperating heads of offices also visit these stations at frequent intervals.

The work of seven of the eleven stations herein mentioned was conducted in close cooperation with the state experiment stations of Montana, North and South Dakota, Nebraska, and Kansas, respectively, and representatives of these stations are constantly in close touch with the field work at their respective localities. Very full permanent records of all the work are kept, both at the field stations and at the central office at Washington, D. C. Both these records and the field work itself are open to the inspection of the public at all times, and such inspection is invited. The experiment stations mentioned use these records in the preparation of publications of their respective stations. With so many trained investigators actively interested in the elimination of all sources of error or inaccuracy, it seems reasonable to claim that the data herein presented are trustworthy and that, covering as they do so extensive an area, they constitute as reliable a basis for safe conclusion concerning the methods of dry-land agriculture in the Great Plains area as can now be found. It is only by a further extension of these investigations that a more reliable basis can be established.

All of the eleven stations from which the data are collected are located within what is generally known as the semiarid area. The meteorological records and the crop yields under ordinary methods indicate, however, that in thirteen seasons out of eighteen the weather conditions were sufficiently favorable to give some basis for the suspicion that these thirteen experiments were conducted under humid rather than semiarid conditions and that they could not therefore be used as a safe basis for conclusions relative to semiarid conditions. When, however, we consider that the average increase in yields from summer tillage as compared with ordinary methods during these thirteen seasons is practically identical for oats and barley and differs by only 2.2 bushels for wheat from those of the remaining five seasons when the drought was severe, the force of this argument is considerably weakened. If we also consider that the only instance where summer tillage increased the yield sufficiently to make the practice profitable was at North Platte in 1908, where conditions were very favorable for crop production under ordinary methods, the argument against the applicability of these results to semiarid conditions ceases to have any weight.[a]

[a] See Table XXXI for precipitation record.

CONTINUOUS CROPPING COMPARED WITH ALTERNATE CROPPING AND SUMMER TILLAGE.

GENERAL STATEMENT.

Before entering into a discussion of the subject of continuous cropping compared with alternate cropping and summer tillage, it will be well to clearly set forth some important considerations that must be constantly borne in mind. They are as follows:

(1) The discussion applies to the Great Plains area only and can have no possible bearing upon practices in regions west of the Rocky Mountains, where soil and climatic conditions are radically different.

(2) These experiments were made with spring-sown grains only and have no bearing whatever upon the methods applicable to fall-sown grains.

(3) The object of the work described under this heading is to test the relative merits of three systems of one-crop farming, namely, (1) ordinary methods; (2) moisture-conservation methods of continuous cropping; and (3) summer-tillage methods of alternate or biennial cropping. This part of the work has nothing whatever to do with crop rotation, except possibly to show that no system of one-crop farming has yet been devised that can serve as a safe basis for a permanent agriculture in the Great Plains area. A discussion of crop rotation is given under another heading (p. 20).

The general plan of that portion of the investigations herein described is identical for all of the eleven stations and is as shown in the accompanying outline and the explanatory notes following:

Outline of plan for experiments with three staple cereal crops with ordinary methods of culture and with moisture-conservation methods, each crop being grown on the same plat for several years either continuously or alternating with summer fallow.

EXPERIMENTS WITH WHEAT.

Plat A. Wheat grown year after year on spring-plowed land by ordinary methods of culture.

Plat B. Wheat grown year after year on fall-plowed land by moisture-conservation methods of culture.

Plat C. Wheat alternating with summer tillage.

Plat D. Summer tillage alternating with wheat.

EXPERIMENTS WITH OATS.

Plat A. Oats grown year after year on spring-plowed land by ordinary methods of culture.

Plat B. Oats grown year after year on fall-plowed land by moisture-conservation methods of culture.

Plat C. Oats alternating with summer tillage.

Plat D. Summer tillage alternating with oats.

EXPERIMENTS WITH BARLEY.

Plat A. Barley grown year after year on spring-plowed land by ordinary methods of culture.
Plat B. Barley grown year after year on fall-plowed ground by moisture-conservation methods of culture.
Plat C. Barley alternating with summer tillage.
Plat D. Summer tillage alternating with barley.

By "ordinary methods" is meant plowing to a depth of about 3 inches in the spring just before seeding, harrowing once, and seeding with a drill; no harrowing after seeding; no treatment of stubble land after harvest except to cut weeds to keep them from seeding.

By "conservation methods" is meant plowing to a depth of 8 inches immediately after harvest, thoroughly harrowing immediately after plowing, keeping the soil in the best of tilth and free from weeds or surface crust by frequent harrowings or diskings until seeding in the spring, thorough harrowing at time of seeding, and light harrowings at intervals to break crust and destroy weeds until the grain reaches a height of about 6 inches. Under certain conditions, thorough disking immediately after harvest and deferring the plowing until the soil is in proper condition has been found to accomplish the desired results more effectually than immediate plowing, and in some cases this practice has been followed.

By "alternate summer tillage" is meant treating the soil after harvest as described under "conservation methods" until the following spring. Instead of then seeding it to crop, it is left bare or fallow and is kept harrowed, disked, and free from weeds or surface crust until midsummer. It is then plowed again and treated the same as Group B thereafter, being seeded in like manner the following spring, Group D being summer tilled and Group C being cropped one year and Group C being summer tilled and Group D being cropped the next, and so on indefinitely, alternately cropping and summer tilling.

The same variety and quantity of seed and the same drill are used upon all the plats of the same series for all groups at each station. It was found impracticable to use the same variety of each of the grains at all of the stations, as it has not been found possible to obtain any one variety of any of these grains adapted to so wide a range of soil and climatic conditions as is found between Montana on the north and Texas on the south. The rule has, therefore, been to select the variety of each of the grains best adapted to the locality. Durum spring wheat has been used at all stations.

It was not practicable to use the same make of drill at all stations, and there were other slight adaptations to local conditions, but the methods of seeding were essentially the same for the respective groups for all stations. The comparisons having been made between groups at each station instead of between stations, the slight differences mentioned could in no possible way affect the conclusions.

The accompanying tables give the yields in bushels per acre for each one of the 216 plats. They also give differences in bushels per acre between the "A," or continuously cropped ordinary-method plats, and "B," or continuously cropped moisture-conservation plats; and the "C" or "D," alternately summer-tilled plats, respectively. The "A," or continuously cropped ordinary-method yields, are used as a basis for all comparison. The three tables represent, respectively, the three series—wheat, oats, and barley. The averages at the foot of each table are the average yields per acre in bushels and the average difference in bushels per acre between the groups for each series, respectively, for all of the 18 tests.

TABLE I.—*Comparison of yields to the acre of wheat series, by groups.*

Station.	Year.	Continuous cropping.		Alternate cropping, Group C or D, summer tillage.	Gain (+) or loss (−) by conservation over ordinary methods, Group B compared with Group A.	Gain (+) or loss (−) by summer tillage over ordinary methods, Group C or D compared with Group A.
		Group A, ordinary methods.	Group B, conservation methods.			
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Judith Basin, Mont.	1909	33.0	33.4	34.0	+0.4	+ 1.0
Dickinson, N. Dak.	1908	24.3	17.7	33.8	−6.6	+ 9.5
Do.	1909	26.8	25.2	35.7	−1.6	+ 8.9
Edgeley N. Dak.	1907	4.1	7.0	9.9	+2.9	+ 5.8
Do.	1908	13.3	15.3	16.0	+2.0	+ 2.7
Do.	1909	28.3	23.3	27.0	−5.0	− 1.3
Highmore, S. Dak.	1907	28.8	29.7	30.0	+ .9	+ 1.2
Do.	1908	26.3	19.7	30 7	−6.6	+ 4.4
Bellefourche, S. Dak.	1909	23.8	23.3	32.2	− .5	+ 8.4
North Platte, Nebr.	1907	24.5	26.0	31.8	+1.5	+ 7.3
Do.	1908	22.7	27.3	40.5	+4.6	+17.8
Do.	1909	23.0	15.3	18.0	−7.7	− 5.0
Akron, Colo.	1909	14.3	10.3	18.5	−4.0	+ 4.2
Hays, Kans.	1908	1.2	4.5	4.2	+3.3	+ 3.0
Garden City, Kans.	1909	2.1	3.2	6.7	+1.1	+ 4.6
Dalhart, Tex.	1909	.0	.0	10.5	.0	+10.5
Amarillo, Tex.	1908	17.0	14.0	16.0	−3.0	− 1.0
Do.	1909	.0	2.8	10.5	+2.8	+10.5
Average.	....	17.49	16.53	22.55	−0.86	+ 5.14

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TABLE II.—*Comparison of yields to the acre of oats series, by groups.*

Station.	Year.	Continuous cropping.		Alternate cropping, Group C or D, summer tillage.	Gain (+) or loss (−) by conservation over ordinary methods, Group B compared with Group A.	Gain (+) or loss (−) by summer tillage over ordinary methods, Group C or D compared with Group A.
		Group A, ordinary methods.	Group B, conservation methods.			
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Judith Basin, Mont	1909	75.3	66.2	78.7	− 9.1	+ 3.4
Dickinson, N. Dak	1908	48.4	32.8	61.9	−15.6	+13.5
Do	1909	55.9	58.4	66.6	+ 2.5	+10.7
Edgeley, N. Dak	1907	21.3	21.4	36.7	+ .1	+15.4
Do	1908	16.9	15.3	....	− 1.6	....
Do	1909	57.5	46.8	55.6	−10.7	− 1.9
Highmore, S. Dak	1907	45.3	47.2	59.4	+ 1.9	+14.1
Do	1908	34.4	32.2	48.4	− 2.2	+14.0
Bellefourche, S. Dak	1909	48.8	46.9	76.7	− 1.9	+27.9
North Platte, Nebr	1907	30.0	36.0	30.0	+ 6.0	.0
Do	1908	34.4	68.5	82.3	+34.1	+47.9
Do	1909	31.3	24.1	46.3	− 7.2	+15.0
Akron, Colo	1909	21.1	14.1	27.7	− 7.0	+ 6.6
Hays, Kans	1908	1.3	3.7	3.5	+ 2.4	+ 2.2
Garden City, Kans	1909	1.0	3.2	7.9	+ 2.2	+ 6.9
Dalhart, Tex	1909	.0	.0	13.4	.0	+13.4
Amarillo, Tex	1908	20.0	32.2	31.6	+12.2	+11.6
Do	1909	.0	.0	23.1	.0	+23.1
Average	....	30.16	30.5	44.11	+ 0.34	+13.18

TABLE III.—*Comparison of yields to the acre of barley series, by groups.*

Station.	Year.	Continuous cropping.		Alternate cropping, Group C or D, summer tillage.	Gain (+) or loss (−) by conservation over ordinary methods, Group B compared with Group A.	Gain (+) or loss (−) by summer tillage over ordinary methods, Group C or D compared with Group A.
		Group A, ordinary methods.	Group B, conservation methods.			
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Judith Basin, Mont	1909	45.2	43.3	49.4	— 1.9	+ 4.2
Dickinson, N. Dak	1908	33.5	23.9	30.0	− 9.6	− 3.5
Do	1909	39.8	39.0	50.0	− .8	+10.2
Edgeley, N. Dak	1907	10.2	9.4	16.0	− .8	+ 5.8
Do	1908	25.0	24.2	24.2	− .8	− .8
Do	1909	27.0	24.7	28.3	− 2.3	+ 1.3
Highmore, S. Dak	1907	30.2	37.1	40.2	+ 6.9	+10.0
Do	1908	29.8	26.0	46.7	− 3.8	+16.9
Bellefourche, S. Dak	1909	23.8	25.0	37.3	+ 1.2	+13.5
North Platte, Nebr	1907	39.0	40.0	39.0	+ 1.0	.0
Do	1908	19.6	43.3	67.7	+23.7	+48.1
Akron, Colo	1909	19.7	16.8	24.6	− 2.9	+ 4.9
Hays, Kans	1908	5.8	12.4	18.9	+ 6.6	+13.1
Garden City, Kans	1909	2.4	4.8	10.0	+ 2.4	+ 7.6
Dalhart, Tex	1909	.0	.0	7.5	.0	+ 7.5
Amarillo, Tex	1908	7.9	13.2	15.2	+ 5.3	+ 7.3
Do	1909	.0	5.8	17.5	+ 5.8	+17.5
Average	....	21.11	22.88	30.74	+ 1.76	+ 9.62

The most significant facts brought out by an inspection of the figures presented in Tables I, II, and III are as follows:

(1) The yields in thirteen out of the eighteen seasons cited are above the normal for even the humid portions of the States where these stations are located, in some cases being more than double the normal.

(2) There are surprisingly small differences between the yields obtained from the three different methods used, these differences being in many instances in the opposite direction from what might be reasonably expected from the popular belief in the efficacy of the methods followed.

(3) There is but a single instance where summer tillage and alternate cropping increased the yields above the ordinary methods sufficiently to pay fully for the extra labor and expense involved. This was at North Platte in 1908. The average results of the three years' tests at this station do not, however, show profitable returns for summer tillage as compared with continuous cropping. The average results of crop rotation have been more profitable than either continuous cropping or alternate cropping and summer tillage. (See Tables XXII and XXIII.)

(4) In all five instances (Edgeley, 1907; Hays, 1908; Garden City, 1909; Dalhart, 1909; and Amarillo, 1909), where severe droughts were experienced, the yields for the summer-tilled plats as compared with the ordinary-method plats were much greater, the ratios being as follows: Edgeley—wheat 2.4 times, oats 1.7 times, barley 1.6 times; Hays—wheat 3.5 times, oats 2.7 times, barley 3.3 times; Garden City—wheat 3.2 times, oats 4.1 times, barley 7.9 times. At both Dalhart and Amarillo, in 1909, the ordinary-method plats were complete failures from drought, while the yields on the summer-tilled plats were as follows: Dalhart—wheat 10.5 bushels, oats 13.4 bushels, barley 7.5 bushels per acre; Amarillo—wheat 10.5 bushels, oats 23.1 bushels, barley 17.5 bushels per acre. None of these yields obtained during these dry years were sufficient to make the crops profitable.

After a careful consideration of all the data submitted and all the arguments for and against the sufficiency of these data as a safe basis for conclusions, the following tentative conclusions are submitted:

CONCLUSIONS CONCERNING SUMMER TILLAGE AND CONTINUOUS CROPPING.

(1) The practice of summer tillage and alternate cropping can not be considered a safe basis for a permanent agriculture in the Great Plains area, where spring-sown wheat, oats, or barley are the staple crops.

(2) Summer tillage will almost invariably increase the yield of wheat, oats, or barley and will materially reduce the danger of complete crop failure due to drought. It may therefore be resorted to as a safeguard or temporary expedient to meet a possible emergency, but it can not be depended upon to produce as profitable spring-sown crops as may be produced by other methods. Very good crops can usually be raised by one plowing and one or two harrowings, as is shown by yields obtained from continuous cropping by ordinary methods. Alternate cropping and summer tillage by methods used in these tests require on an average two plowings, four diskings, and twelve harrowings. Each farmer must decide for himself whether he can afford to perform this additional amount of labor in order to secure an increase in yield, which if the season proves favorable may be small, and to materially reduce the danger of total failure if the season proves unfavorable. He should, however, remember that summer tillage will in no way reduce the many dangers other than drought, such as unseasonable frosts and high winds, to which crops are subject. In fact, these dangers may be materially increased under a system of summer tillage.

It frequently happens that specially favorable soil conditions early in the spring induce such a rank growth of the young grain plants that the injury from both late spring frosts and summer drought is greatly increased. These factors were of such importance as to completely reverse the results at North Platte, Nebr., in 1909. The moisture-conservation plats of wheat on both continuous cropping and alternate cropping gave lower yields than the ordinary-method plats, the loss due to good tillage being 7.7 bushels per acre for continuous cropping and 5 bushels per acre for alternate cropping. Several other instances of the same nature are shown in Tables I, II, and III. This loss on well-tilled plats may in some instances be due to proximate causes other than frost or drought. It seems reasonably certain, however, that the ultimate cause is usually overstimulation of the crop at some stage in its growth. It is a well-recognized fact among farmers that grain usually suffers more severely from rust when the growth is very rank and succulent than when it is less vigorous. A well-tilled soil may sometimes blow worse than a poorly tilled one.

(3) The result of the experiments with moisture-conservation methods upon continuously cropped plats are so contradictory that no definite conclusions can be arrived at. This is true not only where different stations are compared, but where the same station for different years, or the same stations for the same years with different crops, are compared. All the evidence, however, goes to show that the time and depth of plowing and seeding and the harrowing of the grain after seeding are problems that are local in their

nature. The solutions of these problems are also so dependent upon seasonal conditions of soil and climate that no safe generalization concerning them can be made. Each farmer must therefore work out the best practice for his particular farm, crop, and season. It is believed, however, that our investigations[a] show that fairly deep plowing—about 8 inches—and thorough preparation of the seed bed will give better results than shallower plowing on most soils, whether spring or fall plowing is practiced. The deeper the plowing, the more thorough should be the harrowing in order to form a compact seed bed.

CROP ROTATION COMPARED WITH CONTINUOUS CROPPING.

OUTLINE OF THE THREE-YEAR ROTATIONS.

At the same eleven stations described in the previous pages, a series of nine 3-year rotations were established at the same time that the continuous cropping experiments were begun. The plan of these rotations is described in the accompanying outline and in the explanatory notes following. These rotations are identical for all of the eleven stations.

Outline of 3-year rotations.

ROTATION No. 1.

Plat A. Spring wheat on corn ground disked but not plowed.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

ROTATION No. 2.

Plat A. Spring wheat on spring-plowed ground.
Plat B. Oats on spring-plowed ground.
Plat C. Corn on spring-plowed ground.

ROTATION No. 3.

Plat A. Spring wheat on ground plowed early the preceding fall.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

ROTATION No. 4.

Plat A. Oats on corn ground not plowed but disked.
Plat B. Spring wheat on fall-plowed ground.
Plat C. Corn on fall-plowed ground.

ROTATION No. 5.

Plat A. Spring wheat on summer-tilled land.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Summer tilled.

ROTATION No. 6.

Plat A. Barley on corn ground not plowed but disked.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

[a] See the discussion of crop rotation which follows.

ROTATION No. 7.

Plat A. Oats on spring-plowed ground.
Plat B. Barley on spring-plowed ground.
Plat C. Corn on spring-plowed ground.

ROTATION No. 8.

Plat A. Oats on summer-tilled land.
Plat B. Spring wheat on ground plowed early the preceding fall.
Plat C. Summer tilled.

ROTATION No. 9.

Plat A. Oats on spring-plowed ground.
Plat B. Spring wheat on spring-plowed ground.
Plat C. Corn on spring-plowed ground.

The nine 3-year rotations are so planned as to give an opportunity to compare the several rotations considered as units and also to compare the several crops grown in different rotations under systems of soil preparation and following different crops. As each rotation is represented by three plats, each of the crops entering into the rotation is represented every year. This is a very important feature and one that has been neglected in most of the rotation experiments heretofore made. By this system the differences in yield produced by the seasonal peculiarities are eliminated and it may safely be assumed that any difference in yield that occurs in any two crops of the same kind grown the same year in two rotations is due either to the method of soil preparation or to crop sequence. Which of these two factors is the controlling one may usually be determined by an easy method of cross-checking with the same crop in other rotations, whereby one or both factors may be eliminated.

As an example of some of the comparisons that may be made and the conclusions drawn, the following are suggested:

Rotations Nos. 1, 2, and 3 are identical so far as crops and sequence are concerned, but each differs from the other in soil preparation for the wheat crop. Any difference in the wheat yields in rotations Nos. 1 and 3 may safely be attributed to the effects of stubbling in No. 1 instead of fall plowing the corn ground as in No. 3, this being the only variable factor. The two rotations thus as units may be safely compared to determine the effect of stubbling upon the wheat crop and also upon the two crops which follow, namely, oats and corn. The oat crops in these rotations may be safely compared to see whether the effect of the soil preparation for the corn crop is apparent in the subsequent crop of oats. The corn crop in these two rotations being so far removed from the only variable factor should be about equal, and any difference will have to be accounted for in a way not apparent, except that in No. 2 spring plowing has been practiced, while Nos. 1 and 3 are fall plowed.

Rotations Nos. 2 and 3 are identical, except that spring plowing is practiced in No. 2, while No. 3 is fall plowed. This will give an opportunity to compare spring with fall plowing both upon the rotations as units and upon each of the several crops of the rotation.

Rotations Nos. 1 and 4 have the same crops in each, but their sequence is changed, oats instead of wheat being stubbled in after corn, with wheat following oats instead of oats following wheat. A comparison of these two wheat and oats crops will give some very definite information concerning the proper sequence of these two crops, as well as the proper relation of the corn crop to each. The relative effect of wheat and oats upon the following corn crop can also be studied.

Rotations Nos. 1, 2, and 3 may be compared with rotation No. 5 to ascertain the relative merits of summer-fallowing and cropping to corn as a preparation for a wheat crop, taking into consideration that but two crops are grown in three years in the case of No. 5, while three crops are grown in Nos. 1, 2, and 3.

In rotation No. 6 a barley crop has been substituted for the wheat crops which occur in all the preceding rotations. Many comparisons may be made between these six rotations that will throw much light upon sequence as well as cultivation.

Rotation No. 7 is like No. 6, except that the relative positions of oats and barley have been transposed. The same comparison may be made with this as with No. 6.

In rotation No. 8 we have another chance to compare summer fallow with corn as a preparation for small-grain crops, oats being the crop used to follow the summer fallow in this instance. A comparison of No. 8 with No. 4 will bring out the relative value of corn and summer fallow as a preparation for oats, and a comparison with No. 1 and No. 5 will show whether the best results will be obtained from using wheat, oats, or barley as a crop to follow corn or summer-fallow.

Rotation No. 9 is identical with No. 3, except that the sequence is changed.

Besides the comparisons already mentioned, the list of which might be indefinitely extended, each one of the nine rotations may be compared as a unit with any other.

We have seven crops of wheat growing each year, as follows:

No. 1. Wheat after corn—stubbled in.
No. 2. Wheat after corn—spring plowing.
No. 3. Wheat after corn—fall plowing.
No. 4. Wheat after oats—fall plowing.
No. 5. Wheat after summer fallow.
No. 8. Wheat after oats—fall plowing.
No. 9. Wheat after oats—spring plowing.

We have seven crops of corn, grown as follows:

No. 1. Corn after oats—fall plowing.
No. 2. Corn after oats—spring plowing.
No. 3. Corn after oats—fall plowing.
No. 4. Corn after wheat—fall plowing.
No. 6. Corn after oats—fall plowing.
No. 7. Corn after barley—spring plowing.
No. 9. Corn after wheat—spring plowing.

Oats enter into each of the nine rotations, and have been grown as follows:

No. 1. Oats after wheat—fall plowing.
No. 2. Oats after wheat—spring plowing.
No. 3. Oats after wheat—fall plowing.
No. 4. Oats after corn—stubbled in.
No. 5. Oats after wheat—fall plowing.
No. 6. Oats after barley—fall plowing.
No. 7. Oats after corn—spring plowing.
No. 8. Oats after summer fallow.
No. 9. Oats after corn—spring plowing.

Barley enters into but two of the rotations, as follows:

No. 6. Barley after corn—stubbled in.
No. 7. Barley after oats—spring plowing.

An inspection of this tabular arrangement of the crops will at once show that there are a very large number of questions concerning soil preparation and crop sequence that may be definitely answered by this series of experiments, not from the result of a single instance but by a system of cross-checking from the results of several crops grown every year under different systems of soil preparation and crop sequence.

EXPLANATORY NOTES.

The purposes of this series of rotations are to test the effect of crop sequence and time of plowing.

Good farming is practiced upon all the plats. No special methods of moisture conservation are contemplated in this experiment. Plowing is to a depth of 8 inches and is uniform for all plats.

Fall plowing is done as early in the season as practicable. Whether the land is disked or harrowed or left undisturbed after fall plowing is left to the judgment of the man immediately in charge. Whatever practice in this respect is adopted for one of these rotations is followed for all in this series. The same general rule is applied to plowing and the fitting of the seed bed in the spring. Such an amount of work is done upon the land as will put it in good tilth.

In spring plowing for corn the rule has been to have the plowing deferred until corn-planting time, and for the planter to follow as closely after the plowing as possible and the harrow immediately after the planter. In some instances it has seemed desirable to disk or harrow the ground before spring plowing for corn. This is left to the judgment of the man in charge.

The summer-tilled plats in this series have been treated like the summer-tilled plats in the moisture-conservation series discussed in the previous pages.

These rotations were not planned nor are they here presented as the best rotations for the Great Plains area. They are seriously defective in that they make no provision for maintaining or restoring the organic matter to the soil. They were established for the purpose of studying the effects of crop sequence, or the effect that one crop has upon the crops following it, and the relative merits of fall and spring plowing. For these purposes these simple rotations have some marked advantages over longer and better rotations. This phase of the experiments will be but very briefly mentioned at this time, although it is believed that the thoughtful reader may find some very interesting, although possibly not conclusive, evidence on these subjects by a careful study of these tables. This subject will be more fully treated in some future publication. The purpose of introducing these figures at this time is to show that even these defective 3-year rotations have given better net results than either the continuous cropping or alternate cropping and summer tillage described in the foregoing pages. By "better net results" is meant that at nearly all stations the yields have been better for all three crops—wheat, oats, and barley—where the rotation of crops has been practiced than where the same crop has been grown continuously on the same ground. This statement is equally true concerning both ordinary methods and moisture-conservation methods of continuous cropping. The labor and expense involved in raising crops under a system of rotation are not materially greater than where continuous cropping by ordinary methods is practiced. The labor and expense of raising crops under moisture-conservation methods of continuous cropping are materially greater than under a system of crop rotation, as these two systems have been practiced in these experiments.

Where but one crop is raised in two years, as in the case of alternate cropping and summer tillage, the labor and expense per crop are nearly or quite double that of either rotation or continuous cropping by ordinary methods. In order, then, to make the net results as favorable under alternate cropping as under either continuous cropping or crop rotation, the yields should be nearly double. Summer tillage has nearly always increased the yields, but it has seldom doubled them. In only a few instances has this increase been sufficient to pay the bare expenses of the additional labor involved. Crop rotation has therefore given better net returns than either alternate cropping and summer tillage or continuous cropping by either ordinary methods or moisture-conservation methods, as is shown by Tables XXII and XXIII.

A COMMON BASIS OF COMPARISON.

In order to answer many of the important questions concerning the relation and adaptability of rotations, it is apparent that we must have some common basis of comparison for the several crops grown in the rotation. The rotations giving the best yields of wheat seldom give the best yields of oats, and the best rotations calculated on an oat basis are not the best for barley. In order to make the necessary comparisons we must be able to reduce the figures representing the yields in bushels per acre of all the crops in the rotation to a common unit of measurement. This has been done for wheat, corn, oats, and barley.

The Bureau of Statistics reports [a] as follows concerning the average farm price per bushel for the ten years 1900–1909, inclusive:

Average price per bushel for wheat, corn, oats, and barley, in four States, 1900–1909.

State.	Wheat.	Corn.	Oats.	Barley.
	Cents.	*Cents.*	*Cents.*	*Cents.*
North Dakota	68	44	31	38
South Dakota	67	37	29	37
Nebraska	63	35	29	36
Kansas	67	40	33	39
Average	66	39	30	38

These four States were selected as giving a more reliable basis than could be obtained by including Montana, Wyoming, Colorado, Oklahoma, Texas, and New Mexico. All of these latter-named States have a portion of their territory lying within territory where local conditions of supply and demand very seriously affect both the relative and the absolute prices. On the other hand, the four States first named lie entirely within the Plains region, with sufficiently free access to the large grain markets to insure them against any serious influence from purely local conditions. The figures given will therefore be used, after making one correction, for calculating the value of the rotations. This one correction is in the case of the price for wheat. The figures given are the averages for all the wheat marketed in the four States specified. This includes durum as well as common wheats. Durum wheats were used exclusively in our experiments with spring wheat. The price of durum wheat has nearly always been less than the averages for all wheats—just how much lower on the average for the last ten years we have no means of knowing. Neither have we any satisfactory basis for calculating the percentage of durum to the entire wheat crop of these States. It has therefore been decided to arbitrarily reduce the above estimate to 60 cents per bushel for durum wheats. It is probable that the reduction should be greater than this rather than less, but in the absence of any more satisfactory basis the following prices in cents per bushel have been adopted:

Durum wheat	60	Oats	30
Corn	39	Barley	38

[a] Crop Reporter, December, 1909, p. 82.

While these values per bushel seem to be the most reliable obtainable, they are open to several objections, among which are the following:

They are much too low for all crops to agree with present prices, or those obtaining when these investigations were made. As it is the relative rather than the absolute prices of these crops that are of most importance, this defect is not so serious as some others. If these prices were relatively correct, they could be raised horizontally to suit market prices at any given time, without disturbing their relations to each other, by simply multiplying them by some factor which would bring them all up to the proper figure. A much more serious defect is found in the fact that the average prices for the last ten years do not bear the same relation to each other that the crop-producing power of the soil bears to those prices when sown to these crops under exactly the same conditions. To illustrate, we give below the average yields obtained from each of the three grain crops in all the 18 tests under continuous cropping by ordinary methods and by crop rotation, with the value per acre, calculated on the basis of the farm price per bushel for the last ten years:

TABLE IV.—*Average yields on experimental plats, in bushels, and average farm value per acre, based on the average prices for ten years, 1900–1909, inclusive, in North and South Dakota, Nebraska, and Kansas.*

Cropping method.	Wheat.	Oats.	Barley.	Price per bushel.	Farm value per acre.
	Bushels.	*Bushels.*	*Bushels.*	*Cents.*	
Continuous cropping, ordinary methods	17.4			60	$10.44
Do		30.2		30	9.06
Do			21.1	38	8.02
Three-year rotation	19.8			60	11.88
Do		36.3		30	10.89
Do			24.3	38	9.23

It will be seen that wheat under continuous cropping produced a farm value per acre of $10.44, while oats produced only $9.06 and barley $8.02. The land upon which these yields were obtained was the same for each of the three crops. The climatic conditions and the preparation of the soil were the same. The cost of raising the crop was essentially the same for all the crops. Therefore, the farm value per acre should have been the same if the farmer were to receive the same profit on each crop. Such, however, was not the case, as shown by the above figures. In order to make the same profit from all the crops, it would have been necessary to secure 34½ cents per bushel for oats, instead of 30 cents and 49½ cents per bushel for barley. With crop rotation the results are similar; the price for oats should have been 33 cents and for barley 49 cents to make the farm value per acre the same as for wheat at 60 cents per bushel. Figuring wheat on a 90-cents-per-bushel basis, which is approximately the present market price, oats should bring about 51 cents and barley about 73 cents per bushel. This is considerably in excess of present farm prices for oats and barley, which shows that they are at present and have been for the last ten years relatively too low in comparison with wheat.

This is an important consideration with every farmer who is planning to diversify his crops in order to adopt a system of crop rotation. It is evident that in order to receive equal immediate cash returns for his crops he must accomplish one or more of the following results:

(1) He must, by selecting varieties especially adapted to the locality or by better methods of tillage, increase the relative yields of oats and barley as compared with wheat above those obtained in these investigations; or (2) he must, by raising oats or barley of superior quality, obtain prices in advance of the average market price; or (3) he must, by feeding these grains, realize more than the market price for them; or (4) he must, by adopting a rotation of crops instead of cropping continuously to the same crop, improve the condition of his farm, and by reducing the loss from weeds, diseases, and insect attacks increase the yields of all the crops grown so as to make the net returns from his farm equal to or greater than those obtainable from continuous cropping to wheat.

It is probable that most of the results mentioned may be obtained by adopting a proper system of crop rotation. The value of the results so obtained and the best method of obtaining them depend largely upon local conditions of soil and climate, the market prices for grain and live stock, and frequently upon various other conditions more or less local or individual in their nature. Such being the case, each farmer must necessarily depend largely upon his own judgment and knowledge of these conditions in deciding how best to accomplish the desired results.

The discussion of the results of these investigations will, therefore, be confined mainly to showing what may reasonably be expected from increased yields due directly to crop rotation as compared with continuous cropping.

Table V has been prepared by using the same values per bushel as in Table IV and the yields from continuous cropping by ordinary methods at each of the stations as a basis. The figures given in the table in the column headed "Average for wheat and oats" have been used as a basis of comparison with rotations 1, 2, 3, 4, 5, 8, and 9 in Tables XXII and XXIII. The figures in column headed "Average for barley and oats" have been used as a basis of comparison with rotations 6 and 7 in the same tables. The figures given in the columns headed "Wheat at 60 cents," "Oats at 30 cents," and "Barley at 38 cents," respectively, may be used to make comparisons of yields per acre and farm values per acre between continuous cropping and crop rotation for wheat, oats, or barley in any rotation or for any test reported in Tables VI to XIV, inclusive.

TABLE V.—*Yields from continuous cropping by ordinary methods, in bushels and in farm value per acre, at average prices for the ten years 1900–1909, inclusive.*

Station.	Year.	Wheat at 60 cents.		Oats at 30 cents.		Barley at 38 cents.		Average for wheat and oats.	Average for barley and oats.
		Bush.		*Bush.*		*Bush.*			
Judith Basin, Mont.	1909	33.0	$19.80	75.3	$22.59	45.2	$17.20	$21.20	$19.90
Dickinson, N. Dak.	1908	24.3	14.58	48.4	14.52	33.5	12.73	14.55	13.62
Do.	1909	26.8	16.08	55.9	16.77	39.8	15.12	16.42	15.95
Edgeley, N. Dak.	1907	4.1	2.46	21.3	6.39	10.2	3.88	4.43	5.13
Do.	1908	13.3	7.98	16.9	5.07	25.0	9.50	6.53	7.29
Do.	1909	28.3	16.98	57.5	17.25	27.0	10.26	17.11	13.75
Highmore, S. Dak.	1907	28.8	17.28	45.3	13.59	30.2	11.48	15.44	12.53
Do.	1908	26.3	15.78	34.4	10.32	29.8	11.32	13.05	10.82
Bellefourche, S. Dak.	1909	23.8	14.28	48.8	14.64	23.8	9.04	14.46	11.84
North Platte, Nebr.	1907	24.5	14.70	30.0	9.00	39.0	14.82	11.85	11.91
Do.	1908	22.7	13.62	34.2	10.34	19.6	7.45	11.98	8.90
Do.	1909	23.0	13.80	31.3	9.39	....	....	11.59	9.30
Akron, Colo.	1909	14.3	8.58	21.1	6.33	19.7	7.49	7.46	6.91
Hays, Kans.	1908	1.2	.72	1.3	.39	5.8	2.20	.56	1.30
Garden City, Kans.	1909	2.1	1.26	1.0	.30	2.4	.91	.78	.61
Dalhart, Tex.	1909	0.0	0.00	0.0	0.00	0.0	0.00	0.00	0.00
Amarillo, Tex.	1908	17.0	10.20	20.0	6.00	7.9	3.00	8.10	4.50
Do.	1909	0.0	0.00	0.0	0.00	0.0	0.00	0.00	0.00
Average	....	17.4	10.44	30.2	9.06	21.1	8.02	9.75	8.53

The following nine tables, Tables VI to XIV, inclusive, show in detail the yields per acre in bushels and the farm value per acre for each of the three crops grown in the nineteen tests. The farm values have been calculated on the basis of 60 cents for wheat, 30 cents for oats, 38 cents for barley, and 39 cents for corn.

In these tables the average farm values in dollars per acre of the two small-grain crops only in each rotation have been considered. Seven of these rotations contain corn crops, and two of them, Nos. 5 and 8, a year of summer tillage each. There is therefore one factor—the yield of the corn crop—which has so far been neglected in considering the relative yields of the rotations. This omission is to be regretted, but it seemed unavoidable for the following reasons:

(1) The corn crop lends itself much less readily to growing on small plats so as to give results comparable to those of large fields than do wheat, oats, and barley. While careful records of all corn yields have been kept, they are not entitled to the same confidence as the small-grain yields. (2) Very little, if any, of the Great Plains area can be considered as a corn-growing country. In most of the area corn can and will be profitably grown, but a considerable share of the profit from its growth will be derived from the beneficial effect

which the growing of the corn crop has in preparing the soil for the crops of small grain which are to follow it in rotation.

It is assumed that the corn crop will produce enough in the form of fodder and grain to at least pay for the labor involved in its production. The labor involved in raising a crop of corn is no greater than that required to summer till an equal area. In comparing the yields obtained from the small-grain crops in a rotation containing summer tillage with one containing corn it has been assumed that the yields from the summer-tillage rotation must be enough in excess of those from the corn rotation to pay for the summer tillage. Or, to put it in another way, the corn crop must be sufficient to equal in value the excess in yield of the two small-grain crops in the summer-tilled over those in the corn rotation. Whatever form of comparison is used it is assumed that the labor required to produce a crop of corn is approximately the same as to summer till. The corn crop pays for the work bestowed upon it, while the summer-tilled rotation must produce enough more small grain to pay for the cost of the summer tillage.

Corn should therefore be much more commonly grown than it now is in this area, not because it is a profitable crop in itself, but because it takes the place of summer tillage in the rotation and at least pays for the labor bestowed upon it. A corn crop might therefore be considered a complete failure judged from the standpoint of grain production, but still yield enough in the way of rough fodder and be valuable enough in its effect upon subsequent crops in the rotation to make it a very profitable crop.

In the double columns headed "Corn" are given the yields in bushels per acre and the farm value per acre based upon the actual yields of grain wherever the crop matured. The yields of fodder are also given in pounds per acre, but no value is calculated for this portion of the crop. It will be noticed that in many instances a good yield of fodder was obtained without any reported yield of grain. This is due to the failure of the crop to mature. The selection of an earlier maturing variety would undoubtedly in many instances have resulted in a good yield of grain. The corn yields do not enter into the valuation of the rotation. These figures are given simply to show that corn can be grown at these stations.

TABLE VI.—*Yields of wheat, oats, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 1.

Plat A. Spring wheat on corn ground disked but not plowed.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

Station.	Year.	Wheat.		Oats.		Corn.		Corn fodder.	Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont.	1909	34.8	$20.88	68.1	$20.43	....	....	8,160	$20.66
Dickinson, N. Dak.	1908	35.8	21.48	35.3	10.59	....	....	2,050	16.03
Do.	1909	39.8	23.88	64.4	19.32	50.7	$19.77	2,080	21.60
Edgeley, N. Dak.	1907	16.7	10.02	25.9	7.77	....	....	4,150	8.90
Do.	1908	24.0	14.40	26.3	7.89	....	....	2,600	11.14
Do.	1909	33.0	19.80	64.0	19.20	30.8	12.01	3,150	19.50
Highmore, S. Dak.	1906	26.7	16.02	45.3	13.59	33.1	12.91	....	14.81
Do.	1907	21.5	12.90	46.9	14.07	21.4	8.35	....	13.48
Do.	1908	24.3	14.58	28.8	8.64	16.4	6.40	....	11.61
Bellefourche, S. Dak.	1909	29.4	17.64	55.6	16.68	20.7	8.07	3,370	17.16
North Platte, Nebr.	1907	22.3	13.38	26.9	8.07	14.4	5.62	5,080	10.73
Do.	1908	28.6	17.16	60.3	18.09	31.8	12.40	3,620	17.62
Do.	1909	21.7	13.02	23.1	6.93	25.1	9.79	2,490	9.98
Akron, Colo.	1909	25.0	15.00	25.6	7.68	26.4	10.30	1,909	11.34
Hays, Kans.	1908	3.7	2.22	28.5	8.55	4.2	1.64	6,665	5.39
Garden City, Kans.	1909	1.0	.60	3.0	.90	....	.00	2,820	.75
Dalhart, Tex.	1909	.0	.00	.0	.00	....	.00	650	.00
Amarillo, Tex.	1908	8.3	4.98	28.1	8.43	16.6	6.48	2,740	6.71
Do.	1909	.0	.00	10.0	3.00	....	.00	1,610	1.50
Average.	....	20.87	12.52	35.06	10.52	....	....	....	11.52

TABLE VII.—*Yields of wheat, oats, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 2.

Plat A. Spring wheat on spring-plowed ground.
Plat B. Oats on spring-plowed ground.
Plat C. Corn on spring-plowed ground.

Station.	Year.	Wheat.		Oats.		Corn.		Corn fodder.	Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont.	1909	33.1	$19.86	63.1	$18.93	....	....	6,650	$19.40
Dickinson, N. Dak.	1908	35.0	21.00	52.5	15.75	....	....	1,340	18.37
Do.	1909	39.7	23.82	60.6	18.18	49.7	$19.38	2,180	21.00
Edgeley, N. Dak.	1907	13.2	7.92	29.7	8.91	....	....	3,150	8.42
Do.	1908	15.8	9.48	20.6	6.18	....	....	2,500	7.83
Do.	1909	32.6	19.56	63.7	19.11	31.3	12.21	3,350	19.33
Highmore, S. Dak.	1906	27.3	16.38	38.8	11.64	42.7	16.55	....	14.01
Do.	1907	29.0	17.40	41.6	12.48	21.4	8.35	....	14.94
Do.	1908	25.2	15.12	36.9	11.07	28.8	11.23	....	13.10
Bellefourche, S. Dak.	1909	23.9	14.34	42.5	12.75	17.2	6.71	3,180	13.55
North Platte, Nebr.	1907	23.7	14.22	32.3	9.69	17.0	6.63	4,430	11.96
Do.	1908	24.0	14.40	36.9	11.07	31.6	12.32	3,110	12.73
Do.	1909	17.2	10.32	28.1	8.43	25.0	9.75	1,900	9.37
Akron, Colo.	1909	20.8	12.48	18.3	5.49	26.3	10.26	2,760	8.99
Hays, Kans.	1908	1.5	.90	26.0	7.80	16.0	6.24	4,380	4.35
Garden City, Kans.	1909	4.0	2.40	1.3	.39	....	....	2,260	1.39
Dalhart, Tex.	1909	.0	.00	.0	.00	....	....	850	.00
Amarillo, Tex.	1908	8.0	4.80	2.34	7.02	12.9	5.03	2,950	5.91
Do.	1909	.0	.00	.0	.00	....	....	1,500	.00
Average.	....	19.68	11.81	32.44	9.73	16.84	....	....	10.77

TABLE VIII.—*Yields of wheat, oats, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 3.

Plat A. Spring wheat on ground plowed early the preceding fall.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

Station.	Year.	Wheat.		Oats.		Corn.		Corn fodder.	Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont.	1909	31.0	$18.60	61.5	$18.45	....	....	8,960	$18.53
Dickinson, N. Dak.	1908	35.0	21.00	38.9	11.67	....	....	2,510	16.33
Do	1909	37.3	22.38	62.5	18.75	48.3	$18.84	1,940	20.57
Edgeley, N. Dak.	1907	12.6	7.56	30.5	9.15	....	....	3,150	8.35
Do	1908	20.8	12.48	16.9	5.07	....	....	1,900	8.78
Do	1909	32.5	19.50	66.5	19.95	29.0	11.31	2,750	19.72
Highmore, S. Dak.	1906	25.5	15.30	47.2	14.16	39.1	15.25	....	14.73
Do	1907	27.2	16.32	45.3	13.59	22.9	8.93	....	14.96
Do	1908	25.7	15.42	29.7	8.91	19.6	7.64	....	12.16
Bellefourche, S. Dak.	1909	29.9	17.94	53.6	16.08	17.8	6.94	3,415	17.01
North Platte, Nebr.	1907	20.7	12.42	30.6	9.18	19.6	7.64	4,670	10.80
Do	1908	27.7	16.62	60.3	18.09	33.7	13.14	3,430	17.36
Do	1909	24.3	14.58	18.3	5.49	22.6	8.71	2,170	10.04
Akron, Colo.	1909	19.2	11.52	18.8	5.64	25.7	10.02	4,400	8.58
Hays, Kans.	1908	3.9	2.34	20.1	6.03	5.7	2.22	5,700	4.19
Garden City, Kans.	1909	2.2	1.32	.0	.00	....	.00	2,940	.66
Dalhart, Tex.	1909	.0	.00	.0	.00	....	.00	1,000	.00
Amarillo, Tex.	1908	8.5	5.10	27.5	8.25	17.6	6.86	3,250	6.67
Do	1909	.0	.00	17.8	5.34	....	.00	1,430	2.67
Average	....	20.21	12.30	34.0	10.20	....	....	....	11.16

TABLE IX.—*Yields of oats, wheat, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 4.

Plat A. Oats on corn ground, not plowed but disked.
Plat B. Spring wheat on fall-plowed ground.
Plat C. Corn on fall-plowed ground.

Station.	Year.	Oats.		Wheat.		Corn.		Corn fodder.	Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont.	1909	74.1	$22.23	33.3	$19.98	....	....	7,040	$21.11
Dickinson, N. Dak.	1908	67.2	20.16	18.8	11.28	....	....	2,330	15.72
Do	1909	72.5	21.75	34.3	20.58	48.9	$19.07	2,000	21.17
Edgeley, N. Dak.	1907	28.8	8.64	10.5	6.30	....	....	2,850	7.47
Do	1908	23.4	7.02	15.7	9.42	....	....	1,750	8.22
Do	1909	63.7	19.11	28.5	17.10	32.1	12.52	2,950	18.10
Highmore, S. Dak.	1906	61.6	18.48	25.0	15.00	36.1	14.08	....	16.74
Do	1907	48.4	14.52	29.0	17.40	22.6	8.81	....	15.96
Do	1908	35.6	10.68	21.8	13.08	8.4	3.27	....	11.88
Bellefourche, S. Dak.	1909	75.0	22.50	29.7	17.82	19.8	7.72	3,215	20.16
North Platte, Nebr.	1907	40.6	12.18	24.2	14.52	17.7	6.90	4,570	13.35
Do	1908	54.3	16.29	31.3	18.78	30.0	11.70	3,670	17.54
Do	1909	22.5	6.75	16.8	10.08	29.6	11.54	2,730	8.41
Akron, Colo.	1909	21.3	6.39	10.6	6.36	23.1	9.01	2,340	6.38
Hays, Kans.	1908	16.0	4.80	6.7	4.02	5.4	2.11	5,160	4.41
Garden City, Kans.	1909	2.9	.87	.9	.54	....	....	2,440	.70
Dalhart, Tex.	1909	.0	.00	.0	.00	....	....	850	.00
Amarillo, Tex.	1908	22.8	6.84	13.2	7.92	17.6	6.86	3,280	7.38
Do	1909	.0	.00	.0	.00	....	....	1,510	.00
Average	....	38.46	11.54	18.44	11.06	....	....	....	11.30

TABLE X.—*Yields of wheat and oats in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 5.

Plat A. Spring wheat on fallow land.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Summer tillage.

Station.	Year.	Wheat.		Oats.		Average value per acre of wheat and oats.
		Bushels.		*Bushels.*		
Judith Basin, Mont.	1909	38.0	$22.80	67.1	$20.13	$21.47
Dickinson, N. Dak.	1908	33.0	19.80	39.4	11.82	15.81
Do.	1909	37.7	22.62	63.8	19.14	20.88
Edgeley, N. Dak.	1907	11.8	7.08	27.5	8.25	7.66
Do.	1908	19.5	11.70	33.4	10.02	10.86
Do.	1909	29.8	17.88	63.7	19.11	18.50
Highmore, S. Dak.	1906	31.7	19.02	46.6	13.98	16.50
Do.	1907	33.3	19.98	55.0	16.50	18.24
Do.	1908	29.0	17.40	27.8	8.34	12.87
Bellefourche, S. Dak.	1909	31.4	18.84	51.6	15.48	17.16
North Platte, Nebr.	1907	26.0	15.60	31.2	9.36	12.48
Do.	1908	42.2	25.32	54.7	16.41	20.87
Do.	1909	27.2	16.32	19.1	5.73	11.02
Akron, Colo.	1909	18.2	10.92	16.7	5.01	7.96
Hays, Kans.	1908	4.1	2.46	22.8	6.84	11.65
Garden City, Kans.	1909	6.6	3.96	3.3	.99	2.48
Dalhart, Tex.	1909	7.7	4.62	.0	.00	2.31
Amarillo, Tex.	1908	16.5	9.90	24.4	7.32	8.61
Do.	1909	9.5	5.70	15.3	4.59	5.14
Average.	....	28.35	14.31	34.92	10.47	12.39

TABLE XI.—*Yields of barley, oats, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 6.

Plat A. Barley on corn ground, not plowed but disked.
Plat B. Oats on ground plowed early the preceding fall.
Plat C. Corn on ground plowed early the preceding fall.

Station.	Year.	Barley.		Oats.		Corn.		Corn fodder.	Average value per acre of barley and oats.
		Bushels		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont.	1909	42.7	$16.23	57.8	$17.34	....	....	8,320	$16.79
Dickinson, N. Dak.	1908	45.6	17.33	44.7	13.41	....	....	2,100	15.37
Do.	1909	53.8	20.44	61.9	18.57	50.3	$19.62	2,000	19.50
Edgeley, N. Dak.	1907	18.3	6.95	32.5	9.75	....	....	2,650	8.35
Do.	1908	31.9	12.12	15.9	4.77	....	....	2,350	8.45
Do.	1909	33.1	12.58	60.3	18.09	29.8	11.62	2,400	15.33
Highmore, S. Dak.	1906	37.7	14.33	53.8	16.14	36.1	14.08	....	15.24
Do.	1907	25.0	9.50	49.4	14.82	20.0	7.80	....	12.16
Do.	1908	30.0	11.40	36.3	10.89	18.4	7.18	....	11.14
Bellefourche, S. Dak.	1909	47.1	17.90	65.6	19.68	19.2	7.49	3,460	18.79
North Platte, Nebr.	1907	30.6	11.63	23.1	6.93	20.0	7.80	4,410	9.28
Do.	1908	24.9	9.46	49.1	14.73	23.2	9.05	2,870	12.09
Do.	1909	21.5	8.17	19.7	5.91	31.7	12.36	2,030	7.04
Akron, Colo.	1909	24.9	9.46	20.8	6.24	26.1	10.18	2,720	7.85
Hays, Kans.	1908	12.3	4.67	35.5	10.65	5.5	21.45	6,115	7.66
Garden City, Kans.	1909	5.1	1.94	3.1	.93	....	....	2,500	1.44
Dalhart, Tex.	1909	.0	.00	.0	.00	....	....	650	.00
Amarillo, Tex.	1908	7.5	2.85	31.3	9.39	18.3	7.14	3,200	6.12
Do.	1909	.0	.00	.0	.00	....	....	1,220	.00
Average.	....	25.9	9.84	34.78	10.43	....	....	....	10.14

TABLE XII.—*Yields of oats, barley, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 7.

Plat A. Oats on spring-plowed ground.
Plat B. Barley on spring-plowed ground.
Plat C. Corn on spring-plowed ground.

Station.	Year.	Oats.		Barley.		Corn.		Corn fodder.	Average value per acre of oats and barley.
		Bushels		*Bushels*		*Bushels.*		*Pounds.*	
Judith Basin, Mont	1909	74.0	$22.20	39.1	$14.86			7,120	$18.53
Dickinson, N. Dak	1908	60.9	18.27	34.4	13.07			1,480	15.67
Do	1909	70.3	21.09	49.2	18.70	46.7	$18.21	2,000	19.89
Edgeley, N. Dak	1907	24.8	7.44	10.6	4.03			1,950	5.74
Do	1908	24.7	7.41	26.0	9.88			2,550	8.65
Do	1909	60.9	18.27	32.7	12.43	29.8	11.62	2,800	15.35
Highmore, S. Dak	1906	57.5	17.25	29.2	11.10	43.1	16.81		14.17
Do	1907	43.8	13.14	28.3	10.75	28.6	11.15		11.95
Do	1908	40.0	12.00	29.9	11.36	32.6	12.71		11.68
Bellefourche, S. Dak	1909	58.8	17.64	28.1	10.68	20.6	8.03	2,980	14.16
North Platte, Nebr	1907	35.7	10.71	40.2	15.28	22.6	8.81	4,690	12.99
Do	1908	60.3	18.09	22.3	8.47	31.7	12.36	3,630	13.28
Do	1909	35.0	10.50	18.5	7.03	22.1	8.62	2,950	8.77
Akron, Colo	1909	25.6	7.68	22.2	8.44	21.7	8.46	2,380	8.06
Garden City, Kans	1909	3.8	1.14	5.7	2.17			2,660	1.65
Hays, Kans	1908	15.2	4.56	9.2	3.50	4.0	1.56	4,540	4.03
Dalhart, Tex	1909	.0	.00	.0	.00			900	.00
Amarillo, Tex	1908	21.3	6.39	8.1	3.08	17.0	6.63	2,950	4.73
Do	1909	.0	.00	.0	.00			1,380	.00
Average		37.5	11.25	22.83	8.67	16.87	6.58		9.97

TABLE XIII.—*Yields of oats and wheat in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 8.

Plat A. Oats on fallow land.
Plat B. Spring wheat on ground plowed early the preceding fall.
Plat C. Summer tillage.

Station.	Year.	Oats.		Wheat.		Average value per acre of oats and wheat.
		Bushels.		*Bushels.*		
Judith Basin, Mont	1909	66.2	$19.96	40.3	$24.18	$22.02
Dickinson, N. Dak	1908	60.9	18.27	20.5	12.30	15.29
Do	1909	74.7	22.41	35.0	21.00	21.70
Edgeley, N. Dak	1907	30.9	9.27	8.5	5.10	7.19
Do	1908	20.9	6.27	10.3	6.18	6.22
Do	1909	56.2	16.86	26.6	15.96	16.41
Highmore, S. Dak	1906	83.4	25.02	25.0	15.00	20.01
Do	1907	57.8	17.34	32.7	19.62	18.48
Do	1908	46.6	13.98	27.5	16.50	15.24
Bellefourche, S. Dak	1909	85.2	25.56	33.2	19.92	22.74
North Platte, Nebr	1907	40.9	12.27	28.3	16.98	14.63
Do	1908	91.5	27.45	31.3	18.78	23.11
Do	1909	.00	.00	16.8	10.08	5.04
Akron, Colo	1909	28.3	8.49	10.9	6.54	7.52
Hays, Kans	1908	28.8	8.64	4.2	2.52	5.58
Garden City, Kans	1909	5.8	1.74	3.8	2.28	2.01
Dalhart, Tex	1909	10.0	3.00	.0	.00	1.50
Amarillo, Tex	1908	33.4	10.00	13.7	8.22	9.12
Do	1909	25.6	7.68	.0	.00	3.84
Average		44.56	13.37	19.4	11.64	12.51

TABLE XIV.—*Yields of oats, wheat, and corn in bushels per acre and farm value per acre in nineteen tests, 1906–1909, inclusive.*

ROTATION NO. 9.

Plat A. Oats on spring-plowed ground.
Plat B. Spring wheat on spring-plowed ground.
Plat C. Corn on spring-plowed ground.

Station.	Year.	Oats.		Wheat.		Corn.		Corn fodder.	Average value per acre of oats and wheat.
		Bushels.		*Bushels.*		*Bushels.*		*Pounds.*	
Judith Basin, Mont.	1909	70.7	$21.21	31.6	$18.96	....	....	7,280	$20.08
Dickinson, N. Dak.	1908	50.6	15.18	18.7	11.22	....	....	2,800	13.20
Do.	1909	71.3	21.39	30.7	18.42	43.5	$16.97	1,680	19.90
Edgeley, N. Dak.	1907	5.6	1.68	4.2	2.52	....	....	2,300	2.10
Do.	1908	16.9	5.07	13.5	8.10	....	....	2,600	6.59
Do.	1909	58.7	17.61	25.8	15.48	29.3	11.43	3,050	16.54
Highmore, S. Dak.	1906	56.9	17.07	25.7	15.42	38.1	14.86	....	16.25
Do.	1907	47.5	14.25	24.5	14.70	27.1	10.57	....	14.48
Do.	1908	41.6	12.48	24.2	14.52	25.9	10.10	....	13.50
Bellefourche, S. Dak.	1909	62.2	18.66	26.1	15.66	22.7	8.85	4,905	17.16
North Platte, Nebr.	1907	33.4	10.02	20.8	12.48	18.6	7.25	4,830	11.25
Do.	1908	48.2	14.46	17.5	10.50	28.0	10.92	3,490	12.48
Do.	1909	27.5	8.25	16.7	10.00	27.1	10.57	3,350	9.13
Akron, Colo.	1909	17.5	5.25	14.3	8.58	25.3	9.87	2,280	6.92
Hays, Kans.	1908	19.1	5.73	2.2	1.32	4.3	1.68	4,120	3.52
Garden City, Kans.	1909	2.3	.69	2.5	1.50	....	.00	2,900	1.10
Dalhart, Tex.	1909	.0	.00	.0	.00	....	.00	1,200	.00
Amarillo, Tex.	1909	22.5	6.75	5.3	3.18	14.3	5.58	2,690	4.96
Do.	1909	.0	.00	.0	.00	....	.00	1,270	.00
Average	....	34.34	10.30	16.03	9.61	....	....	....	9.95

Tables XV, XVII, and XIX present in convenient form for comparison the yields per acre of each rotation for each test and each crop, the average yields for continuous cropping, and the losses or gains as compared with crop rotations for each test.

In Tables XVI, XVIII, and XX the yields are expressed in farm values per acre instead of in bushels, Tables XV and XVI, XVII and XVIII, XIX and XX being, respectively, companion tables dealing with the same crops, but using different terms of expression.

TABLE XV.—*Yield of wheat, in bushels per acre, in seven 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. Oats disked, wheat fall plowed, corn fall plowed.	No. 5. Wheat on fallow, oats fall plowed, fallow.	No. 8. Oats on fallow, wheat fall plowed, fallow.
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Judith Basin, Mont.	1909	34.8	33.1	31.0	33.3	38.0	[a] 40.3
Dickinson, N. Dak.	1908	[a] 35.8	35.0	35.0	18.8	33.0	20.5
Do.	1909	[a] 39.8	39.7	37.3	34.3	37.7	35.0
Edgeley, N. Dak.	1907	[a] 16.7	13.2	12.6	10.5	11.8	8.5
Do.	1908	[a] 24.0	15.8	20.8	15.7	19.5	10.3
Do.	1909	[a] 33.0	32.6	32.5	28.5	29.8	26.6
Highmore, S. Dak.	1906	26.7	27.3	25.5	25.0	[a] 31.7	25.0
Do.	1907	21.5	29.0	27.2	29.0	[a] 33.3	32.7
Do.	1908	24.3	25.2	25.7	21.8	[a] 29.0	27.5
Bellefourche, S. Dak.	1909	29.4	23.9	29.9	29.7	31.4	[a] 33.2
North Platte, Nebr.	1907	22.3	23.7	20.7	24.2	26.0	[a] 28.3
Do.	1908	28.6	24.0	27.7	31.3	[a] 42.2	31.3
Do.	1909	21.7	17.2	[a] 24.3	16.8	27.2	16.8
Akron, Colo.	1909	[a] 25.0	20.8	19.2	10.6	18.2	10.9
Hays, Kans.	1908	3.7	1.5	3.9	[a] 6.7	4.1	4.2
Garden City, Kans.	1909	1.0	4.0	2.2	.9	[a] 6.6	3.8
Dalhart, Tex.	1909	.0	.0	.0	.0	[a] 7.7	.0
Amarillo, Tex.	1908	8.3	8.0	8.5	13.2	[a] 16.5	13.7
Do.	1909	.0	.0	.0	.0	9.5	.0
Average	....	20.87	19.68	20.21	18.44	23.85	19.40
Average from continuous cropping	....	17.39	17.39	17.39	17.39	17.39	17.39
Gain per acre by rotation compared with continuous cropping	....	3.48	2.29	2.82	1.05	6.48	2.01

Station.	Year.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping.	
					Gain.	Loss.
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Judith Basin, Mont.	1909	31.6	34.59	33.0	1.59	....
Dickinson, N. Dak.	1908	18.7	28.11	24.3	3.81	....
Do.	1909	30.7	36.36	26.8	9.56	....
Edgeley, N. Dak.	1907	4.2	11.07	4.1	6.97	....
Do.	1908	13.5	17.09	13.3	3.79	....
Do.	1909	25.8	29.73	28.3	1.43	....
Highmore, S. Dak.	1906	25.7	26.70	....	....	....
Do.	1907	24.5	28.17	28.8	....	0.63
Do.	1908	24.2	25.34	26.3	....	.96
Bellefourche, S. Dak.	1909	26.1	29.09	23.8	5.29	....
North Platte, Nebr.	1907	20.8	23.71	24.5	....	.79
Do.	1908	17.5	28.94	22.7	6.24	....
Do.	1909	16.7	20.10	23.0	....	2.90
Akron, Colo.	1909	14.3	17.00	14.3	2.70	....
Hays, Kans.	1908	2.2	3.76	1.2	2.56	....
Garden City, Kans.	1909	2.5	3.00	2.1	.90	....
Dalhart, Tex.	1909	.0	1.10	.0	1.10	....
Amarillo, Tex.	1808	5.3	10.50	17.0	....	6.50
Do.	1909	.0	1.36	.0	1.36	....
Average	....	16.01	19.78	....	....	....
Average from continuous cropping	....	17.39	17.39	17.39	....	....
Gain (or loss) per acre by rotation compared with continuous cropping	....	− 1.39	2.39	....	....	....

[a] Rotation giving the best yield of wheat.

TABLE XVI.—*Farm value of wheat, in dollars and cents per acre, in seven 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. Oats disked, wheat fall plowed, corn fall plowed.	No. 5. Wheat on fallow, oats fall plowed, fallow.	No. 8. Oats on fallow, wheat fall plowed, fallow.
Judith Basin, Mont	1909	$20.88	$19.86	$18.60	$19.98	$20.80	$24.18
Dickinson, N. Dak	1908	21.84	21.00	21.00	11.28	19.80	12.30
Do	1909	23.88	23.82	22.38	20.58	22.62	21.00
Edgeley, N. Dak	1907	10.02	7.92	7.56	6.30	7.08	5.10
Do	1908	14.40	9.48	12.48	9.42	11.70	6.18
Do	1909	19.80	19.56	19.50	17.10	17.88	15.96
Highmore, S. Dak	1906	16.02	16.38	15.30	15.00	19.02	15.00
Do	1907	12.90	17.40	16.32	17.40	19.98	19.62
Do	1908	14.58	15.12	15.42	13.08	17.40	16.50
Bellefourche, S. Dak	1909	17.64	14.34	17.94	17.82	18.84	19.92
North Platte, Nebr	1907	13.38	14.22	12.42	14.52	15.60	16.98
Do	1908	17.16	14.40	16.62	18.78	25.32	18.78
Do	1909	13.02	10.32	14.58	10.08	16.32	10.08
Akron, Colo	1909	15.00	12.48	11.52	6.36	10.92	6.54
Hays, Kans	1908	2.22	.90	2.34	4.02	2.46	2.52
Garden City, Kans	1909	.60	2.40	1.32	.54	3.96	2.28
Dalhart, Tex	1909	.00	.00	.00	.00	4.62	.00
Amarillo, Tex	1908	4.98	4.80	5.10	7.92	9.90	8.22
Do	1909	.00	.00	.00	.00	5.70	.00
Average	....	12.52	11.81	12.13	11.06	14.31	11.64

Station.	Year.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping. Gain.	Loss.
Judith Basin, Mont	1909	$18.96	$20.75	$19.80	$0.95	....
Dickinson, N. Dak	1908	11.22	16.87	14.58	2.29	....
Do	1909	18.42	21.81	16.08	5.73	....
Edgeley, N. Dak	1907	2.52	6.64	2.46	4.18	....
Do	1908	8.10	10.25	7.98	2.27	....
Do	1909	15.48	17.90	16.98	.92	....
Highmore, S. Dak	1906	15.42	16.02	....	....	....
Do	1907	14.70	16.90	17.28	....	$0.38
Do	1908	14.52	15.20	15.78	....	.58
Bellefourche, S. Dak	1909	15.66	17.45	14.28	3.17	....
North Platte, Nebr	1907	12.48	14.23	14.70	....	.47
Do	1908	10.50	17.33	13.62	3.71	....
Do	1909	10.00	12.06	13.80	....	1.74
Akron, Colo	1909	8.58	10.20	8.58	1.62	....
Hays, Kans	1908	1.33	2.26	.72	1.54	....
Garden City, Kans	1909	1.50	1.80	1.26	.54	....
Dalhart, Tex	1909	.00	.66	.00	.66	....
Amarillo, Tex	1908	3.18	6.30	10.20	....	3.90
Do	1909	.00	.81	.00	.81	....
Average	....	9.61	[a] 11.87	[b] 10.45	[b] 1.19	....

[a] Average of 19 crops.

[b] Average of 18 crops.

TABLE XVII.—*Yield of oats, in bushels per acre, in nine 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. Oats disked, wheat fall plowed, corn fall plowed.	No. 5. Wheat fallow, oats fall plowed, fallow.	No. 6. Barley disked, oats fall plowed, corn fall plowed.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.
		Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Judith Basin, Mont.	1909	68.1	63.1	61.5	[a]74.1	67.1	57.8	74.0
Dickinson, N. Dak.	1908	35.3	52.5	38.9	[a]67.2	39.4	44.7	60.9
Do.	1909	64.4	60.6	62.5	72.5	63.8	61.9	70.3
Edgeley, N. Dak.	1907	25.9	29.7	30.5	28.8	27.5	[a]32.5	24.8
Do.	1908	26.3	20.6	16.9	23.4	[a]33.4	15.9	24.7
Do.	1909	64.0	63.7	[a]66.5	63.7	63.7	60.3	60.9
Highmore, S. Dak.	1906	45.3	38.9	47.2	61.6	46.6	53.8	57.5
Do.	1907	46.9	41.6	45.3	48.4	55.0	49.4	43.8
Do.	1908	28.8	36.9	29.7	35.6	27.8	36.3	40.0
Bellefourche, S. Dak.	1909	55.6	42.5	53.6	75.0	51.6	65.6	58.8
North Platte, Nebr.	1907	26.9	32.3	30.6	40.6	31.2	23.1	35.7
Do.	1908	60.3	36.9	60.3	54.3	54.7	49.1	60.3
Do.	1909	23.1	28.1	18.3	22.5	19.1	19.7	[a]35.0
Akron, Colo.	1909	25.6	18.3	18.8	21.3	16.7	20.8	25.6
Hays, Kans.	1908	28.5	26.0	20.1	16.0	22.8	[a]35.5	15.2
Garden City, Kans.	1909	3.0	1.3	.0	2.9	3.3	3.1	3.8
Dalhart, Tex.	1909	.0	.0	.0	.0	.0	.0	.0
Amarillo, Tex.	1908	28.1	23.4	27.5	22.8	24.4	31.3	21.3
Do.	1909	10.0	.0	17.8	.0	15.3	.0	.0
Average	....	35.06	32.44	34.00	38.46	34.92	34.78	37.50
Average from continuous cropping	....	30.16	30.16	30.16	30.16	30.16	30.16	30.16
Gain per acre by rotation compared with continuous cropping	....	4.90	2.28	3.84	8.30	4.76	4.62	7.34

Station.	Year.	No. 8. Oats on fallow, wheat fall plowed, fallow.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping. Gain.	Loss.
		Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Judith Basin, Mont.	1909	66.2	70.7	65.8	75.3	....	9.5
Dickinson, N. Dak.	1908	60.9	50.6	50.0	48.4	1.4	....
Do.	1909	[a]74.7	71.3	66.9	55.9	11.0	....
Edgeley, N. Dak.	1907	30.9	5.6	26.2	21.3	4.9	....
Do.	1908	20.9	16.9	22.1	16.9	5.2	....
Do.	1909	56.2	58.7	62.0	57.5	4.5	....
Highmore, S. Dak.	1906	[a]83.4	56.9	54.6	....	....	....
Do.	1907	[a]57.8	47.5	48.4	45.3	3.1	....
Do.	1908	[a]46.6	41.6	35.9	34.4	1.5	....
Bellefourche, S. Dak.	1909	[a]85.2	62.2	61.1	48.8	12.3	....
North Platte, Nebr.	1907	[a]40.9	33.4	32.7	30.0	2.7	....
Do.	1908	[a]91.5	48.2	59.6	34.4	25.1	....
Do.	1909	....	27.5	21.5	31.3	....	9.8
Akron, Colo.	1909	[a]28.3	17.5	21.4	21.1	.3	....
Hays, Kans.	1908	28.8	19.1	23.5	1.3	21.2	....
Garden City, Kans.	1909	[a]5.8	2.3	2.8	1.0	1.8	....
Dalhart, Tex.	1909	[a]10.0	.0	1.1	.0	1.0	....
Amarillo, Tex.	1908	[a]33.4	22.5	26.1	20.0	6.1	....
Do.	1909	[a]25.6	.0	7.7	.0	7.7	....
Average	....	44.58	34.34	36.27	....	....	....
Average from continuous cropping	....	30.16	30.16	30.16	....	....	....
Gain per acre by rotation compared with continuous cropping	....	14.42	4.18	6.11	....	....	....

[a] Rotation giving the best yield of oats.

TABLE XVIII.—*Farm value of oats, in dollars and cents per acre, in nine 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. Oats disked, wheat fall plowed, corn fall plowed.	No. 5. Wheat on fallow, oats fall plowed, fallow.	No. 6. Barley disked, oats fall plowed, corn fall plowed.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.
Judith Basin, Mont	1909	$20.43	$18.93	$18.45	$22.23	$20.13	$17.34	$22.20
Dickinson, N. Dak	1908	10.59	15.75	11.67	20.16	11.82	13.41	18.27
Do	1909	19.32	18.18	18.75	21.74	19.14	18.57	21.09
Edgeley, N. Dak	1907	7.77	8.91	9.15	8.64	8.25	9.75	7.44
Do	1908	7.89	6.18	5.07	7.02	10.02	4.77	7.41
Do	1909	19.20	19.11	19.95	19.11	19.11	18.09	18.27
Highmore, S. Dak	1906	13.59	11.64	14.16	18.48	13.98	16.14	17.25
Do	1907	14.07	12.48	13.59	14.52	16.50	14.82	13.14
Do	1908	8.64	11.07	8.91	10.68	8.34	10.89	12.00
Bellefourche, S. Dak	1909	16.68	12.75	16.08	22.50	15.48	19.68	17.64
North Platte, Nebr	1907	8.07	9.69	9.18	12.18	9.36	6.93	10.71
Do	1908	18.09	11.07	18.09	16.29	16.41	14.73	18.09
Do	1909	6.93	8.43	5.49	6.75	5.73	5.91	10.50
Akron, Colo	1909	7.68	5.49	5.64	6.39	5.01	6.24	7.68
Hays, Kans	1908	8.55	7.80	6.03	4.80	6.84	10.65	4.56
Garden City, Kans	1909	.90	.39	.00	.87	.99	.93	1.14
Dalhart, Tex	1909	.00	.00	.00	.00	.00	.00	.00
Amarillo, Tex	1908	8.43	7.02	8.25	6.84	7.32	9.39	6.39
Do	1909	3.60	.00	5.34	.00	4.59	.00	.00
Average	....	10.52	9.73	10.20	11.54	10.47	10.43	11.25

Station.	Year.	No. 8. Oats on fallow, wheat fall plowed, fallow.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping. Gain.	Loss.
Judith Basin, Mont	1909	$19.86	$21.21	$20.09	$22.59	....	$2.50
Dickinson, N. Dak	1908	18.27	15.18	15.01	14.52	$0.49	....
Do	1909	22.41	21.39	20.07	16.77	3.30	....
Edgeley, N. Dak	1907	9.27	1.68	7.87	6.39	1.48	....
Do	1908	6.27	5.07	6.63	5.07	1.56	....
Do	1909	16.86	17.61	18.59	17.25	1.34	....
Highmore, S. Dak	1906	25.02	17.07	16.37	....	....	....
Do	1907	17.34	14.25	14.52	13.59	.93	....
Do	1908	13.98	12.48	10.78	10.32	.46	....
Bellefourche, S. Dak	1909	25.56	18.66	18.34	14.64	3.70	....
North Platte, Nebr	1907	12.27	10.02	9.82	9.00	.82	....
Do	1908	27.45	14.46	17.19	10.32	6.87	....
Do	1909	.00	8.25	6.44	9.39	....	2.95
Akron, Colo	1909	8.49	5.25	6.43	6.33	.10	....
Hays, Kans	1908	8.64	5.73	7.07	.39	6.68	....
Garden City, Kans	1909	1.74	.69	.85	.30	.55	....
Dalhart, Tex	1909	3.00	.00	.33	.00	.33	....
Amarillo, Tex	1908	10.02	6.75	7.82	6.00	1.82	....
Do	1909	7.68	.00	2.29	.00	2.29	....
Average	....	13.37	10.30	[a] 10.87	[b] 9.05	[b] 1.52	....

[a] Average of 19 crops.

[b] Average of 18 crops.

TABLE XIX.—*Yield of barley, in bushels per acre, in two 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 6. Barley disked, oats fall plowed, corn fall plowed.	No. 7. Corn spring plowed, barley spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Average of all rotations compared with continuous cropping.	
						Gain.	Loss.
		Bushels.	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*	*Bushels.*
Judith Basin, Mont	1909	42.7	39.1	40.9	45.2		4.3
Dickinson, N. Dak	1908	45.6	34.4	40.0	33.5	6.5	
Do	1909	53.8	49.2	51.5	39.8	11.7	
Edgeley, N. Dak	1907	18.3	10.6	14.5	10.2	4.3	
Do	1908	31.9	26.0	28.9	25.0	3.9	
Do	1909	33.1	32.7	32.9	27.0	5.9	
Highmore, S. Dak	1906	37.7	29.2	33.5			
Do	1907	25.0	28.3	26.6	30.2		3.6
Do	1908	30.0	29.9	29.9	29.8	.1	
Bellefourche, S. Dak	1909	47.1	28.1	37.6	23.8	13.8	
North Platte, Nebr	1907	30.6	40.2	35.4	39.0		3.6
Do	1908	24.9	22.3	23.6	19.6	4.0	
Do	1909	21.5	18.5	20.0			
Akron, Colo	1909	24.9	22.2	23.6	19.7	3.9	
Hays, Kans	1908	12.3	9.2	10.8	5.8	5.0	
Garden City, Kans	1909	5.1	5.7	5.4	2.4	3.0	
Dalhart, Tex	1909	.0	.0	.0	.0	.0	
Amarillo, Tex	1908	7.5	8.1	7.8	7.9		.1
Do	1909	.0	.0	.0	.0	.0	
Average		25.9	22.83	24.4	21.1	3.0	

TABLE XX.—*Farm value of barley, in dollars and cents per acre, in two 3-year rotations compared with continuous cropping.*

Station.	Year.	No. 6. Barley disked, oats fall plowed, corn fall plowed.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.	Average yield.	Value of continuous cropping.	Average of all rotations compared with continuous cropping.	
						Gain.	Loss.
Judith Basin, Mont	1909	$16.23	$14.86	$15.54	$17.17		$1.63
Dickinson, N. Dak	1908	17.33	13.07	15.20	12.73	$2.47	
Do	1909	20.44	18.70	19.57	15.12	4.45	
Edgeley, N. Dak	1907	6.95	4.03	5.49	3.88	1.61	
Do	1908	12.12	9.88	11.00	9.50	1.50	
Do	1909	12.58	12.43	12.51	10.26	2.25	
Highmore, S. Dak	1906	14.33	11.10	12.71			
Do	1907	9.50	10.75	10.13	11.47		1.34
Do	1908	11.40	11.36	11.38	11.32	.06	
Bellefourche, S. Dak	1909	17.90	10.68	14.29	9.04	5.25	
North Platte, Nebr	1907	11.63	15.28	13.45	14.82		1.37
Do	1908	9.46	8.47	8.97	7.44	1.53	
Do	1909	8.17	7.03	7.60			
Akron, Colo	1909	9.46	8.44	8.95	7.48	1.47	
Hays, Kans	1908	4.67	3.50	4.08	2.20	1.88	
Garden City, Kans	1909	1.94	2.17	2.06	.91	1.15	
Delhart, Tex	1909	.00	.00	.00	.00	.00	
Amarillo, Tex	1908	2.85	3.08	2.96	3.00		.04
Do	1909	.00	.00	.00	.00	.00	
Average		9.84	8.67	9.26	8.02	1.13	

Table XXI is a summary of preceding tables and shows that the average yields obtained from all rotations were considerably higher than from continuous cropping by ordinary methods.

As we have already shown that neither summer tillage and alternate cropping nor continuous cropping with moisture-conservation methods gave as good net results as continuous cropping by ordinary methods, we will continue to use the yields obtained by ordinary methods as a basis for comparison. This table shows that the average yields for all tests of all rotations were better than the continuous cropping yields for all three crops of wheat, oats, and barley. It also shows that the averages of all tests of each rotation taken separately were better for all crops, with one exception, than continuous cropping, the one exception noted being wheat in rotation No. 9, where it was sown on spring-plowed land after oats. The preceding tables show these same facts in more detail. It would seem, then, that our evidence was quite conclusive as to the superiority of crop rotation over any of the other methods which have so far been discussed.

TABLE XXI.—*Summary of foregoing tables, showing average yields per acre and average farm values per acre.*

CONTINUOUS CROPPING AND ALTERNATE CROPPING AND SUMMER TILLAGE.

Plat and cropping method.	Wheat.		Oats.		Barley.	
	Bush.		*Bush.*		*Bush.*	
C or D. Summer tillage and alternate cropping (1 crop in 2 years)	22.5	$13.50	44.1	$13.23	30.7	$11.67
B. Continuous cropping by moisture-conservation methods	16.5	9.90	30.5	9.15	22.9	8.70
A. Continuous cropping by ordinary methods	17.4	10.44	30.2	9.06	21.1	8.02

ROTATIONS.

Crop.		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.	No. 8.	No. 9.
Wheat	bushels	20.87	19.68	20.21	18.44	23.85			19.40	16.01
	value	$12.52	$11.81	$12.13	$11.06	$14.31			$11.64	$9.61
Oats	bushels	35.06	32.44	34.00	38.46	34.92	34.78	37.50	44.58	34.34
	value	$10.52	$9.73	$10.20	$11.54	$10.47	$10.43	$11.25	$13.37	$10.30
Barley	bushels						25.90	22.83		
	value						$9.84	$8.67		

Item of comparison.	Wheat.		Oats.		Barley.	
	Bush.		*Bush.*		*Bush.*	
Average yield and value per acre from rotations	19.8	$11.87	36.3	$10.89	24.4	$9.26
Average increase in yield compared with continuous cropping by ordinary methods	2.4	1.43	6.1	1.83	3.3	1.24

COMPARISON OF THE RELATIVE FARM VALUE OF CROPS OF WHEAT, OATS, AND BARLEY PRODUCED BY EACH OF THE NINE ROTATIONS AND BY CONTINUOUS CROPPING.

THE TABULAR SUMMARY.

In Tables XXII and XXIII have been brought together in condensed form much of the data contained in the foregoing tables. Table XXII gives the farm value per acre for wheat and oats or barley and oats for each rotation. The figures given in the respective columns of Table XXIII for each rotation were obtained by subtracting the corresponding figures for the farm values of each test of continuous cropping, as given in Table V, from the farm values for each test of each rotation as given in Table XXII. In these comparisons the average farm value per acre for wheat and oats has been used for rotations Nos. 1, 2, 3, 4, 5, 8, and 9, and for barley and oats in rotations Nos. 6 and 7—the basis of valuation, as in all other tables, being 60 cents for wheat, 30 cents for oats, and 38 cents for barley. The second column from the right-hand side of the table gives the loss or gain in dollars per acre of the best rotation, except Nos. 5 and 8, as compared with continuous cropping. The reason for excepting Nos. 5 and 8 is that they are both fallow rotations and are therefore not strictly comparable with the other rotations of this series where a crop is grown every year. This best rotation is printed in black-faced type so as to be readily recognized at a glance.

At the foot of each column is given the average for all tests of the respective rotations. Just below these averages are given their equivalents in bushels per acre of wheat, oats, and barley. It must be constantly borne in mind that the farm values are all based upon wheat at 60 cents, oats at 30 cents, and barley at 38 cents. These prices are at least 50 per cent too low to meet present price conditions. In order, therefore, to meet these conditions, all the farm values expressed in dollars and cents should be multiplied by 1.5, while bushels per acre would, of course, remain the same.

We find from consulting the figures given in this table that all the rotations except No. 9 gave better average results for all the tests than continuous cropping. We also find that the average results for all rotations in each test were better than continuous cropping except at Judith Basin, Mont., 1909; North Platte, Nebr., 1909; and Amarillo, Tex., 1908.

At Judith Basin the crops were all grown on virgin prairie, broken in 1907 and first cropped in 1908. The season of 1909 was especially favorable, so that very large crops were raised by all methods. The slight difference in favor of continuous cropping was therefore of little or no significance. At North Platte the results were very slightly in favor of rotation in 1907 and very markedly so in 1908. The average results of the three years were therefore in favor of rotation, so the results of 1909 can not be considered of great significance. They were due to the fact that a severe freeze about the first of May, followed by high winds, injured the crops on those fields that had had the best tillage and had consequently produced the most vigorous growth more than it did those on the poorer tilled fields where the growth was less advanced. This is not an infrequent occurrence throughout the Great Plains, but it can not be used as a reason for practicing continuous cropping instead of crop rotation. The crops at Amarillo, Tex., were so near a practical failure that the fact that continuous cropping gave slightly better results can not be considered of great significance. It may therefore be safely asserted that the net results of all the tests were strongly in favor of rotation. This becomes more apparent when we consider that the best rotation in the test gave better results than continuous cropping in all except three instances, and the average results showed a difference in favor of rotation amounting to $2.38 per acre; or calculated in bushels of wheat, oats, and barley, 3.91, 7.93, and 6.26 bushels per acre, respectively.

At first sight it might appear that there was little uniformity in the rotation giving the best average results in all the tests or in the ones giving the best results at any given station where two or more years' results have been obtained. A more careful consideration will show, however, that some general uniformity in results is indicated. In just half the tests either rotations Nos. 1 or 6 gave the best results. These two rotations are identical except that in No. 1 wheat was sown on disked corn stubble and in No. 6 barley was substituted for the wheat. The other barley rotation, No. 7, gave the best results in three tests. Nos. 3 and 4 gave the best results in two tests each, while No. 2 gave the best results in only one test.

Rotation No. 9 failed to give the best results in any test. This fact is very significant, as it brings to notice an important feature of crop rotation. This is, that one sequence may give the best results at a station when the plowing is done at one time of year, while the opposite sequence gives the best results when the plowing is done at another time. It seems that the oats-wheat-corn sequence makes a bad combination with spring plowing at all the stations. It seems likely that further investigation will show that there are other combinations which are to be avoided.

When we come to a consideration of the rotation which has given the best results at those stations where two or more tests have been made, we find less difficulty in reconciling the seeming diversity of results.

At Dickinson, N. Dak., rotation No. 1 gave the best results in 1908 and No. 2 in 1909. A change of 60 cents in the relative farm values per acre in 1909 would have made No. 2 the best both years. It is quite probable that a rotation of wheat on disked corn stubble, oats on spring plowing, and corn on spring plowing would give better results than either No. 1 or No. 2 at this station.

At Edgeley, N. Dak., rotation No. 1 gave the best results in 1907 and 1908, while in 1909 No. 3 was best. The difference between No. 1 and No. 3 in 1909 was, however, only 23 cents per acre. These two rotations differ only in that in No. 1 the corn stubble is disked and in No. 3 it is plowed. It may therefore be inferred that No. 1 will give the best average results at this station.

At Highmore, S. Dak., rotation No. 6 gave the best results one year and No. 7 the next. These are both barley rotations. It may therefore be inferred that barley is a profitable crop there, and that neither the sequence nor the time of plowing is of great importance in a 3-year rotation of corn, oats, and barley.

At North Platte, Nebr., a different rotation gave the best results in each of the three tests. The results in the 1909 tests were so affected by adverse weather conditions in May as to have little significance. In 1907 No. 4 and in 1908 No. 1 gave the best results. These two rotations differ only in sequence. In both No. 1 and No. 4 grain was sown on disked corn stubble, and the corn and other small-grain crop were on fall plowing. It would therefore seem that at this station disked corn stubble for one of the small-grain crops and fall plowing for corn and other small-grain crops are the best methods of preparation and that sequence is of relatively small importance.

At Amarillo the crops all suffered so severely from drought in 1909 that the discrepancies in the results of the two years are not significant.

Comparisons of the several rotations will be made in discussing the tables which follow.

TABLE XXII.—*Average farm value, in dollars and cents, per acre, of nine 3-year rotations.*

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. Wheat on fallow, wheat fall plowed, corn fall plowed.	No. 5. Wheat on fallow, oats fall plowed, fallow.	No. 6. Barley disked, oats fall plowed, corn fall plowed.
Judith Basin, Mont	1909	$20.66	$19.40	$18.53	$21.11	$21.47	$16.79
Dickinson, N. Dak	1908	16.03	18.37	16.33	15.72	15.81	15.37
Do	1909	21.60	21.00	20.57	21.17	20.88	19.50
Edgeley, N. Dak	1907	8.90	8.42	8.35	7.47	7.66	8.35
Do	1908	11.14	7.83	8.78	8.22	10.86	8.45
Do	1909	19.50	19.33	19.72	18.10	18.50	15.33
Highmore, S. Dak	1906	14.81	14.01	14.73	16.74	16.50	15.24
Do	1907	13.48	14.94	14.96	15.96	18.24	12.16
Do	1908	11.61	13.10	12.16	11.88	12.87	11.14
Bellefourche, S. Dak	1909	17.16	13.55	17.01	20.16	17.16	18.79
North Platte, Nebr	1907	10.73	11.96	10.80	13.35	12.48	9.28
Do	1908	17.62	12.73	17.36	17.54	20.87	12.09
Do	1909	9.98	9.37	10.04	8.41	11.02	7.04
Akron, Colo	1909	11.34	8.99	8.58	6.38	7.96	7.85
Hays, Kans	1908	5.39	4.35	4.19	4.41	4.65	7.66
Garden City, Kans	1909	.75	1.39	.66	.70	2.48	1.44
Dalhart, Tex	1909	.00	.00	.00	.00	2.31	.00
Amarillo, Tex	1908	6.71	5.91	6.67	7.38	8.61	6.12
Do	1909	1.50	.00	2.67	.00	5.14	.00
Average		11.52	10.77	11.16	11.30	12.39	10.14

Station.	Year.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.	No. 8. Oats on fallow, wheat fall plowed, fallow.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average yield.	Yield from continuous cropping.	Gain or loss of rotation compared with continuous cropping.
Judith Basin, Mont	1909	$18.53	$22.02	$20.08	$19.84	$20.91	−$1.07
Dickinson, N. Dak	1908	15.67	15.29	13.20	15.75	14.34	1.41
Do	1909	19.89	21.70	19.90	20.69	16.32	4.37
Edgeley, N. Dak	1907	5.74	7.19	2.10	7.13	4.59	2.54
Do	1908	8.65	6.22	6.59	8.53	6.70	1.83
Do	1909	15.35	16.41	16.54	17.64	16.36	1.28
Highmore, S. Dak	1906	14.17	20.01	16.25	15.83	....	....
Do	1907	11.95	18.48	14.48	14.96	14.79	.17
Do	1908	11.68	15.24	13.50	12.58	12.55	.03
Bellefourche, S. Dak	1909	14.16	22.74	17.16	17.54	13.88	3.66
North Platte, Nebr	1907	12.99	14.63	11.25	11.94	11.86	.08
Do	1908	13.28	23.11	12.48	16.34	11.29	5.05
Do	1909	8.78	5.04	9.13	8.76	11.10	− 2.35
Akron, Colo	1909	8.06	7.52	6.92	8.18	7.34	.84
Hays, Kans	1908	4.03	5.58	3.52	4.86	.72	4.14
Garden City, Kans	1909	1.65	2.01	1.10	1.35	.74	.61
Dalhart, Tex	1909	.00	1.50	.00	.42	.00	.42
Amarillo, Tex	1908	4.73	9.12	4.96	6.68	7.30	− .62
Do	1909	.00	3.84	.00	1.46	.00	1.46
Average		9.97	12.51	9.95	[a] 11.08	[b] 9.49	1.35

[a] Average of 19 crops. [b] Average of 18 crops.

TABLE XXIII.—*Gain or loss of each rotation for each test as compared with continuous cropping by ordinary methods.*

[The plus sign indicates gain in favor of rotation and the minus sign loss—in terms of dollars and cents per acre for wheat and oats or barley and oats in each rotation. The best rotation, excepting Nos. 5 and 8, each of which has one fallow year and is therefore not strictly comparable with the others, is printed in black-faced type.]

Station.	Year.	No. 1. Wheat disked, oats fall plowed, corn fall plowed.	No. 2. Wheat spring plowed, oats spring plowed, corn spring plowed.	No. 3. Wheat fall plowed, oats fall plowed, corn fall plowed.	No. 4. oats disked, wheat fall plowed, corn fall plowed.	No. 5. Wheat fallow, oats fall plowed, fallow.	No. 6. Barley disked, oats fall plowed, corn fall plowed.
Judith Basin, Mont	1909	−$0.54	−$1.80	−$2.67	**−$0.09**	+$0.27	−$3.09
Dickinson, N. Dak	1908	+ 1.49	**+ 3.82**	+ 1.78	+ 1.17	+ 1.26	+ 1.75
Do	1909	**+ 5.18**	+ 4.58	+ 4.15	+ 4.75	+ 4.46	+ 3.56
Edgeley, N. Dak	1907	**+ 4.47**	+ 4.00	+ 3.93	+ 3.05	+ 3.21	+ 3.22
Do	1908	**+ 4.62**	+ 1.31	+ 2.26	+ 1.70	+ 4.34	+ 1.17
Do	1909	+ 2.38	+ 2.22	**+ 2.61**	+ .99	+ 1.39	+ 1.49
Highmore, S. Dak	1907	− 1.95	− .49	− .47	+ .53	+ 2.81	**− .37**
Do	1908	− 1.44	+ .05	− .89	− 1.17	− .18	+ .32
Bellefourche, S. Dak	1909	+ 2.70	− .91	+ 2.55	+ 5.70	+ 2.70	**+ 6.95**
North Platte, Nebr	1907	− 1.12	+ .11	− 1.05	**+ 1.50**	+ .63	− 2.63
Do	1908	**+ 5.65**	+ .76	+ 5.39	+ 5.57	+ 8.90	+ 3.21
Do	1909	− 1.62	− 2.22	− 1.55	− 3.18	− .57	− 2.35
Akron, Colo	1909	**+ 3.88**	+ 1.54	+ 1.13	− 1.07	+ .51	+ .94
Hays, Kans	1908	+ 4.83	+ 3.80	+ 3.64	+ 3.86	+ 4.10	**+ 6.37**
Garden City, Kans	1909	− .03	+ .61	− .12	− .08	+ 1.70	+ .84
Dalhart, Tex	1909	+ .00	+ .00	+ .00	+ .00	+ 2.31	+ .00
Amarillo, Tex	1908	− 1.39	− 2.19	− 1.43	− .72	+ .51	**+ 1.62**
Do	1909	+ 1.50	+ .00	**+ 2.67**	+ .00	+ 5.14	+ .00
Average		+ 1.59	+ .84	+ 1.22	+ 1.25	+ 2.41	+ 1.32
Equal to wheat at 60 cents....bu		2.65	1.40	2.03	2.08	4.00	2.20
Equal to oats at 30 cents.....do		5.30	2.80	4.06	4.16	8.00	4.40
Equal to barley at 38 cents...do		4.19	2.21	3.21	3.29	6.35	3.47

Station.	Year.	No. 7. Oats spring plowed, barley spring plowed, corn spring plowed.	No. 8. Oats fallow, wheat fall plowed, fallow.	No. 9. Oats spring plowed, wheat spring plowed, corn spring plowed.	Average gain or loss of all rotations compared with continuous cropping.	Difference in favor of the best rotation except Nos. 5 and 8 compared with continuous cropping.
Judith Basin, Mont	1909	−$1.35	+$0.82	−$1.12	−$1.06	−$0.09
Dickinson, N. Dak	1908	+ 2.05	+ .74	− 1.35	+ 1.41	+ 3.82
Do	1909	+ 3.95	+ 5.28	+ 3.48	+ 4.36	+ 5.18
Edgeley, N. Dak	1907	+ .61	+ 2.77	− 2.32	+ 2.55	+ 4.47
Do	1908	+ 1.37	− .30	+ .07	+ 1.84	+ 4.62
Do	1909	+ 1.60	− .70	− .57	+ 1.27	+ 2.61
Highmore, S. Dak	1907	− .58	+ 3.05	− .95	+ .17	− .37
Do	1908	**+ .86**	+ 2.19	+ .45	+ .02	+ .86
Bellefourche, S. Dak	1909	+ 2.32	+ 8.28	+ 2.70	+ 3.66	+ 6.95
North Platte, Nebr	1907	+ 1.08	+ 2.78	− .60	+ .08	+ 1.50
Do	1908	+ 4.40	+11.14	+ .51	+ 5.06	+ 5.65
Do	1909	**− .62**	− 6.55	− 2.46	− 2.35	− .62
Akron, Colo	1909	+ 1.15	+ .07	− .53	+ .85	+ 3.88
Hays, Kans	1908	+ 2.74	+ 5.03	+ 2.97	+ 4.15	+ 6.37
Garden City, Kans	1909	**+ 1.05**	+ 1.23	+ .32	+ .61	+ 1.05
Dalhart, Tex	1909	+ .00	+ 1.50	+ .00	+ .42	+ .00
Amarillo, Tex	1908	+ .23	+ 1.02	− 3.14	− .61	+ 1.62
Do	1909	+ .00	+ 3.84	+ .00	+ 1.46	+ 2.67
Average		+ 1.16	+ 2.34	− .14	+ 1.35	+ 2.79
Equal to wheat at 60 cents....bu		1.93	3.89	− 0.23	2.25	4.65
Equal to oats at 30 cents......do		3.87	7.80	− 1.46	4.50	9.30
Equal to barley at 38 cents....do		3.06	6.16	− 1.37	3.55	7.34

DISKED CORN STUBBLE BETTER THAN SUMMER TILLAGE FOR SPRING WHEAT AND OATS.

Table XXIV gives a comparison between the effects of summer tillage and disked corn stubble as a preparation for wheat and oats.

Rotation No. 1—corn on fall plowing, wheat on disked corn stubble, oats on fall plowing—is identical with No. 4 except that the sequence of the wheat and oats has been changed. Rotation No. 5—summer tillage, wheat on summer-tilled land, oats on fall plowing—is identical with No. 8, except that the sequence of the wheat and oats has been changed. We have therefore two pairs of rotations, 1 and 4 and 5 and 8. In both rotations of the first pair (1 and 4) corn is raised. In one of them (1) wheat is sown on the disked corn stubble. In the other (4) the oats are sown on the disked corn stubble. In the second pair (5 and 8) the land is summer tilled instead of being planted to corn. In one of these (5) wheat is sown on the summer-tilled land. In the other (8) oats are sown on the summer-tilled land.

A comparison of the average farm value per acre of these two pairs of rotations will give the relative merits of disked corn stubble and summer tillage as a preparation for both wheat and oats.

In the column headed "No. 1" is given the average farm value per acre of the two grain crops, wheat and oats, for each test. These values are calculated at 60 cents per bushel for wheat and 30 cents per bushel for oats for rotation No. 1. In the column headed "No. 4" are given the same data for rotation No. 4. In the next column to the right are given the average farm values per acre of the wheat and oats in the two corn rotations (1 and 4). In the columns headed "No. 5" and "No. 8" are given the same data for rotations Nos. 5 and 8, respectively. In the next column are given the average farm values per acre of the wheat and oats in the two summer-tilled rotations (5 and 8). In the next two columns are given the differences in farm value per acre between the average of the two pairs 1 and 4 and 5 and 8, which represent the gain in favor of summer tillage or disked corn stubble, as the case may be, for each test. In these comparisons the value of the corn crop is not included, the oat and wheat crops alone being considered. It is found that in twelve tests the summer-tilled rotations gave better average farm values per acre for the two grain crops than did the corn rotations, while in seven tests the corn rotations gave better average farm values for wheat and oats than the summer-tilled rotations, the average farm value per acre in favor of summer tillage being only $1.04 per acre and the greatest gain of summer tillage over disked corn stubble being only $4.41 per acre.

The cost of the summer tillage was fully equal to, if not more than, the cost of raising the corps of corn. Therefore, the total value of the crops of corn raised should be credited to the corn rotations. Although the yields from the corn plats, as previously explained, were much less satisfactory than those from the small grain plats, we have given them in this instance. In four tests, Judith Basin, Mont., Dickinson, N. Dak., 1908, and Edgeley, N. Dak., 1907 and 1908, the corn did not mature on account of the variety used not being early enough. In two other tests, Garden City, Kans., and Dalhart, Tex., 1909, no grain was produced on account of severe drought. In these six tests the yields of the fodder alone have been given. At Highmore no record was kept of the fodder, so only the grain yields are shown. The record is therefore incomplete and unsatisfactory, but it is sufficient to show the superiority of the corn rotations over the summer-tilled rotations.

The value of the fodder was calculated at $3 per ton. It is possible that this is too high for some localities where wild hay could be obtained for the cost of cutting, stacking, and hauling; on the other hand it was probably too low where hay was scarce and high on account of drought. The average farm value of hay for ten years in the four States of North Dakota, South Dakota, Nebraska, and Kansas has been $4.78 per ton. On this basis corn fodder would be worth at least $3. The average farm value per acre of the grain alone of the corn crop at the twelve stations where the corn matured was $10 per acre, calculated at 39 cents per bushel. The average farm value per acre of fodder in the sixteen tests where a record was kept was $4.67. At three of the tests where corn failed to mature, the wheat and oats gave better yields on the corn stubble than on the summer tillage. This leaves only three tests—Judith Basin, Mont., Garden City, Kans., and Dalhart, Tex.—where the gain was not in favor of the corn rotations. At Garden City, Kans., and Dalhart, Tex., the entire crops of wheat, oats, and corn were a practical failure even on the summer-tilled land, so these tests may be discarded as indecisive. The balance would therefore be in favor of the corn rotations in all the decisive tests, except Judith Basin, if no value whatever were placed upon the corn fodder. A valuation of even 50 cents per ton for the fodder would turn the balance in favor of the corn rotation at Judith Basin.

In the final right-hand column of the table are given the net average gains per acre of the corn rotations over the summer-tilled rotations, including both the grain and fodder of the corn crop. These figures were obtained by adding half the average value of the corn crops to the average value of the wheat and oats in the corn rotations and subtracting the average value of the wheat and oat crops in the summer-tilled rotations.[a]

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[a] The reason for adding one-half instead of the whole of the average farm value per acre of the two corn crops to the average farm value per acre of the two wheat and two oat crops in the corn rotations (1 and 4) is as follows: There are twice as many acres of wheat and oats, taken together, as there are either of corn or of summer-tilled land, respectively, in each of the two pairs of rotations. One-half of the average farm value of the two corn crops should therefore be added to each of the average farm values of the two wheat and the two oat crops in the two corn rotations (1 and 4), and their sum should be divided by two in order to make the net average farm value per acre of the two corn rotations comparable to that of the two summer-tilled rotations (5 and 8). The same end is accomplished by adding one-half the average farm value of the two corn crops to the average farm value of the two wheat and two oat crops in the corn rotations, as is done in the table.

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The results of these tests tend very strongly toward the conclusion that a corn crop is a better preparation for spring wheat or oats than summer tillage under a wide range of soil and climatic conditions in the Great Plains.

TABLE XXIV.—*Disked corn stubble compared with summer tillage as a preparation for crops of wheat and oats.*

Station.	Year.	Average value per acre of wheat and oats.						Gain in favor of summer tillage.[a]	Gain in favor of disked corn stubble.[a]
		Rotation No. 1.	Rotation No. 4.	Rotations Nos. 1 and 4.	Rotation No. 5.	Rotation No. 8.	Rotations Nos. 5 and 8.		
Judith Basin, Mont.	1909	$20.66	$21.11	$20.89	$21.47	$22.02	$21.75	$0.86	....
Dickinson, N. Dak.	1908	16.03	15.72	15.87	15.81	15.29	15.55	....	$0.32
Do.	1909	21.60	21.17	21.39	20.88	21.70	21.29	....	.10
Edgeley, N. Dak.	1907	8.90	7.47	8.18	7.66	7.19	7.42	....	.76
Do.	1908	11.14	8.22	9.68	10.86	6.22	8.54	....	1.14
Do.	1909	19.50	18.10	18.80	18.50	16.41	17.46	....	1.34
Highmore, S. Dak.	1906	14.81	16.74	15.77	16.50	20.01	18.26	2.49	....
Do.	1907	13.48	15.96	14.72	18.24	18.48	18.36	3.64	....
Do.	1908	11.61	11.88	11.75	12.87	15.24	14.05	2.30	....
Bellefourche, S. Dak.	1909	17.16	20.16	18.66	17.16	22.74	19.95	1.29	....
North Platte, Nebr.	1907	10.73	13.35	12.04	12.48	14.63	13.55	1.51	....
Do.	1908	17.62	17.54	17.58	20.87	23.11	21.99	4.41	....
Do.	1909	9.98	8.41	9.19	11.02	5.04	8.03	....	1.16
Akron, Colo.	1909	11.34	6.38	8.86	7.96	7.52	7.74	....	1.12
Hays, Kans.	1908	5.39	4.41	4.90	4.65	5.58	5.12	.22	....
Garden City, Kans.	1909	.75	.70	.73	2.48	2.01	2.24	1.51	....
Dalhart, Tex.	1909	....	....	....	2.31	1.50	1.91	1.91	....
Amarillo, Tex.	1908	6.71	7.38	7.04	8.61	9.12	8.86	1.82	....
Do.	1909	1.50	....	.75	5.14	3.84	4.49	3.74	....
Average	....	11.52	11.30	11.41	12.39	12.51	12.45	1.04	....

Station.	Year.	Returns from corn crop.			Net gain per acre of rotations 1 and 4 in favor of disked corn stubble.
		Fodder.	Grain.	Total.	
Judith Basin, Mont.	1909	$11.47	....	$11.47	$4.87
Dickinson, N. Dak.	1908	3.13	....	3.13	1.89
Do.	1909	2.97	$18.84	21.81	11.00
Edgeley, N. Dak.	1907	4.33	....	4.33	2.93
Do.	1908	3.48	....	3.48	2.88
Do.	1909	4.38	11.82	16.20	9.44
Highmore, S. Dak.	1906	....	14.95	14.95	4.98
Do.	1907	....	9.13	9.13	.93
Do.	1908	....	8.36	8.36	1.88
Bellefourche, S. Dak.	1909	5.26	7.69	12.95	5.18
North Platte, Nebr.	1907	7.01	7.23	14.24	5.61
Do.	1908	5.11	10.27	15.38	3.28
Do.	1909	3.78	10.19	13.97	8.24
Akron, Colo.	1909	4.03	9.73	13.76	8.00
Hays, Kans.	1908	7.86	5.27	13.13	6.35
Garden City, Kans.	1909	3.97	....	3.97	.48
Dalhart, Tex.	1909	1.31	....	1.31	−1.26
Amarillo, Tex.	1908	4.57	6.37	10.94	3.65
Do.	1909	2.13	....	2.13	−2.67
Total	....	74.79	119.85	194.64	....
Average	....	....	....	10.24	4.08

[a] Corn not considered.

DISKING CORN STUBBLE GIVES BETTER RESULTS THAN PLOWING FOR SPRING WHEAT WHICH IS TO FOLLOW.

In Table XXV a comparison has been made between the average farm values of rotations Nos. 1 and 3. These two rotations are identical, except that in No. 1 the corn stubble was disked and in No.3 it was fall plowed. In eleven tests, the disking, and in seven tests, the plowing, gave best results. The average was 36 cents per acre in favor of disking. In none of the tests was the gain in favor of plowing sufficient to more than pay for the extra labor, and in four it was insignificant. On the other hand, the gain from disking was, in five tests, enough, together with the less cost of disking, to make the disking decidedly the better practice. It may therefore be considered that these investigations indicate that disking is the better practice at all the stations.

TABLE XXV.—*Disking compared with plowing corn stubble for spring wheat.*

Station.	Year.	Average value per acre of wheat and oats.		Gain in favor of disking.	Gain in favor of plowing.
		Rotation No. 1, disked.	Rotation No. 3, plowed.		
Judith Basin, Mont	1909	$20.66	$18.53	$2.13	
Dickinson, N. Dak	1908	16.03	16.33		$0.30
Do	1909	21.60	20.57	1.03	
Edgeley, N. Dak	1907	8.90	8.35	.55	
Do	1908	11.14	8.78	2.36	
Do	1909	19.50	19.72		.22
Highmore, S. Dak	1906	14.81	14.73	.08	
Do	1907	13.48	14.96		1.48
Do	1908	11.61	12.16		.55
Bellefourche, S. Dak	1909	17.16	17.01	.15	
North Platte, Nebr	1907	10.73	10.80		.07
Do	1908	17.62	17.36	.26	
Do	1909	9.98	10.04		.06
Akron, Colo	1909	11.34	8.58	2.76	
Hays, Kans	1908	5.39	4.19	1.20	
Garden City, Kans	1909	.75	.66	.09	
Dalhart, Tex	1908				
Amarillo, Tex	1908	6.71	6.67	.04	
Do	1909	1.50	2.67		1.17
Average		11.52	11.16	.36	

THE RELATIVE MERITS OF FALL AND SPRING PLOWING DEPEND UPON LOCAL CONDITIONS OF SOIL AND CLIMATE.

In Tables XXVI and XXVII comparisons have been made between fall-plowed and spring-plowed rotations. In Table XXVI four fall-plowed and three spring-plowed rotations have been used, while in Table XXVII only two rotations have been used. The results of the two tables do not agree. The first table is probably the less trustworthy of the two, as it introduces several other factors, which undoubtedly obscure the results of the time of plowing. The two rotations presented in Table XXVII are strictly comparable, as they differ only in this one factor. Neither of these tables gives results that are at all decisive. The only conclusions that can be drawn are: That the natural character of the soil, its physical condition at the time of plowing, the holding of snow by stubble during the winter, the liability to blowing during the winter, and the kind of crop to be grown must all be considered. It would seem from these results that, until further evidence is secured, the farmer should do his plowing at the time that the soil is in best condition for plowing and when he can use his teams and men to the best advantage. The depth of plowing and the amount of harrowing after plowing must also be determined by local and seasonal conditions.

TABLE XXVI.—*Spring plowing compared with fall plowing.*

Station.	Year.	Fall-plowed rotations.					Spring-plowed rotations.				Difference in favor of fall plowing.
		Average value per acre of wheat and oats. No. 1.	Average value per acre of wheat and oats. No. 3.	Average value per acre of wheat and oats. No. 4.	Average value per acre of oats and barley. No. 6.	Average value per acre, fall-plowed rotations.	Average value per acre of wheat and oats. No. 2.	Average value per acre of barley and oats. No. 7.	Average value per acre of wheat and oats. No. 9.	Average value per acre, spring-plowed rotations.	
Judith Basin, Mont.	1909	$20.66	$18.53	$21.11	$16.79	$19.27	$19.40	$18.53	$20.08	$19.34	−$0.07
Dickinson, N. Dak.	1908	16.03	16.33	15.72	15.37	15.86	18.37	15.67	13.20	15.75	.11
Do.	1909	21.60	20.57	21.17	19.50	20.71	21.00	19.89	19.90	20.26	.45
Edgeley, N. Dak.	1907	8.90	8.35	7.47	8.35	8.27	8.42	5.74	2.10	5.42	2.85
Do.	1908	11.14	8.78	8.22	8.45	9.15	7.83	8.65	6.59	7.69	1.46
Do.	1909	19.50	19.72	18.10	15.33	18.16	19.33	15.35	16.54	17.07	1.09
Highmore, S. Dak.	1906	14.81	14.73	16.74	15.24	15.38	14.01	14.17	16.25	14.81	.57
Do.	1907	13.48	14.96	15.96	12.16	14.14	14.94	11.95	14.48	13.79	.35
Do.	1908	11.61	12.16	11.88	11.14	11.70	13.10	11.68	13.50	12.76	− 1.06
Bellefourche, S. Dak.	1909	17.16	17.01	20.16	18.79	18.28	13.55	14.16	17.16	14.96	3.32
North Platte, Nebr.	1907	10.73	10.80	13.35	9.28	11.04	11.96	12.99	11.25	12.07	− 1.03
Do.	1908	17.62	17.36	17.54	12.09	16.10	12.73	13.28	12.48	12.83	3.27
Do.	1909	9.98	10.04	8.41	7.04	8.87	9.37	8.77	9.13	9.09	− .29
Akron, Colo.	1909	11.34	8.58	6.38	7.85	8.54	8.99	8.06	6.92	7.99	.55
Hays, Kans.	1908	5.39	4.19	4.41	7.66	5.41	4.35	1.65	3.52	3.17	2.24
Garden City, Kans.	1909	.75	.66	.70	1.44	.89	1.39	4.03	1.10	2.17	− 1.28
Dalhart, Tex.	1909	......	......	......	......	......	......	......	......	......	......
Amarillo, Tex.	1908	6.71	6.67	7.38	6.12	4.72	5.91	4.73	4.96	5.20	− .48
Do.	1909	1.50	2.67	......	......	1.04	......	......	......	......	1.04
Average.	......	11.52	11.16	11.30	10.14	......	10.77	9.97	9.43	......	.69

TABLE XXVII.—*Spring plowing compared with fall plowing.*

Station.	Year.	Average value per acre of wheat and oats.		Gain in favor of—	
		Rotation No. 2.	Rotation No. 3.	Spring plowing.	Fall plowing.
Judith Basin, Mont	1909	$19.40	$18.53	$0.87	
Dickinson, N. Dak	1908	18.37	16.33	2.04	
Do	1909	21.00	20.57	.43	
Edgeley, N. Dak	1907	8.42	8.35	.07	
Do	1908	7.83	8.78		$0.95
Do	1909	19.33	19.72		.39
Highmore, S. Dak	1906	14.01	14.73		.72
Do	1907	14.94	14.96		.02
Do	1908	13.10	12.16	.94	
Bellefourche, S. Dak	1909	13.55	17.01		3.46
North Platte, Nebr	1907	11.96	10.80	1.16	
Do	1908	12.73	17.36		4.63
Do	1909	9.37	10.04		.67
Akron, Colo	1909	8.99	8.58	.41	
Hays, Kans	1908	4.35	4.19	.16	
Garden City, Kans	1909	1.39	.66	.73	
Dalhart, Tex	1909	.00	.00	.00	
Amarillo, Tex	1908	5.91	6.67		.76
Do	1909	.00	2.67		2.67
Average		10.77	11.16		.39

THE RELATION OF WHEAT AND OATS TO SUMMER TILLAGE IN A THREE-YEAR ROTATION.

The comparison in Table XXVIII of rotation No. 5, where wheat, and No. 8, where oats, follow summer tillage gives some interesting information. At Judith Basin, Mont., where only one year's results have been secured, the advantage was slightly in favor of oats following summer tillage. At Dickinson, N. Dak., the difference was not only small but also contradictory for the two years. At Edgeley, N. Dak., the advantage was in favor of No. 5, wheat after fallow all three years. At Highmore, S. Dak., the advantage was with No. 8, oats after fallow all three years. At Bellefourche, S. Dak., the single year's results are markedly in favor of No. 8. At North Platte, Nebr., the advantage was with No. 8 in 1907 and 1908 and with No. 5 in 1909. For reasons already explained, the last year's results at this station were reversed by unfavorable weather conditions in May. The results indicate that No. 8 is the better for North Platte. The results of the tests at the other stations were indecisive. It appears, therefore, that at Edgeley the advantage is decidedly in favor of No. 5, wheat after summer tillage. At Highmore, Bellefourche, and North Platte the advantage is as strongly in favor of No. 8, oats after summer tillage. The other stations show no marked advantage in favor of either rotation over the other.

TABLE XXVIII.—*Fallow, wheat, oats (rotation No. 5) compared with fallow, oats, wheat (rotation No. 8).*

Station.	Year.	Average value per acre of—		Gain in favor of—	
		Wheat and oats. Rotation No. 5.	Oats and wheat. Rotation No. 8.	Rotation No. 5.	Rotation No. 8.
Judith Basin, Mont	1909	$21.47	$22.02		$0.55
Dickinson, N. Dak	1908	15.81	15.29	$0.52	
Do	1909	20.88	21.70		.82
Edgeley, N. Dak	1907	7.66	7.19	.47	
Do	1908	10.86	6.22	4.64	
Do	1909	18.50	16.41	2.09	
Highmore, S. Dak	1906	16.50	20.01		3.51
Do	1907	18.24	18.48		.24
Do	1908	12.87	15.24		2.37
Bellefourche, S. Dak	1909	17.16	22.74		5.58
North Platte, Nebr	1907	12.48	14.63		2.15
Do	1908	20.87	23.11		2.24
Do	1909	11.02	5.04	5.98	
Akron, Colo	1909	7.96	7.52	.44	
Hays, Kans	1908	4.65	5.58		.93
Garden City, Kans	1909	2.48	2.01	.47	
Dalhart, Tex	1909	2.31	1.50	.81	
Amarillo, Tex	1908	8.61	9.12		.51
Do	1909	5.14	3.84	1.30	
Average		12.39	12.51		.12

WHEAT, OATS, CORN A BETTER SEQUENCE ON SPRING PLOWING THAN OATS, WHEAT, CORN AT MOST STATIONS.

In Table XXIX a comparison of rotations Nos. 2 and 9 shows that when spring plowing is practiced the wheat-oats-corn sequence gives better results than the oats-wheat-corn sequence, Highmore and Bellefourche, S. Dak., and Judith Basin, Mont., being the only stations where the latter sequence gives better results than the former.

In Table XXX the same comparisons have been made between rotations Nos. 1 and 4. In these rotations the corn stubble was disked instead of plowed and the two other plats in each of the rotations were fall plowed instead of being spring plowed, as were rotations Nos. 2 and 9.

The results of this comparison agree in a general way with those of rotations Nos. 2 and 9, but are less markedly in favor of the corn-wheat-oats sequence, the net gain of this sequence being only 22 cents instead of 82 cents per acre. The four tests giving results in favor of the corn-oats-wheat sequence in Table XXIX also gave like results in Table XXX. There are, however, three additional tests in the latter comparison in favor of the corn-oats-wheat sequence, i. e., Highmore, 1907, North Platte, 1907, and Amarillo, 1908.

TABLE XXIX.—*Comparison of rotations Nos. 2 and 9 in detail, showing the effect of sequence, in dollars and cents per acre.*

Station.	Year.	Value of wheat per acre.		Value of oats per acre.		Average value per acre.	
		Rotation No. 2.	Rotation No. 9.	Rotation No. 2.	Rotation No. 9.	Rotation No. 2.	Rotation No. 9.
Judith Basin, Mont	1909	$19.86	$18.96	$18.93	$21.21	$19.40	$20.08
Dickinson, N. Dak	1908	21.00	11.22	15.75	15.18	18.37	13.20
Do	1909	23.82	18.42	18.18	21.39	21.00	19.90
Edgeley, N. Dak	1907	7.92	2.52	8.91	1.68	8.42	2.10
Do	1908	9.48	8.10	6.18	5.07	7.83	6.59
Do	1909	19.56	15.48	19.11	17.61	19.33	16.54
Highmore, S. Dak	1906	16.38	15.42	11.64	17.07	14.01	16.25
Do	1907	17.40	14.70	12.48	14.25	14.94	14.48
Do	1908	15.12	14.52	11.07	12.48	13.10	13.50
Bellefourche, S. Dak	1909	14.34	15.66	12.75	18.66	13.55	17.16
North Platte, Nebr	1907	14.22	12.48	9.69	10.02	11.96	11.25
Do	1908	14.40	10.50	11.07	14.46	12.73	12.48
Do	1909	10.32	10.00	8.43	8.25	9.37	9.13
Akron, Colo	1909	12.48	8.58	5.49	5.25	8.99	6.92
Hays, Kans	1908	.90	1.32	7.80	5.73	4.35	3.52
Garden City, Kans	1909	2.40	1.50	.39	.69	1.39	1.10
Dalhart, Tex	1909	.00	.00	.00	.00	.00	.00
Amarillo, Tex	1908	4.80	3.18	7.02	6.75	5.91	4.96
Do	1909	.00	.00	.00	.00	.00	.00
Average		11.81	9.61	9.73	10.30	10.77	9.95

Station.	Year.	Gain in value per acre of wheat.		Gain in value per acre of oats.		Gain in value per acre.	
		Rotation No. 2 over No. 9.	Rotation No. 9 over No. 2.	Rotation No. 2 over No. 9.	Rotation No. 9 over No. 2.	Rotation No. 2 over No. 9.	Rotation No. 9 over No. 2.
Judith Basin, Mont	1909	$0.90			$2.28		$0.68
Dickinson, N. Dak	1908	9.78		$0.57		$5.17	
Do	1909	5.40			3.21	1.10	
Edgeley, N. Dak	1907	5.40		7.23		6.32	
Do	1908	1.38		1.11		1.24	
Do	1909	4.08		1.50		2.79	
Highmore, S. Dak	1906	.96			5.43		2.24
Do	1907	2.70			1.77	.46	
Do	1908	.60			1.41		.40
Bellefourche, S. Dak	1909		$1.32		5.91		3.61
North Platte, Nebr	1907	1.74			.33	.71	
Do	1908	3.90			3.39	.25	
Do	1909	.32		.18		.24	
Akron, Colo	1909	3.90		.24		2.07	
Hays, Kans	1908		.42	2.07		.83	
Garden City, Kans	1909	.90			.30	.29	
Dalhart, Tex	1909	.00	.00				
Amarillo, Tex	1908	1.62		.27		.95	
Do	1909	.00	.00				
Average		2.20			.57	.82	

TABLE XXX.—*Comparison of rotations Nos. 1 and 4 in detail, showing the effect of sequence, in dollars and cents per acre.*

Station.	Year.	Value of wheat per acre.	Value of oats per acre.		Value of wheat per acre.	Average value per acre.	
		Rotation No. 1.	Rotation No. 1.	Rotation No. 4.	Rotation No. 4.	Rotation No. 1.	Rotation No. 4.
Judith Basin, Mont	1909	$20.88	$20.43	$22.23	$19.98	$20.66	$21.11
Dickinson, N. Dak	1908	21.48	10.59	20.16	11.28	16.03	15.72
Do	1909	23.88	19.32	21.75	20.58	21.60	21.17
Edgeley, N. Dak	1907	10.02	7.77	8.64	6.30	8.90	7.47
Do	1908	14.40	7.89	7.02	9.42	11.14	8.22
Do	1909	19.80	19.20	19.11	17.10	19.50	18.10
Highmore, S. Dak	1906	16.02	13.59	18.48	15.00	14.81	16.74
Do	1907	12.90	14.07	14.52	17.40	13.48	15.96
Do	1908	14.58	8.64	10.68	13.08	11.61	11.88
Bellefourche, S. Dak	1909	17.64	16.68	22.50	17.82	17.16	20.16
North Platte, Nebr	1907	13.38	8.07	12.18	14.52	10.73	13.35
Do	1908	17.16	18.09	16.29	18.78	17.62	17.54
Do	1909	13.02	6.93	6.75	10.08	9.98	8.41
Akron, Colo	1909	15.00	7.68	6.39	6.36	11.34	6.38
Hays, Kans	1908	2.22	8.55	4.80	4.02	5.39	4.41
Garden City, Kans	1909	.60	.90	.87	.54	.75	.70
Dalhart, Tex	1909	.00	.00	.00	.00	.00	.00
Amarillo, Tex	1908	4.98	8.43	6.84	7.92	6.71	7.38
Do	1909	.00	3.00	.00	.00	1.50	.00
Average		12.52	10.52	11.54	11.06	11.52	11.30

Station.	Year.	Gain in value of wheat.		Gain in value of oats.		Gain in value per acre.	
		Rotation No. 1 over No. 4.	Rotation No. 4 over No. 1.	Rotation No. 1 over No. 4.	Rotation No. 4 over No. 1.	Rotation No. 1 over No. 4.	Rotation No. 4 over No. 1.
Judith Basin, Mont	1909	$0.90			$1.80		$0.45
Dickinson, N. Dak	1908	10.20			9.57	$0.31	
Do	1909	3.30			2.43	.43	
Edgeley, N. Dak	1907	3.72			.87	1.43	
Do	1908	4.98		$0.87		2.92	
Do	1909	2.70		.09		1.40	
Highmore, S. Dak	1906	1.02			4.89		1.93
Do	1907		$4.50		.45		2.48
Do	1908	1.50			2.04		.27
Bellefourche, S. Dak	1909		.18		5.82		3.00
North Platte, Nebr	1907		1.14		4.11		2.62
Do	1908		1.62	1.80		.08	
Do	1909	2.94		.18		1.57	
Akron, Colo	1909	8.64		1.29		4.96	
Hays, Kans	1908		1.80	3.75		.98	
Garden City, Kans	1909	.06		.03		.05	
Dalhart, Tex	1909	.00	.00	.00			
Amarillo, Tex	1908		2.94	1.59			.67
Do	1909	.00		3.00		1.50	
Average		1.46			1.02	.22	

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ROTATIONS FOR THE CONSERVATION OF ORGANIC MATTER IN THE SOIL.

The conservation of the organic matter in the soil is probably the most important problem in crop rotation. In the various 3-year rotations which have been discussed in the foregoing pages no attention has been paid to this important subject for the reasons already given, that its introduction in these experiments would tend to obscure the effects of sequence and methods of soil preparation. A great deal of work has, however, been done at these same stations with various rotations calculated to conserve the organic matter in the soil. There are several reasons why the results from these experiments have not yet reached the stage where any very safe conclusion can be drawn. Among the most important of these reasons are the following:

(1) Rotations planned for this purpose must be of at least four and, preferably, six years' duration; and a complete cycle of the rotation should be completed before results will be at all marked.

(2) The plowing under of sod or green manure is frequently less beneficial to the crops immediately following than to the subsequent crops. Under certain conditions of soil and climate the first effect may be even to reduce rather than to increase the following crop. This is especially true where a green-manure crop is allowed to become too mature before plowing under, where a grass or clover sod is broken when it is not in the best condition for plowing, or where the soil is not properly treated after plowing.

(3) The great diversity of soil and climatic conditions encountered at the several stations has made it impossible always to foresee just how the best results can be obtained. Some experiments and some mistakes had to be made before the best methods of investigation could be worked out.

(4) The growing of most of the cultivated perennial grasses, the biennial and annual legumes, and the winter grains is still in the early experimental stages at many of the stations. The failure to secure a catch of seed and the injury or total loss of the crop by winterkilling has in some instances seriously interfered with carrying out the plans of the experiments.

(5) Experience is enabling us to gradually reduce these sources of error, but they can never be entirely eliminated. It will therefore require a much longer period of time to reach the same degree of accuracy in these investigations as that attained with the simple 3-year rotations and the continuous cropping and summer tillage experiments already described.

(6) Another important consideration in this connection is that the effects of all these methods are cumulative. Continuous cropping or

alternate cropping and summer tillage without the application of barnyard or green manure must in time deplete the soil of its organic matter and consequently reduce both its drought resistance and its fertility. On the contrary, a properly planned and conducted rotation system should maintain or augment the store of organic matter in the soil and thereby increase both its fertility and its drought resistance, and consequently its crop-producing capacity. Such being the case it would be manifestly unreasonable to expect to establish any definite quantitative relations between two such diverging systems until after a lapse of sufficient time to allow the rate of this divergence to become definitely established.

While the results of these investigations have not yet reached the stage where definite quantitative relations can be established, they have, we believe, produced sufficient evidence to warrant us in making certain recommendations and suggestions for rotations in the Great Plains.

In the following pages we have attempted to outline certain systems of crop rotation which will combine the best features of the extensive system of farming with the conservation of the organic matter, as well as the moisture of the soil. These rotations, as well as many others, have been on trial at nearly all the stations mentioned and have given sufficiently favorable results to warrant their recommendation for further trials by farmers in the Great Plains area.

The following tables are intended to represent a quarter section of land divided into as many fields as there are years in the rotation. Of course, this would apply equally as well to a farm of more or less extent than 160 acres, but as a quarter section is the common unit of land measurement in the West we have assumed that each of these rotations is to be practiced upon a single quarter. The letters assigned to the plats indicate the crops to be raised on each plat for as many years as are involved in the particular rotation under consideration. When this cycle has been completed it will be begun over and the same crops will be raised in the same succession continuously as long as the rotation is practiced.

It is quite important in planning a rotation to devote a great deal of careful thought and attention to the matter, as the best results will obtain where the rotations are carried on uninterruptedly for long periods. It is true that many minor changes may be made in the rotation without seriously interfering with its general plan. We have attempted to point out some of the ways in which the following rotations may be modified to suit local conditions.

Where annual crops only are used, the beginning of the rotation is a very simple matter. All that is necessary is to divide the farm into as many fields of uniform size as there are years in the rotation and then seed each field to the crops in the rotation in regular order, as is shown in the tables.

Where biennial or perennial crops enter into the rotation, as is the case with rotations Nos. 1 and 2, it will be necessary the first year to supply some other crop in the place of the perennial, which, when the rotation is once started, will be carried on from the previous year. For instance, in the case of the 6-year rotation (No. 2) the farm should be divided into six fields of equal area, as shown. Field A should be planted to corn, field B to wheat, and field C should be seeded to brome-grass. Field D should also be seeded to brome-grass, as it will remain as a meadow during the following year. Field E, which should be in brome-grass, but would be broken up after the grass was cut, should be planted to some other crop. It is not important what this crop should be, except that if the rotation has been adopted with a view to furnishing the proper quantity of hay it would be desirable to have this field put into some kind of an annual crop that could be cut for hay. Millet, oats and peas sown together, milo, or some of the other nonsaccharine sorghums, could be used for this purpose. Field F would be sown to oats, barley, emmer, or wheat, as shown. After the first year the rotation would go on without further interruption, except that in the case of a failure of the grass to catch, some annual could be substituted without in any way interfering with the general plan of the rotation.

FIVE-YEAR ROTATION (NO. 1).

FIELD A, 32 ACRES.

1910. Corn.
1911. Wheat, winter or spring.
1912. Brome-grass meadow.
1913. Brome-grass meadow.
1914. Oats, barley, emmer, or wheat.

FIELD B, 32 ACRES.

1910. Wheat, winter or spring.
1911. Brome-grass meadow.
1912. Brome-grass meadow.
1913. Oats, barley, emmer, or wheat.
1914. Corn.

FIELD C, 32 ACRES.

1910. Brome-grass meadow.
1911. Brome-grass meadow.
1912. Oats, barley, emmer, or wheat.
1913. Corn.
1914. Wheat, winter or spring.

FIELD D, 32 ACRES.

1910. Brome-grass meadow.
1911. Oats, barley, emmer, or wheat.
1912. Corn.
1913. Wheat, winter or spring.
1914. Brome-grass meadow.

FIELD E, 32 ACRES.

1910. Oats, barley, emmer, or wheat.
1911. Corn.
1912. Wheat, winter or spring.
1913. Brome-grass meadow.
1914. Brome-grass meadow

This rotation is one that has proved very satisfactory in our experiments, and it is believed that with the modifications that may be made in it, it will be found adapted to a large portion of the Great Plains area. It is possible that the order in which the crops are grown might be changed, but from our experience in this particular we have found this arrangement the most satisfactory. This being a 5-year rotation, the farm would be divided into five fields of 32 acres each. There would be 32 acres of corn, 64 acres of small grain, and 64 acres of meadow each year.

Corn.—This crop may be grown either upon fall plowing or spring plowing. The time of planting must be determined by the experience of farmers in the particular locality where it is to be tried. It is believed that, as a broad general proposition, spring plowing gives better results than fall plowing, but there are some notable exceptions to this general rule. If the ground is to be plowed in the fall, the plowing should be done as soon after the preceding crop is harvested as possible. The depth to which the plowing should be done is a matter that depends largely upon local conditions of soil and climate, and also upon the depth to which plowing has been done in previous years. It is not usually desirable to plow more than about 1 inch of soil that has not been previously stirred.

In the northern part of the area it will be impracticable to attempt any cultivation of the ground during the winter when the soil is frozen, but in the southern portion of the area, where the ground is not constantly frozen and where there is more or less winter rain, it would probably be advisable to harrow the ground after rains in order to preserve the moisture. In the spring the land may be disked or harrowed after rains to conserve the moisture until planting time. Where the soil is of such a nature as to cause it to blow badly, the fall, winter, and spring treatment should be such as to reduce this danger to the lowest point. No general rule can be laid down which would be applicable to the many different soils to be found in the area. The planting may be done with a checkrower or with a lister; whichever method is used the ground should be frequently cultivated after planting with a weeder or light harrow, or with some of the implements used for cultivated and listed ground. When the grain has reached the height where this class of implements can not be used, it should be thoroughly cultivated, not only to keep it free from weeds, but to keep the crust broken, so as to conserve the moisture. In cultivating the corn crop, two objects should constantly be kept in view: (1) The cultivation of the soil with reference to the corn crop, and (2) the preparation of the soil for the grain crop which is to follow. Experience has shown that where corn does not grow oftener than once in three years in the rotation it does not pay to plow the land after the corn crop and before the succeeding crop is sown. If a crop of winter wheat is to be raised, the wheat should either be drilled in between the rows of standing corn, as is found desirable in the northern part of the area, or the corn should be cut and either shocked or removed from the field and the grain sown on disked corn stubble.

Wheat.—If spring wheat is to be raised after the crop of corn, it will often be found advantageous to disk or harrow the corn stubble in the fall, after the corn is removed, in order to break up the crust and conserve the moisture resulting from the fall rains when they occur. In the spring the grain can be drilled in upon the corn stubble with either a disk or a shoe drill. If the cornstalks were not removed the previous fall, but were left standing, it will be necessary to break them down with some kind of a stalk cutter, such as is in common use wherever corn is extensively raised. In some instances it may be found necessary to disk the land before drilling in the wheat, but the soil is of such a nature over very considerable areas as to make this unnecessary and in some instances actually undesirable. A light harrowing after seeding is almost unfailingly beneficial, as it helps to cover the seed that may not have been completely covered by the drill, and also levels the surface. Light harrowing after the grain has come up and until it has reached a height where the harrowing will seriously harm the plants is usually desirable. On some soils this work can be better done with some one of the various types of weeders that are on the market. This harrowing of the grain after it is up should be done as soon after rains as the soil is dry enough, so as not to clog the harrow or weeder.

If brome-grass is to be sown with the wheat, the seeding of wheat should be as light as is consistent with a fair yield of grain. It would be impossible to lay down any rule as to the quantity per acre, but we have found 3 pecks per acre satisfactory. The brome-grass seed should be sown at the rate of about 20 pounds of good clean seed per acre. The seed may be sown either with the grass-seed attachment to the drill or broadcast by hand, and should be covered by a light harrowing. Where a man can be found who is accustomed to sowing seed by hand we have found the hand seeding the most satisfactory, as there is great danger of the brome-grass seed becoming clogged in the seeder on account of its light and chaffy nature.

Where winter wheat is raised, the brome-grass may usually be sown in the fall at the time of the seeding of wheat. If a good catch of brome-grass is not obtained from this fall seeding, it is possible to reseed the thin patches in the spring, covering the ground with a light harrow or weeder.

Brome-grass meadow.—If a good catch of brome-grass has been obtained, there should be a good yield of both hay and seed the following year. Where brome-grass seed is in demand, the seed crop is usually much more profitable than the hay crop, but, of course, only a small portion of the total crop of brome-grass can be used for this purpose each year in a locality where it is being extensively grown. The second year's crop of brome-grass usually yields more hay but less seed per acre, so that as a general thing the seed should be saved from the first year's crop and the second year's crop used mainly for hay. We have sometimes found it desirable to cut the seed with a binder, setting it high enough so as not to cut the thick mass of grass at the bottom, and to follow the binder with a mowing machine to cut the hay. In cutting brome-grass for seed great care should be exercised to harvest it at just the right time; that is, as soon as the seed is mature and before it begins to shed. We have frequently seen a crop of seed reduced one-half by a delay of two days in cutting.

After the second year's crop of brome-grass has been cut the sod should be broken in order to prepare the land for the crop of oats, barley, emmer, or wheat which is to follow. The proper time for breaking the sod will depend upon the locality, soil, and climatic conditions. In the northern part of the area it will be found entirely practicable to cut a crop of hay in June, break the sod immediately, and sow a crop of flax upon the sod. In this way two crops can be obtained from the field the same year, and, in addition to the advantage of raising two crops, the soil will be in better condition for the crop of grain which is to follow the next year than it would be if the sod was simply broken and allowed to remain without a crop until the following spring.

Oats, barley, emmer, or wheat.—The treatment of the brome-grass sod from the time it is broken until the seeding of the following spring is a matter concerning which it is very difficult to lay down any very definite rule. The object is, of course, to get the sod as thoroughly rotted and subdued as possible and to get the soil into the best possible condition for the seed bed for the spring crop. The means adopted to attain this end will depend so much upon local conditions, peculiarities of soil, climate, etc., that the farmer will have to depend largely upon his own judgment and experience. If a crop of flax has been raised, the sod will rot much more rapidly than where flax is not raised, and it will usually be found desirable to backset the sod in the fall if there is sufficient moisture in the soil. Where a crop of flax has not been raised, the question of backsetting in the fall or allowing the sod to remain undisturbed until the following spring is one that must depend upon local conditions.

SIX-YEAR ROTATION (NO. 2)

FIELD A, 26⅔ ACRES.

1910. Corn.
1911. Wheat, winter or spring.
1912. Seeded to brome-grass.
1913. Brome-grass meadow.
1914. Brome-grass meadow.
1915. Oats, barley, emmer, or wheat.

FIELD B, 26⅔ ACRES.

1910. Wheat, winter or spring.
1911. Seeded to brome-grass.
1912. Brome-grass meadow.
1913. Brome-grass meadow.
1914. Oats, barley, emmer, or wheat.
1915. Corn.

FIELD C, 26⅔ ACRES.

1910. Seeded to brome-grass.
1911. Brome-grass meadow.
1912. Brome-grass meadow.
1913. Oats, barley, emmer, or wheat.
1914. Corn.
1915. Wheat, winter or spring.

FIELD D, 26⅔ ACRES.

1910. Brome-grass meadow.
1911. Brome-grass meadow.
1912. Oats, barley, emmer, or wheat.
1913. Corn.
1914. Wheat, winter or spring.
1915. Seeded to brome-grass.

FIELD E, 26⅔ ACRES.

1910. Brome-grass meadow.
1911. Oats, barley, emmer, or wheat.
1912. Corn.
1913. Wheat, winter or spring.
1914. Seeded to brome-grass.
1915. Brome-grass meadow.

FIELD F, 26⅔ ACRES.

1910. Oats, barley, emmer, or wheat.
1911. Corn.
1912. Wheat, winter or spring.
1913. Seeded to brome-grass.
1914. Brome-grass meadow.
1915. Brome-grass meadow.

In some of the drier parts of the Great Plains area it will probably be found impracticable to attempt to raise brome-grass with a nurse crop. In such localities rotation No. 1, as previously described, should be modified by making it a 6-year instead of a 5-year rotation. With the 6-year rotation the farm would be divided into six fields of 26⅔ acres each, and we would, therefore, have 26⅔ acres of corn, 53⅓ acres of brome-grass, 53⅓ acres of small grain, and 26⅔ acres sown to brome-grass, but not yielding a crop. All the crops in the rotation would follow each other in the order already specified, except that there would be one year between the wheat crop and the first year of brome-grass meadow, during which the seeding of brome-grass would be done.

When this modification of the rotation is adopted, the following method will be found satisfactory for preparing the land for seeding to brome-grass. The land should be plowed as soon after the crop of wheat has been removed as is practicable. The treatment of the soil after plowing should be such as will carry it through the winter in the best physical condition. As soon as the frost is out of the surface the following spring it should be harrowed, and this harrowing should continue until the ground becomes thoroughly warm and that time of the season has been reached when there is most likelihood of rains. In the Dakotas this time is usually the first week in

June. In other parts of the area it may vary somewhat, but when the time arrives and the soil is thoroughly warm and in good condition and when there is a reasonable prospect of rain the brome-grass should be sown, as heretofore described, at the rate of about 20 pounds per acre and thoroughly harrowed in. The weeds having been kept down by previous harrowings and the soil having become packed into a firm seed bed and being moist and warm, the brome-grass should come up very quickly and evenly and will be able to keep ahead of the weeds, and a good stand ought to be the result in almost any part of the area during years of normal climatic conditions.

FOUR-YEAR ROTATION (NO. 3).

FIELD A, 40 ACRES.

1910. Corn.
1911. Wheat, winter or spring.
1912. Red clover.
1913. Oats, barley, emmer, or wheat.

FIELD B, 40 ACRES.

1910. Wheat, winter or spring.
1911. Red clover.
1912. Oats, barley, emmer, or wheat.
1913. Corn.

FIELD C, 40 ACRES.

1910. Red clover.
1911. Oats, barley, emmer, or wheat.
1912. Corn.
1913. Wheat, winter or spring.

FIELD D, 40 ACRES.

1910. Oats, barley, emmer, or wheat.
1911. Corn.
1912. Wheat, winter or spring.
1913. Red clover.

In some parts of the area clover has been successfully grown, and it is believed that it might be very much more extensively grown than it is at present. As it is a nitrogen gatherer, it is more desirable for improving the condition of the soil than is brome-grass, and we would therefore recommend the modification of rotation No. 2 by making it a 4-year rotation, which would necessitate the dividing of the farm into four fields of 40 acres each, as shown in rotation No. 3. There would then be 40 acres in corn, 80 acres in small grain, and 40 acres in clover each year. The clover can be sown with the wheat at the rate of about 15 pounds per acre. If it proves impracticable to raise clover with the wheat as a nurse crop, the rotation can be changed to a 5-year rotation, seeding the clover on thoroughly prepared ground, as discussed for brome-grass in the 6-year rotation (No. 2). Flax might be raised on the clover sod, as suggested for brome-grass sod.

FOUR-YEAR ROTATION (NO. 4).

Field A, 40 Acres.

1910. Corn.
1911. Wheat, winter or spring.
1912. Winter rye turned under in spring.
1913. Oats, barley, emmer, or wheat.

Field B, 40 Acres.

1910. Wheat, winter or spring.
1911. Winter rye turned under in spring.
1912. Oats, barley, emmer, or wheat.
1913. Corn.

Field C, 40 Acres.

1910. Winter rye turned under in spring.
1911. Oats, barley, emmer, or wheat.
1912. Corn.
1913. Wheat, winter or spring.

Field D, 40 Acres.

1910. Oats, barley, emmer, or wheat.
1911. Corn.
1912. Wheat, winter or spring.
1913. Winter rye turned under in spring.

While we feel confident that brome-grass and red clover can be much more commonly grown throughout this area than at present, we recognize that there probably are localities within the area where neither of these crops can be successfully grown, and it is altogether likely that even in those localities where the crops can be successfully grown during favorable seasons there will be unfavorable seasons when it will be impossible to get a catch of either of them. In order to provide for such emergencies we have included the following 4-year rotation, No. 4, in which we have substituted a crop of winter rye for the clover which occurred in rotation No. 3. The other crops in this rotation will not need further description, as they are to be treated the same as in the rotations described.

The ground for the winter rye should be prepared by plowing it as soon after the wheat crop is removed as possible. It should then be thoroughly packed and harrowed and kept in good tilth and free from weeds until the proper time for seeding has arrived. The date of seeding, of course, will vary somewhat with the latitude. After the rye is seeded it will require no further attention until the following spring or early summer, when it is to be turned under. The date when this should be done will, of course, vary with the season, but experience has shown that the best results are obtained when the rye is turned under after it has attained nearly its full growth but while it is still young and succulent and has not become hard and woody. This stage will vary somewhat in the same locality on account of the difference in weather conditions from season to season, so that each farmer must use his own judgment in determining whether the grain has reached the proper stage for plowing under. As soon as it is plowed under, the ground should be thoroughly packed and harrowed in order to prevent the rye straw from drying out in the soil instead of rotting. After the rye has been turned under, the field should be treated like summer tillage for the remainder of the season until the following spring, provided a spring crop is to be sown. If the field is to be sown to winter grain in the fall, the treatment should be the same as the summer tillage up to the time of seeding.

If this rotation is adopted and the plowing under of the winter rye is carefully done and the after-culture is sufficiently thorough, much better results will undoubtedly be obtained than from the summer tillage without the growing of a crop for turning under. The great objection to summer tillage is the fact that it is very destructive to the organic matter or humus in the soil, while this rotation will preserve and even increase the organic matter in the soil. The cost of seeding the field to rye is not great, and the labor involved is no more than would be necessary for the summer tillage carried on as thoroughly as it should be.

FOUR-YEAR ROTATION (NO. 5).

Field A, 40 Acres.

1910. Corn.
1911. Wheat, winter or spring.
1912. Field peas or cowpeas turned under in spring.
1913. Oats, barley, emmer, or wheat.

Field B, 40 Acres.

1910. Wheat, winter or spring.
1911. Field peas or cowpeas turned under in spring.
1912. Oats, barley, emmer, or wheat.
1913. Corn.

Field C, 40 Acres.

1910. Field peas or cowpeas turned under in spring.
1911. Oats, barley, emmer, or wheat.
1912. Corn.
1913. Wheat, winter or spring.

Field D, 40 Acres.

1910. Oats, barley, emmer, or wheat.
1911. Corn.
1912. Wheat, winter or spring.
1913. Field peas or cowpeas turned under in spring.

Rotation No. 5 is exactly like rotation No. 4 except that field peas or cowpeas will be used in the place of the winter rye. As both of these crops have the power of gathering the free nitrogen from the air and converting it into forms in which it can be used by succeeding crops, they are preferable in this respect to winter rye. The preparation of the land during the fall after the wheat has been removed should be the same as that recommended for fall plowing for other crops. In the spring the field peas or cowpeas should be sown as early as climatic conditions will permit. The time of seeding will, of course, depend upon the locality, and the rate of seeding should depend upon the fertility of the soil. As heavy a seeding should be given as the soil is capable of developing, as it is desirable, of course, to get as large an amount of growth for turning under as possible. Some very favorable results have been obtained by substituting sweet clover (*Melilotus alba*) for peas. When this is done, the sweet clover should be sown with the wheat crop and plowed under the next season before any seeds have matured, as it becomes a very bad weed in some localities.

What has already been said concerning the stage of growth of the rye and also concerning the treatment of the field after plowing under the crop will apply equally well to either field peas, cowpeas, or sweet clover.

THE PRINCIPLES OF CROP ROTATION.

FACTORS INVOLVED.

Crop rotation, with its concomitant features of farm organization, diversification of crops, and stock raising, is destined to become the most important problem in the agricultural development of the Great Plains. It is therefore worthy of the most careful study by all who are interested directly or indirectly in this development. It is one of the most complex and difficult of agricultural problems. The principal difficulties arise from the fact that the planning of a rotation is a long-time proposition, the laying out of plans reaching many years into the future, which makes it necessary to deal with factors which are constantly changing, both absolutely and relatively. Some of these changing factors are: The constantly varying absolute and relative prices of all the crops grown, of the live stock to which some of these crops must be fed, and of the products of this live stock; variable weather conditions; the attacks of diseases and insect enemies, where the same crop is grown too frequently on the same land; the varying cost of labor; the uncertainty and, in some instances, the utter impracticability of raising perennial crops for meadow or pasture; and many others which will readily occur to the thoughtful student of the problem.

In no field of scientific investigation or of the practical application of scientific principles is dogmatism more utterly out of place than in the study or practice of crop rotation. The factors of the problem are so local and individual in their nature, so closely associated with the local characteristics of each farm and its environment and the individual tastes, abilities, and limitations of each farmer, that no definite and specific directions can be given for establishing a rotation for any farm until all the factors are carefully studied. There are, however, certain general principles which are fairly well established. There are others which are strongly indicated by the investigations which have been described, but which may be either firmly established or disproved by a continuation of these investigations. Among the established principles may be mentioned the following:

(1) All crops may be roughly classified under three heads: Exhaustive, intermediate, and restorative. These terms must not be taken too literally. All crops which are harvested and removed from the land take from it more or less plant food and might therefore be said to be "exhaustive." No crop "restores" to the soil any considera-

ble amount of plant food unless it is plowed under for green manure or is allowed to decay upon the surface. But, nevertheless, certain crops leave the land in poorer condition for a subsequent crop of some particular kind than it was before they were raised. These are designated as "exhaustive" crops, and include wheat, oats, barley, rye, and millet. Their ill effects upon subsequent crops may be due to a reduction of the available plant food; to an increased growth of weeds, fungi, or injurious insects; to a change in the physical condition of the soil, particularly its water content; or to a reduction in the quantity or activity of beneficial lower organisms. "Restorative" crops have the opposite effect. They leave the soil in better condition for certain crops than it was before. Among restorative crops may be mentioned corn, potatoes, beans, peas, clover, alfalfa, most cultivated crops grown in the Great Plains, and perennial grasses grown for meadow or pasture. "Intermediate" crops are those that have, in some respects, a beneficial effect upon certain crops which follow them, while in other respects their influence is detrimental. The sorghums, cane, milo, and kafir belong to this class. Their beneficial effects are due to the fact that, like all cultivated crops, they reduce the amount of weeds in subsequent crops; their detrimental effects upon subsequent crops seem to be due to the fact that they are able to exhaust the soil moisture to a greater extent than any other crops commonly grown in the Great Plains.

(2) In addition to and in a certain measure independent of the above-mentioned classification is the problem of crop sequence, or the relations which two crops bear to each other independent of any apparent difference in the conditions of the soil brought about by their growth. For instance, two crops may be equally exhaustive, but when grown consecutively, better results will be obtained if they are grown in one sequence than when the opposite sequence is followed. Oats following wheat generally give better results than wheat following oats. Or, again, a restorative crop may have a more beneficial effect upon some certain exhaustive crop which follows it than it has upon some other equally exhaustive crop. Wheat generally responds more readily to the effects of a corn crop than does oats.

(3) The effects of the preparation of the land—time and depth of plowing, disking instead of plowing, the amount of harrowing and packing of the seed bed, etc.—depend not only upon the crop for which preparation is being made, but also upon the crop grown the preceding year and the previous soil treatment.

(4) The selection of the varieties or strains of the crops grown which are best adapted to the particular locality and to the rotation planned and the determination of the quantity of seed to use and of the method and time of seeding are also of great importance.

(5) The keeping of as much live stock of the most profitable kind and the feeding out upon the farm and the returning of the manure to the land of as large a proportion of the crops raised as is consistent with immediate profits is also of great importance.

In planning a rotation a recognition of the above-mentioned principles will require that the following rules be observed:

RULES TO BE OBSERVED IN PLANNING ROTATIONS.

(1) Select as large a number of restorative and as small a number of exhaustive crops as is consistent with the general plan of farm organization.

(2) Arrange the crops in the rotation so as to have the exhaustive and restorative crops alternate as far as possible.

(3) Observe the proper sequence, both between restorative and exhaustive crops and between two exhaustive crops where it becomes necessary to grow two such crops consecutively.

(4) Select the best varieties or strains and use the quantity of seed and the method and time of seeding best adapted to the locality.

(5) Plow and prepare the seed bed at the time and in the manner best adapted to the crop, the soil, the climate, and the most economical distribution of labor through the year.

(6) Obtain all available information concerning yields, cost, and prices of crops grown in the locality, and plan to grow those crops that will yield the largest net return per acre with the least depletion of soil fertility.

(7) Feed as large a proportion as possible of the crops grown and return the manure to the field.

(8) Raise the kind of live stock yielding the largest net profit and best adapted to the particular farm and locality and to the preferences of the farmer who handles it. Very few farmers ever make a success of raising any kind of live stock the care of which they do not enjoy.

(9) Use perennial grasses, alfalfa, or clover in the rotation wherever practicable, and where it is impracticable to do so raise rye, peas, or sweet clover for green manuring to maintain the humus in the soil.

It is believed that the tentative conclusions drawn from the results of the investigations described in this bulletin will materially aid in the establishment of rotations which will meet the above-mentioned requirements.

CONCLUSIONS FROM EXPERIMENTS.

(1) The practice of summer tillage and alternate cropping has not given results to warrant its recommendation as a safe basis for a permanent agriculture in the Great Plains area, where spring-grown wheat, oats, and barley are the staple crops. It may, however, be resorted to as a safeguard or temporary expedient to guard against

the total loss of the crop where extreme drought is anticipated, but it can not be depended upon to produce as profitable crops under average normal conditions as may be produced by other methods. (See Tables I, II, III, XXI, and XXIII.)

(2) Continuous cropping with moisture-conservation methods, involving early fall plowing and thorough fall, winter, and spring tillage and harrowing after the grain is up in the spring, has not given average results to warrant its practice. There have, however, been a few exceptions to this rule. (See Tables I, II, III, XXI, and XXIII.)

(3) A simple 3-year rotation of corn, wheat, and oats has given more profitable returns than any method of continuous cropping or alternate cropping and summer tillage in fourteen out of seventeen tests. In the three instances where continuous cropping gave better returns the difference was so small as to be practically negligible. (See Table XXIII and the preceding tables, of which it is a summary.)

(4) The two 3-year rotations giving the best average results are No. 1 (wheat on disked corn ground, oats on fall plowing, corn on fall plowing) and No. 6 (barley on disked corn ground, oats on fall plowing, corn on fall plowing). These two rotations are identical except that barley has been substituted for wheat in No. 6. One or the other of these two rotations gave the best results at nine of the eighteen tests: Dickinson, N. Dak., 1909, Edgeley, N. Dak., 1907 and 1908, Highmore, S. Dak., 1907, Bellefourche, S. Dak., 1909, North Platte, Nebr., 1908, Akron, Colo., 1909, Hays, Kans., 1908, and Amarillo, Tex., 1908. (See Table XXIII.)

(5) Rotation No. 7, oats, barley, corn, all on spring-plowed land, gave the best results at three tests: Highmore, S. Dak., 1908, North Platte, Nebr., 1909, and Garden City, Kans., 1909. (See Table XXIII.)

(6) Rotation No. 3 (wheat, oats, corn, all on fall plowing) and rotation No. 4 (oats on disked corn ground, wheat on fall plowing, corn on fall plowing) each gave the best results at two tests: Edgeley, N. Dak., 1909, and Amarillo, Tex., 1909, for No. 3; Judith Basin, Mont., 1909, and North Platte, Nebr., 1907, for No. 4. (See Table XXIII.)

(7) Rotation No. 2 (wheat, oats, corn, all on spring plowing) gave the best results at only one test, Dickinson, N. Dak., 1908. (See Table XXIII.)

(8) Rotation No. 9 (oats, wheat, corn, all on spring plowing) failed to give the best results at any test and averaged 42 cents per acre poorer than continuous cropping. (See Table XXIII.)

(9) Summer tillage had been introduced in rotations Nos. 5 and 8 in place of corn. These two rotations are otherwise identical with rotations Nos. 1 and 4, respectively. A comparison of these two pairs

of rotations shows that in seven out of nineteen tests the corn rotations (1 and 4) produced better crops of wheat and oats than the summer-tilled rotations (5 and 8). In ten of the twelve tests where the yields of wheat and oats were better on summer-tilled rotations than on corn rotations the yield of corn was sufficient to more than offset this difference.

The two tests where the corn crop did not equal in value the gain from summer tillage were Dalhart and Amarillo, Tex. In these tests the crops of wheat and oats averaged only $1.91 and $4.49 per acre, respectively.

The average net gain of the corn rotations over the summer-tilled rotations for all tests was $4.08 per acre and the results were in favor of the corn rotations in seventeen out of nineteen tests. (See Table XXIV.)

(10) Disking has given better average results than plowing corn stubble as a preparation for wheat in eleven out of eighteen tests, the net results being 36 cents per acre in favor of disking. (See Table XXV.)

(11) Fall plowing has given slightly better net results than spring plowing. Local conditions of soil and climate influence the results so profoundly that no general conclusions can be drawn. The natural character of the soil, its physical condition at the time of plowing, its liability to blowing during the fall and winter, and the holding of snow by stubble during the winter must all be considered for each farm and each season in determining the best time of plowing. The most economical distribution of labor through the year is also an important practical consideration. (See Tables XXVI and XXVII.)

(12) When summer tillage is introduced in a rotation containing both wheat and oats, slightly better average results have been obtained when oats follow summer tillage and wheat follows oats than where wheat follows summer tillage and oats follow wheat. Local conditions of soil and climate influence results in this respect to such an extent that no general rule can be made to apply to all stations. Certain stations give markedly better results from one sequence, while others give much better results from the opposite sequence. (See Table XXVIII.)

(13) Where corn, wheat, and oats have been grown in a 3-year rotation, better results have been obtained in twenty-four out of thirty-five tests by following wheat after corn and corn after oats. At Judith Basin, Mont., Highmore and Bellefourche, S. Dak., North Platte, Nebr., and Amarillo, Tex., better results have been obtained from the opposite sequence. The greatest advantage of the corn-wheat-oats sequence was at Edgeley, N. Dak., in 1907, when it

amounted to $6.32 per acre. This was closely followed by North Platte, Nebr., in 1909, and Dickinson, N. Dak., in 1908, where it amounted to $5.24 and $5.17, respectively. Highmore and Bellefourche, S. Dak., are the only stations showing markedly better results from the corn-oats-wheat sequence. The effects of the sequence seem to be less marked where the corn stubble is disked and the other plats fall plowed than where all plats are spring plowed. (See Tables XXIX and XXX.)

(14) Wherever a perennial meadow grass, like brome-grass (*Bromus inermis*), can be profitably grown it should enter into the rotation, which should be not less than five years in duration. The following has given good results: Corn; wheat, winter or spring; brome-grass, two or three years; oats, barley, emmer, or wheat (winter or spring).

Flax may be sown on the brome-grass sod as a catch crop after the hay crop has been harvested. Where this practice is adopted it will of course be impracticable to follow the flax with fall-sown grain, but spring-sown grain can be substituted.

(15) Where it is impracticable to secure a catch of brome-grass or other meadow grass sown with the wheat crop, the grass should be sown separately on carefully prepared ground in May or June. This will require a rotation of at least six years' duration. There will be one year (the year of seeding to grass) during which one field will yield no crop return, but if flax is grown on the meadow sod after the hay has been cut two crops will be obtained from this field in one year. In this way as many crops will be grown as there are fields in the rotation system.

(16) Wherever alfalfa can be profitably grown it may be substituted in whole or in part for the brome-grass without interfering with the general plan of the rotation.

(17) Wherever clover can be profitably grown it can be sown with the brome-grass without changing the general plan of the rotation; or it can be sown separately, either with the wheat in a 4-year rotation or without a nurse crop in a 5-year rotation.

(18) Where neither perennial grasses nor perennial legumes or clovers can be profitably raised, rye, peas, or sweet clover should be raised every fourth year and plowed under for green manure. Rye has so far given better average results than peas, sweet clover, or summer tillage. This seeming superiority may be due to the fact that the quantity of organic matter is greater in the rye and that it can be turned under earlier in the season, thus allowing the rains of June and July to be conserved in the soil instead of being consumed in the growth of the green-manure crop. It seems quite probable that the greater quantity of nitrogen gathered and restored to the

soil by the legumes will in time overcome the advantage which the rye now seems to have.

(19) Wherever winter wheat can be safely grown it should constitute a considerable portion of the small-grain crop. The danger from winterkilling tends to make it a more precarious crop than spring-sown grains. On the other hand, its earlier maturity, which frequently allows it to escape the droughts of early summer, and its higher yield when conditions are favorable give it a marked advantage over spring wheat. It should be raised in rotation with other crops.

When so raised, summer tillage will not usually be necessary or advisable. Under certain circumstances it may be found desirable to summer till, as winter wheat certainly responds much more readily to summer tillage than do spring-sown crops. Summer tillage even for winter wheat can not be recommended as a general or frequent practice in the Great Plains area. It is believed that the plowing under of a green-manure crop early in the season and proper treatment of the soil from that time until seeded to winter grain will usually give as good immediate results as summer tillage. There can be little doubt as to the advantage of green manuring over summer tillage in its ultimate effect upon the soil.

The conclusions concerning summer tillage reached from our investigations throughout the Great Plains area are in general accord with those of Mr. W. P. Snyder, superintendent of the Nebraska Agricultural Experiment Substation, at North Platte, Nebr., and of Mr. W. W. Burr, assistant in dry-land agriculture, detailed to that substation from the Bureau of Plant Industry. We therefore quote from an article prepared by them and published in Bulletin No. 109 of the Agricultural Experiment Station of Nebraska, as follows:

Ultimate effect of summer tilling.—Frequent summer tilling may be more or less detrimental to our land. The changes which break down the humus in the soil go on very rapidly under the conditions afforded by summer tilling and must exhaust the entire supply more quickly than where some method is practiced which does not furnish so good conditions for the destruction of humus in the soil.

We feel safe in recommending summer tillage for small grain, especially winter wheat, but advise that a rotation be followed which will keep up the organic matter in the soil and conserve its fertility. Such a rotation will probably use summer tillage on the same field only once during a series of years, and will have a grass, legume, or some green manuring crop which will put back into the soil the organic material taken from it. Where sufficient barnyard manure is to be had, an application of it once during the rotation will probably keep up the humus and conserve the fertility of the soil. Where manure is used it should be applied as evenly as possible on the land, and disked to mix it with the surface. It should be applied at a time and in such a manner as to be a benefit rather than a harm to the succeeding crop.

From our experience we can not lay down a definite system of rotation for all conditions. The rotations must be worked out to suit the farm where they are to be practiced. A rotation that seems well adapted to our conditions is as follows: Summer tillage, winter wheat, corn, spring grain, cane. Summer till and sow winter wheat; disk and fall plow the wheat stubble for corn the next year; disk the corn stubble for a spring grain—oats, wheat, or barley; apply manure during the winter, disk in spring and plow for cane, which crop completes the rotation. To practice this rotation a farm should have at least five fields. This 5-year rotation gives winter wheat on summer-tilled land to be sold as a cash crop, corn and spring grain to be fed or sold according to conditions, and cane for forage. If the forage and grains are fed, there will be enough manure to apply in the rotation, covering one-fifth of the land each year.

In exclusive grain farming, which is a hazardous proposition at best, some crop must be turned under to keep up the fertility. This is equally true whether summer tilling be practiced or not. We have this year obtained very good results from green manuring with rye and with cowpeas. The yield was not up to that on summer-tilled land, but was nearly as large. In each case the crop was turned under and the land kept well tilled for the balance of the summer, and the land sown to grain in the spring. If this can be done with a reasonable certainty of success, it may be more profitable than summer tilling. It gives much the same condition of the land as summer tillage and at the same time enriches the soil by the addition of humus. In very dry years it is doubtful if this will give as high yields as summer tilling, since there will be hardly enough water to rot the crop turned under and give a good seed bed in which to sow the next crop.

We feel that the practice of summer tilling is and can be kept profitable by systematic rotation of crops in which summer tilling shall be used only occasionally. If used without care it may prove very detrimental. If used judiciously it will tend to free the fields from weeds and guard against total crop failure and to greatly extend the winter wheat growing area.

PRECIPITATION RECORDS.

Table XXXI presents the precipitation records by months for all stations reported upon in this bulletin, not only for the year during which the tests were conducted, but also for the year immediately preceding. A study of this table will give a general idea of the climatic conditions prevailing at each station for each year of the tests. It also furnishes some information concerning the quantity of water which may have been stored in the soil from the previous year. It should, however, be constantly borne in mind that the character of the rains and their distribution through the month greatly influence their availability to the crop. A large part of torrential rains may be lost by run-off. On the other hand, when the rains are less than one-half inch a day they may be almost entirely lost by evaporation. Again, there may be a heavy rainfall during the early part of the month, followed by a severe drought extending through the remainder of that month and the major part of the following month, with heavy precipitation during the later days. Under such circumstances the monthly precipitation for both months may seem to be ample, although crops may have suffered severely. This all goes to show that neither the annual nor the monthly precipitation as here given furnishes a safe basis for judging the weather conditions in their relation to crop production. These considerations apply more aptly to cases where the precipitation seems to be sufficient. If the monthly precipitation shows a marked deficit during the growing season, it is reasonably safe to assume that the crop suffered from drought.

An examination of the accompanying table shows that when the whole record is considered there was an excess above normal precipitation in 16 out of 30 instances and a deficit in 10 instances. There were 4 instances where the record was incomplete.

When we consider only the 19 cases where the observations were made during the same year that these tests were made, we find that there was an excess in 11 instances, a deficit in 6, and incomplete records in 2.

Considering only the observations made at the 11 stations the year previous to the tests reported, we find that in 5 instances there was an excess, in 4 a deficit, and in 2 incomplete records.

It is apparent, therefore, that the average annual precipitation throughout the area was somewhat above normal, both during the years reported in these tests and for the year previous to the first reported tests. A detailed study of Table XXXI in connection with the yields reported in the respective tests may assist the reader in the interpretation of results. For a full discussion of these relations, however, it would be necessary to have the daily as well as the monthly precipitation, for the reasons already stated. These records are, of course, on file in the Office of Dry-Land Agriculture Investigations, but it has not seemed advisable to enter into a discussion of this phase of the subject in this bulletin. It may, however, be taken up in some future publication.

TABLE XXXI.—*Precipitation records for all dry-land agriculture stations in the Great Plains area, beginning one year prior to the years reported upon in this bulletin.*

Station.	Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.
Judith Basin, Mont.[a]	1908	0.55	0.49	0.98	0.61	7.31	2.45	0.20	1.18
Do	1909	.90	.08	1.22	.95	1.84	6.66	4.97	1.28
Dickinson, N. Dak.	1907	.80	.14	.39	.30	1.36	2.52	4.82	1.89
Do	1908	.28	.73	1.42	1.27	3.50	4.30	1.41	1.41
Do	1909	.27	.52	.25	.51	5.78	3.28	1.89	5.54
Edgeley, N. Dak.	1906	.13	T.	.16	1.58	5.59	3.69	3.17	1.56
Do	1907	.42	.06	.21	.35	1.89	1.73	2.77	1.21
Do	1908	.04	.65	1.45	1.26	3.53	3.26	1.19	1.69
Do	1909	.12	.25	T.	.70	4.01	2.80	3.04	1.73
Highmore, S. Dak.	1905	.60	T.	.60	1.39	5.23	5.64	5.54	3.56
Do	1906	.30	.40	.80	2.30	5.00	2.50	1.19	6.74
Do	1907	1.00	.40	1.10	.68	5.11	1.62	3.64	.28
Do	1908	.10	.93	.80	1.55	2.68	5.78	2.49	3.53
Bellefourche, S. Dak.[b]	1908	(c)	(c)	(c)	d 1.09	4.09	1.47	1.26	.62
Do	1909	.17	.23	.19	.77	3.87	5.59	2.58	.55
North Platte, Nebr.	1906	.61	.80	2.22	2.89	2.82	.68	3.14	5.56
Do	1907	.39	.51	.10	.43	2.40	2.69	6.79	2.14
Do	1908	.16	.78	.20	.64	3.95	5.07	3.17	1.57
Do	1909	.29	1.61	.98	.72	2.32	5.46	5.21	1.24
Akron, Colo.	1908	.00	.34	T.	1.70	3.57	b 2.30	b 2.42	b 1.47
Do	1909	T.	1.38	3.06	b .40	b 1.76	b 3.43	b 4.61	b 3.77
Hays, Kans.	1907	.64	.22	.85	.60	.83	4.97	9.15	3.12
Do	1908	T.	.92	T.	2.18	3.06	6.02	2.90	5.86
Garden City, Kans.	1908	.08	.67	.18	.53	1.29	4.95	1.75	2.18
Do	1909	.30	.35	2.15	.20	3.06	3.48	5.22	.81
Dalhart, Tex.	1908	T.	(c)	(c)	2.28	.53	2.83	3.89	1.08
Do	1909	T.	.28	.71	.17	1.64	5.10	1.27	.65
Amarillo, Tex.	1907	1.11	.24	.02	1.25	.99	1.97	1.49	6.20
Do	1908	.26	.72	T.	1.90	3.55	1.73	5.40	2.75
Do	1909	.07	.28	1.28	.50	1.08	4.72	3.63	.87

Station.	Year.	Sept.	Oct.	Nov.	Dec.	Annual.	Average normal.	Above normal.	Below normal.
Judith Basin, Mont.[a]	1908	1.41	6.27	T.	0.22	21.67	15.25	6.42	
Do	1909	4.27	.49	0.30	1.20	25.63		8.18	
Dickinson, N. Dak.	1907	1.11	.10	.02	.22	13.67			0.24
Do	1908	1.67	2.47	.78	.24	19.48	14.95	4.53	
Do	1909	.83	1.08	.29	1.02	21.26		6.31	
Edgeley, N. Dak.	1906	1.45	.93	1.05	.65	19.96		.43	
Do	1907	2.47	.41	T.	T.	11.52			8.01
Do	1908	1.81	1.34	.63	.20	17.05	19.53		2.48
Do	1909	.89	.42	.34	.84	15.14			4.39
Highmore, S. Dak.	1905	.56	1.95	1.29	T.	26.36		10.42	
Do	1906	2.81	2.41	.36	.40	25.21		8.45	
Do	1907	1.04	1.96	.05	.40	17.28			.09
Do	1908	.62	2.19	1.39	.31	22.37	17.37	5.00	
Bellefourche, S. Dak.[b]	1908	.52	1.08	.20	1.02				
Do	1909	1.07	(c)	(c)	(c)				
North Platte, Nebr.	1906	4.25	3.05	1.01	.96	27.99		9.72	
Do	1907	2.91	.14	.31	.80	19.61		1.02	
Do	1908	.24	3.39	.59	.20	19.96	18.88	1.08	
Do	1909	.77	.20	2.24	1.37	22.41		3.53	
Akron, Colo.	1908	b .05	3.20	2.00	T.	17.05	19.06		2.01
Do	1909	b 2.16	.76	.48	.55	22.36	19.06	3.30	
Hays, Kans.	1907	1.75	1.40	.11	1.76	25.40		2.86	
Do	1908	.81	1.76	1.79	.03	25.33	23.48	1.85	
Garden City, Kans.	1908	1.04	1.07	2.72	.23	16.69			2.08
Do	1909	1.20	.75	3.77	.70	22.99	18.77	3.61	
Dalhart, Tex.	1908	.39	.29	.93	.06				
Do	1909	2.12	2.60	1.21	.15	15.99			
Amarillo, Tex.	1907	.91	1.79	.66	1.46	18.09			4.46
Do	1908	1.83	.40	.51	.00	19.05			3.50
Do	1909	2.19	1.18	3.25	.54	19.59	22.55		2.96

a Taken from Weather Report for Utica.
b From observations taken at the agricultural experiment stations and not from Weather Bureau reports.
c No report.
d No record by Weather Bureau observer
T.=trace.

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