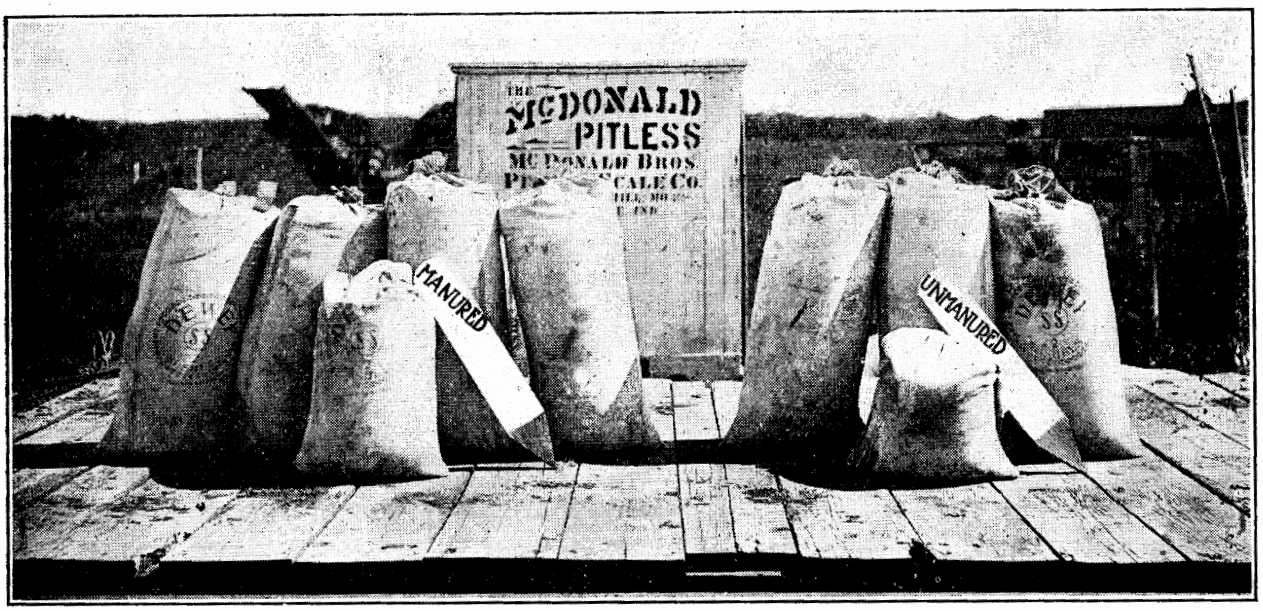
OKLAHOMA
AGRICULTURAL AND MECHANICAL COLLEGE
AGRICULTURAL EXPERIMENT STATION
Stillwater, Oklahoma

WHEAT
Continuous With and Without Manure

By M. A. BEESON



With Lists of Station Projects and Available Publications

BULLETIN NO. 140. APRIL, 1921.

INTRODUCTION

Experiments with wheat have been carried on at the Oklahoma Experiment Station since 1892. Some of the experiments have been completed and dropped and new ones taken up, and others have been changed, while some have been continued with very little alterations. The results of the work done up to 1905 have been published in Bulletins Nos. 47 and 65 which are the last bulletins that have been published. Since these press bulletins and circulars have been gotten out, the last of which is circular No. 32, published in 1914, some of the material used in this bulletin has been published in the previous bulletins and circulars which are now out of print.

WHEAT

Continuous With and Without Manure

In 1892 the continuous culture of winter wheat was begun on an acre plot of virgin land. The soil on which this experiment is conducted is rather thin upland prairie soil belonging to the Kirkland series. This soil is underlaid with a stiff, clay hardpan ranging from seven to eight inches below the surface, which is more or less impervious to water and air. For these reasons the yields on this acre are rather low.

This plot was cropped to wheat annually and maintained as an acre plot until the spring of 1897 when it was divided into two plots of one-half acre each. Table 2 gives the results before the plot was divided.

TABLE 2—YIELDS OF THE ACRE TRACT BEFORE IT WAS DIVIDED OR MANURE APPLIED

Year	Yield per Acre in Bushe'ls
1892-93	10.55
1893-94	20.90
1894-95	Crop failure
1895-96	6.90

Total for 4 years—38.35. Average per year—9.58.

The average yield on this acre for the first four years was abnormally low. The first crop was grown on broken sod and the ground was not in good condition for a crop. The season of 1894-95 was very adverse and the crop was a total failure. This is the only failure in the twenty-six years this acre has been cropped to wheat. Owing to the lack of sufficient moisture in the ground the 1895-96 crop was below normal. There was only 12.69 inches of rainfall from July 1, 1895, to May 1, 1896, while the normal for the same period is 25.25 inches. These conditions, some of which have not occurred again in twenty-six years, are the cause of the low average yield of 9.58 bushels in the first four years.

To determine the plot variation, the acre was divided into two half-acre plots in the spring of 1897 and the plots were numbered 1 and 2. Yields were taken on the divided plots for two years before manure was applied. Table 3 gives the results of two years of plot standardization.

TABLE 3—YIELDS OF PLOTS 1 AND 2 AFTER THE ACRE TRACT WAS DIVIDED AND BEFORE MANURE WAS APPLIED

Year	Bu. Per Acre NO. 1	Bu. Per Acre No. 2
1896-97	17.80	17.90
1897-98	7.00	7.50
Total for 2 years	24.80	25.40
Average yield per acre	12.40	12.70

The season of 1896-97 was excellent for wheat with the exception of excessive rain at harvest time which caused the delay in harvesting until the crop was over ripe and part had gone down. In 1897-98 the crop was damaged greatly by rust and chinch bugs which reduced the yield. It is to be noted that Plot 2 gave a slight increase in yield over Plot 1 both years, showing that if there was any difference, the soil in Plot 2 was slightly better than Plot 1.

At the beginning of the season of 1898-99 the plan for applying manure to one plot was begun. Well rotted manure was to be aplied to Plot 1 at the rate of about 15 tons per acre each year, while Plot 2 was to be continued without manure. The manure was to be applied just before plowing in July, the ground to be plowed 7 to 8 inches deep and disked immediately after plowing. The plots were to be disked or harrowed often enough to keep down the weeds and keep the soil in good tilth. The grain was to be seeded with a drill at the rate of one and one-half bushels per acre. The second year's application of manure seemed to have very little beneficial effect and it was decided not to apply manure any more often than it was thought beneficial.

Five varieties of winter wheat have been grown on these plots since the experiment was begun, but at no time have different varieties been seeded on the two plots the same year. Fultz wheat was grown on the two plots in 1892-93 and 1894195 to 1906-07 inclusive. In the season of 1893-94 Currell wheat was grown. Sibley's New Golden was grown on the plots from 1907-08 to 1910-11 inclusive; Kharkov from 1911-12 to 1915-16 inclusive, and Turkey Red from the season of 1916-17 to 1917-18 inclusive. Variety tests at this Station show that there is very little difference in the yield of these varieties.

TABLE 4—GIVES 23 YEAR'S RESULTS AFTER MANURE WAS APPLIED TO PLOT 1

	Date Manure was applied to Plot 1	Tons per acre	Plot 1 manured Bu. per acre	Plot 2 unmanured Bu. per acre	Increased yield of Plot 1 over Plot 2	Per cent of Increase of Plot 1 over Plot 2
1898-99	July, 1898	15	30.60	12.00	18.60	155
1899-00	July, 1899	11	36.80	18.10	18.70	103.31
1900-01			37.70	28.00	9.70	34.64
1901-02			17.40	15.30	2.10	13.72
1902-03			27.60	20.30	7.30	35.96
1903-04	July, 1904	18	15.70	12.60	3.10	24.60
1904-05			11.68*	4.75*	6.93	145.89
1905-06			23.26	7.10	16.16	227.60
1906-07			14.93	5.20	9.73	187.11
1907-08			15.47	12.90	2.57	19.92
1908-09			25.40	21.70	3.70	17.05
			35.20	18.70	16.50	88.24
1910-11			4.86*	2.28*	2.58	113.15
1911-12	Nov., 1911	24***	20.40	5.32	15.08	283.46
1912-13	Feb., 1913	12***	14.80	5.60	9.20	164.28
1913-14			33.50	23.20	10.30	44.39
1914-15			19.53	15.16	4.37	28.88
1915-16			13.30	7.90	5.40	68.35
1916-17	July, 1916	12	32.00	21.00	11.00	52.38
1917-18			29.22	10.75	18.47	171.90
1918-19			11.65*	7.03*	4.62	65.72
1919-20			34.03	27.30	6.73	24.65
1920-21	Sept., 1920	12***	15.66*	7.26*	8.40	115.70
	Total for 23 years	104	520.69	309.45	211.24	
	Av. per year per acre	4.52	22.63	13.45	9.18	68.26

*Damaged greatly by rust and chinch bugs.
**Damaged by severe drouth.
***Applied as top dressing.

Computed on an acre basis the manured plot has yielded 520.69 bushels of wheat in 23 years while the numanured plot has produced only 309.45 bushels, making a difference in favor of the manured plot of 211.24 bushels for twenty-three years, which is an average increase of 9.18 bushels per acre per year. Before manure was applied Plot 2 gave a slight increase in yield over Plot 1 but after manure was applied to Plot 1 at no time during the twenty-three years did Plot 2 give a greater yield than Plot 1. There has been quite a variation in yields in both plots during this period, but from Figure 3 it will be noted that the yield of the manured plot has never fallen below the yield of the unmanured plot.

HOW OFTEN SHOULD MANURE BE APPLIED AND IN WHAT QUANTITIES?

The percentage of increase which is given in the last column of Table 4 is the number representing the effect of manure on the yields regardless of the influence of many other factors that affect production. In Figure 4 the percentage of increase is represented by a curve.

The manure was applied to Plot 1 at irregular intervals and in varying amounts, ranging from 11 to 24 tons per acre per year.

It will be noted from the above curve that the percentage increases greatly the seasons that manure is applied except where it was applied two years in succession. Twice manure was applied two years in succession and both times the second application failed to give a corresponding percentage of increase.

The percentage of increase is greatest for two years after two of the applications and for three years after one application and then falls rather abruptly and remains low until more manure is applied. This would indicate that the best effect of barnyard manure will not last longer than two or three years under Stillwater climatic conditions, and should be applied once every three or four years. In the western portion of the state where the rainfall is low manure should be used with care and applied as a top dressing in smaller quantities and more often.

At Stillwater our average rainfall for the past twenty-five years is 33.77 inches. During the past 23 years, four applications of barnyard manure were made in July and plowed under and three applications of manure were put on as top dressings, one in November of 24 tons and one in February of 12 tons, all giving the same general results. However, there is less risk to run in securing a good, firm seedbed when manure is applied as top dressing than when plowed under, and it is advisable for farmers in the central and western parts of the state to use barnyard manure as a top dressing.

In the season 1910-11 when the crop was cut short on account of the severe drouth, the manured plot gave the greatest percent of increase of any year, except those immediately following the application of manure, showing that soil containing organic matter is more drouth resistant than soil where the organic matter is depleted.

EFFECT OF MANURE ON QUALITY OF WHEAT

The quality of wheat grown on the manured plot was much better than on the unmanured. The wheat berries from the manured plot were larger and better filled than from the unmanured plot.

During the 11-year period that the weights were taken the manured plot give an average test of 58.6 pounds per bushel, while the wheat on the unmanured plot gave a naverage test of only 55.9 pounds per bushel. According to the present Government Grain Grade this would place wheat from the manured plot in Grade No. 2, while the unmanured would be placed in Grade No. 4.

The 1920 crop gave a test of 60 pounds per bushel on the manured plot, and 55 pounds per bushel for the unmanured plot. This placed the wheat from the manured plot in Grade No. 1 and from the unmanured plot in Grade No. 4. On October 19, 1920, the Kansas City market quoted No. 1 dark hard winter wheat at $2.06, and No. 4 dark hard winter wheat at $1.96, making a difference of ten cents per bushel in favor of the manured plot. Table No. 5 shows the increased value in the 1920 crop and the 23-year average due to manure.

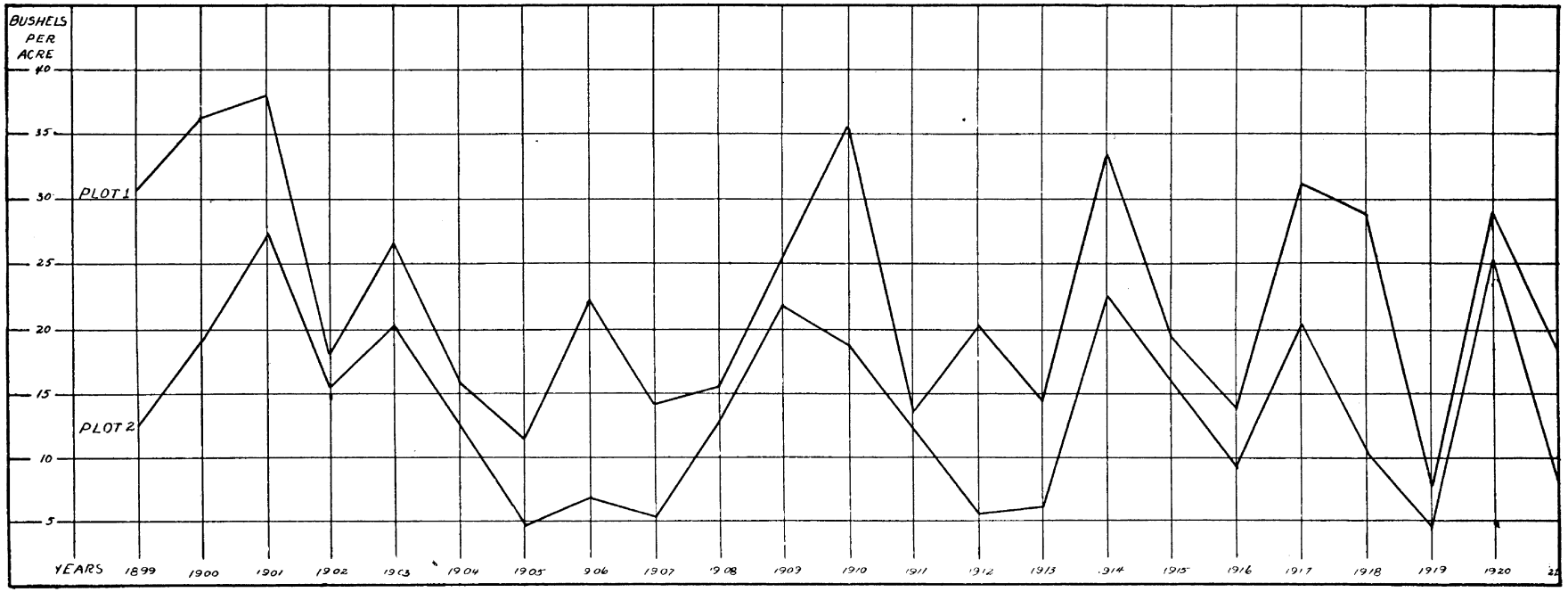


Figure 2—Graph with curves representing the yield of the manured plot and the unmanured plot.

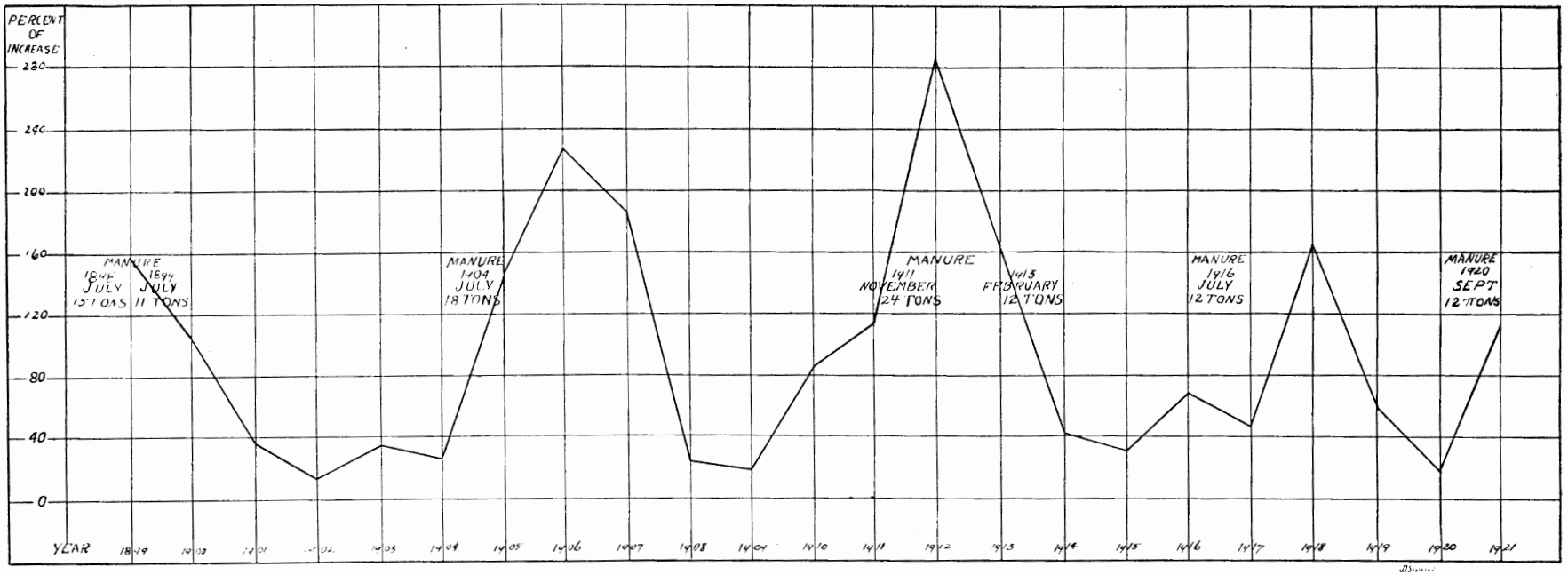


Figure 3—Curve representing the percentage of increase in yield of the manured plot over the unmanured plot.

TABIE 5—SHOWING INCREASED VALUE OF CROP DUE TO MANURE

	Yield per acre	Grade based on weight	Price per Bu. based on grade	Value of crop per acre	Difference per acre due to manure
			1920 CROP		
Manured	34.03	No. 1	$2.06	70.10	$14.53
Uumanured	27.30	No. 4	$1.96	53.50	
			Twenty-Three Year Average		
Manured	22.63	No. 2	$1.07	24.19	$8.79
Unmanured	13.45	No. 4	$1.01	13.58	

*Expense of handling increased yield has been deducted.

In 1920 when the price of wheat was comparatively high the value of wheat from the manured plot was $14.58 more than from the unmanured, due mainly to the effect of the manure. This was the fourth season after the last application of manure, and the increase gave a return of $3.34 per ton of manure in the field.

The price of wheat used for the average yield for the 23-year period is based on the average wagon price at Enid and El Reno, Oklahoma, from 1906 to 1919 furnished by H. N. Dittmer of the Enid Mill and Elevator Company. The average price for this period for Number 2 wheat was $1.07 a bushel and $1.01 for number 4 wheat. Based upon the above price, the manured plot has given an average yearly increase of $8.79 per acre over the unmanured plot, due largely to the effect of manure. An average of 4.62 tons of manure was applied to the manured plot during the 23-year period. From the results of this experiment manure is worth $1.94 in the field when applied to wheat.

It is very evident that it will pay the Oklahoma farmer to apply manure to his wheat land if he will apply it properly. Had the manure been applied more systematically no doubt the beneficial effect of the manure would have been more apparent.

THE RELATION OF AMOUNT AND SEASONAL DISTRIBUTION OF RAINFALL TO YIELDS

Data on rainfall have been kept at Stillwater by the Weather Bureau of the United States Department of Agriculture since 1893. However, there are no rainfall records available for the last six months of the year 1893, and on this account only 26 years, from 1894-95 to 1919-21 are included in this study. The season of 1918-19, 1919-20 are omitted from this study owing to excessive damage to the crop caused by rust.

In making a study of the relation of rainfall to the yields the calendar year is not taken, but the twelve months beginning July 1st, at which time harvesting is completed. Many times there is quite a difference between the rainfall of the calendar year and the seasonal year. In the year 1895, the year of crop failure, the rainfall for the calendar year was 29.85 inches, while the seasonal annual rainfall was only 19. 81 inches. In 1914 the rainfall for the calendar year was 16.79, while the seasonal annual rainfall was 27.33 inches.

In order to eliminate as far as possible the effect of factors other than rainfall, the unmanured plot only is taken and the yields for the 26 years are divided into three groups and the average of these groups studied. The yields above the average are placed in group 1, those yields approximating the average are placed in group 2, and the yields below the average are placed in group 3.

Table 6 gives the yields and annual rainfall for 26 years and the average of each of the three groups.

TABLE 6

Group No.	Year		Yield on Unmanured Plot	Yearly Rainfall, July 1 to June 30
	1900-01		28.00	27.97
	1919-20		27.30	39.90
	1913-14		23.20	27.33
	1908-09		21.70	43.14
	1916-17		21.00	19.01
I	1902-03		20.30	39.06
	1909-10		18.70	26.62
	1899-00		18.10	29.26
	1896-97		17.90	36.52
		I. Average	21.80	32.09
	1901-02		15.30	29.34
	1914-15		15.16	30.24
II.	1907-08		12.90	45.86
	1903-04		12.60	29.38
	1898-99		12.00	35.68
	1917-18		10.75	32.44
		II. Average	13.12	33.82
	1915-16		7.90	38.10
	1897-98		7.50	32.91
	1920121		7.26	53.04
	1905106		7.10	32.94
	1895-96		6.90	35.35
III	1912-13		5.60	24.92
	1911-12		5.32	39.80
	1906-07		5.20	49.51
	1904-05		4.75	35.28
	1910-11		2.28	21.97
	1894-95		0.00	19.91
		III. Average	5.4	34.88

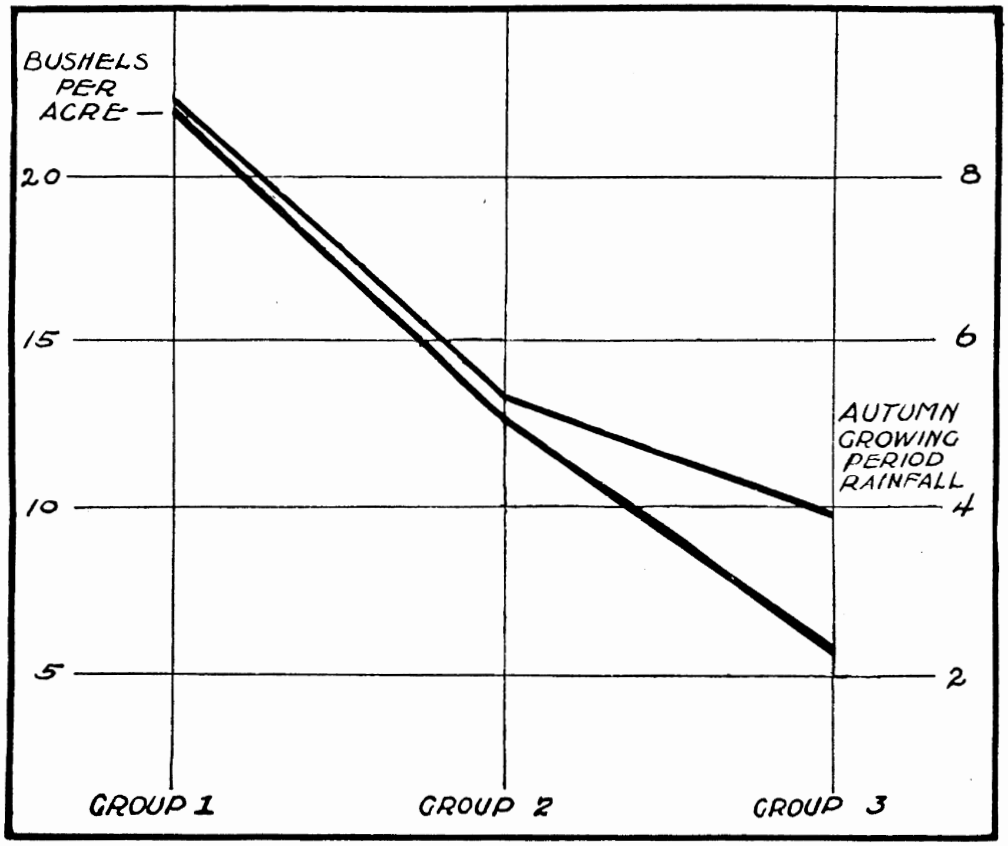


Figure 4, showing the relation between the average rainfall and the average yield in the autumn growing period.

From table No. 6 it will be noted that the average yield for Group I is 21.80 bushels per acre and the average annual rainfall for the same is 32.09 inches. The average yield for Group II is 13.12 bushels and the rainfall is 33.82 inches. The average yield for Group III is 5.43 bushels with an average annual rainfall of 34.88 inches. These results, which cover a period of 26 years, indicate that there is no relation between the annual rainfall and the yields at Stillwater. In the western portion of the state where the rainfall is much less than at Stillwater and on a different type of soil, the variation in the yearly rainfall would possibly cause a corresponding variation in the yields. However, the distribution of seasonal rainfall has more influence on the yields than the annual rainfall.

In making a further study of the relation of yields to rainfall, an attempt is made to divide the season into periods that have a definite relation to the seed bed, the growth, and to the care of the crop. These priods are designated as seed bed preparation period, autumn growing period, winter dormant period, spring growing period, and harvesting period. Table 7 gives the yearly yields and rainfall of five periods in the three groups.

TABLE 7—SHOWING YIELD AND RAINFALL BY PERIODS AND AVERAGE OF THE GROUPS

Group No.	Year	Yield on unmanured plot	Seed bed preparation period July 1 to Sept. 30.	Autumn Growing Period Oct. 1 to Dec. 31	Winter Dormant period Jan. 1 to Feb. 28.	Spring growing period Mar. 1 to May 30	Harvesting period, June
	1900-01	28.00	13.30	3.73	1.21	8.93	.79
	1919-20	27.30	4.76	10.68	.91	15.60	3.26
	1913-14	23.20	9.67	10.84	.65	5.65	.51
	1908-09	21.70	11.14	15.96	1.22	12.48	2.32
	1916-17	21.00	2.71	5.93	1.17	6.40	2.80
I.	1902-03	20.30	9.66	10.33	2.44	15.90	.73
	1909-10	18.70	6.11	9.63	1.63	8.20	1.05
	1899-00	18.10	7.99	8.68	1.02	8.29	3.28
	1896-97	17.90	10.03	5.29	2.32	14.75	4.13
I.	Average	21.80	8.36	9.01	1.39	10.69	2.10
	1901-02	15.30	4.54	4.50	.30	17.81	2.19
	1914-15	15.16	6.84	3.09	7.97	16.96	4.38
	1907-08	12.90	3.08	8.81	6.23	20.46	7.28
II.	1903-04	12.60	8.96	4.55	1.10	8.23	6.54
	1898-99	12.00	11.93	7.55	.95	11.61	3.64
	1917-18	10.75	12.03	2.48	1.48	12.59	3.86
II.	Average	13.12	7.89	5.16	3.00	14.61	4.65
	1915-16	7.90	12.30	6.41	3.49	6.41	9.49
	1897-98	7.50	7.85	1.92	6.53	11.89	4.72
	1920-21	7.26	14.10	13.27	6.66	13.77	9.14
	1905-06	7.10	13.72	5.07	7.22	12.31	1.62
	1895-96	6.90	9.62	9.65	.74	8.08	7.26
III	1912-13	5.60	7.09	1.75	4.02	10.18	1.88
	1911-12	5.32	15.13	5.91	1.21	13.72	3.83
	1906-07	5.20	22.14	3.61	2.71	11.30	9.75
	1904-05	4.75	14.26	1.22	2.96	13.08	3.76
	1910-11	2.28	5.98	2.60	2.72	6.75	3.92
	1894-95	0.00	8.01	1.77	1.50	4.02	4.61
III.	Average	5.43	11.61	3.99	3.31	9.77	5.08

Ordinarily harvesting is completed by July 1st and it has been the policy to seed wheat on this plot as near the first of October as possible. Therefore, the period from July 1st to September 30th has been designated as the seed bed preparation period. From Table 7 there seems to be no definite relation between the average rainfall in this period and the average yield. This possibly is due to the fact that this plot was plowed about July 1st and disked often enough to keep down all weeds

and the soil in good condition to absorb the rainfall during this period. The average rainfall for this period was 9.55 inches and only on one year has the rainfall fallen as low as 2.71 inches which was sufficient to put the seedbed in good condition. This soil is underlaid with a stiff, plastic, clay hardpan anywhere from 7 to 8 inches below the surface which is more or less impervious to water and air and does not absorb moisture readily. On a type of soil which absorbs water more readily the results no doubt would be different.

From October 1 to December 31 is taken as the autumn growing period which is as nearly as can be determined from the time of seeding to the cessation of growth in winter. Of course the latter date must be approximated for in a mild winter the plants may never entirely cease growing and again winter weather may occur at an early date. However, as a rule not before December 25th. From Table 7 there seems to be a relation between the yields and the rainfall of this period. The average yields of the three groups decreased in about the same ratio as the average rainfall for the autumn period for these three groups. The relation between the average rainfall and the average yields in the autumn growing period are shown by curves in Figure 4. Both curves take the same general direction indicating that the yields decrease in about the same ratio as the decrease in rainfall.

During January and February very little, if any growth takes place in the majority of years and this is designated as the winter dormant period. There seems to be a slight inverse relation between the yields and the rainfall in this period. Possibly one cause of the decrease in yields with the increase in rainfall in this period is that as the rainfall increases in January and February, there is more damage by thawing and freezing.

As a rule the spring growing period extends from March 1 to June 1. There seems to be no definite relation between the rainfall of this period and the yields as indicated by the average of the three groups.

Wheat is usually harvested at Stillwater some time between the first and twentieth of June and this month is designated as the harvesting period. From the averages of the three groups in this period, it would indicate that as the rainfall in June increases, the yields decrease. This might be expected for excessive rains at harvest time are detrimental.

From th study of the relation of rainfall to yields there seems to be a possibility of determining from the fall and winter rains whether or not to expect a profitable crop of wheat under Stillwater climatic conditions and on Kirkland type of soil. Should this be possible it will be quite valuable to the farmer, for it would enable him to determine by the last of the winter whether his wheat crop is going to be profitable or not, which will give him time to pasture his wheat off, and then put his land to a spring crop.

SUMMARY

1. Manure applied to wheat in continuous culture gave over a period of 23 years an average increase in yield of 9.18 bushels per acre.
2. The percentage of increased yield in wheat was greatest within the first three years after the manure was applied.
3. The quality of the wheat grown on the manured plot was better than on the unmanured plot.
4. There was no relation between the annual rainfall and the yield of wheat.
5. This experiment indicates that the fall rainfall has an influence on the yield of wheat at Stillwater on the Kirkland type of soil.

ACKNOWLEDGEMENTS

The author wishes to acknowledge his indebtedness to L. A. Moorhouse, O. O. Churchill and A. Daane for their work in connection with this experiment and to J. P. Slaughter, director of the United States weather bureau office, Oklahoma City, Oklahoma, for furnishing rainfall records.

List of Projects

Oklahoma Agricultural Experiment Station

STILLWATER, OKLAHOMA

ADAMS FUND PROJECTS

No.

1 The Effect of Cottonseed Meal and Other Nitrogenous Feeds on the Breeding Qualities of Animals.
2 Factors Affecting Setting of Fruit on the Tomato.
4 A Study in Inheritance of Black Hulled White Kafir.
5 Effect of Lime and Organic Matter on the Impervious Kirkland Upland Soil.
6 Corn Plant Louse.
7 Sheep Breeding.
8 The Development of Fruit Buds.
9 Cowpea Aphis.
10 The White Ant.
12 Reproduction of Queen Bees.
14 A Chemical Study of the Grain Sorghums.
16 The Composition and Properties of Silage Prepared from the Grain Sorghums.
19 Effect of Various Feeds upon the Quality of the Pork Product.
20 Fish Moth.
21 Artificial Fertilization of Queen Bees.
22 Round Worms and Tape Worms of Poultry.
65 Chemical Changes which Take Place in Cottonseed During Growth and Factors Affecting Same.
75 Lung Worms in Sheep.
104 Nodular Worms in Sheep.

HATCH FUND PROJECTS

15 A Study of Factors in Commercial Ice Cream Making, with Special Reference to a Uniform Overrun to be Obtained from Pasteurized Mixes and Emulsified Mixes and Other Factors.
23 Increasing Weight of Brown and White Eggs.
24 The Marketing of Dairy Products in Oklahoma.
25 Factors Influencing Grade of Butter.
26 Studies in Cheese Making.
27 Bacteriology of Butter.
28 Bacteriology of Ice Cream.
31 A Study of the Bacteria which is Found to be the Cause of Honey Bee Paralysis.
32 False Chinch Bug.
33 Apiculture.
36 Protein Supplement for Kafir.
38 Sources of Protein for Poultry Feed.
39 A Study of Immunization of Cattle Against Blackleg by Using Aggressins Manufactured in the Laboratory, Also a Study of Immunity Produced by Using Powder Vaccine of Double Strength.
40 Costs and Production in Advanced Registry Dairy Cow Testing.
41 Methods of Determination of Butterfats in Ice Cream.

No.
42 Bean Diseases.
43 Pecan Investigations.
44 Variety Test of Orchard Fruit.
45 Variety Test of Vegetables.
46 Variety Test of Beans.
47 Sweet Potato Varieties.
48 Bush Fruits.
49 Variety Test of Grapes.
50 Growing Trees for Fence Posts.
51 One and Two Year Old Tree Test.
53 Influence of Range of Egg Laying on Fertility, Hatchability and Egg Laying of Offspring.
54 Evaporation and Conservation of Soil Water.
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57C Crop Rotation and Fertility—Bottom Land Rotation.
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59 Plant Breeding.
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60C Miscellaneous—Rate of Planting Kafir.
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62 Farm Management Survey of Canadian and Other Counties in Oklahoma.
63 Sweet Clover Investigations.
64 Sorghum Smuts and Methods of Control.
69 Cowpea Weevil.
70 Crow Control.
72 Potato Breeding Experiment.
74 Use of Killed and of Sensitized Cultures of Abortion Germ for Cattle as a means of Immunizing Cattle Against Contagious Abortion.
76 A Study of the Formation of Sucrose in the Sweet Sorghums.
78 The Pasteurization of Milk in the Final Container.
79 A Determination of the Biologic Value of the Proteins of Peanuts, Soy Beans, and Coconut (Copra).
80 To Determine the Nature of the Disease Affecting Swine (So-Called Mixed Infection), Particularly After Vaccination for Hog Cholera.
84 Comparative Values of Wet and Dry Mash for Winter Egg Production.
85 Effects of Animal Proteins on Winter Egg Production.
86 Value of Heating Water for Winter Egg Production.
88 Artificial Incubation.
89 Date of Hatching to Laying of First Eggs.
93 Factors Influencing the Manufacture of Commercial Buttermilk.
94 Gelatin Tests of Practical Value.
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