UNIVERSITY OF IDAHO
AGRICULTURAL EXPERIMENT STATION
Department of Soils

Soil and Climatic Factors in Relation to Crop Production on the Palouse Silt Loam of Idaho

A REPORT OF PROGRESS

By
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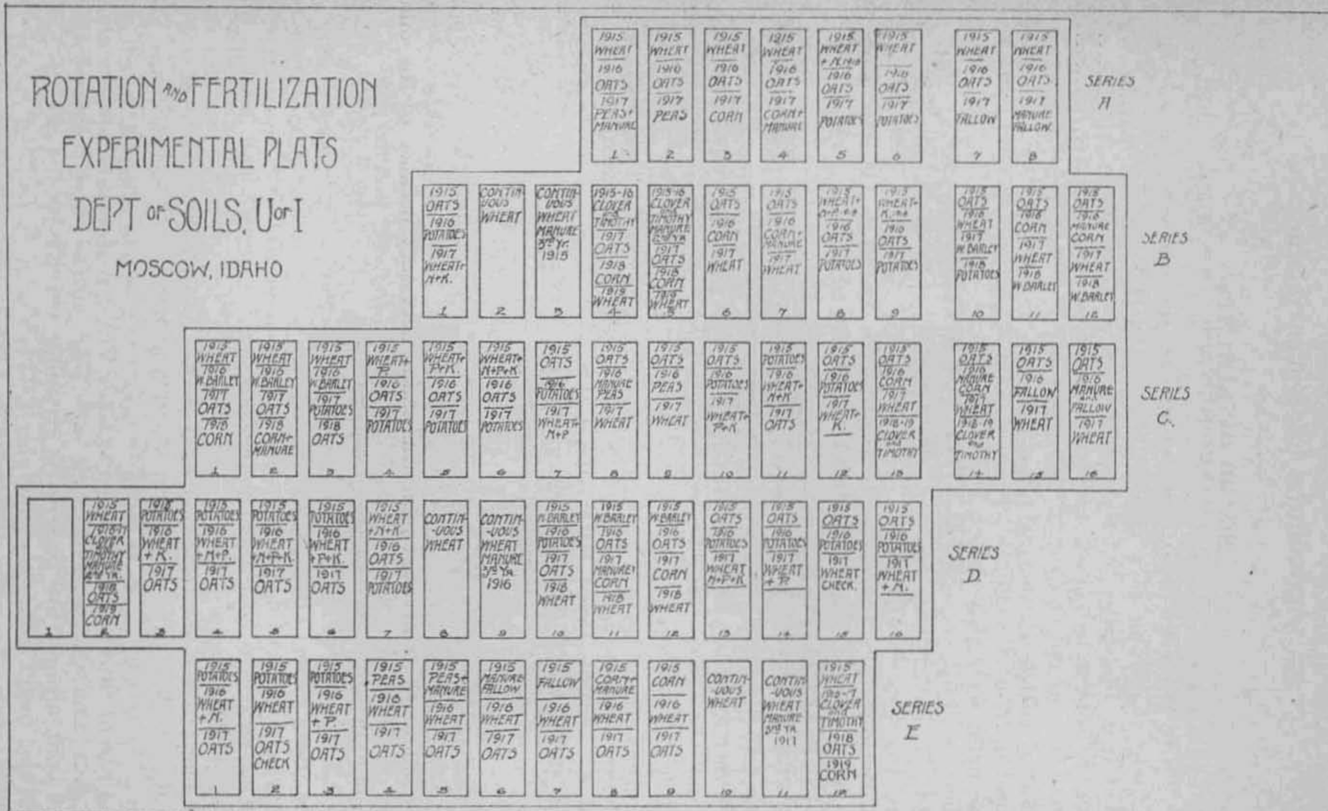
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INTRODUCTION

Up to the year 1840, soil fertility studies were mainly theoretical. It is true that some investigators report data on experiments with soils earlier than that time, but the soil was used in pots, or arguments were made from comparisons of field soils in their unfertilized condition. Practically no enrichment of field soils for comparison with other field soils, not enriched, was made until Boussingault established his experimental fields at Bechelbron, France, about 1835. The first results from these fields were published in 1838. Only a few years later, Lawes and Gilbert established their now famous experimental plots at Rothamstead, England. The value of this statistical method was quickly recognized by other investigators and its use was given an acceleration that still continues. At the present time there is hardly an agricultural school that has not experimental plots in connection.

In some experiments results of value are obtained very quickly. In others such results are obtained only after many years of painstaking work. In any case where the fields are properly situated and laid out, their value increases with the length of time they are continued.

On the plots at the Idaho Agricultural Experiment Station results have been obtained during the last few years that should be of interest and value to every farmer of this and adjoining states. It is considered that they are of such a character that they will be a valuable guide to farmers operating lands on this type of soil, and for this reason the data are here offered as a report of progress.

PLAN OF THE EXPERIMENT

Sixty-four one-tenth acre plots are laid out as indicated in Plate I. It will be observed that the plots are arranged in an awkward and irregular fashion. The arrangement was made necessary because of the difficulty of obtaining a field of uniform slope, drainage, and fertility. The Palouse silt loam, the prevailing type of soil on this and adjoining farms, is formed of numerous hills of very irregular contour as is seen in Fig. 1. Even upon so small an area as that occupied by this field it is impossible to have the plots of as uniform a condition as desired. It has, therefore, been necessary to have plots under the same treatment and bearing the same rotation on different parts of the field.

There are eight rotations used in the experiment. They are: (1) wheat, oats, and peas; (2) wheat, oats and fallow; (3) wheat, oats, and corn; (4) wheat, oats, and potatoes; (5) continuous wheat; (6) wheat, timothy and clover two years, oats, and corn; (7) wheat, barley, potatoes, and oats; and (8) wheat, barley, oats, and corn. These rotations have been built around the system of cropping which prevails on this soil, grain two years and fallow one year. This system is founded upon very definite conditions which prevail here, a fact that should be borne in mind when attempt is made at improvement. The fields operated by one person are large, wild oats predominate as a noxious weed, and continu-

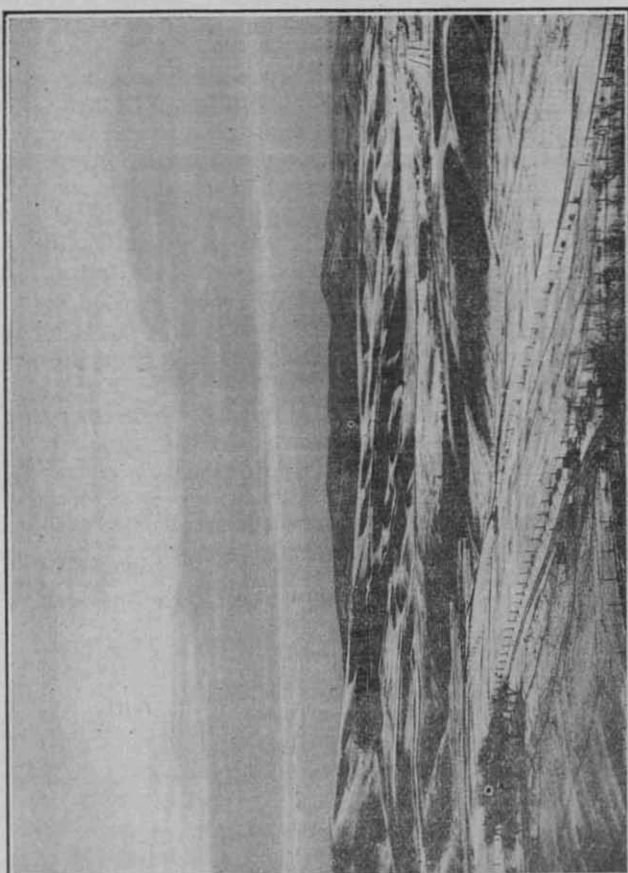

FIGURE I.—Contour of Palouse Silt Loam

ous cropping to grains reduces the productiveness for grains. Lastly, the farmers of the area have not yet learned the proper method of using manure under our conditions.

Various cultivated crops have been substituted for the wasteful summer fallow. Every rotation contains at least two grain crops because this is essentially a grain growing region. Manured plots are run beside the unmanured plots. Hay crops are put into the rotations to determine their effect upon the value of crops produced, for it is believed that it will be more profitable to produce grasses and legumes rather than wheat or oat hay, and that the area ultimately will become one of diversified farming rather than one of single crop farming as it now is.

In rotation number four, three of the elements of plant nutrition, nitrogen, phosphorus, and potassium, were introduced singly and in various combinations in an endeavor to find out the deficiency of which of the three, if any, is limiting the crops in this soil. Data for 1918 indicates that a deficiency of no fertilizing element was the limiting factor in that year. Data for the other three years indicate that a deficiency of nitrogen does become the limiting factor in years of ample moisture supply, but that deficiencies of phosphorus and potassium, in the present stage of development do not limit the production of crops on this soil.

CROPS

The growth of crop on a plot is used as a measure of the virtue of the rotation practiced and the fertility of the soil. This fact has necessitated the restriction of each crop to one variety as far as practicable. The varieties in use are: wheat, Red Russian; oats, Swedish Select; peas, Blue Prussian; corn, Rustlers' White Dent; barley, White Winter; potatoes, Gold Coin and Early Ohio; clover, Medium Red. It should be noted that some of these varieties may not be those considered best for this area, but that they suited our purpose best.

CULTURAL METHODS

All plots except those that have been fallowed the preceding summer or have borne a cultivated crop are plowed in the fall as far as possible. Those that do not receive a fall crop are then left in the rough over winter. Those receiving a fall crop, both the ones that have had a crop and the ones that have been fallowed, are double disked and harrowed until a good seed-bed is produced. The time at which fall crops can be planted depends largely upon the previous crop. The fallow plots can be sown earliest. Then come the plots that have grown peas; corn, when cut for silage; and potatoes, in order. The plots that have grown grain often come last because they are too dry to plow until considerable rain has fallen. Early potatoes have now been substituted for the Gold Coin in order that the wheat following them may be planted earlier.

Peas are treated as a cultivated crop in order that the land may have better cultivation and a more thoro eradication of weeds be accomplished. They are sown with a grain drill in double rows by plugging two adjacent holes and leaving the next two open. This leaves every alternate space eighteen inches wide. These spaces are cultivated and the weeds in the rows and in the narrower spaces are removed by hand.

For spring planting the plots that have been left rough over winter are double disked and harrowed as soon as the ground is dry enough. The crops are then planted when the proper season arrives. The winter grain is harrowed as early as possible in the spring to break up a slight crust which forms during the winter. The teeth are set slightly slanting. This operation destroys the early crop of weeds without materially injuring the grain and allows the latter to get a good start before the second crop of weeds comes on. It also forms a mulch to conserve moisture.

USE OF FERTILIZERS

Manures and fertilizers when used on grain are applied as a surface dressing in the fall before the grain is up or in the spring when the grain is only three to six inches high. This method is possible only where the soil is porous enough to absorb all the rainfall and where torrential rainfalls do not occur. The application must be made well before the dry season of summer arrives so that the manure will not lie unleached upon the surface of the ground. If allowed to remain upon the surface of the soil during the hot season, the manure suffers serious losses of plant foods, as well as of humus forming material. When manure is used upon cultivated crops or upon fallow land it is applied before plowing at the same rate as when used as a surface dressing, about twenty loads per acre. Manure should be plowed under in the fall so that the organic matter may form humus during the winter and the soil may settle well around the woody material before planting time. When soil is manured in the winter and plowed in the spring, it should be rolled immediately before or after planting to insure a good germination.

In this experiment commercial fertilizers are used as a surface dressing since they are used on fall wheat only. Nitrogen is added as nitrate of soda, two hundred pounds per acre; phosphorus as acid phosphate, one hundred pounds per acre; and potassium as muriate of potash, one hundred pounds per acre. Fertilizing with muriate of potash had to be suspended last season because of the high price of the salts of potassium. This part of the experiment is to be resumed this season. The salts were applied with a hand drill. Where they are used upon larger plots or in the field, they can be applied more economically with a grain drill, or a fertilizer drill where such a machine is available. In order to apply fertilizers with a grain drill they must be free from moisture and large lumps or they will clog the drill and cause considerable difficulty. To insure the proper condition in this regard the salts should be mixed with about twice their bulk of *dry* soil and the lumps broken down to the size of a pea. They should be applied as soon as practicable after being mixed with the soil.

Other forms of salts may be used to carry the fertilizing elements. The salt of sulphate of ammonia, for instance, probably will do as well as the nitrates. Indeed in field trials sulphate of ammonia has given indication that it is just as efficient a carrier of nitrogen as nitrate of soda. It has the advantage over the nitrate of having the nitrogen in a more concentrated form, so that less will be necessary to get the same amount of nitrogen. However, the higher price of sulphate of ammonia, leaves little choice between the two. Ground rock phosphate may be used in place of the acid phosphate, and in soils inclined to be acid in nature it is believed that this would be the better form. We do not advise the use of phosphatic fertilizers on this type of soil except as carriers of nitrogen or organic matter. Dried blood or tankage carries a high percentage of nitrogen as well as being a phosphatic fertilizer. Either of these may be used when obtainable at a reasonable price, not for the phosphorus so much as for the nitrogen and organic matter.

RATES OF SEEDING

Wheat, oats and barley are drilled at the rates of ninety pounds, sixty-four pounds and ninety-six pounds per acre respectively. Timothy and clover mixture is used at the rates of seven pounds of clover and three pounds of timothy per acre, and is sown with the seeder attachment on a grain drill. Corn is planted ten pounds per acre, three feet apart in the row and rows three and one-half feet apart. Potatoes are planted by hand, eighteen inches apart in the row and rows four and one-half feet apart. This makes about six hundred pounds per acre.

RESULTS

The results to be reported may be classified in the following way: (1) Results with fertilizers and manure, (2) Yields of various crops, (3) Effect upon yields of wheat of various crops preceding the wheat, (4) Value of manure when used in the different rotations, (5) Value of crops obtained from various rotations, and (6) Effect of climatic factors on crop yields on this type of soil.

RESULTS WITH FERTILIZERS

Table 1 gives the data obtained by the use of commercial fertilizers in the instances where only one element of nutrition can account for the changes in yield. Check plots received the same treatment as the treated plots used for comparison except that they received no fertilizer. The figures for nitrate of soda are averages of all plots receiving this salt regardless of what else they received. Those for phosphorus and potassium are for plots that received the salts designated, but not nitrate of soda. They may or may not have received both phosphorus and potassium. This method of comparing results was thought advisable because if the averages of all plots receiving phosphorus, or all plots receiving potassium, had been taken, we should include some plots that had also received nitrogen and the figures representing the increase due to the use of nitrogen, would show only a part of the actual gain. Had the phosphorus or potassium shown an appreciable effect, the results would have to be tabulated differently.

INFLUENCE OF FERTILIZERS

TABLE I.

Average Yields of Different Crops Under Various Fertilizer Treatment.

Crop	Fertilizer Treatment	Year and Yield—Bushels per Acre 1915	1916	1917	1918	Average
Wheat	None	25.2	65.8	32.4	21.8	36.1
"	200 pounds Nitrate of Soda per acre	30.3	71.8	30.3	25.8	39.5
"	100 pounds Muriate of Potash per acre	26.7	65.2	25.0	23.1	35.0
"	100 pounds acid Phosphate per acre	24.8	61.4	28.4	21.0	33.9
Oats	None		62.4	50.9	16.5	42.1
"	200 pounds Nitrate of Soda per acre		82.2	45.9	15.3	47.4
"	100 pounds Muriate of Potash per acre		62.5	46.9	17.8	41.8
"	100 pounds acid Phosphate per acre		60.9	38.3	16.3	38.5
Potatoes	None			115.5	168.5*	141.5
"	200 pounds Nitrate of Soda per acre			124.9	141.0	132.9
"	100 pounds Muriate of Potash per acre			122.2	142.8	132.5
"	100 pounds acid Phosphate per acre			84.4*	149.3	116.8

* These extraordinary figures are unaccounted for. Certainly the fertilizer treatment can not account for them.

In this table a number of things at once attract attention. Perhaps the most striking is the great variation in the yields of wheat and oats. The variation is due to the variations in climatic conditions,—principally the variation in rainfall and maximum temperatures in June and the early part of July. The correlation between climatic factors and crop yields is of sufficient importance to justify its discussion under a separate topic which appears upon later pages of this bulletin.

In considering Table 1 cognizance must be taken of the fact that the statistical method used in this investigation will give definite evidence of the deficiencies of one factor of productiveness only when the other requirements are well supplied. The nitrogen, phosphorus or potassium can not be considered a major limiting factor when the moisture falling during the growing season plus that in the soil at the beginning of the growing season is not sufficient to mature a crop.

All of the data in this table except that for the year 1918 indicate a deficiency of nitrogenous plant food. They also give some indication of a deficiency of phosphorus and potassium, but the results with these elements are not consistent and are not sufficiently well marked to justify the conclusion that these elements are deficient.

The results, as measured by the weight of crop, are always supplemented by the observations of the appearance of the crop while it is growing. The plots which receive nitrate of soda can always be differentiated from the others by their appearance during the growing period. These plots produce plants that are darker green and have a decidedly more vigorous growth than the rest of the plots. The same condition is observable wherever manure has been properly used. The conclusion is that a deficiency of nitrogen is the most likely factor to limit the growth of crop on this soil. Phosphorus and potassium may become limiting factors, but it is very doubtful if they are limiting factors at this time.

The value and influence of manure upon this soil is shown in a variety of rotations. It was believed that manure could be used on the Palouse silt loam to advantage, as well as upon other types of soil, and in almost all rotations a manured plot was run beside one not manured. The most remarkable results were observed on the continuous wheat rotation. It is true that continuous cropping to wheat is not a practice of any consequence anywhere, but the argument is that, if manuring will benefit the soil in any cropping system whatsoever, it will benefit it in all cropping systems if the proper method of application can be found and its proper place in the rotation can be discovered. Table II gives the yields of wheat upon unmanured plots and upon plots manured every three years.

TABLE II

Effect of Manure upon Yield of Wheat when Applied to Soils Cropped Continuously to Wheat.

Year of Manuring	Number of Plot	Yields by Years—Bushels per Acre 1915	1916	1917	1918	Average
1915 and 1918............	B-3	25.5	25.0	5.8	17.4	18.0
Unmanured	B-2	23.5	23.2	6.4	12.3	16.3
1916	D-9		32.2	11.2	24.8	22.7
Unmanured	D-8		24.5	10.7	15.1	16.8
1917	E-11			17.4	21.4	19.5
Unmanured	E-10			8.8	14.3	11.6

Average unmanured plots............14.2
Average manured plots.................19.9

Results with the rotation, fallow, wheat, and oats with the manure added to the fallow and plowed under indicate that there is but little increase to be expected for using the manure in this way. Table III gives the results by this method.

TABLE III

Effect of Manure Upon Yields of Wheat and Oats When Plowed Under With the Fallow Plots of the Rotation, Wheat, Oats, Fallow.

Year of Manuring	Number of Plot	Yields by Crops and Years—Bushels per Acre 1916	1917	1918
1915	E-6	Wheat 69.0	Oats 39.0	
Unmanured	E-7	Wheat 63.5	Oats 36.1	
1916	A-8		Wheat 24.4	Oats 10.1
Unmanured	A-7		Wheat 24.9	Oats 13.7
1917	C-16			Wheat 30.7
Unmanured	C-15			Wheat 25.8

In the rotation, peas, oats, and wheat, the manure was plowed in with the wheat stubble. It was not always well rotted, but did not interfere in the cultivation of the peas which were planted in rows as pointed out in another connection. In all the plots except E-3 and E-4 the yields of peas were lower upon the manured than on the unmanured plots, considering the normal yields of wheat on the same plots. However, in every case of the wheat following the peas, the yields were increased by the use of the manure. The same effect is carried to the third year and shows upon the oats. Table IV gives the detailed figures in this rotation.

TABLE IV

Effect of Manure Upon the Yields in the Rotation, Peas, Wheat and Oats.

Year of Manuring	Number of Plot	Yields by Crops and Years—Bushels per Acre 1915	1916	1917	1918
1915 and 1918	A-1	Peas 24.5	Wheat 52.0	Oats 45.0	Peas 17.0
Unmanured ..	A-2	Peas 29.8	Wheat 50.5	Oats 41.9	Peas 21.9
1916	C-8		Peas 39.8	Wheat 24.9	Oats 16.7
Unmanured ..	C-9		Peas 41.6	Wheat 23.2	Oats 15.7
1917	E-5			Peas 9.6	Wheat 16.8
Unmanured ..	E-4			Peas 9.4	Wheat 16.9

The cause of the loss in the yields of peas by the addition of manure probably lies in the method of applying the manure and it is doubtful if there would be a loss if the manure had been thoroly rotted and plowed down in the fall preceding the planting of the peas. A rolling of the soil either just before or just after seeding may probably overcome the difficulty, at least if the inhibition of seed setting is caused by the excessive looseness of the soil. That the effect is in the inhibition of the setting of seed is shown by the fact that where manure is applied, the growth is invariably more vigorous than where manure has not been used. In 1915 plot C-8 produced 217 pounds of dry vines, whereas, C-9, which produced more seed, produced but 187 pounds of dry vines. The vines for other years have not been weighed. To determine the best method of using manure on this soil is a problem still confronting us. Indeed

in the rotation indicates that this is a vital problem.

Plots bearing corn instead of peas in the rotation just discussed gave better results with the crop receiving the manure. The manure was disked into the corn land in the spring before planting the crop. Table V gives the detailed data for these six plots.

TABLE V

Effect of Manure Upon the Yields of Crops When Added to Corn in the Rotation, Corn, Wheat, and Oats.

Year of Manuring	Number of Plot	Yields by Crop and Year—Bushels per A. 1915	1916	1917	1918	Normal Yields of Wheat Average
1915 & 1918	E-8	Corn*	Wheat 46.9	Oats 34.4	Corn 38.6	24.2
Unmanured	E-9	Corn*	Wheat 50.2	Oats 35.0	Corn 41.6	36.7
1917	B-7		Corn 8 T	Wheat 25.3	Oats 13.3	37.5
Unmanured	B-6		Corn 8 T	Wheat 20.4	Oats 15.0	38.0
1918	A-4			Corn 3.6T	Wheat 18.5	37.8
Unmanured	A-3			Corn 3.1T	Wheat 16.9	39.8

* Yields not measured.

These experiments both with manure and commercial fertilizers indicate that the soil is not producing to capacity without fertilization. The recompense for fertilizing can be calculated if we set a price on each of the crops. The incomes tabulated upon the following pages are based on the following prices which are about average for the years that this experiment has been running. Wheat one dollar per bushel, oats thirty-five dollar per ton, peas five dollars per hundred pounds, potatoes fifty cents per bushel, and corn silage five dollars per ton. These are about average prices for the time during which the experiment has been conducted.

TABLE VI

Incomes Obtained by the Use of Manure and Nitrate of Soda Compared with Those of Unfertilized Plots in Various Rotations.

1. Rotation Wheat, Oats, and Potatoes.

Treatment	Crops	Incomes by Years—Dollars per Acre 1915	1916	1917	1918	Totals
Nitrate of Soda	Wheat	$30.30	$71.50	$30.30	$23.80	$155.90
	Oats		46.00	25.70	9.25	80.25
	Potatoes			62.45	70.50	132.95
		Average Annual per Acre				$ 41.01
Untreated	Wheat	25.20	65.80	32.40	21.80	145.20
	Oats		34.95	28.50	8.75	72.02
	Potatoes			57.75	84.25	142.00
		Average Annual per Acre				$ 39.91
Difference in favor of fertilizing 1 year						1.10
Difference in favor of fertilizing 3 years						3.30
	2. Continuous Wheat Rotation.					
Manure	Wheat	25.51	24.90	6.40	17.40	74.21
	Wheat		32.60	11.20	24.80	68.60
	Wheat			17.40	21.40	38.80
		Average Annual per Acre				$ 20.16
	Wheat	23.46	23.10	5.80	12.30	64.62
	Wheat		24.10	10.70	15.10	50.40
				11.20	24.80	36.00
		Average Annual per Acre				$ 16.77
Difference in favor of manure 1 year						3.39
Difference in favor of manure 3 years						10.17
	3. Rotation: Peas, Wheat, Oats.					
Manure 1915 and 1918	Peas	75.00	123.90	31.80	52.50	283.20
Manure 1916	Wheat		53.90	25.90	19.30	99.10
Manure 1917	Oats			26.25	9.35	35.60
		Average Annual per Acre				$ 46.43
Untreated	Peas	84.60	124.30	29.20	65.80	303.90
Untreated	Wheat		48.90	23.20	16.90	87.00
Untreated	Oats			23.95	8.53	32.48
		Average Annual per Acre				$ 47.26

Difference against manure 1 year					.83
Difference against manure 3 years					2.49

4. Rotation: Corn, Wheat, Oats.

Manures 1915 and 1918	Corn	40.00	18.00	31.20	89.20
Manured 1916	Wheat		24.80	18.50	43.30
Manured 1917	Oats			7.45	7.45
		Average Annual per Acre			$ 23.33
Untreated	Corn	39.00	15.50	27.50	82.00
Untreated	Wheat		24.40	16.40	36.80
Untreated	Oats			8.40	8.40
		Average Annual per Acre			$ 21.20
Difference in favor of manure 1 year					2.13
Difference in favor of manure 3 years					6.39

5. Rotation: Fallow, Wheat, Oats.

Manures 1915 and 1918	Wheat	62.80	25.20	30.60	118.60
Manured 1917	Oats		21.0	4.85	26.25
		Average Annual 1 year			$ 16.09
Untreated	Wheat	56.50	24.90	25.80	107.20
Untreated	Oats		20.20	7.65	27.85
		Average Annual per Acre			$ 15.03
Difference in favor of manure 1 year					1.06
Difference in favor of manure 3 years					3.18

These tables indicate plainly the necessity and value of manure in this area. Some indication is also given in regard to the best methods of application. That manure should not be plowed under before planting peas seems to be clearly shown. Corn is not adversely affected as the peas are. Never-the-less, the increase due to the use of the manure is not as great as when the manure is applied as a surface dressing to wheat. According to our present information, manure is best applied to a grain crop as a light surface dressing, using a manure spreader. Corn ground is a good place to use the manure, spreading thin and plowing under in the fall of the year, but this procedure, as well as that of using manure on fallow ground, is not to be advised except when the grain on the sown land is so high as to be injured by tramping. The fallow plot, if one is maintained, is a good place to use the manure, but it is strongly believed that better results than those given can be obtained by applying the manure as a surface dressing in the fall after the wheat has been sown. An argument against the fallow plot appears later in this paper. The figures upon the nitrate plot are hardly fair, as two fertilized plots were planted to Early Ohio potatoes in 1918, whereas, the checks had Gold Coin, a higher yielding variety. The Early Ohio yielded only 140.8 bushels per acre. The Gold Coin yielded 153.9 bushels per acre upon the average.

EFFECT OF PRECEDING CROP ON YIELDS OF WHEAT AND OATS

The effect of various crops preceding the wheat crop is shown in Table VI, the figures being averages of six plots.

TABLE VI

Average Yields of Wheat Following Different Crops.

Preceding Crop	Year and Average Yield of Wheat and Oats—Bushels per Acre						
	1916	1917		1918		Average	
	Wheat	Wheat	Oats	Wheat	Oats	Wheat	Oats
Fallow	63.1	23.5	35.8	25.7	11.2	37.4	23.5
Potatoes	63.4	27.8	44.5	22.9	16.4	38.0	30.4
Peas	51.2	24.1	43.4	16.9	16.2	30.7	29.8
Corn	48.5	22.8	34.6	17.7	14.1	29.7	24.4

It must be noted that the figures given include both fertilized and unfertilized plots. The averages given are struck from six plots as already pointed out, three of the six being fertilized and the other three not fertilized. Three fallow plots, three pea plots, and three corn plots received barn-yard manure. Three wheat plots succeeding potatoes received nitrate of soda. The oat yields here given are in all cases those obtained the second year after fertilization, or the second year from the cultivated crop. The oats follow the wheat invariably in the rotations under observation. Since the data have been collected from so many plots and under varying conditions of climate, as will be shown in another connection, it is considered that they are thoroly reliable and the following deductions should be entirely dependable.

Wheat gives heavier yields when grown after potatoes than when grown after fallow, peas, or corn. Yields after fallow, peas, and corn are heavier in the order given. The heavier yields of oats the second year after cultivation come in the order following potatoes, peas, corn, and fallow.

These data plainly point to the fallacy of practicing summer fallowing when the necessity for conserving the moisture thru the growing period for a succeeding crop does not demand it. It is probably true that grains ordinarily yield more heavily when sown upon fallowed land than when sown on land that has grown peas or corn, but the yields of these crops pay many times more than their production cost over the cost of fallowing. This fact is strikingly brought out in Table VII, which presents the comparative incomes of several rotations calculated upon the same prices as those used in Table V. The total income is for the same plots used in Table VI.

TABLE VII

Gross Incomes for Four Rotations—Dollars per Acre.

Rotation Beginning	Values of Crops by Years 1915		1916		1917		1918		Total 3 yrs.
1915	Fallow		Wheat	$63.10	Oats	$20.99			$83.09
1916			Fallow		Wheat	23.50	Oats	$6.27	29.77
			Average Annual Income per Acre						$ 18.81
1915	Corn	$48.80	Wheat	23.30	Oats	34.30			96.40
1916			Corn	32.00	Wheat	22.80	Oats	7.95	62.75
			Average Annual Income per Acre						$ 26.29
1915	Potatoes	6.85	Wheat	63.40	Oats	24.78			95.03
1916			Potatoes	73.15	Wheat	27.80	Oats	9.18	110.13
			Average Annual Income per Acre						$ 32.03
1915	Peas	81.30	Wheat	51.20	Oats	23.90			156.40
1916			Peas	122.10	Wheat	24.00	Oats	9.18	155.17
			Average Annual Income per Acre						$ 51.93

This table is a distinct argument against summer fallowing. Corn, which gave the lowest income of all rotations in which crops were substituted for the summer fallow, gave $22.44 for the extra labor in growing the corn. Potatoes and peas gave $39.66 and $99.35 respectively. Surely these amounts far over balance the extra cost in producing the crops. Accurate accounts of the costs have not been kept because the plots are small and the costs would in no wise be comparable to the costs in operating large fields.

INFLUENCE OF CLIMATE

It will be noticed in the preceding tables that the crops produced upon the plots vary greatly from year to year. The average yield of oats in 1916 was 65.5 bushels per acre. In 1918 it was 15.4 bushels. With wheat a similar variation was observed though not such a great difference. The same was true with the peas, but the corn and the potatoes do not show nearly such strong differences. These variations, being so constant, must have very definite causes. The differences came in the years more than in the individual plots.

Really phenomenal results were obtained in 1916 when, notwithstanding that thirty per cent of the crop was smut, one plot gave a yield of seventy-six bushels per acre of wheat. In the same year a yield of ninety-six bushels per acre of oats is recorded, and the heaviest yields of corn, peas, and potatoes were obtained. In contrast to this in 1918, the highest yield of wheat was only 26.6 bushels per acre without any smut whatever. The highest yield of oats for this year was only 21.3 bushels per acre. The difference between these two years should indicate the factors, which, aside from the fertility considerations, control the production of this area. Tables VIII and IX taken with the appended notes give some very important data upon climate, rainfall, temperatures, and the extraordinary occurrences in these factors.

TABLE VIII

Monthly and Annual Precipitation at Moscow, Idaho, 1915 to 1918, Inclusive.

	Precipitation—Inches			
Month	1915	1916	1917	1918
January	1.36	2.19	2.86	3.21
February	1.32	2.03	1.55	1.96
March	1.53	4.88	1.13	.46
April	2.07	1.01	3.63	.46
May	4.08	1.36	1.81	.94
June	.40	2.20	.72	.95
July	.78	1.12	.05	.93
August	.08	1.17	.00	.80
September	.31	.61	1.57	.75
October	1.66	.30	T	2.15
November	3.22	2.64	1.39	1.41
December	2.13	1.90	5.79	1.50
Annual	18.94	21.44	20.50	17.10

TABLE IX

Mean Monthly Maximum and Minimum Temperatures 1915-1918

	1915*		1916**		1917***		1918****	
Month	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
January	32.2	26.1	23.3	7.0	29.8	17.9	35.9	24.9
February	42.3	36.7	38.6	24.9	34.4	24.0	37.8	24.4
March	52.3	43.9	47.4	32.4	37.3	23.2	48.0	37.1
April	55.2	48.0	55.4	35.2	47.9	33.1	57.6	33.9
May	61.4	51.8	58.8	37.4	59.4	41.1	62.3	37.7
June	69.9	56.2	69.3	45.4	69.2	44.4	79.6	50.4
July	80.0	52.3	74.6	48.8	85.5	52.0	83.1	54.1
August	87.9	72.7	79.8	51.1	84.7	52.3	74.0	52.4
September	68.6	39.1	70.7	43.6	73.9	48.4	74.5	50.0
October	59.8	29.5	57.8	33.2	62.8	37.5	50.7	41.2
November	40.0	37.1	39.9	25.9	50.8	36.0	37.0	30.0
December	35.3	29.5	29.5	17.3	43.8	34.9	31.7	23.6

* Highest temperature August 10 and 29, 97 degrees F., June had only four days over 80 degrees, July only three days (20, 21, 24) over 90 degrees. August showed high temperatures.

** Highest temperature June 16, 96 degrees. June had two days above 90 degrees and two days above 80 degrees. July had eight days over 80 degrees, none over 90 degrees; latter part of August 22 to 31 over 90 degrees.

*** Highest temperature July 16, 99 degrees. June had a uniform had no rain fall.

**** Highest temperatures July 18, 100 degrees. June had five days over 90 degrees and eighteen days over 80 degrees, averaging 86 degrees. July had ten days over 90, averaging 93.7 and nineteen days over 80 averaging 88.5. August was comparatively cool, the mean maximum being only 74 degrees.

As would be expected, the differences in rainfall and temperature which affected the crop production are seen to be in the summer months when the crops are growing. In 1916 two months have a high mean maximum temperature, July 85 degrees F. and August 87 degrees F. These, it will be observed, were after the crops had reached the stage of fruition. The means for May and June were ordinary. In June and July there were no extended periods of very high temperature, only two days over 90 deg. F. A period of high temperatures came in August, but the crops were then matured. In this year there was an exceptionally high and uniform precipitation for the growing months, June getting the phenomenal amount of 2.2 inches. In 1918 when the lowest yields of grains were obtained, extraordinarily high temperatures came in June, giving the month a mean maximum of 79.6, over ten degrees higher than the average for the other three years. In addition to this a hot dry wind blew for two consecutive days during the hottest period. July also had a period of hot dry weather. The hot blasts of June seemed to blight the crops so that they never recovered. The rainfall was uniform during this season and was not very low. In April and May, however, little rain fell so there was not sufficient moisture in the soil to carry the crops over the hot period of June. It may be noted here that the best rains of June came after the hot spell.

The yields of wheat in 1917 were low, principally because of winter killing, an average of less than half a stand coming thru the winter. From these facts it is concluded that the fertility factors had little to do with the limiting of production in 1917 and 1918. The farmers should by no means become discouraged with the results of these two years, as the factors which cut down the yields during them very rarely interfere.

Another thing respecting the relation of climate to yields of crops should be pointed out here. The resistance of potatoes and corn to injury by drought conditions is noteworthy. Whereas the hot weather of 1918 cut down other grain crops at least fifty per cent, it had but little effect upon the yields of corn. It had no apparent effect upon the yields of potatoes. Peas were severely injured by the drought of 1917 when less than an inch of rain fell during June, July, and August. In 1918 they were damaged by the hot blast of June, but yielded better than in the previous year.

SUMMARY

The rotation and fertilizer experiments at the University of Idaho have been planned to obtain the following data: (1) To determine the most successful rotation practicable in this area; (2) to determine the effect of manure upon this type of soil; (3) to determine the crops that may be most profitably used to replace the summer fallow method.

The fertilizer and manure plots have been run side by side and have been run in triplicate to eliminate as far as possible the irregularities of the soil and the variations of the seasons.

The rotations experimented with have been based upon the system of cropping used almost universally in this area.

The cultural methods used were those most suitable for this soil and are thoroly practicable.

Only one variety of each crop has been used except where changes have been necessary to overcome some slight disadvantage of the one started.

The data with fertilizers indicate that nitrogen is the plant food element most likely to become the limiting factor when the deficiency is a plant food element.

Manure may be advantageously used, but a study of its proper use is necessary. Good results are obtained by using it as surface dressing upon wheat and by plowing it into ground that is to be planted to corn.

Potatoes have the most beneficial effect on a succeeding wheat crop. The others in order are fallow, peas, and corn.

The planting of corn, peas, or potatoes is much more economical than the practice of summer fallowing every third year.

The amount of moisture may prove a serious limiting factor in the production of the Palouse silt loam. Therefore, in its cultivation, attention should be paid to the conservation of moisture.

Potatoes and corn are much less seriously affected by the lack of rain during the growing season or the occurrence of high temperatures than wheat, oats, or peas.