



Flathead County soils in relation to their inherent fertility status
by Donald R Graham

A THESIS Submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree
of Master of Science in Soils
Montana State University
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Abstract:

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Attempts to relate a particular fertility level to each soil type were not successful due to the limited number of soil test samples and field trials, the influence of differential past management within soil types, the influence of weed infestations, and uneven irrigation on certain trials.

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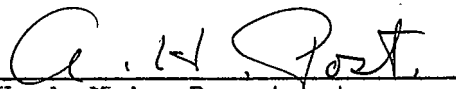
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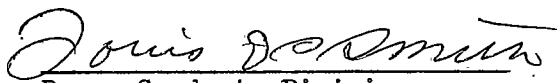
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Montana State College

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ABSTRACT

Eight Western Montana soils were investigated by laboratory and field trials to determine relative levels of available nitrogen, phosphorus, potassium, and boron. Fertility levels of each soil were determined by computing the median of chemical determinations from each soil. Soil test data from each trial site were compared to the median of the series to determine how well the site represented the fertility status of the series. Results of each field trial were weighed against these comparisons and interpretations were made accordingly.

Nitrogen caused significant yield response in barley on most soils, with thirty pounds per acre generally producing near maximum yields. Phosphorus fertilization of spring barley caused inconsistent responses, not related to soil test phosphorus. Potassium response occurred on potatoes only when soil test potassium was low. Boron did not affect potato yields on any soil studied.

Attempts to relate a particular fertility level to each soil type were not successful due to the limited number of soil test samples and field trials, the influence of differential past management within soil types, the influence of weed infestations, and uneven irrigation on certain trials.

INTRODUCTION

Within the last century soil has been recognized as a collection of natural bodies which can be classified and mapped on the basis of physical properties such as profile development, depth, color, texture, structure, and slope. Large areas of the United States have been mapped in detail. These maps are of value in determining soil management problems and predicting erosion hazards and crop yield. They also serve as a method of land evaluation and give legislators and others an approximation of conservation needs and the resource potential of our agricultural land.

A major potential use of soil survey information involves the determination of relationships between soil mapping units and fertility characteristics. A map which distinguishes soil of one fertility status from another with reasonable accuracy would prove invaluable in predicting fertilizer needs.

An attempt was made to study certain soil types of Flathead County, Montana, in relation to their fertility characteristics. Flathead County, typical of the intermountain area, possesses an abnormal complexity of soils including several Great Soil Groups in a relatively small area. As indicated by a detailed soil survey report, many fields or management units contain several soil types (24).

It was the purpose of this study to investigate several questions relating to soil fertility in the Flathead County area. First, what is the fertility status of several Flathead County soils? Is there any

relationship between soil type and fertility status? Is it possible to make fertilizer recommendations on the basis of individual soils or groups of soils?

This thesis will not adequately answer any of these questions due to the limitations involved but should give some indication of the problems. The results of this study should be of particular value in the expansion of a soil research program in the area.

REVIEW OF LITERATURE

Phosphorus

Many researchers in the field of soil fertility have studied the influence of genetic soil characteristics upon nutrient availability. Several Canadian scientists, using greenhouse techniques, investigated the effects of phosphorus and potassium on ten soil types, each represented by nine surface soils (4, 14, 15). Soil tests indicated that the amount of phosphorus and potassium extracted from the soils varied significantly between soil types. Data from four successive crops showed that the relative effect of applied phosphorus and potassium on yield and plant uptake varied significantly between soil types.

Smith (22) studied chemical soil test data accumulated over a ten year period as a basis for an inventory of the fertility status of Oklahoma soils. Variations in nutrient and acidity levels were attributed to interrelated influences of the factors of soil formation. Soils which were developed under similar factors of formation appeared to possess similar nutrient and acidity levels.

Shrader, et al, (21) presented several statistical methods for evaluating the relative effect of soil type on the crop yield obtained in a long time rotation-fertility experiment. They found that all methods of analysis used indicated that differences in yield were associated with soil types.

Young, et al, (25) studied eight New York soil types. They found that there was a significant difference in the phosphorus supplying

power of these soils. Soil tests accurately indicated the phosphorus availability in all soils except one where adequate quantities of phosphorus were supplied to plants even though the soil test indicated a less than adequate level.

Dennis and Chesniv (10) studied the phosphorus availability by horizons of soils by considering the yield and chemical composition of alfalfa grown on soils selected from each horizon. They found a different distribution of the phosphorus between soils studied. For example, the A and D horizons of Thurman series possessed larger amounts of available phosphorus than the B horizon, Carrington decreased in available phosphorus with depth while Grete increased in available phosphorus with depth.

Studies have been made in Nebraska relating phosphorus status to soil type (10). Phosphorus levels of the A horizon differed greatly between soils of the same series. However, the phosphorus levels of the lower horizons were strikingly similar among the members of each series studied. The differences in the phosphorus levels of the surface soils is considered to be due to management practices or erosion.

Baumgardner and Barber (7) studied phosphorus uptake in a greenhouse using soil and plant analysis. They attributed phosphorus availability to the effects of parent material, organic matter, and soil drainage characteristics. On the same soil, Bishop and Barber (8) found that the acidity or alkalinity of the extracting solution affects soil test results and should be considered in interpretations. It

appeared that some soils contain large amounts of calcium phosphate which is soluble in acid extractions while other soils contain a relatively large amount of aluminum phosphate which is more soluble in alkaline extractions and iron phosphate which is soluble in both acid or alkaline extracts.

Allaway and Rhoades (1) have attributed the changes in the nature and distribution of phosphorus in soils formed from calcareous loess to several factors. First, there apparently is some movement of phosphorus within the soil profile since the total phosphorus content of soils with a lime horizon tends to be at maximum near the top of the lime horizon. Secondly, in soils which remain neutral or only slightly acid during soil formation, a conversion of acid-soluble forms of phosphorus to organic phosphorus compounds seems to occur. This organic phosphorus generally is concentrated in the surface horizons. Thirdly, in soils that are leached and become acid, phosphorus accumulates on the surface of soil particles. The formation of these adsorbed phosphates is apparently inaugurated in the surface horizons of the profile but may occur in deeper horizons of highly leached soils.

Potassium

Allaway and Pierre (2) determined that high lime soils require more exchangeable potassium than acid soils in order to support good crop growth.

Rouse and Bertramson (20), studying Indiana soils, concluded that a definite relationship exists between the potassium supplying

power and the amount of illite present in the silt and clay fractions. Potassium supplying power was found to be inversely related to the amount and type of potassium fixation which occurs.

Pearson (18), investigating soils of Alabama, found considerable variation between the soils studied with respect to their rate of release of potassium. It appeared that soils containing montmorillonite released potassium more readily than did kaolinitic soils.

Attoe (5) recognized that the transformation of exchangeable potassium into non-exchangeable forms upon drying may vary widely between soils. His investigation suggests two types of potash fixation; that which proceeds in moist soils, is increased by liming and fixes potassium in a form fairly soluble in 0.5 N HCl, and that which proceeds only on drying, is fairly independent of pH, and fixes potassium in a form fairly insoluble in 0.5 N HCl.

Garman (11), after examining 17 Ohio and New York soils, determined that potassium release from both surface and subsurface soils followed the order Brown Forest Gray-Brown Podzolic Brown Podzolic Podzol.

Pope and Cheney (19) investigated 20 soils representing seven soil types. They determined the amount of non-exchangeable potassium removed by ladino clover in the greenhouse and found a definite correlation between potassium availability and soil type. They concluded that the amount of non-exchangeable potassium removed depended upon the parent material, the degree of weathering and drainage characteris-

tics of the soil.

Nitrogen

The effects of soil formation on organic matter has been shown by Jenny (12). At constant temperatures, organic matter increases logarithmically with increasing moisture. If the moisture remains constant, organic matter declines logarithmically as the temperature rises.

Allison (3) estimated that the percentage of nitrogen in the soil which is released to one crop is related to the soil texture. The percent release varied from 1.25 on clay soil to 6 percent on sand soil.

Debetz (9), growing spring wheat on two soil types with varying moisture and nitrogen levels found that increasing nitrogen and moisture increased the grain yield on both soils. On one soil, increasing nitrogen increased protein while increasing moisture decreased the protein. He concluded that the difference in characteristics of soil types was largely due to their difference in texture.

Soil Moisture

The difference in moisture characteristics between soils will undoubtedly affect their management requirements. An appraisal of these characteristics may be an important criterion for making specific fertilizer recommendations. Bartelli and Peters (6) determined soil moisture characteristics for 31 soil types representing the major Great Soil Groups recognized in Illinois. Available soil moisture and field

capacity were shown to vary by textural classes for each of the soil groups studied. Soil moisture characteristics appeared to be consistent within each of the soil types studied.

MATERIALS AND METHODS

The fertility status of eight soil types in Flathead County, Montana, have been investigated by several methods. First, available soil analysis data from each soil type was compiled and studied. Then, the nitrogen and phosphorus level of each soil was investigated by imposing four rates of nitrogen and three rates phosphorus on barley grown on each soil. The potassium and boron levels of several soils were studied, using four rates of two sources of potassium and one rate of boron on potatoes. The soils included in the study are Creston silt loam, Flathead fine sandy loam, Kalispell loam, Tally fine sandy loam, Swims silty clay loam, Somers silty clay loam, Walters silty clay loam, and Kiwanis loam.

Soil Types¹

Creston silt loam is a Chernozem soil developed under tall grass from glacial alluvium. It is a very productive soil containing relatively high levels of organic matter, phosphorus, and potassium as shown in Table I. This soil occurs primarily in the east-central portion of the valley on broad terraces (Figure 1).

Flathead fine sandy loam intergrades with Creston on the North and continues up the valley interspersed with bodies of other soils. Flathead is also a Chernozem developed under tall grass. It is similar

¹Detailed soil series descriptions appear in the Appendix.

to Creston except that it possesses a thicker solum, coarser texture, and lacks a marked accumulation of calcium carbonate. Flathead soils possess slightly lower levels of organic matter, phosphorus, and potassium than Creston.

Kalispell loam is a Chestnut soil developed under a moderate cover of grass. It generally occurs in the central and western portion of the valley in relatively small areas, interspersed by other soils. Kalispell is lighter colored than Creston or Flathead and has a thinner solum. Pronounced horizons of calcium carbonate are found below the solum. Kalispell contains organic matter levels similar to Creston, a relatively high potassium level but a very low phosphorus level. Almost one-third of Kalispell surface samples showed effervescence with hydrochloric acid while only about ten percent of the Creston and Flathead soil samples were calcareous at the surface.

Kalispell is often associated with a complex of Tally, Blanchard, and Flathead series. These three soils are so closely associated that it is impractical to map them separately. Blanchard is a very light, highly erodable soil occupying dunelike topography which generally is not tilled. Tally is a Chestnut soil developed from alluvium under grass vegetation. It possesses a calcium carbonate accumulation similar to Kalispell but has greater depth and lighter textures. Tally soils contain slightly lower organic matter than Kalispell. Both soils possess a relatively high potassium level and a low phosphorus level. Tally has a lower pH and less calcareous surface soil than Kalispell.

Table I. Median soil analysis data of 8 soil series.

Soil	No. of samples	pH	Cond	K ₂ O	P ₂ O ₅	O.M.	Lime*
Greston	42	7.7	14	450	75	3.5%	12%
Flathead	33	7.5	5	340	51	2.9%	9%
Kalispell	53	8.2	14	550	37	3.4%	32%
Tally	19	7.5	13	525	45	3.0%	10%
Somers	40	8.2	17	350	22	4.0%	18%
Swims	34	8.4	15	380	24	3.0%	47%
Kiwanis	14	8.4	14	250	25	2.2%	36%
Walters	16	8.0	13	400	250	3.1%	30%

*The percentage of soils which showed effervescence with hydrochloric acid.

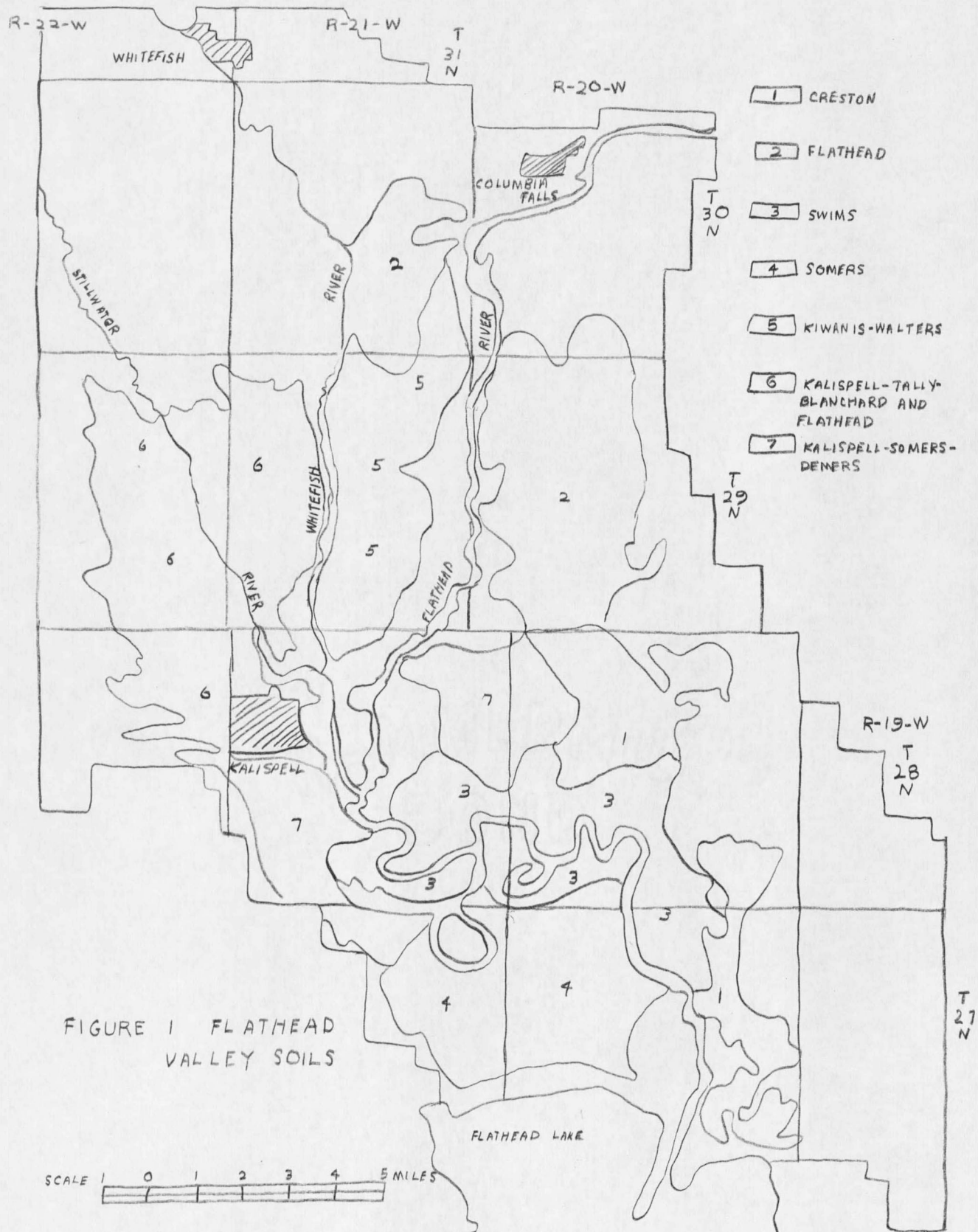


FIGURE 1 FLATHEAD
VALLEY SOILS

Somers silty clay loam is a Chestnut soil developed under grass vegetation with a scattering of pine trees. It occupies positions on low terraces adjacent to major streams and rivers. Somers is finer textured and more poorly drained than most soils in the area. It possesses a moderate calcium carbonate horizon below the solum. This soil possesses a high organic matter content and an average potassium level. Phosphorus levels are extremely low while pH is relatively high. Less than 20 percent of Somers soil samples were calcareous at the surface.

Swims silty clay loam is a Gray Wooded soil developed under moderate to dense pine forest from recent alluvium. It is lighter colored and more subject to flooding than Somers, but has similar depth, texture, and drainage characteristics. Ground water generally occurs within ten feet of the surface. Swims soils have about average organic matter and potassium levels. Very low phosphorus levels occur and almost one-half of Swims soils are calcareous at the surface. Swims soils possess a relatively high pH.

Kiwanis loam, a Regosol, is underlain by gravel and is calcareous almost to the surface. It occurs in the central portion of the valley between the Flathead and Whitefish rivers. The native vegetation of Kiwanis was predominantly grass with moderate stands of conifers. About one-third of the Kiwanis soils are calcareous at the surface. This soil possesses very low organic matter, phosphorus, and potassium levels.

Walters silty clay loam occurs in association with Kiwanis. It

is a Gray Wooded soil developed under a forest vegetation. Walters is similar to Swims in depth and texture. It contains a slight calcium carbonate accumulation in the B horizon. Compared to the other soils in the study, Walters has average organic matter, potassium, and pH, with a relatively high phosphorus level.

Soil Chemical Analysis

Chemical soil analysis data were obtained from the Flathead County Soil Testing Laboratory operated by the Flathead County Extension Service and Montana State College. Determinations included conductivity, pH, organic matter, available phosphorus, available potassium, and free lime. Data from soil samples taken within each of the eight soil series were compiled. The median determinations for each soil series were found and used to describe the fertility level of each soil.

Organic matter was determined using a method similar to that described by Jackson (13). This consisted of treating a prescribed amount of soil with potassium dichromate in the presence of concentrated sulfuric acid until the organic matter was oxidized. The extract was filtered and the amount of potassium dichromate remaining was determined colorimetrically. The organic matter content was computed by comparison with a standard curve.

Available phosphorus was determined using the Bray No. 1 method described by Smith, et al (23). The soil was extracted with a solution of ammonium fluoride in hydrochloric acid. Chloromolybdic acid and chlorostannous acid were added to the extract. The phosphorus content

was determined colorimetrically from phosphomolybdate which develops color intensities corresponding to the concentration of phosphorus.

Potassium was determined by a method described by the Oregon Agricultural Experiment Station.¹ Soil was extracted with ammonium acetate, filtered, and the potassium content determined with a flame photometer.

Field Trial Procedures

Sites representative of each soil type were selected and field trials involving either nitrogen and phosphorus rates on barley or potassium rates and boron on potatoes were established. Soil analysis data and cropping history of each experiment appear in Table II. Trial locations are shown in Figure 2.

Nitrogen and Phosphorus on Barley

Nitrogen and phosphorus in the form of ammonium nitrate and treble superphosphate, respectively, were banded into the soil of prescribed plots in one foot rows. This was done with a belt seeder placed on a Planet, Jr. drill which was mounted on a small wheel tractor. Phosphorus rates of 0, 40, and 80 pounds of P_2O_5 and nitrogen rates of 0, 15, 30, and 45 pounds of N per acre were applied in a factorial arrangement.

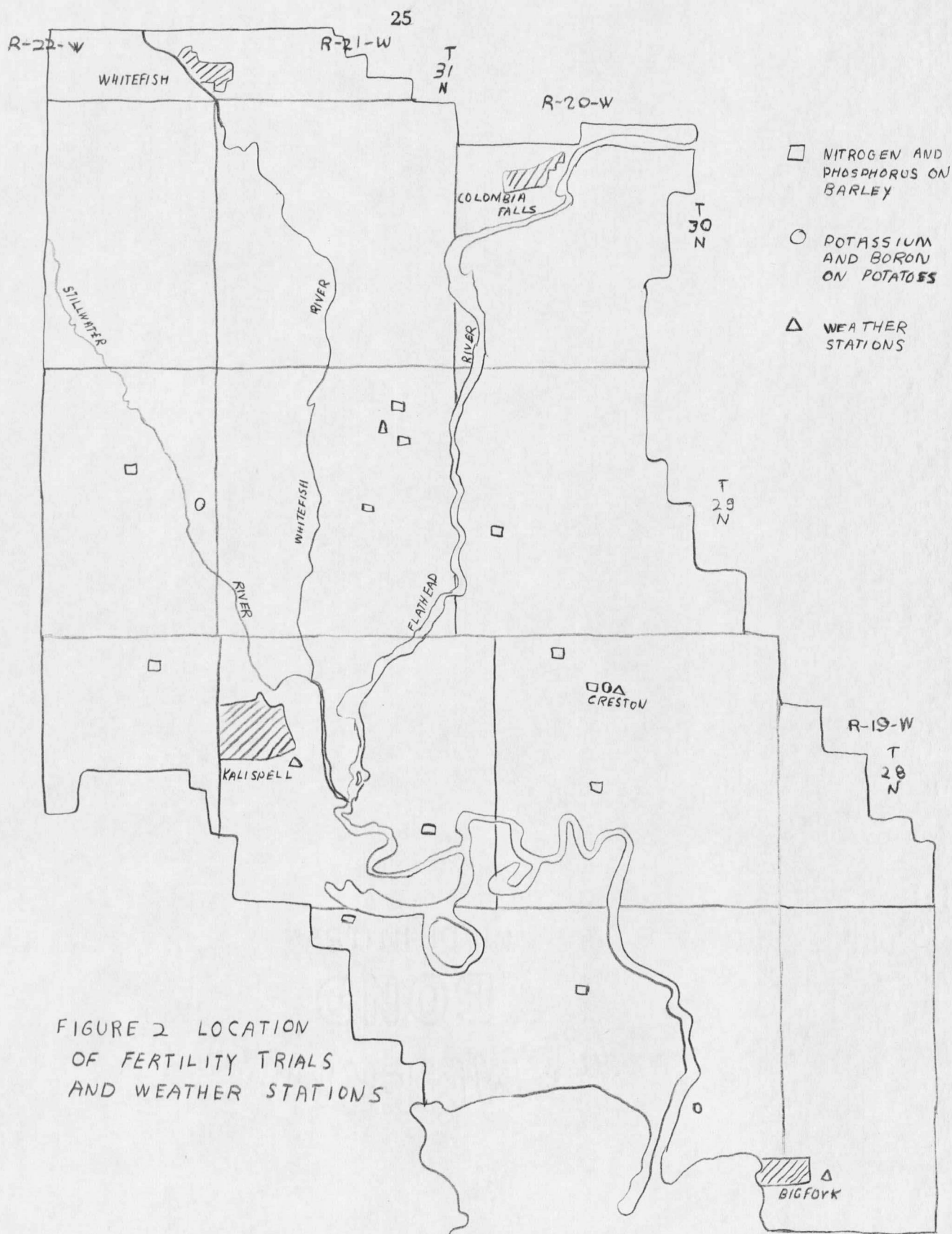
Barley was seeded in approximately the same row that the ferti-

¹Oregon State College, Agricultural Experiment Station mimeographed leaflet S-34, Nov. 1954.

Table II. Chemical analysis and past management of field trials.

Soil Series	Trial	Date	Farmer	Soil Analysis			pH	Past Management
				O.M. ¹	P ₂ O ₅ ²	K ₂ O ³		
Greston	A ⁴	1960		4.5	24		7.5	peas-gr-fal ⁶
	B ⁵	1961				530		clo-clo-gr-pot
Flathead	A	1960		2.3	36		8.2	ww-spr gr-fal
	A	1961		2.0	23		7.2	gr-fal
	B	1961	Johnson			326		
	B	1961	Mangle			212		
	B	1961	Dubay			246		
Kalispell	A	1960		3.4	74		7.4	gr-gr-fal
	B	1961				280		
Tally	A	1960		3.2	44		8.1	gr-gr-hay
Somers	A	1960		5.2	76		7.6	gr-fal
Swims	A	1960		4.1	104		7.8	gr-fal
	A	1961	Fritz	3.7	84		8.0	gr-fal
	A	1961	Seney	2.3	41		7.9	gr-fal
	A	1961	Greer	2.3	188		7.4	gr-fal
Kiwanis	A	1960		2.7	13		8.1	alfalfa
Walters	A	1960		3.4	74		7.9	alfalfa-gr-gr

¹percent organic matter²available phosphorus, pounds per acre³available potassium, pounds per acre⁴nitrogen and phosphorus on barley⁵potassium and boron on potatoes⁶gr-grain, clo-clover, pot-potatoes, ww-winter wheat, spr gr-spring grain, fal-fallow.



lizer was applied. Plots were twenty feet long by four rows wide and were replicated three times. Fertilizing and seeding were done during the first week in May. Sixteen feet of each of the two center rows were harvested about the middle of August. The grain was cleaned and weighed later at the Northwestern Branch Experiment Station.

Potassium and Boron on Potatoes

A split tubular shoe was placed on the belt seeder which facilitated the placement of potassium below and on both sides of planted potato seed pieces. Potassium of two sources, potassium chloride (muriate of potash) and potassium sulfate, were applied at rates of 0, 25, 50, 75, and 100 pounds of K_2O per acre. A boron rate, 4 pounds boron per acre, was also incorporated into the trials.

The plots consisted of two twenty foot rows spaced about forty inches apart. Fertilizing was done soon after the fields were planted, about the last week in May. Ten feet of each row were harvested and weighed during the first week in October.

Statistical Methods

Statistical analysis of the nitrogen and phosphorus experiments was done following procedures set forth by Ostle (17) using analysis of variance of factorials with a randomized block design (pp. 349). Statistical analysis of the potassium on potatoes experiment was done following procedures for a randomized complete block design (pp. 293). In all cases, the 5 percent confidence level was used for testing significance.

DISCUSSION AND RESULTS

Weather

Weather stations exist at four locations in Flathead County.

The Creston and Bigfork weather stations are located in the southeastern portion of the valley as shown in Figure 2. Stations are also located in Kalispell in the southwestern area and at Flathead County Airport in the central portion of the County. Average monthly temperatures were comparable between weather stations as shown in Table III. However, precipitation varied significantly between weather stations during both years of this investigation (Table IV).

During the 1960 growing season temperatures averaged 0.5 degrees below normal with only July possessing higher than normal temperatures. Almost every month of 1960 received below normal precipitation. The dry June and hot, dry July drastically reduced spring grain yields.

Most months of 1961 received near normal rainfall, while temperatures averaged two degrees above normal. June received less than normal rainfall which was offset by higher than normal precipitation during the earlier months. Crop yields in 1961 were near normal.

Comparisons of precipitation between weather stations indicate that precipitation increases in an easterly direction across the valley. This is probably due to the high mountain range bordering the east side of the valley which causes warm air to rise resulting in condensation producing rain. Annual precipitation is undoubtedly affected by the mountain ranges to the north and east, particularly in those areas near

Table III. Average monthly temperatures and departures from long-term mean.

	Creston	Big Fork	Kalispell	Flathead	Departures*
<u>1960</u>					
April	44.3	44.3	44.1	43.0	-0.7
May	50.6	50.1	50.7	50.2	-2.2
June	59.6	60.0	60.0	58.0	-0.4
July	68.8	71.9	70.7	69.8	3.8
August	60.6	62.0	61.6	61.0	-3.0
<u>1961</u>					
April	42.0	42.4	41.8	40.5	-3.2
May	52.6	52.5	53.7	52.4	0.0
June	64.7	66.3	65.8	64.2	5.8
July	66.2	69.8	68.1	68.9	2.9
August	67.8	70.9	69.9	69.1	5.1

Table IV. Total precipitation and departures from long-term mean.

	Creston	Big Fork	Kalispell	Flathead	Departures*
<u>1960</u>					
January	1.67	1.74	1.00	1.30	- .02
February	1.10	1.03	.72	.83	- .12
March	1.01	1.10	.86	1.11	.10
April	1.23	1.47	.60	.82	- .20
May	3.27	3.36	2.35	3.34	1.71
June	.69	1.37	.37	.62	-1.81
July	.13	.21	.07	.03	-1.13
Total	9.10	10.28	5.97	8.05	-1.47
<u>1961</u>					
January	.65	.93	.67	.75	- .57
February	1.46	1.36	1.51	1.32	.40
March	1.96	2.99	1.54	1.12	.11
April	2.26	2.21	2.34	2.01	.99
May	4.02	4.27	3.00	2.35	.72
June	1.45	1.06	.71	.71	-1.72
July	.76	.26	.84	1.20	.04
Total	12.56	13.08	10.61	9.46	- .03

the edges of the valley. These complex rainfall patterns may have had considerable effect upon soil formation. Rainfall probably was of major significance in determining whether a grass or forest dominated in the native vegetation.

Rainfall distribution appears to be rather constant throughout the year except for a relatively dry period in late July and early August. It is debatable whether a fallow season to conserve soil moisture is effective.¹ Supplemental irrigation is economical for most crops if ample ground water is available.

Effect of Nitrogen and Phosphorus Fertilization

Creston silt loam

The effect of nitrogen and phosphorus fertilization on Creston silt loam is shown in Table V. Both nitrogen and phosphorus caused significant increases in the yield of barley. Yields increased about five bushels per acre from each of the first two increments of nitrogen and decreased slightly from the third increment. Economically the first two increments were practical since the returns due to the response were about twice the cost of the nitrogen. The low rainfall and the effect on nitrate accumulation of the previous crop of peas may have reduced the effectiveness of the last increment of nitrogen.

Phosphorus at a 40 pound rate increased barley yields about five

¹Reports of the Northwestern Branch Experiment Station, Kalispell, Montana.

Table V. Effect of nitrogen and phosphorous fertilization on barley grain yields, Creston silt loam, 1960.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	11.2	17.4	29.4	21.4	23.2
	Rep. 2	32.0	22.5	31.9	14.7	
	Rep. 3	<u>19.8</u>	<u>18.8</u>	<u>30.3</u>	<u>32.4</u>	
	Total	63.0	58.7	91.6	65.5	
40	Rep. 1	12.9	27.8	27.3	22.5	28.9
	Rep. 2	27.8	28.4	32.7	32.7	
	Rep. 3	<u>31.3</u>	<u>27.6</u>	<u>39.4</u>	<u>36.8</u>	
	Total	72.0	83.8	99.4	92.0	
80	Rep. 1	11.9	17.9	23.6	24.3	26.8
	Rep. 2	26.8	29.4	30.6	30.9	
	Rep. 3	<u>22.8</u>	<u>38.0</u>	<u>34.4</u>	<u>31.0</u>	
	Total	61.5	85.3	88.6	86.2	
Nitrogen Average		21.8	25.3	31.1	27.1	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	621.0	310.5		
Nitrogen	3	405.1	135.0	5.29*	3.05
Phosphorous	2	179.7	89.9	3.52*	3.44
N x P	6	110.0	18.3	0.72	2.55
Error	22	561.8	25.5		
Total	35	1877.6			

$\bar{x}$ 26.3
G.V. 19.2

*significant at the 5 percent confidence level.

bushels per acre and produced yields at least as high as the 80 pound rate. This response is economical. The 40 pound rate of phosphorus is apparently near the top of the response curve. Therefore, lower rates may have given equal response at less cost. The phosphorus level of this soil was extremely low compared to the median of the series. Thus, other Creston soils may not show a significant response to phosphorus.

Flathead fine sandy loam

Results of a nitrogen-phosphorus trial on Flathead fine sandy loam in 1960 appear in Table VI. Nitrogen produced significant barley yield increases with each increment of nitrogen. Since each increment increases the yield only about two bushels per acre, nitrogen fertilization was not economical. During years of more normal rainfall a steeper nitrogen response curve may occur which would result in an economical response. Check yields were extremely low with plants showing signs of drought damage. Plants on plots which received nitrogen did not appear to be damaged, indicating that nitrogen increased the efficiency of moisture use.

There was no significant phosphorus response in this trial even though the phosphorus level according to soil test was very low. The available phosphorus in this soil is apparently higher than the soil test indicated.

A similar trial on Flathead fine sandy loam in 1960 showed response to both nitrogen and phosphorus as seen in Table VII. This soil possessed organic matter and phosphorus levels similar to those of the

Table VI. Effect of nitrogen and phosphorous fertilization on barley grain yields, Flathead fine sandy loam, 1960.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	6.4	7.7	10.2	11.0	9.2
	Rep. 2	7.0	9.0	10.1	13.9	
	Rep. 3	4.6	7.2	8.2	15.6	
	Total	18.0	23.9	28.5	40.5	
40	Rep. 1	5.1	11.3	12.6	13.6	11.0
	Rep. 2	7.4	9.6	12.2	12.8	
	Rep. 3	8.5	8.6	13.5	16.7	
	Total	21.0	29.5	38.3	43.1	
80	Rep. 1	8.9	10.1	11.5	12.3	10.7
	Rep. 2	9.8	10.0	12.1	18.8	
	Rep. 3	6.9	9.4	6.6	11.9	
	Total	25.6	29.5	30.2	43.0	
Nitrogen Average		7.2	9.2	10.8	14.1	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	10.5	5.3		
Nitrogen	3	227.7	75.9	21.24*	3.05
Phosphorous	2	21.1	10.6	2.95	3.44
N x P	6	15.4	2.6	0.71	2.55
Error	22	78.6	3.6		
Total	35	353.3			

$\bar{x}$ 10.3
G.V. 5.8

*significant at the 5 percent confidence level.

Table VII. Effect of nitrogen and phosphorous fertilization on barley grain yields, Flathead fine sandy loam, Experiment Station, 1961.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	5.8	7.2	15.0	12.6	12.1
	Rep. 2	10.9	16.6	11.3	22.2	
	Rep. 3	<u>1.7</u>	<u>11.3</u>	<u>19.3</u>	<u>11.6</u>	
	Total	18.4	35.1	45.6	46.4	
40	Rep. 1	3.5	11.8	22.6	24.8	17.2
	Rep. 2	7.6	22.0	27.8	28.6	
	Rep. 3	<u>2.4</u>	<u>16.8</u>	<u>15.3</u>	<u>22.6</u>	
	Total	13.5	50.6	65.7	76.0	
80	Rep. 1	8.2	10.3	20.2	22.6	16.9
	Rep. 2	13.8	17.4	26.9	18.5	
	Rep. 3	<u>3.8</u>	<u>9.1</u>	<u>27.3</u>	<u>25.0</u>	
	Total	25.8	36.8	74.4	66.1	
Nitrogen Average		6.4	13.6	20.6	20.9	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	188.3	94.2		
Nitrogen	3	1277.0	425.7	30.34*	3.05
Phosphorous	2	193.0	96.5	6.88*	3.44
N x P	6	177.3	29.6	2.11	
Error	22	308.6	14.0		
Total	35	2144.2			

$\bar{x}$ 15.4

G.V. 24.3

*significant at the 5 percent confidence level.

1960 trial on Flathead sandy loam. Each of the first two increments of nitrogen resulted in economic barley yield increases. This year more optimum weather conditions existed and no drought effects were noted.

Forty pounds of phosphorus increased yields about five bushels per acre with no increase at a higher rate. The reason for the difference in phosphorus response between this trial and the 1960 trial is not clearly understood. It is apparently due to yearly variations or differences in soil.

Kalispell loam

The results of a nitrogen-phosphorus trial on Kalispell loam are presented in Table VIII. Significant responses occurred with each of the first two increments of nitrogen, increasing barley yields about five bushels per acre. All plants showed signs of moisture stress, particularly in plots which had not received nitrogen. This soil possesses an organic matter content comparable to the median of the series. Nitrogen responses could be expected on Kalispell soils during some years.

No phosphorus response occurred in this trial. The phosphorus level of this soil was considerably higher than the median of the series. Therefore, phosphorus response may occur on some Kalispell soils.

Tally fine sandy loam

The effect of nitrogen and phosphorus fertilizers on barley

Table VIII. Effect of nitrogen and phosphorous fertilization on barley grain yields, Kalispell loam, 1960.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	3.1	9.2	10.5	9.6	8.3
	Rep. 2	2.1	8.5	14.0	12.4	
	Rep. 3	1.6	7.1	9.4	12.2	
	Total	6.8	24.8	33.9	34.2	
40	Rep. 1	1.3	9.1	8.8	13.4	8.0
	Rep. 2	2.4	8.4	12.2	11.0	
	Rep. 3	1.6	5.8	14.3	8.1	
	Total	5.3	23.3	35.3	32.5	
80	Rep. 1	2.8	6.9	10.7	15.6	7.8
	Rep. 2	1.6	6.9	10.6	5.4	
	Rep. 3	1.3	7.9	14.1	10.3	
	Total	5.7	21.7	35.4	31.3	
Nitrogen Average		2.0	7.8	11.6	10.9	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	2.3	1.2		
Nitrogen	3	518.6	139.5	39.7*	3.05
Phosphorous	2	1.4	0.7	.2	3.44
N x P	6	2.7	0.5	.1	2.55
Error	22	95.9	4.4		
Total	35	620.9			

$\bar{x}$ 8.1
C.V. 26.0

*significant at the 5 percent confidence level.

grown on Tally fine sandy loam in 1960 are shown in Table IX. No fertilizer treatment gave significant yield responses. Plot averages indicated that economical yield increases resulted from 15 and 30 pounds of nitrogen. These increases were not statistically significant probably due to the large variation within treatments as exemplified by the high coefficient of variability. The trial was irrigated resulting in relatively high yields. It appears that in most non-irrigated trials in 1961 water was the most significant limiting factor since both irrigated trials, Tally and Walters, produced relatively high yields. Neither of these soils is considered to be particularly productive. The reason for the abnormal variation in the trial is unknown but could be due to soil or irrigation irregularities. Irrigation was performed by overhead sprinklers and shifting wind may have prevented uniform distribution of water.

The organic matter content of this soil was comparable to the median of the series. Though the results of this trial are not conclusive, it would appear that nitrogen responses may occur on some Tally soils. Phosphorus levels were quite low on this site as well as on most Tally soils. There is little indication of phosphorus response on this soil. Likewise, other Tally soils may not respond to phosphorus.

Swims silty clay loam

Results of a 1960 trial on Swims silty clay loam appear in Table X. Fifteen pounds of nitrogen produced significant yield increases amounting to about five bushels per acre. Additional nitrogen did not

Table IX. Effect of nitrogen and phosphorous fertilization on barley grain yields, Tally fine sandy loam, 1960.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	59.1	41.9	54.9	57.2	47.1
	Rep. 2	31.8	47.3	45.0	61.4	
	Rep. 3	<u>41.3</u>	<u>45.3</u>	<u>46.6</u>	<u>34.7</u>	
	Total	132.2	133.5	146.5	153.3	
40	Rep. 1	45.0	51.7	47.9	58.1	50.7
	Rep. 2	40.4	45.2	60.9	61.7	
	Rep. 3	<u>34.5</u>	<u>53.2</u>	<u>57.0</u>	<u>53.1</u>	
	Total	119.9	150.1	165.8	172.9	
80	Rep. 1	43.8	49.6	49.4	45.8	49.4
	Rep. 2	38.2	40.6	43.8	36.1	
	Rep. 3	<u>61.9</u>	<u>55.5</u>	<u>58.7</u>	<u>69.1</u>	
	Total	143.9	145.7	151.9	151.0	
Nitrogen Average		44.0	47.7	51.6	53.0	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	141.9	71.0		
Nitrogen	3	413.3	137.8	1.45	3.05
Phosphorous	2	46.1	23.1	0.24	3.44
N x P	6	255.7	42.6	0.45	2.55
Error	22	2081.3	94.6		
Total	35	2938.3			

$\bar{x}$ 49.1
C.V. 33.0

Table X. Effect of nitrogen and phosphorous fertilization on barley grain yields, Swims silty clay loam, 1960.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	14.4	18.5	14.8	28.7	20.3
	Rep. 2	20.1	22.6	28.4	16.3	
	Rep. 3	<u>15.3</u>	<u>17.9</u>	<u>19.1</u>	<u>27.5</u>	
	Total	49.8	59.0	62.3	72.5	
40	Rep. 1	14.4	25.9	30.0	31.3	23.6
	Rep. 2	25.5	23.8	24.6	22.4	
	Rep. 3	<u>17.6</u>	<u>20.0</u>	<u>23.5</u>	<u>23.8</u>	
	Total	57.5	69.7	78.0	77.5	
80	Rep. 1	14.7	22.2	25.3	15.9	20.3
	Rep. 2	15.7	28.2	24.9	25.3	
	Rep. 3	<u>16.6</u>	<u>22.8</u>	<u>17.2</u>	<u>16.3</u>	
	Total	47.0	73.2	66.4	57.5	
Nitrogen Average		17.1	22.4	23.0	23.1	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	67.7	33.9		
Nitrogen	3	219.3	73.1	3.80*	3.05
Phosphorous	2	84.4	42.2	2.19	3.44
N x P	6	88.5	13.8	0.77	2.55
Error	22	422.9	19.2		
Total	35	882.8			

x 21.4

G.V. 20.5

*significant at the 5 percent confidence level.

affect yields. This is the only trial where 15 pounds of nitrogen produced maximum yields. The organic matter content of this soil was considerably higher than the median of the series. Other Swims soils may respond to higher rates of nitrogen. The phosphorus level of this soil was relatively high compared to the median of the series. Other Swims soils may show response with phosphorus even though this soil did not.

In 1961, trials were established on Swims silty clay loam at three locations: the Greer farm in the southeastern portion of the valley, the Fritz farm in the central portion, and the Seney farm in the southwestern part of the valley. The trial results from the Fritz and Greer farms are shown in Table XI and Table XII, respectively. Neither of the trials responded significantly to nitrogen or phosphorus. Both trials were seriously infested with wild oats which apparently influenced the results. The trial on the Fritz farm visually showed increased wild oat growth in the nitrogen plots. This competition undoubtedly affected the results. Both trials possessed higher phosphorus levels than the median of the series. The Fritz trial was relatively high in organic matter while the Greer trial was quite low. The Greer trial was relatively high in available phosphorus. These trials illustrate that weed infestation can significantly influence fertilizer response.

Results of the trial on the Seney farm are presented in Table XIII. Significant responses occurred from both nitrogen and phosphorus. The first increment of nitrogen increased yields about seven bushels per acre, followed by an additional 13 bushel increase from the second

Table XI. Effect of nitrogen and phosphorous fertilization on barley grain yields, Swims silty clay loam on the Earl Fritz farm, 1961.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	63.7	42.4	44.3	67.6	46.3
	Rep. 2	60.3	28.3	26.6	34.1	
	Rep. 3	<u>49.5</u>	<u>39.8</u>	<u>39.3</u>	<u>59.4</u>	
	Total	173.5	110.5	110.2	161.1	
40	Rep. 1	41.9	54.9	55.1	43.0	46.4
	Rep. 2	52.9	41.8	50.9	55.9	
	Rep. 3	<u>34.7</u>	<u>46.4</u>	<u>36.4</u>	<u>43.3</u>	
	Total	129.5	143.1	142.4	142.2	
80	Rep. 1	51.8	42.7	37.8	48.4	42.8
	Rep. 2	35.4	48.4	31.5	39.2	
	Rep. 3	<u>28.1</u>	<u>41.3</u>	<u>48.6</u>	<u>60.1</u>	
	Total	115.3	132.4	117.9	147.9	
Nitrogen Average		46.5	42.9	41.2	50.1	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	352.9	176.5		
Nitrogen	3	42.7	14.2	0.15	3.05
Phosphorous	2	109.2	54.6	0.56	3.44
N x P	6	127.4	21.2	0.22	2.55
Error	20	1944.7	97.2		
Total	33	2576.9			

$\bar{x}$ 45.2

C.V. 21.8

Table XII. Effect of nitrogen and phosphorous fertilization on barley grain yields, Swims silty clay loam soil, Gordon Grier farm, 1961.

		Nitrogen in pounds per acre				
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				Phosphorous Average
0	Rep. 1	12.9	11.3	10.4	12.3	18.1
	Rep. 2	15.9	17.1	22.9	20.1	
	Rep. 3	<u>21.3</u>	<u>20.4</u>	<u>25.4</u>	<u>27.6</u>	
	Total	50.1	48.8	58.7	60.0	
40	Rep. 1	13.1	15.3	17.5	14.9	20.2
	Rep. 2	14.9	17.3	17.5	16.9	
	Rep. 3	<u>25.3</u>	<u>24.1</u>	<u>31.1</u>	<u>34.1</u>	
	Total	53.3	56.7	66.1	65.9	
80	Rep. 1	14.6	13.0	18.8	15.9	18.8
	Rep. 2	14.9	13.1	20.0	18.4	
	Rep. 3	<u>17.8</u>	<u>34.7</u>	<u>23.4</u>	<u>20.7</u>	
	Total	47.3	60.8	62.2	55.0	
Nitrogen Average		16.7	18.5	20.8	20.1	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	815.1	407.6		
Nitrogen	3	87.8	29.3	1.98	3.05
Phosphorous	2	26.3	13.1	0.89	3.44
N x P	6	33.4	5.6	0.38	2.55
Error	22	325.8	14.8		
Total	35	1288.4			

$\bar{x}$ 19.0
C.V. 20.3

Table XIII. Effect of nitrogen and phosphorous fertilization on barley grain yields, Swims silty clay loam soil, Ben Seney farm, 1961.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	50.3	82.3	82.1	73.0	66.4
	Rep. 2	55.7	52.0	76.3	63.4	
	Rep. 3	55.7	73.4	66.1	66.5	
	Total	161.7	207.7	224.5	202.9	
40	Rep. 1	61.6	61.8	80.4	65.8	64.7
	Rep. 2	52.8	43.8	78.8	76.3	
	Rep. 3	52.3	54.7	79.4	68.9	
	Total	166.7	160.3	238.6	211.0	
80	Rep. 1	73.8	75.6	73.4	84.8	73.5
	Rep. 2	43.8	73.3	81.6	75.4	
	Rep. 3	70.4	65.1	89.3	76.4	
	Total	187.2	214.0	244.3	236.6	
Nitrogen Average		57.3	64.7	78.6	72.3	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	349.7	174.9		
Nitrogen	3	2285.9	762.0	12.03*	3.05
Phosphorous	2	530.2	265.1	4.18*	3.44
N x P	6	448.7	74.8	1.18	2.55
Error	22	1393.8	63.3		
Total	35	5008.3			

 $\bar{x}$ 68.2

C.V. 11.7

*significant at the 5 percent confidence level.

increment. The third increment apparently decreased yields slightly. Organic matter content of this soil was relatively low compared to the median of the series.

Phosphorus increased yields about seven bushels per acre when eighty pounds were applied. At the forty pound rate no response occurred. Fixation of considerable amounts of the first increment of phosphorus may be the explanation. This is the only Swims soil investigated with phosphorus levels as low as the median of the series. There probably are other Swims soils which will respond to phosphorus.

Somers silty clay loam

The results of a trial of Somers silty clay loam appear in Table XIV. Both nitrogen and phosphorus gave significant responses in barley yield. Each increment of nitrogen increased yields about two bushels per acre which was not enough to offset the cost of the nitrogen. The organic matter of this soil was the highest of any soil under investigation and considerably higher than the median of the series.

Forty pounds of phosphorus increased barley yields about five bushels per acre. This soil possessed considerably higher phosphorus levels than the median of the series. On the basis of this trial, Somers soils probably will respond to nitrogen rates up to 45 pounds per acre and to phosphorus rates up to 40 pounds.

Kiwanis loam

The trial on Kiwanis loam in 1960 was a complete crop failure

Table XIV. Effect of nitrogen and phosphorous fertilization on barley grain yields, Somers silty clay loam, 1960.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	19.6	11.9	15.1	27.1	19.4
	Rep. 2	9.0	25.1	21.3	25.5	
	Rep. 3	<u>11.9</u>	<u>15.4</u>	<u>24.9</u>	<u>25.9</u>	
	Total	40.5	52.4	61.3	78.5	
40	Rep. 1	32.2	19.8	28.8	28.6	24.8
	Rep. 2	21.0	27.2	31.2	26.8	
	Rep. 3	<u>14.4</u>	<u>20.1</u>	<u>21.6</u>	<u>26.2</u>	
	Total	67.6	67.1	81.6	81.6	
80	Rep. 1	25.2	31.7	36.3	34.4	25.3
	Rep. 2	15.9	16.9	21.3	22.9	
	Rep. 3	<u>21.6</u>	<u>20.9</u>	<u>27.8</u>	<u>29.1</u>	
	Total	62.7	69.5	85.4	86.4	
Nitrogen Average		19.0	21.0	25.4	27.4	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	132.0	66.0		
Nitrogen	3	402.9	134.3	4.48*	3.05
Phosphorous	2	257.0	128.5	4.29*	3.44
N x P	6	58.9	9.8	0.33	2.55
Error	22	659.8	30.0		
Total	35	1510.6			

 $\bar{x}$ 23.2

C.V. 23.6

*significant at the 5 percent confidence level.

due to drought damage. The grain dried up while in the boot stage. There was no difference in the appearance of the barley plants due to fertilizer. This soil is the shallowest of the soil types included in the investigation and occurs in the drier portion of the valley. It does not appear unreasonable to experience a crop failure under these conditions. Many of the farms on this soil are irrigated.

Walters silty clay loam

The effect of nitrogen and phosphorus on barley yields when grown on Walters silty clay loam is presented in Table XV. A significant response to nitrogen was obtained, with 15 pounds increasing yield about seven bushels per acre. The second increment increased yield about three bushels per acre and the third increment, less than two bushels per acre. It is doubtful whether the third 15 pound increment was economical. The organic matter content of this soil was comparable to the median of the series. This trial was irrigated and gave relatively high yields.

Walters series possesses considerably higher phosphorus levels according to soil test than other soils included in the study. However, the phosphorus level of the soil at this trial was relatively low. Even so, phosphorus gave no yield response.

Summary

All trials responded significantly to nitrogen with the exception of a trial on Tally fine sandy loam and two trials on Swims silty

Table XV. Effect of nitrogen and phosphorous fertilization on barley grain yields, Walters silty clay loam, 1960.

		Nitrogen in pounds per acre				Phosphorous Average
		0	15	30	45	
Phosphorous Lbs./Acre		Bushels per acre				
0	Rep. 1	47.8	44.7	34.1	58.4	45.8
	Rep. 2	48.1	42.2	45.6	55.0	
	Rep. 3	<u>38.5</u>	<u>50.0</u>	<u>43.4</u>	<u>42.2</u>	
	Total	134.4	136.9	123.1	155.6	
40	Rep. 1	44.7	49.8	55.6	66.9	50.2
	Rep. 2	37.8	54.4	65.1	49.9	
	Rep. 3	<u>37.6</u>	<u>44.8</u>	<u>51.6</u>	<u>44.5</u>	
	Total	120.1	149.0	172.3	161.3	
80	Rep. 1	52.8	59.4	60.3	60.1	49.8
	Rep. 2	36.8	39.6	54.1	44.1	
	Rep. 3	<u>28.7</u>	<u>52.6</u>	<u>52.9</u>	<u>56.6</u>	
	Total	118.3	151.6	167.3	160.8	
Nitrogen Average		41.4	48.6	51.4	53.1	

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	360.6	180.3		
Nitrogen	3	714.6	238.2	4.95*	3.05
Phosphorous	2	141.3	70.7	1.47	3.44
N x P	6	463.8	77.3	1.61	2.55
Error	22	1058.9	48.1		
Total	35	2739.2			

 $\bar{x}$ 48.6

C.V. 14.3

*significant at the 5 percent confidence level.

clay loam. The trial on Tally soil was extremely variable and the results are probably not reliable. Both of the trials on Swims soil which did not respond to nitrogen were complicated by wild oat infestations. Other Swims soils did respond to nitrogen.

Generally maximum yields were produced from thirty pounds of nitrogen. Two trials responded to the third 15 pound increment of nitrogen but demonstrated response curves which rose so slowly that no rate was economical. Both of these trials were conducted in 1960. During a year of more favorable moisture these trials may have shown economical response. There appeared to be no relationship between nitrogen response and organic matter content.

It is interesting that nitrogen did not cause any significant yield decreases in the dry year, 1960. Nitrogen rates apparently increased the efficiency of moisture use. This was particularly evident on the trials where the check yield was extremely low and was definitely affected by moisture stress.

Only trials on Creston, Flathead, Swims, and Somers gave significant responses to phosphorus. Each of these trials also responded to nitrogen. Several trials which were very low in soil test phosphorus gave no response to fertilizer phosphorus. Phosphorus did not generally increase yields economically. These findings suggest that generally phosphorus fertilization of barley is not practical.

Effects of Potassium and Boron Fertilization

Flathead fine sandy loam

The effect of potassium fertilizer on potatoes grown at the Mangle farm on Flathead fine sandy loam in northern Lake County is shown in Table XVI. Both sources of potassium resulted in significant yield responses. Generally, the yield appeared to increase with each increment of potassium. Apparently the top of the yield response curve was not reached by the highest rate of the experiment since the last increment gave an appreciable response. The source of potassium did not appear to influence the yield of potatoes. Neither did there appear to be any response from boron.

A trial on the Abe Dubay farm showed no consistent response from potassium or boron (Table XVII). Some rates of potassium appeared to give economic responses when plot averages were compared. Since no treatment was significantly different from the check plot average, differences may not be real.

These two trials possessed the lowest available potassium levels according to soil tests of any of the five sites studied and should be the most likely to exhibit response. Further studies are needed on the effect of potassium on potato yield and quality before any reliable recommendation can be made.

A trial on the K. B. Johnson farm indicated no response from either potassium or boron (Table XVIII). The available potassium level was slightly higher than on the other Flathead soils.

Kalispell loam

Table XVI. Effect of potassium and boron fertilization on potato yields, Flathead fine sandy loam, Walt Mangle farm, Lake County, 1961.

	Treatments											
	0	0	0	0	0	0	0	0	0	4	4	4
# Boron	0	0	0	0	0	0	0	0	0	0	0	0
# K ₂ O*	0	25	50	75	100	0	0	0	0	0	0	50
# K ₂ O**	0	0	0	0	0	25	50	75	100	0	50	0
Cwt. per Acre												
Rep. 1	222.4	228.9	248.5	222.4	281.2	222.4	248.5	222.4	261.6	215.8	261.6	235.4
Rep. 2	228.9	242.0	255.1	287.8	261.6	228.9	255.1	255.1	287.8	215.8	228.9	255.1
Rep. 3	215.8	215.8	268.1	215.8	274.7	228.9	215.8	248.5	235.4	202.7	209.3	268.1
Average	222.4	228.9	257.2	242.0	272.5	226.7	239.8	242.0	261.6	211.4	233.3	252.9

* Lbs. K₂O as muriate of potash

** Lbs. K₂O as potassium sulfate

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	1753.5	876.8		
Treatments	11	10350.3	940.9	2.88*	2.26
Error	22	7185.4	326.6		
Total	35	19289.2			

$\bar{X}$ 240.9

C.V. 7.5

* Significant at the 5 percent confidence level.

Table XVII. Effect of potassium and boron fertilization on potato yields, Flathead fine sandy loam, Abe Dubay farm, Lake County, 1961.

Treatments												
# Boron	0	0	0	0	0	0	0	0	0	4	4	4
# K ₂ O*	0	25	50	75	100	0	0	0	0	0	0	50
# K ₂ O**	0	0	0	0	0	25	50	75	100	0	50	0
Cwt. per Acre												
Rep. 1	242.0	255.1	242.0	215.8	202.7	300.8	235.4	189.7	235.4	183.1	222.4	202.7
Rep. 2	183.1	202.7	235.4	307.4	274.7	176.6	307.3	255.1	228.9	235.4	235.4	235.4
Rep. 3	294.3	261.6	346.6	287.8	340.1	235.4	327.0	359.7	274.7	294.3	228.9	242.0
Average	239.8	239.8	274.7	270.3	272.5	237.6	289.9	268.2	246.3	237.6	228.9	226.7

51

* Lbs. K₂O as muriate of potash

** Lbs. K₂O as potassium sulfate

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	27372.8	13686.4		
Treatments	11	14627.3	1329.8	0.76	2.26
Error	22	38236.4	1738.0		
Total	35	80236.5			

$\bar{X}$ 252.7
C.V. 16.5

Table XVIII. Effect of potassium and boron fertilization on potato yields, Flathead fine sandy loam, K. B. Johnson farm, 1961.

					Treatments							
# Boron	0	0	0	0	0	0	0	0	0	4	4	4
# K ₂ O*	0	25	50	75	100	0	0	0	0	0	0	50
# K ₂ O**	0	0	0	0	0	25	50	75	100	0	50	0
Cwt. per Acre												
Rep. 1	228.9	215.8	209.3	196.2	196.2	215.8	209.3	196.2	183.1	242.0	163.5	222.4
Rep. 2	176.6	202.7	202.7	215.8	196.2	183.1	176.6	235.4	215.8	235.4	196.2	202.7
Rep. 3	202.7	189.7	196.2	202.7	235.4	189.7	202.7	150.4	189.7	209.3	189.7	196.2
Average	202.7	202.7	202.7	204.9	209.3	196.2	196.2	194.0	196.2	228.9	183.1	207.1

* Lbs. K₂O as muriate of potash

** Lbs. K₂O as potassium sulfate

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	684.3	342.2		
Treatments	11	4020.4	365.5	0.86	2.26
Error	22	9323.9	450.5		
Total	35	14028.6			

$\bar{X}$ 202.0
C.V. 10.5

Table XIX shows that neither potassium nor boron had any effect upon the potato yield of Kalispell loam. The available potassium level of this soil was slightly higher than on the Flathead soils.

Creston silt loam

No response occurred from either potassium or boron on Creston silt loam as shown in Table XX. This trial shows a large amount of variation which can not readily be explained. The available potassium level of this soil was quite high.

Summary

All three trials on Flathead soil possessed available potassium levels lower than the median of the series. However, two of these occurred in Lake County some distance away where low potassium levels are more common.¹ At any rate, only trials with very low available potassium levels gave responses.

Kiwanis soils have a median available potassium level which is considerably less than the other soils under investigation. They could be expected to be the first to exhibit general potassium deficiencies in the County. However, trials on low potassium soils using hay as a crop indicated no potassium response.² It is expected that in the future

¹Potato tissue analyses have indicated low potassium levels in this area. Files NW Branch Experiment Station.

²1961 Annual Report, Northwestern Branch Experiment Station, Kalispell, Montana.

Table XIX. Effect of potassium and boron fertilization on potato yields, Kalispell loam, 1961.

					Treatments							
# Boron	0	0	0	0	0	0	0	0	0	4	4	4
# K ₂ O*	0	25	50	75	100	0	0	0	0	0	0	50
# K ₂ O**	0	0	0	0	0	25	50	75	100	0	50	0
Cwt. per Acre												
Rep. 1	255.1	261.6	255.1	255.1	261.6	242.0	274.7	255.1	268.1	248.5	228.9	248.5
Rep. 2	294.3	261.6	255.1	235.4	248.5	274.7	274.7	248.5	255.1	228.9	242.0	248.5
Rep. 3	255.1	235.4	255.1	242.0	242.0	242.0	261.6	222.4	242.0	268.1	228.9	235.4 ⁵⁴
Average	278.2	252.9	255.1	210.8	250.7	252.9	270.3	242.0	255.1	248.5	233.3	244.1

* Lbs. K₂O as muriate of potash

** Lbs. K₂O as potassium sulfate

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	983.7	491.9		
Treatments	11	3592.7	326.7	1.93	2.26
Error	22	3721.0	169.1		
Total	35	8297.4			

X 249.5
C.V. 5.2

Table XX. Effect of potassium and boron fertilization on potato yields, Creston silt loam, 1961.

	Treatments											
	0	0	0	0	0	0	0	0	0	4	4	4
# Boron	0	0	0	0	0	0	0	0	0	0	0	0
# K ₂ O*	0	25	50	75	100	0	0	0	0	0	0	50
# K ₂ O**	0	0	0	0	0	25	50	75	100	0	50	0
Cwt. per Acre												
Rep. 1	372.8	300.8	398.9	327.0	307.4	327.0	291.0	320.5	291.0	300.8	333.5	320.5
Rep. 2	294.3	281.2	268.1	323.7	313.9	307.4	294.3	343.4	300.8	300.8	287.8	369.5
Rep. 3	317.2	402.2	274.7	359.7	300.8	271.4	333.5	313.9	340.1	313.9	278.0	300.8
Average	328.1	328.1	313.9	336.8	307.4	301.9	306.3	325.9	310.6	305.2	299.8	330.3

* Lbs. K₂O as muriate of potash

** Lbs. K₂O as potassium sulfate

Analysis of Variance

Source	df	SS	MS	F	F 5%
Replications	2	108079.8	54039.9		
Treatments	11	54232.4	4930.2	0.50	2.26
Error	22	215347.0	9788.5		
Total	35	377659.2			

$\bar{X}$ 316.2
C.V. 31.3

certain Flathead County soils will respond to potassium.

CONCLUSIONS

The conclusions of this investigation are as follows:

1. Barley responded significantly to nitrogen on most Flathead County soils. The optimum rate of nitrogen varied both between and within soil types. No nitrogen rate gave a negative response.
2. Phosphorus did not generally give a yield response when applied to barley. About one-third of the trials showed a significant response to phosphorus but only one was economical. Occurrence of response was not specifically related to soil test phosphorus levels.
3. The probability of potassium response on most Flathead County soils is slight. Certain areas of very low potassium levels may be exceptions.
4. Boron did not affect potato yields on any of the soils studied.
5. Attempts to combine soil types into soil groups of similar fertility status have not been successful for several reasons:
 - a. The number of field trials and soil test samples was too limited to present an adequate picture of the fertility characteristics of any soil type studied.
 - b. Past management practices have probably been responsible for some of the variability encountered within soil types.
 - c. Weed infestations and inadequate irrigation have influenced fertilizer response on certain trials.
6. General recommendations for the fertilization of barley on

the basis of this investigation are as follows:

- a. Kiwanis, Tally, and Swims, 15 pounds of nitrogen (N) per acre.
- b. Kalispell, Flathead, and Walters, 15 to 30 pounds of nitrogen (N) per acre.
- c. Creston and Somers, 30 pounds of nitrogen (N) and 20 to 40 pounds of phosphorus (P_2O_5) per acre.

LITERATURE CITED

1. Allaway, W. H., and Rhoades, H. F. Forms and distribution of phosphorus in the horizons of some Nebraska soils in relation to profile development. *Soil Sci.* 72:119-128. 1951.
2. Allaway, W. H., and Pierre, W. H. Availability, fixation and liberation of potassium in high-lime soils. *J. Am. Soc. Agron.* 31:940-953. 1939.
3. Allison, F. E. Nitrogen and soil fertility. *Soils, The 1957 Yearbook of Agriculture*, House Document No. 30, Washington D. C. 1957.
4. Atkinson, H. J., Giles, G. F., and MacLean, A. J. Fertility studies on soil types: II. The physical and chemical composition of soils from Carlton and Grenville Counties in Ontario. *Can. J. of Agr. Sci.* 33:116-124. 1953.
5. Attoe, O. J. Potassium fixation and release in soils occurring under moist and drying conditions. *Soil Sci. Soc. Amer. Proc.* 11:145-149. 1953.
6. Bartelli, L. J., and Peters, P. B. Integrating soil moisture characteristics with classification units of some Illinois soils. *Soil Sci. Soc. Amer. Proc.* 23:149-150. 1959.
7. Baumgardner, M. F., and Barber, Stanley A. Effect of soil types on correlation of soil-test values with crop response. *Soil Sci.* 82:409-418. 1956.
8. Bishop, William D., and Barber, Stanley A. The effect of soil phosphorus compounds on soil test correlation. *Soil Sci. Amer. Proc.* 22:435-439. 1958.
9. Debetz, S. Effect of soil type, soil moisture and nitrogen fertilizer on the growth of spring wheat. *Can. J. Soil Sci.* 41:44-51. 1961.
10. Dennis, E. J., and Chesniv, Leon. The availability of phosphorus to alfalfa in the horizons of four Eastern Nebraska soils. *Soil Sci. Soc. Amer. Proc.* 17:49-52. 1953.
11. Garman, William L. Potassium release characteristics of several soils from Ohio and New York. *Soil Sci. Soc. Amer. Proc.* 21: 52-58. 1957.

12. Jenny, H. Factors of Soil Formation. McGraw-Hill Book Company, Inc., New York. 1941.
13. Jackson, M. L. Soil Chemical Analysis. Prentice-Hall, Inc. 1958.
14. Lutwick, L. E., MacLean, A. J., and Bishop, R. E. Fertility studies on soil types: V. The effect of continued cropping in the greenhouse on the phosphorus supplying power of soils. Can. J. Agr. Sci. 35:101-110. 1955.
15. MacLean, A. J., Lutwick, L. E., and Bishop, R. F. Fertility studies on soil types: VI. The effect of continued cropping in the greenhouse on the potassium supplying powers of soils. Can. J. Agr. Sci. 35:397-406. 1955.
16. Olson, R. A., Dreier, A. F., and Sorenson, R. G. The significance of subsoil and soil series in Nebraska soil testing. Agron. J. 50:185-188. 1958.
17. Ostle, Bernard. Statistics in Research. The Iowa State College Press, Ames, Iowa. 1958.
18. Pearson, R. W. Potassium-supplying power of eight Alabama soils. Soil Sci. 74:301-309. 1952.
19. Pope, A., and Cheney, H. B. The potassium supplying power of several Eastern Oregon Soils. Soil Sci. Soc. Amer. Proc. 21: 75-79. 1957.
20. Rouse, R. Dennis, and Bertramson, B. R. Potassium availability in several Indiana soils: Its nature and methods of evaluation. Soil Sci. Soc. Amer. Proc. 14:113-123. 1950.
21. Shrader, W. D., Riechen, F. F., and Englehorn, A. J. Effect of soil type differences on crop yield on Clarion-Webster soils in Iowa. Agron. J. 49:204-207. 1957.
22. Smith, R. S. The differential response of two soil associations to rock phosphate. Agron. J. 42:495-498. 1950.
23. Smith, F. W., Ellis, B. G., Grava, G. Use of acid-fluoride solutions for the extraction of available phosphorus in calcareous soils and in soils to which rock phosphate has been added. Soil Sci. Soc. Amer. Proc. 21:400-404. 1957.
24. Williams, B. H., and Jackson, R. K. Soil Survey, Upper Flathead Valley Area, Montana. U.S.D.A. Soil Conservation Service. 1960.

25. Young, R. A., Lathwell, D. J., and Bradfield, R. Greenhouse and laboratory investigation of phosphorus, potassium, and sodium relations in soils and crops. Cornell Ag. Exp. Memoir. 351: 1-31. 1958.

APPENDIX

Soil Profile Descriptions of Soil Types Investigated

Creston silt loam

Location: North side of road, 740 feet west of road intersection in the SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 5, T. 28 N., R. 20 W.

- A_{1p} 0 to 12 inches dark grayish-brown to very dark grayish brown or very dark brown (10 YR 3.5/2, dry; 2.5/2, moist) silt loam; weak, fine, granular or crumb structure; soft when dry, friable when moist; neutral; boundary clear.
- B₂ 12 to 18 inches brown to dark brown (7.5 YR 4/2, dry; 3/3, moist) silt loam; weak, very coarse, prismatic structure; soft when dry, very friable when moist; neutral; boundary clear.
- C_{ca} 18 to 33 inches very pale brown to brown (10 YR 7/3, dry; 5/3, moist) silt loam; weak, coarse, subangular blocky structure; soft when dry, very friable when moist; calcareous; accumulation of calcium carbonate; boundary gradual.
- C 33 to 42 inches very pale brown to brown (10 YR 7/3, dry; 5/3, moist) loam; massive; soft when dry, very friable when moist; calcareous, grades to stratified silt and sand.

Flathead fine sandy loam

- A₁₁ 0 to 12 inches very dark grayish-brown to very dark brown or black (10 YR 3/1.5, dry; 2/1.5, moist) fine sandy loam; moderate, fine, granular structure; soft when dry, very friable when moist; about neutral; boundary clear.
- A₁₂ 12 to 24 inches very dark grayish-brown to very dark brown (10 YR 3/2, dry; 2/2, moist) fine sandy loam; weak, very coarse prisms that readily separate into moderate, fine, granular structure; soft when dry, very friable when moist; about neutral; boundary clear.
- B₂ 24 to 34 inches brown to dark reddish-brown (7.5 YR 4/2, dry; 5 YR 3/2, moist) fine sandy loam; weak, coarse prisms that separate into weak, medium, subangular blocky structure; soft when dry, very friable when moist; about neutral; boundary gradual.
- B₃ 34 to 44 inches pale-brown to brown or dark-brown (10 YR 6/3, dry; 7.5 YR 4/3, moist) light fine sandy loam or loamy fine sand; massive in place but breaks into weak, coarse, subangular blocky structure; soft and nearly single grained when dry, very friable when moist; slightly alkaline; boundary clear.

Flathead fine sandy loam, cont.

C 44 to 54 inches pale-brown to brown (10 YR 6/3, dry; 5/3, moist)
loamy fine sand; massive or single grained; soft
and very friable; moderately calcareous; spots of
lime accumulation weakly cement the sand and form
weak, fine, subangular, blocklike lumps that are
slightly hard when dry and slightly firm when
moist.

Kalispell loam

Location: NW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 2, T. 28 N, R. 22 W.

- A_{1p} 0 to 8 inches dark grayish-brown to very dark brown (10 YR 4/2, dry; 2/2, moist) loam; weak, fine and very fine, granular structure; soft when dry, very friable when moist; about neutral in reaction; boundary clear.
- B₂ 8 to 13 inches pale-brown to dark-brown (10 YR 5.5/3, dry; 3/3, moist) silt loam; weak, very coarse, prismatic and coarse, blocky structure; little or no clay coatings on peds; soft to slightly hard when dry, friable when moist; neutral to slightly calcareous in lower 1 inch; boundary clear.
- C_{ca} 13 to 30 inches pale-yellow to light olive-brown (2.5 Y 7/3, dry; 5/4, moist) silt loam; massive in place but breaks into weak, medium and fine, subangular blocks or lumps; when dry slightly hard, when moist slightly firm in place but very friable when disturbed; abundant accumulation of floury lime carbonate; boundary gradual.
- C 30 to 45 inches pale-yellow to light olive-brown (2.5 Y 7/3, dry; 5/3, moist) very fine sandy loam; massive; soft when dry, friable when moist; calcareous.

Tally fine sandy loam

Location: 1,225 feet north and 30 feet west of southeast corner of sec. 15, T. 29 N., R. 22 W.

- A_{1p} 0 to 8 inches dark grayish-brown to very dark brown (10 YR 4/2, dry; 2/2, moist) fine sandy loam; weak, fine, crumb structure; soft, loose, and nearly single grained when dry, very friable when moist; reaction about neutral; boundary clear.
- B₂ 8 to 15 inches brown to dark-brown (7.5 YR 5/3, dry; 3/3, moist) fine sandy loam; very weak, coarse, prismatic and weak, coarse, blocky structure; soft when dry, very friable when moist; reaction about neutral; boundary clear.
- C_{ca} 15 to 30 inches light-gray to grayish-brown (10 YR 7/2, dry; 5/2, moist) fine sandy loam; massive; soft when dry, friable when moist; moderate accumulation of floury lime carbonate; boundary gradual.
- C₁ 30 to 40 inches pale-yellow to grayish-brown (2.5 Y 7/3, dry; 5/2, moist) loamy fine sand; massive to loose and single-grained; calcareous.

Swims silt loam

- A₀ 1 to 0 inches forest litter consisting of pine needles and the leaves of deciduous trees and shrubs; lower one-fourth inch matted and well decomposed.
- A₁ 0 to 1 inch dark-gray to black (10 YR 4/1, dry; 2/1, moist) silt loam; moderate, thin, platy and moderate, medium, granular structure; slightly hard when dry, very friable when moist; non-calcareous; boundary clear.
- A₂ 1 to 4 inches light brownish-gray to dark grayish brown (10 YR 6/2, dry; 3.5/2, moist) light silty clay loam; moderate, medium and coarse, platy structure and weak, fine and medium, subangular blocky structure; slightly hard when dry, very friable when moist; many fine pores and root channels; non-calcareous; boundary abrupt.
- B₂ 4 to 11 inches pinkish-gray to brown (7.5 YR 7/2, dry; 4.5/2, moist) light silty clay loam; weak, coarse, prismatic structure and fine and medium, subangular blocky structure; blocks very porous and have a few smooth faces, but surface not coated with clay; slightly hard when dry, friable when moist; thin

Swims silt loam, cont.

clay coating in root channels and wormholes; non-calcareous; boundary clear.

B_{ca} 11 to 17 inches pinkish-gray to brown (7.5 YR 7/2, dry; 5/2, moist) silt loam; weak, coarse, prismatic and thick, platy structure separating into weak, medium sub-angular blocky; interior of peds faintly stained to mottled pale brown and light yellowish brown; slightly hard when dry, friable when moist; many pores and root channels, some thinly coated with clay, moderate effervescence with dilute hydrochloric acid; boundary clear.

G_{1ca} 17 to 25 inches very pale brown to brown (10 YR 7/3, dry; 5/3, moist) silt loam; few, faint, fine, yellowish-brown mottles; massive in place, except for thin, horizontal strata that break easily into fine blocks; slightly hard when dry, firm when moist; numerous fine pores and a few roots and root channels; violent effervescence with hydrochloric acid; few, fine, white segregations of lime; boundary clear.

G₂ 25 to 40 inches pinkish-white to pinkish-gray (7.5 YR 8/2, dry; 6/2, moist) silt loam; massive, except for hori-

Swims silt loam, cont.

zental strata $\frac{1}{4}$ to $\frac{1}{2}$ inch thick; firm to moderately friable when moist; calcareous but no segregated lime; boundary gradual.

G₃ 40 to 54 inches similar to horizon above but contains thin lenses of very fine sandy loam; boundary gradual.

G₄ 54 to 60 inches loamy fine sand; massive or single-grained; calcareous.

Somers silty clay loam

Location: SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 17, T. 27 N., R. 20 W.

- A_{1p} 0 to 8 inches gray to very dark gray (10 YR 5/1, dry; 3/1, moist)
 silty clay loam; moderate, very fine, granular
 structure; soft when dry, very friable when moist;
 about neutral; boundary abrupt.
- B₂ 8 to 12 inches grayish-brown to dark grayish-brown (10 YR 5.5/2,
 dry; 4/2, moist) silty clay loam; weak, coarse,
 prismatic and weak to moderate, medium, blocky
 structure; slightly hard when dry, friable when
 moist; slightly alkaline; boundary clear.
- C_{ca} 12 to 22 inches light-gray or very pale brown to pale-brown (10
 YR 7/2.5, dry; 6/3, moist) silty clay loam; massive
 in place but breaks to weak, subangular blocks;
 slightly firm when moist; calcareous, including
 moderate amount of segregated lime; boundary grad-
 ual.
- C 22 to 30 inches very pale brown to pale brown (10 YR 7/3, dry;
 6/3, moist) stratified or varved silt loam and
 silty clay loam; breaks to weak, fine, blocks;
 slightly firm when moist; calcareous; boundary
 abrupt.

Somers silty clay loam, cont.

D 30 inches plus light-gray to light brownish-gray (10 YR 7/2, dry;
6/2, moist) loamy fine sand; single-grained; loose;
calcareous.

Kiwanis loam

Location: West side of road, 560 feet south of the north quarter-section corner in NE $\frac{1}{2}$ NW $\frac{1}{2}$ sec. 28, T. 29 N., R. 21 W.

- A₁₁ 0 to 2 inches dark grayish-brown (10 YR 4/2, dry; 2/2, moist) loam; weak, fine, granular structure; soft when dry; very friable when moist; neutral reaction; boundary clear.
- A₁₂ 2 to 9 inches grayish-brown to very dark grayish-brown (10 YR 5/2, dry; 3/2, moist) loam; weak, soft, crumb structure; soft when dry, very friable when moist; neutral reaction; boundary clear.
- C 9 to 39 inches very pale brown to pale-brown (10 YR 8/3, dry; 6/3, moist) fine sandy loam; massive but breaks into soft, irregular lumps; calcareous; boundary abrupt.
- D₁ 39 to 58 inches light-gray to light brownish-gray (10 YR 7/2, dry; 6/2, moist) loose, coarse sand; calcareous; boundary gradual.
- D₂ 58 to 70 inches same as layer above except that gravel is abundant.

Walters very fine sandy loam

Location: NE $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 4, T. 29 N., R. 21 W.

- A₀₀ 2 to 0 inches loose mat of fairly fresh conifer needles.
- A₁ 0 to 2 inches gray to very dark brown (10 YR 4.5/1, dry; 2/2, moist) very fine sandy loam, weak, fine, crumb structure; loose and single grained when dry, very friable when moist; slightly acid; boundary abrupt.
- A₂ 2 to 10 inches very pale brown to pale brown (10 YR 7/3, dry; 6/3, moist) very fine sandy loam; massive to weak, coarse, platy structure; hard when dry, very friable when moist; slightly acid; boundary clear.
- B₂ 10 to 13 inches pale-brown to dark-brown (10 YR 6/3, dry; 7.5 YR 3/3, moist) silt loam; weak, subangular blocky structure; slightly hard when dry, but centers of peds are hard and slightly darker; friable when moist but centers of peds are firm; about neutral in reaction; boundary clear.
- B_{ca} 13 to 24 inches pale-brown to brown (10 YR 6.5/3, dry; 7.5 YR 4/3, moist) fine sandy loam; massive, except for the presence of a few, firm or hard, small lumps; soft when dry, friable when moist; calcareous; boundary clear.

Walters very fine sandy loam, cont.

C 24 to 34 inches light-gray to pale-brown (10 YR 7/2, dry; 6/3, moist) fine sandy loam; massive; soft when dry, very friable when moist; calcareous; has a few, fine, firm spots of segregated lime carbonate; grades to coarse sand at depth of 3 to 4 feet.

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