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


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.

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A THESIS

Submitted to the Graduate Faculty

in

partial fulfillment of the requirements

for the degree of

Master of Science in Soils

at

Montana State College

Approved:

Head, Major Department

Chairman, Examining Committee

Dean, Graduate Division

Bozeman, Montana
June, 1963

# ACKNOWLEDGEMENT

The author is grateful to those who assisted him in the preparation of this thesis. To Wes Roath who contributed much to the planning phase of the thesis and to Walt Mauritson who gathered the soil test data, I give special thanks. Also, the cooperation of the farmers who contributed land for the experiments is greatly appreciated.

The author is very grateful for the patient guidance and thoughtful suggestions of Dr. M. G. Klages.

It seems fitting to acknowledge the significant contributions of the late Dr. J. C. Hide who guided the author through several courses and was a constant inspiration.

Special thanks to my wife, Carole, who provided encouragement and shared the frustrations of getting the job done.

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ABSTRACT

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# 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 Crete 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 characteristics 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 Types[1]

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

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[1]Detailed 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 | $K_2O$ | $P_2O_5$ | O.M. | Lime* |
|---|---|---|---|---|---|---|---|
| Creston | 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.

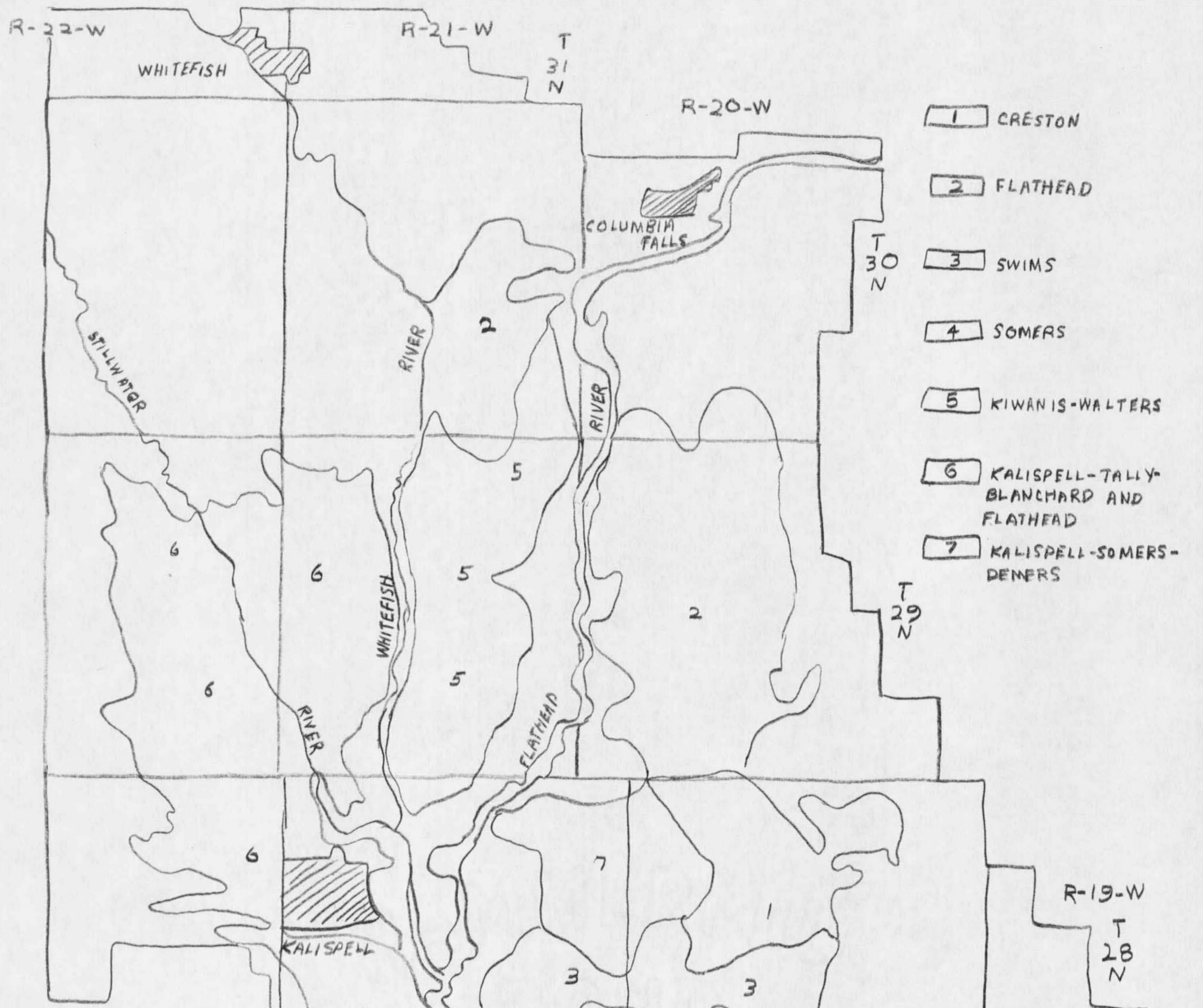


FIGURE 1 FLATHEAD VALLEY SOILS

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-

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