Influence of soil profile and site characteristics on the response of winter wheat to K on Montana soils
by Bernard Eugene Schaff

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Soils
Montana State University

Abstract:
Eighteen sites throughout Montana were selected to study soil and climatic factors that influence the response of winter wheat to K fertilizer. Rates of 0, 22, 45» 90, and 135 Kg K/ha were applied with 45 and 56 Kg/ha of N and P, respectively, The sites were characterized according to Soil Taxonomy classification parameters, For each site 14 chemical and physical properties were determined for each genetic horizon and seven site characteristics were identified. A multiple linear stepwise regression program was used to determine the relationship of the chemical, physical, and site characteristics to percent yield response of winter wheat to applied K, The genetic horizon variables were analyzed by major horizon as well as by sequence of horizon. Statistically significant variables (p=0.1) from the major horizon and horizon sequence analyses were grouped with significant site characteristics in a combined overall analysis. Variables with the highest correlation with percent yield response in the combined analysis, in decreasing order, were: l) mean annual soil temperature at 50 cm.; 2) moist consistence of the Ap; 3) moist; and 4) dry consistence of the B horizon; and 5) the clay content of the ca horizon. For these five variables an R^2 of .88 was obtained. Results from combined analysis for horizon sequence showed that correlations existed in decreasing order, with: l) mean annual soil temperature at 50 cm.; 2) extractable Ca++ (me/l00g) in the 2nd horizon; 3) pH of the 2nd horizon; and 4) the percent montmorillonite in the soil of the 4th horizon. For these four variables an R^ of .83 was obtained.

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Date Mar 6, 1979

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ABSTRACT

Eighteen sites throughout Montana were selected to study soil and climatic factors that influence the response of winter wheat to K fertilizer. Rates of 0, 22, 45, 90, and 135 Kg K/ha were applied with 45 and 56 Kg/ha of N and P, respectively. The sites were characterized according to Soil Taxonomy classification parameters. For each site 14 chemical and physical properties were determined for each genetic horizon and seven site characteristics were identified. A multiple linear stepwise regression program was used to determine the relationship of the chemical, physical, and site characteristics to percent yield response of winter wheat to applied K. The genetic horizon variables were analyzed by major horizon as well as by sequence of horizon. Statistically significant variables ($p = 0.1$) from the major horizon and horizon sequence analyses were grouped with significant site characteristics in a combined overall analysis. Variables with the highest correlation with percent yield response in the combined analysis, in decreasing order, were: 1) mean annual soil temperature at 50 cm.; 2) moist consistence of the A_p; 3) moist; and 4) dry consistence of the B horizon; and 5) the clay content of the ca horizon. For these five variables an R^2 of .88 was obtained. Results from combined analysis for horizon sequence showed that correlations existed in decreasing order, with: 1) mean annual soil temperature at 50 cm.; 2) extractable Ca^{++} (me/100g) in the 2nd horizon; 3) pH of the 2nd horizon; and 4) the percent montmorillonite in the soil of the 4th horizon. For these four variables an R^2 of .83 was obtained.

INTRODUCTION

Over the years, research in Montana has indicated that predicting the response of small grains to the additions of potassium (K) is unpredictable (Skogley, 1975). Crop responses occur frequently even though the standard soil test indicates adequate levels of extractable K in most soils of the region.

In 1971, a major research effort was initiated to study the cause of the unpredictability of K response and to develop a reliable K soil test. Haby (1974) studied numerous extraction techniques to determine whether some procedure other than the standard soil test (neutral normal, NH_4OAC extraction) would more accurately predict the response of small grains to K. In addition, Phillips (1973) studied the release of K from certain types of clay minerals dominant in Montana soils. Wang (1975) looked at the fixation and release of K (in samples collected from field trial soils) during several months of incubation.

These research projects help us to better understand the reaction of K in Montana soils. Nevertheless the problem of accurately predicting crop response to K has not been solved. Extraction of soil K, by any known method (chemical, exchange resin, living cells, etc.) probably cannot serve as the basis for a reliable K soil test for our region. Some method which has a closer functional relationship to K availability in the soil and uptake by plants must be developed. Research reports indicate that diffusion of the K ion to the plant root is probably the controlling factor in K uptake from soils

(Barber 1962, Massee 1973). However, conventional extraction procedures were not designed to measure ion diffusion through soils.

Numerous soil properties influence ion diffusion in soils. Other soil factors may partially regulate K availability. This study was initiated to determine the relationship between soil classification parameters and response of winter wheat to K in Montana. It was hypothesized that soils have certain inherent genetic characteristics which influence K availability (probably related to diffusion of K to plant roots) and which can be expressed by soil classification determinations. To study this hypothesis, a number of soils on which small grain soil fertility field research experiments were conducted were simultaneously characterized for their physical, chemical, and climatic properties. These properties were then correlated with winter wheat response to added K fertilizers in the field.

LITERATURE REVIEW

Customarily, soil fertility researchers have focused their attention on plant nutrient needs without emphasizing the soil type or series on which the work was conducted. Sometimes crop responses are reported for specific soil types without determining the relationship between crop response and soil characteristics. Consequently, very little information is available on the influences which soil type characteristics may have on crop response to fertilizer nutrients. The information that is available indicates soil type characteristics can exert a major influence on plant response (Prince, 1957, McLean et al., 1953, Russ and Bell, 1962, Carlson and Nimlos, 1970).

In relating crop response as influenced by soil types, Shrader, et al., (1957) stated "An important hypothesis in soil classification is that crop yield may be associated with soil type differences. The validity of this hypothesis is supported by a wealth of observations but only by very limited experimental data". In support of their hypothesis, long term rotation fertility experiments were conducted. Results indicated yield differences were associated with soil types and the relative productivity of the soil type depended upon the crop and management system under consideration.

Support of Shrader and associates' hypothesis can be found in the "Committee 6 Report" (Olsen, 1977) in which an attempt was made to determine what was known in the U.S. and other regions concerning soil type influences on crop response to fertilizers. General conclusions were that soil types do influence crop response, but not much importance has yet been attached to this relationship by most researchers.

The research reported by Fehrenbacher et al. (1972) is an example of studies to relate crop responses with groups of soil types. Soil associations were ranked according to crop response as influenced by management practices and past production history. Out of this ranking a productivity index (PI) was developed for each soil association in the state of Illinois. Based on its PI, the relative productivity of each association is predicted for wheat, corn, and soybeans.

In similar work, Carson and Nimlos (1970) found that five soil series with different site indexes (SI) were significantly different in their responses to tree growth. Nelson et al. (1945) reported on a study where oats was grown on 23 different soil types. Yields differed due to various rates of N, P and K on different soil types. Santhirasegain (1968) reported that Paspalum conmersonii (a forage grass) responded differently to various rates of N, P and K on each of three soil series. Russ and Bell (1962) also reported that yield differences in corn were influenced by soil types.

It is recognized that there are differences between soil types or series in their physical and chemical properties. In fact, soil classification is partially based on such differences. Atkinson et al. (1953) report differences between soil types in both physical and chemical properties. Beckett and Nafady (1968) reported a correlation between soil series and the "Potential Buffering Capacity" of a soil for K. Olson et al. (1958) found that soil pH, and extractable P and K were related to soil series. They stated that current soil classification information can be very useful in predicting crop needs for P and K.

Nutrient uptake by plants also may be influenced by soil series. White et al. (1970) found that the concentration of N, P, K, Ca, Mg, Al, Mn, Zn, Fe and Cu in the inner bark of loblolly pine differed in trees grown on different soil series. Prince (1957) reported that differences in the concentration of trace elements from different soil types was reflected in the amounts in the leaves of corn grown on these soils. McLean et al. (1953) found that the relative effect of applied P on the uptake of P varies significantly according to soil type. In related work by Hanway et al. (1960) on 9 different soil series, results indicated that 1) exchangeable K content, 2) the effect of drying on release of exchangeable K, and 3) mineralogical X-ray patterns were different for each soil series.

Munn (1977) studied the productivity of some Western Montana soils and the influences that soil profile characteristics have on the productivity of specific plant habitats. His results indicated that the thickness of the Mollic epipedon (surface horizon) had the highest correlation value with plant productivity. Soil morphological characteristics proved more useful in modeling site productivity than did estimated climatic data or site nutrient data.

Some variations occuring within a series have been attributed to past and present management practices (Beckett and Nafady, 1968, Shrader et al., 1957). Likewise, it is expected that differences in crop response on different soils may not be as predicted if management practices are not the same.

MATERIAL AND METHODS

Site Selection

With the help of local county agents 34 sites were selected (24 sites in 1973 and 10 in 1974) in the major wheat areas of the eastern two thirds of Montana. These sites were in fields of farmer-cooperators who were considered to be average or better in their management program. Due to circumstances such as hail, weed infestation or other problems, data from only 24 sites were collected. Of these 24 sites, 18 were winter wheat, 2 were barley, and 4 spring wheat. Because of the small number of sites of barley and spring wheat only the data from winter wheat are reported. Table 1 lists some pertinent information relative to these sites.

The plots were located for ease of accessibility, preferably near a road or towards the edge of a fallow strip. Where barley or spring wheat were at the same site with winter wheat, the plots were located in adjacent or nearly adjacent strips.

The plots were located at least 20 feet into the field to minimize the "edge effect". The site was 140 x 60 feet in 1973 and 240 x 60 feet in 1974. Each individual treatment plot was 10 x 20 feet. Plots were laid out with the length of the site running parallel and the width perpendicular to the drill rows.

Fertilizer Variables

A randomized complete block with three replications and 14 treatments in 1973 and 24 treatments in 1974 was used. The fertilizer

Table 1. Cooperators, county, legal description and soil series for the 18 winter wheat sites. 1973 and 1974.

Cooperators	County	Legal Description	Soil Series
1973			
Loren Perry	Chouteau	$SE\frac{1}{4}$, Sec 31, T23N, R10E	Gerber
Don Holland	Rosebud	$NE\frac{1}{4}$, Sec 20, T6N, R42E	Edgar
Gary Helm	Garfield	$NE\frac{1}{4}$, Sec 32, T17N, R43E	Cherry
John Pehl	Prairie	$SW\frac{1}{4}$, Sec 20, T12N, R52E	Chanta
Larry Erpelding	Rosebud	$SE\frac{1}{4}$, Sec 15, T6N, R41E	Fort Collins
Ray Cash	Musselshell	$NW\frac{1}{4}$, Sec 30, T5N, R25E	Bainville
John Jergenson	Blaine	$NE\frac{1}{4}$, Sec 10, T31N, R18E	Williams
Marvin Works	Chouteau	$SE\frac{1}{4}$, Sec 24, T28N, R9E	Evanston
Pete Miklovich	Big Horn	$SW\frac{1}{4}$, Sec 29, T6S, R36E	Arnegard
William Daum	Yellowstone	$SW\frac{1}{4}$, Sec 18, T4S, R26E	Absarokee
Virgil Hanks	Gallatin	$SW\frac{1}{4}$, Sec 32, T2S, R5E	Amsterdam
1974			
Henry Lassila	Cascade	$SW\frac{1}{4}$, Sec 33, T21N, R5E	Gerber
Marvin Works	Chouteau	$SE\frac{1}{4}$, Sec 34, T29N, R5E	Evanston
Ned Schaff	Golden Valley	$NE\frac{1}{4}$, Sec 6, T5N, R22E	Manburn
Elmer Visser	Madison	$NE\frac{1}{2}$, Sec 9, T3S, R1W	Evanston
John Pehl	Prairie	$SW\frac{1}{4}$, Sec 20, T12N, R52E	Chanta
Don Holland	Rosebud	$NW\frac{1}{4}$, Sec 23, T6N, R42E	Deacon
Sime Inc.	Gallatin	$SW\frac{1}{4}$, Sec 31, T2S, R5E	Bozeman

variables were part of a larger soil fertility research project, but only 5 treatments for each year are pertinent to this research project. Details concerning the other variables can be found in the Soils Annual Report (1973, 1974).

All of the sites were fertilized in the fall prior to seeding of dryland winter wheat. The influence of K fertilizer rates was measured on plots receiving blanket applications of 45 and 56 Kg/ha of nitrogen and phosphorus, respectively. The rates of K applied were 0, 22, 45, 90, and 136 Kg/ha of K. Materials employed were ammonium nitrate (34-0-0), triple superphosphate (0-45-0) and muriate of potash (0-0-60).

Weather Station

At each location a small weather station as described by Sims and Jackson (1971) was set up. Each cooperator agreed to obtain readings once a week. Measurements included the amount of rainfall (and date), soil temperature at 50 cm, evaporation from an open pan and the growth stage for the crop as expressed by the Feeke's scale (Large, 1954).

Agronomic Data Collection

Sometime after the crop was headed, but prior to harvest, a three-foot swath was cut around the border of the site and between each of the three replications. This reduced the individual plot length to approximately 18.5 feet, but removed an area of potential fertilizer "overlap" from the harvest area and also allowed for ease of plot separation during harvest. A small-plot combine with a cutting width of 4.5 feet was used to harvest the center area of the 10 foot wide plot. The length of the harvest area for each plot was measured so that an accurate yield calculation per unit area was procurable. Grain from each plot was sacked and taken to the laboratory where yield, test weight and protein content were determined.

Soil Classification and Horizon Sampling

At each site a small pit extending through the solum was dug for soil classification and sampling collection. Soil Conservation Service (SCS) personnel assisted in classifying (USDA, 1951, 1975) the soil and collecting samples from each genetic horizon down through the Cca horizon (if present). In some cases samples were obtained to a depth of 60 inches (1975 cm). For samples beyond the solum a bucket auger or a hydraulic soil probe was used.

Physical Properties

The hydrometer method was used for the determination of the percent sand, silt, and clay (Day, 1965). The paraffin wax procedure was used in determining the air dried bulk density (Blake, 1965).

The values used for moist and dry consistence are arbitary values as described in the Montana Automated Data Processing System for Soil Inventories (Decker, et al. 1975). The value given is dependent upon the amount of pressure required to crush a soil particle when placed between the thumb and forefinger under moist and air dried soil moisture conditions. As the soil ped becomes firmer the value of consistence becomes greater. The values ranged from 41 for loose to 46 for extremely firm moist consistence and 61 for loose to 66 for extremely firm dry consistence.

Chemical Properties and Clay Types

The pH and electrical conductivity (E.C.) were determined on a 2:1 water to soil dilution as used by the Montana State University Soil Testing Laboratory. Percent organic matter was determined by the procedure described by Sims and Haby (1970). Cation exchange capacity (C.E.C.) was determined by theNaOAC saturation procedure as described by Chapman (1965). Exchangeable cations was determined by the neutral, normal NH_4OAC extraction procedure as used by the Montana State University Soil Testing Laboratory. All analyses were made on each horizon except for organix matter which was determined only on the surface two horizons.

The percent montmorillonite and vermiculite were estimated using Alexiades and Jackson procedure (1965). Following saturation of the clay fraction with KCL percent vermiculite was estimated by the amount of K^+ that is fixed while montmorillonite was estimated by the amount of exchangeable K^+.

The percent illite was estimated using the hydrofluoric-perchloric acid digest ion (Pratt, 1965) for total K^+. The total concentration of

K^+, in PPM, was then divided by 8.3 (Jackson, 1965).

Site Characteristics

Mean annual soil temperature was obtained from established S.C.S. soil series description based on the soil series name for each site. Mean annual soil temperature is a long term average for that particular soil series.

Initial soil temperature was the temperature of the soil at 50 cm. at the initiation of the weather station, approximately the 1st of May. Soil temperature at 50 cm. for boot stage (Feeke's growth stage 10) was obtained from the weekly readings that the cooperators submitted.

The value for total rainfall was the cummulative amount from the initiation of the weather station (1st of May) to the date of harvest (middle of August).

The depth to the zone of accumulation of secondary carbonates (Ca) was measured from the surface to the top of the Ca horizon.

The value for aspect represents the number of 45° degree units clockwise from north with north being 1. For example (see diagram) west is 270° from north with a value of 7.

The values for parent material mode are coded values used in the Montana Automated Data Processing System for Soil Inventories (Decker, et al. 1975). The coded value represents the means by which the soil material was deposited. For example, the coded value of 4 represents