



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

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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, and 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 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: 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.

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TO K ON MONTANA SOILS

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A thesis submitted in partial fulfillment
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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. Santhirasegala (1968) reported that Paspalum commersonii (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 occurring 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 arbitrary 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 the NaOAC 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 organic 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.

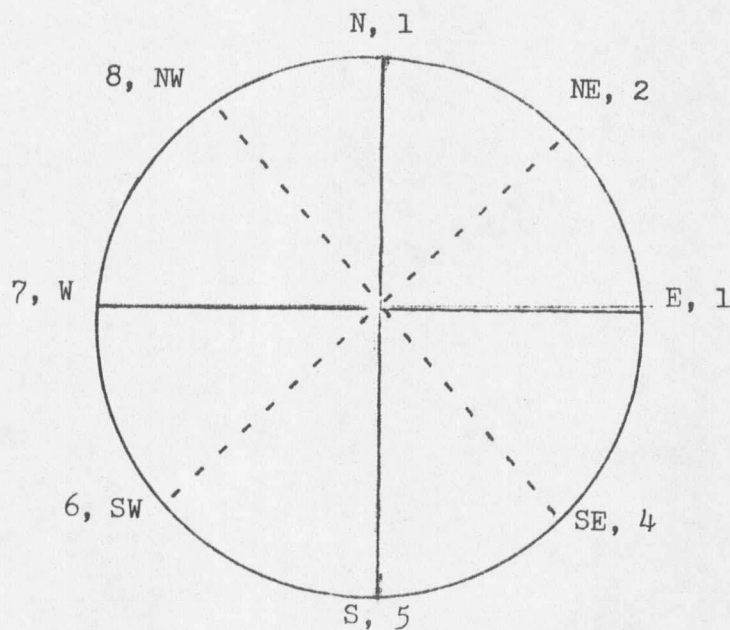
The value for total rainfall was the cumulative amount from the initiation of the weather station (1st of May) to the date of harvest (middle of August).

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

loess parent material, meaning the soil profile was developed from soil material blown in by wind; the coded value of 3 represents glacial till deposits.



Calculation of Other Parameters

Percent montmorillonite, vermiculite, and illite in the soil was obtained by multiplying the percent clay in the soil times the percent clay mineral fraction in the clay.

The ratio of montmorillonite/vermiculite was obtained by dividing the percent montmorillonite by the percent vermiculite. This was done for both the soil and clay portions.

Concentration of K, in me/100g, was divided by the C.E.C. of the soil to determine the ratio of K to C.E.C.

The ratio of $K^+ / (Ca^{++} + Mg^{++})^{\frac{1}{2}}$ was determined by using the concentration (me/100g) of the respective cations from extraction analysis.

Data Compilation

The data were compiled in two different manners. In the first case the data from each major horizon were handled separately. Where there was more than one genetic horizon of the same type (A_{p1} , A_{p2} and B_{21T} , B_{22T}) they were averaged together to represent the major horizon (see Table 2). In the second case there was no consideration given to the horizon, they were run in the numerical sequence as they occurred in the profile (A_p , 1st horizon; A_{p2} , 2nd horizon, etc.).

Table 2. The grouping of genetic horizons from profile description for major horizon analysis and horizon sequence analysis.

Major Horizon	Profile Description	Horizon Sequence		Profile Description	Major Horizon
A_p	A_p	1	1	A_{p1}	A_p
				A_{p2}	
B	B_{2T}	2	2	B_{21T}	B
	B_{3ca}	3	3	B_{22}	
ca				C_{1ca}	ca
		4	4		
		5			

The depth to which the major horizons extended varied from site to site. The depth of the A_p varied from 15-25 cm. The B horizon's lower depth varied from 30-56 cm. and that of the ca varied from 51-122 cm. In the case of the horizon sequence, they varied as follows: for the 1st horizon from 10-20 cm for the lower depth; 2nd horizon from 23-51 cm.; 3rd horizon from 31-84 cm.; and for the 4th horizon from 51-152 cm.

The 1st horizon was composed of data from the A_p being either from an A_{p1} or A_p . However, the 2nd horizon was composed of data from the A_p (A_{p2}) and sometimes a portion of the B horizon (see Table 2). The 3rd horizon was composed of data from the B horizon except where there was no B horizon present. The 4th horizon predominately contained data from a ca horizon, being either from a B_{3ca} or C_{1ca} horizon.

The second approach was considered important because plant roots would intercept successively lower horizons in order and not at all dependent on what the next lower horizon happened to be.

To obtain the significant variables that would adequately describe the influences that the soil profile parameters and/or site characteristics have on the influences of K fertilizer on winter wheat response additional analyses were conducted. The significant variables from the site characteristics as determined by the regression equation ($p = 0.1$), were combined with the significant major horizon

variables. Also, the significant site characteristics were combined with the significant numerical horizon sequence variables for a separate combined analysis.

Statistical Methods

The variables were inserted into a SPSS (Statistical Procedures for Social Sciences, Nie et al. 1975) multiple stepwise regression program. With the use of this program any site with missing data for one of its variables could be used and not affect the use of the remaining variables. This was the case for bulk density where the values were missing for 6 sites in some of the horizons. Caution must be used in interpreting results obtained with some missing values because the R^2 value for the equation may be inflated. The analysis for R^2 is based on the number of sites with complete data and not on the actual number of sites analyzed. For example, if data are missing for one variable in 4 sites, the R^2 is based on 17 sites and not on the original 21 sites. Still the regression of the other remaining variables is analyzed over the 21 sites.

The F value selected for entering into the regression equation was 2.25. This value represents approximately the 90% confidence limit, depending upon the degrees of freedom for each equation.

Determination of Y

A quadratic multiple regression analysis was used to obtain the calculated maximum yield at each site. From the regression

analysis an equation was obtained as follows:

$$\hat{Y} = a + b_1 X + b_2 X^2$$

where;

Y = Calculated yield

a = Intercept of the Y axis or where X = 0

b_1 = Regression coefficient, linear

b_2 = Regression coefficient, quadratic

X = Rate of K fertilizer applied

By taking the derivative of the original equation the rate of K fertilizer needed for maximum yield was obtained. The equation becomes;

$$\hat{Y} = b_1 + 2b_2 X$$

Then setting Y = 0 and solving for X;

$$2b_2 X + b_1 = 0$$

$$X = -b_1 / 2b_2$$

where;

X = Rate of K fertilizer for maximum yield response

By inserting the value of X into the original equation one can then solve for maximum yield ($\hat{Y}$).

In this analysis, if the maximum calculated rate of fertilizer exceeded 136 Kg/ha, 136 Kg/ha was used as the maximum rate since this was the highest rate used in the study. Extending the curve beyond the point of applied fertilizer could lead to some erroneous or non

warranted conclusions.

After the maximum yield ($\hat{Y}$) was obtained a ratio of $\hat{Y}$ to the intercept (a) was calculated and reported as percent change in yield (Y). This value was used as the dependent variable in a multiple stepwise linear regression.

Values for the calculated rate of K fertilizer (X) for maximum yield, calculated maximum yield ($\hat{Y}$), intercept yield value (a), and the percent change in yield (Y) are presented in Table 3.

Table 3. Calculated rate of K fertilizer (X) for maximum yield, calculated maximum yield ($\hat{Y}$), Y intercept; check rate yield (a), and percent yield increase with respect to a (Y) for 18 winter wheat sites. 1973 and 1974.

Cooperators	X rate Kg/ha	$\hat{Y}$ yield Kg/ha	a yield Kg/ha	Y percent
1973				
Loren Perry	92	3323	3209	104
Don Holland	70	3734	3364	111
Gary Helm	70	2231	2427	92
John Pehl	64	2885	436	98
Larry Erpelding	89	3923	2939	124
Ray Cash	135	2845	2501	114
John Jergenson	99	3401	2845	109
Marvin Works	72	1786	1564	114
Pete Miklovich	81	2966	2521	118
William Daum	82	1827	1537	119
Virgil Hanks	78	2906	3135	93
1974				
Henry Lassila	135	2798	2629	106
Marvin Works	75	2380	2029	117
Ned Schaff	90	1247	1510	83
Elmer Visser	99	1915	1591	120
John Pehl	35	2420	2117	114
Don Holland	35	3667	2973	123
Sime Inc.	94	4368	3998	109

RESULTS AND DISCUSSION

Agronomic Data

The yield, test weight and percent protein data for the winter wheat sites are presented in Table 4. In 1973 the yields ranged from 1439 Kg/ha on William Daum's at a rate of 22 Kg K/ha to a high of 3920 Kg/ha at a rate of 90 Kg K/ha at Larry Erpelding's. In 1974, grain yields ranged from 1096 Kg/ha on Ned Schaff's at a rate of 90 Kg K/ha to a high of 4451 Kg/ha on Sime Inc. at the same rate of fertilizer application. The greatest yield response to added K in 1973 was on Larry Erpelding's site ($P = .06$). The yield increased 762 Kg/ha (from 3166 Kg/ha on the check plots to 3928 Kg/ha on the 90 Kg K/ha). The least yield response occurred at Loren Perry's ($P = .19$) with a difference of only 113 Kg/ha from the check yield to the high yield response at 90 Kg/ha.

In 1974, the greatest response (789 Kg/ha) occurred at Don Holland's ($P = .23$) where the check yield was 2873 Kg/ha and the yield at 135 Kg/ha was 3662 Kg/ha. In contrast, at Ned Schaff's ($P = .48$) the addition of K had very little effect on yield response. In fact on three of the four K treatments the yield was less than that where no K was added.

In general, K fertilizer increased the yields of winter wheat during 1973 and 1974. The rate at which the maximum yield most often occurred varied from site to site. However, in most cases, the maximum yield occurred at either the 45 or 90 Kg K/ha rate.

Table 4. Yield, test weight and percent protein of winter wheat as influenced by K⁺ fertilizer in 1973 and 1974.

Cooperators	Yield, Kg/ha						Test weight, Kg/hl						Grain protein, %					
	K, Kg/ha						K, Kg/ha						K, Kg/ha					
	0	22	45	90	135	Pa/	0	22	45	90	135	P	0	22	45	90	135	P
1973																		
Loren Perry	3263	3129	3299	3376	3268	.19	81.5	81.5	81.4	81.3	81.6	.09	12.2	12.0	12.8	12.2	11.9	.01
Don Holland	3247	3691	3753	3546	3471	.12	73.9	79.5	79.4	79.7	79.5	.15	13.7	13.0	12.5	12.1	12.4	.22
Gary Helm	2341	2484	2173	2209	2406	.08	77.8	78.1	77.4	77.5	77.4	.05	14.4	14.7	14.4	14.2	14.2	.74
John Pehl	3027	2757	2885	2986	2901	.67	77.0	78.2	78.7	79.4	78.6	.08	12.4	11.7	11.4	11.6	11.2	.31
Larry Erpelding	3166	3473	3738	3920	3725	.06	82.2	82.6	82.4	82.4	82.2	.16	9.9	10.3	10.1	10.0	10.9	.14
Ray Cash	2580	2467	2474	2836	2689	.66	74.6	75.0	75.2	77.4	75.9	.57	14.6	14.7	14.6	14.3	14.1	.90
John Jergenson	2796	2994	3046	3033	3086	.89	80.5	80.9	81.4	81.0	80.7	.54	13.3	14.0	13.7	13.0	13.3	.63
Marvin Works	1617	1539	1828	1775	1614	.86	75.8	76.2	76.4	76.7	75.7	.91	15.3	14.4	13.9	14.3	14.1	.66
Pete Miklovich	2558	2603	2963	2942	2771	.38	80.1	80.4	80.6	80.3	80.4	.84	13.5	13.7	13.6	13.7	13.2	.72
William Daum	1617	1439	1921	1801	1697	.37	79.4	78.3	79.8	79.7	79.2	.48	14.4	14.9	13.5	14.5	14.3	.94
Virgil Hanks	3181	2717	3341	2688	3035	.03	78.9	79.6	79.6	79.2	79.4	.16	14.1	13.9	13.7	13.7	13.6	.58
1974																		
Henry Lassila	2526	2788	2762	2648	2822	.69	73.9	73.4	74.4	74.8	74.5	.07	19.3	18.6	18.6	18.9	18.6	.08
Marvin Works	2031	2131	2416	2298	2168	.44	74.9	75.3	76.0	76.4	75.4	.54	14.3	14.7	13.6	13.2	14.2	.75
Ned Schaff	1485	1320	1504	1096	1359	.48	78.8	77.4	78.9	77.1	79.2	.56	15.3	14.0	12.9	14.1	12.7	.60
Elmer Visser	1537	1751	1900	1804	1911	.48	78.6	79.0	78.9	77.5	77.0	.10	16.3	14.9	15.1	14.6	16.1	.21
John Pehl	2035	2316	2251	2274	2447	.53	72.2	77.9	72.9	73.8	73.4	.22	16.4	16.3	16.2	16.3	15.9	.94
Don Holland	2873	3369	3481	3540	3662	.23	79.7	81.2	80.9	81.2	81.4	.08	11.8	11.4	10.8	10.5	10.6	.04
Sime Inc.	3973	4256	4086	4451	4257	.31	74.8	78.6	79.1	78.4	78.0	.58	12.8	12.7	12.7	12.6	13.3	.26

a/ Probability level for 4 and 8 degrees of freedom.

The test weight of winter wheat did not seem to be influenced much by the addition of K fertilizer (Table 4). In most cases the difference between treatments on test weight was less than 1 Kg/hl. However, in several cases, the addition of K fertilizer increased test weight. In 1974 at John Pehl's ($P = .08$) a 22 Kg/ha application of K increased test weight from 72.2 Kg/hl on the check to 77.9 Kg/hl. In 1973, the test weight on Don Holland's ($P = .08$) increased from 73.9 Kg/hl on the check to over 79 for all treatments which received K fertilizer. Some other smaller increases in test weight can also be noted.

The influence of K fertilizer on percent grain protein of winter wheat was very similar to that of test weight (Table 4). In most cases the change in percent protein was less than one percent. In some cases a slight decrease in protein resulted from certain rates of K addition. For example, at Don Holland's ($P = .04$) in 1974 the percent protein of grain from the check plot was greater than that from any plot receiving K.

Chemical and Physical Soil Data

Data from chemical and physical analyses of soils are listed in Table 5. Results indicate that the soils under study were typical Montana agricultural dryland soils. The organic matter content ranged from a low of 0.7 percent to a high of 3.3 percent in the A_p horizon. pH values of upper horizon were predominantly in the 7.0 to

Table 5. Chemical and physical properties of soils, by genetic horizon, for 18 winter wheat sites. 1973 and 1974.

Cooperator - Larry Erpelding (1973)																		
Soil Series - Fort Collins Loam																		
Horizon	Depth cm	pH	O.M. %	E.C. mmhos/ cm	C.E.C. meg/ 100g	B.D. g/cm ³	Clay %	Silt %	Sand %	Ca me/100g	Mg me/100g	K me/100g	Na me/100g	Mont. %	Verm. %	Illite %	Consistence	
																	Dry	Moist.
A ₂	15	7.3	.7	.6	13.7	1.6	18	38	44	8.5	1.9	.61	.3	36	8	16	62	43
B ₂ T	43	7.5	1.0	.4	19.1	1.6	25	40	35	12.8	7.2	.45	.1				64	43
B ₃ Ca	53	8.3		.8	13.5	1.6	29	34	37	36.6	8.0	.31	.3				64	43
C ₁ ca	86	8.5		.7	12.4	1.7	25	34	41	35.3	7.7	.26	.3	31	1	9	64	43
C ₂	119	9.0		.7	9.7	1.5	17	20	63	31.9	9.4	.19	.4					
Cooperator - Ray Cash (73)																		
Soil Series - Bainville Clay Loam																		
A _{p1}	15	8.0	1.9	.6	16.0	1.6	26	34	40	15.1	2.1	.82	.3	36	3	20	63	43
A _{p2}	25	7.9	1.6	.8	14.6	1.6	29	30	41	19.2	2.5	.57	.2				63	43
C ₁	33	8.1		.8	11.8	1.7	31	32	37	38.9	3.1	.36	.4	24	14.1	10	63	43
C ₂ ca	152	8.2		.8	10.7	1.7	31	38	31	38.2	3.6	.31	.2				63	43
Cooperator - John Jergenson (73)																		
Soil Series - Williams																		
A _p	13	7.2	2.2	1.4	13.4	1.5	24	34	42	21.1	2.9	.93	.3	33	8	17	64	43
B ₂ 1T	23	7.0	1.5	.3	24.7	1.6	26	47	27	16.4	6.3	.93	.2				64	43
B ₂ 2T	36	7.6		.6	24.7	1.5	34	45	21	25.2	6.5	.55	.2				64	43
B ₂ 3ca	46	8.2		.7	16.3	1.6	38	37	25	36.3	6.0	.33	.3				64	43
B ₃ ca	56	8.3		.7	14.0	1.6	38	35	27	30.5	7.5	.27	.3				64	43
C ₁ ca	86	8.4		.8	14.0	1.6	42	31	27	36.3	9.6	.34	.4	30	9	12	64	43

Table 5. Continued.

Cooperator - William Daum (73)
Soil Series - Absarokee Clay Loam

Horizon	Depth cm	pH	C.M. %	E.C. mmhos/ cm	C.E.C. meg/ 100g	B.D. g/cm ³	Clay %	Silt %	Sand %	Ca me/100g	Mg me/100g	K me/100g	Na me/100g	Mont. %	Verm. %	Illite %	Consistence	
																	Dry	Moist.
A _p	10	6.9	1.5	.9	15.1	1.4	30	28	32	14.4	3.8	.88	.3	33	18	15	62	43
B ₂₁ T	33	6.9	1.3	.3	27.5	1.7	43	30	27	17.6	7.9	1.12	.2				63	43
B ₂₂ T	41	7.8		.7	22.5	1.7	35	38	27	37.5	7.7	.63	.3				63	43
C _{1ca}	152	8.2		.7	16.9	1.6	31	40	29	39.1	6.6	.51	.3	23	13	9	63	43

Cooperator - Loren Perry (73)
Soil Series - Gerber Clay Loam

A _p	15	6.2	2.9	.5	17.8	1.4	28	34	38	9.6	2.8	1.06	.2	35	17	20	64	43
B ₂₁ T	36	6.7	1.6	.4	23.8	1.6	39	22	39	15.4	4.8	1.02	.3				64	43
B ₃	43	8.0		.7	18.1	1.6	27	20	43	38.2	4.7	.65	.4				64	43
C _{ca}	97	8.2		.8	14.9	1.7	35	30	35	38.2	7.0	.37	.2	31	15	13	64	43

Cooperator - Don Holland (73)
Soil Series - Edgar Loam

A _p	18	7.7	1.1	.5	12.0	1.6	18	28	54	9.5	3.2	.66	.2	35	8	15	62	43
B	33	7.9	1.0	.5	13.7	1.6	15	32	53	19.0	5.5	1.33	.3				64	43
B ₃ Ca	46	8.3		.7	13.7	1.5	21	36	43	36.1	5.1	.87	.3					
C _{ca}	64	8.5		.7	11.2	1.6	21	32	47	32.9	7.6	.34	.3	26	11	9		42
C ₂	152	8.7		.5	10.2	1.4	13	36	61	31.4	8.2	.24	.2					

Table 5. Continued.

Cooperator - Marvin Works (73)
Soil Series - Evanston Clay Loam

Horizon	Depth cm	pH	O.M.	E.C.	C.E.C.	B.D.	Clay	Silt	Sand	Ca	Mg	K	Na	Mont.	Verm.	Illite	Consistence	
			%	mmhos/ cm	meg/ 100g	g/cm ³	%	%	%	me/100g	me/100g	me/100g	me/100g	%	%	%	Dry	Moist.
Ap	15	6.6	1.5	.7	11.8	1.6	24	34	42	7.9	2.7	.97	.2	25	14	22	64	43
B21T	38	7.1	.7	.4	17.8	1.6	28	19	53	9.5	5.2	.75	.1				64	43
B22T	56	7.6		.4	24.7	1.7	24	25	51	18.5	6.4	.64	.1				64	43
B3ca	69	8.1		1.0	12.3	1.7	26	25	49	32.1	5.9	.55	.2				64	43
C1ca	117	8.6		.8	12.3		26	27	47	33.1	7.3	.44	1.0	27	17	14	64	43

Cooperator - Gary Helm (73)
Soil Series - Cherry Silt Loam

Ap	13	8.1	2.3	.7	15.4	1.5	32	42	26	21.1	4.1	1.04	.3	26	8	21	63	
E2	20	8.3	1.7	.6	16.6	1.5	39	43	19	35.3	2.4	.62	.3				63	43
B3ca	30	8.4		.7	11.0	1.3	37	42	21	35.8	1.4	.35	.4				63	43
C1ca	102	8.6		.8	7.9	1.5	29	36	35	32.5	1.3	.32	.4	29	10	19	63	43
C2		8.9		.6	5.1	1.5	19	28	53	29.5	.9	.24	.4					
C3		9.3		.7	7.1	1.4	27	40	33	27.2	1.5	.37	2.0					

Cooperator - Pete Miklovich (73)
Soil Series - Arnegard Loam

Ap	18	6.8	2.2	.4	16.0	1.8	26	32	42	9.9	3.4	.97	.2	27	19	15	62	43
E21T	41	7.0	2.0	.4	20.0	1.8	35	24	41	10.9	4.5	1.01	.1				63	43
B22T	51				17.2	1.7	31	30	39	12.8	5.8	1.02	.9					
C1ca	152	8.2		.5	15.7	1.7	29	24	47	32.7	5.5	.40	.2	36	14	10	62	43

Table 5. Continued.

Cooperator - John Pehl (73)
Soil Series - Chanta or Attewan Loam

Horizon	Depth cm	pH	O.M. %	E.C. mmhos/ cm	C.E.C. meg/ 100g	B.D. g/cm ³	Clay %	Silt %	Sand %	Ca me/100g	Mg me/100g	K me/100g	Na me/100g	Mont. %	Verm. %	Illite %	Consistence Dry Moist.	
A _p	20	7.2	1.4	.4	12.9	1.7	16	36	48	7.5	2.6	.67	.2	29	4	14	63	43
E ₂	51	8.3	1.0	.4	14.0	1.7	18	33	49	9.4	3.2	.42	.4				64	43
C _{1ca}	84	8.4		.9	9.4	1.4	24	49	57	35.6	7.7	.21	.5	16	6	5	64	43
C _{2ca}	152	8.7		.9	8.9	1.7	21	38	41	32.5	9.3	.22	.5					

Cooperator - Virgil Hanks (73)
Soil Series - Amsterdam Silt Loam

A _p	18	7.8	3.3	.8	26.7	1.3	28	54	18	25.3	2.9	.67	.4	36	9	12	63	42
B _{21T}	38	7.7	1.5	.6	25.9	1.6	37	48	15	24.1	3.8	.60	.3				64	43
B ₃	48	7.8		.7	22.9	1.4	31	54	15	22.9	4.0	.49	.3				64	43
C _{ca}	76	8.1		.8	16.6	1.3	37	50	13	38.7	4.0	.42	.3	26	5	7	64	43

Cooperator - Henry Lassila (74)
Soil Series - Gerber Silty Clay

A _p	15	7.2	2.5	.5	30.3		47	30	23	6.8	9.2	1.98	.2	39	7	22	65	43
B _{2T}	33	7.9	1.9	.7	35.1		55	26	19	20.0	14.2	1.43	.4				65	43
B _{3ca}	61	8.4		.8	34.1		57	26	17	20.0	15.8	1.17	.9				65	44
C _{1ca}	97	8.5		1.0	34.1		57	26	17	20.0	16.4	1.15	1.5	39	10	15	65	44

Table 5. Continued.

Cooperator - Marvin Works (74)
Soil Series - Evanston Loam

Horizon	Depth cm	pH	C.M. %	E.C. mmhos/ cm	C.E.C. meq/ 100g	B.D. g/cm ³	Clay %	Silt %	Sand %	Ca me/100g	Mg me/100g	K me/100g	Na me/100g	Mont. %	Verm. %	Illite %	Consistence Dry Moist.	
A _p	15	8.0	1.3	.4	19.2		25	32	43	4.8	5.3	1.07	.2	30	15	19	63	43
B _{2T}	25	8.0	1.3	.7	21.6	1.4	31	30	39	8.4	6.7	.82	.2				63	43
B _{2ca}	69	8.3		.6	19.2		29	40	31	20.0	6.5	.56	.2				63	42
C _{1ca}	117	9.3		1.2	14.8	1.7	29	44	27	16.0	11.6	.40	1.3	36	8	15	63	42
C ₂	152	9.5		2.0	18.3	1.5	33	30	37	13.6	12.5	.52	2.4				63	43

Cooperator - Sime, Inc. (74)
Soil Series - Bozeman

A _{p1}	13	7.6	3.1	1.6	31.9		31	54	15	9.6	5.7	1.57	.2	46	12	13	63	43
A _{p2}	23	7.6	3.2	1.1	31.9		31	52	17	9.6	5.9	1.20	.2				65	44
B _{21T}	43	7.9	1.3	.5	29.3		29	52	19	8.8	6.4	.89	.2				62	42
B _{3ca}	53	8.1		.7	24.2		27	56	17	20.4	5.1	.73	.2				63	42
C _{1ca}	60	8.3		.6	23.2		27	56	17	21.2	5.1	.68	.1	30	14	9	63	42

Cooperator - Ned Schaff
Soil Series -

A _{p1}	10	8.6	1.6	.7	17.7	1.4	23	16	61	18.8	2.4	.85	.1	29	4	14		
A _{p2}	18	8.5	1.6	.6	14.3		21	20	59	18.0	2.4	.80	.1				63	42
E _{2T}	28	8.3		.8	17.2		23	16	61	18.0	2.4	.58	.2				63	42
C _{1ca}	36	8.3		.7	18.7		57	20	23	20.4	2.4	.31	.1	24	6	9	63	42

Table 5. Continued.

Cooperator - Elmer Visser (74)																		
Soil Series - Evanston																		
Horizon	Depth cm	pH	O.M. %	E.C. mmhos/ cm	C.E.C. meg/ 100g	B.D g/cm ³	Clay %	Silt %	Sand %	Ca me/100g	Mg me/100g	K me/100g	Na me/100g	Mont. %	Verm. %	Illite %	Consistence	
																	Dry	Moist.
A _p	12	8.0	1.8	.7	32.4	1.9	31	24	45	10.4	8.0	1.62	.1	40	10	14	63	43
B _{2T}	30	7.7		.7	39.4	1.8	41	10	49	10.8	11.1	1.57	.1				64	44
B ₃	40	8.4		.6	22.7		21	6	73	8.8	8.8	.87	.1				64	43
C _{1ca}	58	8.7		.8	28.8		31	12	57	19.6	15.8	1.05	.4	45	9	9	63	43
C _{2ca}	122	8.8		.8	28.8	1.6	29	20	51	17.6	16.4	1.17	1.3				63	42
Cooperator - John Pehl (74)																		
Soil Series - Chanta																		
A _{p1}	13	7.7	1.9	.4	15.4		19	46	35	4.4	3.3	.90	.11	29	5	17	63	43
A _{p2}	23	7.9	1.5	.4	13.8	1.7	19	44	37	4.4	3.5	.73	.1				64	44
B ₂₁	35	8.0	1.0	.3	15.7		19	34	47	4.8	4.2	.61	.1				63	43
B ₂₂	58	8.5		.3	17.7		21	42	37	5.6	5.3	.61	.1				63	43
C _{1ca}	89	8.6		.5	14.3	1.34	25	42	33	18.8	8.2	.31	.1	35	0	8	63	43
Cooperator - Don Holland (74)																		
Soil Series - Deacon																		
A _{p1}	10	8.1	1.3	.5	16.3		19	40	41	4.0	4.2	1.10	.2	42	3	15	62	43
A _{p2}	20	7.8	1.2	.3	17.7		23	36	41	4.4	4.5	.90	.1				63	43
B ₂	38	8.0	1.1	.3	20.7	1.4	25	36	39	4.8	5.3	.82	.1				63	43
C _{1ca}	51	8.5		.5	16.3	1.5	23	36	41	18.8	6.5	.45	.1	28	6	8	62	42
C ₂	152	9.1		.6	16.3		25	42	33	18.4	12.0	.47	.8				62	42

8.0 range. At only 4 locations was the pH below 7.0 and in no instance was it below 6.0. A gradual increase in pH values with horizon depth is apparent for all soils, with the value exceeding 9.0 in 3 soils at the lower depths.

A low level of soluble salts in all soils is verified by E.C. readings of less than 2 mmhos/cm. for all horizons. In only a few samples did the E.C. value equal or exceed 1 mmhos/cm.

The C.E.C. of A_p horizons ranged from about 10 to slightly greater than 30 me/100 g. The lowest C.E.C. value was found in the C_2 horizon at Gary Helm's (5.1 me/100 g) while the highest value was 35.1 me/100 g in the B_{2T} at Henry Lassila's. Generally, C.E.C. value decreased with depth unless there was an increase of clay in the horizon, then there was an accompanying increase in C.E.C.

Most bulk density values were between 1.4 and 1.7 g/cm³. (Several values are missing for B.D. due to lost samples.) The amount of clay ranged from 13 percent to a high of 57 percent. At most sites there was eluviation of clay from the A_p and illuvation into the B horizon. In some soils the C horizon had the greatest clay content. The percent sand ranged from 13 percent to 73 percent. Silt content varied from 6 - 56 percent.

Concentration of extractable Ca^{++} varied from a low of 4.0 me/100 g to a high of 39.8 me/100 g. At all locations there was an increase in the amount of extractable Ca^{++} with depth. A large

increase in amount of extractable Ca^{++} generally occurred when a horizon was also designated as a ca horizon. The amount of extractable Mg^{++} ranged from less than 1 me/100 g to 16.4 me/100 g. The concentration of extractable Mg^{++} also increased with depth. Concentration of extractable K^+ in the surface horizon was from a low of .61 me/100 g (238 ppm) to a high of 1.98 me/100 g (772 ppm). At all locations the concentration of extractable K^+ decreased with depth. The amount of decrease varied among locations, from less than .5 me/100 g to over 1.00 me/100 g. The amount of extractable Na^+ ranged from less than .07 me/100 g to 2.4 me/100 g. However, at most locations the concentration was less than 0.50 me/100 g at all depths. The high level of Na^+ occurred at Marvin Works' at a depth of 152 cm. This coincides with the highest E.C. (2.0 mmhos/cm) of any horizon from all locations.

The amount of clay minerals present in the A_p varied from 25 - 43 percent for montmorillonite; from 3 - 19 percent for vermiculite; and 13 - 23 percent for illite. In the ca horizon the amount varied from 16 - 46 percent for montmorillonite, 0 - 18 percent for vermiculite, and 6 - 19 percent for illite. At some locations more montmorillonite was present in the A_p than in the ca and at other locations the opposite was true. The same was true for vermiculite. However, illite decreased with depth. This may be partially responsible for the observed decrease of extractable K^+ with depth.

The values for moist and dry consistence ranged from 42 - 44 for moist and 62 - 65 for dry consistence. There was no general trend for either moist or dry consistence with depth.

Site Characteristic Data

Site characteristic data are listed in Table 6.

Initial soil temperature, taken approximately the first of May, in 1973 was warmer than that of 1974. The range of initial soil temperature in 1973 was from a low of 10 C to a high of 16 C. In comparison the range in 1974 was from 6 C to 14 C. One reason for this difference is that in 1973 the initial soil temperature was taken a few days later in the spring than in 1974. The soil temperature at boot growth stage varied from a low of 12 C to a high of 18 C in 1973 and in 1974 the variation was from 14 C to 20 C. This suggests that 1974 was probably a somewhat warmer growing season than was 1973. The soil temperature at harvest for 1973 ranged between 18 C and 23 C and between 18 C and 20 C in 1974. The mean annual soil temperature for all locations varied from 6.3 C to 9.7 C for both 1973 and 1974 sites.

In 1973, rainfall during the period of approximately April 15th to August 15th varied throughout the state. It fluctuated from a low of 4.3 cm at Ray Cash's to a high of 14.9 cm at John Pehl's. In 1974, rainfall varied from 7.1 cm at Sime's Inc. to 15.0 cm at Marvin Works'.

Table 6. Site characteristic data for 18 winter wheat sites. 1973 and 1974.

Cooperators	Soil temperature - 50 cm, C°				Rainfall cm.	Depth to ca, cm	Aspect ^{a/}	Slope Percent	Elev m.	Parent Material ^{b/} mode
	Initial	Boot	Harvest	Mean Ann.						
1973										
Loren Perry	12	15	19	6.9	9.7	36	8	2	945	3
Don Holland	12	17	20	9.7	12.6	33	3	2	853	2
Gary Helm	13	13	18	6.3	11.1	20	8	1	777	1
John Pehl	15	16	20	6.9	14.9	51	1	2	853	2
Larry Erpelding	12	15	18	9.7	12.6	43	6	4	838	2
Ray Cash	12	18	21	9.7	4.3	33	5	2	1067	1
John Jergenson	13	15	21	7.0	13.0	36	1	5	823	3
Marvin Works	16	15	23	9.4	9.1	69	7	1	844	3
Pete Miklovich	12	17	18	6.3	4.7	51	4	4	975	1
William Daum	12	12	19	6.9	4.7	41	3	2	1219	1
Virgil Hanks	10	16	19	6.3	11.1	48	3	2	1590	4
1974										
Henry Lassila	13	15	19	6.9	12.0	33	2	1	1067	3
Marvin Works	8	18	20	8.3	15.0	25	8	1	844	3
Ned Schaff	14	20	20	-	13.3	28	1	5	1128	1
Elmer Visser	7	14	18	8.3	9.6	40	3	2	1500	2
John Pehl	10	16	20	6.9	11.2	58	1	2	853	2
Don Holland	11	16	18	9.7	14.6	38	2	2	853	2
Sime Inc.	6	15	18	6.3	7.1	43	2	3	1590	4

^{a/} See text, P for discussion of aspect designation.

^{b/} See text, P for discussion of parent material mode.

The depth to the ca horizon from the surface varied from 20 cm to 69 cm. The percent slope ranged from 1 to 5 percent with a full range of aspects (1 - 8). Elevation at the sites ranged from 838 m to 1590 m.

Analysis of Site Characteristics

A list of site characteristics is presented in Table 7. Regression equations for those characteristics which were significantly related to percent yield response from K fertilizer (90 % confidence limit) are presented in Table 8. The site characteristic with the highest correlation to winter wheat response to K fertilizer is the mean annual soil temperature at 50 cm. This variable alone had an R^2 of .56. With the addition of percent slope the R^2 increased to .64. Other site characteristics were not significantly related to yield response.

Table 7. Site characteristics used in multiple stepwise regression program.

Initial soil temperature	Depth to ca
Boot soil temperature	Aspect
Harvest soil temperature	Percent slope
Mean annual soil temperature	Elevation
Rainfall	Parent material mode

Table 8. Multiple linear regression equations for significant site characteristics relating percent yield response (Y) of winter wheat to applied K fertilizer for 18 sites. 1973 and 1974.

Equations	R ²	F
$Y = 81.72 + 3.78X_5^a$	.56	20.29
$Y = 70.62 + 4.42X_5 + 2.51X_8^b$	.64	13.33

a/ X_5 = Mean annual soil temperature at 50 cm

b/ X_8 = Percent slope

The relationship between mean annual soil temperature at 50 cm. and yield response was positive; that is, the warmer soils responded to K fertilizer more consistently than the colder soils. Since diffusion is temperature dependent a higher rate of diffusion should occur in warmer soils than in cold soils. Thus, the increased soil solution concentration of K^+ resulting from fertilizing can diffuse more rapidly to the plant root where it is available for uptake and yield response. The data also suggest that colder soils require a larger rate of K fertilizer to obtain the same relative yield response as that on warmer soils. In this case, diffusion would be increased by a greater soil solution concentration of K^+ at the higher rates of application. Also, the influence of soil temperature may be partially due to its influence on root metabolism. It has been reported (Thomas, 1968) that as root temperature increases

the uptake of K^+ increases. Montana soils are relatively cold during April - June portion of the growing season. Roots during early spring are seldom more than a few degrees above freezing. At this same time requirements for plant nutrients are greater as rapid growth is occurring. Hence, root temperature may be very important in crop response to K fertilizer and may help explain the positive relation which exists.

The percent slope was also positive in relation to yield response. The influence of slope may be derived from an indirect effect on soil temperature and soil moisture. Generally the more level a field is the less will be surface runoff in the spring. This should increase stored soil moisture. The slope of the field and the aspect of the slope relative to the angle of the sun early in the spring could be influencing soil temperature. A field with a 0 - 1 % slope with an aspect of S.W. will probably be cooler than a soil with a 3 - 4 % slope with the same aspect because of the angle of the sun to the soil surface. However, it is not totally clear why slope has emerged as a significant site variable, but it is obvious that it is not very important. The R^2 value was increased by only 0.08 when it was included in the regression equation.

Major Horizon Analysis

A_p Horizon

Table 9 presents the independent variables used in the stepwise

regression analysis for each horizon (with the exception of organic matter which was analyzed on the surface two horizons and the clay minerals which were analyzed only for the surface and the ca horizon). The significant variables as predicted by the regression equation are presented in Table 10.

Table 9. Horizon variables used in multiple stepwise regression program.

pH	Vermiculite; % in clay
Organic matter	Illite; % in clay
Electrical conductivity	Dry consistence
Cation exchange capacity	Moist consistence
Bulk density	$K^+ / C.E.C.$
Clay, %	$K^+ / (Ca^{++} + Mg^{++})^{\frac{1}{2}}$
Silt, %	Montmorillonite; % in soil
Sand, %	Vermiculite; % in soil
Ca^{++} , me/100 g	Illite; % in soil
Mg^{++} , me/100 g	Ver/Mont; clay
K^+ , me/100 g	Mont/Illite; clay
Na^+ , me/100 g	Ver/Mont; soil
Montmorillonite; % in clay	Mont/Illite; soil

The most influential factor in the A_p horizon on crop response to K fertilizer was moist consistence. This variable alone had an R^2 of .41. Dry consistence entered the regression analysis next and increased the R^2 to .54. Percent montmorillonite in the clay fraction increased R^2 to .70, and finally the ratio of vermiculite to montmorillonite in the soil increased R^2 to .79.

Table 10. Multiple linear regression equations for significant A horizon variables relating percent yield response (Y) ^P of winter wheat to applied K fertilizer for 18 sites, 1973 and 1974.

Equations	R ²	F
$Y = -630.53 + 17.23X_{18}^a$	.41	10.38
$Y = -402.18 + 19.14X_{18}^b - 4.91X_{17}^b$	.54	8.11
$Y = -398.13 + 19.84X_{18}^c - 5.89X_{17}^c + 8.07X_{13}^c$	.70	10.07
$Y = -438.96 + 19.44X_{18}^d - 5.24X_{17}^d + 11.01X_{13}^d + 21.68X_{28}^d$	.79	11.20

a/ X_{18} = Moist consistence

b/ X_{17} = Dry consistence

c/ X_{13} = Montmorillonite; % in clay

d/ X_{28} = Vermiculite/montmorillonite-soil

Moist consistence, percent montmorillonite and the ratio of vermiculite to montmorillonite in the soil were positively related to yield response, while dry consistence was negatively related.

Why moist and dry consistence are related to crop response is not known. However, a number of important soil physical, chemical and mineralogical factors are known to influence consistence. Some factors that influence consistence are the amount of clay, (as well as silt, sand and coarse fragments) clay type, bulk density, amount of organic matter and amount and type of cations. How and to what degree each of these factors influences consistence will regulate how

consistence influences crop response to K fertilizer. Research will be required to investigate these relations, but it appears that consistence may function as an integrator of several factors which themselves influence ionic diffusion in soil.

In general, there is a direct positive relation between percent montmorillonite in the soil and CEC. However the relationship between montmormillonite and CEC and related effects on response to K fertilizers are not clear.

The influence of the ratio of vermiculite to montmorillonite on yield response perhaps is related to the phenomenon of K^+ ion fixation by vermiculite. Vermiculite can render the K^+ ion temporarily unavailable by trapping the ion between its interlayer structure.

The change in ratio of vermiculite to montmorillonite is due mostly to a greater difference in vermiculite content of different soils. The montmorillonite percentage is reasonably similar in the A_p horizon (see Table 5 pages 23 - 28). Hence, at a high ratio value fixation of the K^+ ion by vermiculite would likely take place, reducing the amount of the K^+ ion in soil solution. When K fertilizer is then applied the amount of K^+ in solution should increase to allow a larger yield response.

B horizon

The variables which applied to the B horizon are listed in Table 9. The regression equations for significant parameters are presented

in Table 11.

The level of extractable calcium (me Ca^{++} /100 g) was the first variable to enter the regression equation with an R^2 of only .23. The only other significantly correlated variable for the B horizon was moist consistence, which increased R^2 to .44. It can be noted that these R^2 values are considerably less than those of the A_p horizon (which went to .79), suggesting a lesser importance of the B horizon in controlling crop response.

Table 11. Multiple linear stepwise regression equations for significant B horizon variables relating percent yield response (Y) of winter wheat to applied K fertilizer for 17 sites. 1973 and 1974.

Equations	R^2	F
$Y = 119.97 - .69 X_9^a$	.23	3.38
$Y = -417.69 - .69 X_9 + 12.52 X_{18}^b$	.44	3.98

a/ $X_9 = \text{Ca}^{++}$, me/100 g

b/ $X_{18} = \text{Moist consistence}$

As the extractable Ca^{++} concentration of the B horizon increased, the response to K fertilizer decreased. This effect can probably be explained as a result of direct competition between K^+ and Ca^{++} . Particularly in soils which contain free lime, Ca^{++} is so dominant that frequently additional fertilizers (especially K) are required for maximum crop production.

The moist consistence of the B horizon had a positive relationship with respect to yield response. This is the same relationship which was expressed in the A_p horizon, and again consistence can be viewed as an integrator of several factors which regulate ion diffusion in the soil solution.

ca Horizon

Variables pertaining to the ca horizon are included in Table 9. Regression equations for the significant parameters are presented in Table 12.

In the ca horizon, the horizon of accumulation of secondary carbonates, the percent clay was the variable of greatest influence on crop response with an R^2 of .31. The next variable to enter the equation was the ratio of $K^+/(Ca^{++} + Mg^{++})^{\frac{1}{2}}$ which increased R^2 to .54. No other parameters of the ca horizon were significantly related.

Table 12. Multiple linear regression equations for significant ca horizon variables relating percent yield response (Y) of winter wheat to applied K fertilizer for 18 sites. 1973 and 1974.

Equations	R^2	F
$Y = 129.44 - .62X_6^a$	.31	6.70
$Y = 123.92 - .70X_6 + 85.82X_{22}^b$	.54	8.24

a/ X_6 = percent clay

b/ X_{22} = Ratio $K^+/(Ca^{++} + Mg^{++})^{\frac{1}{2}}$

The percent clay was negatively related to yield response. This is the opposite relationship as that expressed for percent montmorillonite in the A_p horizon. Since montmorillonite generally composes the bulk of the clay mineral in these soils this reversal is somewhat surprising. Lai et al. (1961) reported that as the clay content increases ion diffusion decreases. If diffusion is controlling K ion uptake, then as clay content increases diffusion and K⁺ uptake should decrease. The addition of K fertilizer should help overcome this decreased rate of ion diffusion on high clay soils. The fact that the opposite relation exists calls for some alternative explanation, which at this time is not apparent. However, several factors influence clay behavior and clay influences several other factors. The amount of clay in a soil influences both soil water relations and the C.E.C. Also, not only the amount of clay influences diffusion, but the type of clay mineral can be important. Some of these factors may be influencing crop response to K fertilizers and masking the expected influences reported for increasing clay content.

The ratio of $K^+ / (Ca^{++} + Mg^{++})^{\frac{1}{2}}$ which has been referred to as the intensity factor (Beckett, 1968) for K⁺ availability was positively related to yield response. This result is not consistent with expectations. It has been reported that soils with high intensity factors are more capable of supplying adequate K⁺ for crop growth than those with low intensity factors. More response to added K⁺

would be expected on soils with low $K^+/(Ca^{++} + Mg^{++})^{\frac{1}{2}}$ than on those with a high ratio. The reversal of this relation in this study is further evidence that extractable cation functions are not reliable by themselves for predicting crop response to K fertilizer in Montana.

Combined analysis of Site Characteristics and Genetic Horizons.

The significant variables, as determined by the regression equations from the major horizon and site characteristics, were combined for an overall analysis. The purpose was to determine the most significant variables that would predict the response of winter wheat to K fertilizer. The variables used in the overall analysis are listed in Table 13. The regression equations for the significant parameters are presented in Table 14.

Table 13. Significant major horizon parameters and site characteristics used in a multiple linear regression equation for combined analysis.

<u>Site</u>	<u>A_p horizon</u>
Mean annual soil temperature at 50 cm	Moist consistence
Percent slope	Dry consistence
	Montmorillonite; % in soil
	Verm/Mont; % in soil
<u>B horizon</u>	Clay; %
Extractable Ca (me/100 g)	$K^+/(Ca^{++} + Mg^{++})^{\frac{1}{2}}$
Moist consistence	
Dry consistence	
	<u>Ca horizon</u>
	Clay, %
	$K^+/(Ca^{++} + Mg^{++})^{\frac{1}{2}}$

Table 14. Multiple linear regression equations for significant variables from combined analysis relating percent yield response (Y) of winter wheat to applied K fertilizer for 18 sites. 1973 and 1974.

Equations	R ²	F
$Y = 80.99 + 3.92X_1^a$	.56	19.43
$Y = 68.131 + 3.72X_1 + .35X_{12}^b$	.66	13.62
$Y = 408.17 + 4.17X_1 + .41X_{12} + 5.44X_{14}^c$	.76	13.68
$Y = 160.62 + 3.31X_1 + .47X_{12} - 7.64X_{14} + 9.11X_{15}^d$	.81	13.11
$Y = 335.99 + 5.26X_1 + .50X_{12} - 12.34X_{14} + 11.20X_{15} + .55X_{16}^e$	.88	15.94

a/ X_1 = Mean annual soil temperature at 50 cm.

b/ X_{12} = Moist consistence; A_p horizon

c/ X_{14} = Dry consistence; B horizon

d/ X_{15} = Moist consistence; B horizon

e/ X_{16} = Clay %; ca horizon

The most highly correlated variable from the overall analysis was mean annual soil temperature at 50 cm. It entered the regression equation at an R² of .56. Moist consistence of the A_p increased R² to .66. With the addition of dry consistence of the B horizon R² increased to .76. When moist consistence of the B horizon was added, R² increased to .81. The last variable of significance was the clay content of the ca horizon which increased R² to .88.

All of these parameters were positively related to percent yield response, except for dry consistence which was negatively related. Regression analysis for the ca horizon alone indicated a negative relation between percent clay and percent yield response. The sign reversal for this relation in the combined analysis is confusing, but may be due merely to statistical manipulations and the influence that one parameter may have on subsequent ones. In this analysis, dry consistence has a strong negative influence, which may have carried over to the relatively small (numerically) influence represented for percent clay.

Interpretations concerning why these factors are of importance have been discussed previously. However, it is important to note that in this combined analysis no chemical parameters were sufficiently related to yield response to be significant in regression with these five physical soil properties.

Horizon Sequence

First Horizon

The variables used in the horizon sequence are the same as used for the major horizons. (See Table 9, page 36). Regression equations for percent yield response as related to horizon variables are presented in Table 15.

The variable of greatest significance in the regression equation was extractable Ca^{++} (me/100 g) with an R^2 of .37. Dry consistence was the next variable, increasing R^2 to .53. Moist consistence increased R^2 to .65. The last variable to enter the equation was percent illite in the clay fraction which increased R^2 to .77.

Extractable Ca^{++} and percent illite were negatively related to yield response while moist and dry consistence were both positively related.

Table 15. Multiple linear regression equations for significant 1st horizon variables relating percent yield response (Y) of winter wheat to applied K fertilizer for 18 sites. 1973 and 1974.

Equations	R^2	F
$Y = 122.15 - 1.10X_9^a$	.37	8.18
$Y = 100.67 - .89X_9 + .32X_{17}^b$	.53	7.24
$Y = -902.7 - .227X_9 + .40X_{17} + .23.07X_{18}^c$	.65	7.64
$Y = -1307.93 - .032X_9 + .49X_{17} + .32.89X_{18} - 13.9X_{15}^d$	.77	9.06

a/ $X_9 = \text{Ca}^{++}$, me/100 g

b/ $X_{17} = \text{Dry consistence}$

c/ $X_{18} = \text{Moist consistence}$

d/ $X_{15} = \text{Illite, \% of clay}$

Some possible reasons for why Ca^{++} and moist and dry consistence influence yield response have previously been discussed. However,

in the previous analysis dry consistence was negatively related while in this case it is positively related. Again, this appears to be related to the fact that dry consistence has a very small numerical value and sign reversal could occur quite easily from other related influences.

As the percent illite increased the yield response decreased. Illite will release K^+ for plant use as it weathers. The higher the illite content of a soil the more K^+ it can contribute for plant growth, thus decreasing the need for supplemental K^+ .

Second Horizon

The regression equations for the 2nd horizon are listed in Table 16.

Of the variables listed in Table 9 (page 36) only two were significantly related to yield response to K^+ . Extractable Ca^{++} was again the first variable into the regression equation. This was followed by pH. These variables combined to produce an R^2 of .48.

Calcium influenced yield response in the second horizon in the same manner as it did in the first. The effect of pH on yield response was also negative; that is, as pH increased yield response decreased. One possible explanation for this is that pH and Ca^{++} are closely related. In general as Ca^{++} concentration increases the pH of the soil also increases. Therefore, the effect that pH has would be very similar to that of Ca^{++} . However, the range in pH of

soils in this study was quite narrow and the influence of this relationship is probably minimized due to its limited range.

Table 16. Multiple linear regression equations for significant 2nd horizon variables relating percent yield response (Y) of winter wheat to applied K fertilizer for 18 sites. 1973 and 1974.

Equations	R^2	F
$Y = 122.49 - .89X_9^a$	.34	8.43
$Y = 183.12 - .79X_9 - 8.12X_1^b$	.48	6.82

a/ $X_9 = Ca^{++}$, me/100 g

b/ $X_1 = pH$

Third Horizon

Variables used in regression of the third horizon from the surface are given in Table 9 (page 36). Results of the analysis are presented in Table 17.

Table 17. Multiple linear regression equations for significant 3rd horizon variables relating percent yield response (Y) of winter wheat to applied K fertilizer for 18 sites. 1973 and 1974.

Equations	R^2	F
$Y = 122.84 - 22.29X_3^a$	.20	3.44
$Y = 124.95 - 32.15X_3 + .18X_{10}^b$	.33	3.14

a/ $X_3 = \text{Electrical Conductivity}$

b/ $X_{10} = Mg^{++}$, me/100 g

Electrical conductivity (E.C.) was the first variable of significance to enter the regression equation with an R^2 value of .20. Extractable Mg^{++} (me/100 g) was the only other significant variable. Combined, these two factors produced an R^2 of .33. The low R^2 value for these two parameters suggest limited value for predicting crop response to K fertilizer. All of the soils in this study were considered to be good agricultural soils with no salt problem, thus E.C. would not be expected to have a large influence. However, because E.C. is directly related to the ionic concentration of the soil solution (even in non-salty soils) it may be an indirect measure of the K^+ status of the solution. Because Na^+ was low in these soils (see Table 5) the increase in E.C. may have been partially due to increased concentration of K^+ in the soil solution. If this is true, then a low E.C. value would mean a low amount of K^+ in soil solution. With the addition of K fertilizer the concentration in solution would increase, increasing the uptake of K^+ and resulting in a larger yield response. At a high E.C. the K^+ in solution may have been sufficient for plant uptake and no yield response would result from the addition of K fertilizer.

Extractable Mg^{++} was related to yield response in the opposite manner from that for extractable Ca^{++} ; One would expect the two to similarly influence yield response to K. However, the positive relation between extractable Mg^{++} and yield response to supplemental

K does support literature reports in which Mg^{++} and K^+ have been shown to be competitive for uptake by plant roots (Thomas and Hipp, 1968).

Fourth Horizon

The factor in the fourth horizon from the soil surface which was most influential on crop response to added K was percent clay, with an R^2 of .27. The only other significantly related variable was the percent montmorillonite of the soil, increasing R^2 to .54 (see Table 18).

Table 18. Multiple linear regression equation for significant 4th horizon variables relating percent yield response (Y) of winter wheat to applied K fertilizer for 18 sites, 1973 and 1974.

Equations	R^2	F
$Y = 126.64 - .55X_6^a$	.27	4.70
$Y = 129.01 - 1.47X_6 + .27X_{23}^b$	.54	7.07

a/ X_6 = Clay, %

b/ X_{23} = Montmorillonite; % in soil

Percent clay was negatively related to yield response while percent montmorillonite was positively related. Both of these factors emerged as significant parameters in previous regression analysis and some possible reasons for their influences were discussed in earlier sections (see pages 38 and 41).

Combined Analysis of Site Characteristics and Horizon Sequence

This combined analysis included all variables from site characteristics and individual horizon sequence analysis which had significant F ratios. Table 19 provides a list of significant variables and Table 20 the resultant regression equations.

Table 19. Significant horizon sequence and site characteristic variables used in a multiple linear stepwise regression for combined analysis.

<u>Site</u>	<u>1st horizon</u>
Mean annual soil	Extractable Ca^{++} (me/100 g)
temperature at 50 cm.	Dry consistence
Percent slope	Moist consistence
	Illite, % of clay
<u>2nd horizon</u>	<u>3rd horizon</u>
Extractable Ca^{++} (me/100 g)	Electrical conductivity
pH	Extractable Mg^{++} (me/100 g)
	<u>4th horizon</u>
	Clay, %
	Montmorillonite; % of soil

Mean annual soil temperature at 50 cm. was again the most important factor relating crop response to K fertilizer. Alone it provided an R^2 of .56. The next variable of significance was extractable Ca^{++} in the second horizon increasing R^2 to .73. Montmorillonite content of the soil from the fourth horizon was the third most highly correlated horizon sequence variable, increasing R^2 to .78. The last significant variable was pH of the second horizon which increased R^2 to .83.

Table 20. Multiple linear regression equations for combined site and horizon sequence variables relating percent yield response (Y) of winter wheat to applied K fertilizer for 18 sites. 1973 and 1974.

Equations	R^2	F
$Y = 81.78 + 3.78X_1^a$	.56	20.28
$Y = 95.24 + 3.24X_1 - .65X_{10}^b$	.73	20.40
$Y = 82.69 + 3.14X_1 - .59X_{10} + 4.98X_{14}^c$	.78	17.42
$Y = 120.03 + 2.91X_1 - .56X_{10} + 3.68X_{14} - 4.55X_9^d$	.83	15.56

a/ X_1 = Mean annual soil temperature at 50 cm.

b/ X_{10} = Ca^{++} , me/100 g; 2nd horizon

c/ X_{14} = Montmorillonite; % in soil; 4th horizon

d/ X_9 = pH; 2nd horizon

Mean annual soil temperature at 50 cm. and the percent montmorillonite in soil from the fourth horizon were both positively related to yield response, while extractable Ca^{++} and pH of the second horizon were negatively related. Some possible explanations for these influences were discussed above (see pages 34, 37, 39 and 46).

SUMMARY AND CONCLUSION

In 1973 and 1974, 18 winter wheat sites were selected to study the influence that soil profile and site characteristics have on the response of winter wheat to K fertilizer. Rates of 0, 22, 45, 90, and 135 Kg K/ha with a blanket application of 45 and 56 Kg/ha of N and P respectively, were applied in the fall prior to the seeding of dryland winter wheat in a randomized complete block design. All sites were classified by local S.C.S. personnel to determine their soil series. In addition, they determined some of the 10 site characteristic parameters. Soil samples were obtained from each genetic horizon. Fourteen chemical and physical soil properties for each horizon and 10 site characteristics were inserted separately into a multiple linear regression program with percent change in yield from added K being the dependent variable. To determine their relation to yield response, the horizon variables were analyzed in two ways: 1) as major horizons and 2) in the order they occurred in the profile (horizon sequence). The significant variables from each of these analyses were grouped with the significant site characteristic variables for a combined analysis, either by major horizon or horizon sequence.

Mean annual soil temperature at 50 cm. was most important variable in relating to percent change in yield of winter wheat to K fertilizer. This factor alone accounted for 56 percent of the observed variability in percent change in yield. Moist and dry consistence of the A_p and B

were the most influential parameters of the major horizon analysis. Moist and dry consistence were also significant in the 1st horizon sequence analysis.

Percent clay of the ca horizon and percent montmorillonite of the soil in the 4th horizon were the only other significant variables for their respective combined analysis. Since both of these variables increased R^2 only .05, and plants generally obtain the majority of their nutrients from surface soil horizons, the importance of these two variables can probably be considered as minimal relative to uptake of K^+ by the plant.

In the horizon sequence analysis the concentration of extractable Ca^{++} in both the 1st and 2nd horizons was the most highly related to percent yield response of winter wheat to K fertilizer. The fact that extractable Ca^{++} was the most important factor in these first two horizons and its position as second in importance in the combined analysis (by horizon sequence) suggest that extractable Ca^{++} is probably playing an important role in the response of winter wheat to K^+ fertilizer.

The influence of these variables, mainly mean annual soil temperature, moist and dry consistence, and the concentration of extractable Ca^{++} , on the response of winter wheat to K fertilizer are probably related to diffusion. Olsen and Kemper (1968) described the diffusion of an ion in the soil by the following equation;

$$\frac{dq}{dt} = DA \frac{dC}{dL}$$

where;

q = Quantity of ion (grams)

t = Time (seconds)

D = Diffusion coefficient ($\text{cm}^2 \text{sec}^{-1}$)

A = Cross-sectional area (cm^2)

C = Concentration ($\text{g}\cdot\text{cm}^{-3}$)

L = Distanced ion moved (cm)

Therefore, the factors that influence D and C will determine the rate at which K^+ can diffuse to the plant root. Factors that influence D include soil temperature, clay content, type of clay, bulk density and soil moisture. Except for soil temperature and soil moisture the remaining factors (clay type, clay content and bulk density) all relate to soil consistence. How these factors quantitatively influence consistence is not known. However, consistence is probably an integrator of these and other physical and chemical properties that may be influencing D, and thus, the availability of K^+ at the plant root surface. A factor which influences C (ionic concentration) is the presence of other ions. The importance of extractable Ca^{++} could be through an influence on K^+ diffusion by alternating (decreasing) the effective concentration of K^+ .

Since plants take up 95% of their nutrients from the surface foot, one would expect the surface horizon variables to play a major role in the response of winter wheat to K^+ fertilizer. This expectation is supported by results from this study. Larger R^2 values were associated with significant A_p or 1st horizon parameters than those for lower horizons. Furthermore, the total R^2 value for all significant parameters for either the A_p or 1st horizons was nearly as large as the total R^2 values from combined analysis, including site characteristics (A_p horizon total $R^2 = .79$; 1st horizon, $R^2 = .77$; combined analysis, total $R^2 = .88$ and $.83$ for major horizon and horizon sequence respectively).

Results from this investigation are significant from several aspects. First, they will illustrate that soil taxonomic classification parameters, soil profile and site characteristics influence winter wheat response to K fertilizer. An array of sites in order of decreasing percent yield increases illustrates some of these findings (See Table 21). Two points appear of particular importance: 1) the moist responsive sites had a mesic temperature regime (Erpelding and Holland - 73), while two of the least responsive sites had a cryic temperature regime (Hanks and Sime). This is consistent with the regression analysis based on mean annual soil temperature, where the warmer soils had larger responses to K fertilizer than did the colder soils. 2) As indicated by the family name, the fine textured soils

Table 21. Array of sites in order of decreasing percent yield response to K fertilizer and some soil taxonomic characteristics for each site.

Percent Y	Cooperator	Series	Classification	Temp. Regime	Moisture Regime	Family
124	Erpelding	Fort Collins	Ustollic Haplargid	Mesic	Aridic	Fine loamy
123	Holland (73)	Edgar	Ustollic Camborthid	Mesic	Aridic	Fine loamy
120	Visser	Evanston	Aridic Argibroll	Frigid	Aridic	Fine loamy
119	Daum	Absarokee	Typic Argibroll	Frigid	Ustic	Fine
118	Miklovich	Arnegard	Pachic Haplobroll	Frigid	Ustic	Fine loamy
117	Works (74)	Evanston	Audic Argiboroll	Frigid	Aridic	Fine loamy
114	Cash	Bainville	Ustic Torriorthent	Mesic	Ustic	Fine silty
114	Works (73)	Evanston	Aridic Argiboroll	Frigid	Aridic	Fine loamy
114	Pehl (74)	Chanta	Aridic Haploboroll	Frigid	Aridic	Fine loamy
111	Holland (74)	Deacon	Aridic Haplustoll	Mesic	Aridic	Fine loamy
109	Sime	Bozeman	Pachic Cryboroll	Cryic	Ustic	Fine silty
109	Jorgenson	Williams	Typic Argiboroll	Frigid	Ustic	Fine loamy
106	Lassila	Gerber	Vertic Argiboroll	Frigid	Ustic	Fine
104	Perry	Gerber	Vertic Argiboroll	Frigid	Ustic	Fine
98	Pehl (74)	Chanta	Aridic Haploboroll	Frigid	Aridic	Fine
93	Hanks	Amsterdam	Typic Cryoboroll	Cryic	Ustic	Fine silty
92	Helm	Cherry	Typic Ustochrept	Frigid	Ustic	Fine silty
83	Schaff	Manburn	Borollic Haplorgid	Frigid	Ardic	Loamy

responded to a lesser degree than did the coarse textured soils. In other words soils with a clay percentage of over 35% (fine) and those that had less than 15% sand and less than 35% clay (fine silt) responded less to K fertilizer than the soils that had over 15% sand and less than 35% clay (fine loamy).

Second, those parameters which were most highly related to winter wheat response to K are known to influence ion diffusion through soils. Thus, these results provide further support for the hypothesis that K^+ diffusion in soils is important in regulating K availability to crops. The development of a reliable soil test for K will probably require that some of these soil or site characteristics be considered so that the soil test has a closer functional relation to K diffusion in the soil.

Thirdly, results indicate that some or all of the significant variables could be incorporated for use in a reliable soil test. Those parameters which were most highly related to winter wheat response to K fertilizer can be readily determined in the field, from a soil series description, or from a sample taken for laboratory analysis. Properties of the A_p and B horizons provide the best correlations, so that deep sampling should not be required. However, it may be necessary to sample to a depth of more than 15 cm. which is the current practice.

Finally, these results provide further evidence that a single chemical extraction procedure will not provide the basis for a reliable soil test for this region. Certain extractable cation values (Ca^{++} concentration of the B horizon; ratio of K^+ to $(\text{Ca}^{++} + \text{Mg}^{++})^{\frac{1}{2}}$ in the ca horizon; Ca^{++} concentration of the 1st and 2nd horizons in sequence; Mg^{++} concentration of the 3rd horizon) were significantly related to yield response to K fertilizer when individual horizons were analyzed statistically. However, when all significant parameters (including these extractable cation values) were combined to determine which were most closely related to yield response, Ca^{++} concentration of the 2nd horizon in sequence was the only one significantly related at the 90% confidence level. All other significant parameters except pH of the 2nd horizon, are not those which can be obtained by soil extraction.

Further research is required to determine the cause-and-effect relations between crop response to K fertilizer and these significant soil and site characteristics. The present study was designed only to determine what significant relations might exist. Use of these results in developing a reliable K soil test will also require additional research. More years of data will be required at more sites, and other important crops of the region should be studied. However, present indications are that this research should lay the foundation for a reliable K soil test for the northern plains - intermountain

region based largely on soil classification parameters.

APPENDIX

SOIL SERIES:

EVANSTON CLAY LOAM

SURVEY SAMPLE NO.:

S78MT 15 5

LOCATION:

200 FT N 1330 FT W OF SE 1/4 CORNER OF SEC 24, T28N, R9E

CLASSIFICATION:

ARIDIC ARGIDHOLLIS; FINE-LOAMY, MIXED

SITE NO.:

78 5

SLOPE:

01%

AIR TEMPERATURE

ANNUAL: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

WATER TABLE:

DEPTH: CM.

PRECIPITATION:

CM.

PERMEABILITY:

MODERATELY SLOW

PHYSIOGRAPHY:

ALLUVIAL OR COLLUVIAL FANS

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

GLACIAL TILL

ELEVATION:

0844 METERS

KIND:

SUMMER: DEGREES F

SUMMER: DEGREES F

MONTH: DEGREES F

CONTROL SECTION LIMITS --

DRAINAGE CLASS: WELL DRAINED

MONTH SAMPLED:

MAY

ASPECT:

WEST

WINTER: DEGREES F

WINTER: DEGREES F

KIND: NO WATER TABLE

UPPER: CM LOWER: CM

STONINESS: CLASS

HORIZON

PROFILE DESCRIPTION

A P 0 - 15 CM. (0 - 6 IN.)
 GRAYISH BROWN (10YR 5/2) CLAY LOAM ; V DK GRAYISH BROWN (10YR 3/2) MOIST ;
 WEAK FINE CRUMB STRUCTURE ; SLIGHTLY STICKY, SLIGHTLY PLASTIC
 FRIABLE, HARD ; NONCALCAREOUS (HCL + 1N) ; CLEAR WAVY BOUNDARY .

B 21T 15 - 38 CM. (6 - 15 IN.)
 GRAYISH BROWN (10YR 5/2) CLAY LOAM ; DARK GRAYISH BROWN (10YR 4/2) MOIST ;
 WEAK TO MODERATE FINE & MEDIUM PRISMATIC STRUCTURE AND WEAK
 FINE & MEDIUM SUBANGULAR BLOCKY ; STICKY, PLASTIC, FRIABLE, HARD ;
 NONCALCAREOUS (HCL + 1N) ; GRADUAL WAVY BOUNDARY .

B 22T 38 - 56 CM. (15 - 22 IN.)
 DARK GRAYISH BROWN (10YR 4/2) CLAY LOAM ; V DK GRAYISH BROWN (10YR 3/2)
 MOIST ; WEAK MEDIUM PRISMATIC STRUCTURE AND WEAK MEDIUM
 SUBANGULAR BLOCKY ; STICKY, PLASTIC, FRIABLE, HARD ;
 NONCALCAREOUS (HCL + 1N) ; GRADUAL WAVY BOUNDARY .

B 3 56 - 69 CM. (22 - 27 IN.)
 GRAYISH BROWN (10YR 5/2) SILTY CLAY LOAM ; DARK GRAYISH BROWN (10YR 4/2)
 MOIST ; WEAK MEDIUM SUBANGULAR BLOCKY STRUCTURE ; STICKY, PLASTIC,
 FRIABLE, HARD ; MILDLY EFFERESCENT (HCL + 1N) ; GRADUAL WAVY
 BOUNDARY .

C 1CA 69 - 117 CM. (27 - 46 IN.)
 LIGHT GRAY (2.5Y 7/2) SILTY CLAY LOAM ; GRAYISH BROWN (2.5Y 5/2) MOIST ;
 STICKY, PLASTIC, FRIABLE, HARD ; VIOLENTLY EFFERESCENT (HCL + 1N) ;
 GRADUAL WAVY BOUNDARY .

C 2CA 117 - 152 CM. (46 - 60 IN.)
 LIGHT GRAY (2.5Y 7/2) SILTY CLAY LOAM ; GRAYISH BROWN (2.5Y 5/2) ; STICKY,
 PLASTIC, FIRM, HARD ; VIOLENTLY EFFERESCENT (HCL + 1N) .

REMARKS:

MARVIN WORKS 1973 CHEATEAU COUNTY

SOIL SERIES:

EVANSTON

SURVEY SAMPLE NO.:

ST8MT 57 18

LOCATION:

MADISON COUNTY, 1650 FT S & 100 FT. W OF THE NE CORNER OF S9, T35, R1W

CLASSIFICATION:

ARIDIC ARGIBOROLLS: FINE-LOAMY, MIXED

SITE NO.:

7R 18

SLOPE:

GENTLY SLOPING

AIR TEMPERATURE

ANNUAL: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

WATER TABLE:

DEPTH: CM.

PRECIPITATION:

333 CM.

PERMEABILITY:

MODERATE

PHYSIOGRAPHY:

STREAM, OUTWASH OR PLAINS TERRACES

MICRORELIEF:

ON SLOPE

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

ALLUVIUM

ELEVATION:

1500 METERS

KIND:

PLANE

SUMMER:

DEGREES F

WINTER:

DEGREES F

MONTH:

CONTROL SECTION LIMITS --

DRAINAGE CLASS:

WELL DRAINED

MONTH SAMPLED:

JULY

ASPECT:

EAST

WINTER:

DEGREES F

WINTER:

DEGREES F

KIND:

NO WATER TABLE

UPPER:

CM

LOWER:

CM

STONINESS:

CLASS

HORIZON

PROFILE DESCRIPTION

A P

0 - 12 CM. (0 - 5 IN.)

DARK GRAYISH BROWN (10YR 4/2) CRUSHED ; GRAVELLY HEAVY CLAY LOAM ;
 V DK GRAYISH BROWN (10YR 3/2) CRUSHED MOIST ; WEAK TO MODERATE FINE
 SUBANGULAR BLOCKY DRY STRUCTURE AND WEAK TO MODERATE VERY FINE & FINE
 GRANULAR DRY PARTING TO ; SLIGHTLY HARD, FRIABLE, SLIGHTLY STICKY,
 SLIGHTLY PLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ;
 COMMON TO MANY FINE VOID INTERSTITIAL PORES ; 15 PERCENT SAPROLITE
 FRAGMENTS > 2 MM ; NONCALCAREOUS (HCL) ; NEUTRAL PH- 7.0 ; ABRUPT
 SMOOTH BOUNDARY .

B 21T

12 - 30 CM. (5 - 12 IN.)

BROWN (10YR 4/3) CRUSHED ; GRAVELLY HEAVY CLAY LOAM ; DARK BROWN (10YR 3/3)
 CRUSHED MOIST ; STRONG MEDIUM & COARSE SUBANGULAR BLOCKY DRY STRUCTURE
 AND STRONG VERY FINE & FINE ANGULAR BLOCKY DRY PARTING TO ; HARD,
 FIRM, STICKY, PLASTIC ; COMMON TO MANY FINE ROOTS
 THROUGHOUT HORIZON ; COMMON FINE IRREGULAR AND TUBULAR PORES ; MANY
 DISTINCT V DK GRAYISH BROWN (10YR 3/2) CLAY SKINS
 IN HORIZONTAL & VERTICAL PED FACES ; 15 PERCENT SAPROLITE FRAGMENTS > 2 MM ;
 NONCALCAREOUS (HCL) ; NEUTRAL PH- 7.0 ; GRADUAL IRREGULAR BOUNDARY .

B 31

30 - 40 CM. (12 - 16 IN.)

YELLOWISH BROWN (10YR 5/4) CRUSHED ; DK. YELLOWISH BROWN (10YR 4/4) CRUSHED
 MOIST ; MODERATE MEDIUM & COARSE SUBANGULAR BLOCKY DRY STRUCTURE ;
 HARD, FRIABLE, SLIGHTLY STICKY, PLASTIC ; COMMON FINE ROOTS
 THROUGHOUT HORIZON ; MANY FINE VOID INTERSTITIAL PORES ; MANY
 DISTINCT CLAY SKINS AS BRIDGES BETWEEN SAND GRAINS ; 30 PERCENT SAPROLITE
 FRAGMENTS > 2 MM ; NONCALCAREOUS (HCL) ; MILDLY ALKALINE PH- 7.6 ;
 CLEAR WAVY BOUNDARY .

C 17CA

40 - 58 CM. (16 - 23 IN.)

WHITE (10YR 8/1) INTERIOR ; SANDY CLAY LOAM ; PALE BROWN (10YR 6/3)
 INTERIOR ; LIGHT GRAY (10YR 7/2) INTERIOR MOIST ; BROWN (10YR 5/3)
 INTERIOR MOIST ; MASSIVE ; SLIGHTLY HARD, FRIABLE, SLIGHTLY STICKY,
 SLIGHTLY PLASTIC ; COMMON TO MANY FINE ROOTS THROUGHOUT HORIZON ;
 COMMON TO MANY FINE IRREGULAR AND TUBULAR PORES ; 50 PERCENT SOFT
 MEDIUM & COARSE MASSES OF LIME ; VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ;
 MODERATELY ALKALINE PH- 8.2 ; CLEAR WAVY BOUNDARY .

C 20CA

58 - 122 CM. (23 - 48 IN.)

PALE BROWN (10YR 6/3) CRUSHED ; GRAVELLY FINE SANDY LOAM ; BROWN (10YR 5/3)
 CRUSHED MOIST ; MASSIVE ; SLIGHTLY HARD, VERY FRIABLE,
 SLIGHTLY STICKY, SLIGHTLY PLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ;
 FEW TO COMMON FINE VOID INTERSTITIAL PORES ; 20 PERCENT SAPROLITE
 FRAGMENTS > 2 MM ; 10 PERCENT SOFT FINE & MEDIUM MASSES OF LIME ;
 MODERATELY EFFERVESCENT (HCL) ; MODERATELY ALKALINE PH- 8.2 ; GRADUAL
 IRREGULAR BOUNDARY .

C 30

122 - 152 CM. (48 - 60 IN.)

LIGHT BROWNISH GRAY (10YR 6/2) CRUSHED ; GRAVELLY LOAMY FINE SAND ; BROWN
 (10YR 5/3) CRUSHED MOIST ; SINGLE GRAIN ; LOOSE, LOOSE,
 NONSTICKY, NONPLASTIC ; 30 PERCENT SAPROLITE FRAGMENTS ;
 MODERATELY EFFERVESCENT (HCL) ; MILDLY ALKALINE PH- 7.6 ; NOT REACHED
 BOUNDARY .

REMARKS:

ELMER VISSER

SOIL SERIES:

GERBER

SURVEY SAMPLE NO.:

S78MT 13 3

LOCATION:

200 FT N 100 S OF CENTER OF SEC SW 1/4 SEC 33T21NR5E

CLASSIFICATION:

VERTIC ARGIBOROLLS: FINE

SITE NO.:

78 3

SLOPE:

01%

AIR TEMPERATURE

ANNUAL: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

WATER TABLE:

DEPTH: CM.

PRECIPITATION:

CM.

PERMEABILITY:

SLOW

PHYSIOGRAPHY:

STREAM, OUTWASH OR PLAINS TERRACES

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

GLACIAL TILL
CALCAREOUS . HORIZONTAL

ELEVATION: 1067 METERS

KIND: CONCAVE

SUMMER: DEGREES F

SUMMER: DEGREES F

MONTH:

CONTROL SECTION LIMITS --

DRAINAGE CLASS: WELL DRAINED

MONTH SAMPLED: AUGUST

ASPECT: NORTHEAST

WINTER: DEGREES F

WINTER: DEGREES F

KIND: NO WATER TABLE

UPPER: CM LOWER: CM

STONINESS: CLASS

HORIZON

PROFILE DESCRIPTION

A P

0 - 15 CM. (0 - 6 IN.)
 GRAYISH BROWN (10YR 5/2) CRUSHED ; SILTY CLAY ; VERY DARK BROWN (10YR 2/2)
 CRUSHED MOIST ; MODERATE FINE & MEDIUM GRANULAR DRY STRUCTURE ;
 VERY STICKY , VERY PLASTIC , FRIABLE , VERY HARD ; NONCALCAREOUS
 (HCL + 1N) ; CLEAR WAVY BOUNDARY .

B 2T

15 - 33 CM. (6 - 13 IN.)
 DARK GRAYISH BROWN (10YR 4/2) CRUSHED ; CLAY ; VERY DARK GRAYISH BROWN (10YR 3/2)
 CRUSHED MOIST ; WEAK MEDIUM & COARSE PRISMATIC DRY STRUCTURE
 PARTING TO WEAK TO MODERATE MEDIUM SUBANGULAR BLOCKY DRY ; VERY HARD ,
 FRIABLE , VERY STICKY , VERY PLASTIC ; COMMON DISTINCT CLAY SKINS
 ON PED FACES ; NONCALCAREOUS (HCL + 1N) ; GRADUAL WAVY BOUNDARY .

B 3CA

33 - 64 CM. (13 - 25 IN.)
 GRAYISH BROWN (2.5Y 5/2) CRUSHED ; CLAY ; DARK GRAYISH BROWN (2.5Y 4/2)
 CRUSHED MOIST ; WEAK MEDIUM ANGULAR BLOCKY DRY STRUCTURE ; VERY HARD ,
 FIRM , VERY STICKY , VERY PLASTIC ; MILDLY EFFERVESCENT (HCL + 1N)
 DISCONTINUOUS ; CLEAR WAVY BOUNDARY .

C 1CA

63 - 96 CM. (25 - 38 IN.)
 LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED ; CLAY ; DARK GRAYISH BROWN (2.5Y 4/2)
 CRUSHED MOIST ; WEAK MEDIUM ANGULAR BLOCKY STRUCTURE ; VERY HARD ,
 VERY STICKY , FIRM , VERY PLASTIC ; MILDLY EFFERVESCENT (HCL + 1N)
 CONTINUOUS ; CLEAR WAVY BOUNDARY .

C 2

96 - 150 CM. (38 - 60 IN.)
 LIGHT BROWNISH GRAY (2.5Y 6/2) CRUSHED ; CLAY ; DARK GRAYISH BROWN (2.5Y 4/2)
 CRUSHED MOIST ; VERY WEAK MEDIUM ANGULAR BLOCKY DRY STRUCTURE ;
 VERY HARD , FIRM , STICKY , MODERATELY THIXOTROPIC ;
 MILDLY EFFERVESCENT (HCL + 1N) DISCONTINUOUS ; CLEAR WAVY BOUNDARY .

REMARKS:

HENRY LASSILA, CASCADE COUNTY

SOIL SERIES:

MANBURN VARIANT

SURVEY SAMPLE NO.:

S78MT 37 3

LOCATION: T5N R22E SEC 6 NE 1/4
CLASSIFICATION:

SITE NO.: 78 3
SLOPE: 05%
AIR TEMPERATURE
SOIL TEMPERATURE
WATER TABLE:
PRECIPITATION:
PERMEABILITY:
PHYSIOGRAPHY:
MICRORELIEF:
VEGETATION:
PARENT MATERIAL:

COUNTY: GOLDEN VALLEY
CLASS: GENTLY SLOPING
ANNUAL: DEGREES F
ANNUAL: DEGREES F
DEPTH: CM.
CP.
MODERATE
ROLLING OR HILLY UPLANDS
ON SLOPE
CROPS - DRYLAND
PARTLY WEATHERED
CALCAREOUS SANDSTONE

ELEVATION: METERS
KIND: CONVEX
SUMMER: DEGREES F
SUMMER: DEGREES F
MONTH:
CONTROL SECTION LIMITS --
DRAINAGE CLASS: WELL DRAINED

MONTH SAMPLED: JULY
ASPECT: NORTH
WINTER: DEGREES F
WINTER: DEGREES F
KIND: NO WATER TABLE
UPPER: CM LOWER: CM
STONINESS: CLASS 0

RESTIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE
AND LITHOLOGY AND COMPOSITION UNKNOWN . HORIZONTAL

HORIZON

PROFILE DESCRIPTION

A 11P

0 - 10 CM. (0 - 4 IN.)
BROWN (10YR 4/3) CRUSHED ; SANDY LOAM ; DARK BROWN (10YR 3/3) CRUSHED
MOIST ; WFAK TO MODERATE FINE & MEDIUM GRANULAR DRY STRUCTURE ;
COMMON MEDIUM ROOTS THROUGHOUT HORIZON ; FEW TO COMMON FINE TUBULAR
PORES ; FEW SANDSTONE FRAGMENTS ; MILDLY EFFERVESCENT (HCL + 1N)
CONTINUOUS ; CLEAR SMOOTH BOUNDARY .

A 12P

10 - 18 CM. (4 - 7 IN.)
BROWN (10YR 4/3) CRUSHED ; SANDY CLAY LOAM ; DARK BROWN (10YR 3/3) CRUSHED
MOIST ; MODERATE COARSE PLATY DRY STRUCTURE ; SLIGHTLY STICKY ,
SLIGHTLY PLASTIC , VERY FRIABLE , SLIGHTLY HARD ; COMMON
FINE & MEDIUM ROOTS THROUGHOUT HORIZON ; FEW TO COMMON FINE TUBULAR
PORES ; FEW FRAGMENTS ; MILDLY EFFERVESCENT (HCL + 1N) CONTINUOUS ;
ABRUPT SMOOTH BOUNDARY .

B 20T

18 - 28 CM. (7 - 11 IN.)
BROWN (10YR 5/3) CRUSHED ; SANDY CLAY LOAM ; BROWN (10YR 4/3) CRUSHED
MOIST ; NONSTICKY , NONPLASTIC , VERY FRIABLE , SLIGHTLY HARD ;
COMMON MEDIUM & COARSE ROOTS THROUGHOUT HORIZON ; FEW FINE TUBULAR
PORES ; FEW FRAGMENTS ; MODERATELY EFFERVESCENT (HCL + 1N) CONTINUOUS ;
ABRUPT SMOOTH BOUNDARY .

C 1CA

28 - 36 CM. (11 - 14 IN.)
LT. YELLOWISH BROWN (2.5Y 6/3) CRUSHED ; SANDY LOAM ; OLIVE BROWN (2.5Y 4/3)
CRUSHED MOIST ; MASSIVE DRY ; NONSTICKY , NONPLASTIC , VERY FRIABLE ,
SLIGHTLY HARD ; FEW TO COMMON MEDIUM ROOTS THROUGHOUT HORIZON ; FEW
FINE TUBULAR PORES ; FEW MIXED SEDIMENTARY FRAGMENTS ;
VIOLENTLY EFFERVESCENT (HCL + 1N) CONTINUOUS ; ABRUPT SMOOTH BOUNDARY .

R

36 - CM. (14 - IN.)

REMARKS:

PLOT LOCATED ON NED SCHAFF OF BELMOUNT GOLDEN VALLEY COUNTY

SOIL SERIES:

FORT COLLINS

SURVEY SAMPLE NO.:

S78MT 87 15

LOCATION:

ON LARRY ERPLDING SE 1/4, SEC 15, T6N R41E

CLASSIFICATION:

USTOLIC MAPLARGIDS; FINE-LOAMY, MIXED, MESTC

SITE NO.: 78 15

COUNTY: ROSEBUD

ELEVATION: 8838 METERS

MONTH SAMPLED:

SLOPE: 04%

CLASS:

KIND:

ASPECT: SOUTHWEST

AIR TEMPERATURE

ANNUAL:

DEGREES F

SUMMER:

DEGREES F

WINTER:

DEGREES F

SOIL TEMPERATURE

ANNUAL:

DEGREES F

SUMMER:

DEGREES F

WINTER:

DEGREES F

WATER TABLE:

DEPTH:

CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: CM LOWER: CM

PERMEABILITY:

DRAINAGE CLASS:

STONINESS: CLASS

PHYSIOGRAPHY:

VEGETATION:

PARENT MATERIAL:

ALLUVIUM

HORIZON

PROFILE DESCRIPTION

A	P	0 - 15 CM. (0 - 6 IN.) GRAYISH BROWN (10YR 5/2) LOAM ; DARK GRAYISH BROWN (10YR 4/2) MOIST ; WEAK MEDIUM & COARSE SUBANGULAR BLOCKY STRUCTURE .
B	3CA	43 - 53 CM. (17 - 21 IN.) LIGHT BROWNISH GRAY (10YR 6/2) CLAY LOAM ; GRAYISH BROWN (10YR 5/2) MOIST ; WEAK MEDIUM & COARSE PRISMATIC STRUCTURE ; MODERATELY EFFERVESCENT (HCL + 1N) ; GRADUAL SMOOTH BOUNDARY .
C	1CA	53 - 86 CM. (21 - 34 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) SANDY CLAY LOAM ; GRAYISH BROWN (2.5Y 5/2) MOIST ; WEAK COARSE SUBANGULAR BLOCKY STRUCTURE ; VIOLENTLY EFFERVESCENT (HCL + 1N) ; GRADUAL SMOOTH BOUNDARY .
C	2	86 - 119 CM. (34 - 47 IN.) LIGHT GRAY (2.5Y 7/2) LOAM ; LIGHT BROWNISH GRAY (2.5Y 6/2) MOIST ; MASSIVE ; MODERATELY EFFERVESCENT (HCL + 1N) .
C	3	119 - 152 CM. (47 - 60 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) SANDY LOAM ; GRAYISH BROWN (2.5Y 5/2) MOIST ; MASSIVE ; MODERATELY EFFERVESCENT (HCL + 1N) .

REMARKS:

SOIL SERIES:

DEACON

SURVEY SAMPLE NO.:

ST8NT 87 17

LOCATION:

ROSEBUD CO SW1/4 OF NW1/4 S23, R42E, T6N

CLASSIFICATION:

ARIDIC MAPLUSTOLLS: FINE-LOAMY, MIXED, MESIC

SITE NO.:

ROSEBUD

ELEVATION: 8853 METERS

MONTH SAMPLED: JULY

SLOPE:

CLASS: NEARLY LEVEL

KIND: PLANE

ASPECT: NORTHEAST

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: 025 CM LOWER: 100 CM

PERMEABILITY:

MODERATE

DRAINAGE CLASS: WELL DRAINED

STONINESS: CLASS 0

PHYSIOGRAPHY:

STREAM, OUTWASH OR PLAINS TERRACES

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

ALLUVIUM
MIXED LITHOLOGY

HORIZON

PROFILE DESCRIPTION

A 11P

0 - 10 CM. (0 - 4 IN.)
 BROWN (10YR 5/3) CRUSHED ; DARK BROWN (10YR 3/3) CRUSHED MOIST ;
 MODERATE FINE GRANULAR STRUCTURE ; SOFT, FRIABLE,
 SLIGHTLY STICKY, SLIGHTLY PLASTIC ; MANY FINE ROOTS
 THROUGHOUT HORIZON ; NONCALCAREOUS (HCL) ; ABRUPT SMOOTH BOUNDARY .

A 12P

10 - 20 CM. (4 - 8 IN.)
 BROWN (10YR 5/3) CRUSHED ; SANDY LOAM ; DARK BROWN (10YR 3/3) CRUSHED
 MOIST ; WEAK COARSE PRISMATIC STRUCTURE ; SLIGHTLY HARD, FRIABLE,
 SLIGHTLY STICKY, SLIGHTLY PLASTIC ; MANY FINE ROOTS
 THROUGHOUT HORIZON ; MANY FINE TUBULAR PORES ; NONCALCAREOUS (HCL) ;
 ABRUPT SMOOTH BOUNDARY .

B 20

20 - 38 CM. (8 - 15 IN.)
 BROWN (10YR 5/3) CRUSHED ; LOAM ; DARK BROWN (10YR 3/3) CRUSHED MOIST ;
 WEAK COARSE PRISMATIC STRUCTURE ; SLIGHTLY HARD, FRIABLE,
 SLIGHTLY STICKY, SLIGHTLY PLASTIC ; MANY FINE ROOTS
 THROUGHOUT HORIZON ; MANY FINE TUBULAR PORES ; NONCALCAREOUS (HCL) ;
 CLEAR SMOOTH BOUNDARY .

C 10CA

38 - 51 CM. (15 - 20 IN.)
 PALE BROWN (10YR 6/3) CRUSHED ; SANDY LOAM ; BROWN (10YR 4/3) CRUSHED
 MOIST ; MASSIVE ; SOFT, VERY FRIABLE, SLIGHTLY STICKY,
 SLIGHTLY PLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY
 FINE TUBULAR PORES ; COMMON THREAD-LIKE MASSES OF LINE ;
 VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; CLEAR SMOOTH BOUNDARY .

C 20

51 - 152 CM. (20 - 60 IN.)
 VERY PALE BROWN (10YR 7/3) CRUSHED ; LOAM ; YELLOWISH BROWN (10YR 5/4)
 CRUSHED MOIST ; MASSIVE ; SOFT, VERY FRIABLE, SLIGHTLY STICKY,
 SLIGHTLY PLASTIC ; FEW FINE ROOTS THROUGHOUT HORIZON ; MANY FINE
 TUBULAR PORES ; FEW FINE MASSES OF LINE ; MODERATELY EFFERVESCENT (HCL) .

REMARKS:

DON HOLLAND

SOIL SERIES:

CHAMTA

SURVEY SAMPLE NO.:

S78MT 79 16

LOCATION:

PRAIRIE COUNTY SE 1/4 OF SW 1/4 S20,T12N,R52E

CLASSIFICATION:

ARIDIC HAPLOBOROLLS; FINE-LOAMY OVER SANDY OR SANDY-SKELETAL, MIXED

SITE NO.:

78 16

SLOPE:

02%

AIR TEMPERATURE

ANNUAL: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

WATER TABLE:

DEPTH: CM.

PRECIPITATION:

CM.

PERMEABILITY:

MODERATELY SLOW

PHYSIOGRAPHY:

STREAM, OUTWASH OR PLAINS TERRACES

VEGETATION:

CROPS - ORYLAND

PARENT MATERIAL:

ALLUVIUM

ELEVATION:

0893 METERS

KIND:

SUMMER: DEGREES F

SUMMER: DEGREES F

MONTH:

CONTROL SECTION LIMITS --

DRAINAGE CLASS: WELL DRAINED

MONTH SAMPLED:

JULY

ASPECT:

NORTH

WINTER: DEGREES F

WINTER: DEGREES F

KIND: NO WATER TABLE

UPPER: 025 CM LOWER: 100 CM

STONINESS: CLASS 0

HORIZON

PROFILE DESCRIPTION

A 11P

0 - 13 CM. (0 - 5 IN.)

BROWN (10YR 5/3) CRUSHED ; LOAM ; V DK GRAYISH BROWN (10YR 3/2) CRUSHED
 MOIST ; STRONG FINE GRANULAR STRUCTURE ; SLIGHTLY HARD, FRIABLE,
 SLIGHTLY STICKY, SLIGHTLY PLASTIC ; MANY FINE ROOTS
 THROUGHOUT HORIZON ; NONCALCAREOUS (HCL) ; ABRUPT SMOOTH BOUNDARY .

A 12P

13 - 23 CM. (5 - 9 IN.)

DARK BROWN (10YR 3/3) CRUSHED MOIST ; LOAM ; STRONG VERY COARSE PLATY
 STRUCTURE AND MODERATE FINE ANGULAR BLOCKY PARTING TO ; HARD
 FIRM, SLIGHTLY STICKY, SLIGHTLY PLASTIC ; MANY FINE ROOTS
 THROUGHOUT HORIZON ; MANY FINE TUBULAR PORES ; NONCALCAREOUS (HCL) ;
 CLEAR SMOOTH BOUNDARY .

B 21

23 - 35 CM. (9 - 14 IN.)

BROWN (10YR 5/3) CRUSHED ; LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ;
 MODERATE COARSE PRISMATIC STRUCTURE ; SLIGHTLY HARD, FRIABLE,
 SLIGHTLY STICKY, SLIGHTLY PLASTIC ; MANY FINE ROOTS
 THROUGHOUT HORIZON ; MANY FINE TUBULAR PORES ; NONCALCAREOUS (HCL) ;
 CLEAR SMOOTH BOUNDARY .

B 22

35 - 58 CM. (14 - 23 IN.)

BROWN (10YR 5/3) CRUSHED ; LOAM ; BROWN (10YR 4/3) CRUSHED MOIST ;
 WEAK COARSE PRISMATIC STRUCTURE ; SLIGHTLY HARD, FRIABLE,
 SLIGHTLY STICKY, SLIGHTLY PLASTIC ; MANY FINE ROOTS
 THROUGHOUT HORIZON ; MANY FINE TUBULAR PORES ; NONCALCAREOUS (HCL) ;
 CLEAR SMOOTH BOUNDARY .

C 10CA

58 - 89 CM. (23 - 35 IN.)

LIGHT GRAY (2.5Y 7/2) CRUSHED ; SILT LOAM ; BROWN (10YR 5/3) CRUSHED
 MOIST ; MASSIVE ; SLIGHTLY HARD, FRIABLE, SLIGHTLY STICKY,
 SLIGHTLY PLASTIC ; COMMON FINE ROOTS THROUGHOUT HORIZON ; MANY
 FINE TUBULAR PORES ; COMMON THREAD-LIKE MASSES OF LIME ;
 VIOLENTLY EFFERVESCENT (HCL) CONTINUOUS ; CLEAR SMOOTH BOUNDARY .

IIC 20

89 - 152 CM. (35 - 60 IN.)

GRAVELLY GRAVEL ; SINGLE GRAIN .

REMARKS:

JOHN PEHL

SOIL SERIES:

WILLIAM SERIES

SURVEY SAMPLE NO.:
LOCATION:
CLASSIFICATION:

SW 1/4 OF NE 1/2 SEC 10 T31N, R 36E
TYPIC ARGIBOROLLS; FINE-LOAMY, MIXED

STONY 5 13

SITE NO.: 78 13
SLOPE: 05%
AIR TEMPERATURE
SOIL TEMPERATURE
WATER TABLE:
PRECIPITATION:
PERMEABILITY:
PHYSIOGRAPHY:
VEGETATION:
PARENT MATERIAL:

COUNTY: BLAINE
CLASS: MODERATELY SLOPING
ANNUAL: DEGREES F
ANNUAL: DEGREES F
DEPTH: CM.
CM.

ELEVATION: 0823 METERS

KIND:
SUMMER: DEGREES F
SUMMER: DEGREES F
MONTH:
CONTROL SECTION LIMITS --
DRAINAGE CLASS: WELL DRAINED

MONTH SAMPLED: MAY
ASPECT: NORTH
WINTER: DEGREES F
WINTER: DEGREES F
KIND: NO WATER TABLE
UPPER: CM LOWER: CM
STONINESS: CLASS

ROLLING OR HILLY UPLANDS
CROPS - DRYLAND
GLACIAL TILL

HORIZON

PROFILE DESCRIPTION

A P	0 - 13 CM. (0 - 5 IN.) DARK GRAYISH BROWN (10YR 4/2) LOAM ; V DK GRAYISH BROWN (10YR 3/2) MOIST ; MODERATE FINE CRUMB STRUCTURE ; SLIGHTLY STICKY, SLIGHTLY PLASTIC ; FRIABLE ; NONCALCAREOUS (HCL + 1N) ; ABRUPT WAVY BOUNDARY .
B 21T	13 - 23 CM. (5 - 9 IN.) BROWN (10YR 4/3) CLAY LOAM ; BROWN (10YR 5/3) ; V DK GRAYISH BROWN (10YR 3/2) MOIST ; DARK BROWN (10YR 3/3) MOIST ; STRONG MEDIUM PRISMATIC STRUCTURE ; STICKY, PLASTIC, FRIABLE, HARD ; NONCALCAREOUS (HCL + 1N) ; ABRUPT BOUNDARY .
B 22T	23 - 36 CM. (9 - 14 IN.) LIGHT OLIVE BROWN (2.5Y 5/3) CLAY LOAM ; OLIVE BROWN (2.5Y 4/3) MOIST ; MODERATE MEDIUM PRISMATIC STRUCTURE ; STICKY, PLASTIC, FRIABLE, ; HARD ; NONCALCAREOUS (HCL + 1N) ; CLEAR BOUNDARY .
B 23T CA	36 - 46 CM. (14 - 18 IN.) LT. YELLOWISH BROWN (2.5Y 6/3) CLAY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/3) MOIST ; WEAK TO MODERATE MEDIUM PRISMATIC STRUCTURE ; STICKY, ; SLIGHTLY PLASTIC, VERY FRIABLE, HARD ; MILDLY EFFERVESCENT (HCL + 1N) ; CLEAR BOUNDARY .
B 3CA	46 - 56 CM. (18 - 22 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CLAY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/3) MOIST ; WEAK MEDIUM & COARSE PRISMATIC STRUCTURE ; STICKY, ; SLIGHTLY PLASTIC, VERY FRIABLE, HARD ; MILDLY EFFERVESCENT (HCL + 1N) ; GRADUAL BOUNDARY .
C 1CA	56 - 86 CM. (22 - 34 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) CLAY LOAM ; LIGHT OLIVE BROWN (2.5Y 5/3) MOIST ; WEAK COARSE PRISMATIC STRUCTURE ; STICKY, ; SLIGHTLY PLASTIC, VERY FRIABLE, HARD ; MILDLY EFFERVESCENT (HCL + 1N) ; GRADUAL BOUNDARY .

REMARKS:

JOHN JERGENSEN BLAINE COUNTY

SOIL SERIES:

EVANSTON LOAM

SURVEY SAMPLE NO.:

S78MT 15 6

LOCATION:

600 FT N 200 FT W OF SE CORNER SEC 34, T29N R9E

CLASSIFICATION:

ARIDIC ARGIBOROLLS; FINE-LOAMY, MIXED

SITE NO.: 78 6

COUNTY: CHOUTEAU

ELEVATION: 0844 METERS

MONTH SAMPLED: JULY

SLOPE: 01%

CLASS: NEARLY LEVEL

KIND:

ASPECT: NORTHWEST

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH: CONTROL SECTION LIMITS --

KIND: NO WATER TABLE

PRECIPITATION:

CM.

DRAINAGE CLASS: WELL DRAINED

UPPER: CM LOWER: CM

PERMEABILITY:

MODERATELY SLOW

STONINESS: CLASS 0

PHYSIOGRAPHY:

ALLUVIAL OR COLLUVIAL FANS

MICRORELIEF:

ON SLOPE

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

GLACIAL TILL

LITHOLOGY AND COMPOSITION UNKNOWN. HORIZONTAL

HORIZON

PROFILE DESCRIPTION

A P

0 - 13 CM. (0 - 5 IN.)
 GRAYISH BROWN (10YR 5/2) CRUSHED; SILT LOAM; V DK GRAYISH BROWN (10YR 3/2)
 CRUSHED MOIST; WEAK FINE GRANULAR DRY STRUCTURE; SLIGHTLY HARD
 FRIABLE, STICKY, PLASTIC; NONCALCAREOUS (HCL + 1N); CLEAR WAVY
 BOUNDARY.

B 21T

15 - 25 CM. (6 - 10 IN.)
 GRAYISH BROWN (10YR 5/2) CRUSHED; CLAY LOAM; DARK GRAYISH BROWN (10YR 4/2)
 CRUSHED MOIST; WEAK TO MODERATE MEDIUM & COARSE PRISMATIC STRUCTURE;
 SLIGHTLY HARD, FRIABLE, STICKY, PLASTIC; NONCALCAREOUS (HCL + 1N);
 GRADUAL WAVY BOUNDARY.

B 3C1

25 - 69 CM. (10 - 27 IN.)
 WHITE (2.5Y 8/2) LOAM; DARK GRAYISH BROWN (2.5Y 4/2) MOIST;
 LIGHT BROWNISH GRAY (2.5Y 6/2); VERY WEAK MEDIUM ANGULAR BLOCKY STRUCTURE;
 SLIGHTLY STICKY, SLIGHTLY PLASTIC, VERY FRIABLE, SLIGHTLY HARD;
 MILDLY EFFERESCENT (HCL + 1N); GRADUAL WAVY BOUNDARY.
 WHITE (2.5Y 8/2) SILT LOAM; DARK GRAYISH BROWN (2.5Y 4/2) MOIST;
 LIGHT BROWNISH GRAY (2.5Y 6/2); SLIGHTLY STICKY, SLIGHTLY PLASTIC;
 VERY FRIABLE, SLIGHTLY HARD; VIOLENTLY EFFERESCENT (HCL + 1N);
 GRADUAL WAVY BOUNDARY.

C 2

117 - 152 CM. (46 - 60 IN.)
 LIGHT BROWNISH GRAY (2.5Y 6/2) CLAY LOAM; GRAYISH BROWN (2.5Y 5/2) MOIST;
 STICKY, PLASTIC, FRIABLE, SLIGHTLY HARD; MILDLY EFFERESCENT
 (HCL + 1N).

REMARKS:

MARVIN WORKS, 1974 CHEATEAU COUNTY

SOIL SERIES:

GERBER CLAY LOAM

SURVEY SAMPLE NO.:

S78MT 15 7

LOCATION:

SE 1/4 OF SE 1/4 OF SEC. 21, T23N, R10E

CLASSIFICATION:

VERTIC ARGISBOROLLS; FINE, MONTMORILLONITIC

SITE NO.: 78 7

COUNTY: CHOUTEAU

ELEVATION: 0945 METERS

MONTH SAMPLED: MAY

SLOPE: 02%

CLASS:

KIND:

ASPECT: NORTHWEST

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: CM LOWER: CM

PERMEABILITY:

MODERATELY SLOW

DRAINAGE CLASS: WELL DRAINED

STONINESS: CLASS

PHYSIOGRAPHY:

ALLUVIAL OR COLLUVIAL FANS

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

GLACIAL TILL

HORIZON

PROFILE DESCRIPTION

A P 0 - 15 CM. (0 - 6 IN.)
 DARK GRAYISH BROWN (10YR 4/2) CLAY LOAM ; VERY DARK GRAY (10YR 3/1) MOIST ;
 WEAK FINE CRUMB STRUCTURE ; STICKY , PLASTIC , FRIABLE , HARD ;
 NONCALCAREOUS (HCL + 1N) ; CLEAR WAVY BOUNDARY .

B 2T 15 - 36 CM. (6 - 14 IN.)
 BROWN (10YR 5/3) ; BROWN (10YR 4/3) MOIST ; WEAK TO MODERATE
 FINE & MEDIUM PRISMATIC STRUCTURE ; STICKY , PLASTIC , FRIABLE ,
 HARD ; NONCALCAREOUS (HCL + 1N) ; GRADUAL WAVY BOUNDARY .

B 3CA 36 - 43 CM. (14 - 17 IN.)
 LIGHT BROWNISH GRAY (2.5Y 6/2) ; GRAYISH BROWN (2.5Y 5/2) MOIST ; WEAK
 MEDIUM PRISMATIC STRUCTURE PARTING TO WEAK MEDIUM SUBANGULAR BLOCKY ;
 STICKY , PLASTIC , FRIABLE , HARD ; MILDLY EFFERVESCENT (HCL + 1N) ;
 GRADUAL WAVY BOUNDARY .

C 1CA 43 - 97 CM. (17 - 38 IN.)
 LIGHT GRAY (2.5Y 7/2) CLAY LOAM ; GRAYISH BROWN (2.5Y 5/2) MOIST ;
 VERY WEAK SUBANGULAR BLOCKY STRUCTURE ; STICKY , PLASTIC , FRIABLE ,
 HARD ; VIOLENTLY EFFERVESCENT (HCL + 1N) ; GRADUAL WAVY BOUNDARY .

C 2 97 - 122 CM. (38 - 48 IN.)
 LIGHT BROWNISH GRAY (2.5Y 6/2) CLAY LOAM ; GRAYISH BROWN (2.5Y 5/2) MOIST ;
 STICKY , PLASTIC , FRIABLE , VERY HARD ; MILDLY EFFERVESCENT (HCL + 1N) ;
 GRADUAL WAVY BOUNDARY .

C 3 122 - 152 CM. (48 - 60 IN.)
 LIGHT BROWNISH GRAY (2.5Y 6/2) ; GRAYISH BROWN (2.5Y 5/2) MOIST ;
 SLIGHTLY STICKY , PLASTIC , FRIABLE , HARD ; MILDLY EFFERVESCENT
 (HCL + 1N) .

REMARKS:

LORIN PERRY 1973 CHOUTEAU COUNTY

SOIL SERIES:

ABSAROOKEE CLAY

SURVEY SAMPLE NO.:

ST8NT 111 10

LOCATION:

WILLIAM DAUM (RANCH) YELLOWSTONE CT. SW 1/4 SEC 18, T4S R26E

CLASSIFICATION:

TYPIC ARGISBOROLLS: FINE, MONTMORILLONITIC

SITE NO.: 78 10

COUNTY: YELLOWSTONE

ELEVATION: 1219 METERS

MONTH SAMPLED:

SLOPE: 02%

CLASS:

KIND:

ASPECT: EAST

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: CM LOWER: CM

PERMEABILITY:

MODERATELY SLOW

DRAINAGE CLASS: WELL DRAINED

STONINESS: CLASS

PHYSIOGRAPHY:

ROLLING OR HILLY UPLANDS

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

RESIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE

HORIZON

PROFILE DESCRIPTION

A P

0 - 10 CM. (0 - 4 IN.)
 GRAYISH BROWN (10YR 5/2) CLAY LOAM ; DARK GRAYISH BROWN (10YR 4/2) MOIST ;
 WEAK FINE GRANULAR STRUCTURE ; STICKY , PLASTIC , FRIABLE ,
 SOFT ; NONCALCAREOUS (HCL + 1N) ; CLEAR WAVY BOUNDARY .

B 21T

10 - 33 CM. (4 - 13 IN.)
 BROWN (10YR 4/3) CLAY LOAM ; DARK BROWN (10YR 3/3) MOIST ; MODERATE
 MEDIUM PRISMATIC STRUCTURE AND MODERATE MEDIUM ANGULAR BLOCKY ; STICKY ,
 PLASTIC , FRIABLE , SLIGHTLY HARD ; NONCALCAREOUS (HCL + 1N) ; GRADUAL
 BOUNDARY .

B 22T

33 - 41 CM. (13 - 16 IN.)
 BROWN (10YR 5/3) CLAY ; BROWN (10YR 4/3) MOIST ; MODERATE MEDIUM
 PRISMATIC STRUCTURE AND MODERATE MEDIUM ANGULAR BLOCKY ; STICKY ,
 PLASTIC , FRIABLE , SLIGHTLY HARD ; NONCALCAREOUS (HCL + 1N) ; GRADUAL
 BOUNDARY .

C 1CA

41 - CM. (16 - IN.)
 LIGHT BROWNISH GRAY (2.5Y 6/2) CLAY LOAM ; GRAYISH BROWN (2.5Y 5/2) MOIST ;
 MASSIVE ; STICKY , PLASTIC , FRIABLE , SLIGHTLY HARD ;
 MODERATELY EFFERVESCENT (HCL + 1N) .

REMARKS:

SOIL SERIES:

AMSTERDAM SILT

SURVEY SAMPLE NO.:

STONY 31 1

LOCATION:

V HANKS FERTILIZER TEST PLOT SOUTHWEST OF BOZEMAN SE 1/4 OF SW 1/4 SEC 32, T25R5E

CLASSIFICATION:

TYPIC CRYOBOROLLS; PINE-SILTY, MIXED

SITE NO.:

78 1 COUNTY: GALLATIN

ELEVATION: 1590 METERS

MONTH SAMPLED: JULY

SLOPE:

02%

CLASS:

KIND:

ASPECT: EAST

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: 20 DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH: CONTROL SECTION LIMITS --

KIND: NO WATER TABLE

PRECIPITATION:

CM.

DRAINAGE CLASS: WELL DRAINED

UPPER: CM LOWER: CM

PERMEABILITY:

MODERATE

STONINESS: CLASS

PHYSIOGRAPHY:

VEGETATION:

PARENT MATERIAL: EOLIAN, LOESS

HORIZON

PROFILE DESCRIPTION

A P 0 - 18 CM. (0 - 7 IN.)
 DARK GRAYISH BROWN (10YR 4/2) SILT LOAM ; BLACK (10YR 2/1) MOIST ;
 MODERATE FINE GRANULAR STRUCTURE ; SLIGHTLY STICKY , PLASTIC ,
 VERY FRIABLE , SLIGHTLY HARD ; ABRUPT SMOOTH BOUNDARY .

B 2T 18 - 38 CM. (7 - 15 IN.)
 GRAYISH BROWN (10YR 5/2) SILTY CLAY LOAM ; BROWN (10YR 4/3) MOIST ;
 MODERATE MEDIUM PRISMATIC STRUCTURE AND MODERATE FINE ANGULAR BLOCKY ;
 STICKY , PLASTIC , FRIABLE , HARD ; CLEAR SMOOTH BOUNDARY .

B 3 38 - 48 CM. (15 - 19 IN.)
 PALE BROWN (10YR 6/3) SILT LOAM ; BROWN (10YR 5/3) MOIST ; MODERATE
 MEDIUM PRISMATIC STRUCTURE AND WEAK MEDIUM ANGULAR BLOCKY ;
 SLIGHTLY STICKY , SLIGHTLY PLASTIC , VERY FRIABLE , HARD ; CLEAR
 SMOOTH BOUNDARY .

C 1CA 48 - 76 CM. (19 - 30 IN.)
 LIGHT GRAY (10YR 7/2) SILT LOAM ; WHITE (10YR 8/2) ; PALE BROWN (10YR 6/3)
 MOIST ; LIGHT GRAY (10YR 7/2) MOIST ; WEAK COARSE PRISMATIC
 STRUCTURE ; STICKY , PLASTIC , FRIABLE , HARD ; GRADUAL SMOOTH
 BOUNDARY .

C 2CA 76 - 152 CM. (30 - 60 IN.)
 LIGHT GRAY (10YR 7/2) VERY FINE SANDY LOAM ; GRAYISH BROWN (10YR 5/2)
 MOIST ; MASSIVE ; SLIGHTLY STICKY , PLASTIC , , SLIGHTLY HARD .

REMARKS:

SOIL SERIES:

ROZEMAN SILT LOAM

SURVEY SAMPLE NO.:

578MT 31 16

LOCATION:

T2S R5E SEC 31 SW 1/4

CLASSIFICATION:

SITE NO.: 78 16

COUNTY: GALLATIN

ELEVATION: METERS

MONTH SAMPLED: AUGUST

SLOPE: 20%

CLASS: NEARLY LEVEL

KIND: CONCAVE

ASPECT: NORTHEAST

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: CM LOWER: CM

PERMEABILITY:

MODERATELY SLOW

DRAINAGE CLASS: WELL DRAINED

STONINESS: CLASS

PHYSIOGRAPHY:

ROLLING OR HILLY UPLANDS

MICRORELIEF:

ON CREST AND SLOPE

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

HIGHLY WEATHERED FOLIAN, LOESS

CALCAREOUS. HORIZONTAL

HORIZON

PROFILE DESCRIPTION

A 11P

3 - 12 CM. (0 - 5 IN.)
 V DK GRAYISH BROWN (10YR 3/2) CRUSHED ; HEAVY SILT LOAM ; BLACK (10YR 2/1)
 CRUSHED WET ; MODERATE TO STRONG MEDIUM & COARSE GRANULAR MOIST
 STRUCTURE ; STICKY , FRIABLE , PLASTIC , SLIGHTLY HARD ; MANY
 FINE & MEDIUM ROOTS THROUGHOUT HORIZON ; COMMON TUBULAR CONTINUOUS PORES ,
 FINE PORES ; NONCALCAREOUS (HCL + IN) ; MILDLY ALKALINE PH- 7.6 ;
 ABRUPT SMOOTH BOUNDARY .

A 12P

13 - 23 CM. (5 - 9 IN.)
 DARK BROWN (10YR 3/3) CRUSHED ; HEAVY SILT LOAM ; V DK GRAYISH BROWN (10YR 3/2)
 CRUSHED MOIST ; WEAK TO MODERATE COARSE PLATY MOIST STRUCTURE
 PARTING TO WEAK TO MODERATE COARSE ANGULAR BLOCKY MOIST ; STICKY ,
 PLASTIC , FIRM , VERY HARD ; MANY FINE & MEDIUM ROOTS
 THROUGHOUT HORIZON ; TUBULAR PORES , FEW TO COMMON FINE PORES ;
 NONCALCAREOUS (HCL + IN) ; ABRUPT SMOOTH BOUNDARY .

B 21T

23 - 43 CM. (9 - 17 IN.)
 BROWN (10YR 5/3) CRUSHED ; SILTY CLAY LOAM ; BROWN (10YR 4/3) CRUSHED
 MOIST ; MODERATE TO STRONG COARSE PRISMATIC MOIST STRUCTURE ;
 SLIGHTLY STICKY , PLASTIC , VERY FRIABLE , SOFT ; COMMON
 FINE & MEDIUM ROOTS THROUGHOUT HORIZON ; COMMON TO MANY FINE & MEDIUM
 TUBULAR PORES ; NONCALCAREOUS (HCL + IN) ; CLEAR SMOOTH BOUNDARY .

B 3CA

43 - 53 CM. (17 - 21 IN.)
 PALE BROWN (10YR 6/3) CRUSHED ; SILT LOAM ; BROWN (10YR 5/3) MOIST ;
 WEAK TO MODERATE COARSE ANGULAR BLOCKY MOIST STRUCTURE ; SLIGHTLY STICKY ,
 PLASTIC , VERY FRIABLE , SLIGHTLY HARD ; COMMON FINE & MEDIUM ROOTS
 THROUGHOUT HORIZON ; COMMON TO MANY MEDIUM TUBULAR PORES ;
 MODERATELY EFFERVESCENT (HCL + IN) DISCONTINUOUS ; CLEAR SMOOTH BOUNDARY .

C 1CA

53 - 60 CM. (21 - 24 IN.)
 LIGHT GRAY (10YR 7/1) CRUSHED ; SILT LOAM ; PALE BROWN (10YR 6/3) CRUSHED
 MOIST ; WEAK TO MODERATE COARSE SUBANGULAR BLOCKY MOIST STRUCTURE ;
 SLIGHTLY STICKY , SLIGHTLY PLASTIC , VERY FRIABLE , SLIGHTLY HARD ;
 COMMON FINE & MEDIUM ROOTS THROUGHOUT HORIZON ; COMMON TO MANY
 FINE & MEDIUM TUBULAR PORES ; VIOLENTLY EFFERVESCENT (HCL + IN) CONTINUOUS .

REMARKS:

SINE INC. GALLATIN GATEWAY

SOIL SERIES:

CHERRY SILTY CLAY

SURVEY SAMPLE NO.:

S78MT 33 14

LOCATION:

N 1/4 SEC. 32 T 17 N R 43E

CLASSIFICATION:

ARIDIC HAPLODOROLLS; FINE-SILTY, MIXED

SITE NO.:

COUNTY: GARFIELD

ELEVATION: 0777 METERS

MONTH SAMPLED:

SLOPE:

CLASS:

KIND:

ASPECT: NORTHWEST

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: CM LOWER: CM

PERMEABILITY:

DRAINAGE CLASS:

STONINESS: CLASS

VEGETATION:

PARENT MATERIAL: RESIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE

HORIZON

PROFILE DESCRIPTION

A P 0 - 13 CM. (0 - 5 IN.)
 LIGHT BROWNISH GRAY (2.5Y 6/2) SILTY CLAY LOAM ; DARK GRAYISH BROWN (2.5Y 4/2)
 MOIST ; MODERATE MEDIUM GRANULAR STRUCTURE ; SLIGHTLY STICKY ,
 SLIGHTLY PLASTIC ; MILDLY EFFERVESCENT (HCL + 1N) ; CLEAR BOUNDARY .

B 2 13 - 20 CM. (5 - 8 IN.)
 LIGHT BROWNISH GRAY (2.5Y 6/2) SILTY CLAY LOAM ; DARK GRAYISH BROWN (2.5Y 4/2)
 MOIST ; MODERATE MEDIUM PRISMATIC STRUCTURE ; SLIGHTLY STICKY ,
 SLIGHTLY PLASTIC , FRIABLE , SLIGHTLY HARD ; MODERATELY EFFERVESCENT
 (HCL + 1N) ; CLEAR BOUNDARY .

B 3CA 20 - 30 CM. (8 - 12 IN.)
 PALE YELLOW (5Y7/3) SILTY CLAY LOAM ; PALE OLIVE (5Y6/3) MOIST ; MODERATE
 MEDIUM PRISMATIC STRUCTURE ; SLIGHTLY STICKY , SLIGHTLY PLASTIC ,
 FRIABLE , SLIGHTLY HARD ; MODERATELY EFFERVESCENT (HCL + 1N) ; GRADUAL
 BOUNDARY .

C 1CA 30 - 102 CM. (12 - 40 IN.)
 PALE YELLOW (5Y7/3) FINE SANDY LOAM ; PALE OLIVE (5Y6/3) MOIST ; WEAK
 MEDIUM SUBANGULAR BLOCKY STRUCTURE ; MODERATELY EFFERVESCENT (HCL + 1N) .

REMARKS:

G. HELM, GARFIELD COUNTY

SOIL SERIES:

ARNEGARD LOAM

SURVEY SAMPLE NO.:

S78MT 3 9

LOCATION:

PETE NICHLOVICH RANCH BIG HORN CT. NW 1/4 OF SE 1/4 SEC 29, T6S, R36E

CLASSIFICATION:

PACHIC HAPLOBOROLLS; FINE-LOAMY, MIXED

SITE NO.: 78 9

COUNTY: BIG HORN

ELEVATION: 0975 METERS

MONTH SAMPLED:

SLOPE: %

CLASS:

KIND:

ASPECT:

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: CM LOWER: CM

PERMEABILITY:

MODERATE

DRAINAGE CLASS: WELL DRAINED

STONINESS: CLASS

PHYSIOGRAPHY:

ALLUVIAL OR COLLUVIAL FANS

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

RESIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE

HORIZON

PROFILE DESCRIPTION

A P

0 - 18 CM. (0 - 7 IN.)

DARK GRAYISH BROWN (10YR 4/2) LOAM ; VERY DARK GRAY (10YR 3/0) ; WEAK
 FINE GRANULAR STRUCTURE ; NONSTICKY , NONPLASTIC , FRIABLE ,
 SOFT ; NONCALCAREOUS (HCL * 1N) ; CLEAR WAVY BOUNDARY .

B 21

18 - 41 CM. (7 - 16 IN.)

DARK GRAYISH BROWN (10YR 4/2) CLAY LOAM ; V DK GRAYISH BROWN (10YR 3/2)

MOIST ; , PLASTIC , FRIABLE ; MILDLY EFFERVESCENT (HCL * 1N) ; GRADUAL
 BOUNDARY .

B 22

41 - 51 CM. (16 - 20 IN.)

BROWN (10YR 5/3) CLAY LOAM ; BROWN (10YR 4/3) MOIST ; MODERATE
 FINE & MEDIUM SUBANGULAR BLOCKY STRUCTURE ; MODERATELY EFFERVESCENT
 (HCL * 1N) ; GRADUAL BOUNDARY .

C CA

51 - CM. (20 - IN.)

PALE BROWN (10YR 6/3) LOAM ; BROWN (10YR 5/3) MOIST ; MASSIVE ;
 SLIGHTLY STICKY , NONPLASTIC , FRIABLE , SOFT .

SOIL SERIES:

CHANTA ATTEWAN

SURVEY SAMPLE NO.:

S78MT 79 11

LOCATION:

TERRY BENCH SE 1/4 OF SW 1/4 S 20, T12N, R52E

CLASSIFICATION:

ARIDIC HAPLOBOROLLS; FINE-LOAMY OVER SANDY OR SANDY-SKELETAL , MIXED

SITE NO.: 78 11

COUNTY: PRARIE

ELEVATION: 0853 METERS

MONTH SAMPLED:

SLOPE: 02%

CLASS:

KIND:

ASPECT: NORTH

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: CM LOWER: CM

PERMEABILITY:

DRAINAGE CLASS:

PHYSIOGRAPHY:

STONINESS: CLASS

VEGETATION:

PARENT MATERIAL: ALLUVIUM

HORIZON

PROFILE DESCRIPTION

A P

0 - 20 CM. (0 - 8 IN.)

GRAYISH BROWN (10YR 5/2) LOAM ; V DK GRAYISH BROWN (10YR 3/2) MOIST ;

NONCALCAREOUS (HCL * 1N) .

B

20 - 51 CM. (8 - 20 IN.)

GRAYISH BROWN (10YR 5/2) LOAM ;

DARK GRAYISH BROWN (10YR 4/2) MOIST ;

WEAK MEDIUM PRISMATIC STRUCTURE ; NONCALCAREOUS (HCL * 1N) ; CLEAR

SMOOTH BOUNDARY .

C 1CA

51 - 84 CM. (20 - 33 IN.)

LIGHT GRAY (2.5Y 7/2) LOAM ; VIOLENTLY EFFERVESCENT (HCL * 1N) .

IIC 2

84 - 152 CM. (33 - 60 IN.)

REMARKS:

J. PEHL PRAIRIE COUNTY

SOIL SERIES:

BAINVILLE CLAY

SURVEY SAMPLE NO.:

S78MT 111 4

LOCATION:

RAY CASH (PANCH) YELLOWSTONE CT. NW 1/4 SEC 30 T 5 N R52E

CLASSIFICATION:

USTIC TURRIORTHENTS; FINE-SILTY , MIXED (CALCAREOUS) , MESTC

SITE NO.: 78 4

COUNTY: YELLOWSTONE

ELEVATION: 1067 METERS

MONTH SAMPLED:

SLOPE: 02%

CLASS:

KIND:

ASPECT: SOUTH

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: CM LOWER: CM

PERMEABILITY:

MODERATE

DRAINAGE CLASS: WELL DRAINED

PHYSIOGRAPHY:

ROLLING OR HILLY UPLANDS

STONINESS: CLASS

VEGETATION:

CROPS - DRYLAND

PARENT MATERIAL:

RESIDUAL MATERIAL, LOCAL COLLUVIUM OR SOLIFLUCTATE

HORIZON

PROFILE DESCRIPTION

A 11P

0 - 15 CM. (0 - 6 IN.)

PALE BROWN (10YR 6/3) CLAY LOAM ; GRAYISH BROWN (10YR 5/2) MOIST ;
FINE GRANULAR STRUCTURE ; SLIGHTLY STICKY , PLASTIC , FRIABLE ,
SLIGHTLY HARD ; GRADUAL BOUNDARY .

A 12P

15 - 25 CM. (6 - 10 IN.)

PALE BROWN (10YR 6/3) ; BROWN (10YR 5/3) MOIST ; MODERATE COARSE
SUBANGULAR BLOCKY STRUCTURE ; SLIGHTLY STICKY , PLASTIC , FRIABLE ,
SLIGHTLY HARD ; GRADUAL BOUNDARY .

C 1

25 - 33 CM. (10 - 13 IN.)

GRAYISH BROWN (2.5Y 5/2) CLAY LOAM ; GRAYISH BROWN (2.5Y 5/2) MOIST ;
MODERATE FINE & MEDIUM ANGULAR BLOCKY STRUCTURE ; MODERATELY EFFERVESCENT
(HCL * 1N) ; GRADUAL BOUNDARY .

C 2CA

33 - CM. (13 - IN.)

LIGHT GRAY (2.5Y 7/2) CLAY LOAM ; WHITE (2.5Y 8/2) ; LIGHT OLIVE BROWN
(2.5Y 5/4) MOIST ; MEDIUM MASSIVE ; STICKY , PLASTIC , FRIABLE ,
SLIGHTLY HARD ; VIOLENTLY EFFERVESCENT (HCL * 1N) .

SOIL SERIES:

EDGAR LOAM

SURVEY SAMPLE NO.:

S78M 87 12

LOCATION:

CLIFFORD WRIGHT RANCH AT ROSEBUD HOLLAND ROSEBUD CT NE 1/4, SEC 20, T6N, R42E

CLASSIFICATION:

USTOLIC CAMBORTHIDS: FINE-LOAMY, MIXED, MESIC

SITE NO.: 78 12

COUNTY: ROSEBUD

ELEVATION: 0853 METERS

MONTH SAMPLED:

SLOPE: 02%

CLASS:

KIND:

ASPECT: EAST

AIR TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

SOIL TEMPERATURE

ANNUAL: DEGREES F

SUMMER: DEGREES F

WINTER: DEGREES F

WATER TABLE:

DEPTH: CM.

MONTH:

KIND: NO WATER TABLE

PRECIPITATION:

CM.

CONTROL SECTION LIMITS --

UPPER: CM LOWER: CM

PERMEABILITY:

DRAINAGE CLASS:

STONINESS: CLASS

PHYSIOGRAPHY:

VEGETATION:

PARENT MATERIAL:

ALLUVIUM

HORIZON

PROFILE DESCRIPTION

A	P	0 - 18 CM. (0 - 7 IN.) GRAYISH BROWN (10YR 5/2) LOAM ; DARK BROWN (10YR 3/3) MOIST ; WEAK MEDIUM GRANULAR STRUCTURE ; NONCALCAREOUS (HCL * 1N) .
B	1	18 - 33 CM. (7 - 13 IN.) BROWN (10YR 5/3) LOAM ; DARK GRAYISH BROWN (10YR 4/2) MOIST ; VERY WEAK COARSE PRISMATIC STRUCTURE ; CLEAR SMOOTH BOUNDARY .
B	3CA	33 - 46 CM. (13 - 18 IN.) LIGHT BROWNISH GRAY (10YR 6/2) LOAM ; GRAYISH BROWN (10YR 5/2) MOIST ; VERY WEAK COARSE PRISMATIC STRUCTURE ; MODERATELY EFFERVESCENT (HCL * 1N) ; GRADUAL SMOOTH BOUNDARY .
C	1CA	46 - 64 CM. (18 - 25 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) SILT LOAM ; GRAYISH BROWN (2.5Y 5/2) ; MASSIVE ; VIOLENTLY EFFERVESCENT (HCL * 1N) ; GRADUAL WAVY BOUNDARY .
C	2	64 - 152 CM. (25 - 60 IN.) LIGHT BROWNISH GRAY (2.5Y 6/2) LOAM ; GRAYISH BROWN (2.5Y 5/2) MOIST ; MASSIVE ; MODERATELY EFFERVESCENT (HCL * 1N) .

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(continued)

N378

cop.2 Influence of soil profile and site characteristics on the response of a winter wheat to K...

[illegible]

N 378
Sch 135
Cap 2