Spring wheat yields on two contrasting aridic argiborolls in northcentral Montana
by Brian David Schweitzer

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Soil Science
Montana State University
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Abstract:
Spring wheat yield data were collected on two soils of north-central Montana. The soils are Scobey and Kevin series which are both Aridic Argiborolls. These soils occur in complexes on glacial till in northern Montana. Soil plots were identified within single fields allowing examination of the soils yield performance independent of other variables such as management and climate.

Wheat grown on Scobey plots always outyielded wheat on Kevin plots. Average yield on Scobey was 262 percent of average yield on Kevin. Wheat on Scobey plots yielded an average of 4653 kg/ha and wheat on Kevin averaged 1772 kg/ha.

Wheat on the two soils utilized nearly the same quantity of water. Available P, NO3-N, CaCO3 (p = .01); organic matter, and extractable K (p = .05) were correlated with soil series. Water is usually considered to be the most yield limiting factor in Montana dryland wheat production, but in this study, yield differences between soil series;were due to soil fertility rather than soil water.

Soil yield performance data collection procedures of this study could be adapted by the Soil Conservation Service. These procedures would be more accurate and useful than the data collection system presently used.
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Date  [July 10, 1980]
SPRING WHEAT YIELDS ON TWO CONTRASTING ARIDIC ARGIBOROLLS IN NORTHCENTRAL MONTANA

by

BRIAN DAVID SCHWEITZER

A thesis submitted in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

in

Soil Science

Approved:

[Signatures]

MONTANA STATE UNIVERSITY
Bozeman, Montana

August, 1980
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Spring wheat yield data were collected on two soils of north-central Montana. The soils are Scobey and Kevin series which are both Aridic Argiborolls. These soils occur in complexes on glacial till in northern Montana. Soil plots were identified within single fields allowing examination of the soils yield performance independent of other variables such as management and climate.

Wheat grown on Scobey plots always outyielded wheat on Kevin plots. Average yield on Scobey was 262 percent of average yield on Kevin. Wheat on Scobey plots yielded an average of 4653 kg/ha and wheat on Kevin averaged 1772 kg/ha.

Wheat on the two soils utilized nearly the same quantity of water. Available P, NO$_3$-N, CaCO$_3$ ($p = .01$); organic matter, and extractable K ($p = .05$) were correlated with soil series. Water is usually considered to be the most yield limiting factor in Montana dryland wheat production, but in this study, yield differences between soil series were due to soil fertility rather than soil water.

Soil yield performance data collection procedures of this study could be adapted by the Soil Conservation Service. These procedures would be more accurate and useful than the data collection system presently used.
INTRODUCTION

There is a need for detailed soil performance data. A producer cannot choose a realistic level of management inputs unless the expected yield is known. A reasonable yield goal can only be estimated by soil performance studies under known management and climatic conditions. Results of such studies can assist 1) farmers in management decisions, 2) land use planners in feasibility studies, and 3) private and public agencies in land appraisal.

The Soil Conservation Service (SCS) presently provides yield predictions in published soil survey reports. The soil survey manual (Soil Survey Staff, 1951) states that "performance judgments are based upon evidence afforded by actual yield data from sample areas of the soil mapping units", but this approach is seldom utilized.

The most useful performance data includes yield predictions for a given soil under a wide range of management and climate. For example, on a given soil, a producer could predict crop yields based upon specific management practices and climate. This information allows accurate cost/benefit predictions prior to planting.
OBJECTIVES

Objectives of this study were: 1) to collect actual field yield data from Scobey and Kevin soils, and 2) to determine the significance of these soils to crop yield by comparing spring wheat yields on two soils within one field. Management and macroclimate are nearly identical. Therefore, the yield difference must be due to soil.
REVIEW OF LITERATURE

The art of soil classification and mapping is at least 4,000 years old (Thorp, 1935). During this century, it became apparent that the mere classification of a soil does not sufficiently aid the resource manager. The next logical step was to provide recommendations about potential uses of soils for engineering and edaphological purposes. Presently, the SCS provides this information in all published soil surveys.

One of the most important applications of soil surveys is the prediction of crop yields from particular soil units. Predicted yields can help producers set realistic yield goals and link productivity to land evaluation (Soil Survey Staff, 1951).

Presently yield predictions are compiled in three manners:
1) interviews with producers and visual field observations; 2) examination of farm records, and 3) actual yield determination from sample areas of the soil unit (Odell, 1958). The last technique is the most accurate, but is seldom employed.

Yield data collection has been studied for many years. Soybeans, winter wheat, oats and corn yields were examined on Clinton Silt Loam for seven years. This central Illinois (Rust & Odell, 1957) study included records from several farms under a wide range of management. Another Illinois study employed multiple curvilinear regression
analysis of crop yields on soil units under varied management and climatic conditions. The study included data from seven hundred farm production records. The length of the production records varied from five to twenty-five years. The crop yields on each soil unit increased or decreased from year to year, up to fifty-six percent (Rust & Odell, 1957).

In one study (Henao, 1976), soil productivity ratings were based upon over thirty physical and chemical properties. The intent was to examine such factors as: percent carbon in the plow layer, plant available water holding capacity of the soil profile, bulk density in the subsoil horizons, pH by horizon, depth to the top of the calcium carbonate horizon, and assign numerical yield values contributed by each factor. Another report (deJong and Rennie, 1967) concluded, "it is impossible to assess the practical significance of specific soil physical properties in terms of wheat production on the basis of current research information."

A model was designed in Oklahoma (Allgood and Gray, 1977) to assign soil productivity ratings for yield prediction on different soils. They tried two systems. The first utilized laboratory data, field observations and published yield information. The second system was based solely on diagnostic soil characteristics included in Soil Taxonomy. Water was the most yield limiting factor in this study. Parameters that affected soil moisture such as slope, clay percent,
and percent organic matter were most important in predicting yield.

There are three basic components of yield: soil, climate, and management. Yield prediction accuracy suffers when any of these independent components is not accurately identified or held constant. To overcome this problem, some workers have compared yields on different soil units within individual fields. This approach holds management and microclimate constant so yield differences are attributed to soil alone (Ferguson & Gorby, 1966; Rennie & Clayton, 1960; Spratt & McIver, 1971). They demonstrated that yields can vary substantially, as much as 300 percent, between soils on glacial till catenas of the northern great plains when other variables are held constant. Furthermore, these investigations demonstrated that each soil responded differently to fertilizer treatments.
METHODS

Spring wheat was planted by five cooperating farm operators during May, 1979. Plots were identified and marked after the crop was seeded, but prior to germination. There were two plots per site, one on Scobey soils and one on Kevin, both within one field. Each plot measured 1.55m x 7.63m. Four farms had one site per field (1, 2, 3, 7) and one farm had three sites in one field (4, 5, 6) as can be seen in Figure 1 and legal descriptions of sites are in Table 1. Soil series chosen for this study occur on glacial till in northern Montana. The Scobey series (Figure 2) is identified as the most extensively cultivated soil in Montana (Center, 1977). The Kevin soil series is found in complexes with the Scobey. They are both Aridic Argiborolls (Appendix IV). The Scobey is in the fine, montmorillonitic and Kevin is in the fine loamy, mixed family. Kevin contains CaCO₃ in the plow layer and Scobey does not.

Scobey and Kevin soils were formed on the same parent material. The differences between the two soils in the study are a result of geologic wind and water erosion moving material from the erosional or Kevin landscape positions to the depositional or Scobey positions. Due to its landscape position, these Scobey soils are deeper, more fertile and have a higher available water holding capacity than Kevin soils.
Figure 1. Location of Sites.
TABLE 1. QUESTIONNAIRE SUMMARY

<table>
<thead>
<tr>
<th>Plot</th>
<th>Farm Operator</th>
<th>Legal Description</th>
<th>Seed Variety</th>
<th>Total Initial Water in 120cm Profile</th>
<th>Rainfall During Growing Season cm</th>
<th>Summer Followed on Previous Crop</th>
<th>Number of Tines Tilled Prior to Planting</th>
<th>Stand Establishment</th>
<th>Estimated Crop Loss Due to Weeds</th>
<th>Planting Date</th>
</tr>
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<tr>
<td>1</td>
<td>Walter Fouts</td>
<td>S#W, W#S</td>
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<td>Fallow</td>
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<td>10.6</td>
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<td>2</td>
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<td>9.7</td>
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<td>4</td>
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<tr>
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<td>W#W, W#W</td>
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<td>4</td>
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*S = Scooby
K = Kevin
Figure 2a. Typical Scobey Landscape. Study area is more severely undulating.

Figure 2b. Scobey Soil Profile.
Soil Identification

The Scobey and Kevin soils were identified by extracting a core sample and examining color, texture and pH. If a soil effervesced when 10% hydrochloric acid (HCl) was applied to the Ap horizon, it was identified as Kevin. When the soil effervesced only at depths of eleven inches or greater, it was identified as Scobey. Scobey soils are usually located in depression to midslope positions, while Kevin soils occupy the slope and crown positions. The SCS has mapped the complex as 60% Scobey and 40% Kevin.

Spring Soil Samples

Soil samples were collected as the plots were identified during the week of May 20, 1979. Twenty subsamples were extracted from the Ap horizon of each plot, mixed and subsampled to obtain a 600 gram sample. The soil samples were analyzed by the Montana State University Soil Testing Laboratory.

Each sample was analyzed for: pH, extractable K, available P, organic matter percent and CaCO₃ percent by standard Montana State University Soil Testing Laboratory procedures.

These procedures are: 1) available P by modified Bray #1 (Smith, F. W. et al., 1957; Olsen, S. R. and L. A. Dean, 1965), 2) percent CaCO₃ by adding HCl and measuring CO₂ loss (Williams, 1948), 3) extractable K by the neutral, normal NH₄OAC extraction procedure as modified by the
Montana State University Soil Testing Laboratory, 4) NO₃-N by the chromotropic acid method (Sims, J. R. and Jackson, G. D., 1971), 5) percent organic matter was determined by the simplified colormetric method (Sims and Haby, 1970), and 6) pH was determined on 2:1 water to soil paste.

Two 5.7cm diameter core samples were extracted to a depth of 120 cm because this is the spring wheat rooting depth (Israelsen and Hansen, 1962). The cores were separated into 30cm increments, frozen and analyzed for NO₃-N. Soil water content was measured gravimetrically.

Precipitation

Rain gauges were placed in three locations near study sites. Gauge 1 represents site 1, gauge 2 represents sites 2, 3 and sites 4, 5, 6, 7 are represented by rain gauge 3. The cooperating farmers recorded precipitation data. Locations of gauges are marked on the sample area map in Figure 1.

Harvest

The crop was examined during the growing season to detect any obvious disease or insect problems that would substantially reduce yield. A 0.6 x 6.1m plot was harvested from the middle of each plot on September 1, 1979. Forty random spikes from each plot were collected during harvest to determine the average number of kernels per spike. Random was defined as selecting the 40th, 80th and 120th spike from
every 5th furrow in the plot. If the designated spike was sterile, the next spike was selected. The harvested grain was weighed to determine total yield. Using kernels per spike data and total yield data (yield/kernel weight x kernels per spike), stand density was calculated. Total protein percent was analyzed using the Udy dye method (Association of Official Agricultural Chemists, 1965).

Soil Temperature

A soil thermometer was placed at a depth of 50cm near site 1.

Fall Soil Samples

Spring soil sampling procedures were repeated on September 1, 1979. The fall samples were analyzed for: pH, extractable K, available P, organic matter percent, NO₃-N and soil water.

Management Data Sheets

Questionnaires were prepared dealing with management of the crop. All factors including tillage, climate, insects, disease, seed variety and cropping history that would effect crop yield were considered. The questionnaires are shown in Appendix I and summarized in Table 1.

Statistical Methods

The "paired t" test (Jerome, C. R., 1964) was selected to analyze statistical differences between Scobey and Kevin. The "paired t" allowed comparison of yield and chemical soil properties between Scobey
and Kevin plots within single sites. By comparing soils within single sites, management and climate differences were minimized.
RESULTS

Results of spring soil sample analysis and harvested grain are summarized in Table 2.

Yield

Wheat yield was correlated with soil series (p = .01). The average yield on Scobey was 4653 kg/ha and Kevin soils averaged 1772 kg/ha. Wheat yield values are shown in Figure 3.

Number of Kernels per Spike

Kernels per spike were correlated with soil series (p = .05). The average number kernels/spike on Scobey was 27.2 and 20.6 on Kevin. Kernels/spike values are shown in Figure 4.

Stand Density

Stand density was correlated with soil series (p = .01). Stand density on Scobey plots averaged 345 spikes/m$^2$ and 134 spikes/m$^2$ on Kevin. Stand density values are shown in Figure 5.

Wheat Protein

Wheat protein percent was correlated with soil series (p = .05). Wheat grown on Scobey plots averaged 14.4% protein and the average of wheat grown on Kevin was 13.5%. Wheat protein values are shown in Figure 6.
TABLE 2. SUMMARY OF SPRING SOIL ANALYSIS AND HARVESTED GRAIN DATA

<table>
<thead>
<tr>
<th>Plot</th>
<th>Yield* kg/ha</th>
<th>Kernels/Spike**</th>
<th>Stand Density m2*</th>
<th>Percent Protein**</th>
<th>Available Phosphorus, ppm*</th>
<th>NO3-N kg/ha*</th>
<th>Extractable Potassium, ppm**</th>
<th>Organic Matter, %**</th>
<th>CaCO3, %*</th>
<th>pH**</th>
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<td>318</td>
<td>1.5</td>
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<td>8.1</td>
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</table>

S = Scobey  
K = Kevin  
*Significant at (p = .01) level  
**Significant at (p = .05) level
Figure 3. Spring Wheat Yield on Paired Scobey (shaded) and Kevin (unshaded) Soils.
Figure 4. Number of Kernels Per Spike in Scobey (shaded) and Kevin (unshaded) Soils.
Figure 5. Stand Density in Paired Scobey (shaded) and Kevin (unshaded) Soils.
Figure 6. Percent Protein of Spring Wheat in Paired Scobey (shaded) and Kevin (unshaded) Soils.
Soil Analyses

The spring soil samples revealed distinct differences between Scobey and Kevin. Spring analyses are reported in the following section.

Fall soil analyses were similar to spring analyses, but were not statistically analyzed. Fall analyses are reported in Appendix III.

Available P

Available P was correlated with soil series (p = .01). Average available P in Scobey was 70 ppm and 19 ppm in Kevin plots. Available P values are shown in Figure 7.

Organic Matter

Organic matter percent was correlated with soil series (p = .05). The average organic matter percent was 2.3% in Scobey plots and Kevin plots averaged 1.3%. Organic matter values are shown in Figure 8.

CaCO₃

CaCO₃ was correlated with soil series (p = .01). Average CaCO₃ percent in the Ap horizon of Kevin plots was 4.40% and .66% in Scobey. CaCO₃ values are shown in Figure 9.

NO₃-N

NO₃-N was correlated with soil series (p = .01). Soil profiles
Available Phosphorus

Figure 7. Available P in Paired Scobey (shaded) and Kevin (unshaded) Soils.
Figure 8. Organic Matter Percent in Paired Scobey (shaded) and Kevin (unshaded) Soils.
Figure 9. CaCO₃ Percent in Paired Scobey (shaded) and Kevin (unshaded) Soils.
in Scobey plots had an average of 169 kg/ha NO\textsubscript{3}-N and Kevin plots averaged 48 kg/ha. NO\textsubscript{3}-N values are reported in Figure 10.

**Extractable K**

Extractable K was correlated with soil series (p = .05). Scobey plots had an average of 454 ppm of extractable K and the Kevin average was 250 ppm. Extractable K values are shown in Figure 11.

**pH**

The pH of the Ap horizon was correlated with soil series (p = .05). Average pH of Kevin plots was 8.1 and Scobey plots averaged 7.8. The pH values are shown in Figure 12.

**Water Utilization**

Water utilization was defined as: total water in a 120cm profile at planting minus total water in a 120cm profile at harvest plus precipitation during the growing season. Results are tabulated in Tables 3 and 4 and shown in Figure 13.

Water utilization was not correlated with soil series. The Scobey plots used an average of 20.7cm and Kevin plots averaged 18.1cm.

**Soil Temperature**

Soil temperature data is reported in Appendix IV.
Figure 10. \(\text{NO}_3^-\text{N}\) in Paired Scobey (shaded) and Kevin (unshaded) Soils.
Figure 11. Extractable K in Paired Scobey (shaded) and Kevin (unshaded) Soils.
Figure 12. pH in Paired Scobey (shaded) and Kevin (unshaded) Soils.
TABLE 3. SUMMARY OF WATER UTILIZATION DATA

<table>
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<tr>
<th>Plot</th>
<th>Initial H$_2$O in 120cm Profile</th>
<th>Rainfall cm</th>
<th>Fall H$_2$O in 120cm Profile</th>
<th>Water Utilization cm</th>
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<tr>
<td>1</td>
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<td>K 1.3</td>
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<td>13.7</td>
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</table>

S = Scobey
K = Kevin
<table>
<thead>
<tr>
<th>Date Received</th>
<th>Amount Recorded, cm</th>
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</thead>
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<td></td>
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<tr>
<td>June 3</td>
<td>.85</td>
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<tr>
<td>June 11</td>
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<tr>
<td>June 25</td>
<td>.06</td>
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<tr>
<td>July 3</td>
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<td>July 5</td>
<td>1.75</td>
</tr>
<tr>
<td>August 2</td>
<td>.96</td>
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<tr>
<td><strong>Total</strong></td>
<td><strong>13.05</strong></td>
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</table>
Figure 13. Water Utilization by Paired Scobey (shaded) and Kevin (unshaded) Soils.
DISCUSSION

Wheat on Scobey plots always outyielded wheat on Kevin plots at the same site. This means that under identical management and macro-climate, these Scobey soils have a higher spring wheat yield performance than these Kevin soils. In examining the data from this study, there is little value in comparing yields and soil data between sites because there is no practical mechanism of holding management and climate constant.

Site 1

Site 1 was the most unusual site in the study. Wheat yields on the Scobey were within the standard deviation of other Scobey's, but wheat yields on the Kevin were one-third higher than the next highest yielding Kevin. Both Scobey and Kevin had high NO$_3$-N values relative to the rest of the sites. I cannot explain the unusually high NO$_3$-N soil test results. Water utilization was extremely high in IS. This may have been due to the high NO$_3$-N levels initiating a vigorous leaf system which increased transpiration demand.

Site 2

Scobey on site 2 had the highest yielding plot in this study. 2S had adequate NO$_3$-N and available P, so water probably became the limiting factor.
Site 3

Low soil fertility is largely responsible for site 3 yielding less wheat than all but one other site. NO₃-N and available P were lower in site 3 than any other site. In response to low NO₃-N levels, grain protein was also the lowest in the study.

Sites 4, 5, 6

These sites were within one field. Even though management was constant, yields and soil fertility varied greatly between representatives of the same soil series. This variability is expected in soils on glacial till. The churning effects of the glacier probably caused this spatial variability. This variability is not great enough to disqualify the soils from the Scobey or Kevin soil series, but can have great effects on soil fertility and consequently grain yield.

Site 7

This was the lowest yielding site in the study. The field containing this site had been growing crested wheat grass for the previous 15 years. The farmer had not summer fallowed the field and consequently stored water was extremely low. Prior to planting, the farmer plowed the field five times in order to prepare a seed bed. This further depleted the soil water. Due to the low water status, especially in the plow layer, stand density (a function of plant
population and tillering) was so low that the crop did not fully utilize the July rainfall.

Water Utilization

Water utilization was defined as water in a 120cm profile at planting minus water in the same profile at harvest, plus growing season precipitation. However, Kevin occurs on erosional and Scobey on depositional positions on undulating topography (0-4%). Therefore, I assume that during the heavy rainfall on July 3, 1979 some water did not infiltrate the Kevin plots and flowed onto the Scobey plots. There was no obvious erosional indication of this occurrence, but based upon interviews with farmers, the rain fell with great intensity.

Extractable K

K levels were correlated (p = .05) with soil series. The procedure used for extracting K (neutral, normal NH₄OAC extraction as modified by the Montana State University Soil Testing Laboratory) may not accurately indicate plant available K. Schaff (1979) demonstrated that K soil test values are not correlated with winter wheat yield response to K fertilization on Montana soils.

Differential Fertilization

The author has demonstrated contrasting soil performance for spring yield on Scobey-Kevin complexes. A "soil complex consists of
two or more recognized taxonomic units that occur together in a regular pattern and are so intimately associated geographically that they cannot be separated by the boundaries at the scale used" (Soil Survey Staff, 1951).

The Scobey-Kevin complex, as with others on glacial tills of the Northern Great Plains, should be managed differentially. Farmers have long recognized soil performance differences in their fields, but have managed whole fields uniformly. An important management tool could be "differential fertilization". Differential fertilization is defined as fertilizing at varied rates, according to type of soil within one field. Kevin soils can require up to 3.5 times as much phosphorus as Scobey soils within a single field (Figure 14). When these complexes are fertilized uniformly, fertilization rates are too high for parts of the field and too low for others. Differential fertilization would put the fertilizer where it is needed.

A Canadian farmer was interviewed who operates a farm one mile north of the sample area. His fields were on similar topography to the Scobey-Kevin complex. He mentioned that prior to seeding, he broadcast high rates of 0-46-0 on the erosional (Kevin-like) portions of his fields and they now yield nearly as much wheat as the depositional (Scobey-like) soils.

Although the Canadian got yield responses with additions of broadcast P fertilizer, a more efficient response could be attained
Figure 14. Recommended Fertilizer for Paired Scobey (shaded) and Kevin (unshaded) Soils Based on the Montana Extension Fertilizer Guide for Nonirrigated—Spring Wheat (Christensen and Wilson, 1977).
with "band" applications. When P is placed in a narrow band with the seed, lower rates are required than when broadcasting. Banding is more efficient (Tisdale, S. L. and Nelson, W. L., 1966) because it decreases the P-Ca contact zone which can minimize P fixation by Ca. Cool soil temperatures early in the growing season (Russel, F. W., 1973) also restricts uptake of P by roots. High P concentration in bands near the seed minimizes the problem.

Equipment is not presently commercially available that will differentially band fertilize. A farmer could modify the grain drills to facilitate differential band fertilization for less than $1,000.

There are at least 500,000 acres in Montana where complexes, similar to the Scobey-Kevin complex, are cultivated. Differential fertilization would increase crop yields by at least three bushels. If a bushel of wheat is worth $3.65, the returns from differential fertilization in this state would be at least 5.5 million dollars additional gross income.

Collection System for Soil Yield Performance

The soil performance data collection technique discussed in this thesis could be readily applied by the SCS and others. Scientists employed for soil mapping or information dissemination could be shifted to soil yield performance data collection during a week in the spring and fall. Utilizing current personnel in this manner, data could be
When soil performance data has been collected on key soils for several cropping years, the entire state could benefit. The Extension Service could base fertilizer recommendations on soil test values and soil series. USDA crop harvest estimates and property tax assessments would be more accurate. Costs of urban sprawl into croplands could also be calculated more readily than is presently possible.

A soil yield performance collection technique is currently being investigated by the SCS and the Montana Cooperative Extension Service in Montana. With small modifications, youth groups such as 4-H and FFA in cooperation with the SCS and Montana Cooperative Extension Service could aid in collection of yield, climate and soil test data.
CONCLUSIONS

1. Soils within a single field can have highly contrasting wheat yield performances.
2. Soil fertility, not water, was apparently the most yield limiting factor on soils in this study.
3. Producers should investigate differential fertilization on the glacial till complexes of northcentral Montana.
4. Soil performance data can be collected both accurately and inexpensively on soils in Montana.
5. Measuring soil productivity on contrasting soils within a single field is a good method of comparing soils' yield performance because management and macroclimate are held essentially constant.
APPENDICES
Site: 1 Scobey and 1 Kevin
County: Blaine
Range & Township: R 26E, T 37N
Field Description: SE¼, Sec. 3
Manager
Name Walter Fouts
Address Turner, Montana
Phone 379-2641

Climate
*Initial water supply  S = 19.8cm  K = 4.2cm
*Rainfall in growing season  13.04cm
Estimated hail loss  0
Estimated wind shatter loss  0
Other climatic factors that may have contributed to or deleted from your harvested yield During high intensity rainfall an unknown quantity of water may not have infiltrated profile on all K sites and most S sites may have had additional run-on.

Cultural
Summer fallow - number times and implement(s) used in cultivation 5
Tool bar - duckfoot
Continuous cropping _____ Number of times and implement(s) used _____

Condition of seedbed at planting: 1 = excellent  5 = poor 1 2 3 4 5

Planting date     May 21, 1979

Harvest date     September 1, 1979

Seed variety     Bounty 309

Was there good stand establishment? 1 = excellent  5 = poor 1 2 3 4 5

How many years has this site been cropped? 40

What is the cropping history for the previous 5 years? Fallow, wheat, fallow, wheat, fallow

Estimate yield reduction due to:

Weeds ______ 0 ______ bu.

Insects ______ 0 ______ bu.

Disease ______ 0 ______ bu.

Winter kill ______ 0 ______ bu.

Fertility

Attach soil test result, amount, kind, and method of fertilizer application.

No fertilizer applied

Soil test results are in Table 1.
Soil identified at sampling site: S = Scobey  K = Kevin  
(series or phase)

Soil identified by (name of soil scientist) Brian Schweitzer

Most recent soil map (title and year): mapping complete, but not published

Soil map unit symbol (from the map): 

Elevation: 2900 feet

Slope (%): 0-4%

Kind: S = 3  K = 1  
(1=conves, 2=plane, 3=concave)

Surface drainage: S = 1  K = 3  
(1=run-on exceeds run-off,  
2=neutral,  
3=run-off exceeds run-on,  
4=can not be evaluated)

Depth to mottles: not in profile

Erosion Control Practices applied: 2  
(1=contour,  
2=strip crop,  
3=cover crop,  
4=no-till,  
5=min. till)
APPENDIX II

SERIES DESCRIPTION

Scobey Series

The Scobey series consists of deep, well drained soils that formed in glacial till. Scobey soils are nearly level to strongly rolling and are on glaciated plains. The mean annual precipitation is about 17 inches, and the mean annual air temperature is about 42°F.

_Taxonmomic Class:_ Fine, montmorillonitic Aridic Argiborolls.

_Typical Pedon:_ Scobey clay loam, cultivated. (Colors are for dry soil unless otherwise noted.)

_\text{Ap}——0 \text{ to } 6 \text{ inches}; \text{grayish brown (10YR 5/2) clay loam, very dark grayish brown (10YR 3/2) moist; strong fine granular structure; hard, friable, sticky and plastic; many fine roots; many fine and medium pores; 10 percent pebbles; neutral (pH 6.5); clear wavy boundary. (6 to 8 inches thick)}

_\text{B2t}——6 \text{ to } 12 \text{ inches}; \text{brown (10YR 5/3) light clay, dark brown (10YR 4/3) moist; peds coated dark grayish brown (10YR 4/2) and very dark grayish brown (10YR 3/2) moist; strong fine and medium prismatic structure that separates to strong fine subangular blocky; very hard, friable, sticky and plastic; many fine roots; many fine tubular pores; thick continuous clay films on peds and pebbles; 5 percent pebbles; neutral (pH 6.8); clear wavy boundary. (4 to 10 inches thick below Ap)}
B3ca--12 to 19 inches; grayish brown (2.5Y 5/2) heavy clay loam, dark grayish brown (2.5Y 4/2) moist; strong medium prismatic structure that separates to moderate medium blocky; very hard, friable, sticky and plastic; many fine roots; many fine tubular pores; moderately thick discontinuous clay film, on peds and pebbles; 5 percent pebbles; few soft masses of segregated lime and few lime-coated pebbles; strongly effervescent; mildly alkaline (pH 8.0); gradual wavy boundary. (2 to 12 inches thick)

Clca--19 to 39 inches; light brownish gray (2.5Y 6/2) clay loam till, dark grayish brown (2.5Y 4/2) moist; weak coarse and very coarse prismatic structure that separates to weak angular blocky; very hard to extremely hard, firm, sticky and plastic; common fine roots; many fine pores; many soft masses and film of segregated lime; 10 percent pebbles; few shale and lignite chips and random distribution of few lime-coated pebbles; strongly effervescent; mildly alkaline (pH 8.3); gradual wavy boundary. (20 to 30 inches thick)

C2cs--39 to 80 inches; grayish brown (2.5Y 5/2) clay loam glacial till, dark grayish brown (2.5Y 4/2) moist; weak thick platy structure; extremely hard, firm, sticky and plastic; few roots, common fine pores; few lignite and shale chips and few pebbles; slight effervescents; mildly alkaline (pH 7.6 to 8.0).

Type Location: Blaine County, Montana; north of road, about 500 feet west and 100 feet north of SE corner of section 5, T 34N, R 24E.
Range in Characteristics: Rounded and subangular very hard pebbles, cobbles and stones comprising 2 to 15 percent by volume are randomly distributed through the soil. Fine and coarse sands comprise 20 to 40 percent of the less than 2mm soil fraction. Hues are 10YR or 2.5Y. The mean annual soil temperature ranges from 42 to 46 degrees F. The average summer soil temperature ranges from 60 to 64 degrees F. The mollic epipedon is 7 to 14 inches thick and includes all or part of the argillic horizon. Depth to the Ccs horizon is 30 inches or more. Some pedons lack a Ccs horizon.

The Ap horizon has chroma of 2 or 3. It is clay loam or loam and has less than 35 percent clay. An Al horizon 2 or 3 inches thick occurs under native grass cover, and it has 18 to 25 percent clay. Main surface textures are loam or clay loam.

The B2t horizon has value of 4 or 5 dry, 2 or 3 moist and chroma of 2 through 4 crushed or rubbed. It averages about 40 percent clay and ranges from 36 to 45 percent. This horizon has moderate or strong prismatic or blocky structure. Some pedons have thin discontinuous silt coatings or skeletons on the faces of peds. Reaction is neutral or mildly alkaline.

The C horizon has value of 5 or 6 dry, 4 or 5 moist and chroma of 2 or 3. It is clay loam but has lenses of loam or sandy clay loam. Bulk density of the compacted till ranges from 1.6 to 1.8. This horizon is mildly to strongly alkaline.
Competing Series: These are the Acree, Ethridge, Holderness, Morop, Phillips, Tanna, and Ulric series. Acree soils have hue of 7.5YR or redder. Ethridge soils are on glacial meltwater deposits and have less than 5 percent gravel or stones. Holderness soils lack secondary calcium carbonate accumulations. Morop soils contain 15 to 30 percent stones and are formed on slopewash derived primarily from basalt. Phillips soils lack a mollic epipedon and have a thin A2 horizon. Tanna soils are underlain with bedrock at depths of 20 to 40 inches. Ulric soils lack compacted glacial till at depths of less than 40 inches.

Geographic Setting: Scobey soils are nearly level to strongly rolling and are on glaciated plains at elevations of 2,400 to 4,000 feet. They formed in calcareous clay loam, continental deposited glacial till with few rounded subangular hard rock pebbles, cobbles, and stones. The deposit is presumably of middle to early Wisconsin Age. The mean annual precipitation is 10 to 14 inches, 80 percent of which falls in spring and early summer. Mean annual temperature ranges from 40 to 45 degrees F. Mean January temperature ranges from 10 to 16 degrees F. The (32 degrees F.) growing season ranges from 100 to 135 days.

Geographically Associated Soils: These are the Acel Elloam, and Thoeny soils and the competing Ethridge and Phillips soils. Acel soils have hard and massive epipedons and a large increase in clay in the Bt horizon over that in the A horizon; also, they occur in swales
and depressions. Elloam and Thoeny soils have natric horizons.

**Drainage and Permeability:** Well drained; medium runoff; moderately slow permeability in the solum and slow in the underlying till.

**Use and Vegetation:** Used mainly for dryland farming of small grain. Some areas are used for range. The principal native grasses are western wheatgrass, needleandthread, bluebunch wheatgrass, blue grama, prairie junegrass, fringed sagewort, green needlegrass, Canby bluegrass, and forbs and shrubs.

**Distribution and Extent:** Scobey soils are extensive in the glaciated plains of northern Montana.

**Series Established:** Milk River Area, Montana, 1928.

National Cooperative Soil Survey

U. S. A.
Kevin Series

The Kevin series consists of deep, well drained soils that formed in glacial till. Kevin soils are on glaciated plains. The mean annual precipitation is about 12 inches and the mean annual air temperature is about 44°F.

**Taxonomic Class:** Fine-loamy, mixed Aridic Argiborolls.

**Typical Pedon:** Kevin clay loam, cultivated. (Colors are for dry soil unless otherwise noted.)

- **Ap**—0 to 7 inches; grayish brown (10YR 5/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate fine gradular structure; hard, friable, sticky and plastic; many very fine roots; many fine pores; 5 percent pebbles; mildly alkaline (pH 7.6); abrupt smooth boundary. (4 to 8 inches thick)

- **B2t**—7 to 9 inches; brown (10YR 5/3) heavy clay loam, dark brown (10YR 4/3) moist; moderate medium prismatic structure parting to moderate medium subangular blocky; very hard; friable, sticky and plastic; many very fine roots; many fine pores; moderately thick continuous grayish brown (10YR 5/2) and very dark grayish brown (10YR 3/2) moist clay films on faces of peds; 5 percent pebbles; slightly effervescent; mildly alkaline (pH 7.8); clear wavy boundary. (2 to 5 inches thick)

- **B3ca**—9 to 19 inches; grayish brown (2.5Y 5/2) light clay loam, dark grayish brown (2.5Y 4/2) moist; moderate medium prismatic
structure parting to weak medium subangular blocky; very hard, friable, sticky and plastic; common very fine roots; many very fine pores; 5 percent pebbles with lime crusts on surface; many very fine masses of lime; strongly effervescent; moderately alkaline (pH 8.4); gradual smooth boundary. (12 to 20 inches thick)

Cle--19 to 30 inches; grayish brown (2.5Y 5/2) light clay loam, dark grayish brown (2.5Y 4/2) moist; weak coarse prismatic structure; very hard, friable, sticky and plastic; common very fine roots; common very fine pores; 5 percent pebbles with lime crusts on surface; few lignite chips; common fine masses of lime; strongly effervescent; strongly alkaline (pH 8.6); gradual smooth boundary.

C2--30 to 44 inches; light brownish gray (2.5Y 6/2) light clay loam, dark grayish brown (2.5Y 4/2) moist; massive; very hard, friable, sticky and plastic; few roots; 5 percent pebbles; few fine masses of lime; strongly effervescent; strongly alkaline (pH 8.6); clear smooth boundary.

C3--44 to 60 inches; grayish brown (2.5Y 5/2) clay loam, dark grayish brown (2.5Y 4/2) moist; massive; very hard, firm, sticky and plastic; few roots; 5 percent pebbles; few fine lignite chips; few fine masses of lime and few fine seams of gypsum; strongly effervescent; moderately alkaline (pH 8.4).

Type Location: Cascade County, Montana; 1,400 feet north and 150 feet east of the SW corner of section 11, T 22N, R 4E.
Range in Characteristics: The depth to free lime is less than 10 inches and some cultivated pedons are calcareous to the surface. Depth to the base of the argillic horizon is less than 10 inches. The particle size control section is clay loam and has 27 to 35 percent clay. Rock fragments average from 5 to 15 percent. The mean annual soil temperature is 39° to 46°F. Hue ranges from 10YR to 5Y.
The A horizon has chroma of 2 or 3. It is clay loam, gravelly loam or loam. This horizon is mildly or moderately alkaline.
The B2t horizon has chroma of 2 or 3. It has moderate or strong prismatic and blocky structure, and it is slightly or strongly effervescent. The B3ca horizon has value of 5 or 6 dry, 4 or 5 moist, and chroma of 2 or 3. It has weak to strong prismatic or blocky structure, and has common or many soft nodules and threads of lime. This horizon ranges from mildly through strongly alkaline.
The C horizon is mainly massive but some pedons have weak prismatic or platy structure in the upper part. It is moderately or strongly alkaline.

Competing Series: These are the Assinniboine, Bostwick, Cheeseman, Duffson, Evanston, Jarre, Joplin, Marmarth, Morval, Notter, Perrypark, Peyton, Telstad, Turret, and Villa Grove series. Assinniboine, Bostwick, Cheeseman, Duffson, Evanston, Jarre, Marmarth, Morval, Notter, Perrypark, Peyton, Telstad, Turret, and Villa Grove soils are deeper than 10 inches to the base of the argillic horizon.
Joplin soils have 20 to 27 percent clay in the control section.

Geographic Setting: Kevin soils are nearly level to strongly rolling and are on glaciated plains at elevations of 2,200 to 4,000 feet. The soils formed in calcareous, clay loam, continental glacial till of an early or pre-Wisconsin glacial substage. The climate is cool, dry semiarid with long, cold, dry winters and moist springs and summers. Mean annual precipitation ranges from 10 to 14 inches, most of which falls during the spring and early summer. Mean annual temperature ranges from 40° to 49°F., mean January temperature from 8° to 20°F., and mean July temperature from 62° to 72°F. The (32°F.) growing season is 105 to 135 days.

Geographically Associated Soils: These are the Absher, Elloam, Hillon, Phillips, Scobey, Sunburst, and Thoeny soils. Absher, Elloam, and Thoeny soils have ochric epipedons and natric horizons. Hillon and Sunburst soils have ochric epipedons and no diagnostic subsurface horizons. Phillips soils have ochric epipedons. Scobey soils have the base of the argillic horizon at depths greater than 10 inches.

Drainage and Permeability: Well drained; slow to rapid runoff; moderately slow or slow permeability.

Use and Vegetation: These soils are used for nonirrigated cropland and the more strongly rolling morainic areas are used for range. The native vegetation is mainly western wheatgrass, needleandthread, green needlegrass, clubmoss, and fringed sagewort.
Distribution and Extent: Kevin soils are extensive and occur on the glaciated plains of northern Montana.


National Cooperative Soil Survey

U. S. A.
### APPENDIX III

#### FALL SOIL TEST RESULTS

<table>
<thead>
<tr>
<th>Site &amp; Plot #</th>
<th>Total NO₃-N to depth of 120cm kg/ha</th>
<th>Available P ppm</th>
<th>Extractable K ppm</th>
<th>pH</th>
<th>Organic Matter %</th>
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<tbody>
<tr>
<td>1 S</td>
<td>158</td>
<td>87</td>
<td>767</td>
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<td>2.9</td>
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<tr>
<td>1 K</td>
<td>33</td>
<td>48</td>
<td>398</td>
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<tr>
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<td>803</td>
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<tr>
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<td>232</td>
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S = Scobey  
K = Kevin
### APPENDIX IV

SOIL TEMPERATURE AT DEPTH OF 50cm ON PLOT 1 S

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<th>Date Recorded 1979</th>
<th>Soil Temperature °C</th>
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<td>18.9</td>
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<td>September 1</td>
<td>17.2</td>
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LITERATURE CITED


