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

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

of

MASTER OF SCIENCE

in

Soil Science

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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, 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 (Genter, 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 $CaCO_3$ 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.

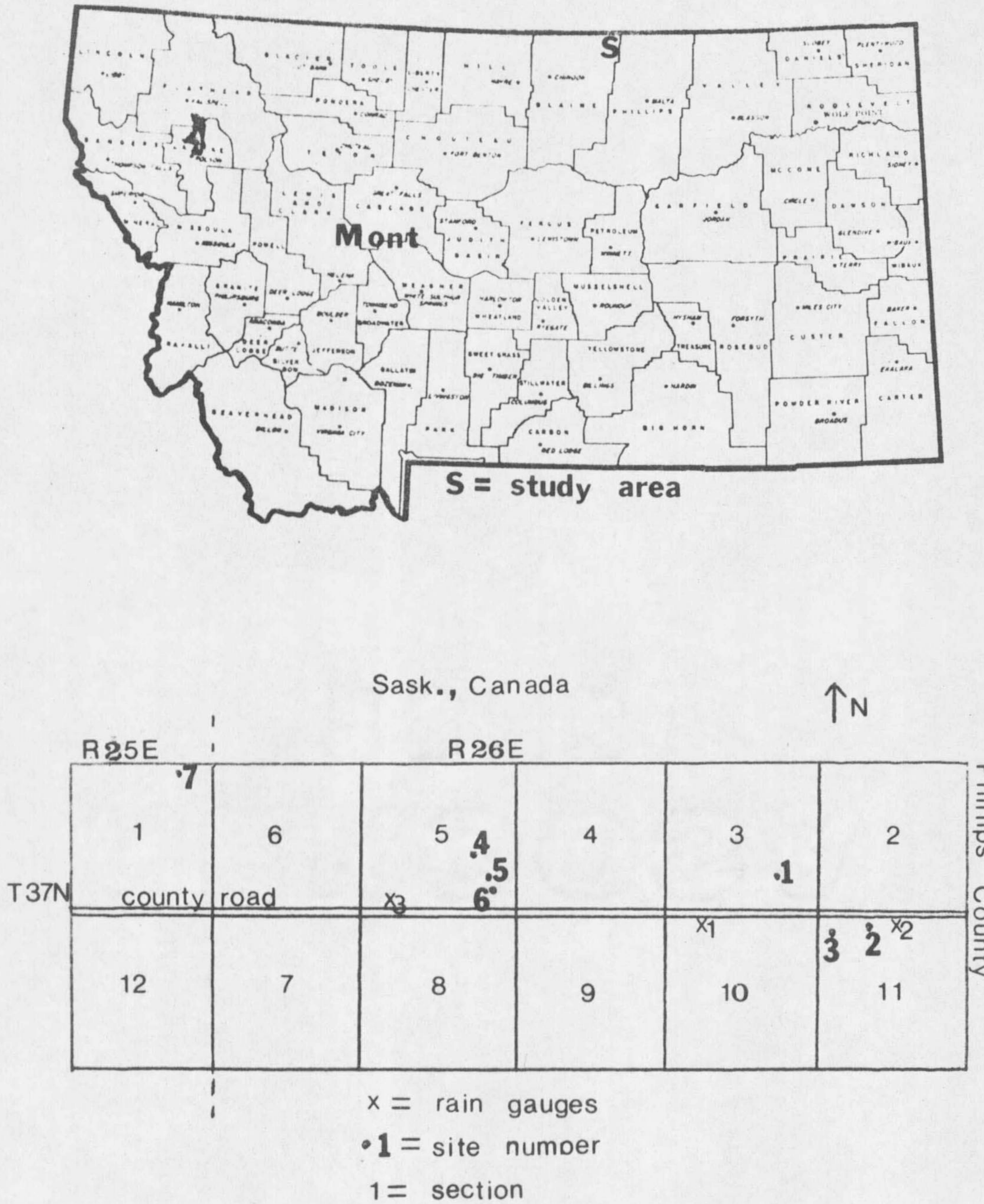

Figure 1. Location of Sites.

TABLE 1. QUESTIONNAIRE SUMMARY

Plot	Farm Operator	Legal Description	Seed Variety	Total Initial Water in 120cm Profile	Rainfall During Growing Season cm	Previous Crop	Summer Fallowed on Previous Year	Number of Times Tilled Prior to Planting	Stand Establishment 1 = Excellent 5 = Poor	Estimated Crop Loss Due to Weeds kg/ha	Planting Date 1979
1 S*	Walter Fouts	SE¼, NW¼, SE¼, Sec. 3 T 37N, R 26E	Bounty 309	19.8	13.04	Fallow	Yes	5	1	0	May 21
K*	Walter Fouts	SE¼, NW¼, SE¼, Sec. 3 T 37N, R 26E	Bounty 309	4.2	13.04	Fallow	Yes	5	1	0	May 21
2 S	Glenn Hutton	NW¼, NE¼, NW¼, Sec. 11 T 37N, R 26E	Bounty 309	9.3	12.37	Fallow	Yes	3	2	67	May 24
K	Glenn Hutton	NW¼, NE¼, NW¼, Sec. 11 T 37N, R 26E	Bounty 309	6.9	12.37	Fallow	Yes	3	2	67	May 24
3 S	Rick Glabofski	NW¼, NW¼, NW¼, Sec. 11 T 37N, R 26E	Bounty 309	6.1	12.37	Fallow	Yes	5	4	134	May 20
K	Rick Glabofski	NW¼, NW¼, NW¼, Sec. 11 T 37N, R 26E	Bounty 309	8.7	12.37	Fallow	Yes	5	4	134	May 20
4 S	Allen Billmyer	NE¼, NW¼, SE¼, Sec. 5 T 37N, R 26E	Butte	8.5	13.30	Fallow	Yes	4	2	33	May 26
K	Allen Billmyer	NE¼, NW¼, SE¼, Sec. 5 T 37N, R 26E	Butte	11.0	13.30	Fallow	Yes	4	2	134	May 26
5 S	Allen Billmyer	SW¼, NE¼, SE¼, Sec. 5 T 37N, R 26E	Butte	10.6	13.30	Fallow	Yes	4	2	67	May 26
K	Allen Billmyer	SW¼, NE¼, SE¼, Sec. 5 T 37N, R 26E	Butte	9.7	13.30	Fallow	Yes	4	2	33	May 26
6 S	Allen Billmyer	NW¼, SE¼, SE¼, Sec. 5 T 37N, R 26E	Butte	9.0	13.30	Fallow	Yes	4	2	67	May 26
K	Allen Billmyer	NW¼, SE¼, SE¼, Sec. 5 T 37N, R 26E	Butte	8.2	13.30	Fallow	Yes	4	2	67	May 26
7 S	Sid Egbert	NE¼, NW¼, NE¼, Sec. 1 T 37N, R 25E	Prodax	6.8	13.30	Crested Wheat Grass	No	5	4	33	May 29
K	Sid Egbert	NE¼, NW¼, NE¼, Sec. 1 T 37N, R 25E	Prodax	1.28	13.30	Crested Wheat Grass	No	5	4	33	May 29

*S = Scobey
K = Kevin

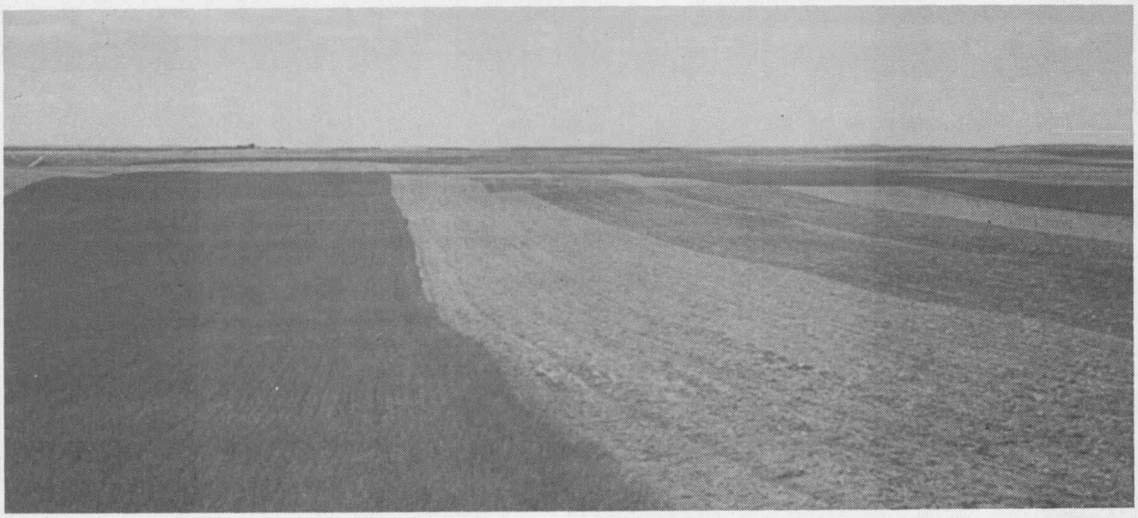

Figure 2a. Typical Scobey Landscape. Study area is more severely undulating.

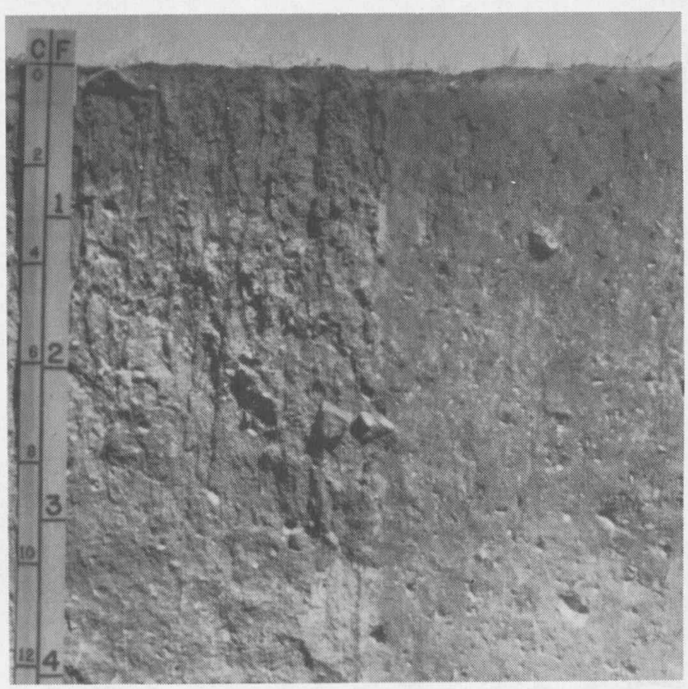

Figure 2b. Scobey Soil Profile.

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 (HCI) 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 $CaCO_3$ 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 $CaCO_3$ by adding HCI and measuring CO_2 loss (Williams, 1948), 3) extractable K by the neutral, normal NH_4OAC extraction procedure as modified by the

Montana State University Soil Testing Laboratory, 4) NO_3-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 NO_3-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, NO_3-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

Plot		Yield* kg/ha	Kernels/ Spike**	Stand Density m^2*	Percent Protein**	Available Phosphorus, ppm*	NO_3-N kg/ha*	Extractable Potassium, ppm**	Organic Matter, %**	$CaCO_3$, %*	pH**
1	S	5468	22.3	407	15.5	113	382	750	3.4	0.74	6.8
	K	3398	20.6	274	15.1	29	118	310	1.7	2.13	7.8
2	S	6501	37.3	339	14.5	63	193	318	1.9	0.63	7.8
	K	1863	23.4	129	14.1	25	39	282	0.9	5.80	8.1
3	S	3306	31.6	235	11.3	41	38	247	1.3	0.72	8.0
	K	1545	25.9	105	11.1	13	28	240	1.2	5.35	8.1
4	S	3840	22.0	292	17.2	51	121	255	1.5	0.61	8.1
	K	1377	19.8	120	15.3	14	45	216	1.0	5.08	8.3
5	S	6313	22.5	489	13.7	70	169	487	2.3	0.53	7.6
	K	1365	19.8	121	13.9	14	16	186	1.5	4.59	8.2
6	S	5009	23.7	366	15.5	57	140	454	2.0	0.70	8.0
	K	2315	20.7	131	13.4	21	61	247	1.3	4.39	8.3
7	S	2136	30.7	156	13.0	92	43	664	3.4	0.72	7.3
	K	546	14.3	59	11.0	18	30	318	1.5	3.52	8.1

S = Scobey
K = Kevin

*Significant at (p = .01) level

**Significant at (p = .05) level

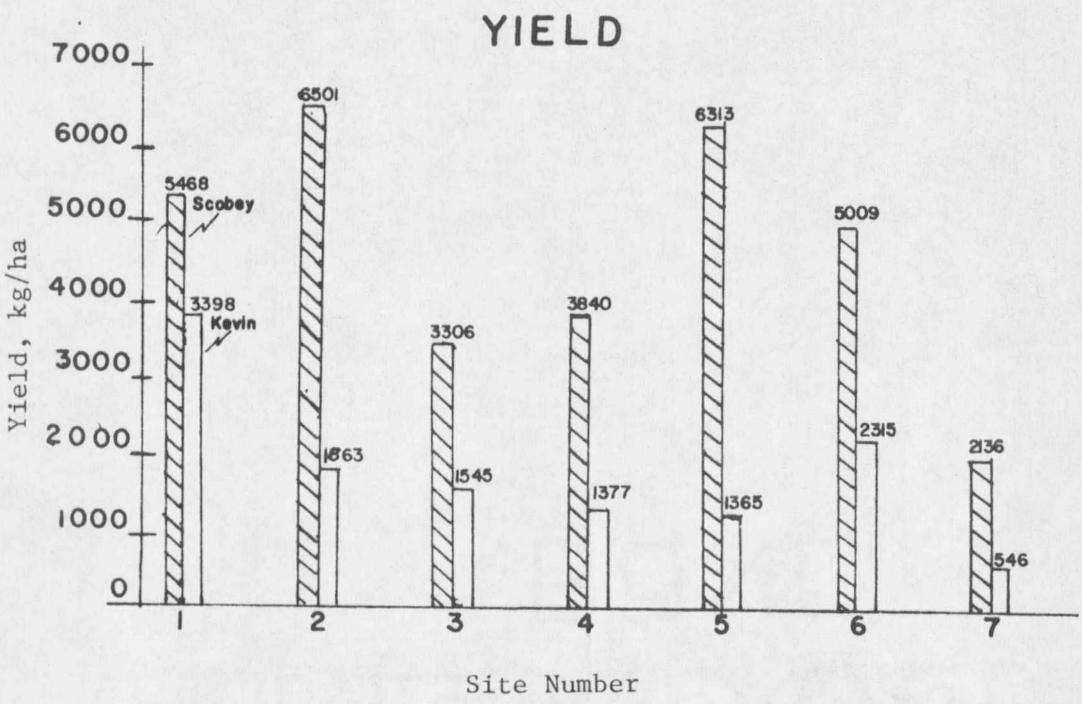

Figure 3. Spring Wheat Yield on Paired Scobey (shaded) and Kevin (unshaded) Soils.

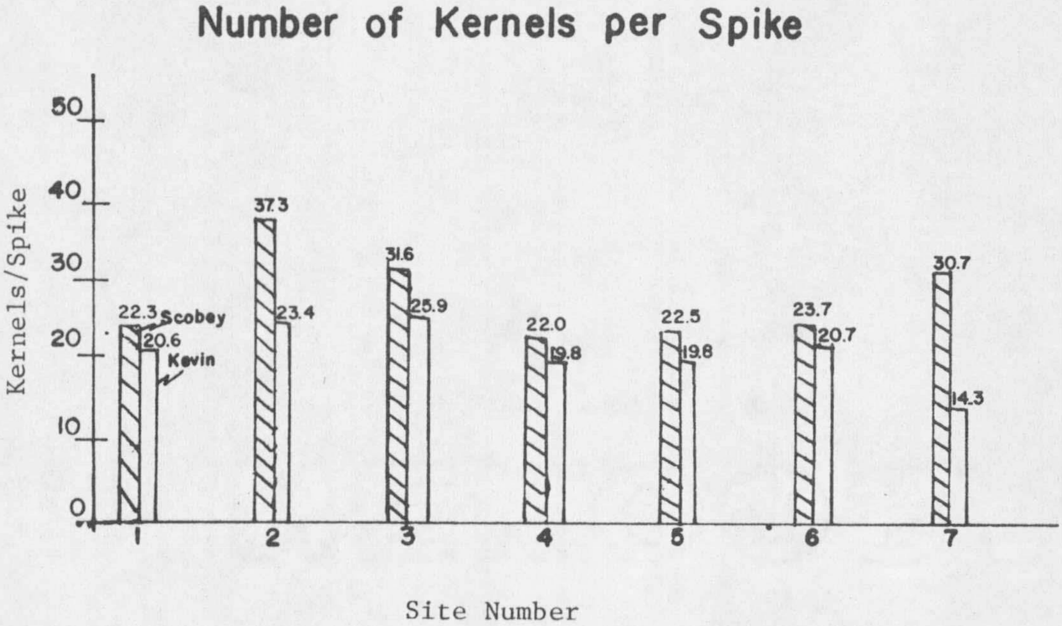

Figure 4. Number of Kernels Per Spike in Scobey (shaded) and Kevin (unshaded) Soils.

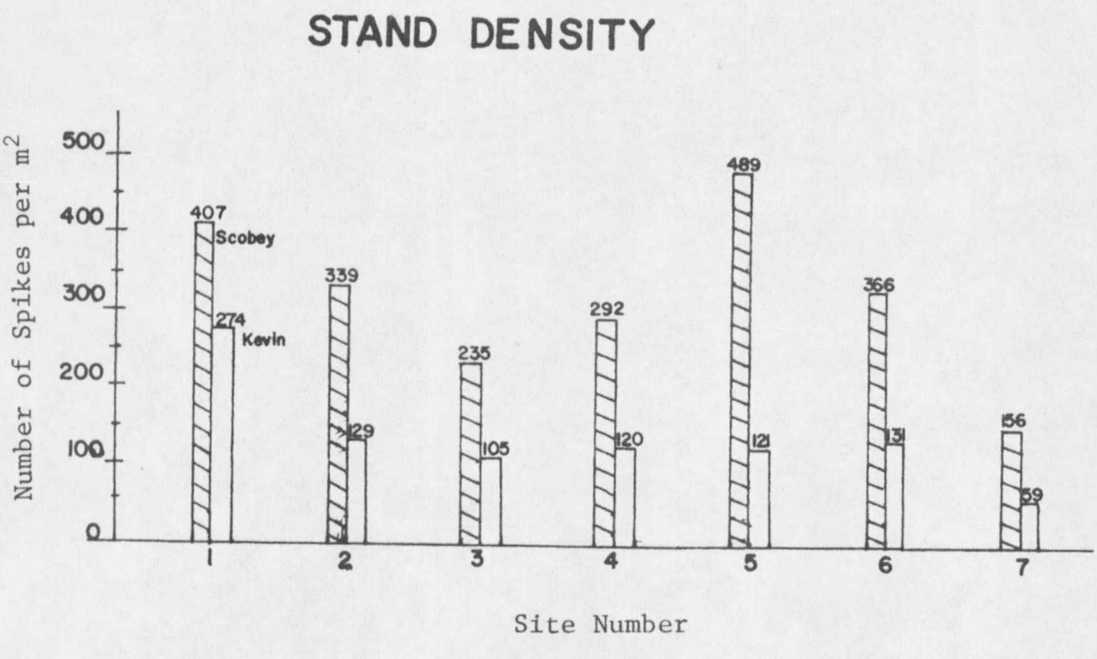

Figure 5. Stand Density in Paired Scobey (shaded) and Kevin (unshaded) Soils.

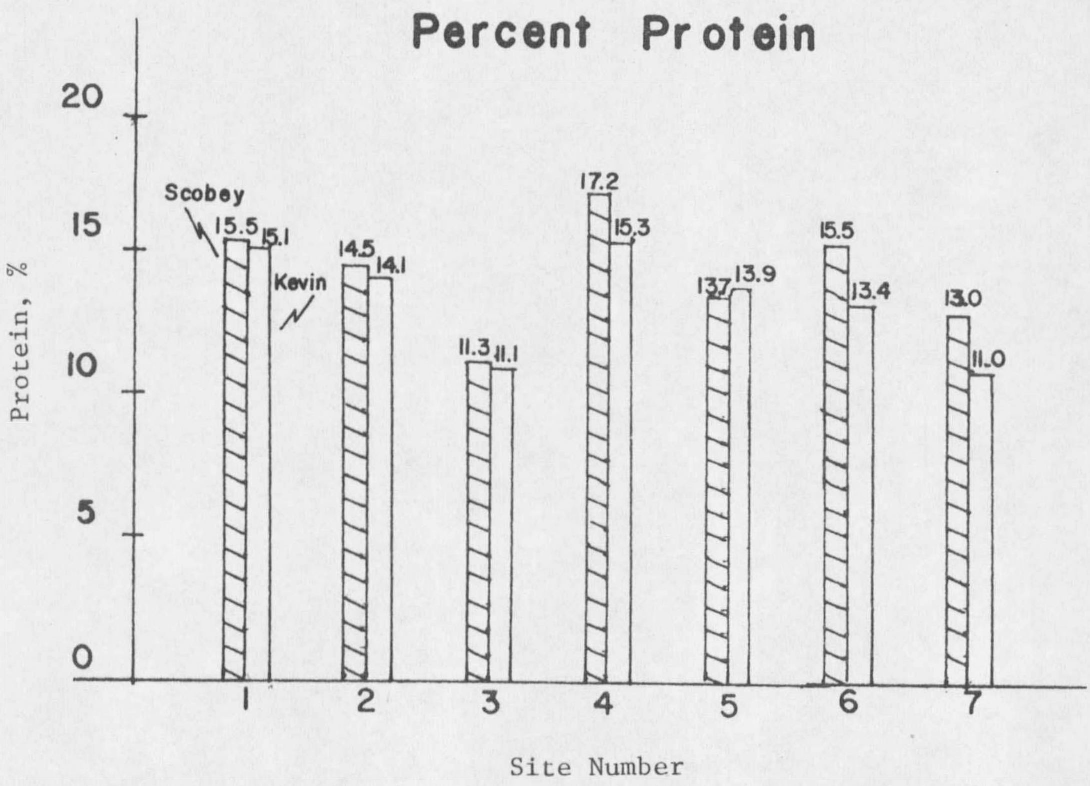

Figure 6. Percent Protein of Spring Wheat in Paired Scobey (shaded) and Kevin (unshaded) Soils.

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.

$CaCO_3$

$CaCO_3$ was correlated with soil series ($p = .01$). Average $CaCO_3$ percent in the Ap horizon of Kevin plots was 4.40% and .66% in Scobey. $CaCO_3$ values are shown in Figure 9.

NO_3-N

NO_3-N was correlated with soil series ($p = .01$). Soil profiles

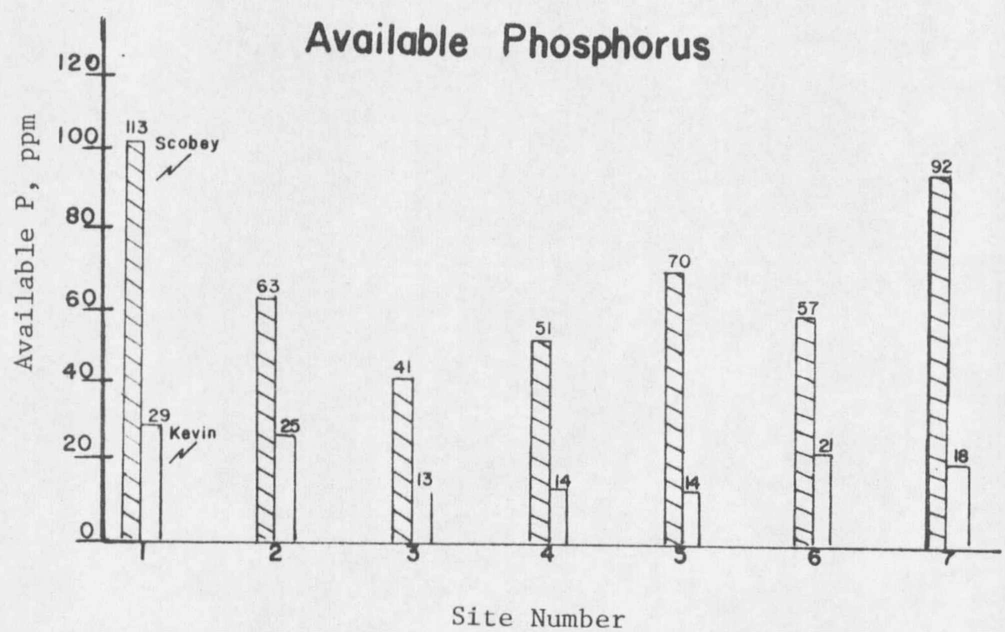

Figure 7. Available P in Paired Scobey (shaded) and Kevin (unshaded) Soils.

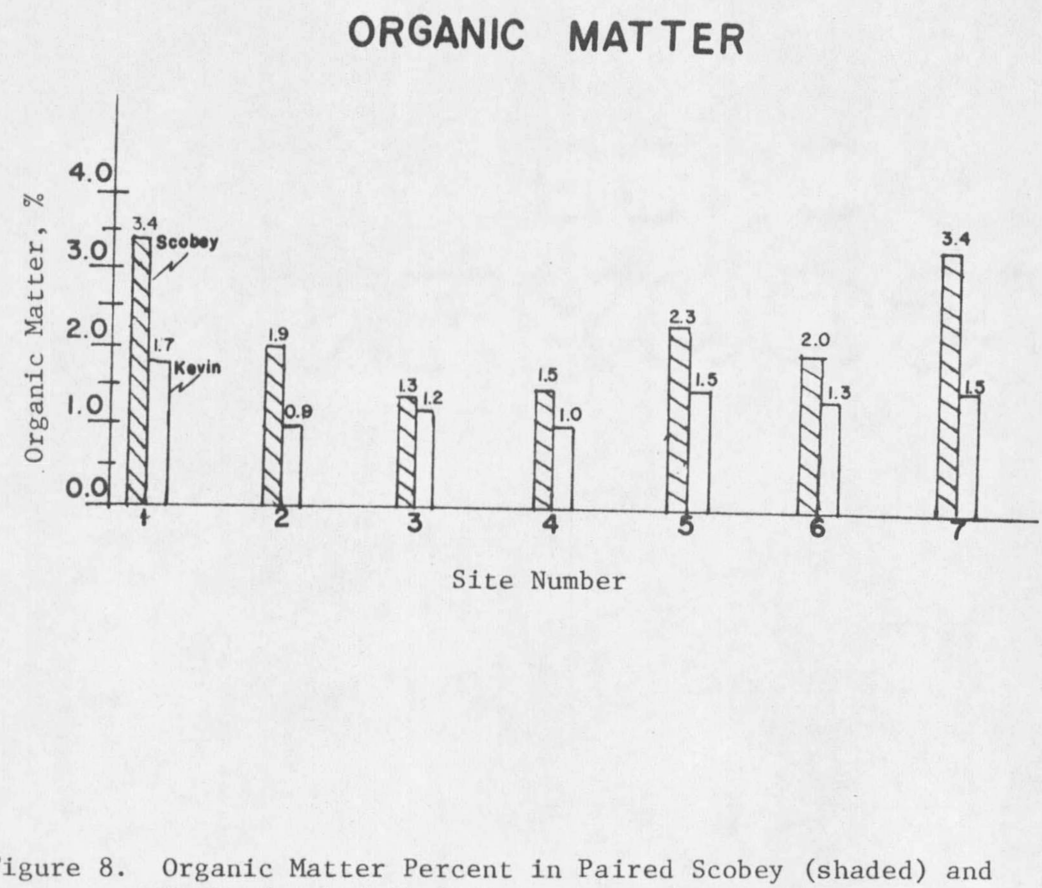

Figure 8. Organic Matter Percent in Paired Scobey (shaded) and Kevin (unshaded) Soils.

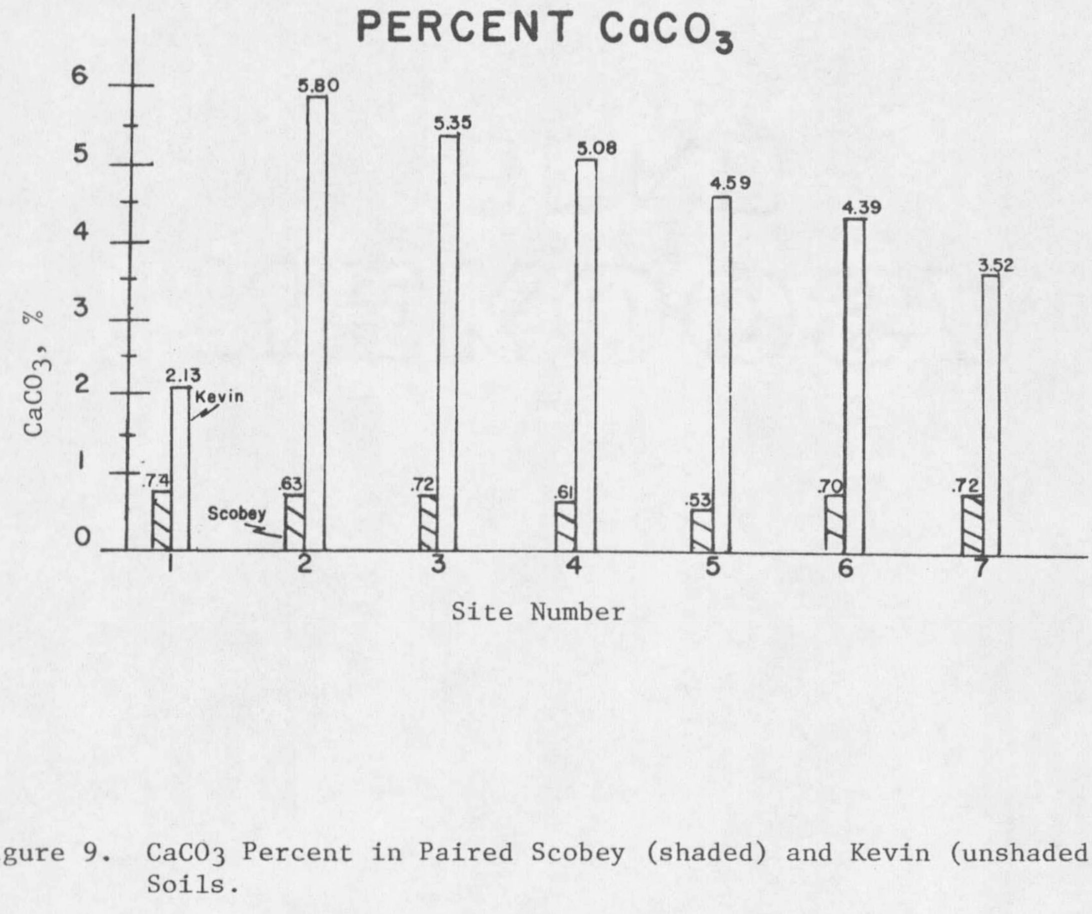

Figure 9. $CaCO_3$ Percent in Paired Scobey (shaded) and Kevin (unshaded) Soils.

in Scobey plots had an average of 169 kg/ha NO_3-N and Kevin plots averaged 48 kg/ha. NO_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.

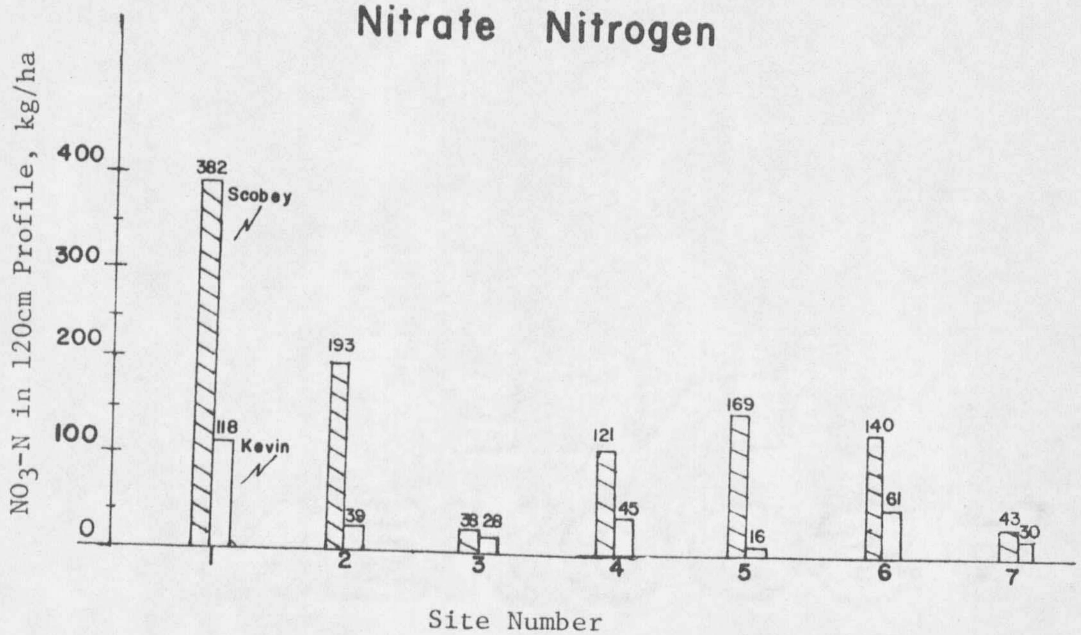

Figure 10. NO_3-N in Paired Scobey (shaded) and Kevin (unshaded) Soils.

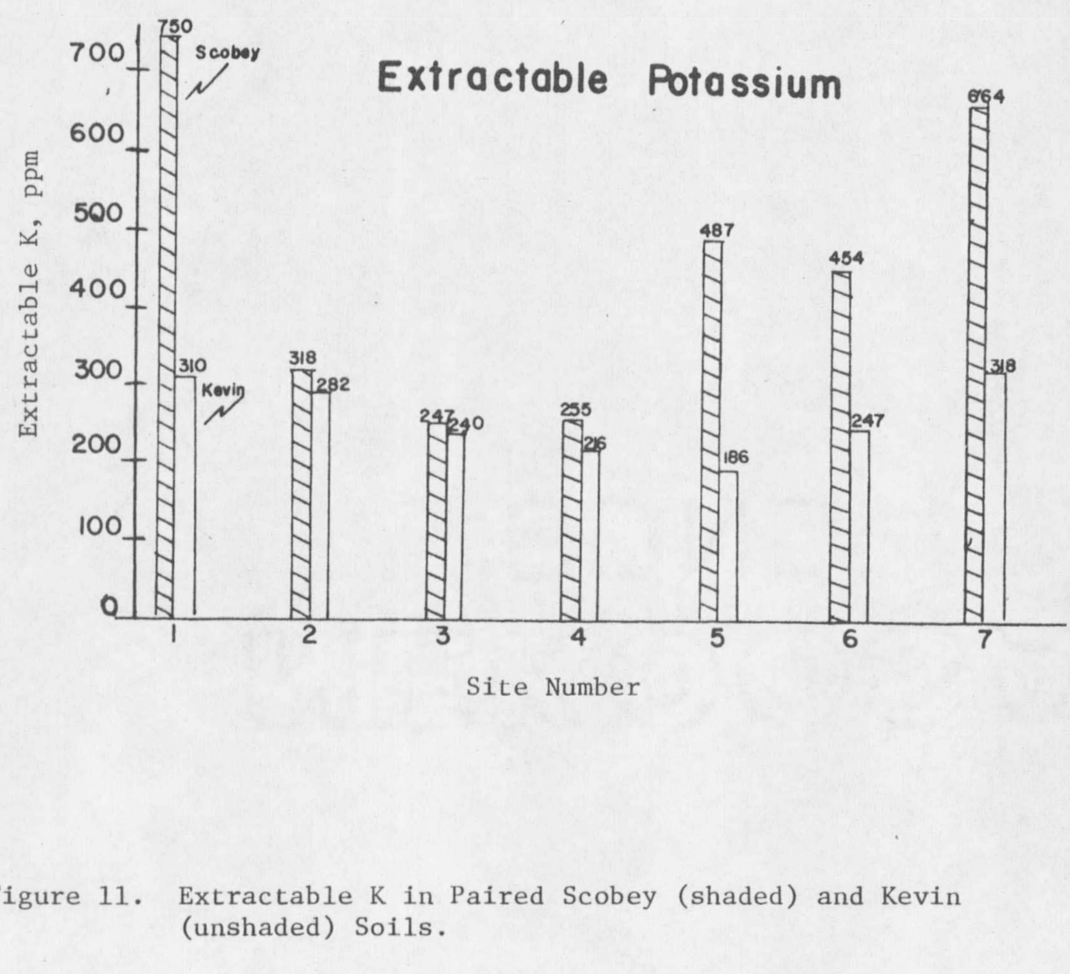

Figure 11. Extractable K in Paired Scobey (shaded) and Kevin (unshaded) Soils.

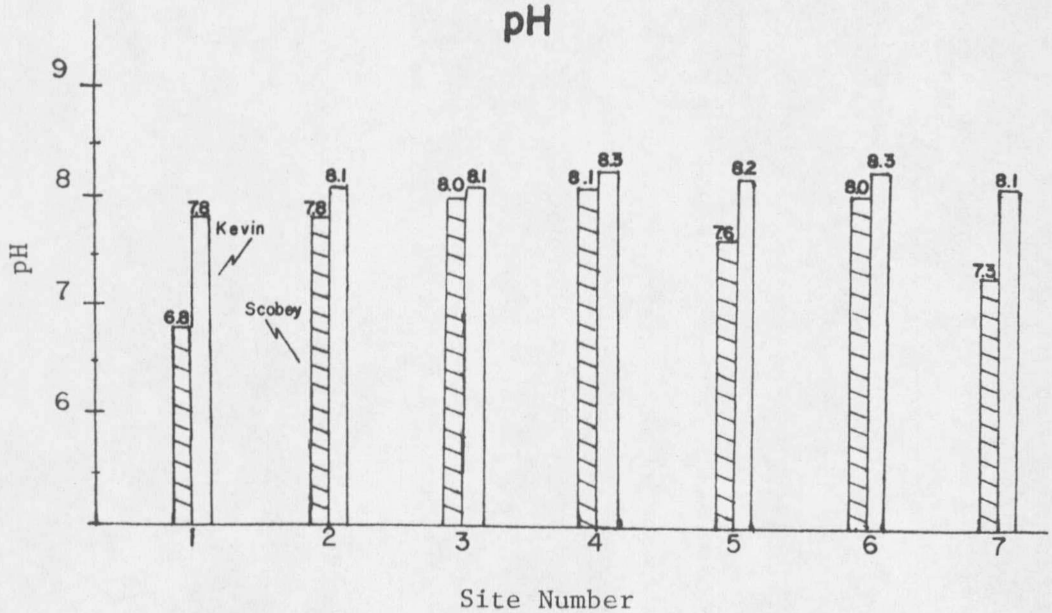

Figure 12. pH in Paired Scobey (shaded) and Kevin (unshaded) Soils.

TABLE 3. SUMMARY OF WATER UTILIZATION DATA

Plot		Initial H_2O in 120cm Profile	Rainfall cm	Fall H_2O in 120cm Profile	Water Utilization cm
1	S	19.8	13.04	4.44	28.4
	K	4.2	13.04	0.44	16.8
2	S	9.3	12.37	0.37	21.3
	K	6.9	12.37	0.87	18.4
3	S	6.1	12.37	0.47	18.0
	K	8.7	12.37	2.57	18.5
4	S	8.5	13.3	2.5	19.3
	K	11.0	13.3	4.0	20.3
5	S	10.6	13.3	2.7	21.2
	K	9.7	13.3	2.0	21.0
6	S	9.0	13.3	1.1	21.2
	K	8.2	13.3	3.4	18.1
7	S	6.8	13.3	4.8	15.3
	K	1.3	13.3	0.9	13.7

S = Scobey
K = Kevin

TABLE 4. PRECIPITATION DURING GROWING SEASON

Date Received	Amount Recorded, cm Site 1	2, 3	4, 5, 6, 7
June 3	.85	.70	.90
June 11	.11	.09	.14
June 25	.06	.08	.07
July 3	9.31	8.95	9.55
July 5	1.75	1.69	1.63
August 2	.96	.86	1.01
Total	13.05	12.37	13.30