SPATIAL RESPONSE OF MAIZE TO CONSERVATION TILLAGE AND POTASSIUM PLACEMENT ON VARIABLE SOILS

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Abstract

Most previous tillage research has normally involved a comparison of implements using small plots and assumptions of reasonable uniformity of texture and nutrient availability across the experimental site. We investigated the response of high oil maize to three tillage systems (no-till, strip-till and chisel tillage) and three potassium (K) rates in six replications of 153-m long plots involving different soil series (determined with a 1 to 5-m accuracy by professional soil classifiers) and initial soil exchangeable K concentrations. High oil maize response to tillage and K treatments on this variable soil site in eastern Indiana (2000-2002) was evaluated both by analyzing the mean treatment response and site-specific responses (based on 216 individual sampling positions). Mean responses indicated that maize yields were unaffected by tillage systems, but that both ear-leaf K and grain yield were increased with fertilizer K. Site-specific responses indicated that ear-leaf K concentrations varied more with soil series and soil exchangeable K status than with tillage. However, maize leaf K and yield responses to fertilizer K treatments were generally unaffected by either soil series or alternate ranges in initial soil K status. The use of precision agriculture tools in evaluating crop response to tillage systems requires sufficiently incremental documentation of inherent soil properties. Our experiences indicate that precision agriculture tools present both new opportunities and new challenges in tillage system research.

Materials and Methods:

A field experiment to examine tillage and K management effects on spatial variability of high of high oil maize (HOC) performance was established in east central Indiana (40°27' North Latitude, 85°15' West Longitude). The research was conducted across four distinct soil series within the experimental area that had been in no-till production for five years. Maize was planted following no-till soybean.

Soil series in the experimental field were classified by soil scientists on a 1 to 5m sampling basis (Figure 1). All soil series were derived from dense glacial till materials with native vegetation of deciduous trees. Blount silt loam (fine, illitic, mesic Aeric Ochraqualfs) is located on the crests of the existing drainage ways and is classified as being nearly level with somewhat poor drainage. Condit silt loam (Typic Epiaqualfs) has somewhat poor drainage and is predominately found on the drainage way slopes (varying from 0-1 %). Glynwood silt loam (fine, illitic, mesic Aquic Hapludalfs), on the slopes of the till drainage ways, is a moderately well drained soil normally with a 1-4 percent slope. Pewamo silty clay loam (fine, mixed, mesic Typic Aargiaquolls) is found in the natural drainage ways and has poor drainage. Outlines of the main tillage treatments blocks are also shown in Figure 1.

The experimental design was a split-plot design with completely randomized main tillage blocks, with K fertility sub-units. Individual plot dimensions were 4.6 meters wide by 153 meters long, and consisted of 6 rows of maize. The four center rows were mechanically harvested allowing for a 1.5 m buffer zone between the individual plots. A detailed treatment description is given below:

Main Plot (Tillage)

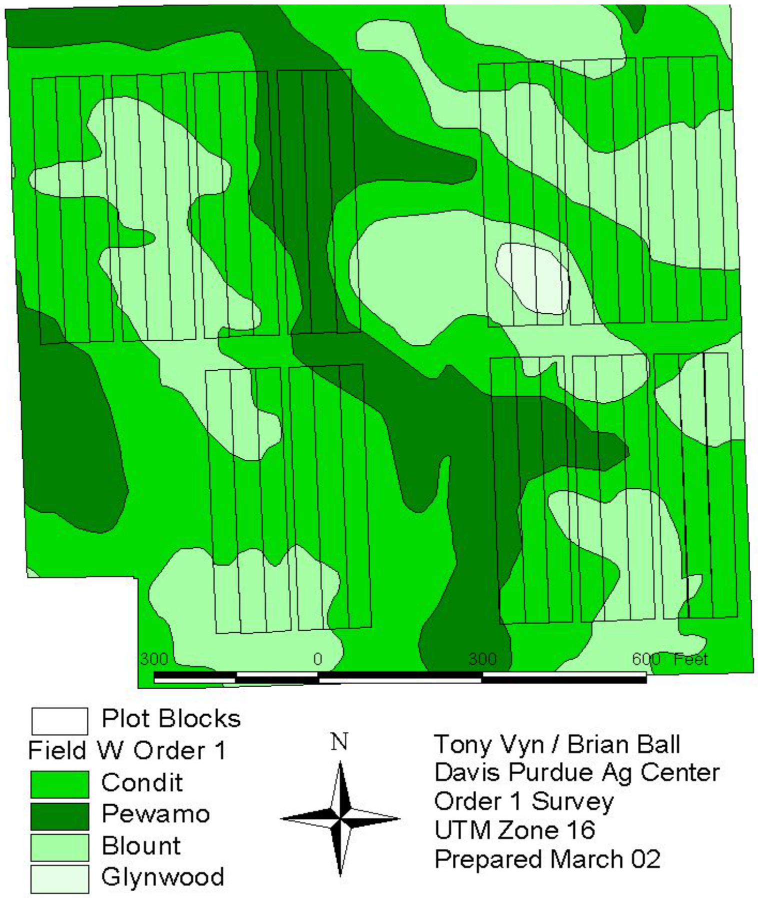
1. No-tillage (NT). Planter was equipped with single 2 cm fluted coulter per row with tined row cleaners.
2. Fall chisel, with spring cultivation (CT). A Brillion chisel plow at a depth of 15 cm, followed in the spring by a single pass of a Glencoe field cultivator.
3. Fall Strip tillage (ST). A DMI 2500 tool bar to a depth of 20 cm with mole knife shanks and no additional tillage in the spring.

Sub Plots (K rate and placement)

1. No K (No K). No K was applied to the plot.
2. Fall K (Fall K). Broadcast application of 165 kg ha^{-1} of K_20 as 0-0-60 in NT and CT main plots. In the ST treatment, the same rate of K fertilizer was placed in the intended row areas at a depth of 20 cm with a DMI 2500.
3. Fall K plus Spring starter (F & S). Fall K application (as stated in #2 above) was followed by additional 56 kg ha^{-1} of K_20 in a 5 cm x 5 cm liquid starter band placed at planting.

Maize was planted in 76-cm row widths. Pioneer High Oil hybrid 34B25 was planted on May 12, 2000 and May 1, 2001 at populations of 77,000 seeds ha^{-1} using a John Deere 7200 Max Emerge planter. Planting depths were between 3-4 cm in all tillage treatments. Nitrogen and phosphorus starter fertilizer was applied to all plots at a rate of 42 kg/ha N and 28 kg/ha P_2O_5 as all, or part of, a liquid blend. In treatments of spring applied K, an additional 56 kg ha^{-1} was applied in the starter. The starter was banded 5cm below and to the side of the seed. Sidedress application of 213 kg N ha^{-1} of anhydrous ammonia was applied at the V4 to V6 corn growth stage in both years.

Figure 1. Order 1 soil survey of the experimental field, eastern blocks were planted to maize in 2000 and western blocks in 2001.



Soil samples were taken at four sampling positions at 30m intervals in each plot to determine both the initial exchangeable K status and the extent of stratification that was present in the soil. These measurements were essential in understanding the variability in response (or lack of response) to both tillage operations and alternate K rates.

Several plant parameters were recorded throughout the growing season. In the four sampling positions per plot, measurements included early season population, early season height, ear-leaf K, yield, grain moisture, oil content, starch content, protein content, and grain K levels. Only ear-leaf K and yield response in 2000 and 2001 will be discussed here.

Grain yield was obtained from the combine's Ag Leader yield monitor. The flow data (recorded as lb sec^{-1}) was exported into Microsoft Excel and converted to 15.5% moisture and then to Mg ha^{-1} sec^{-1}. Five adjacent flow points were averaged together to give a smoothed yield estimate. Then the closest average yield point to the sampling point was assigned the yield for that area (a distance of approximately 7.62 m). This assignment was done in ArcView software package (ESRI, ArcView 3.2, 2000; Environ. Systems Research Institute, Inc., Redlands, CA, USA.) through the geo-processing "join" function. These averaged yield values for each sample area was the value used in the statistical analysis in both years.

Results and Discussion:

Soil K stratification was observed across all tillage and broadcast treatments. Figure 2 shows the mean soil K concentrations for the combined year data. In 2000 the concentrations at the 0-5 cm depth averaged 228 mg kg^{-1}, while in 2001 the 0-5 cm concentration average was only 179 mg kg^{-1}. Soil concentrations averaged 107 mg kg^{-1} in the 5-15 cm depth and 96 mg kg^{-1} at the 15-25 cm depth for both years. Potassium stratification, therefore, was somewhat more pronounced in 2000 than in 2001.

Figure 2. Combined year soil exchangeable K concentration at 3 depths.

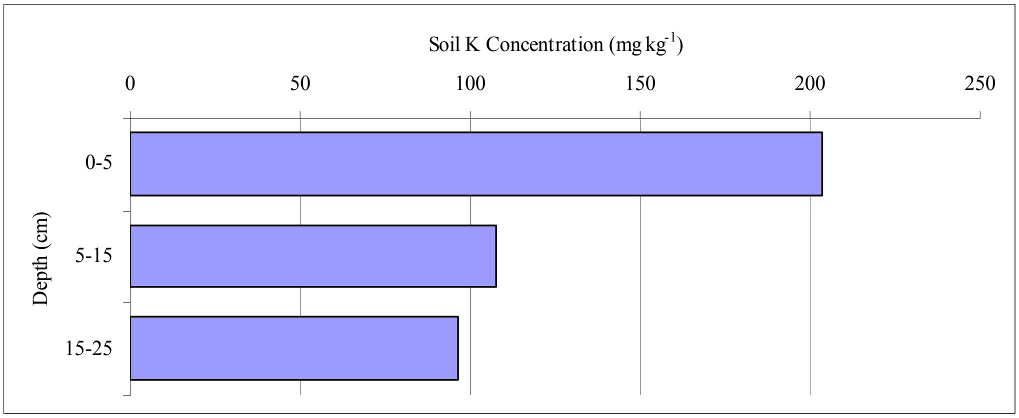


Table 1. Ear-leaf K concentrations as affected by tillage, K fertilizer, soil series, and soil exchangeable K (5-15 cm depth) in 2000 and 2001.

2000

Treatment	Average	Soil Series: Blount	Soil Series: Condit	Soil Series: Pewamo	Soil Exchangeable K (mg kg^{-1}): <90	Soil Exchangeable K (mg kg^{-1}): 90-125	Soil Exchangeable K (mg kg^{-1}): >125
	Ear-leaf K (%)						
No-till	1.82	1.74	1.85	1.90	1.72	1.84	1.91
Chisel	1.85	1.77	1.91	1.96	1.65	1.91	1.94
Strip-till	1.82	1.74	1.83	1.91	1.71	1.84	1.94
No K	1.72 *b*	1.62	1.77	1.79	1.52	1.80	1.86
Fall K	1.86 *a*	1.77	1.89	1.93	1.74	1.91	1.93
F&S	1.91 *a*	1.86	1.92	2.04	1.82	1.89	1.99
Mean	1.83	1.75 B	1.86 A	1.92 A	1.69 C	1.86 B	1.93 A

2001

Treatment	Average	Soil Series: Blount	Soil Series: Condit	Soil Series: Pewamo	Soil Exchangeable K (mg kg^{-1}): <90	Soil Exchangeable K (mg kg^{-1}): 90-125	Soil Exchangeable K (mg kg^{-1}): >125
	Ear-leaf K (%)						
No-till	1.33 *b*	1.16	1.44	1.36	1.10	1.44	1.46
Chisel	1.47 *a*	1.34	1.55	1.49	1.35	1.48	1.59
Strip-till	1.41 *a*	1.25	1.48	1.57	1.29	1.54	1.55
No K	1.29 *b*	1.14	1.35	1.44	1.12	1.40	1.46
Fall K	1.44*ab*	1.24	1.52	1.56	1.26	1.46	1.63
F&S	1.48 *a*	1.38	1.59	1.41	1.36	1.61	1.52
Mean	1.40	1.25 B	1.49 A	1.47 A	1.25 B	1.49 A	1.53 A

Table 2. Grain yield as affected by tillage, K fertilizer, soil series, and soil exchangeable K (5-15 cm depth) in 2000 and 2001.

2000

Treatment	Average	Soil Series: Blount	Condit	Pewamo	Soil Exchangeable K (mg kg^{-1}): <90	90-125	>125
	Grain Yield (Mg ha^{-1})						
No-till	7.94	7.54	8.14	8.79	8.09	7.63 *b*	8.31
Chisel	8.44	8.64	8.34	7.86	8.45 ab	9.29a *a*	7.76 b
Strip-till	8.47	8.40	8.32	8.90	8.46	8.62 *a*	8.33
No K	7.97 B	7.71	7.97	8.38	7.49	8.55	8.14
Fall K	8.08 B	8.26	8.05	7.69	8.63	7.97	7.73
F&S	8.80 A	8.60	8.77	7.73	8.89	9.03	8.54
Mean	8.28	8.19	8.26	8.52	8.33	8.51	8.13

2001

Treatment	Average	Soil Series: Blount	Condit	Pewamo	Soil Exchangeable K (mg kg^{-1}): <90	90-125	>125
	Grain Yield (Mg ha^{-1})						
No-till	11.19	11.16	11.24	10.97	11.32	11.10	11.17
Chisel	11.15	10.87	11.22	11.42	10.80	11.21	11.48
Strip-till	11.35	11.20	11.52	11.02	11.31	11.41	11.40
No K	10.95 B	10.71	11.05	11.00	10.84	10.88	11.14
Fall K	11.26AB	11.20	11.28	11.23	11.18	11.22	11.45
F&S	11.48 A	11.32	11.64	11.18	11.41	11.62	11.47
Mean	11.23	11.07	11.33	11.14	11.14	11.24	11.35

Data followed by the same letter, or no letter, within a row or within a column are not significantly different according to a protected LSD *P* = 0.05 or a t test (GLM model) at t_{crit} = 0.05. Letters distinguishing differences among individual tillage and K treatment means within columns are italicized, among SEK within rows are shown in lower case. Overall means within a column are shown in upper case. No K=no K, Fall K=fall applied K, F&S=fall and spring applied K.

Ear-leaf potassium indicates the level of midseason K nutrition. We observed 0.4% higher ear-leaf K concentrations in 2000 than in 2001 (Table 1). This higher result may be due to the wetter soil conditions in the week before sampling, and thus higher avalable K from the soil. We observed no differences among tillage systems in 2000, and lower ear-leaf K values in NT treatment compared with CT and ST in 2001. Significant increases in ear-leaf K were observed with increasing K fertilizer rate in both years. Treatment interactions, or group interactions with either tillage or K fertility treatments were not significant in either year. The latter suggests that corn leaf K response to tillage and K was consistent across all soil groups and SEK ranges.

Higher K fertilizer rates were also associated with an increase in ear-leaf K concentrations of NT and ST in conventional maize in previous studies (Vyn and Janovicek, 2001; Vyn et al., 2002). They also found that K in the starter likewise increased ear-leaf K in normal yellow dent maize (YDC) as we observed with HOC.

Yield differences varied between years due to climatic conditions. Tillage did not affect grain yields in either year; however, higher K rates increased yields in both years (Table 2). A particularly large yield advantage occurred with starter K band application in 2000. Highest yields occured in the F&S treatment. This positive response is an indication of the possible importance of K in the starter or, alternatively, a possible response associated with more K fertilizer. Except for a tillage x SEK interaction for yield in 2000 (the result of an enhanced post-emergence plant population loss with high soil K), HOC yield response to tillage and K fertility treatments was consistent across soil series and SEK groupings. Grain oil concentrations, however, were affected more by initial soil K concentrations than by fertilizer K treatments (Vyn and Ball, 2002).

Previous studies have also demonstrated maize yield increases with additional K fertilizer application, or in response to placement in no-till and strip-till systems (Bordoli and Mallarino, 1998; Mallarino et al. 1999; Vyn and Janovicek, 2001; Vyn et al. 2002).

Conclusions:

Preliminary analyses of site-specific data within and among replicated plots indicated that HOC maize leaf K and yield response to tillage and K fertilizer treatments was not affected by either soil series or the soil exchangeable K status of individual sampling positions. The consistency of HOC response to tillage treatments across variable soils suggests that there is a wide degree of latitude in adoption of conservation tillage systems in HOC maize production. Although further research on potentially spatial response of maize to tillage is warranted, any attempt to investigate spatial variability in maize response to tillage and associated fertility management requires accurate soil series and soil fertility information. The latter has both time and cost considerations.

References:

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