STRIP-TILLED CORN RESPONSES TO DEEP PLACEMENT OF PHOSPHORUS AND POTASSIUM (2005 UPDATE)

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Introduction

Reduced tillage systems modify some of the most important variables related with the plant-soil-weather environment and consequently affect the last expression of this relation: yield. A possibly more restrictive root growth scenario (due to lower soil temperatures and higher mechanical impedance), as well as pronounced horizontal and vertical stratification in nutrients within the soil profile (particularly for no-till systems) could lead to a reduction in root uptake of nutrients. This situation is of particular relevance for the less soil mobile nutrients, such as phosphorus (P) and potassium (K).

Among the different fertilizer application methods for P and K in corn-soybean rotation systems in the Corn Belt states, broadcasting is most common. This method further increases the stratification of nutrients under reduced tillage systems because of little or no soil incorporation. Any decline in P and K fertility rates driven by concerns for higher fertility prices (or environmental issues with P) may also deepen the concerns for the resultant impacts of stratification on crop yield. Moreover, a continued increase in mean corn yields per year attained as a result of higher yielding hybrids, higher plant populations and possibly improved management of N fertilizers will result in greater P and K nutrient harvest from the system.

Strip tillage and deep banding of P and K fertilizers may be one alternative combination of management practices to partially overcome the constraints discussed above while aiming to realize high yield potential in a given environment. Strip tillage increases soil temperature in early spring and improves the physical condition of the soil for seed germination and seedling emergence, thus assuring proper crop stands and higher early growth rates than commonly occur in no-till. Deep placement of P and K may be a way to enhance rooting system access to P and K and help corn plants to more efficiently recover applied fertilizers than by broadcasting alone.

The purpose of this research is to investigate the effects of the depth of P and K placement on corn yield and phenotypic responses specifically in intended high yield environments. Better understanding of processes involved might permit improved fertility recommendations to farmers as corn yields continue to increase.

Materials and Methods

SITE AND WEATHER

In 2005, the research was conducted at the Purdue Agronomy Center for Research and Education (ACRE) at West-central Indiana.

The soil was a Drummer silty clay loam soil (3.4 % OM) with mean soil test levels for P and K considered as "High" testing and generally above critical levels (P 15ppm; K 125ppm) for corn by the Tri-State Fertility Recommendation bulletin (Table1).

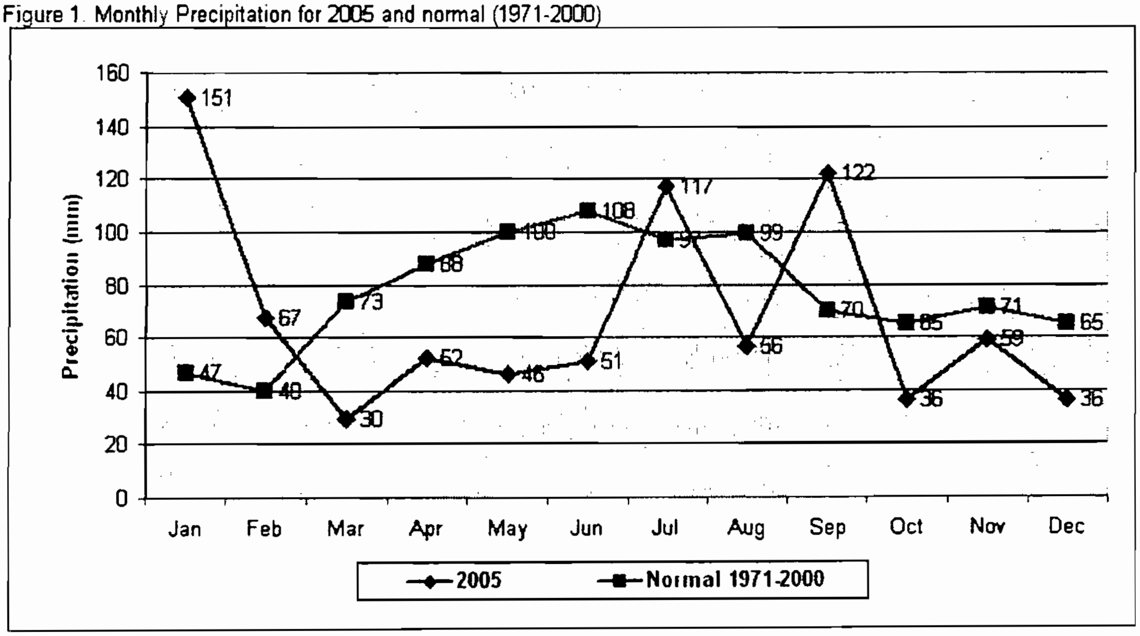
This field has been under reduced tillage systems for at least 5 years, and the experiment was first started for the corn-soybean rotation on this site in 2003.

Table 1. Soil test results. Deep P and K placement study, ACRE, Spring 2005.

Depth (cm)	pH	OM	P_M3	K_M3	CEC_M3
0-10	6.57	3.61	24.63	217.35	21.63
10-20	6.46	3.18	25.76	92.45	21.54
20-40	6.35	2.60	10.78	78.29	22.67

Total annual precipitation was 100 mm lower compared to 30-year normals (1971-2000). The first two months of the year got above-normal rainfall, which may have led to soils with moisture levels near their water holding capacities. On the other hand a shortage of rains happened during the period between March-June, which coincides with planting and most of the vegetative growth perio. This drier situation continued for most of the year. However, above-normal rains occurred in July, just at the most critical period of the crop for yield determination (Figure 1).

Figure 1. Monthly Precipitation for 2005 and normal (1971-2000)



Referring to the mean air temperature (C°) pattern for 2005, the year started being warmer than normal until March, and then behaved near long-term averages during the growing season of the crop. Total GDD in 2005 was 200 higher than normal showing a small positive difference (+79 GDD) for 2005 through the early growth stage of the crop (March–May) whereas during the critical period for yield determination (June-August) the observed difference behaved the opposite (-93 GDD) (Table 2).

Table 2. Mean Air temperature and GDD (divided by periods) for 2005 and normal (1971-2000), ACRE.

Mean Temp.(C⁰)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2005	-2.72	0.42	2.14	12.41	15.47	22.87	22.99	23.19	20.54	12.57	6.10	-4.62
Normal	-3.81	-1.08	4.83	10.67	16.81	21.97	24.17	23.00	19.14	12.58	5.81	-0.81

GDD	2005	Normal
Jan - Feb	37	0
Mar - May	689	610
Jun - Aug	2044	2137
Sept - Dec	940	764
	3710	3511

FIELD PRACTICES AND CROP MANAGEMENT

Strip-till and fertility placement treatments were applied in fall 2004. A 6-row DMI 2500 equipped with a Gandy air distribution system and mole knives was used for establishing the banded treatments at a depth of 6-8 inches. The same unit was raised out of soil to apply the broadcast treatment.

Corn was planted (32,000 plants/acre) on top of the fall strip-tilled rows on April 15, together with a uniform starter application on all plots (see Table 3).

Two Pioneer hybrids with different maturities were planted:
(1) 31G68 (118 CRM) (2) 31N28 (119 CRM)

Table 3. Field practices and Crop management.

CULTURAL PRACTICES USED FOR PK CORN, 2005 Field 131, ACRE		
Field Operation	Date	Application Details
Tillage	11/16/04	Strip-till with DMI 2500 (mole knives)
Lime Application		None
Fertility Application	11/16/04	Various treatments
Planting	4/15	
Starter fertility/planter		15 gal/ acre 9-18-9 plus zinc, pump setting = 4.7
Insecticide/planter		Force 3G, 5 oz/1000 row feet, banded over row
Herbicide Application	4/14	Pre-plant: Harness Extra 5.6 @ 5 pt/ac, Roundup WeatherMax 1 pt/ac with ammonium sulfate @ 17 lbs/100 gallons of water
	5/18	Post-emerge: Clarity @ 1 pt/ac
Nitrogen Applications	5/18	150 lbs N/a as UAN (28%) @ 45 gal/a, 6 row, pump setting = 4.0
	6/1	150 lbs N/a as UAN (28%) @ 45 gal/a, 6 row, pump setting = 4.0
Harvest	10/1	Almaco/John Deere 700 Combine
Fall Fertility Application	11/3 and 11/4	

The plots were harvested using a John Deere/Almaco model 700 combine equipped with a 4-row corn head. All other required management practices (N fertilization, weed control, insect control) were performed according with the objective of achieving a high yielding environment. Additional broadcast K (119 lb/ac) had been applied on half of each fertility placement plot before seeding the prior no-till soybean crop in 2004.

TREATMENTS AND MEASUREMENTS

The design of the research was a split-split plot with corn hybrid as main plot, fertility placement as subplot, and the additional application of prior broadcast K as sub-subplot. Fertility placement alternatives consisted of 5 treatments: check, broadcast P+K, banded P+K (depth 6-7"), banded P alone (depth 6-7"), and banded K alone (depth 6-7"). For all fall fertilizer treatments – whether deep banding or broadcasting - the rates of P_2O_5 were 88 pounds/acre applied as 0-46-0 whenever P was required, and rates of K_2O were 115 pounds/acre applied as 0-0-60 whenever K was required. The sub-plot size was 15 feet wide (6 rows) and 75 feet long (Table 4).

Table 4. Possible random combination of treatments within each main plot.

Hybrid	Pioneer 31N28 Pioneer 31G68									
Fert. Placement	Check		Broadcast P-K		Banded P-K		Banded P		Banded K	
Extra K App.		-/+ K	-/+ K		-/+ K			-/+ K	-/+ K	

Soils samples were taken on all plots at 3 depth intervals (0-4", 4-8" and 8-16") in the spring of 2005 after the fertility treatments were established.

Growth and development of the crop were characterized throughout the growing season by measuring the following parameters: height (V4 – V9 – R1), biomass (V9), biomass nutrient concentration (V9), SPAD at the ear leaf (R1, R3, R4, R5, R6) and fourth leaf below the ear (R4, R5), ear leaf nutrient concentration (R1), stalk diameter (R1 and R6) and grain nutrient concentration. Whole plot yield was obtained by combine-harvesting the center 4 rows of each plot and then correcting to 15.5% moisture content.

Statistical analysis was performed using SAS Procedures.

Preliminary Results

Just three of the entire set of variables had been statistically analyzed when this report was written, so only these results are presented and discussed here.

YIELD

Fertility treatments resulted in significantly different yield responses (Table 5). Broadcast P+K was the highest yielding treatment, banded K alone and banded P+K were the second best treatments (although not different from each other), and the lowest-yielding treatments were the banded P alone and check treatments. No statistically significant differences were observed either between hybrids or between the additional K sub-treatments (Table 5).

Table 5. Fertility, hybrid and extra K effects on final grain yield in 2005.

Treatment	Yield (kg/ha)		Hybrids	Yield (kg/ha)	Additional K	Yield (kg/ha)
Broadcast P-K	13494	A	Pioneer 31-G-68	12685	No plus K	12609.61
Banded K	12944	B	Pioneer 31-N-28	12525	Plus K	12600.17
Banded P-K	12613	B				
Banded P	12153	C				
Check	11821	C				

Means with different letters are significantly different

These results suggest that yields are not compromised by broadcast P and K application even if the soil is highly stratified for exchangeable K (Table 1). Deep banding P and (or) K never improved yields relative to broadcast P and K application. Deep banding P alone had no effect on yields, and this suggests that P was not limiting in this experiment because of the inherently high levels that existed, perhaps because there was little P stratification in the upper 20 cm (Table 1), and because a uniform starter band application was applied to all treatments.

Some prior studies have suggested that the growing conditions most conducive to positive corn yield responses to deep banded P and K are those seasons with low rainfall during late spring or early summer in reduced tillage system with stratification of both nutrients. In our case, we did not have significant stratification in P, and we may have had enough rainfall since the broadcast P+K application in the fall of 2004 that more than enough exchangeable K was available from that application.

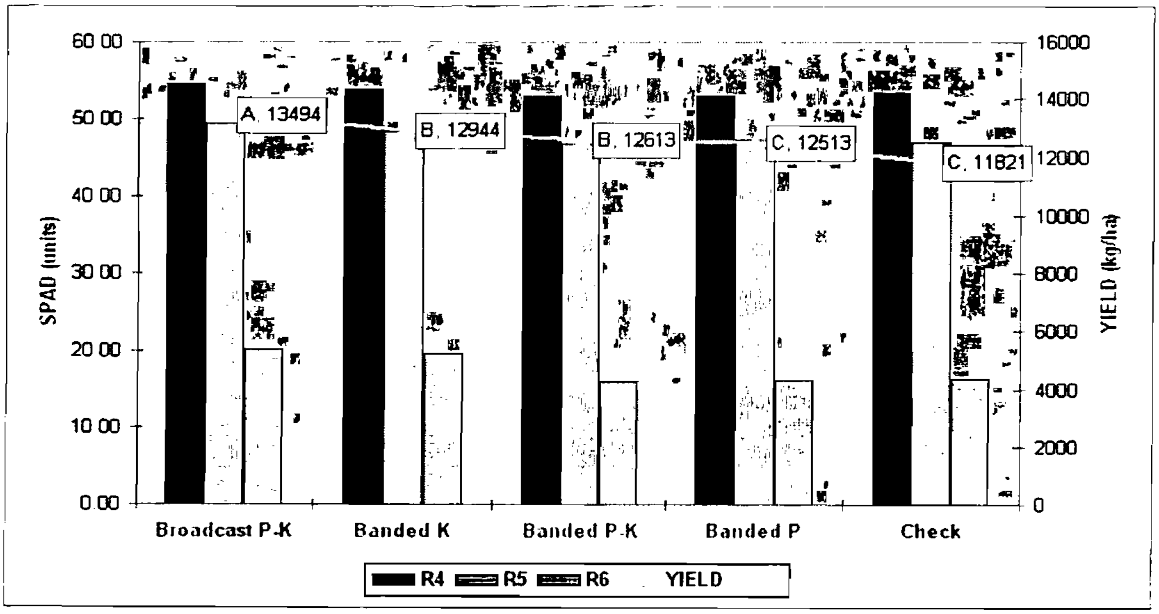
EAR LEAF SPAD MEASUREMENTS: R4, R5, R6

SPAD has two features that make it a valuable nutrient diagnostic tool: first is its capability of estimating leaf chlorophyll content – as an indirect parameter of the N status of the plant – and second is its high correlation between measurements at advanced growth stages (R3 through R6) and yield. Both of them can be used to assess the response to banded P and K.

P deficiencies may be detected by SPAD because of its impact in reducing the photosynthesis rates per unit of leaf area. Also, some studies have suggested a probable role of K in nitrate absorption or translocation as related to the osmotic function of the K located in the vacuoles, which could indirectly alter leaf chlorophyll concentration. In addition, K deficiency symptoms are related to marginal leaf chlorosis and other sub-clinical forms of this symptom; these latter effects may be sensed by SPAD.

No significant differences were observed among fertility treatments, or additional K application sub-treatments, at any of the growth stages (Figure 2, Table 6). However, there appears to be a slightly positive association between the treatments' yields and relative SPAD responses.

Figure 2. SPAD measurements at different growth stages. Yield is included for comparison.



△ Yield. Means with different letters are significantly different

Table 6. Fertility treatments, hybrid and additional K application effects on SPAD at R4, R5 and R6.

	SPAD (Units of SPAD)				SPAD (Units of SPAD)					SPAD (Units of SPAD)		
Treatment	R4	R5	R6	Hybrids	R4	R5	R6		Additional K	R4	R5	R6
Broadcast P-K	54.59	49.48	20.25	Pioneer 31-G-68	51.79	43.51	11.44	B	No plus K	53.66	47.72	18.16
Banded K	53.87	48.28	19.58	Pioneer 31-N-28	55.25	51.95	23.97	A	Plus K	53.63	47.73	17.25
Banded P-K	52.92	46.82	16.04	Means with different letters are significantly different								
Banded P	53.00	47.23	16.23									
Check	53.23	46.86	16.44									

On the other hand, when considering both hybrids, a consistent significant difference was detected in all three growth stages. The hybrid Pioneer 31N28 showed higher SPAD values than Pioneer 31G68 (Table 6). Other research has shown that SPAD differences are common between hybrids and between hybrid maturity groups.

STALK DIAMETER: R1, R6

The corn stalk is a critical reservoir of soluble carbohydrates generated by the photosynthetic system of the plant mainly during the grain filling period. A dynamic relation exists between them, as the stalk becomes a source of carbohydrates anytime the photosynthetic source is limited by a stress. This is why some stalk parameters can help us understand the nutritional supply-demand balance in the plant. One of the nutrients involved in this situation is K, because it plays an important role in stalk diameter and strength by means of aiding in photosynthesis, enhancing sugars and starch translocation and maintaining turgor.

There were no significant differences in stalk diameter among fertility treatments or additional K applications at the R1 sampling stage (Table 7). At the R6 maturity stage significant differences in stalk diameter were observed among the fertility treatments (Table 7, Figure 3). Hybrid P 31-G-68 had larger stalk diameter than P 31-N-28 for both sampling stages although they were significantly different just at R1. There were no significant differences between additional K application or hybrids in stalk diameter at R6 (Table 7).

Table 7. Fertility treatments, hybrid and additional K application effects on stalk diameter at R1 and R6.

	Stalk diameter (mm)	
Treatment	R1	R6
Broadcast P-K	25.95	23.26 A-B
Banded K	25.79	23.07 A-B
Banded P-K	25.66	22.58 B
Banded P	25.33	23.39 A
Check	24.84	22.79 A-B

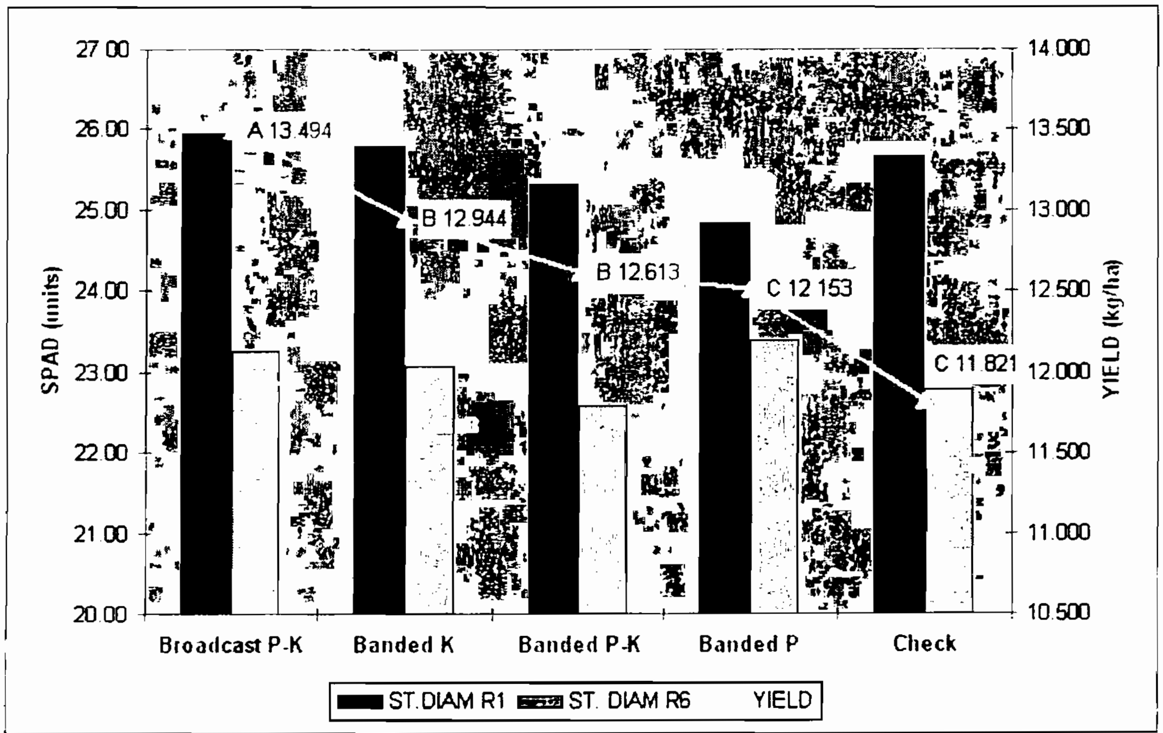
	Stalk diameter (mm)	
Hybrid	R1	R6
Pioneer 31-G-68	26.32 A	23.25
Pioneer 31-N-28	24.69 B	22.78

Means with different letters are significantly different

	Stalk diameter (mm)	
Additional K	R1	R6
No plus K	25.50	22.87
Plus K	25.53	23.16

Deep banding of P+K resulted in the lowest stalk diameter while deep banding of P alone had the highest value for stalk diameter at R6 – although it was not statistically different from that of broadcast P-K, banded K and check treatments. What was perhaps most interesting is that the least change in stalk diameter between R1 and R6 periods occurred in the band P treatment.

Figure 5. Stalk diameter at R1 and R6 for the fertility placement treatments. Yield is included for comparison.



△ Yield. Means with different letters are significantly different

□ Stalk diameter R6. Means with different letters are significantly different

For the two growth stages at which stalk diameter was measured the three fertility treatments including either broadcast or deep-banded K – the ones that yielded better – follow a trend between stalk diameter and yield similar to the one observed for SPAD. Improved K uptake has been shown to have a positive effect both over stalk diameter and strength, reducing lodging.

Preliminary Conclusions

Fertility treatments that included K fertilizer (either broadcast or deep-banded) resulted in the highest yields in 2005. Corn plants in treatments with K fertilizer did not have larger stalk diameters or higher leaf SPAD readings during the grain filling period, so the yield response may be due to other factors. There was little lodging evident at harvest. We are still analyzing the leaf nutrient concentrations at flowering, and that might provide more clues as to how the yield response occurred.

There was no advantage associated with deep banding of either P or K; in fact, broadcasting seemed to be the preferred method even when all plots were strip-tilled in the fall. Yields were highest after broadcast P and K, and on-farm application costs would normally be lower for broadcast than for deep banding. Above average rainfalls from November 04 to February 05 – after the fall broadcast treatment application – and a warmer condition during the growing season might be some of the reasons that led to these results.

In this medium K testing soil, no response was observed to the additional broadcast application of K in the spring of the prior soybean crop year (March of 2004). However, there was a positive yield response to K that was fall applied prior to corn, and especially when the K fertilizer was broadcast together with P fertilizer.

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