HYBRID AND POTASH EFFECTS ON ROOT GROWTH IN RIDGE-TILL CORN

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ABSTRACT

Potassium deficiency symptoms often appear in ridge-till and no-till corn even when soil test values for potassium are high. Certain hybrids are more sensitive to the problem than others. Two techniques were used to assess root activity and density in a three year experiment at the West Central Experiment Station, Morris, MN. We compared two tillage systems (fall chisel and ridge till), two hybrids (Pioneer 3732 and 3737) and three fertilizer treatments (control and 40 lb/A banded or broadcast K_2O). Using rubidium, strontium and lithium as tracers for root activity, we have consistently found higher root activity in fall chisel systems, especially near the surface. Hybrid 3737 generally has higher root activity at the 3 inch depth, while 3732 has higher activity at 6 and 12 inch depths, especially early in the season. Data from the root core technique also confirm higher surface root densities of 3737 compared to 3732 especially in the midrow area. Banded applications of K_2O increase root activity with depth.

INTRODUCTION

Potassium (K) deficiency is a common problem in ridge-till and no-till corn production in Minnesota as well as Iowa and South Dakota, and can result in reduced corn yields. The deficiency occurs even on soils with high to very high soil test K values. Severity of the deficiency varies with hybrid. Band application of 40-50 lb. K_2O/acre in the previous fall or as a starter fertilizer at planting can correct the problem. At the 1992 North Central Extension-Industry Soil Fertility Conference, we presented some background information and experimental results confirming this problem (Rehm, 1992). Findings contained in that report were the catalyst for the present study. The purpose of this research is to identify the physiological basis for early season K deficiency in ridge till by examining the development and morphology of root systems for a sensitive and tolerant hybrid in a ridge-tillage planting system.

OBJECTIVES

The research described in this study is designed to:

1. Determine more precisely the effect of potash placement on root growth and subsequent corn yield in a ridge-till planting system as contrasted to a fall chisel planting system.

2. Quantify root growth in both ridge-till and fall chisel planting systems as affected by corn hybrid.

MATERIALS AND METHODS

This study has been ongoing since the fall of 1990 at the West-Central Experiment Station at Morris, Minnesota. Three factors (tillage system, hybrid, K_2O treatment) were combined in a complete factorial with 4 replications. A split-plot arrangement was used. Tillage system (fall chisel, ridge-till) was the main plot. The sub-plots were hybrids (Pioneer 3732, Pioneer 3737) and potash fertilizer treatment. The three potash fertilizer treatments were: 1) control, 2) 40 lb. K_2O/acre in a fall-applied band, and 3) 40 lb. K_2O/acre broadcast. During the 1991 growing season we used the same experimental design, but included a no-till treatment and excluded the broadcast K treatment.

Each year, the potash was fall applied. When applied in a band, the K_2O was placed at a depth of 3-4 inches below the soil surface directly beneath the existing row. The banded and broadcast application of K_2O was made before the fall chisel plow operation. All treatments received 10-34-0 as a starter at planting and ample N as anhydrous ammonia in the fall. A recommended herbicide program was used for weed control after planting.

One major objective of this study is to quantify root growth as affected by tillage system and corn hybrid. To do this, non-essential cations (strontium, rubidium, lithium) were hand injected to various depths at a distance of 4 inches perpendicular to the row. These tracers were injected shortly after emergence. Plant and soil samples were collected at approximately 30 (V4), 40 (V6-8), and 60 (tasseling) days after planting. The plant samples were dried, weighed, ground and analyzed for potassium, strontium (Sr), rubidium (Rb), and lithium (Li). To estimate root activity, total uptake of the tracers is calculated on a per plant basis. Amounts of these non-essential ions taken up by uninjected plants are subtracted to obtain net uptake due to the presence of the injected tracer. Amounts of Rb, Sr and Li taken up by the corn plant differ due to chemistry of the ions and physiology of the plant. To convert all the tracer uptake values to a common measure (net Rb uptake per plant), we established a plot in the border where the same amounts of each ion were injected at the same depth to determine ratios of uptake of Rb/Sr and Rb/Li.

In 1992 and 1993, soil samples were also collected at approximately 30 and 45 days after emergence. Roots were separated from the soil by washing and root length was measured. Root density was calculated from the root length and soil volume measurements. Soil samples for root measurement were collected from the control treatment for both hybrids in both tillage systems.

Grain yields were measured in late October. Moisture samples were collected and grain yields were corrected to 15.5% moisture.

RESULTS AND DISCUSSION

In 1991, corn yields were the same for the ridge till and fall chisel systems (Table 1), but total shoot weight in the ridge till treatment was lower at 30, 40 and 60 DAP (data not shown). There was a significant effect of hybrid and K_2O application. In 1992, yields were substantially below potential because of the extremely cool growing season. Tillage, K application and hybrid all affected grain yield (Table 1).

Table 1. Grain yields at Morris, MN in 1991 and 1992.

Tillage System	Hybrid	K_2O Treatment	Grain Yield	
			1991	1992
			(bu/acre)	
Fall Chisel	3732	0	163.0	79.3
		40 (band)	164.1	102.0
		40 (bdcst)	-	97.5
Fall Chisel	3737	0	169.9	100.6
		40 (band)	182.4	111.2
		40 (bdcst)	-	101.2
Ridge-Till	3732	0	159.2	53.6
		40 (band)	178.5	93.3
		40 (bdcst)	-	57.8
Ridge-Till	3737	0	175.5	58.4
		40 (band)	178.0	101.6
		40 (bdcst)	-	68.7

Root activity as measured by cation uptake

Uptake of the non-essential cations, strontium, rubidium and lithium, injected at 3, 6 and 12 inch depths, was used as a measure of root activity. Data for the 1991-93 growing seasons are presented in Tables 2-4. In 1991, there were few differences due to treatment (Table 2). At approximately V8, there was twice as much root activity at the 3 inch depth in chisel compared to ridge, and 3737 had higher activity at 12 inches than 3732, especially in the ridge tillage planting system.

Table 2. Root activity at three depths as estimated by net rubidium uptake during the 1991 growing season.

Planting Treatment	3" Depth Days after Planting 30	40	60	6" Depth Days after Planting 30	40	60	12" Depth Days after 30	40	60
	------- mg net Rb uptake/plant -------								
Tillage Main Effects									
Chisel	2.19	7.87	6.32	0.27	1.85	4.51	0.020	0.34	1.36
Ridge	2.07	3.61	5.56	0.21	1.73	4.37	0.024	0.30	1.57
Hybrid Main Effects									
3732	2.01	5.70	6.02	0.31	1.88	4.27	0.014	0.30	1.20
3737	2.25	5.79	5.86	0.19	1.70	4.80	0.031	0.35	1.74
Tillage X Hybrid Interaction									
Chisel									
3732	1.93	7.95	7.07	0.38	1.55	4.51	0.011	0.29	1.22
3737	2.44	7.80	5.57	0.17	2.15	4.89	0.029	0.40	1.51
Ridge									
3732	2.08	3.44	4.97	0.23	2.21	4.03	0.016	0.31	1.18
3737	2.05	3.78	6.15	0.20	1.25	4.70	0.032	0.29	1.96

In 1992, root activity was higher with chisel compared to ridge tillage, especially near the surface (Table 3). At the 3 inch depth, root activity was 40-70% higher in chisel plots; at the 6 inch depth, it was 30-40% higher. Hybrid 3737 had about twice the root activity of 3732 at the 3 inch depth for both tillage systems for the first two sampling dates. Hybrid 3732 had more root activity at the 6 and 12 inch depths until the third sampling date. At 40 DAP in the ridge tilled plots, 3737 had three times the root activity of 3732 at the 3 inch depth.

Table 3. Root activity at three depths as estimated by net rubidium uptake during the 1992 growing season.

Treatment	3" Depth Days after Planting 30	40	60	6" Depth Days after Planting 30	40	60	12" Depth Days after Planting 30	40	60
	mg net Rb uptake/plant								
Tillage Main Effects									
Chisel	1.69	7.07	9.23	0.09	2.71	15.18	0.04	0.92	10.30
Ridge	0.97	5.02	5.50	0.07	1.88	11.39	0.03	0.83	9.82
Hybrid Main Effects									
3732	0.93	3.69	6.06	0.11	2.66	12.85	0.04	0.95	8.26
3737	1.74	8.41	8.66	0.05	1.93	14.09	0.02	0.79	11.86
Tillage x Hybrid Interactions									
Chisel									
3732	1.16	5.08	7.24	0.11	2.76	14.67	0.05	1.07	8.58
3737	2.22	9.08	11.21	0.06	2.66	15.70	0.02	0.76	12.02
Ridge									
3732	0.70	2.30	4.88	0.10	2.56	10.30	0.03	0.83	7.93
3737	1.25	7.74	6.12	0.03	1.19	12.47	0.03	0.82	11.70

Again in 1993, root activity was greater with the fall chisel planting system (Table 4). Root activity was approximately 40% higher at the 3 inch depth, and 100% higher at the 6 inch depth. Averaged over tillage treatments, Hybrid 3737 had higher root activity than 3732 at the 3 inch depth, but lower activity at the 6 inch depth. In 1993, for the ridge tilled plots, 3737 and 3732 did not differ as much as in 1992.

Table 4. Root activity at three depths as estimated by net rubidium uptake during the 1993 growing season.

Treatment	3" Depth Days after Planting 30	3" Depth Days after Planting 40	6" Depth Days after Planting 30	6" Depth Days after Planting 40	12" Depth Days after Planting 30	12" Depth Days after Planting 40
	- - - - - - - - - - - - - mg net Rb uptake/plant - - - - - - - - - - - - - - -					
Tillage Main Effects						
Chisel	0.32	2.91	0.10	1.13	0.001	0.02
Ridge	0.23	1.99	0.05	0.58	0.002	0.02
Hybrid Main Effects						
3732	0.21	2.28	0.09	0.97	0.001	0.02
3737	0.34	2.63	0.06	0.74	0.002	0.01
Tillage x Hybrid Interaction						
Chisel						
3732	0.19	2.97	0.13	1.22	0.001	0.017
3737	0.46	2.86	0.08	1.05	0.001	0.015
Ridge						
3732	0.23	1.58	0.06	0.71	0.001	0.024
3737	0.22	2.41	0.04	0.44	0.003	0.013

Root density as measured by the root core technique

In addition to the tracer injection technique to measure root activity, we determined root density from soil cores sampled at V4-6 and V8 in 1992 and 1993. Tables 5 and 6 show the root core data for the earlier growth stage, and Figures 1 - 4 show results from the second sampling time. At the first sampling, cores were taken in the row (adjacent to the corn plant) and 2 inches from the row. Depth increments were 0-3 inches, 3-6 inches and 6-12 inches.

In 1992, in the ridge tilled plots, 3737 had 20% more roots than 3732 in the row (0-3 inch depth) and 40% more 2 inches from the row (Table 5). Hybrid 3732 had higher root densities for the 3-6 inch depth. In 1993, the differences between the hybrids in the ridge till planting system were much more dramatic (Table 6). Hybrid 3737 had three to four times higher root density in the top 3 inches, with little or no difference between the hybrids from 3-6 inches.

Table 5. Root length density at V6 as measured by the root core technique, 1992.

		Ridge Till Distance from Row		Fall Chisel Distance from Row	
	Depth (inches)	0 in.	2 in.	0 in.	2 in.
		(cm/cm^3)			
3732	0 - 3	0.23	0.11	0.23	0.11
	3 - 6	0.14	0.07	0.06	0.07
3737	0 - 3	0.27	0.16	0.24	0.15
	3 - 6	0.03	0.05	0.06	0.13

Table 6. Root length density at V4 as measured by the root core technique, 1993.

		Ridge Till Distance from Row		Fall Chisel Distance from Row	
	Depth (inches)	0 in.	2 in.	0 in.	2 in.
		(cm/cm^3)			
3732	0 - 3	0.07	0.08	0.37	0.30
	3 - 6	0.04	0.05	0.08	0.05
3737	0 - 3	0.27	0.24	0.31	0.29
	3 - 6	0.04	0.04	0.08	0.07

For the second sampling, cores were taken in the row, and at positions 3, 6 and 12 inches from the row. Although we sampled to the 24 inch depth, only the 0-6 and 6-12 inch increments are reported here, because these show the greatest differences.

In 1992, there was little difference between the ridge and chisel systems in terms of maximum root density (ridge = 0.62 cm/cm^3, chisel = 0.52 cm/cm^3). In the ridge tilled plots, surface roots close to the row were actually denser for 3732 than for 3737, but for both tillage treatments, 3737 had more surface roots in the positions 6 and 12 inches from the row (Figs. 1 and 2).

In 1993, there were much larger differences between tillage systems and hybrids (Figs. 3 and 4). The chisel plots had twice the root density of the ridge tilled plots (maximum root density = 0.59 cm/cm^3 in chisel versus 0.30 in ridge) and hybrid 3737 had higher root densities than 3732. Again, in the ridge tillage planting system, there was little difference between hybrids at the in row and 3 inches from the row positions, but 3737 had much higher densities at 6 and 12 inches from the row (Fig. 3). Even in the chisel treatment, 3737 had about twice the density of 3732 at the 0-6 inch depth (Fig. 4).

Summary of root data

Both types of root measurements indicate that 3737 has higher root activity and density in the surface, especially at interrow positions more than 3 inches from the row. Hybrid 3732 has higher activity and density deeper in the soil profile, but by tasseling time, 3737 catches up. It seems that the advantage of hybrid 3737 in this system is that it extends more roots laterally and fewer vertically in the early growth stages, while 3732 ramifies mostly near the row and then extends vertically. Since potassium accumulation occurs at the surface in reduced tillage situations, the root morphology of 3737 should be more successful.

Potash effects on root distribution

As indicated by the yield data (Table 1) and results reported here previously (Rehm, 1992), a rate of 40 lb. K_2O per acre in a banded application can correct the early season K deficiency (when K soil test values are high). Table 7 shows the effects of K_2O applied in a band or broadcast on the root activity as measured by uptake of the injected tracers. While there was no difference in 1991, data for the following two years show increased root activity at the 6" (1992 and 1993) and 12" (1992) depth with the banded application compared to the control or broadcast application.

RIDGE TILL, 1992

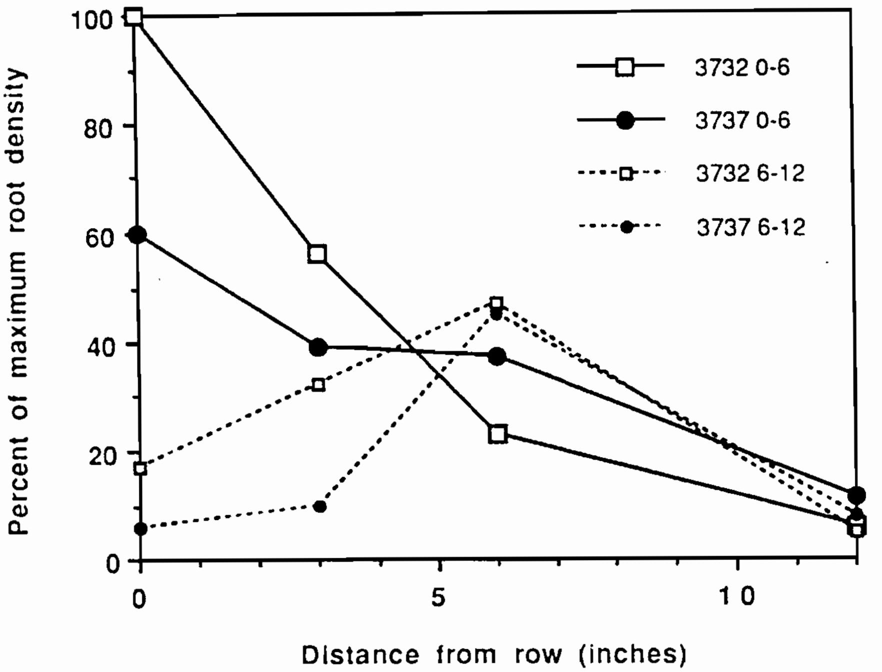

Fig. 1. Percent of maximum root density ($0.62\ cm/cm^3$) at V8 as measured by the root core technique.

FALL CHISEL, 1992

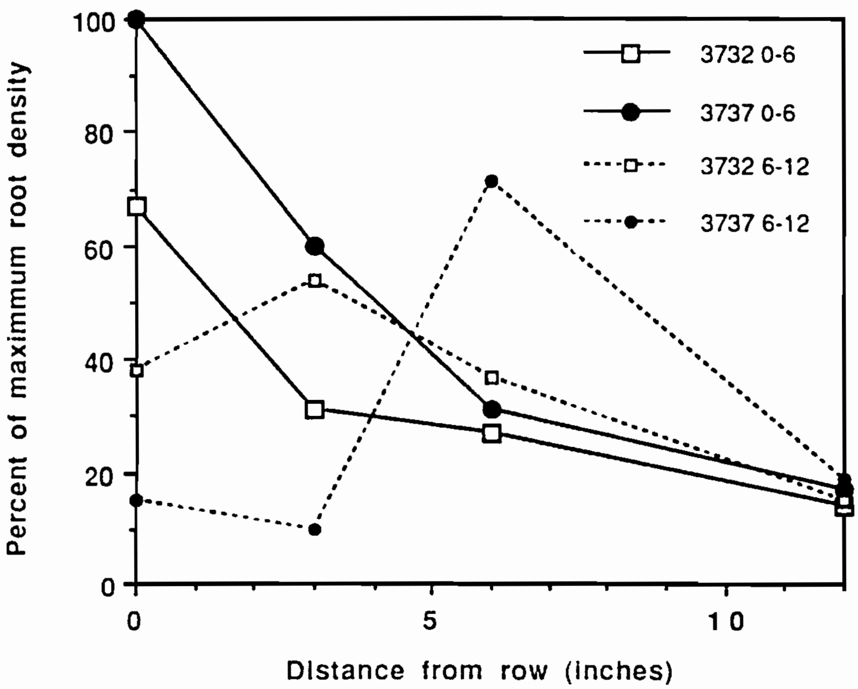

Fig. 2. Percent of maximum root density ($0.52\ cm/cm^3$) at V8 as measured by the root core technique.

RIDGE TILL, 1993

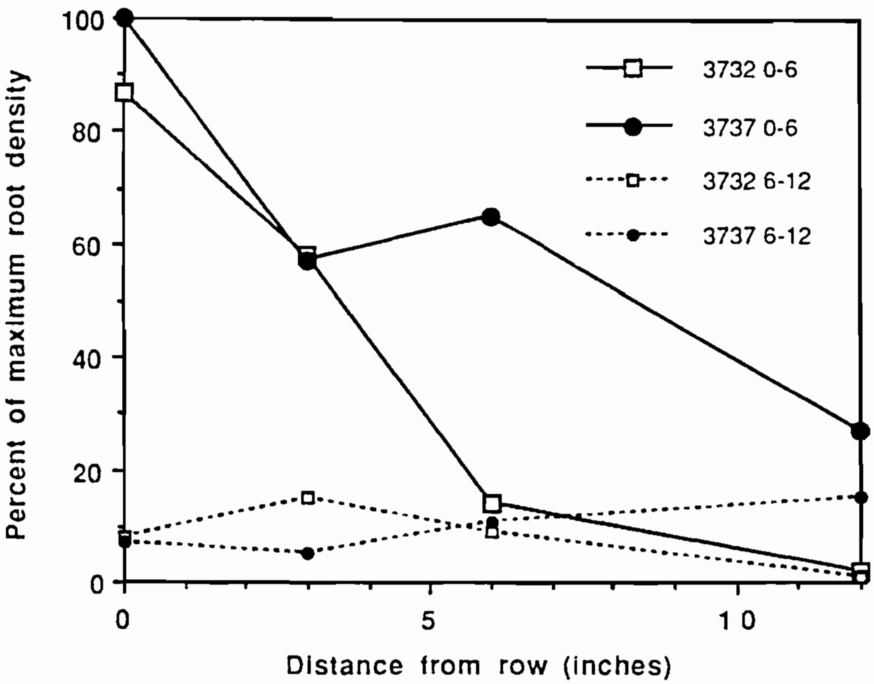

Fig. 3. Percent of maximum root density ($0.30\ cm/cm^3$) at V8 as measured by the root core technique.

FALL CHISEL, 1993

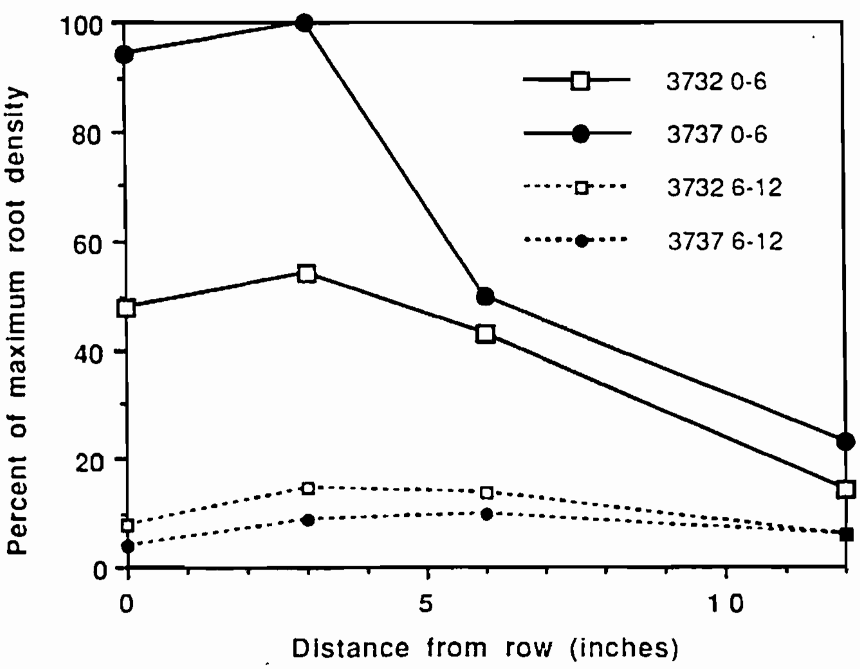

Fig. 4. Percent of maximum root density ($0.59\ cm/cm^3$) at V8 as measured by the root core technique.

Table 7. Effects of potash fertilizer on root activity at three depths as estimated by net rubidium uptake.

	3" Depth Days after Planting			6" Depth Days after Planting			12" Depth Days after Planting		
1991	30	40	60	30	40	60	30	40	60
	- - - - - - - - - - - - - mg net Rb uptake/plant - - - - - - - - - - - - - - -								
0 K	2.07	6.03	6.43	0.23	1.87	4.66	0.026	0.26	1.46
40 lb. Band	2.19	5.46	5.46	0.25	1.72	4.22	0.025	0.39	1.48
1992									
0 K	1.02	5.84	7.92	0.07	1.63	10.97	0.034	0.61	9.85
40-Band	1.04	7.65	7.70	0.09	3.31	18.31	0.041	1.40	11.86
40-Bdcst	1.94	4.63	5.36	0.08	1.94	10.74	0.025	0.61	8.47
1993									
0 K	0.26	2.47	---	0.11	0.83	---	0.001	0.02	---
40-Band	0.36	2.48	---	0.07	1.17	---	0.002	0.02	---
40-Bdcst	0.16	2.42	---	0.05	0.58	---	0.002	0.01	---

Research in Progress

Root activity and density measurements will be made for at least two more growing seasons. We hope to use some excavation or root box techniques to confirm qualitatively and pictorially the differences in morphology suggested by our data. In addition, we are comparing other measures of plant available K to the ammonium acetate test. We believe this extraction method may be an inadequate soil test for ridge tilled corn in the North Central States.

Citation

Rehm, G. 1992. Response of ridge-till corn to potash fertilization. Proceedings of the 22nd North Central Extension-Industry Soil Fertility Conference. Nov. 18-19, 1992. Bridgeton, MO. p. 139.

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