Progress Report

Relationships Between Corn Rootworm Protection and Potassium Nutrition
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Summary of Objectives and Methods

This project is assessing impacts of corn rootworm protection on corn grain yield and potassium (K) nutrition. This objective is being achieved by evaluating nine three-year field trials with continuous corn first established at Iowa State University (ISU) research farms in 2006 and 2007. Four conventional plot trials were established at four ISU research farms in 2006 (Sites 1 through 4) and five new similar trials were established in 2007 (Sites 5 through 9). The four trials established in 2006 and were evaluated for a second year in 2007 and a third year in 2008. The five trials established in 2007 were evaluated for a second year in 2008 and will be continued in 2009 for a third year. All nine sites had corn the previous two years, and all were managed with chisel-plow/disk tillage. The trials were at the Central, Northern, Northeast, Southeast, and Southwest research farms. Treatments replicated four times were two hybrids and five K fertilizer treatments. One hybrid was resistant to glyphosate and European corn borer and the other was an isoline with the addition of rootworm resistance. No insecticide was applied for the susceptible hybrid. Information about hybrids used and initial soil-test values is summarized in Table 1. The hybrids used sometimes differed across sites in order to use hybrids recommended for each region, and sometimes differed in consecutive years at each site when improved hybrids were released and seed of the first hybrids used would not be readily available to producers. The K treatments for first-year trials were 0, 30, 60, 120, and 180 lb K_2O/acre (potassium chloride fertilizer). For the second and third year evaluations, a K rate of 180 lb K_2O/acre was applied only to plots that had received the 30-lb rate the first year. High rates of N and P fertilizers were applied across plots of all trials.

Soil samples were collected each year from all plots at each site before applying K fertilizer treatments and planting corn. The soil sampling depth and K testing methods were those recommended in Iowa (6-inch sampling depth, ammonium-acetate K test). Initial soil-test K (STK) across sites ranged from values borderline between Very Low and Low to Optimum and High to Very High according to Iowa State University soil-test interpretations (Table 1). Plant measurements included grain yield, an assessment of rootworm root injury in selected plots and plant tissue sampling to measure nutrient concentration. Grain yield was measured from all plots of all trials. Because of the high cost of field labor and chemical analysis, rootworm incidence was measured for the two corn hybrids at three contrasting K treatments (0, 60, and 180 lbs K_2O rates) of all replications at all trials. For assessment of rootworm incidence, roots from five plants were excavated from each selected plot in the middle of July and rootworm effects on roots was evaluated visually by using the relative scale recommended by ISU and Monsanto. The above-ground part of the plants was weighed, chopped, and a tissue sample was collected to measure nutrient concentration by standard tissue testing methods. Also, ear leaves of corn were sampled from all plots to be analyzed for K concentration.

Summary Results

A previous progress report summarized corn yield results for field trials conducted in 2006. This report includes those results and also summarizes yield from trials conducted in 2007 and 2008 (22 site-years). The report summarizes results of plant tissue nutrient analyses only for the trials conducted in 2006 and 2007 (13 site-years) because analyses results for the 2008 season have not been completed. Results summarized at this time should be considered preliminary until all sample data can be reported. Although statistical analyses were conducted for the yield and plant-tissue data summarized and the report often refers to statistically significant responses, all results and conclusions should be considered preliminary and subject to minor change because no detailed outliers analysis has been conducted.

Corn Grain Yield Response to Hybrid and K Fertilization

On average across all K rates the rootworm-resistant corn hybrid yielded at least 4 bu/acre more than the susceptible hybrid in 14 of the 22-site-years (Table 2), although the difference was statistically significant only at seven site-years. On average across all sites, the rootworm resistant hybrid yielded 8 bu/acre more than the susceptible hybrid, while the statistically significant yield differences ranged from 4 to 32 bu/acre. A clear yield benefit was observed for the rootworm resistant hybrid over the susceptible hybrid in most site-years with the exception of Site 3 in 2008, Site 5 in 2008, and Site 6 in 2007.

Potassium fertilization increased corn grain yield at few sites (Table 2). We expected large to moderate responses in Sites 1, 2, 5, 6, and 8 because initial STK was Low (where moderate to large response to K is likely) or Optimum (where a small response is likely). The yield increases due to K fertilization were statistically significant at six of 22 site-years, and yield increases seldom differed among the K application rates. We expected an increased response to K in second- and third-year trials compared to the first year because STK of the control plots would decrease but this was not always the case. On average across applied K rates, corn grain yield for the fertilized plots was 5 bu/acre or higher for one or both hybrids at 10 site-years, but large responses across both hybrids (9 bu/acre or larger) were observed only at Site 2 in 2006, Site 3 in 2008, and Site 8 in 2007 and 2008. There were no statistically significant interactions between hybrid and K fertilizer rate that were reasonable (an interaction at one site was illogical and likely due to random variation), which means that the hybrid responses to soil or fertilizer K were statistically similar in spite of usually higher yield levels for the hybrid with rootworm resistance. Data in Fig. 1 summarizes corn yields and yield responses to K fertilizer for averages across the six site-years with a significant yield increase due to K fertilization. The data indicate a slightly larger difference between hybrids at low K fertilizer rates, which would suggest a slightly lower K need for the resistant hybrid in spite of a higher yield level. However, this interactive trend did not reach statistical significance.

Rootworm Injury and Relationship to Grain Yield Differences

Table 3 shows results from the rootworm injury evaluations. Potassium fertilization had no effect on rootworm injury, and small apparent effects were inconsistent across locations, hybrids, or years. When averaged across K rates, the results showed that there was significantly higher

injury on the rootworm susceptible hybrid as compared to the resistant hybrid in 19 site-years. The root rating index for the rootworm resistant hybrid ranged from 0.01 to 0.43 on the ISU 0 to 3 rating scale. However, the root rating index for the rootworm susceptible hybrid ranged from 0.07 to 2.37 on the 0 to 3 scale.

Study of rootworm injury and grain yield differences between hybrids indicate that, as expected, that largest yield differences tended to occur with moderate to high rootworm pressure. For example, the rootworm resistant hybrid yielded much more than the susceptible hybrid at Sites 2 and 7 in 2007 (Table 2), while on average rootworm injury was 2.16 and 1.81, respectively (Table 3). However, there were moderate to large yield differences between hybrids at some site-years where the rootworm injury ratings were low (for example, at Sites 1 and 6 in 2008). Because the hybrids used at each site were isolines, the existence of yield differences between hybrids at sites with low rootworm pressure must be attributed to a failure of the one-time root evaluation at detecting injury. Also, in a few instances there was moderate rootworm injury for the susceptible hybrid and not for the rootworm resistant hybrid but the resistant hybrid did not yield much more than the susceptible hybrid (for example, at Site 8 in 2007). This unexpected result may also be explained by imperfections of the rootworm injury evaluations or recovery of the susceptible hybrid after the evaluations were made.

Nutrient Concentration in Vegetative Plant Tissue and Uptake

Hybrid and K fertilizer effects on ear-leaf N, P, and K concentrations and also on both nutrient concentration and uptake in whole plants (at the R1 growth stage) were studied for trials conducted in 2006 and 2007. Usually there was an ear-leaf K concentration response to K fertilization that reached statistical significance in eight site-years, but there were small and largely inconsistent differences between hybrids (Table 4). Study of whole-plant data showed that K fertilization had very variable, small, and infrequent effects on whole-plant dry weight (Table 5). Means across all sites showed, however, slightly higher weight for the resistant hybrid, no response to K by the resistant hybrid, but a small responsive trend by the susceptible hybrid (Table 5). Data in Table 6 show no consistent whole-plant K concentration differences between hybrids but a frequent K concentration response to K fertilization at many sites that reached statistical significance in 10 site-years. The whole-plant K uptake data integrated results for K concentration and dry matter weight (Table 7). Potassium fertilization also increased plant K uptake but the response reached statistical significance a bit less frequently (in eight site-years) than for K concentration, probably due to inconsistent and variable effects on whole-plant dry weight. However, averages across sites showed an obvious interaction between hybrid and K rate because total K uptake was higher for the resistant hybrid without K fertilization but was similar for both hybrids when K was applied. This effect that was evident even for averages across all sites, which is demonstrated by Fig. 2.

Study of corn hybrid and K fertilizer effects on the concentrations N and P in ear-leaf or whole-plant tissue across locations and years showed increases in some site-years, decreases in a few others, but most often no clear effects (not shown). These results should be expected because of complex dilution and concentration of the nutrients in the dry matter that frequently have been shown before in the literature. Therefore, in this report we summarize the most useful results, which were the net effects on N and P uptake by whole-plants at the R1 growth stage. Table 8

summarizes whole-plant N uptake and Table 9 summarizes P uptake. Study of K fertilization rate effects showed, however, few and inconsistent effects of hybrid or K fertilization. Also, averages across all sites in which whole-plant K uptake responded to K fertilization showed no N or P uptake differences due to K rate or hybrid.

Nutrient Removal with Grain Harvest

Potassium fertilization and hybrid had small and inconsistent effects on grain K, N, or P concentrations (data not shown). Therefore, nutrient removal tended to follow the yield trends. Because there were frequent and large yield differences between hybrids and the yield response to K fertilizer was moderate to large only in few site-years, the mean yield differences due to hybrid across all K rates had the most obvious effects on nutrient removal (Table 10). The K removal difference was as high as 9 lb K_2O/acre and averaged 2 lb K_2O/acre across sites, while the matching yield increases were as high as 33 bu/acre and averaged 8 bu/acre across sites. Hybrid rootworm resistance and yield level had the largest effects on K removal at Sites 2 and 7 in 2007, where K removal was increased by 7 and 9 lb K_2O/acre, respectively. It is important to note that in these two sites, the yield differences between the two hybrids were the largest in the study, and the resistant hybrid yielded 19 and 33 bu/acre higher than the susceptible hybrid, respectively. Grain N removal was significantly higher for the resistant hybrid as compared to the susceptible hybrid at nine site-years. The N removal difference was up to 22 lb N/acre (at Site 2 in 2007) and averaged 6 bu/acre across all sites, while the matching yield increases were as high as 33 bu/acre and averaged 8 bu/acre across sites. The P removal difference was as high as 11 lb P_2O_5/acre (also at Site 2 in 2007) and averaged 2 lb P_2O_5/acre across sites. The data in Fig. 3 shows the average relative effect of rootworm resistance across all sites (13 site-years in 2006 and 2007) on grain yield, grain nutrient concentration, and nutrient removal with grain harvest. The graph further demonstrates a very small or no effect of rootworm resistance on grain nutrient concentration but increased N, P, and K removal due to higher grain yield.

Preliminary Conclusions

The conclusions should be considered preliminary because only preliminary outlier and statistical analysis were conducted and additional trials will be harvested in 2009. The available grain yield and plant analysis results support two important preliminary conclusions. One is that the corn hybrid with rootworm resistance often yielded more than the susceptible hybrid, and that the yield differences often were observed even with little rootworm injury. The other is that rootworm resistance seldom affected grain yield or nutrient uptake response to K fertilization. Study of yield responses at each site-year showed no meaningful interactions between hybrid and K fertilization, although averages across the five site-years that showed a response to K showed a slightly larger yield difference between hybrids at low K rates but the difference did not reach statistical significant. Whole-plant (at the R1 growth stage) dry weight and K uptake responses showed a more clear interaction between hybrids and K fertilization than for grain yield at the several K-responsive sites and also for averages across all sites. This interaction suggested a higher K uptake by the rootworm resistant hybrid when no K fertilizer was applied. Therefore, the preliminary results suggest that use of rootworm resistance corn hybrids often will result in increased grain yield compared with susceptible hybrids without application of insecticide but will have small or no effect in K fertilization needs compared with susceptible hybrids in spite of

a likely better K uptake and yield with K deficiency. An important consideration is, however, that because of the higher yield level and nutrient removal use of rootworm resistant hybrids will require higher P and K fertilization rates to maintain desirable soil-test levels over time.

Table 1. Year, corn hybrid, and selected initial soil-test values for field trials in 22 site-years.

			Corn Hybrid		Soil-Test Values		
Site	**Region**	**Year**	**Resistant**	**Susceptible**	**K**	**pH**	**OM**
					mg K kg^{-1}		
1	N. East	2006	DKC51-39 (YGPL)	DKC50-20 (RR2/YGCB)	123	6.1	3.3
		2007	DKC52-59 (VT3)	DKC52-63 (RR2/YGCB)			
		2008	DKC52-59 (VT3)	DKC52-63 (RR2/YGCB)			
2	North	2006	DKC51-39 (YGPL)	DKC50-20 (RR2/YGCB)	167	6.4	5.2
		2007	DKC52-59 (VT3)	DKC52-63 (RR2/YGCB)			
		2008	DKC52-59 (VT3)	DKC52-63 (RR2/YGCB)			
3	S. East	2006	DKC63-64 (YGPL)	DKC6381 (RR2/YGCB)	269	6.0	4.8
		2007	DKC63-42 (VT3)	DKC63-46 (RR2/YGCB)			
		2008	DKC63-42 (VT3)	DKC63-46 (RR2/YGCB)			
4	S. West	2006	DKC60-18 (YGPL)	DKC60-19 (RR2/YGCB)	203	6.9	2.3
		2007	DKC63-42 (VT3)	DKC63-46 (RR2/YGCB)			
		2008	DKC63-42 (VT3)	DKC63-46 (RR2/YGCB)			
5	Central	2007	DKC61-69 (VT3)	DKC61-73 (RR2/YGCB)	91	5.4	3.6
		2008	DKC61-69 (VT3)	DKC61-73 (RR2/YGCB)			
6	N. East	2007	DKC52-59 (VT3)	DKC52-63 (RR2/YGCB)	130	6.4	2.6
		2008	DKC52-59 (VT3)	DKC52-63 (RR2/YGCB)			
7	North	2007	DKC52-59 (VT3)	DKC52-63 (RR2/YGCB)	191	6.1	4.5
		2008	DKC52-59 (VT3)	DKC52-63 (RR2/YGCB)			
8	S. East	2007	DKC63-42 (VT3)	DKC63-46 (RR2/YGCB)	164	5.7	4.6
		2008	DKC63-42 (VT3)	DKC63-46 (RR2/YGCB)			
9	S. West	2007	DKC63-42 (VT3)	DKC63-46 (RR2/YGCB)	202	6.2	3.8
		2008	DKC63-42 (VT3)	DKC63-46 (RR2/YGCB)			

Table 2. Effects of hybrids with or without rootworm resistance and K fertilization rates on corn grain yield.

			Treatment (lb K_2O $acre^{-1}$)						
Site	**Year**	**Hybrid**	**0**	**30**	**60**	**120**	**180**	**30+180 †**	**Avg.**
			---------- bu $acre^{-1}$ ----------						
1	2006	Resistant	180	178	177	172	178	-	177
		Susceptible	168	164	167	154	167	-	164
	2007	Resistant	180	-	181	185	183	186	183
		Susceptible	177	-	177	179	178	185	179
	2008	Resistant	147	-	148	142	146	159	148
		Susceptible	130	-	135	133	132	140	134
2	2006	Resistant	178	193	190	195	198	-	191
		Susceptible	183	184	186	190	185	-	185
	2007	Resistant	174	-	167	169	163	171	169
		Susceptible	137	-	138	135	135	141	137
	2008	Resistant	169	-	173	159	167	167	167
		Susceptible	161	-	159	154	152	169	159
3	2006	Resistant	216	221	224	212	218	-	218
		Susceptible	213	213	206	200	207	-	208
	2007	Resistant	184	-	196	196	190	190	191
		Susceptible	192	-	192	184	187	186	188
	2008	Resistant	160	-	175	165	158	164	164
		Susceptible	153	-	167	163	160	175	164
4	2006	Resistant	195	188	184	190	197	-	191
		Susceptible	187	189	181	195	187	-	188
	2007	Resistant	173	-	172	175	173	173	173
		Susceptible	171	-	166	175	172	171	171
	2008	Resistant	208	-	198	211	203	213	207
		Susceptible	191	-	190	207	196	211	199
5	2007	Resistant	169	171	170	163	178	-	170
		Susceptible	159	164	157	163	174	-	163
	2008	Resistant	193	-	183	190	179	193	188
		Susceptible	191	-	188	189	190	195	190
6	2007	Resistant	175	181	175	179	178	-	178
		Susceptible	176	179	181	182	188	-	181
	2008	Resistant	162	-	168	162	163	172	165
		Susceptible	156	-	157	153	157	160	156
7	2007	Resistant	169	178	161	168	169	-	169
		Susceptible	147	156	150	152	145	-	150
	2008	Resistant	180	-	177	177	176	189	180
		Susceptible	169	-	172	172	171	181	173
8	2007	Resistant	186	201	203	197	196	-	196
		Susceptible	190	194	191	200	195	-	194
	2008	Resistant	136	-	148	149	149	166	150
		Susceptible	121	-	143	145	142	153	141
9	2007	Resistant	189	187	188	191	188	-	188
		Susceptible	188	185	184	185	184	-	185
	2008	Resistant	209	-	215	213	215	217	214
		Susceptible	194	-	195	190	191	205	195

† A rate of 180 lb K_2O/acre was applied the second year to plots receiving the 30-lb rate the first year.

Table 3. Corn rootworm injury ratings at all trials.

Site	Year	Hybrid	Treatment (lb K_2O $acre^{-1}$) 0	60	180	Average
			---------- Root Injury Index ----------			
1	2006	Resistant	0.01	0.02	0.01	0.01
		Susceptible	0.78	1.12	0.92	0.94
	2007	Resistant	0.11	0.11	0.10	0.10
		Susceptible	1.20	1.59	1.13	1.31
	2008	Resistant	0.05	0.05	0.04	0.05
		Susceptible	0.62	0.71	0.50	0.61
2	2006	Resistant	0.04	0.01	0.01	0.02
		Susceptible	0.65	0.38	1.04	0.69
	2007	Resistant	0.10	0.10	0.10	0.10
		Susceptible	1.79	2.03	1.62	1.81
	2008	Resistant	0.04	0.03	0.04	0.04
		Susceptible	0.11	0.29	0.24	0.21
3	2006	Resistant	0.38	0.20	0.10	0.22
		Susceptible	2.50	2.20	2.43	2.37
	2007	Resistant	0.11	0.24	0.11	0.15
		Susceptible	0.98	0.79	1.00	0.92
	2008	Resistant	0.05	0.04	0.05	0.05
		Susceptible	1.18	0.93	0.95	1.02
4	2006	Resistant	0.01	0.01	0.01	0.01
		Susceptible	0.06	0.07	0.08	0.07
	2007	Resistant	0.10	0.09	0.09	0.09
		Susceptible	0.42	0.61	0.55	0.52
	2008	Resistant	0.05	0.04	0.04	0.05
		Susceptible	0.24	0.21	0.14	0.20
5	2007	Resistant	0.08	0.09	0.07	0.08
		Susceptible	0.58	0.85	0.41	0.61
	2008	Resistant	0.09	0.07	0.50	0.22
		Susceptible	0.14	0.09	0.42	0.22
6	2007	Resistant	0.51	0.42	0.36	0.43
		Susceptible	0.65	0.42	0.49	0.52
	2008	Resistant	0.05	0.06	0.05	0.06
		Susceptible	0.23	0.25	0.25	0.24
7	2007	Resistant	0.08	0.10	0.09	0.09
		Susceptible	2.04	2.04	2.39	2.16
	2008	Resistant	0.05	0.06	0.08	0.07
		Susceptible	0.45	0.98	0.37	0.60
8	2007	Resistant	0.14	0.12	0.12	0.12
		Susceptible	1.77	1.80	1.90	1.82
	2008	Resistant	0.05	0.05	0.06	0.05
		Susceptible	0.62	1.08	0.90	0.86
9	2007	Resistant	0.10	0.09	0.11	0.10
		Susceptible	0.70	0.62	0.69	0.67
	2008	Resistant	0.05	0.05	0.05	0.05
		Susceptible	0.65	0.89	0.62	0.72

Table 4. Ear-leaf K concentration at the R1 corn growth stage.

			Treatment (lb K_2O $acre^{-1}$)						
Site	**Year**	**Hybrid**	**0**	**30**	**60**	**120**	**180**	**30+180 †**	**Avg.**
			---------- % K ----------						
1	2006	Resistant	1.87	1.77	1.81	1.95	1.95	-	1.87
		Susceptible	1.81	1.89	1.94	2.03	2.08	-	1.95
	2007	Resistant	1.58	-	1.66	1.76	1.79	1.66	1.69
		Susceptible	1.69	-	1.64	1.84	1.91	1.72	1.76
2	2006	Resistant	1.03	1.10	1.01	1.28	1.39	-	1.16
		Susceptible	0.98	1.13	1.10	1.20	1.40	-	1.16
	2007	Resistant	0.84	-	0.89	1.07	1.06	1.28	1.03
		Susceptible	0.86	-	0.87	1.03	1.11	1.38	1.05
3	2006	Resistant	1.76	2.10	2.01	2.09	2.11	-	2.01
		Susceptible	1.73	2.21	2.28	1.97	2.12	-	2.06
	2007	Resistant	2.05	-	2.26	2.27	2.16	2.50	2.25
		Susceptible	2.08	-	2.48	2.32	2.55	2.44	2.37
4	2006	Resistant	1.93	2.03	1.95	2.05	2.06	-	2.00
		Susceptible	1.92	2.04	1.96	2.10	2.02	-	2.01
	2007	Resistant	1.42	-	1.51	1.66	1.66	1.74	1.60
		Susceptible	1.43	-	1.48	1.69	1.64	1.83	1.61
5	2007	Resistant	1.03	0.89	1.17	1.08	1.29	-	1.09
		Susceptible	1.09	0.99	1.25	1.17	1.35	-	1.17
6	2007	Resistant	1.67	1.69	1.70	1.83	1.87	-	1.75
		Susceptible	1.79	1.76	1.85	1.85	1.85	-	1.82
7	2007	Resistant	1.30	1.41	1.39	1.37	1.40	-	1.37
		Susceptible	1.22	1.28	1.35	1.36	1.35	-	1.31
8	2007	Resistant	1.49	1.63	1.64	1.69	1.79	-	1.65
		Susceptible	1.45	1.61	1.82	1.73	1.86	-	1.69
9	2007	Resistant	1.54	1.60	1.68	1.72	1.80	-	1.67
		Susceptible	1.44	1.66	1.80	1.64	1.90	-	1.69

† A rate of 180 lb K_2O/acre was applied the second year to plots receiving the 30-lb rate the first year.

Table 5. Whole-plant dry weight at the R1 corn growth stage.

Site	Year	Hybrid	Treatment (lb K_2O $acre^{-1}$) 0	60	180	Average
			---------- g $plant^{-1}$ ----------			
1	2006	Resistant	83	70	66	73
		Susceptible	68	66	83	72
	2007	Resistant	101	92	97	97
		Susceptible	95	100	103	99
2	2006	Resistant	98	106	98	101
		Susceptible	95	94	108	99
	2007	Resistant	108	118	120	116
		Susceptible	126	126	126	126
3	2006	Resistant	212	213	191	205
		Susceptible	177	223	191	197
	2007	Resistant	130	148	128	136
		Susceptible	110	126	114	117
4	2006	Resistant	134	145	149	143
		Susceptible	131	125	137	131
	2007	Resistant	142	131	145	140
		Susceptible	131	131	132	131
5	2007	Resistant	91	83	89	88
		Susceptible	84	78	87	83
6	2007	Resistant	96	94	89	93
		Susceptible	91	97	100	96
7	2007	Resistant	101	99	107	102
		Susceptible	107	108	105	107
8	2007	Resistant	118	131	128	126
		Susceptible	116	123	127	122
9	2007	Resistant	144	131	147	141
		Susceptible	112	121	120	118
		Means for resistant	120	120	120	120
		Means for susceptible	111	117	118	115

Table 6. Whole-plant K concentration at the R1 corn growth stage.

Site	Year	Hybrid	Treatment (lb K_2O $acre^{-1}$) 0	60	180	Average
			---------- % ----------			
1	2006	Resistant	1.56	1.59	1.75	1.63
		Susceptible	1.51	1.58	1.85	1.65
	2007	Resistant	1.31	1.36	1.55	1.41
		Susceptible	1.21	1.19	1.75	1.38
2	2006	Resistant	0.87	1.05	1.16	1.03
		Susceptible	0.90	0.96	1.26	1.04
	2007	Resistant	0.79	0.84	0.90	0.84
		Susceptible	0.80	0.80	1.00	0.87
3	2006	Resistant	1.51	1.85	1.80	1.72
		Susceptible	1.58	1.86	1.81	1.75
	2007	Resistant	1.39	1.39	1.61	1.46
		Susceptible	1.60	1.62	1.76	1.66
4	2006	Resistant	1.43	1.50	1.65	1.52
		Susceptible	1.50	1.54	1.66	1.56
	2007	Resistant	1.13	1.04	1.07	1.08
		Susceptible	1.12	1.08	1.20	1.13
5	2007	Resistant	0.90	0.90	1.07	0.96
		Susceptible	0.89	0.95	1.18	1.00
6	2007	Resistant	1.21	1.44	1.65	1.43
		Susceptible	1.34	1.49	1.59	1.47
7	2007	Resistant	1.28	1.38	1.50	1.39
		Susceptible	1.09	1.29	1.30	1.22
8	2007	Resistant	0.98	1.12	1.26	1.12
		Susceptible	1.09	1.23	1.19	1.17
9	2007	Resistant	1.09	1.06	1.19	1.11
		Susceptible	1.00	1.13	1.27	1.13
		Means for resistant	1.19	1.27	1.40	1.28
		Means for susceptible	1.20	1.28	1.45	1.31

Table 7. Whole-plant K uptake at the R1 corn growth stage.

Site	Year	Hybrid	Treatment (lb K_2O $acre^{-1}$) 0	60	180	Average
			g K $plant^{-1}$			
1	2006	Resistant	1.31	1.12	1.16	1.19
		Susceptible	1.04	1.05	1.53	1.21
	2007	Resistant	1.30	1.24	1.50	1.35
		Susceptible	1.16	1.20	1.79	1.38
2	2006	Resistant	0.86	1.12	1.15	1.04
		Susceptible	0.85	0.90	1.36	1.04
	2007	Resistant	0.85	1.00	1.08	0.98
		Susceptible	1.01	1.02	1.28	1.10
3	2006	Resistant	3.37	3.97	3.42	3.59
		Susceptible	2.69	4.13	3.45	3.42
	2007	Resistant	1.74	2.12	2.09	1.99
		Susceptible	1.68	2.06	1.92	1.89
4	2006	Resistant	1.93	2.17	2.46	2.19
		Susceptible	1.97	1.93	2.27	2.05
	2007	Resistant	1.60	1.38	1.54	1.51
		Susceptible	1.47	1.40	1.59	1.49
5	2007	Resistant	0.83	0.74	0.95	0.84
		Susceptible	0.75	0.74	1.04	0.84
6	2007	Resistant	1.16	1.35	1.48	1.33
		Susceptible	1.23	1.44	1.60	1.42
7	2007	Resistant	1.28	1.38	1.59	1.41
		Susceptible	1.17	1.41	1.37	1.32
8	2007	Resistant	1.16	1.48	1.60	1.41
		Susceptible	1.25	1.50	1.51	1.42
9	2007	Resistant	1.57	1.38	1.76	1.57
		Susceptible	1.11	1.38	1.53	1.34
		Means for resistant	1.46	1.57	1.68	1.57
		Means for susceptible	1.34	1.55	1.71	1.53

Table 8. Whole-plant N uptake at the R1 corn growth stage.

Site	Year	Hybrid	Treatment (lb K_2O $acre^{-1}$) 0	60	180	Average
			g N $plant^{-1}$			
1	2006	Resistant	1.67	1.32	1.31	1.43
		Susceptible	1.37	1.33	1.65	1.45
	2007	Resistant	1.76	1.42	1.66	1.61
		Susceptible	1.55	1.57	1.69	1.60
2	2006	Resistant	1.94	2.21	1.93	2.03
		Susceptible	1.97	1.95	2.12	2.01
	2007	Resistant	1.51	1.74	1.59	1.61
		Susceptible	1.84	2.01	1.92	1.92
3	2006	Resistant	3.93	4.04	3.44	3.80
		Susceptible	3.24	4.31	3.79	3.78
	2007	Resistant	1.55	1.71	1.40	1.55
		Susceptible	1.50	1.46	1.30	1.42
4	2006	Resistant	2.73	3.05	3.22	3.00
		Susceptible	2.74	2.62	2.80	2.72
	2007	Resistant	2.11	1.65	1.91	1.89
		Susceptible	1.94	1.79	1.76	1.83
5	2007	Resistant	1.62	1.39	1.38	1.46
		Susceptible	1.52	1.28	1.42	1.41
6	2007	Resistant	1.44	1.44	1.40	1.43
		Susceptible	1.45	1.48	1.62	1.51
7	2007	Resistant	1.59	1.44	1.59	1.54
		Susceptible	1.76	1.71	1.58	1.68
8	2007	Resistant	1.54	1.71	1.72	1.66
		Susceptible	1.56	1.61	1.75	1.64
9	2007	Resistant	2.05	1.77	1.91	1.91
		Susceptible	1.50	1.64	1.49	1.54
		Means for resistant	1.96	1.91	1.88	1.92
		Means for susceptible	1.84	1.91	1.91	1.89

Table 9. Whole-plant P uptake at the R1 corn growth stage.

			Treatment (lb K_2O $acre^{-1}$)			
Site	**Year**	**Hybrid**	**0**	**60**	**180**	**Average**
			---------- mg P $plant^{-1}$ ----------			
1	2006	Resistant	158	123	116	132
		Susceptible	131	123	158	137
	2007	Resistant	188	166	178	178
		Susceptible	177	179	202	186
2	2006	Resistant	286	299	284	290
		Susceptible	290	264	292	282
	2007	Resistant	265	279	274	273
		Susceptible	297	278	310	295
3	2006	Resistant	431	419	309	386
		Susceptible	359	468	349	392
	2007	Resistant	235	248	217	233
		Susceptible	202	257	193	217
4	2006	Resistant	242	265	300	269
		Susceptible	274	229	280	261
	2007	Resistant	256	189	216	220
		Susceptible	208	189	188	195
5	2007	Resistant	181	135	170	162
		Susceptible	167	130	160	153
6	2007	Resistant	174	176	170	173
		Susceptible	175	183	195	184
7	2007	Resistant	264	265	261	263
		Susceptible	264	282	241	262
8	2007	Resistant	145	170	172	162
		Susceptible	159	174	162	165
9	2007	Resistant	213	179	219	204
		Susceptible	164	177	174	172
		Means for resistant	234	224	222	227
		Means for susceptible	221	226	223	223

Table 10. Grain yield, nutrient concentration, and nutrient removal for corn hybrids resistant and susceptible to rootworm (averages across all K fertilizer rates).

Site	Year	Hybrid	Yield	Potassium		Nitrogen		Phosphorus	
			bu a^{-1}	%	lb K_2O a^{-1}	%	lb N a^{-1}	%	lb P_2O_5 a^{-1}
1	2006	Resistant	177	0.31	37	1.29	128	0.21	49
		Susceptible	164	0.30	33	1.28	118	0.22	45
	2007	Resistant	183	0.35	43	1.20	123	0.25	58
		Susceptible	179	0.34	41	1.15	115	0.25	57
2†	2007	Resistant	170	0.39	45	1.29	123	0.29	63
		Susceptible	137	0.39	36	1.32	101	0.30	53
3	2006	Resistant	218	0.27	39	1.47	180	0.25	71
		Susceptible	208	0.28	39	1.47	172	0.27	71
	2007	Resistant	191	0.37	48	1.03	111	0.27	66
		Susceptible	188	0.37	47	1.01	107	0.28	67
4	2006	Resistant	191	0.34	44	1.26	135	0.26	64
		Susceptible	188	0.33	42	1.27	133	0.25	61
	2007	Resistant	173	0.31	36	1.11	107	0.22	49
		Susceptible	171	0.31	35	1.15	110	0.22	47
5	2007	Resistant	170	0.33	38	1.36	129	0.22	48
		Susceptible	163	0.34	37	1.31	120	0.22	46
6	2007	Resistant	178	0.37	44	1.26	125	0.26	60
		Susceptible	181	0.35	42	1.25	127	0.25	59
7	2007	Resistant	169	0.43	48	1.33	126	0.29	63
		Susceptible	150	0.41	41	1.44	121	0.29	57
8	2007	Resistant	196	0.37	49	1.04	114	0.25	63
		Susceptible	194	0.37	48	1.05	114	0.25	62
9	2007	Resistant	188	0.31	40	1.31	138	0.24	59
		Susceptible	185	0.31	39	1.28	133	0.25	59

† Grain samples for analysis were not collected at Site 2 in 2006.

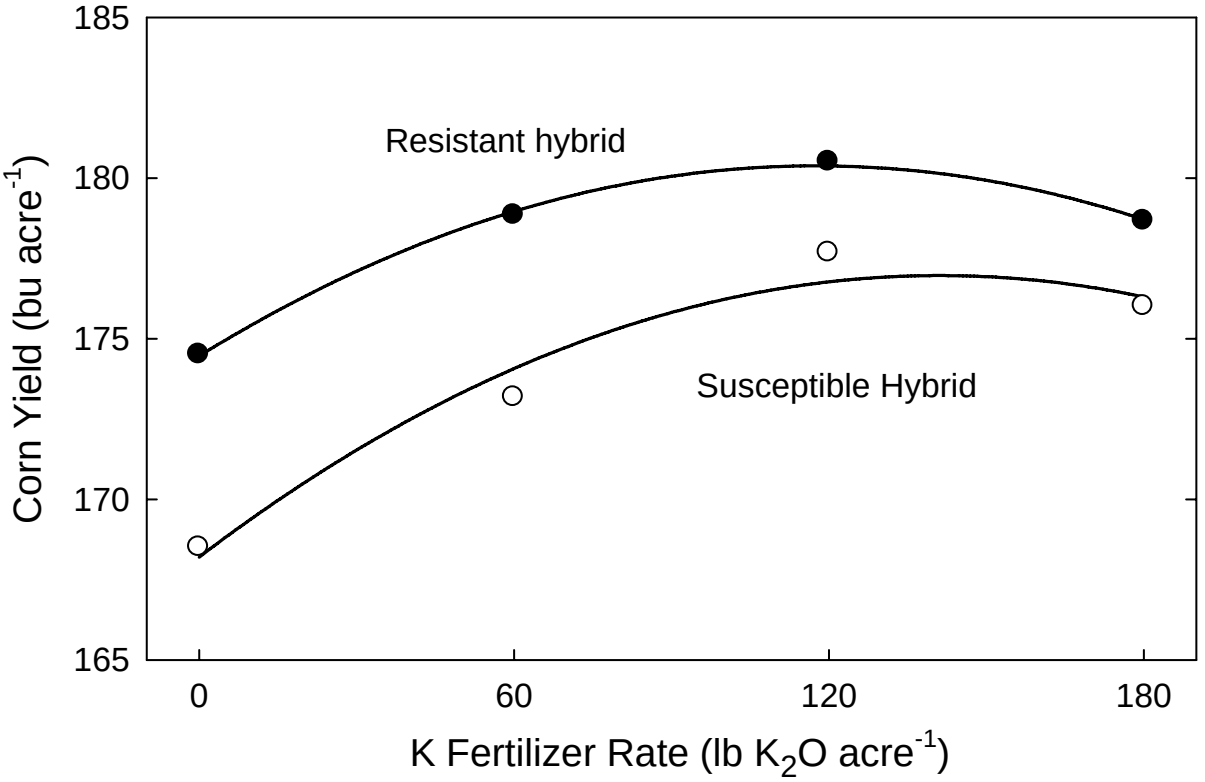

Fig. 1. Corn grain yield response to K fertilization as affected by hybrid resistance to rootworm injury. Means across all first- and second-year trials with a statistically significant response to K (an apparent interaction between hybrid and K was not significant).

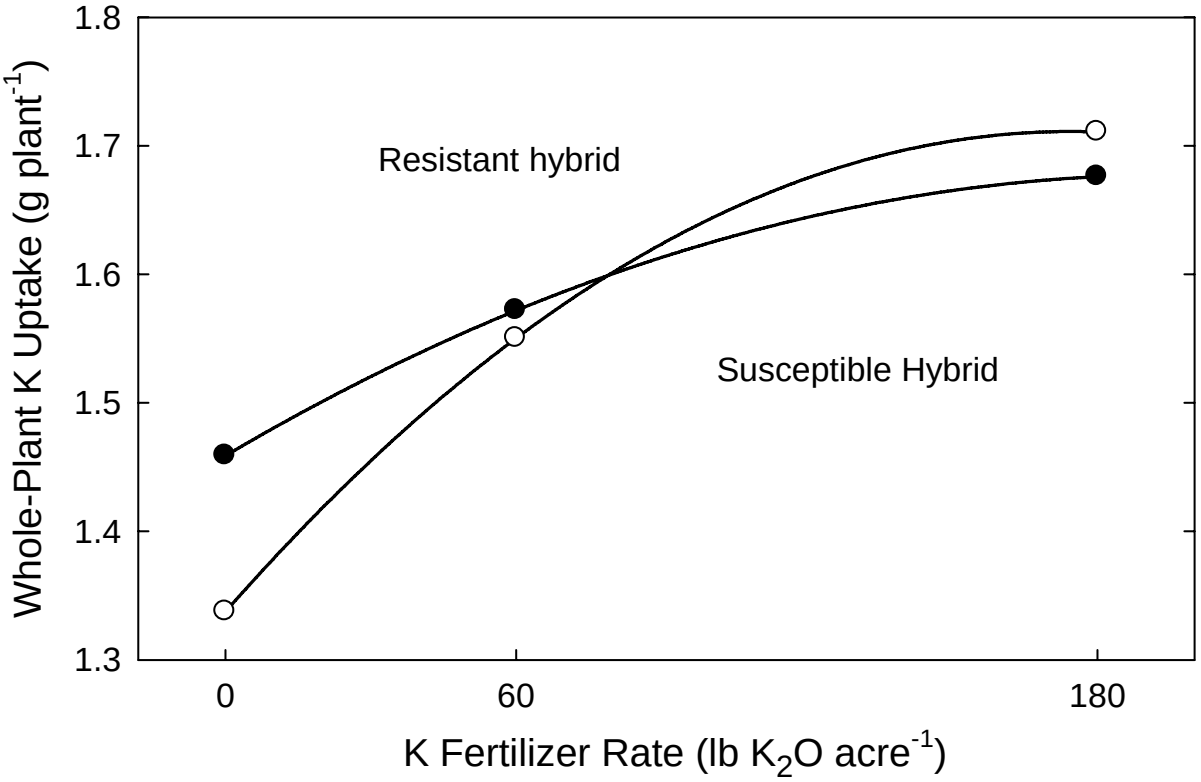

Fig. 2. Corn whole-plant K uptake (at the R1 growth stage) response to K fertilization as affected by hybrid resistance to rootworm injury. Means across 13 site-years in 2006 and 2007. The interaction between hybrid and K was statistically significant.

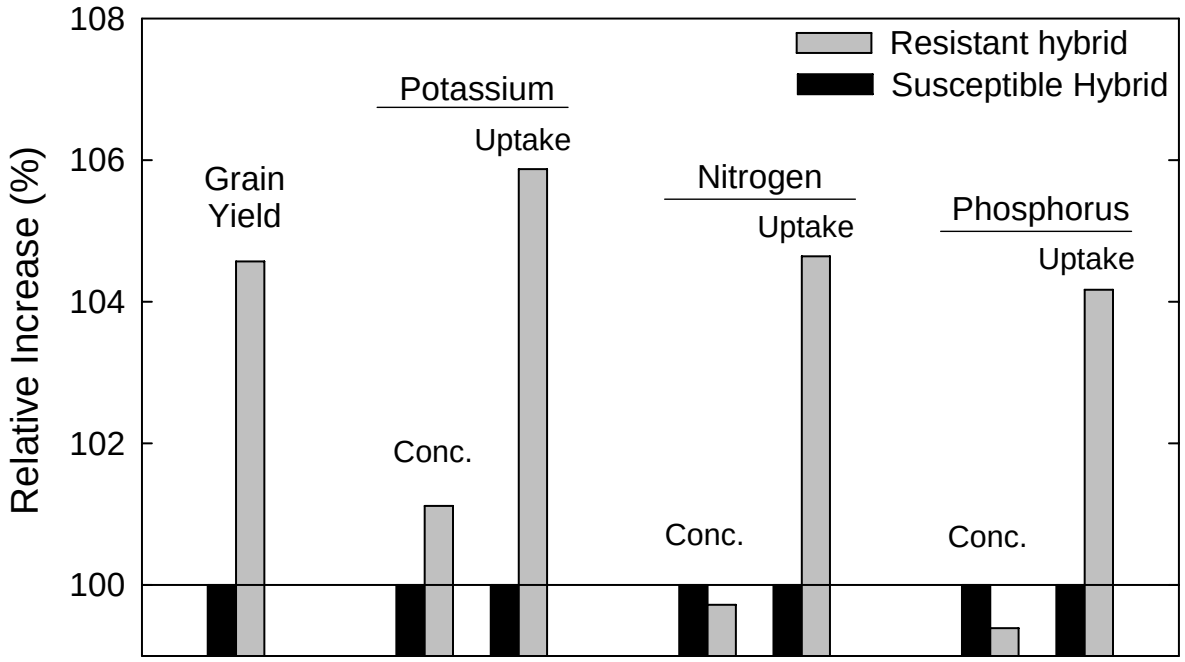

Fig. 3. Relative effect of rootworm resistance compared with a susceptible hybrid on grain yield, grain nutrient concentration, and nutrient removal with grain harvest. Means across 13 site-years in 2006 and 2007.