EARLY SEASON NUTRIENT UPTAKE FROM COMBINATIONS OF NITROGEN, PHOSPHORUS, AND POTASSIUM APPLIED IN STARTER FERTILIZER IN TWO CORN HYBRIDS

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Abstract

Conventional small plot field trials were established to study the effect nitrogen (N), phosphorus (P), and potassium (K) applied as starter fertilizer on early season growth and nutrient uptake of two corn hybrids with and without the Bt-rootworm gene. Eight locations were studied over two years comparing a non-starter check, N only, K only, NP, NPK, and NK starter fertilizer combinations on early season growth and nutrient uptake. Sites tested High initially in both P and K. One or more starter treatments significantly ($P \leq 0.10$) increased early growth and uptake of N, P, and K at three locations over 2 years of this study. At these locations starter P significantly increased early growth (EG) and nutrient uptake while N and K only increased them at 1 site. At the site where a significant K effect was found, it was greatest only when N was applied. Hybrids only differed for EG and nutrient uptake during the second year, and this difference could not be attributed to damage from corn rootworm. The data shows that overall farmers can increase EG and uptake of nutrients in spite of high soil tests with starter P, but these effects may not be widespread and may be limited to specific growing conditions within a region or year.

Introduction

Minnesota corn (*Zea mays* L.) farmers utilize starter fertilizers with the hopes of increasing early growth and nutrient uptake. This increased growth could potentially speed up the time to reproductive development and allow more time for grain production, which could be beneficial in a northern climate where the growing season is shorter. Many corn producers rely on liquid fertilizer sources because of ease of handling and many planters are equipped to apply fertilizer in the seed furrow. Commercial blends of ammonium polyphosphate (10-34-0) have been used for many years because of widespread availability and lower cost compared with other liquid fertilizer sources. Higher yields and higher prices of traditional starter choices have caused many farmers to consider alternatives to maximize yields and minimize cost.

Liquid fertilizer formulations with K are sold, but the benefits from K in starter are not clearly understood, especially in the Northern Corn Belt. Most research to date has shown that N and P in a starter mix, either alone or in combination, are usually the main nutrients responsible for increasing early plant growth. For example, Bermudez and Mallarino (2004) looked at starter response from N and P starter in high P testing soils and attributed most yield responses to N. Recent starter work in Iowa (Kaiser et al., 2005) as well as work in Minnesota (Vetsch and Randall, 2002) has shown potential yield benefits from N, P, and K starter mixes. However, in the case of Kaiser et al., (2005) most of the responses could be associated with fields testing Low in P or K. Work in Minnesota and Iowa (Rehm, 1992; Bardoli and Mallarino, 1998; Mallarino et al., 1999) has shown a potential yield benefit from banded K even when soil test levels should be optimum for crop production. Since many farmers have the ability to band fertilizer with the planter, the benefits of different starter blends should be studied to identify if best combinations of nutrients exist under different growing conditions in regions across Minnesota.

Small plot field trials were established at multiple locations across Minnesota with the following objectives: 1) determine the impacts of nutrients applied alone or in combination as starter fertilizer on early season growth and nutrient uptake of corn; 2) to examine potential interactions between nutrients to and identify synergistic relationships between nutrients in terms of early plant growth and nutrient uptake; and 3) to examine early season growth and nutrient uptake differences between two near isoline hybrids.

Materials and Methods

Eight field trials were established over two years in Southern Minnesota (Table 1). Locations were selected to represent common soil series in major corn growing areas. A single composite soil sample consisting of 10 to 15 individual soil cores were taken from each replication to six inches depth before fertilizer application. Most locations tested High for P (Bray-P1 test) or K (ammonium acetate test) according to current Minnesota recommendations (Table 1). Current recommendations for the Bray-P1 test in Minnesota are $\leq$5 ppm, Very Low; 6-10, Low; 11-15, Medium; 16-20, High; and $\geq$21 Very High. For the ammonium acetate K test $\leq$40, Very Low; 41-80, Low; 81-120, Medium; 121-160, High; and $\geq$161, Very High (Rehm et al., 2006). Broadcast N, P, and K fertilizer was applied based on current university guidelines for corn production based on initial soil test values (Rehm et al., 2006).

Trials were arranged in a randomized complete split block design. Main plots consisted of five starter fertilizer treatments consisting of N only (N); N and P (NP); N, P, and K (NPK); K only (K); N and K (NK); and a non-starter control (Chk). Main plot treatments were arranged randomly within each replication. A John Deere 7000 series planter was equipped with 3 fertilizer pumps to apply three commercially available fertilizer sources simultaneously two inches beside and below the seed furrow. Sources used for this study were 28-0-0 urea-ammonium nitrate solution, 10-34-0 (ammonium polyphosphate solution), and 0-0-30 (N-P_2O_5-K_2O) solutions. Targeted starter rates applied 10 lbs N, 20 lbs P_2O_5, or 20 lbs K_2O in the different combinations. All equipment was calibrated before application to ensure proper application rates.

Subplots consisted of two corn hybrids planted in strips over each treatment within each replication. The two hybrids were 100 day relative maturity hybrids within a near-isoline. Hybrid 1 consisted of glyphosate, Bt-corn borer, and Bt-corn rootworm resistance while Hybrid 2 consisted of glyphosate and Bt-corn borer resistance only. Identical hybrids and planting populations (35,000 seeds per acre) were used at all locations both years. Hybrid strips consisted of 8-30” rows (20 feet wide) and plot lengths were always 40 feet at each location. Previous crop varied by location (Table 1). Tillage was consistent with farmers’ normal practices, but generally consisted of fall chisel plow tillage followed by spring field cultivation when the previous crop was corn and spring field cultivation only when the previous crop was soybean. All herbicide application was done by the farmer cooperators.

Early plant growth was measured by sampling six plants at the V4-V5 growth stage (Richie et al., 1986) from non-harvest rows in each plot. Plants were dried at 65^{o}C, ground to pass through a 2 mm sieve, and analyzed for total N, P, and K. Total N was analyzed with a LECO CHN-2000 analyzer (LECO Corp.), while total P and K were analyzed with and ICP following a wet digestion procedure. Nutrient uptake was calculated based on total nutrient concentration and dry weight.

Statistical analysis was conducted for main treatment effects and their interaction within and across location using the PROC GLM procedure in SAS (SAS Institute, 2000). When analysis indicated a significant ($P \leq 0.10$) effect of nutrient application, fertilizer treatment sums of squares were partitioned into single degree of freedom contrasts to assess the effect of N, P, and K at each location. Briefly the effect of N was assessed comparing the Chk and K vs. N and NK treatments; P by N and NK vs. NP and NPK; and K by Chk, N, and NP vs. K, NK, and NPK. Significant interactions were studied using the SLICE effect in the LSMEANS statement in PROC GLM. Relationships between variables across sites and years were studied using the PROC CORR procedure in SAS.

Results and Discussion

Early growth (EG) responded significantly ($P \leq 0.10$) to one or more starter treatments at three sites (Table 2). Starter P increased EG at two sites while N or K increased EG at only one site (Site 2). Single degree of freedom contrasts at Site 2 indicated that response to K was greatest when N was applied. All 3 responsive locations were on similar soil types in similar areas of Minnesota (Table 1). Early growth did not differ between hybrids in 2008, but growth averages across starter treatments were greater with hybrid 2 in 2009. Differences between responses each year could be due to differing weather patterns early in the growing season, intrinsic differences between plant growth between the near-isoline hybrids, or to differences in germination of the seed used in the study. It is unlikely that differences were due to any rootworm damage since roots were dug at the time of plant sampling and there was no clear indication of root worm damage at that time, and none was expected this early in the growing season. Analysis across locations showed no significant effect on EG due to hybrid or treatment; however, there were a significant interactions for year and hybrid and year and starter treatment. Analysis across locations and within years showed a difference between starter treatments across 2008 sites. In that year, all starter treatments except for K only increased EG over the Chk and the NPK starter mix increased growth the greatest. The significant interaction between year and hybrid was due to the greater plant mass of Hybrid 2 during 2009.

Nitrogen uptake (NUP) responded significantly to one or more starter treatments at the same three sites (Table 3) as EG. Similarly, NUP was higher in treatments receiving P at two locations and N or K at another. At Site 2, K increased NUP, but only when N was applied with it. Following with EG, NUP was not affected by hybrid in 2008, but was significantly affected by hybrid at all four locations in 2009. This may be due to the fact that stand counts (data not shown) were lower for hybrid 2, possibly allowing for larger plants and increased nutrient uptake from less competition. Across locations stand counts taken from the harvest areas averaged 33,150 plants ac^{-1} for Hybrid 2 and 34,960 for hybrid 1 during 2009. Analysis across locations and within years was similar to 2008 EG trends with all starter treatments except K only increasing NUP over the control, NPK starter mix increasing NUP the most, and hybrid effects being significant across the 2009 locations. Across locations NUP was correlated with EG (r = 0.98) to a much greater extent than with N concentration (r = -0.13). Overall, there were no increases in NUP when EG was not increased.

Phosphorus uptake (PUP) responded significantly to one or more starter treatments at four sites (Table 4). Patterns of responses were similar to early plant growth and NUP at all locations, except for Site 5 where starter treatment did not affect EG or NUP. Starter P increased PUP at Sites 3 and 7, starter N at Site 2, and both P and K at Site 5. Again, most uptake increases were due to increased EG and not concentration. The difference in response at Site 5 could not be determined since there were no significant increases in EG or P concentration (not shown) at this site. Correlation between EG and PUP across locations (Table 6) was stronger (r = 0.98) than for P concentration (r = -0.24). As expected from above statements for EG and NUP, PUP was significantly affected by hybrid only in 2009 where it was significant across all locations and caused a significant interaction between year and hybrid in the ANOVA analysis across locations.

Potassium uptake (KUP) responded significantly to one or more starter treatments at three sites and hybrids differed at three sites (Table 5). Response trends were identical to EG and N uptake except for hybrid response at Site 8, which was not significant. Increased K uptake was more often associated with starter P applications (2 sites) than with K applications (1 site). The lack of response to K is reasonable since most locations tested high in K even though past research has shown luxury uptake of K in spite of high soil test levels. However, at these locations there was no evidence of luxury uptake of K since uptake was more highly correlated with EG (r = 0-94) than with plant K concentration (r = 0.17) across locations (Table 6). Analysis across locations in 2008 was similar to PUP trends with N, NP, and NPK starter treatments increasing KUP over the control and NPK creating the greatest increase. Similar to PUP but different from EG and NUP, the treatment receiving both N and K produced K uptake increases between the Chk and K only treatment and the N, NP, and NPK treatments.

Conclusions

In sites testing High in soil P and K, starter fertilizer containing N, P, and K can increase plant growth and nutrient uptake. Nutrient uptake was highly correlated with EG and not early plant nutrient concentration indicating no luxury consumption at any location. When a starter treatment increased EG it was often due to P. Starter N and K sometimes increased EG and nutrient uptake, but at only 1 location. All responsive locations were of similar regions within the state. Differences existed between hybrids for all measured variables during 1 year, but reasons for the differences could not be clearly identified by site or treatment factors.

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Tables

Table 1. Trial location, predominant soil series, and initial soil test values.

Site	Year	County	Planting Date	Previous Crop	Predominant Soil: Series	Predominant Soil: Subgroup‡	Soil Test†: P	Soil Test†: K	Soil Test†: pH	Soil Test†: SOM
							--------mg kg^{-1}--------			---g kg^{-1}---
1	2008	Sibley	16-May	Soybeans	Canisteo-Glencoe	Cu. Endoaquoll	15	190	7.3	58
2	2008	Yellow Medicine	14-May	Soybeans	Ves	Ca. Hapludoll	27	289	5.6	41
3	2008	Redwood	21-May	Corn	Ves	Ca. Hapludoll	21	159	5.3	44
4	2008	Dakota	16-May	Corn	Lindstrom	Cu. Hapludoll	84	436	6.6	64
5	2009	Olmsted	24-Apr	Soybeans	Littleton	Cu. Hapludoll	24	125	7.1	45
6	2009	Faribault	3-May	Corn	Fostoria	A. Hapludoll	45	218	5.8	52
7	2009	Redwood	28-Apr	Corn	Ves	Ca. Hapludoll	21	166	5.8	37
8	2009	Brown	3-May	Soybeans	Hanska	T. Endoaquoll	20	129	5.9	43

† P, Bray P-1 phosphorus; K, ammonium acetate potassium; pH, soil pH; SOM, soil organic matter.

‡ A., Aquic; Ca., Calcic; Cu., Cummulic; T., Typic.

Table 2. Hybrid and treatment effects on V5 plant weight.

		Treatment†							Statistics‡					
Site	Hybrid	Chk	N	NP	NPK	K	NK	Avg	T	H	T x H	N	P	K
		---g plant^{-1}---							---$P \geq F$---					
1	1	7.5	8.9	8.7	8.9	8.0	8.0	8.3	0.36	0.60	0.59			
	2	8.2	8.9	7.7	8.5	8.7	8.4	8.4						
	Avg	7.9	8.9	8.2	8.7	8.4	8.2							
2	1	6.5	7.5	7.8	8.5	6.8	7.2	7.4	<0.01	0.24	0.19	<0.01	0.25	0.05
	2	6.3	6.9	6.9	8.2	6.0	8.3	7.1						
	Avg	6.4	7.2	7.4	8.4	6.4	7.8							
3	1	3.1	3.5	4.8	4.5	3.4	3.3	3.8	0.01	0.28	0.84	0.31	<0.01	0.14
	2	3.2	3.7	4.5	4.1	3.0	3.0	3.6						
	Avg	3.2	3.6	4.7	4.3	3.2	3.2							
4	1	6.4	6.6	7.1	7.6	6.5	7.0	6.9	0.38	0.90	0.65			
	2	6.8	7.1	6.7	7.8	6.0	6.9	6.9						
	Avg	6.6	6.9	6.9	7.7	6.3	7.0							
5	1	3.4	3.2	3.8	4.0	3.6	4.1	3.7	0.18	<0.01	0.53			
	2	4.2	4.1	4.5	4.5	4.3	4.3	4.3						
	Avg	3.8	3.7	4.2	4.2	3.9	4.2							
6	1	1.8	1.7	1.9	2.1	1.8	1.7	1.8	0.41	<0.01	0.85			
	2	2.2	2.3	2.5	2.5	2.5	2.3	2.4						
	Avg	2.0	2.0	2.2	2.3	2.2	2.0							
7	1	3.5	2.8	3.3	3.6	2.7	2.9	3.1	0.08	0.02	0.62	0.37	0.01	0.60
	2	3.9	3.9	4.9	4.4	4.1	3.8	4.2						
	Avg	3.7	3.4	4.1	4.0	3.4	3.4							
8	1	6.6	5.7	6.1	5.9	5.7	5.9	6.0	0.70	0.04	0.48			
	2	6.4	6.9	7.4	7.2	6.1	6.6	6.8						
	Avg	6.5	6.3	6.8	6.6	5.9	6.3							

† Chk, non-starter control; N, N only; NP, N+P; NPK, N+P+K; K, K only; NK, N+K; Avg, treatment average.

‡ Probability of H, hybrid main effect; T, treatment main effect; TxH interaction between treatment and hybrid main effect; N, response to nitrogen; P, response to phosphorus; K, response to potassium are significant at the P>0.10 level.

Table 3. Starter NPK treatment and hybrid effects on early corn N uptake.

		Treatment†							Statistics‡					
Site	Hybrid	Chk	N	NP	NPK	K	NK	Avg	T	H	T x H	N	P	K
		---mg plant^{-1}---							---$P \geq F$---					
1	1	317	335	377	344	368	387	355	0.31	0.48	0.41			
	2	347	375	373	364	316	367	357						
	Avg	332	355	375	354	342	377							
2	1	273	304	325	355	280	294	305	0.01	0.37	0.24	0.01	0.18	0.06
	2	268	289	287	344	250	345	297						
	Avg	270	296	306	349	265	320							
3	1	134	143	150	140	195	188	158	<0.01	0.19	0.88	0.28	<0.01	0.19
	2	132	129	155	127	182	171	149						
	Avg	133	136	152	133	188	180							
4	1	241	241	234	264	271	286	256	0.13	0.62	0.66			
	2	254	213	269	258	262	305	260						
	Avg	248	227	252	261	266	295							
5	1	129	124	142	151	135	154	139	0.19	0.01	0.65			
	2	158	152	165	176	166	168	164						
	Avg	143	138	154	164	151	161							
6	1	83	82	78	81	96	98	86	0.32	<0.01	0.17			
	2	97	111	105	106	109	105	106						
	Avg	90	97	91	94	103	102							
7	1	145	106	112	118	147	149	129	0.02	0.03	0.71	0.59	0.01	0.34
	2	152	153	152	152	193	174	163						
	Avg	148	130	132	135	170	161							
8	1	243	214	210	230	241	231	228	0.33	0.01	0.55			
	2	242	231	268	262	285	282	262						
	Avg	242	223	239	246	263	257							

† Chk, non-starter control; N, N only; NP, N+P; NPK, N+P+K; K, K only; NK, N+K; Avg, treatment average.

Table 4. Starter NPK treatment and hybrid effects on early corn P uptake.

		Treatment†							Statistics‡					
Site	Hybrid	Chk	N	NP	NPK	K	NK	Avg	T	H	T x H	N	P	K
		mg plant^{-1}							*P* ≥*F*					
1	1	34.3	34.9	40.8	35.8	38.4	41.3	37.6	0.38	0.36	0.43			
	2	36.8	40.4	41.3	39.1	32.4	39.8	38.3						
	Avg	35.6	37.7	41.1	37.5	35.4	40.6							
2	1	27.2	32.5	32.9	35.8	28.9	29.3	31.1	0.07	0.71	0.13	<0.01	0.12	0.13
	2	27.6	30.0	31.0	34.8	26.1	35.3	30.8						
	Avg	27.4	31.3	31.9	35.3	27.5	32.3							
3	1	12.7	13.5	14.1	13.2	18.4	17.8	15.0	0.01	0.67	0.91	0.46	<0.01	0.27
	2	13.6	12.8	14.5	13.1	17.8	16.5	14.7						
	Avg	13.2	13.2	14.3	13.2	18.1	17.2							
4	1	30.6	28.1	28.6	32.6	33.0	35.4	31.4	0.28	0.99	0.56			
	2	31.0	25.8	33.1	29.8	31.1	37.5	31.4						
	Avg	30.8	27.0	30.9	31.2	32.1	36.5							
5	1	13.6	13.8	16.8	17.8	15.1	17.4	15.7	0.07	0.01	0.86	0.18	0.02	<0.01
	2	17.8	17.8	19.5	20.9	18.8	19.7	19.1						
	Avg	15.7	15.8	18.1	19.4	17.0	18.5							
6	1	7.1	7.1	6.8	6.8	8.5	8.9	7.5	0.23	<0.01	0.37			
	2	8.6	9.6	9.2	8.8	9.7	9.6	9.3						
	Avg	7.9	8.4	8.0	7.8	9.1	9.3							
7	1	14.1	10.3	10.0	10.9	14.0	13.7	12.2	0.01	0.03	0.46	0.24	<0.01	0.24
	2	14.3	15.3	14.4	13.6	19.6	16.6	15.6						
	Avg	14.2	12.8	12.2	12.3	16.8	15.2							
8	1	26.3	23.8	21.4	24.8	26.0	25.2	24.6	0.51	0.02	0.59			
	2	26.6	24.2	28.3	26.9	32.1	29.9	28.0						
	Avg	26.5	24.0	24.9	25.9	29.1	27.6							

† Chk, non-starter control; N, N only; NP, N+P; NPK, N+P+K; K, K only; NK, N+K; Avg, treatment average.

‡ Probability of H, hybrid main effect; T, treatment main effect; TxH interaction between treatment and hybrid main effect; N, response to nitrogen; P, response to phosphorus; K, response to potassium are significant at the P>0.10 level.

Table 5. Starter NPK treatment and hybrid effects on early corn K uptake.

		Treatment†							Statistics‡					
Site	Hybrid	Chk	N	NP	NPK	K	NK	Avg	T	H	T x H	N	P	K
		mg plant^{-1}							*P* ≥*F*					
1	1	226	252	288	246	276	280	261	0.22	0.55	0.68			
	2	240	280	292	271	227	278	265						
	Avg	233	266	290	259	251	279							
2	1	206	226	236	269	213	222	229	0.03	0.81	0.36	0.02	0.23	0.10
	2	212	223	227	262	189	268	230						
	Avg	209	224	232	265	201	245							
3	1	111	121	122	119	164	167	134	0.05	0.54	0.83	0.28	<0.01	0.99
	2	113	111	131	113	149	158	129						
	Avg	112	116	126	116	157	162							
4	1	244	236	252	270	286	297	264	0.26	0.62	0.59			
	2	274	221	276	254	271	322	270						
	Avg	259	228	264	262	278	310							
5	1	90	101	119	121	109	141	113	0.14	0.09	0.47			
	2	129	125	120	151	140	155	137						
	Avg	110	113	120	136	125	148							
6	1	60	61	58	62	68	71	63	0.69	0.01	0.40			
	2	73	83	83	81	77	82	80						
	Avg	67	72	71	71	72	77							
7	1	138	106	95	116	114	142	118	0.05	0.02	0.59	0.38	0.03	0.25
	2	134	153	133	148	165	179	152						
	Avg	136	129	114	132	139	160							
8	1	240	213	194	224	209	234	219	0.26	0.26	0.69			
	2	218	209	227	242	227	262	231						
	Avg	229	211	210	233	218	248							

† Chk, non-starter control; N, N only; NP, N+P; NPK, N+P+K; K, K only; NK, N+K; Avg, treatment average.

‡ Probability of H, hybrid main effect; T, treatment main effect; TxH interaction between treatment and hybrid main effect; N, response to nitrogen; P, response to phosphorus; K, response to potassium are significant at the P>0.10 level.

Table 6. Correlations coefficients between measured variable across sites (n=384)†.

	PN	PP	PK	NUP	PUP	KUP
EG	-0.29	0.41	-0.14	0.98	0.98	0.94
PN		0.04	0.02	-0.13	-0.24	-0.31
PP	0.04		0.15	0.43	0.57	0.45
PK	0.02	0.15		-0.15	-0.09	0.17
NUP	-0.13	0.43	-0.15		0.97	0.92
PUP	-0.24	0.57	-0.09	0.97		0.94

† Coefficients > 0.082 are significant at $P \leq 0.10$.

EG, V5 early plant growth; PN, V5 N concentration; PP, V5 P concentration; PK, V5 K concentration; NUP, V5 N uptake; PUP, V5 P uptake; KUP, V5 K uptake.

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