NPPC Project #00-010

Agronomic Feasibility of Growing Low-Phytate Corn

Michael A. Schmitt
Professor of Soil Science
Dep. of Soil, Water, and Climate
University of Minnesota-St. Paul

Gyles W. Randall
Professor of Soil Science
Southern Research and Outreach Center-Waseca
University of Minnesota

Final Report
National Pork Producer Council

June 30, 2001

Table of Contents

Stated Objectives from Original Proposal

The objectives of this research are to investigate the questions around low phytate corn. Will low phytate (LP) corn yield less than their genetic counterparts with normal phytate levels? How will the phytate content be affected by fields "right behind the barn," which have very high soil test P levels? Will fertilizer phosphorus (P) strategies affect phytate P percentages? Is there an overall reduction in P in the grain, stover, or both in conjunction with the phytate reduction in the grain?

Introduction

The main phosphorus (P) storage unit in corn grain is phytic acid, or phytate. This P form is unavailable to swine, thus, most of the grain P goes directly from the feed into the manure without adding any nutritional value to the animal. To compensate, supplemental (inorganic) P is added to swine diets when mixing their rations. In an effort to decrease the amount of P in swine manure, corn breeders have selected corn mutants that contain significantly less phytate, while attempting to maintain overall equal P amounts, and are now transferring this trait back into standard hybrids. Thus, swine diets can rely more on corn grain P rather than supplemental feed P for swine's dietary P needs and the amount of P being applied to soils is less.

The objective of this project is to evaluate the consistency and range in grain P content and grain yield as affected by soil P levels in corn hybrids that contain normal and low-phytate (LP) characteristics. A secondary objective is to evaluate the overall P uptake by these altered corn lines to determine if total P uptake by the plant has been affected by this genetic selection.

Materials and Methods

Three sites were selected in south-central and southeastern Minnesota that had varying manure histories or fertilizer P histories within each site (soil test P values are given in Table 1; all tables are in Appendix A.). At one site (Rosemount), two commercial P rates (0 and 90 lb/A P_2O_5) were broadcast applied preplant within each of the three manure history (none, low, and high) areas. Four corn genetic treatments (Hybrid A, Hybrid A-low phytate, Hybrid B, Hybrid B-low phytate) were then planted within each subplot area for this one site. Pioneer Hi-Bred International provided these hybrid pairs. At the other two sites (Rochester and Waseca), one hybrid (B), with its LP and standard lines, was seeded across the three main plot treatments (soil P test levels).

Preplant commercial N was uniformly applied across each site and recommended management/cultural practices were used throughout the growing season. Two 15-ft rows of each plot were then hand-harvested for grain yield.

One 15-ft row was then harvested for stover yield. Samples of both grain and stover were collected for phosphorus analysis.

Results and Discussion

Grain yield data are presented in Tables 2, 3, 4, and 5. Table 3 contains the three-site data set for Hybrid B and Tables 3, 4, and 5 contain each site's data. The LP trait (phytate content) decreased yields at all locations although this decrease was only statistically significant at the Rosemount and Rochester locations (Table 6).

Although there were yield differences based on the original hybrids used in this study, the effect of the LP trait was fairly consistent between both hybrids. Hybrid B had a 12.3% average grain yield decrease when the LP characteristic was included in the genetic make-up (Table 2). Hybrid A, which was only evaluated at one location (Rosemount) in 2000, had an 11.7% yield decrease for the LP genetics compared to the standard corn (Table 3).

Yield decreases of 10+% when including a new trait are noticeable to crop producers. The 2000 data provided the greatest differences when comparing standard and LP traits in this 3-year project. Based on two prior years' of data from similar studies, the effect of the LP trait on grain yield was approximately a 7% reduction in Year 1 and a 3% reduction in Year 2. Two possible situations are creating these differences with the inclusion of the LP trait. One is the plant breeding efforts we chose to use with the project—we selected to use the same genetics for the same three years of this project and these hybrids were not completely converted when the project started. Thus, some of these grain yield differences could be due to extraneous donor genes still present in the LP lines of corn. The second situation could be from a confounding factor related to management. In all years, the standard lines of corn were obtained from public seed sources, whereas the LP lines were obtained from the breeding program at Pioneer. The difference between these sources is that the public seed had a general seed treatment coating while the LP lines were not treated. Compared to earlier years, the seed in 2000 was planted in early May and this may have led to an early season vigor issue that stayed with the treatments all season. Visual notes indicated suppressed growth of the LP corn throughout the season in 2000.

The effect of manure rate history/soil test P levels on the grain yields of the hybrids was statistically significant at the 5% level for all sites (Table 6). Using a weighted average from all sites and both hybrids in 2000, the yields averaged 140, 149, and 156 bu/acre for the "none", "low", and "high" manure histories based on previous manure/fertilizer treatments, respectively. This response to manure history is most likely from a combination of several factors associated with the manure application/soil P build-up such as improved soil tilth, increased soil organic matter, slow release nutrient release, increased microbial activity, etc. It is interesting to note that there were yield increases even at the locations where the soil test P levels would not predict a yield response. The grain yield response to manure history/soil test P levels was very consistent for all three years of this study.

The influence of fertilizer P application rates at Rosemount, which had two P rates applied (0 and 90 lbs/acre), had no effect on grain yield. This affirms that the soil test P levels for all treatments were adequate and that the increased yields based on manure history was not primarily a P effect. There also was no statistically significant P fertilizer by manure history interaction (Pr>F = 0.3476, Table 6).

Grain P concentrations were unaffected by the LP trait across all locations in 2000 (Tables 3, 4, and 5). This response is not consistent with previous years, as the LP corn averaged around 3% less total P across all hybrids, sites, and years. This is a characteristic that did significantly different between the two hybrids used in the study. Manure history/soil test P levels had a significant effect on grain P concentrations (Table 6), with P concentrations increasing proportionally with the soil test P levels. Any variation in grain P concentrations due to the LP trait was overshadowed by the variation in grain P due to manure history.

Stover yield data was similar to the response measured for grain yields (Tables 3, 4, and 5) with only occasional effects of the LP trait on stover yields with very positive, significant effects due to manure history/soil test P level. Stover P concentrations were very similar to grain P concentrations, with the hybrid effect at Rosemount contributing to significant differences at this location.

Total P removal was significantly related to manure history/soil test P levels and the phytate trait at all sites (Table 6). The LP corn lines had reduced total P removal. P removal for Hybrid B was reduced 7%, 10%, and 19% with the LP line for Rosemount, Waseca, and Rochester, respectively (Tables 3, 4, and 5). The LP trait in Hybrid A, grown only at Rosemount, reduced total P removal by 9% for Hybrid A (Table 3). The primary contributing factor for these differences is related to the lower grain and stover yields with the LP lines of corn.

Summary

Low phytate lines of corn were compared to traditional corn lines at three sites in 2000. For one of the hybrid pairs, which were grown at all three sites, the average yields were 136 bu/acre for the low phytate corn, a 12% yield reduction from the standard line. At one site, we compared two hybrid pairs and found that the yield reduction was 12% for both hybrids. At all sites, the effect of soil test P level, which can be a good indicator of previous manure history, had a relatively large effect (9%) on grain yield. Where the soil P test was lowest, yields averaged 138 bu/acre and increased to 146 for the medium soil P test range, and was 152 bu/acre at the highest soil P test range. There was no significant reduction in grain P content associated with the LP characteristic for this growing season, however, there was a reduction in total P removal due to the influence of the yield differences.

The yield difference and total P removal reduction found with the LP hybrids indicate that there may be a background effect occurring, possibly due to extraneous donor genes initially crossed into the LP corn lines. With further conversions of these lines, the negative background effects could be significantly reduced and possibly eliminated. It should also be noted that some of our yield reductions with the LP corn may be due to early season stress from the lack of an overall seed treatment application.

Publications

Schmitt, M.A., G.W. Randall, D.S. Ertl, T.K. Iragavarapu, and P.R. Carter. 2000. Environmental ramifications and production implications of growing low phytate corn. In 1999 Corn and Soybean Research Conf., Chicago, IL, 8-10 Dec., 1999. Am. Seed Trade Assoc., Washington, DC.

Schmitt, M.A., and G.W. Randall. 2000. Growing low-phytate corn. In Crop Pest Management Short Course Proceedings. 5 pgs. St. Paul, MN. 22-23 Nov. 1999. Univ. Minn. Ext. Serv., IPM, St. Paul, MN.

Appendix A. Tables.

Table 1. Soil test P measured using the Bray test.

Manure History	Location: Rosemount	Waseca	Lawler
	- - - - - - - - - ppm - - - - - - - -		
None	30	5	31
Low	48	12	54
High	74	25	71

Table 2. Effects of the low phytate (LP) characteristic for Hybrid B and manure history on corn grain yield at three Minnesota locations in 2000.

Manure History	Genetics: Standard	Low-Phytate	Average
	- - - - - - - - bu/acre- - - - - - - -		
None	147.9	129.0	138.4
Low	155.0	136.3	145.7
High	162.1	142.6	152.3
Average	155.0	136.0	

Table 3. Effect of corn genetics and manure history on grain yield, grain percent P, stover yield, stover percent P, and total P removal, Rosemount, 2000.

	Manure History	Genetics				
		Hybrid B	B -- LP	Hybrid A	A -- LP	Average
Grain Yield		- - - - - - - - - - - -bu/acre- - - - - - - - - - - -				
	None	162.1	139.8	161.7	130.4	149.1
	Low	169.4	144.0	161.2	155.1	156.5
	High	157.4	145.9	176.4	155.3	158.8
	Average	162.4	143.2	166.7	147.3	
Grain P		- - - - - - - - - - - - -%- - - - - - - - - - - -				
	None	0.271	0.263	0.265	0.278	0.269
	Low	0.272	0.271	0.283	0.275	0.275
	High	0.274	0.291	0.286	0.280	0.283
	Average	0.272	0.275	0.278	0.278	
Stover Yield		- - - - - - - - - -tons DM/acre- - - - - - - - - -				
	None	2.96	2.56	2.63	2.79	2.74
	Low	3.27	2.64	3.23	3.00	3.04
	High	2.85	2.81	2.89	3.53	3.02
	Average	3.03	2.68	2.92	3.14	
Stover P		- - - - - - - - - - - - - - -%- - - - - - - - - - - - -				
	None	0.064	0.077	0.052	0.059	0.063
	Low	0.072	0.075	0.054	0.066	0.067
	High	0.083	0.101	0.064	0.082	0.083
	Average	0.073	0.084	0.057	0.069	
Total P Removal		- - - - - - - - - -lbs P/acre-- - - - - - - - -				
	None	26.4	22.5	25.9	24.3	24.90
	Low	24.6	21.4	23.0	20.1	22.26
	High	25.1	25.9	27.6	26.4	26.2
	Average	25.5	23.3	25.6	23.9	

Table 4. Effect of corn genetics and manure history on grain yield, grain percent P, stover yield, stover percent P, and total P removal, Waseca, 2000.

	Manure History	Genetics: Hybrid B	B -- LP	Average
Grain Yield		--------bu/acre--------		
	None	117.1	110.8	114.0
	Low	138.2	133.5	135.9
	High	151.8	143.7	147.8
	Average	133.8	127.5	
Grain P		-----------%-----------		
	None	0.171	0.148	0.159
	Low	0.241	0.219	0.230
	High	0.255	0.258	0.256
	Average	0.217	0.202	
Stover Yield		--------tons DM/acre--------		
	None	2.16	1.98	2.07
	Low	2.40	2.54	2.47
	High	2.69	2.52	2.61
	Average	2.39	2.31	
Stover P		-----------%-----------		
	None	0.035	0.038	0.036
	Low	0.057	0.059	0.058
	High	0.080	0.074	0.077
	Average	0.055	0.055	
Total P Removal		-------lbs P/acre-------		
	None	11.6	9.3	10.5
	Low	18.6	17.3	18.0
	High	22.8	21.3	22.0
	Average	17.1	15.3	

Table 5. Effect of corn genetics and manure history on grain yield, grain percent P, stover yield, stover percent P, and total P removal, Rochester, 2000.

	Manure History	Genetics: Hybrid B	B -- LP	Average
Grain Yield		--------- -bu/acre- ---------		
	None	164.4	136.4	150.4
	Low	157.4	131.5	144.5
	High	177.0	138.2	157.6
	Average	166.3	135.4	
Grain P		----------- -%- -----------		
	None	0.221	0.190	0.205
	Low	0.245	0.233	0.239
	High	0.244	0.280	0.262
	Average	0.236	0.234	
Stover Yield		--------- -tons DM/acre- ---------		
	None	2.64	2.19	2.42
	Low	2.62	2.03	2.32
	High	2.97	2.38	2.67
	Average	2.74	2.20	
Stover P		----------- -%- -----------		
	None	0.069	0.068	0.069
	Low	0.094	0.094	0.094
	High	0.097	0.103	0.100
	Average	0.087	0.088	
Total P Removal		-------- -lbs P/acre- --------		
	None	21.0	15.4	18.2
	Low	23.2	18.4	20.8
	High	26.1	23.2	24.6
	Average	23.4	19.0	

Table 6. Statistical significance of various corn characteristics as affected by manure history, P fertilizer rate (at Rosemount site only), and phytate content at three locations, 2000.

	Grain Yield	Grain P	Stover Yield	Stover P	Total P Removal
	------------	------	Pr.>F	------	------------
Rosemount					
Soil Test P (STP)	0.0001	0.0942	0.0187	0.0001	0.0001
Fertilizer P (FP)	0.9679	0.3363	0.6848	0.0552	0.2028
STP x FP	0.3478	0.0880	0.1751	0.0019	0.0001
Phytate Trait (PT)	0.0001	0.8211	0.0015	0.0001	0.0002
PT x FP	0.0833	0.7972	0.6619	0.2918	0.3414
PT x STP	0.0002	0.6377	0.0138	0.2591	0.0138
PT x STP x FP	0.0266	0.1085	0.2158	0.7260	0.0079
Waseca					
Soil Test P (STP)	0.0276	0.0008	0.0075	0.0005	0.0012
Phytate Trait (PT)	0.4897	0.0969	0.3915	0.9676	0.0726
STP x PT	0.5053	0.3852	0.2478	0.5720	0.9062
Rochester					
Soil Test P (STP)	0.0202	0.2980	0.0282	0.0175	0.0010
Phytate Trait (PT)	0.0001	0.8953	0.0001	0.8495	0.0013
STP x PT	0.2738	0.2209	0.7947	0.9224	0.5874