

Enhanced Efficiency Phosphorus Application for a Corn-Soybean Rotation

Investigators:

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Objectives and Relevance:

Phosphorus (P) is an essential plant nutrient that is taken up by plants as inorganic ions (H_2PO_4^- and HPO_4^{2-}) found in soil solution. Phosphorus in plants is an important structural element in nucleic acids (RNA and DNA), serves as an energy transfer element (ATP), and has a critical role in cellular regulation, and carbon partitioning. Soluble forms of P or P bound to clay particles can be lost from agricultural land through runoff and surface erosion. Unless the soil is coarse-textured, has a shallow depth to bedrock, has preferential flow paths, has high initial soil test P, or artificial drainage is present, the potential for P leaching is generally considered very low. Soil P sorption reactions (i.e., adsorption and precipitation) reduce plant available P in the soil solution and the relative capacity of a soil for P sorption is dependent on such soil properties as the type and proportion of clay in the soil, the soil pH, and the amount of soil organic matter (Pierzynski et al., 2005)

With high fertilizer costs, farmers are evaluating application rates and considering enhanced efficiency P applications or treatments. This project was expanded to include additional P-enhancing products. AVAIL[®] (Specialty Fertilizer Products, Leawood, KS), NutriLife MAX[®] (Advanced Microbial Solutions, Pilot Point, TX), and P₂O₅ Max[®] (P-Max, Rosen's Inc., Fairmont, MN) are three new products that may enhance the efficiency of P-based fertilizers. AVAIL is a P enhancing product for granular phosphate fertilizers including DAP, MAP, and other phosphate fertilizers. It was designed to reduce the impact of metals in the soil around the fertilizer granule on plant uptake, and P sorption, and allow P to be more available to the plant. This product primarily binds with calcium, iron, manganese, and aluminum to prevent precipitation of P. When applied to single crops, Blevins (2009) reported a 19 to 22 bu/acre increase in corn grain yields when AVAIL was added to MAP at 20 lbs P₂O₅/acre and applied as a broadcast or banded treatment. Dunn (2009) reported increased Bray-P1 soil test P availability and a 4 bu/acre yield increase in soybean yield after applying 50 lbs P₂O₅/acre with AVAIL. Similarly, rice yields increased 8 bu/acre when reduced rates of triple super phosphate were applied (25 lbs P₂O₅/acre) with AVAIL. P-Max increases P uptake and improves root surface area resulting in better nutrient absorption and higher yields (Rosen's Diversified Inc, 2010). NutriLife MAX improves fertilizer uptake, thus contributing to overall plant vigor and quality (Advanced Microbial Solutions, 2005). In addition, banded applications of P may also increase P efficiency (Minor et al., 1993). Phosphate placement in the rooting zone of moist soil was suggested to improve efficiency if farmers desired to apply reduced rates. Strip-till applications may also limit P loss if soil particles were eroded into surface waters.

The objectives of this research were to:

1. evaluate the effect of P placement, rate, and P enhanced efficiency products on grain yield and P uptake in a corn-soybean rotation, and
2. determine the effect of P source, P enhancer, and ag lime on grain yield and P uptake in a corn-soybean rotation.

Procedures:

General. A two-year rotational crop study utilizing P fertilizer applications for corn was initiated in 2010, and will evaluate the subsequent impact on soybean yield and/or uptake. Research trials were established at the Greenley Memorial Research Center near Novelty, Delta Center near Portageville, and Hundley-Whaley Center near Albany. Each site was arranged as a randomized complete block design with four replications. Soils were initially characterized for soil organic C, pH (0.01 M CaCl₂), and exchangeable K, Ca and Mg at each site (data not presented). Soil test P (Bray P1) concentrations were determined prior to application from each replication at each site. Soil test P will be determined following soybean harvest for each treatment. Grain yields were determined and grain collected (Novelty and Albany) to evaluate for starch, protein, and oil concentration (Foss Infratec, Eden Prairie, MN). Grain moisture was adjusted to 15% prior to analysis. All data were subjected to analysis of variance and means separated using Fisher's Protected LSD ($P = 0.05$). Data were combined over factors and locations when appropriate as indicated by the analysis of variance (data not presented).

P placement, rate, and enhancer. Sites to accomplish objective 1 included Novelty and Albany. Treatments included a factorial arrangement of application placement (i.e., surface broadcast of strip-till), MAP rate (0, half the recommended rate, and recommended rate), and the presence and absence of two enhanced phosphorus efficiency products [AVAIL[®] (Specialty Fertilizer Products, Leawood, KS) at 0.5 gal/ton and P₂O₅ Max[®] (P-Max, Rosen's Inc., Fairmont, MN) at 1 gal/ton]. Plots were 10 to 15 by 70 ft. Phosphorus treatments were deep banded using a Yetter[®] 2984 strip-till system equipped with high residue Maverick[®] units (Yetter Manufacturing, Inc., Colchester, IL) with a rolling basket and dry fertilizer application tubes at the Novelty site. Phosphorus treatments were deep banded using a Yetter[®] 2984 strip-till system equipped with residue manager wheels (Yetter Manufacturing, Inc., Colchester, IL), B-33 mole knife, and opposing closing wheel disks at the Albany site. A Gandy Orbit Air (Gandy Company, Owatonna, MN) fertilizer applicator was used to deliver fertilizer behind the applicator knife in the strip till system. Phosphorus was broadcast applied with a hand spreader. Ammonium nitrate fertilizer was broadcast applied for the appropriate treatments to balance the N contribution of MAP as the rate was reduced. The planter was equipped with Shark-tooth[®] (Yetter Manufacturing, Inc., Colchester, IL) residue cleaners used in tandem with a no-till coulters. The residue cleaners performed well in heavy residue of the no-till plots and provided a smooth seedbed above strip-tilled plots. Management information is available in Table 1. Tissue and grain samples were collected to determine crop P uptake due to the effects of the treatments at both locations and are currently being analyzed by the University of Missouri Soil and Plant Testing Laboratory.

P source, P enhancer, and ag lime. Research to accomplish objective 2 was conducted at Novelty and Portageville. Treatments include a factorial arrangement of a P source [non-treated

control and a broadcast application of DAP (diammonium phosphate) or TSP (triple superphosphate), presence or absence of the phosphorus efficiency products [AVAIL[®] (Specialty Fertilizer Products, Leawood, KS) at 0.5 gal/ton, NutriLife MAX[®] at the Novelty location only (Advanced Microbial Solutions, Pilot Point, TX) at 1 gal/ton, and P₂O₅ Max[®] (P-Max, Rosen's Inc., Fairmont, MN) at 1 gal/ton], and broadcast surface application of ag lime (0 and recommended rate). Plots were 10 by 40 ft. The Novelty site was no-till and rain fed, while the Portageville was conventional tillage with furrow irrigation. Management information is available in Table 2. Tissue (Novelty and Portageville) and grain (Novelty) samples were collected to determine crop P uptake and are currently being analyzed by the University of Missouri Soil and Plant Testing Laboratory.

Results:

P placement, rate, and enhancer. Corn was planted early at Novelty and replanted due to a poor overall stand at Albany. Harvested plant population was 9,400 plants/acre greater with strip-till than no-till at Novelty, while there was no difference among tillage systems at Albany (Table 3). Tillage system had no effect on silage dry weight. Grain moisture was slightly greater (0.5 %) with no-till corn at both locations, but test weight was 0.3 lbs/bu greater with strip-till at Novelty. There was no effect of P enhancer or rate on plant population, silage dry weight, grain moisture, test weight at Novelty, or grain yield (Table 4). However, there was an interaction between P placement and enhancer (Figure 1). There was no effect of P enhancer on grain yield when broadcast applied in a no-till system, but AVAIL increased yield 8 bu/acre when applied in a strip-tilled band compared to P without an enhancer.

P source, P enhancer, and ag lime. AVAIL and P-Max P enhancers were evaluated at Portageville, and AVAIL, P-Max, and NutriLife MAX were evaluated at Novelty in 2010. Phosphorus enhancer had no effect on plant population, test weight at Novelty, moisture at Novelty, or grain yield (Table 5). Silage yields were greater at Novelty than Portageville. At Novelty, AVAIL increased silage yield 1.2 tons/acre when compared to the absence of a P enhancer. Silage yields were ranked non-treated control = AVAIL ≥ P-Max at Portageville. NutriLife MAX was added at the Novelty location, but there was no significant difference ($P = 0.91$) between P enhancer treatments and the non-treated control (Figure 2).

Lime was applied at 3.6 and 2 ton/acre at Novelty and Portageville, respectively. Both sites were corn following corn, and the harvested plant population was approximately 20,000 plants/acre (Table 6). Plant population was similar among P sources in the absence of lime, but was 2,600 and 3,200 plants/acre lower where TSP and DAP were applied, respectively. There was no effect of P source and lime application on silage yield at Novelty or Portageville, and there was no effect of P source or lime on test weight or moisture at Novelty. Grain yields were 7 bu/acre greater with TSP compared to DAP. Ammonium nitrate was added to TSP to balance the N present in DAP. This readily available N source with TSP may have contributed to the yield differences between the P sources. The recommended lime rate increased silage yields 1.1 tons/acre at Novelty, but grain yields were similar between lime treatments. However, recommended lime had no effect on silage yields at Portageville, but grain yields increased 11 bu/acre compared to the non-treated control.

Summary:

- Strip-till increased plant population 9,400 plants/acre and test weight 0.3 lbs/bu compared to no-till at Novelty.
- AVAIL increased corn grain yield 8 bu/acre when applied with P in a strip-till band at Novelty and Albany.
- There was no effect of P enhancer on grain yield when broadcast applied in a no-till system at Novelty and Albany. Similarly, there was no difference in grain yield among P enhancers at Novelty and Portageville.
- Grain yields were 7 bu/acre greater with TSP compared to DAP.
- Lime increase silage yields 1.1 tons/acre when compared to the non-treated control at Novelty, but grain yields were similar among lime treatments. However, lime had no effect on silage yields at Portageville, but grain yields increased 11 bu/acre.
- The corn plots will rotate into soybean and another location will be identified to repeat this research in 2011.

Timetable:***2011***

March	Soil sampling
April	Corn planting for the 2011/2012 trials
April/May	Soybean planting in 2010 trial
July	Tissue sampling
September	Harvest and grain sample P for corn and soybean
Oct/Nov	Soil sample from all treatments following soybean harvest
December	Submission of annual report

2012

March	Soil sampling
April/May	Soybean planting in 2011 trial
July	Tissue sampling
September	Harvest and grain sample P for soybean
Oct/Nov	Soil sample from all treatments following soybean harvest
December	Submission of final report

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Table 1. Field and management information for the P placement, rate, and enhancer experiment at Novelty and Albany in 2010.

Management information	Novelty	Albany
	Corn 2010 [†]	Corn 2010
Previous crop	soybean	oybean
Plot size	10 by 75 ft	15 by 75 ft
Hybrid or cultivar	DK 62-54	DK 63-84
Planting date	14 Apr.	30 May
Seeding rate	30,000 seeds/acre	30,000 seeds/acre
Tissue harvest date	7 Sep.	9 Sep.
Harvest date	30 Oct.	15 Oct.
Fertilizer		
P application (date & 1x rate)	13 Apr. 100 lbs P ₂ O ₅ /acre	15 Apr., 100 lbs P ₂ O ₅ /acre
Additional fertilizer (date, source, & rate)	6 May, Urea (180 lbs N/acre) + Agrotain (1 gal/ton)	19 Apr., urea (150 lbs N/acre) + Agrotain (1 gal/ton)
Weed management		
Burndown	NA	NA
Preemergence	16 Apr., Lumax (3 qt/acre) + Banvel (1 pt/acre)	15 Apr., Lumax (3.2 qt/acre); 30 May, Balance Pro (4 oz/acre)
Postemergence	22 June, Roundup PowerMAX (30 oz/acre) + AMS (17 lbs/100 gal)	21 June, Roundup PowerMAX (24 oz/acre)
Insect management	16 Apr., Warrior (1.5 oz/acre)	NA
Disease management	NA	NA

[†]Abbreviations: NA, None applied.

Table 2. Field and management information for the P source, P enhancer, and ag lime experiment at Novelty and Portageville in 2010.

Management information	Novelty	Portageville
	Corn 2010 [†]	Corn 2010
Previous crop	Corn	Corn
Plot size	10 by 45 ft	10 by 45 ft
Hybrid or cultivar	DK 61-69 VT3	Croplan Genetics 68-31
Planting date	26 May	7 Apr.
Seeding rate	30,000 seeds/acre	30,000 seeds/acre
Tissue harvest date	7 Sep.	16 Aug.
Harvest date	1 Oct.	8-9 Sep.
Fertilizer		
P application (date & rate)	27 Apr. 105 lbs P ₂ O ₅ /acre	6 Apr. 50 lbs P ₂ O ₅ /acre
Lime application (date & rate)	1 Apr., 3.6 ton/acre	1 Apr., 2 ton/acre
Additional fertilizer (date, source, & rate)	12 Apr., Anhydrous ammonia (235 lbs N/acre)	7 Apr., Urea (50 lbs N/acre) + Agrotain (1 gal/ton)
Sidedress N	11 June, 32% UAN (150 lbs N/acre)	5 May, Urea (150 lbs N/acre) + Agrotain (1 gal/ton)
Weed management		
Burndown	21 Apr. Roundup PowerMAX (15 oz/acre)	5 Apr., Cornerstone 32 oz/acre
Preemergence	21 Apr., Bicep II Magnum (1.65 qt/acre)	9 Apr., Bicep II Magnum (1.5 qt/acre) + Atrazine (2 qt/acre)
Postemergence	22 June, Roundup PowerMAX (22 oz/acre)	8 May, Atrazine (1 qt/acre) + Glyphosate (32 oz/acre)
Insect management	NA	NA
Disease management	NA	NA

[†]Abbreviations: NA, None applied.

Table 3. The effect of P placement on harvested corn population, silage dry weight, grain moisture, and test weight at Novelty and Albany in 2010. Data were combined over P enhancer, rate, and location unless otherwise denoted below.

P placement	Population		Silage dry weight	Grain moisture	Test weight [†]
	Novelty	Albany			
	----- no./acre -----		lbs/acre	%	lbs/bu
No-till broadcasted	18,000	19,000	12,100	16.8	55.1
Strip-till banded	27,400	21,900	11,700	16.3	55.4
LSD [‡] (<i>P</i> = 0.05)	----- 2,400 -----		-- NS --	0.3	0.1

[†]Novelty location only.

[‡]Abbreviations: LSD, least significant difference; NS, non-significant.

Table 4. The effect of P rate and enhancer on harvested corn population, silage dry weight, grain moisture, test weight, and yield at Novelty and Albany in 2010. Data were combined over P placement and location.

P enhancer	Rate	Population	Silage dry weight	Grain moisture	Test weight [†]	Yield
	lbs P ₂ O ₅ /acre	no./acre	lbs/acre	%	lbs/bu	bu/acre
None	0	21,700	12,200	16.6	55.3	100
	50	23,200	11,800	16.9	55.3	94
	100	21,800	12,200	16.7	55.3	98
AVAIL	0	21,200	12,900	16.5	55.3	100
	50	20,400	10,900	16.7	55.3	98
	100	20,900	11,600	16.7	55.3	98
P-Max	0	21,400	12,800	16.6	55.3	103
	50	21,200	11,600	16.3	55.3	94
	100	21,400	11,400	16.3	55.4	96
LSD (<i>P</i> = 0.1)		-- NS --	-- NS --	-- NS --	-- NS --	-- NS --

[†]Novelty location only.

Table 5. The effect of P enhancer on harvested population, silage dry weight, test weight, moisture, and grain yield at Novelty and Portageville in 2010. Data were combined over lime treatment and location when appropriate.

P enhancer	Population	Silage dry weight		Test weight [†]	Moisture [†]	Yield
		Novelty	Portageville			
	no./acre	-----	lbs/acre -----	lbs/bu	%	bu/acre
Non-treated	19,600	15,100	14,000	51.1	26.4	135
AVAIL	20,400	17,500	13,000	51.2	25.8	135
P-Max	19,100	15,400	12,700	51.2	25.7	136
LSD (<i>P</i> = 0.1)	-- NS --	-----	1,100 -----	-- NS --	-- NS --	-- NS --

[†]Novelty location only.

Table 6. The effect of P source and lime application on harvested plant population, silage dry weight, and grain yield at Novelty and Portageville in 2010. Data were combined over P enhancer, location, and lime treatment when appropriate.

P source [†]	Harvested population		Silage dry weight		Test weight [‡] lbs/bu	Moisture [‡] %	Yield bu/acre
	----- Lime -----		----- Lime -----				
	None	Recommended	None	Recommended			
	----- no./acre -----		----- lbs/acre -----				
Non-treated	19,600	21,900	13,400	15,700	51.1	26.2	132
TSP	20,400	19,300	15,200	14,800	51.2	25.8	139
DAP	19,400	18,700	13,500	15,000	51.1	26.0	135
LSD (<i>P</i> = 0.1)	----- 1,300 -----		----- NS -----		-- NS --	-- NS --	6

[†]Abbreviations: DAP, diammonium phosphate; LSD = least significant difference; NS = non-significant; TSP, triple super phosphate.

[‡]Novelty location only.

Table 7. The effect of lime on silage and grain yields at Novelty and Portageville in 2010. Data were combined over P source and enhancer.

Lime application	Silage yield		Grain yield	
	Novelty	Portageville	Novelty	Portageville
	----- lbs/acre -----		----- bu/acre -----	
Non-treated	14,900	13,100	160	105
Recommended	17,100	13,200	159	116
LSD (<i>P</i> = 0.1)	----- 900 -----		----- 5 -----	

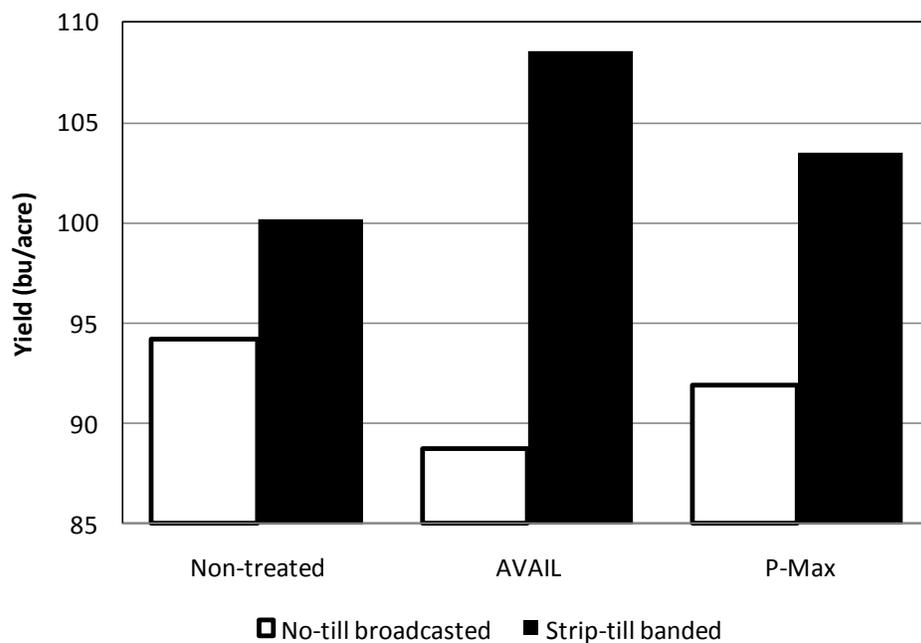


Figure 1. The effect of P placement (no-till surface broadcasted and strip-till banded) and enhancer (non-treated control, AVAIL, and P-Max) on grain yield at Novelty and Albany in 2010. LSD ($P = 0.1$) was 8 bu/acre.

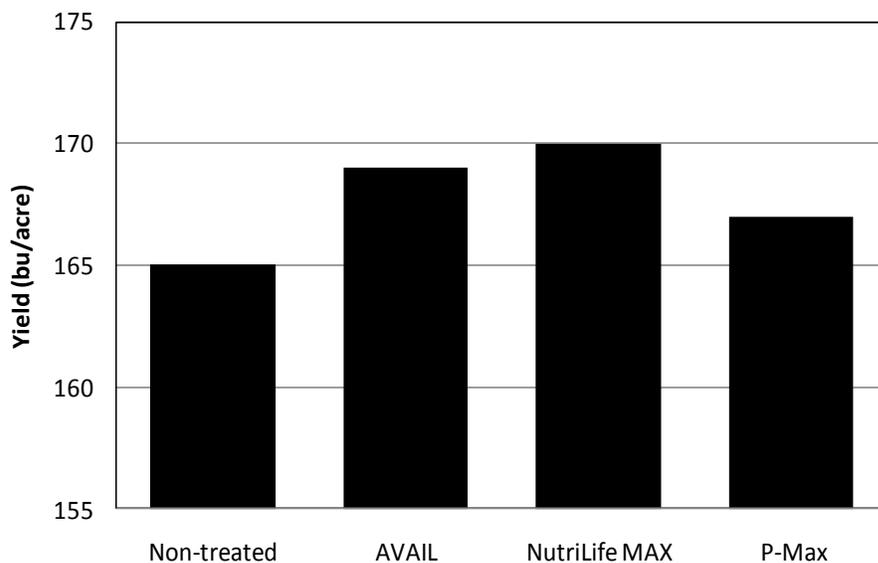


Figure 2. Corn grain yield response to P enhancers at Novelty in 2010. There was no significant ($P = 0.91$) yield difference among treatments. Data were averaged over lime treatments and P sources.

Budget:

CATEGORIES	Year 2011	Year 2012	Total*
A. Salaries			
Technical assistance or graduate research assistant (50%)	\$14,382	\$14,670	\$42,875
B. Fringe Benefits			
Fringe for graduate student	\$1,995	\$2,095	\$6,080
TOTAL SALARIES AND FRINGE BENEFITS	\$16,377	\$16,765	\$48,955
C. Travel			
Travel to field site	\$0	\$0	\$0
To present research findings at National Meetings	\$0	\$1000	\$1000
TOTAL TRAVEL COSTS	\$0	\$1000	\$1000
D. Equipment	\$0	\$0	\$0
TOTAL EQUIPMENT use and maintenance COSTS	\$0	\$0	\$0
E. Other Direct Costs			
Soil analysis	\$1680	\$1020	\$4080
Grain analysis	\$2560	\$2560	\$7680
Tissue analysis	\$2560	\$2560	\$7680
Field supplies	\$500	\$500	\$1500
Publication cost	\$0	\$500	\$500
Off-site PI's (2)	\$6,000	\$6,000	\$18,000
TOTAL OTHER DIRECT COSTS	\$13,300	\$13,140	\$39,440
TOTAL REQUEST	\$29,677	\$30,905	\$89,395

*Included the 2010 (Year 1) budget.

Budget narrative:

Salaries and fringe benefits: Funds are requested for partial support of a research technical support and/or graduate research assistant.

Presentations, publications, and documentation: This will help defray cost of publication and documentation of results and conclusions as well as assist travel and board for presentation of results

Other Direct Costs: Covers cost of analysis, sample containers, fertilizer, seed, plot preparation, planting, weed control harvesting, flags, and other field supplies and operations.