EFFECTS OF PHOSPHORUS FERTILIZER RATE, TIMING, AND ADDITION OF FERTILIZER ENHANCER ON POTATO YIELD AND QUALITY

Matthew J. Repking and Carrie A.M. Laboski
University of Wisconsin-Madison, Madison, Wisconsin

Introduction

Potato plants are very inefficient in their ability to utilize soil phosphorus (P) on some soils (Kelling et al., 1997). The optimum soil test P category for potato is more than three times greater than for other crops (Laboski et al., 2006). Being a high value crop, potato growers generally tend to apply more P fertilizer than recommended because it is inexpensive insurance if a yield response to applied P would occur. State nutrient management regulation requires growers to write and follow a nutrient management plan. This regulation also requires that nutrient application rates should conform to University of Wisconsin Extension (UWEX) guidelines. The potato growers feel that UWEX fertilizer recommendations for P are too low and could potentially reduce potato yield and quality.

Avail® is a relatively new fertilizer product that claims to improve P availability in the soil when coated on dry or mixed with liquid fertilizers. Avail® has a high cation exchange capacity and it is hypothesized that calcium, iron and aluminum bind to Avail® instead of P, thus allowing P to potentially be more available to plants (Murphy, 2005). Avail® coated MAP was shown to have some benefit for potato production in the calcareous soils of Idaho (Hopkins et al., 2005).

The objective of the study was to evaluate the effect of P rate and timing and use of Avail® on potato yield and quality.

Materials and Methods

In 2006, research was conducted at six locations: Hancock and Spooner Ag Research Stations (H and S), three grower fields (CF, WS, TW), and the Antigo Airport (A). In 2007, research was conducted at five locations: Hancock and Spooner Ag Research Stations (H and S) and three grower fields (WS, TW1, TW2). Soil samples were collected prior to planting at 0 to 15 and 15 to 30 cm in each plot and analyzed for Bray1-P. Soil samples were also taken to 15 cm in each plot and composited within the replications. These samples were analyzed for P, K, Ca, Mg, pH, and organic matter (Table 1).

Potatoes were planted on 13, 27, 28 April and 3, 22, 23 May at H, CF, WS, S, A, and TW locations, respectively in 2006. In 2007, potatoes were planted on 27, 30 April and 4, 23, 23 May at H, WS, S, TW1, and TW2 locations, respectively. Russet Burbank potatoes were planted at H, CF, WS and S, using cut seed. Frito Lay 1867 was planted at A, TW, TW1, and TW2 locations using B size seed. At all locations except CF, TW1, and TW2 potatoes were planted in 0.90 m rows with seed pieces being spaced approximately 0.31 m apart. At CF, potatoes were planted in 0.75 m rows with seed pieces being spaced approximately 0.31 m apart. At TW1 and TW2 locations, potatoes were planted in 0.90 m rows with seeds pieces being spaced 0.23 m apart. Plot sizes were four rows wide and 5.29 meters long in 2006 and 2007 at all locations, except TW1 and TW2, which were six rows wide. Treatments are provided in Table 2. At planting, furrows were left open so that treatments could be applied; after treatments were applied the furrows were closed. The experimental design was randomized complete block with four replications.

All non-fertility cultural practices, including irrigation, were based on standard potato production practices. All potassium fertilizer was broadcast at planting as 0-0-60 at a rate of 112, 291, 67, 112, 246, and 67 kg K_2O ha^{-1} for H, CF, WS, A, S, and TW locations, respectively in 2006. In 2007, 0-0-60 was broadcast at planting at a rate of 112 kg K_2O ha^{-1} at all locations. In 2006, the total amount of nitrogen fertilizer applied (preplant and in season) at H, CF, WS, A, S, and TW locations was 263, 233, 271, 84, 188, and 114 kg N ha^{-1}. Nitrogen and potassium fertilizer rates varied by location based on soil test level and grower practices.

In 2006 at location H, the second application of nitrogen at tuberization never occurred. Potatoes looked deficient on 12 July and additional applications of ammonium nitrate were applied on 17 and 24 July at a rate of 56 kg ha^{-1} on both dates (these amounts are included in the total above). Early blight had already set in and these additional applications failed to revive the crop. Vines had senesced by 7 August and tubers failed to bulk properly.

Potatoes were harvested on 19, 26, 26 September and 2, 4, 6 October for S, A, TW, WS, CF, and H locations, respectively in 2006. Harvest dates for 2007 were 18, 20, 20 September and 8 October for WS, TW1, TW2, and H locations, respectively. All potatoes were graded and specific gravity measured at Hancock ARS with the exception of the potatoes at location S which were graded at Spooner ARS.

Results and Discussion

The results presented below represent the 2006 season and location S for 2007; tuber grading for all other 2007 locations has not yet occurred. For locations H, CF, WS, A, and TW the tuber classes analyzed were culls, B size, A size, US No. 1 and total tuber yield. The definition of individual tuber classes were: culls are misshaped or diseased, B size is less than 4.76 cm diameter, US No.1 are 170 to 369 gram tubers, and A size is calculated by subtracting B size and culls from total yield. At location S the grading system does not allow for US No.1 tubers to be graded out.

The most desirable size class for Russet Burbank is US No.1, followed by A size tubers in general. At locations, H and CF there was no significant (p<0.05) difference between treatments with regard to total yield, A size, and, US No. 1 tubers (Table 3). There was a significant difference between treatments for cull tubers at these locations where the smallest amount of culls were obtained with 146 and 73 kg P_2O_5 ha^{-1} as TSP at locations H and CF, respectively. There was a significant difference between treatments for B size tubers at location H where the largest amount of B size tubers was obtained with 73 kg P_2O_5 ha^{-1} as TSP. At location CF there was no significant difference between treatments for B size tubers. At location WS there was no significant difference between treatments with regard to total, US No. 1, culls, B size, and A size tuber yield. At location S in 2006, there was a significant difference between treatments with regard to A size and total tuber yield. The largest yield for both A size and total tuber yield was 146 kg P_2O_5 ha^{-1} as MAP+Avail. There was no significant difference between treatments for cull and B size tuber yield. In 2007, there was a significant difference between treatments with regard to cull tuber yield with 218 kg P_2O_5 ha^{-1} as MAP+Avail having the least amount of culls. There was no significant difference between treatments with regard to B size, A size, and total tuber yield in 2007. At locations A and TW, tubers are primarily grown for seed production and B size tubers are highly desirable. At location A, there was no significant difference (p>0.05) between treatments for total, US No. 1, and cull tuber yield (Table 3). B size tuber yield was maximized with 73 kg P_2O_5 ha^{-1} as TSP sidedress. However, 146 kg P_2O_5 ha^{-1} as TSP starter and 73 kg P_2O_5 ha^{-1} as MAP+Avail produced yields not significantly different than the sidedress treatment. A size tuber yield was maximized by 73 kg P_2O_5 ha^{-1} MAP+Avail. At TW, there was no significant difference between treatments (Table 3).

Specific gravity, a measure of tuber quality, was only significantly affected by P application at location H where 73 kg P_2O_5 ha^{-1} as MAP+Avail had the greatest specific gravity. It should be noted that this significance may be a result of tubers failing to bulk prior to vine senescence.

The effect of time of application on yield was assessed with specific contrasts of 73 kg P_2O_5 ha^{-1} applied as starter or at sidedress. Sidedress P applications significantly increased culls at location CF and decreased US No. 1 tubers at location A, when compared to starter P. Otherwise there was no significant difference between time of P application on total, US No. 1, cull, B size and A size tuber yields at H, CF, WS, A, and TW locations.

The effect of Avail® on yield was assessed with specific contrasts of 73 kg P_2O_5 ha^{-1} applied as MAP+Avail or as TSP. The MAP+Avail significantly increased cull tuber yield at location CF and increased A size tubers at location A, when compared to TSP. Otherwise, there was no significant difference between MAP+Avail and TSP on total, US No. 1, cull, B size, and A size tuber yields at H, CF, WS, A, and TW locations. MAP+Avail did have the highest total yield at four of the five locations, with an increase of 5.7, 8.8, 5.3, and 2.3 Mg ha^{-1} at H, CF, WS, and A, respectively. In 2006, at location S, the effect of MAP+Avail on yield was assessed with specific contrasts by comparing 146 and 218 kg P_2O_5 ha^{-1} applied as TSP to 146 and 218 kg P_2O_5 ha^{-1} applied as MAP+Avail. MAP+Avail had a greater total and A size tuber yield compared to TSP. There was no significant difference for B size and cull tuber yield. In 2007, the same specific contrasts was made by comparing 73, 146, and 218 kg P_2O_5 ha^{-1} applied as MAP with 73, 146, and 218 kg P_2O_5 ha^{-1} applied as MAP+Avail. There was no significant difference between MAP+Avail and MAP for cull, B size, A size and total tuber yield in 2007. Through not significant the following observations were made. The MAP+Avail treatments at locations WS, A, TW, and S in 2006 and 2007 had a lower yield of cull tubers when compared to similar rates of starter at these locations. The A sized tuber yield of MAP+Avail was greatest when compared to similar rates of TSP at all locations in 2006.

The effect of rate of P in starter fertilizer on yield was assessed with a general linear model with means separation using Fisher's protected LSD for rates of TSP applied as starter. At locations H, CF, WS, A, and TW there was no significant difference between P rates with regard to culls, B size, A size, US No. 1, and total tuber yield. At location CF, there was a significant difference between rates for culls. The 0 kg P_2O_5 ha^{-1} TSP had the greatest of yield of cull tubers and 73 kg

P_2O_5 ha^{-1} TSP had the smallest yield of cull tubers at location CF for the treatments. In 2006, at location S, as P rate increased total yield increased and then plateaued at 146 kg P_2O_5 ha^{-1} total yield. There was no significant difference between treatments with regard to A size, B size, and cull tuber yield. In 2007, there was no significant response to P rate for any tuber category.

Generally there was no significant response to P fertilizer application for locations H, CF, WS, A, and TW suggesting our current fertilizer recommendations are more than adequate because 34 to 146 kg P_2O_5 ha^{-1} was recommended and no P fertilizer was needed. At location S in 2006, the recommendation was 174 kg P_2O_5 ha^{-1} and total yield plateaued at 146 kg P_2O_5 ha^{-1}, thus providing additional support for current fertilizer recommendations. At location H, the recommendation was 146 kg P_2O_5 ha^{-1} and there was no response, but the tubers failed to bulk which likely impacts the results. There was no response to P at location S in 2007, though the fertilizer recommendation was 280 kg P_2O_5 ha^{-1}.

Conclusions

These results provide support for the current UWEX fertilizer recommendations in that application of P fertilizer to soils testing high or excessively high did not result in increased potato yield or quality. For soils testing very low and low, the current UWEX fertilizer recommendations were correct at one of three sites and resulted in over application of P at two of three sites. Use of Avail® tended to increase tuber yield and specific gravity, although not always statistically significant. There was no significant benefit from applying the P at sidedress to make it more available to the plant later in the growing season.

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Table 1. Soil Characterization and initial soil test analysis.

Location	Soil Name†	Taxanomic name	P*	P fert. rec.‡	pH	OM
			mg kg^{-1}	kg P_2O_5 ha^{-1}		g kg^{-1}
2006						
H	Plainfield s	Mixed, mesic Typic Udipsamments	62 (L)	146	6.55	12.8
CF	Sparta ls	Sandy, mixed, mesic Entic Hapuldolls	246 (EH)	34	6.63	15.5
WS	Richford ls	Loamy, mixed superactive, mesic Arenic Hapludalfs	186 (EH)	34	5.98	10.8
A	Antigo sil	Coarse-loamy over sandy, mixed, superactive, frigid Haplic Glossudalfs	265 (H)	84	5.7	26.0
TW	Antigo sil	Coarse-loamy over sandy, mixed, superactive, frigid Haplic Glossudalfs	242 (H)	84	5.5	28.0
S	Mahtomedi ls	Mixed, frigid Typic Udipsamments	35 (VL)	174	6.4	20.0
2007						
H	Plainfield s	Mixed, mesic Typic Udipsamments	48 (VL)	174	6.82	14.0
WS	Coloma s	Mixed, mesic Lamellic Udipsamments	152 (H)	84	6.38	14.0
TW1	Antigo sil	Coarse-loamy over sandy, mixed, superactive, frigid Haplic Glossudalfs	140 (L)	213	5.03	31.0
TW2	Antigo sil	Coarse-loamy over sandy, mixed, superactive, frigid Haplic Glossudalfs	180 (O)	101	5.3	28.0
S	Cress sl	Sandy, mixed, frigid Humic Dystrudepts	90 (VL)	280	6.8	14.0

† ls, loamy sand; s, sand; sl, sandy loam; sil, silt loam.

* Soil test P level with interpretation category in parenthesis. L, low; O, optimum; H, high, EH, excessively High.

‡ P fertilizer recommendation is based on soil test P levels and interpretation categories in Laboski et at. (2006).

Table 2. Treatments for all locations in 2006 and 2007.

Treatment	P Source*	P Rate	P Timing†
		kg P_2O_5 ha^{-1}	
2006-All locations except S			
1	None	0	None
2	TSP	73	Starter
3	TSP	146	Starter
4	MAP+Avail	73	Starter
5	TSP	73	Sidedress
2006-S			
1	None	0	None
2	TSP	73	Starter
3	TSP	146	Starter
4	TSP	218	Starter
5	TSP	291	Starter
6	MAP+Avail	146	Starter
7	MAP+Avail	218	Starter
2007-All locations except S			
1	None	0	None
2	MAP	73	Starter
3	MAP	146	Starter
4	MAP+Avail	73	Starter
5	MAP+Avail	146	Starter
6	MAP	73	Sidedress
2007-S			
1	None	0	None
2	MAP	73	Starter
3	MAP	146	Starter
4	MAP	218	Starter
5	MAP+Avail	73	Starter
6	MAP+Avail	146	Starter
7	MAP+Avail	218	Starter

*TSP, triple super phosphate (0-46-0); MAP, monoammonium phosphate (11-52-0).

†Starter, fertilizer applied at planting approximately 5 cm to the side of the seed piece; Sidedress, fertilizer applied at first flower by cutting a 3cm deep furrow along the top side of the hill, applying the fertilizer and closing the furrow.

Table 3. Yield and specific gravity for locations H, CF, WS, A, and TW for 2006.

P Source†	P Rate**	Grade Cull	B size	A size	US No. 1	Total	S.G.§
	kg P_2O_5 ha^{-1}	----------Mg ha^{-1}----------					
Location H							
None	0	3.08 ab‡	8.94 c	39.41	13.92	51.43	1.075 b
TSP	73	2.73 bc	11.04 bc	35.76	9.07	49.52	1.075 b
TSP	146	1.84 c	11.73 ab	34.62	9.33	48.19	1.075 b
Avail +MAP	73	4.15 a	13.26 a	37.82	9.03	55.23	1.079 a
TSP	73s	3.20 ab	9.51 c	38.03	11.61	50.72	1.075 b
p		0.011	0.007	0.467	0.163	0.320	0.014
LSD (0.05)		1.11	2.18	n.s. *	n.s.	n.s.	0.0025
CV,%		24.21	13.01	10.56	28.91	24.21	0.153
Location CF							
None	0	8.49 a	3.47	55.80	31.35	67.75	1.074
TSP	73	1.72 b	2.88	65.61	38.65	70.21	1.079
TSP	146	5.44 ab	2.21	63.22	33.14	71.87	1.080
Avail +MAP	73	5.87 a	4.16	68.96	36.47	78.99	1.079
TSP	73s	8.29 a	3.31	55.27	32.57	66.88	1.077
p		0.016	0.194	0.068	0.493	0.215	0.763
LSD (0.05)		3.89	n.s.	n.s.	n.s.	n.s.	n.s.
CV,%		42.39	20.78	11.51	18.50	10.38	0.658
Location WS							
None	0	9.43	5.25	42.73	31.85	57.41	1.058
TSP	73	12.21	5.63	39.70	30.93	57.53	1.066
TSP	146	11.26	4.94	41.47	32.43	57.67	1.063
Avail +MAP	73	10.88	7.13	44.70	34.62	62.70	1.071
TSP	73s	9.14	7.29	45.86	35.55	62.29	1.053
p		0.139	0.800	0.647	0.563	0.812	0.115
LSD (0.05)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
CV,%		55.83	56.6	14.42	21.14	14.62	0.873
Location A							
None	0	3.85	0.74 bc	20.52 c	9.36	25.10	1.075
TSP	73	3.95	0.56 c	25.94 ab	12.42	30.45	1.073
TSP	146	6.69	0.94 ab	24.32 abc	10.23	31.95	1.080
Avail +MAP	73	2.99	0.98 ab	28.86 a	15.22	32.83	1.079
TSP	73s	3.98	1.12 a	21.57 bc	9.31	26.66	1.074
p		0.298	0.041	0.0257	0.065	0.104	0.655
LSD (0.05)		n.s.	0.36	5.12	n.s.	n.s.	n.s.
CV,%		55.55	27.10	13.73	25.69	14.67	0.711
Location TW							
None	0	2.03	2.70	45.14	18.64	49.87	1.073
TSP	73	4.19	3.21	46.01	18.56	53.42	1.070
TSP	146	2.45	2.67	46.06	16.71	51.19	1.071
Avail +MAP	73	2.67	3.67	45.87	17.19	52.20	1.074
TSP	73s	3.41	3.65	45.75	19.89	52.81	1.072
p		0.389	0.186	0.887	0.599	0.377	0.944
LSD (0.05)		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
CV,%		54.49	20.95	3.08	16.49	5.02	0.802

† TSP, triple superphosphate (0-46-0); MAP, monoammonium phosphate (11-52-0).
‡ Values within each column followed by the same letter are not significantly different at the 0.05 probability level.
* n.s., treatments within for a given location column are not significantly different at the 0.05 probability level.
**s, sidedress.
§S.G., specific gravity.

Table 4. Yield and specific gravity for location S for 2006 and 2007.

P Source†	P Rate	Grade Cull	B size	A size	Total
	kg P_2O_5 ha^{-1}	Mg ha^{-1}			
Location S 2006					
None	0	18.31	5.07	21.34 d‡	44.77 c
TSP	73	22.15	6.22	24.36 cd	52.73 b
TSP	146	20.69	7.23	28.93 abcd	56.81 ab
TSP	218	23.75	7.51	27.92 abcd	59.22 ab
TSP	291	18.17	5.01	33.32 abc	56.48 ab
MAP+Avail	146	20.24	5.55	37.58 a	63.36 a
MAP+Avail	218	19.27	6.61	36.26 ab	62.13 a
p		0.674	0.192	0.018	0.002
LSD (0.05)		n.s*	n.s	9.58	7.76
CV,%		24.44	25.34	21.53	9.24
Location S 2007					
None	0	8.31 a	4.72	30.09	43.12
MAP	73	8.69 a	4.13	32.63	45.44
MAP	146	8.54 a	4.52	30.85	43.09
MAP	218	5.13 b	4.87	35.82	45.18
MAP+Avail	73	7.31 ab	3.99	32.63	43.92
MAP+Avail	146	6.77 ab	4.43	31.52	42.72
MAP+Avail	218	4.67 b	5.43	34.12	44.21
p		0.044	0.689	0.703	0.936
LSD (0.05)		2.92	n.s	n.s	n.s
CV,%		27.83	26.19	15.20	9.57

† TSP, triple superphosphate (0-46-0); MAP, monoammonium phosphate (11-52-0).
‡ Values within each column followed by the same letter are not significantly different at the 0.05 probability level.
* n.s., treatments within a column for a given location are not significantly different at the 0.05 probability level.

PROCEEDINGS OF THE

THIRTY-SEVENTH NORTH CENTRAL EXTENSION-INDUSTRY SOIL FERTILITY CONFERENCE

Volume 23

November 14-15, 2007
Holiday Inn Airport
Des Moines, IA

Program Chair:

Greg Schwab
University of Kentucky
Lexington, KY
(859) 257-9780
gjschw2@uky.edu

Published by:

International Plant Nutrition Institute
772 – 22nd Avenue South
Brookings, SD 57006
(605) 692-6280
Web page: www.IPNI.net