Effects of phosphorus fertilizer rate, timing, and addition of fertilizer enhancer on potato yield and quality

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Abstract

This study was conducted to evaluate the effect of phosphorus (P) rate and timing and the use of Avail® on potato yield and quality. Treatments were applied as either starter fertilizer at rates of 73 and 146 kg P_2O_5 ha^{-1} with and without Avail® and as sidedress P applied at 73 kg P_2O_5 ha^{-1}. There were 11 locations in Wisconsin (7 coarse- and 4 fine-textured soils) in 2006 and 2007. Avail® was more influential on total yield than rate or timing for 2006. Avail® increased total tuber yield by 5.21 Mg ha^{-1} at 6 of 11 locations, although not always statistically significant. There was a significant response to P fertilizer at 1 location, in 2006. In 2007, total yields increased and plateaued, as P fertilizer rate increased. Seven locations had a non significant yield increase when 73 kg P_2O_5 ha^{-1} was applied. There was no significant benefit to applying P at sidedress. Specific gravity, a measure of tuber quality, was only significantly affected by P application at one location in 2006.

Introduction

Potato plants are very inefficient in their ability to use 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 enhancing product that claims to improve P availability in the soil when coated on dry or mixed with liquid fertilizers. Avail® is maleic-itaconic copolymer, sodium salt with 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

Table 1. Soil characterization and initial soil test analysis.

Location	Soil Name†	Taxonomic 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 Hapludolls	246 (EH)	34	6.63	15.5
WS	Richford ls	Loamy, mixed superactive, mesic Arenic Hapludalfs	186 (EH)	34	5.98	10.8
S	Mahtomedi ls	Mixed, frigid Typic Udipsamments	35 (VL)	174	6.4	20.0
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
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
S	Cress sl	Sandy, mixed, frigid Humic Dystrudepts	90 (VL)	280	6.8	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

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

Locations and treatments

- In 2006, six locations: Hancock and Spooner Ag Research Stations (H and S), three grower fields (CF, WS, TW) and Antigo Airport (A).
- In 2007, five locations: Hancock and Spooner Ag Research Stations (H and S), three grower fields (WS, TW1, TW2).
- Info regarding soil series and initial soil test levels for each location can be found in Table 1.
- All locations except CF, TW1, and TW2 plot size: 3.60 m by 5.29 m.
- Location CF plot size: 3.04 m by 5.29 m. Locations TW1 and TW2 plot size: 5.40 m by 5.29 m.
- Seed piece spacing at all locations was 0.31 m apart except TW1 and TW2 where seed was spaced 0.23 m.
- Russet Burbank potatoes were planted at H, S, CF, and WS and are grown for processing.
- Frito Lay 1867 potatoes were planted at TW, A, TW1, and TW2 and are grown for seed production.
- Treatments for each location are provided in Table 2.
- Nitrogen and potassium were equalized for all treatments at a given location.

Statistical analysis of yield

- Most desirable size classes for Russet Burbank are US No.1 and A size tubers.
- Most desirable size class for Frito Lay 1867 is B size tubers.
- ANOVA with Fisher's LSD was used to assess treatment effects on yield and quality.
- 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.
- Effect of Avail® on yield was assessed with specific contrast of MAP+Avail® or TSP/MAP at the same rates of P applied.
- Effect of rate of P in starter fertilizer on yield was assessed with ANOVA with means separation using Fisher's protected LSD for rates of TSP and MAP applied as starter.
- In 2006 tubers at location H failed to bulk properly due to early blight; thus data may not be representative of normal conditions.

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

Location	P Source*	P Rate	P Timing†
		kg P_2O_5 ha^{-1}	
2006			
‡,**	None	0	None
‡,**	TSP	73	Starter
‡,**	TSP	146	Starter
**	TSP	218	Starter
**	TSP	291	Starter
‡	MAP+Avail®	73	Starter
**	MAP+Avail®	146	Starter
**	MAP+Avail®	218	Starter
‡	TSP	73	Sidedress
2007			
‡‡,***	None	0	None
‡‡,***	MAP	73	Starter
‡‡,***	MAP	146	Starter
***	MAP	218	Starter
‡‡,***	MAP+Avail®	73	Starter
‡‡,***	MAP+Avail®	146	Starter
***	MAP+Avail®	218	Starter
‡‡	MAP	73	Sidedress

*TSP, triple super phosphate (0-46-0); MAP, monoammonium phosphate (11-52-0).
†Starter, fertilizer applied at planting approximately 5 cm to to the side of the seed piece; Sidedress, fertilizer applied at first flower by cutting a 3 cm deep furrow along the top side of the hill, applying the fertilizer and closing the furrow.
‡Locations: H, CF, WS, A, and TW.
**Location: S.
‡‡ Location: H, WS, TW1 and TW2.
*** Location: S.

Results and Discussion

Table 3. Yield and specific gravity for all locations in 2006.

P Source†	P Rate*	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
MAP+Avail®	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
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
MAP+Avail®	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
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
MAP+Avail®	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
CV,%		55.83	56.6	14.42	21.14	14.62	0.873
Location S							
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	-
CV,%		24.44	25.34	21.53	-	9.24	-
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
MAP+Avail®	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	0.026	0.065	0.104	0.655
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
MAP+Avail®	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
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.
*s, sidedress.
§ S.G., specific gravity

Russet Burbank

2006

- No significant effect of treatment (Table 3) on A size, US No.1, and total yield at H, CF, and WS.
- A size, US No.1 and total yield for MAP+Avail® were not significantly different than TSP at H, CF, and WS locations.
- At location S, yield increased with P rate and treatments with Avail® had significantly greater yield than the same rates without Avail®.
- A size, US No.1, and total yield for sidedress P applications were not significantly different than starter P.
- No significant difference between rates of starter P fertilizer for A size, US No.1 and total yield at H, CF, and WS locations.

2007

- No significant effect of treatment (Table 4) on A size, US No.1, and total yield at H, WS, and S.
- A size, US No.1, and total yield for sidedress P applications were not significantly different than starter P.
- A size, US No.1, and total yield for MAP+Avail® were not significantly different than MAP.

Frito Lay 1867

2006

- At TW location, there was no significant difference between treatments with regard to B size and total tuber yield.
- At A location, there was a significant difference between treatments for B size yield with greatest yield being sidedress P and no significant difference for total tuber yield.
- B size and total yield for sidedress P applications were not significantly different than starter P at A and TW locations.
- B size and total yield for MAP+Avail® were not significantly different than TSP at A and TW locations. No significant difference between rates of starter P fertilizer for B size and total yield at A and TW locations.

2007

- At TW1 location, there was a significant difference between treatments with regard to B size yield and 218 kg P_2O_5 ha^{-1} MAP+Avail® had the greatest yield.
- Otherwise, at TW1 and TW2 locations, there was no significant difference between treatments with regard to B size and total yield.
- MAP+Avail® did increase B size tuber yield at locations TW1 and TW2, although not always significant.
- No significant difference between rates of starter P fertilizer for B size and total yield at TW1 and TW2 locations.
- Increasing P rates did not significantly increase yield at TW1 and TW2.

Fertilizer rates vs. fertilizer recommendations

- University of Wisconsin P fertilizer recommendations are based on total yield goal and always resulted in an over application of P compared to the rate needed to maximize yield.
  - 11 kg P_2O_5 ha^{-1} at two locations.
  - 15-35 kg P_2O_5 ha^{-1} at four locations.
  - 100-280 kg P_2O_5 ha^{-1} at five locations.
- Russet Burbanks average change in yield for the 73 kg P_2O_5 ha^{-1} rate compared to control:
  - All seven locations: total and A size tuber yield change was 2.09 and 1.76 Mg ha^{-1} , respectively.
  - Four of seven locations had a yield increase, although not always significant: total and A size tuber yield change was 4.14 and 5.06 Mg ha^{-1}, respectively.
  - Russet Burbanks are paid on A size tuber yield, this would result in an additional $387 ha^{-1} for all locations and $1113 ha^{-1} for responsive locations, while 73 kg P_2O_5 MAP cost $54.04 ha^{-1}.
- Russet Burbanks average change in yield for the 146 kg P_2O_5 ha^{-1} rate compared to 73 kg P_2O_5 ha^{-1}:
  - All seven locations: total and A size tuber yield change was 0.21 and -0.09 Mg ha^{-1}, respectively.
  - Two of seven locations with yield increase, although not always significant: total and A size tuber yield was 2.85 and 4.14 Mg ha^{-1}, respectively. The increased yield included one location with very low soil test and one with an excessively high soil test P level.
- Frito Lay 1867 average change in yield for the 73 kg P_2O_5 ha^{-1} rate compared to control:
  - All four locations: total and B size tuber yield change was 3.65 and 0.03 Mg ha^{-1},respectively.
  - This suggests that for silt loam soils when soil test P is >140 ppm there is likely no response to additional fertilizer for B size tubers.

Conclusions

- Fertilizer recommendations are more than adequate for potato growers in Wisconsin, at all locations total yield plateued before the fertilizer recommendation was reached.
- Rates of starter P may not have been statistically different but economically adding 73 kg P_2O_5 ha^{-1} had a return of $333.13-$1059.16 ha^{-1} for Russet Burbanks, but this increase may have been attained at a lower rate.
- 73 kg P_2O_5 ha^{-1} effected B size and total yield of Frito Lay 1867 differently, thus growers need to define marketing objectives to justify economical fertilizer P application rates.
- Growers tend to apply 146-219 kg P_2O_5 ha^{-1}, large P applications are unnecessary based on this research and increase the potential for P loss and reduce profitability. Thus, convincing growers to apply lower rates would be an improvement over current practices.
- Avail® increased total tuber yield by 5.21 Mg ha^{-1} at 6 of 11 locations, although not always statistically significant.
- There was no significant benefit to applying P at sidedress to make it more available to the plant later in the growing season.

Table 4. Yield and specific gravity for all locations in 2007.

P Source†	P Rate*	Cull	B size	A size	US No. 1	Total	S.G.§
	kg P_2O_5 ha^{-1}	Mg ha^{-1}					
Location H							
None	0	4.17	6.14	49.43	21.83	59.74	1.080
MAP	73	5.23	5.07	52.64	24.99	62.94	1.081
MAP	146	4.56	6.34	51.53	25.05	62.43	1.082
MAP+Avail®	73	3.82	6.18	52.35	24.97	62.35	1.080
MAP+Avail®	146	4.46	6.05	53.38	24.18	62.77	1.080
MAP	73s	3.97	5.77	47.43	21.64	57.17	1.080
p		0.485	0.656	0.743	0.565	0.698	0.976
CV,%		32.33	18.97	12.04	15.13	9.73	0.299
Location WS							
None	0	2.22	5.80	33.75	8.63	41.77	1.079
MAP	73	3.39	6.75	37.93	9.89	48.07	1.082
MAP	146	4.89	5.91	37.39	11.56	48.19	1.083
MAP+Avail®	73	2.72	3.84	37.59	10.92	44.14	1.082
MAP+Avail®	146	3.06	6.51	36.71	9.83	46.28	1.086
MAP	73s	3.54	4.82	33.75	6.71	36.20	1.080
p		0.409	0.101	0.154	0.263	0.127	0.079
CV,%		52.96	25.99	16.13	30.01	14.48	0.274
Location S							
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	6.67 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	-
CV,%		27.83	26.19	15.20	-	9.57	-
Location TW1							
None	0	1.89	4.80 ab	34.10	7.98	40.78	1.094
MAP	73	1.56	4.24 b	38.36	10.34	44.15	1.091
MAP	146	2.08	4.32 b	39.88	9.13	46.16	1.092
MAP	218	1.42	4.54 b	38.00	8.15	43.91	1.093
MAP+Avail®	73	1.57	4.72 b	37.60	7.00	43.89	1.094
MAP+Avail®	146	1.81	4.63 b	39.49	8.71	45.94	1.095
MAP+Avail®	218	1.75	5.58 a	37.71	7.58	44.97	1.093
p		0.899	0.048	0.448	0.756	0.485	0.462
CV,%		43.83	12.08	9.89	34.89	8.32	0.251
Location TW2							
None	0	2.54	4.39	39.56	8.25	46.49	1.091
MAP	73	2.65	4.74	41.43	9.30	48.82	1.094
MAP	146	1.94	4.70	43.02	12.00	49.65	1.088
MAP	218	2.27	5.11	42.69	9.04	50.08	1.092
MAP+Avail®	73	2.67	5.05	40.57	9.56	48.29	1.096
MAP+Avail®	146	1.97	4.93	42.26	10.55	49.15	1.091
MAP+Avail®	218	1.88	6.03	44.80	11.75	52.71	1.088
p		0.486	0.052	0.098	0.115	0.078	0.083
CV,%		31.53	12.79	5.58	5.58	5.05	0.369

† 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.
*s, sidedress.
§ S.G., specific gravity

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