

## Effectiveness of In-Season Potash Applications<sup>1</sup>

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Potatoes use substantial amounts of potassium. In a survey of commercial potato fields Dow et al. (1978) found potassium removal in the tubers ranged from 203 to 397 lbs K/a and was directly proportional to tuber yields. Hence, fertilizer recommendations for K on potatoes are commonly quite high. For example, current Wisconsin recommendations call for 260 lb K<sub>2</sub>O/a on sandy soils testing in the 100 to 130 ppm soil test K range (Kelling et al., 1991).

According to Roberts and McDole (1985) there are few constraints on methods of applying K effectively. They suggest it can be successfully broadcast, banded or sidedressed. However, Berger et al. (1961) concluded that KCl banded in the row with phosphorus and nitrogen inhibited the uptake of P and reduced tuber yield and dry matter content compared to where K<sub>2</sub>SO<sub>4</sub> was used. Separation of the chloride from the P (by broadcasting the KCl) restored the P uptake and yields. Similarly, several Maine studies also showed reduced P uptake by potatoes where an excess of KCl is present. More recently, several commercial organizations have suggested that some advantage may be gained by using lower rates of early season potassium, and then making one or more applications during the growing season usually through the irrigation system.

To evaluate the effectiveness of in-season potash applications several experiments were conducted over the past 3 years at Rhinelander, Hancock and Antigo, Wisconsin.

### Methods and Materials

#### Experiment 1

This experiment was designed to evaluate the timing and source of potassium additions, especially considering late applications of 8-0-8-6 (the commercially available form of potassium nitrate, combined with calcium nitrate). This experiment was conducted at Rhinelander Agricultural Experiment Farm using the Atlantic variety. Details as to the specific treatments used are shown on the results table.

Soil at this site is a Vilas loamy sand. Potatoes were planted using 300 lb/a 8-46-0 mixed with 50 lb K<sub>2</sub>O/a as 0-0-50 starter fertilizer except for the no-potash control which did not receive the 0-0-50 in the starter. Supplemental nitrogen was split between emergence and hilling and where calcium was applied it was usually added as gypsum preplant broadcast. Potato petioles and leaflet and petioles were sampled for analysis. Soil test

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<sup>1</sup>Portions of this work are supported by Great Salt Lake Minerals Corp., Vicksberg Chemical Co., the Wisconsin Potato Industry Board and the College of Agricultural and Life Sciences, and is gratefully acknowledged.

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Table 1. Chronologies for the various in-season potash experiments.

	Rhinelander			Hancock			Antigo	
	1991	1992	1993	1992	1993	1993	1992	1993
Variety	Atlantic	Atlantic	Atlantic	R. Burbank	R. Burbank	Atlantic	Atlantic	Atlantic
Soil test P (ppm) *	180	255	200	108	132	245	245	140
Soil test K (ppm)	121	80	106	49	57	119	119	92
Planting date	21 May	12 May	11 May	23 Apr	28 Apr	14 May	14 May	18 May
Starter fertilizer grade	10-15-20	9-46-0	9-46-0	10-52-0	10-52-0	10-52-0	10-52-0	10-52-0
rate (lb/a)	600	300	250	300	300	300	300	300
Suppl N rate (lb/a)	150	200	200	200	200	200	200	200
Tmt. applic. dates								
Preplant	20 May	11 May	11 May	20 Apr	26 Apr	13 May +	13 May +	17 May
Emergence	6 Jun	3 Jun	7 Jun	21 May	20 May	4 Jun	4 Jun	8 Jun
Hill	25 Jun	24 Jun	25 Jun	9 Jun	3 Jun	10 Jul	10 Jul	2 Jul
H + 10	6 Jul	2 Jul	2 Jul	19 Jun	14 Jun	22 Jul	22 Jul	14 Jul
H + 20	14 Jul	9 Jul	14 Jul	29 Jun	23 Jun	31 Jul	31 Jul	27 Jul
H + 30	25 Jul	28 Jul	27 Jul	8 Jul	6 Jul	11 Aug	11 Aug	10 Aug
Petiole sample dates								
Pet 1 (~40 dae)	25 Jul	28 Jul	14 Jul	--	6 Jul	31 Jul	31 Jul	27 Jul
Pet 2 (~55 dae)	5 Aug	10 Aug	27 Jul	14 Jul	19 Jul	11 Aug	11 Aug	10 Aug
Pet 3 (~70 dae)	--	--	23 Aug	29 Jul	2 Aug	26 Aug	26 Aug	23 Aug
Leaf & Pet sample date	5 Aug	10 Aug	27 Jul	14 Jul	19 Jul	11 Aug	11 Aug	10 Aug
Harvest date	24 Sep	21 Sep	21 Sep	15 Sep	15 Sep	1 Oct	1 Oct	22 Sep

\* Check plots, post-harvest  
+ killing frost on 20 Jun 92

94janlan/4

levels, planting date, and other dates important to the experiment and the other experiments reported herein are shown in Table 1.

Plots in these and the other experiments were harvested by digging the two center rows (20 ft each) from each plot and collecting the tubers. Tubers were graded into US1A, B, and cull and a subsample (approximately 20 lbs/plot) was size graded into <6, 6-13, and >13 oz. A subsample (approx. 15 of the largest tubers) of US1A grade potatoes were rated for incidence of internal brown spot and hollow heart. A post-harvest soil sample of the plow layer was also taken.

#### Experiment 2

This experiment examines the relative effectiveness of the various placement methods when the K is supplied at less than optimal and at excessive rates. It is designed to determine if the use of any of the placement methods, including applications made in-season, result in more efficient use of the applied material. Only  $K_2SO_4$  was used at either 100 or 400 lb  $K_2O/a$  applied all broadcast preplant; all in the row as starter; all broadcast just prior to hilling; one half preplant, one half row; one half preplant, one half hilling; or one half row and one half hilling. This experiment is being conducted at Hancock and Antigo, on a Plainfield loamy sand or on Antigo silt loam, respectively.

#### Experiment 3

Experiment 3 also specifically examines the use of  $KNO_3$  as a potash source when applied in-season as a supplement to more standard potassium applications. All treatments receive 100 lb  $K_2O/a$  as KCl in starter and a second 100 lb  $K_2O/a$  will be applied as KCl or  $KNO_3$  split between emergence and hilling or split 4 times later in the season (hilling and hilling + 10, 20, or 30 days). This experiment includes a separate control where KCl is used as the potash source and the N as  $NH_4NO_3$  is also split late in the season. It is being conducted at Hancock and Antigo.

For all experiments, insect, weed management and irrigation were dictated by need and followed standard farm practice at each location. Statistics were performed using the SAS statistical package for factorial or single factor ANOVA as is appropriate for each specific experiment. Tuber value is defined by assigning a value of \$10/cwt for US1A 6-13 oz; \$4/cwt for US1A <6 or > 13 oz; and \$2/cwt for B and cull grade. The probability ( $Pr > F$ ) values reported in the results tables represent the likelihood that differences between treatment means are due to random error. For example, a  $Pr > F = 0.10$  means there is a 10% chance that the differences between treatment means are random.

### Results and Discussion

Results of the Rhinelander evaluation of potassium nitrate/calcium nitrate (8-0-8-6) liquid fertilizer are shown in Table 2. Some of the treatments used in the experiment are not shown to expedite the focus of this discussion, namely the influence of in-season potash applications when compared to more conventional methods of application. Note that total yields were quite modest in all three of the years due to such factors as less than optimal irrigation in 1991 and 1992; extreme disease pressure in 1991, mid-season frost in 1992 and very poor stand in 1993. In spite of these difficulties there was generally a response to potassium (and sometimes

Table 2. Effect of potassium, nitrogen and calcium source and time of application on Atlantic tuber yield, grade, and value at Rhineland, WI, 1991-1993.

Potassium		Calcium		Yield		Grade A		Yield, USDA 6-13 oz.			Value	
Source	Time	Source Time		1991	1992	1993	1991	1992	1993	1991	1992	1993
----- Cwt/a -----												
---	---	---	---	---	---	---	---	---	---	---	---	---
KCl/KS	PP/R	---	---	243	145	---	80	78	109	12	---	720
KCl/KS	PP/R	---	---	296	251	169	90	83	128	73	---	839
KS/KCl	R/EH	CaS	PP	353	239	194	91	87	193	80	1893	946
KS/KCl	R/Split	CaS	PP	261	293	191	91	84	113	127	20	943
KS/KN	R/Split	CaS	PP	344	238	190	90	79	164	95	33	1001
KS/KN	R/Split	KN	Split	317	231	151	89	79	133	86	9	726
Pr > F				0.23	0.10	0.03	0.97	0.17	0.00	0.09	0.15	0.06

KCl = potassium chloride; KS = potassium sulfate; CaS = calcium sulfate; KN = potassium nitrate (8-0-8-6 Ca); PP = preplant broadcast; R = row applied with planter; EH = split between emergence and hilling applied in band on hill; split in 25% each at hilling, H + 10, H + 20, and H + 30 days.

Total K<sub>2</sub>O = 150 lb/a that includes 50 lb K<sub>2</sub>O/a as KS with planter except for control.

94-janlan/2

calcium) observed. Although in 1991 and 1993 results from splitting the K as KCl into small in-season applications were comparable to those where equal amounts were applied broadcast and row, the split treatments were not advantageous. Furthermore, in two of the years (1992 and 1993) the split applications as 8-0-8-6 were a disadvantage with yields about equal to those from the no-potash check. Grade, size grade, yield of prime tubers and value results tended to follow the same pattern as those for total yield.

Table 3 shows the influence of timing/placement method on tuber yield and quality where 100 or 400 lb/a  $K_2O$  was applied by all methods. The no-potash control is not included in the statistical analysis of these data. It is clear that responses to potash were seen at Hancock in both years and at Antigo in 1993. At Antigo in 1992 the probability value for rate from a separate experiment was  $Pr > F = 0.26$ . In all cases these rate experiments showed that the optimum rate was about 200 lb  $K_2O/a$  (data not shown). A severe frost occurred at Antigo on 20 Jun 1992 which killed all of the above-ground vegetative growth (about 8-12 inches). New sprouts developed from the stems at the soil surface, but the crop was obviously set back and overall yields were about 30% lower than usual.

The data in Table 3 also show that few significant differences in placement/timing were detected, even at the 10% level, at either location in either year for any of the parameters except for hydrometer values at Antigo in 1993. Furthermore, the interaction between rate and placement was only significant for size grade (somewhat fewer <6 and more 6-13 oz. tubers) at Hancock in 1993 for the treatments which included a hilling application at the low rate (data not shown). This influence was not seen at the high rate or at any other parameter, location, or year. There does appear to be a tendency for somewhat lower yields where the potash is applied as a combination of row + hilling bands. This combination had the lowest yields in 3 or the 4 site-years; however, even in these cases, the  $Pr > F$  values ranged from 0.27 to 0.45.

These data do show that potassium applied at hilling can be used by the crop, but there does not appear to be a yield or efficiency advantage for applying later K.

Results from experiment 3, as shown in table 4, show the same trends that were exhibited in experiments 1 and 2 even more dramatically. In both years at Hancock, and to a lesser extent at Antigo, responses to potash were seen, but there appears to be some actual disadvantage to applying the K as  $KNO_3/Ca(NO_3)_2$ . Furthermore, the Hancock results also show that splitting the K as KCl, although better than  $KNO_2/Ca(NO_3)_2$ , was not as effective as applying all of the potash in the row.

Part of the source differences observed may be due to the additional splitting of the nitrogen with the 8-0-8-6 since applications of ammonium nitrate at emergence and hilling were adjusted to account for the nitrogen in the potassium carrier. Nitrogen application for the KCl row/split treatment was also divided similarly, however.

#### Petiole K levels

Petiole samples (40 petioles/plot) were taken from plots included in

Table 3. Main effect of time of potassium application on potato tuber yield, grade and value at two Wisconsin locations, 1992-1993.

Treatment	Yield		Grade A		Yield US1A 6-13 oz.		Value		Hydrometer	
	1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
	---cwt/a---		-----%-----		--cwt/a--		----\$/a----			
Hancock										
0 K Check <sup>+</sup>	411	244	76	58	157	28	2387	945	1.094	1.086
Preplant (PP)	477	298	77	60	190	57	2828	1299	1.096	1.082
Row (R)	460	299	76	61	181	55	2702	1288	1.095	1.083
Hilling (H)	465	294	78	60	204	60	2879	1305	1.097	1.085
PP + R	463	317	77	62	179	54	2919	1351	1.095	1.084
PP + H	478	317	79	64	205	54	2943	1362	1.095	1.086
R + H	449	285	76	65	176	54	2634	1264	1.095	1.083
Pr > F	0.30	0.45	0.50	0.30	0.17	0.99	0.21	0.98	0.52	0.47
Antigo										
0 K Check <sup>+</sup>	311	378	76	86	106	92	2030	1957	23.4 <sup>*</sup>	1.095
Preplant (PP)	323	388	77	87	110	90	2103	1992	23.4	1.091
Row (R)	320	398	75	85	137	88	2259	2003	23.2	1.091
Hilling (H)	309	402	77	85	116	91	2072	2036	23.8	1.095
PP + R	365	400	78	86	168	128	2630	2261	22.9	1.093
PP + H	341	395	74	87	138	98	2365	2065	23.2	1.094
R + H	295	409	77	86	106	108	1946	2171	23.5	1.094
Pr > F	0.27	0.95	0.73	0.82	0.15	0.12	0.20	0.40	0.47	0.05

Potassium applied at 100 and 400 lb K<sub>2</sub>O/a as K<sub>2</sub>SO<sub>4</sub> at both locations; Russet Burbank at Hancock, Atlantic at Antigo.

\* Dry matter determined gravimetrically at Antigo in 1991.

<sup>+</sup> Not included in statistical analysis.

Table 4. Effect of K application timing and source on potato tuber yield, grade and value at two Wisconsin locations, 1991-1993.

Treatment Rate	Source	Placement	Yield		Grade A		Yield US1A 6-13 oz.		Value		Hydrometer	
			1992	1993	1992	1993	1992	1993	1992	1993	1992	1993
Hancock												
0	--	--	388	244	71	51	124	29	2073	916	1.095	1.084
200	KCl	Row	481	264	75	60	192	35	2840	1056	1.092	1.081
200	K <sub>2</sub> SO <sub>4</sub>	Row	498	303	76	63	187	60	2873	1347	1.093	1.084
100/100	KCl/KNO <sub>3</sub>	Row/EH	438	234	79	52	181	9	2653	765	1.092	1.083
100/100	KCl/KNO <sub>3</sub>	Row/Split	434	224	75	56	170	12	2536	772	1.093	1.085
100/100	KCl	Row/Split	424	253	82	48	168	14	2551	831	1.092	1.083
Pr > F			0.00	0.02	0.00	0.02	0.00	0.00	0.00	0.00	0.32	0.54
Antigo												
0	--	--	316	384	80	81	121	80	2118	1874	23.9*	1.098
200	KCl	Row	350	458	80	86	157	146	2480	2578	21.7	1.088
200	K <sub>2</sub> SO <sub>4</sub>	Row	357	411	79	88	132	88	2369	2078	22.7	1.094
100/100	KCl/KNO <sub>3</sub>	Row/EH	292	409	77	86	104	92	1927	2078	23.1	1.088
100/100	KCl/KNO <sub>3</sub>	Row/Split	299	388	69	86	98	77	1965	1905	24.0	1.092
100/100	KCl	Row/Split	356	428	81	86	147	88	2444	2124	22.8	1.086
Pr > F			0.12	0.35	0.07	0.06	0.28	0.13	0.24	0.16	0.01	0.00

EH = half at emergence and half at hilling; split = 25% at hilling and 25% each at hilling + 10, H + 20, and H + 30 days. Russet Burbank at Hancock and Atlantic at Antigo.

\* Dry matter determined gravimetrically at Antigo in 1992.

94janlan/1

experiments 1 and 3 at about 40, 55 and 70 days after emergence in both 1992 and 1993. Results of these samplings are shown in Table 5. It is obvious that less K was taken up at both Rhinelander and Hancock in 1993 than in 1992. This may have been at least partly due to the very wet weather in 1993 which may have leached some of the potash on these sandy soils.

Relative to the issue of in-season K applications it is interesting to note that only at Hancock for the first two samplings in 1993 and at Antigo for the second sampling in 1993 was there an apparent increased level of K in the tissue when the fertilizer K was applied at emergence/hilling or later. The row or preplant applications generally resulted in comparable petiole K at any given sampling time where the same amount of total K was applied.

#### Summary

These several experiments show that in-season applications of potash can be utilized by the plant, and where deficiencies are detected, applications of potash are recommended to correct the problem. However, these data do not support the concept that in-season potash applications are yield or quality enhancing, nor do they appear to improve efficiency of fertilizer use. These data support the statement of Roberts and McDole (1985) that there are few constraints on how potash should be applied. Although we did not include fall preplant broadcast in these experiments we continue to believe that this method results in some risk of K leaching losses on sandy and organic soils. These experiments also show no advantage to using potassium nitrate as a K source for in-season applications. In some cases, especially where early-season N rates were reduced to compensate for the nitrate applied with the potassium, yields and quality were actually reduced.

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Table 5. Effect of potassium source and time of application on petiole K levels at several times during the growing season.

Potassium			Calcium			1992						1993					
Rate	Source	Placement	Source	Placement		Petiole 1	Petiole 2	Petiole 3	Petiole 1	Petiole 2	Petiole 3	Petiole 1	Petiole 2	Petiole 3			
----- %K -----																	
Experiment 1 - Rhineland																	
0	--	--	--	--		28 Jul (55 dae)	10 Aug (68 dae)	14 Jul (37 dae)	27 Jul (50 dae)	23 Aug (77 dae)							
100/50	KCl/KS	PP/R	--	--		7.0	5.1	6.5	4.4	2.9							
100/50	KCl/KS	PP/R	--	--		9.6	7.6	7.8	5.9	5.4							
50/100	KS/KCl	R/EH	CaS	PP		8.7	7.2	8.1	5.6	5.9							
50/100	KS/KCl	R/Split	CaS	PP		9.6	7.5	8.0	6.0	5.0							
50/100	KS/KN	R/Split	CaS	PP		8.7	7.4	9.4	5.5	4.2							
50/100	KS/KN	R/Split	KN	split		7.7	6.8	7.3	5.7	3.7							
Pr>F						0.01	--	--	0.00	--							
Experiment 2 - Hancock																	
0	--	--	--	--		14 Jul (54 dae)	29 Jul (69 dae)	6 Jul (46 dae)	19 Jul (59 dae)	2 Aug (73 dae)							
200	KCl	R	--	--		4.9	1.3	3.6	2.0	0.8							
200	KS	R	--	--		8.8	5.5	5.4	3.8	2.4							
100/100	KCl/KN	R/EH	--	--		8.0	4.7	5.4	3.8	2.1							
100/100	KCl/KN	R/Split	--	--		8.7	3.9	6.5	5.8	4.2							
100/100	KCl	R/Split	--	--		8.6	4.2	6.2	4.8	1.9							
Pr>F						9.2	5.2	5.8	4.5	2.9							
						0.00	--	--	0.00	--							
Experiment 3 - Antigo																	
0	--	--	--	--		31 Jul (41 dae)	26 Aug (67 dae)	27 Jul (49 dae)	10 Aug (63 dae)	23 Aug (76 dae)							
200	KCl	R	--	--		8.1	6.9	7.5	6.7	4.7							
200	KS	R	--	--		12.5	11.7	8.6	8.3	5.0							
100/100	KCl/KN	R/EH	--	--		11.0	9.9	8.9	8.7	6.1							
100/100	KCl/KN	R/Split	--	--		10.9	8.5	8.3	9.4	5.8							
100/100	KCl/KN	R/Split	--	--		11.3	9.4	8.0	9.1	4.7							
100/100	KCl	R/Split	--	--		12.0	10.6	9.1	9.5	6.1							
Pr>F						--	--	--	0.00	--							

EH = half at emergence and half at hilling; split = 25% at hilling and 25% each at hilling + 10, H + 20, and H + 30 days after emergence.

Russet Burbank at Hancock and Atlantic at Antigo and Rhinelander.

\* \* dae after emergence based on hilling from killing frost on 20 June