The Effects of Potassium Carriers and Levels of Potassium and Nitrogen Fertilization On the Yield and Quality of Sugar Beets[1]

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Received for publication March 21, 1968

High levels of potassium in the petioles of sugarbeets are conducive, if not essential, to the production of high yields (5).[3] High levels of potassium in the root at harvest are undesirable, however, as potassium along with amino-nitrogen account for a large proportion of the non-sucrose contaminants of the clear juice.

Considerable research on the effects of potassium carriers on the quality of crops other than sugarbeets has been reported. There is evidence that KCl applied at high rates decreases the specific gravity of potatoes and lowers the quality of fruits and tobacco (4,6,7,8). One possible explanation of these observations is that the number of soil bacteria is reduced by chloride-containing potassium fertilizers. Yung (9) found that fertilizers containing chloride destroyed nitrifying and cellulose decomposing bacteria and increased the proportion of fungi in the microflora. Nearly all workers cited agree that the detrimental effects of KCl on crop quality are not present when K_2SO_4 is used as the potassium source.

The primary objective of this work was to determine if KCl, KNO_3, K_2SO_4 or $(K_2SO_4 + MgSO_4)$[4] differentially affects the yield and/or quality[5] of sugarbeets. Special emphasis was placed on finding any detrimental effect on sugar beet juice quality when KCl was applied. Additional objectives were to determine if rates of potassium or nitrogen fertilization or their interactions affect the yield and quality of beets.

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[3] Numbers in parentheses refer to literature cited.

[4] Sul-PO-Mag is available from International Minerals and Chemical Co., Skokie, Ill., composed of a mixture of K and Mg sulfates containing 18% K and 11% Mg, and hereafter denoted as $KMgSO_4$.

[5] The term quality in this paper refers to the percent of sucrose in the beets, the percent clear juice purity, the amount of recoverable sugar from an acre and the relative proportion of the clear juice impurities, amino-nitrogen, potassium and sodium.

Materials and Methods

Experiments with potassium carriers were conducted at three locations in 1965 and were repeated at two of the locations in 1966. Two of these locations were on mineral soils typical of the sugarbeet growing area near the Saginaw Bay in Michigan. Location 1 was a Kawkawlin loam with a high test for potassium, and location 2 a Sims clay loam with a medium test for potassium. Location 3 was on an organic soil (Houghton muck).

Four potassium carriers, KCl, KNO_3, K_2SO_4 and $KMgSO_4$, were applied in replicated plots in randomized complete block designs at each location. At location 1, potassium was applied at rates of 100 and 200 pounds K_2O per acre, nitrogen at 30 and 60 pounds in 1965, and 30 and 150 pounds in 1966. Potassium was applied at the rate of 240 pounds K_2O per acre at location 2, and nitrogen was applied at the constant rate of 70 pounds per acre. At location 3, potassium was applied at rates of 200 and 600 pounds K_2O and 60 pounds nitrogen was applied. A 500-pound per acre NaCl application was made on one-half of the plots at location 3.

The treatment materials, along with 5 pounds per acre boron and 14 pounds manganese, were spread uniformly on the plot surface and mixed with the soil by means of a spring-tooth harrow just prior to planting. Phosphorus was banded at planting at the rates of 240 pounds P_2O_5 per acre for locations 1 and 2 and 100 pounds per acre for location 3.

Petiole samples were taken from all plots in late July and in early October by randomly selecting 20 of the youngest mature petioles from each plot. The petioles were dried in a forced air oven at 60°C, ground and analyzed for potassium, sodium, magnesium and calcium.

At harvest, yield weights were recorded and ten beets were chosen from each plot in such a manner as to avoid selecting extra large or extra small roots and to obtain a uniformity of sampling. The ten beet samples were analyzed for percent sucrose and percent clear juice purity (1, 2). In addition, some of the samples were analyzed for the clear juice impurities, sodium and potassium (flame photometry) and amino nitrogen (3). Recoverable sugar values were calculated. Analyses of variance were employed in order to facilitate the interpretation of the data. Values of least significant difference were calculated for means judged significantly different at the 5% level. The error possible in applying the least significant difference to more than two means is recognized.

Results

No significant differences in yield, percent sucrose, percent clear juice purity, or concentration of amino nitrogen, sodium, or potassium in the clear juice were noted at location 1 in 1965 or 1966. The possibility of a response to magnesium where $KMgSO_4$ was applied was checked by adding $MgSO_4$ to K_2SO_4 plots in amounts equivalent to the amounts of magnesium in the $KMgSO_4$ plots. No response to magnesium was found.

Neither sugarbeet yield nor quality was significantly different when 200 pounds of K_2O was applied than when 100 pounds was applied. Percent sucrose, percent clear juice purity and amount of sugar recoverable from an acre were reduced when 150 pounds of nitrogen was applied in 1966.

Table 1 shows that sugarbeets treated with KCl had a higher percent potassium in their petioles in July than beets treated with KNO_3. When $KMgSO_4$ was the carrier of potassium, a higher percent potassium was obtained than when either KNO_3 or K_2SO_4 was the carrier. Sixty pounds of nitrogen per acre decreased the percent potassium in petioles in July in comparison to 30 pounds per acre. There were no differences in the percentages of potassium in the petioles in October. Beets treated with KCl had a higher percent calcium in their petioles than beets treated with KNO_3 or K_2SO_4, and a higher percent magnesium than beets treated with KNO_3, K_2SO_4 or $KMgSO_4$. The application of 60 pounds of nitrogen increased the percent magnesium in petioles in October.

The data from location 1 for 1966 are presented in Table 2. When KCl served as the potassium source, sugarbeet petioles contained higher concentrations of potassium, sodium and magnesium than when any of the other carriers tested served as the potassium source. Petioles contained greater concentrations of potassium when either the higher rate of potassium or the lower rate of nitrogen was applied. The sodium concentration of petioles in October and the magnesium concentration in July and October were increased by the application of 150 pounds of nitrogen per acre.

At location 2 (Table 3), the yield and quality of sugarbeets were not affected by potassium carriers with the exception that plots treated with KCl had a higher concentration of potassium in the clear juice as an impurity in 1965. Beets grown where KCl was applied had higher percents potassium, calcium, and magnesium, and lower percent sodium in petioles than did beets on plots where other carriers were applied.

Table 1.—The effects of two rates of application of four potassium carriers and two nitrogen levels on the nutrient uptake of sugarbeets at location 1 (Kawkawlin loam) in 1965.

K carrier	Percent K in petioles		Percent Na in petioles		Percent Ca in petioles		Percent Mg in petioles	
	July	October	July	October	July	October	July	October
KCl	4.02	5.16	1.92	1.38	0.92	0.97	0.68	0.49
KNO_3[1]	3.61	4.78	1.91	1.31	0.82	0.78	0.65	0.39
K_2SO4	3.74	4.89	1.80	1.25	0.86	0.79	0.70	0.37
$KMgSO_4$	4.20	5.06	1.91	1.40	0.87	0.87	0.65	0.43
LSD 5%	0.34	NS	NS	NS	NS	0.13	NS	0.06
K_2O Lbs/A								
100	3.83	4.95	1.92	1.32	0.87	0.81	0.66	0.41
200	3.95	5.00	1.85	1.35	0.87	0.88	0.67	0.44
N Lbs/A								
30	4.02*	5.08	1.87	1.35	0.87	0.85	0.66	0.40
60	3.76	4.68	1.90	1.32	0.87	0.84	0.67	0.44*

[1] KNO_3 plots where 200 lbs K_2O and 30 lbs N were applied received part of their K as K_2SO_4 in order to avoid applying over 300 lbs N.

* Significantly higher at 5% level.

Table 2.—The effects of two rates of application of four potassium carriers and two nitrogen levels on the nutrient uptake of sugarbeets at location 1 (Kawkawlin loam) in 1966.

K carrier	Percent K in petioles		Percent Na in petioles		Percent Ca in petioles		Percent Mg in petioles	
	July	October	July	October	July	October	July	October
KCl	4.64	4.71	1.91	1.02	0.99	0.88	0.75	0.51
KNO_3[1]	3.92	4.25	1.82	1.01	0.84	0.70	0.58	0.40
K_2SO_4	4.18	4.29	1.82	0.87	0.85	0.72	0.58	0.40
$KMgSO_4$	4.24	4.27	1.96	1.00	0.79	0.69	0.59	0.41
LSD 5%	0.35	0.33	NS	NS	0.10	0.11	0.07	0.07
K_2O Lbs/A								
100	4.12	4.24	1.82	0.92	0.87	0.74	0.62	0.43
200	4.37*	4.57**	1.94	1.00	0.87	0.75	0.64	0.43
N Lbs/A								
30	4.45**	4.60**	1.86	0.92	0.90	0.73	0.60	0.38
150	4.03	4.21	1.90	1.03*	0.84	0.76	0.65*	0.48**

[1] KNO_3 plots where 200 lbs K_2O and 30 lbs N were applied received part of their K as K_2SO_4 in order to avoid applying over 30 lbs N.

* Significantly higher at the 5% level.

** Significantly higher at the 1% level.

Table 3.—The effects of four potassium carriers on the yield, quality and nutrient uptake of sugarbeets at location 2 (Sims clay loam) in 1965 and 1966.

1965

K carrier	Yield-tons/A	Percent sucrose	Percent clear juice purity	Pounds sugar/A	Impurities in clear juice Mg/100 g sucrose			Percent K in petioles		Percent Na in petioles		Percent Ca in petioles		Percent Mg in petioles	
					Amino N	K	Na	July	October	July	October	July	October	July	October
O-K	20.9	13.4	94.3	4908	233	1188	51	6.14	5.01	0.57	0.44	0.84	0.47	0.58	0.34
KCl	22.4	13.2	94.1	5202	232	1414	45	6.84	6.66	0.48	0.33	0.95	0.55	0.57	0.42
KNO_3	23.7	13.5	94.1	5598	240	1183	47	6.28	5.78	0.53	0.40	0.82	0.44	0.52	0.31
K_2SO_4	22.3	13.9	94.6	5500	212	1055	40	6.47	6.20	0.52	0.36	0.81	0.44	0.54	0.30
$KMgSO_4$	22.4	13.5	94.6	5329	205	1159	48	6.47	6.11	0.49	0.42	0.74	0.37	0.47	0.30
LSD 5%	NS	NS	NS	NS	NS	228	NS	NS	0.58	NS	0.06	NS	0.11	0.07	NS

1966

K carrier	Yield-tons/A	Percent sucrose	Percent clear juice purity	Pounds sugar/A	Percent K in petioles		Percent Na in petioles		Percent Ca in petioles		Percent Mg in petioles	
					July	October	July	October	July	October	July	October
O-K	14.9	15.8	96.2	4330	3.82	4.37	0.81	0.51	0.68	0.83	0.52	0.44
KCl	14.5	16.1	95.8	4219	4.74	5.62	0.71	0.47	0.65	1.08	0.67	0.55
KNO_3	13.5	15.8	95.7	3875	3.97	5.26	0.71	0.63	0.64	0.93	0.48	0.47
K_2SO_4	14.5	16.1	95.0	4189	4.18	4.84	0.66	0.36	0.59	0.77	0.47	0.42
$KMgSO_4$	15.8	16.3	95.8	4694	4.81	5.06	0.84	0.60	0.57	0.85	0.46	0.49
LSD 5%	NS	NS	NS	NS	NS	0.59	NS	0.15	NS	NS	0.10	0.10

No differences in yield or quality of sugarbeets were found when two rates of potassium, two rates of sodium chloride and four potassium carriers were applied on the Houghton muck. Petiole analyses for sugarbeets grown on this organic soil are given in Table 4. The relative levels of potassium in the petioles are extremely high in July compared with those in other experiments and in October. This is perhaps an indication of luxury consumption of potassium.

Interactions noted at location 1 are given in Table 5. In 1965, significant interactions were found between rate of potassium fertilization and rate of nitrogen fertilization. A higher yield and more recoverable sugar were produced when 30 pounds of nitrogen per acre was applied with 100 pounds of K_2O than when 200 pounds of K_2O was applied. Applying 60 pounds of nitrogen per acre reduced the amount of recoverable sugar on areas where K_2O was applied at 100 pounds.

Table 4.—The effects of potassium carriers on the percents of potassium, sodium, calcium and magnesium in the petioles of sugarbeets from plots receiving no sodium chloride at location 3 (Houghton muck) in 1965.

K carrier	Percent K in petioles		Percent Na in petioles		Percent Ca in petioles		Percent Mg in petioles	
	July	October	July	October	July	October	July	October
O-K	13.22	6.67	1.53	1.45	0.36	0.31	0.52	0.31
KCl	12.91	8.78	1.52	1.98	0.38	0.34	0.54	0.30
KNO_3	13.75	8.18	1.62	1.08	0.47	0.30	0.59	0.28
K_2SO_4	12.79	8.13	1.56	1.09	0.40	0.31	0.51	0.28
$KMgSO_4$	13.89	8.82	1.57	1.00	0.44	0.35	0.67	0.29
LSD 5%	0.87	0.70	NS	0.26	NS	NS	NS	NS

Table 5.—Interactions in the yield and quality of sugarbeet data as affected by two rates of application of potassium carriers and two nitrogen levels at location 1 (Kawkawlin loam) in 1965 and 1966.

1965

K_2O Lbs/A	Yield — tons/A 30 lbs N	Yield — tons/A 60 lbs N	LSD 5% level	Pounds sugar/A 30 lbs N	Pounds sugar/A 60 lbs N	LSD 5% level
100	22.6	21.4	NS	6887	6366	454
200	21.2	22.0	NS	6414	6631	NS
LSD 5%	1.3	NS		454	NS	

1966

K carrier	Percent sugar 100 lbs K_2O	Percent sugar 200 lbs K_2O	LSD 5% level	Pounds sugar/A 100 lbs K_2O	Pounds sugar/A 200 lbs K_2O	LSD 5% level
KCl	16.8	16.1	NS	7595	6710	620
KNO_3	15.8	17.0	0.8	6988	7487	NS
K_2SO_4	16.9	16.3	NS	7330	7454	NS
$KMgSO_4$	17.1	16.7	NS	7493	7511	NS
LSD 5%	0.8	0.8		NS	NS	

In 1966, KNO_3 applied at the rate of 100 pounds K_2O per acre produced sugarbeets with a lower percent sucrose than did the other carriers. When 200 pounds per acre of K_2O was applied as KNO_3, the beets produced had a higher percent sucrose than beets for which KCl was the potassium source. The application of KNO_3 at the rate of 200 pounds K_2O per acre resulted in a higher percent sucrose than its application at 100 pounds per acre. Recoverable sugar was reduced by applying 200 pounds of K_2O as KCl.

Discussion

The major portion of the research presented was done on a soil with a high potassium test (location 1 soil tested 240 pounds ammonium-acetate extractable potassium per acre). This soil was chosen because it was believed that effects injurious to the quality of sugar beets would be more likely to occur at higher soil potassium concentrations. The data indicate that the potassium carriers tested were all similar in their effect on the yield and quality of sugarbeets at given levels of potassium and nitrogen fertilization.

Decreases in the recoverable sugar per acre for sugarbeets when 200 pounds of K_2O as KCl was applied may be due to factors discussed earlier in this paper and observed in potatoes, fruits, and tobacco. The reason beets treated with KCl at the rate of 100 pounds K_2O per acre had a higher percent sucrose than those treated with KNO_3 may possibly be explained by the greater uptake of potassium from KCl.

The percent sucrose, percent clear juice purity and recoverable sugar of beets were markedly reduced by the application of 150 pounds of nitrogen in comparison to 30 pounds. This effect is consistent with many studies.

Inverse relationships between the relative amounts of potassium and sodium in sugarbeet petioles is apparent in the data from these experiments, indicating that there may be some substitution of sodium for potassium.

Summary

The yield and quality of sugarbeets grown on three soil types and in two successive years were affected similarly by the four potassium carriers: KCl, KNO_3, K_2SO_4 and $KMgSO_4$. For the experiments carried out, the rate of potassium applied to a soil with a high potassium test did not affect the yield or quality of beets. Sugarbeets supplied with 150 pounds of nitrogen were of lower quality than beets supplied with 30 pounds of nitrogen per acre. Some evidence is given to indicate that KCl applied at a rate of 200 pounds K_2O per acre reduced the quality of sugarbeets in comparison to KCl applied at 100 pounds K_2O per acre and to KNO_3 applied at a rate of 200 pounds per acre.

Highest concentrations of potassium generally occurred in petioles of sugarbeets to which KCl had been applied. When 150 pounds of nitrogen per acre was applied, sugarbeet petioles contained higher concentrations of magnesium and lower concentrations of potassium than did petioles of beets to which only 30 pounds nitrogen per acre was applied. Higher concentrations of potassium were found in petioles from beets which were supplied with 200 pounds of K_2O in comparison to beets to which 100 pounds of K_2O was applied. In general, the concentration of potassium in sugarbeet petioles was higher in October than in July, while the opposite trend was noted for the concentrations of sodium, calcium and magnesium at the two mineral soil locations. Sugarbeets grown on Houghton muck had high concentrations of potassium in their petioles. The relative concentrations were lower in October than in July.

The application of 500 pounds of NaCl had no effect on the yield or quality of sugarbeets grown on Houghton muck.

Acknowledgment

The partial financial support of this project by the Southwest Potash Corporation is appreciated.

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