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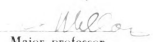
thesis entitled

The Effect of the Application of Common
Salt on the Composition of Different
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THE EFFECT OF THE APPLICATION OF COMMON SALT ON
THE COMPOSITION OF DIFFERENT VARIETIES OF SUGAR
BEETS, CELERY, AND PEAS.

by

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A THESIS

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THE EFFECT OF THE APPLICATION OF COMMON SALT
ON THE COMPOSITION OF DIFFERENT VARIETIES OF
SUGAR BEETS, CELERY, AND PEAS.

INTRODUCTION

It has long been recognized that certain crops show yield responses from the application of common salt to the soil in which they grow. The earliest investigation of this subject in this country was pioneered in 1894 by Wheeler and Adams (12) and continued by Hartwell (7,8) and his associates. Since then a copious literature concerning this general field has accumulated. It seems sufficient in a treatise of this nature, however, to cite only a number of reviews of the subject.

Lehr (9) has made a comprehensive survey of the European literature. Several other excellent reviews of the subject are available, among the most notable of which are the abstracts of Willis (13). A concise summary of the literature concerning the effects of sodium upon plant growth is presented by Miller (10), while Haas (3) gives a thorough discussion of the information relating to the influence of chloride on plants.

Since 1924, Harmer at Michigan State College has

carried on an extensive study of the effects of salt on the yield of a number of crops grown on organic soil. More recently Harmer and Benne (5,6) have investigated the effect of salt on the composition of crops, sodium having been given particular attention. Numerous other investigators have worked with several crops responsive to the addition of salt, but only two have in any way dealt with varietal differences. The first of these, Van Itallie (9), compared the potassium and sodium contents of four fodder beet varieties with one variety of sugar beets. The other, Haas (2), in his study of the chloride content of the pinnae and fruit from a large number of date palm varieties found a wide variation among the varieties grown under similar conditions. The same variety, grown in different localities, also showed considerable variation in chloride content.

EXPERIMENTAL PROCEDURE

This study has been confined to crops grown on the set of twenty plots known as the "Salt series" on the College Experimental Muck Farm in Clinton County, Michigan. These plots were established by Dr. Harmer in 1942 on virgin muck. Five treatments in duplicate are concerned in this study. Eight of these plots had received three annual applications of 1000 pounds per

acre of a 0-10-30 commercial fertilizer. The potash in this mixture was supplied from commercial muriate of potash containing 60% potash. The two remaining plots, number 36 in each replication, were given an equivalent amount of potassium in the form of Carlsbad Mine-Run Potash. The plot designations together with the amounts of salt applied are given below.

Plot (East and West Replication)	Pounds of Salt per Acre (Applied Annually Since 1942)
23	None
24	500
36	778*
39	1000
42	None

Both the fertilizer and salt were broadcasted on the surface each spring and thoroughly disked in. Four varieties of celery were transplanted to the plots in the summer of 1945 while three varieties of sugar beets were sown that spring. All were harvested in the fall of 1945 and representative samples taken for chemical analysis. In 1945 samples of the entire plants of the Lincoln variety of peas sown in the spring were secured

*The equivalent amount of 25% Carlsbad Potash contains 56% salt making an annual salt application of 778 pounds per acre.

Table 1. Effects of applying salt to muck soil upon the content of potash, chloride, and soda in four varieties of celery grown thereon.

Plot	Annual Salt Application	Yield Tons per acre	Increase ¹	% Moisture	Percentage			In Crop								
					Water-			Free Basis			Fresh Weight Basis					
					K ₂ O	Inc ¹	Cl	Inc ¹	Na ₂ O	Inc ¹	K ₂ O	Inc ¹	Cl	Inc ¹	Na ₂ O	Inc ¹
Summer								Pascal								
33 / 42	0	42.0	---	92.68	6.62	---	3.28	---	0.70	---	0.485	---	0.240	---	0.051	---
34	500	46.7	11.2	93.30	6.40	-3.3	4.67	42.4	1.98	184.8	0.429	-11.6	0.313	30.4	0.133	160.8
39	1000	49.2	17.1	93.06	6.21	-6.3	5.37	63.6	2.59	272.2	0.431	-11.1	0.372	55.0	0.180	252.9
36	778 ²	51.9	23.6	93.56	6.07	-8.3	5.68	6673.0	2.24	220.8	0.391	-19.4	0.365	52.1	0.144	182.4
Average	Increase	7.3	17.4	0.63	-0.39	-6.0	1.96	59.7	1.57	226.0	-0.068	-14.0	0.110	45.8	0.101	198.0
A and C								Special 763								
33 / 42	0	40.5	---	91.60	5.58	---	2.62	---	0.62	---	0.468	---	0.220	---	0.052	---
34	500	48.2	19.0	92.80	5.44	-2.6	4.70	79.2	2.97	380.1	0.391	-16.4	0.338	53.6	0.214	311.5
39	1000	53.5	32.1	92.80	4.99	-10.4	6.17	135.3	3.38	445.2	0.360	-23.1	0.444	101.8	0.243	367.3
36	778 ²	52.6	29.9	92.96	5.22	-6.4	5.73	118.5	3.17	411.8	0.367	-21.6	0.403	83.2	0.223	328.8
Average	Increase	10.9	26.9	1.25	-0.36	-6.5	2.91	111.0	2.55	412.4	-0.095	-20.3	0.175	79.5	0.175	336.5
Supreme								Golden								
33 / 42	0	39.9	---	91.92	6.12	---	3.13	---	0.73	---	0.494	---	0.253	---	0.059	---
34	500	49.2	23.3	92.48	6.18	1.0	5.90	88.6	2.55	248.8	0.403	-18.4	0.385	52.2	0.166	181.4
39	1000	48.7	22.1	93.12	5.49	-10.2	6.48	107.0	3.14	330.1	0.378	-23.5	0.446	76.3	0.216	266.1
36	778 ²	48.2	20.8	93.36	4.81	-21.4	6.33	102.2	3.37	362.0	0.319	-35.4	0.420	66.1	0.224	279.7
Average	Increase	8.8	22.1	1.40	-0.63	-10.2	3.11	99.3	2.29	313.7	-0.127	-25.7	0.164	64.8	0.143	242.4
Superplume																
33 / 42	0	34.0	---	91.52	6.03	---	2.81	---	0.67	---	0.511	---	0.238	---	0.057	---
34	500	44.8	31.8	92.78	5.51	-8.6	5.46	94.4	3.14	367.9	0.398	-22.1	0.394	65.6	0.227	298.2
39	1000	46.3	36.2	93.30	4.99	-17.2	6.98	148.7	3.75	457.4	0.335	-34.4	0.468	96.6	0.251	340.4
36	778 ²	44.3	30.3	93.30	5.19	-13.9	6.41	128.4	3.52	424.1	0.348	-31.9	0.430	80.7	0.236	314.0
Average	Increase	11.1	32.6	1.61	-0.80	-13.2	3.47	123.8	2.80	416.5	-0.151	-29.6	0.193	81.1	0.181	317.5

¹ Percentage increase (+) or decrease (-) resulting from salt applications

² 25% Carlsbad Potash containing 56% salt.

Chemical Composition

Water---With every variety the application of salt slightly increased the amount of water present in the plant at harvest time.

Potash---The percentage of potash in all varieties decreased with the application of salt. Superplume showed the greatest decrease while Summer Pascal displayed the least. With the salt application Summer Pascal averaged 17% more potash than did the yellow varieties.

Chlorides---With increasing salt applications there was a marked rise in the chloride content of every variety. Without salt A&C Special 763 showed the lowest and Summer Pascal the highest chloride content. Whereas Superplume absorbed the most chloride with the addition of salt, Summer Pascal absorbed the least.

Soda---A marked rise in the soda content of all varieties resulted from increasing applications of salt. The greatest increase in soda as the result of salt applications was attained by Superplume while Summer Pascal showed considerably less than any of the yellow varieties.

Mineral Removal From Soil

Table 2 shows the effect of varying salt applications with four celery varieties on the amount of potash, chloride,

Table 2. Effect of applying salt to a muck soil upon the removal of potash, chlorides, and soda by four varieties of celery and their variation in their ability to recover applied salt.

Plot	Annual Salt Application	Pounds Removed Per Acre						% of applied sodium removed
		K ₂ O	Inc ¹	Cl	Inc ¹	Na ₂ O	Inc ¹	
Summer Pascal								
33 / 42	0	407.4	---	201.6	---	42.8	---	---
34	500	400.7	-1.6	292.3	45.0	124.2	190.0	30.7
39	1000	424.1	4.1	366.0	81.6	177.1	313.4	25.3
36	778 ²	405.9	-0.4	378.9	88.0	149.5	248.9	25.9
Average	Increase	2.8	0.7	144.1	71.5	107.5	250.8	27.3
A and C Special 763								
33 / 42	0	379.1	---	178.2	---	42.1	---	---
34	500	376.9	*0.6	325.8	82.8	206.3	389.6	61.9
39	1000	385.2	1.6	475.1	166.6	260.0	517.3	41.1
36	778 ²	386.1	1.8	424.0	137.9	234.6	457.0	46.7
Average	Increase	3.6	1.0	230.1	129.1	191.5	454.7	49.9
Supreme Golden								
33 / 42	0	394.2	---	201.9	---	47.1	---	---
34	500	396.6	0.6	378.8	87.6	163.3	246.9	43.8
39	1000	368.2	-6.6	434.4	115.2	210.4	346.9	30.8
36	778 ²	307.5	-22.0	404.9	100.5	215.9	358.7	40.9
Average	Increase	*36.8	-9.3	204.1	101.1	149.4	317.5	38.5
Superplume								
33 / 42	0	347.5	---	162.8	---	38.8	---	---
34	500	356.6	2.6	353.0	116.8	203.4	424.7	62.1
39	1000	310.2	-10.7	433.4	166.2	232.4	499.7	36.5
36	778 ²	308.3	-11.3	381.0	134.0	209.1	439.5	41.3
Average	Increase	-22.5	-6.5	226.3	139.0	176.2	454.6	46.6

¹ Percentage increase (+) or decrease (-) resulting from salt applications.

² 25% Carlsbad Potash containing 56% salt.

and soda removed. The percent of the applied sodium which was recovered by the variety is also given.

Potash---Summer Pascal removed more potash from the soil than did any of the other varieties while Superplume removed the least. The salt and mine-run applications did not appreciably effect the amount of potash removed by Summer Pascal and A & C Special 763. The 500-pound salt application had no appreciable effect on the potash removal by Supreme Golden and Superplume, but the heavier salt applications resulted in a slight decrease in the amount removed. The least potash was removed by Supreme Golden receiving mine-run potash.

Chlorides---The amount of chloride removed by the crop increased in all varieties with the amount of salt applied. The mine-run potash application resulted in less chloride removed than from the 1000-pound salt application with all varieties except Summer Pascal. Superplume without salt removed the least chloride. With the heaviest salt application the largest amount of chloride was removed by A & C Special 763 and the least by Summer Pascal.

Soda---The amount of soda removed by the crop increased in all varieties with the increase in salt applications. With Supreme Golden the application of mine-run potash resulted in the removal of slightly more soda

than from the 1000-pound salt application. With the heaviest salt application A & C Special 763 removed the most soda and Summer Pascal the least.

Proportion of Applied Sodium in Harvested Crop---
Superplume removed the highest percentage of the sodium applied in the salt while Summer Pascal removed the lowest percentage.

Mineral Ratios

Table 3 presents the ratio of these three mineral constituents to each other as found in the dried plant material.

Potash-Soda---The widest spread in potash to soda occurs in celery from those areas receiving no salt. This ratio decreased markedly with all varieties as the salt application increased. Supreme Golden has a slightly wider ratio with the 1000-pound salt application than with the mine-run potash. Of all four varieties Summer Pascal, a green variety, showed the widest ratio of potash to soda whereas all of the other varieties showed quite similar ratios.

Potash-Chloride---With all four varieties the potash-chloride ratio decreases as the salt applications increased. With all three salt treatments Summer Pascal showed a slightly wider ratio of potash to chloride while those

Table 3. Ratio of contents of mineral constituents in four varieties of celery grown on muck soil receiving salt applications. (Water-free basis)

Plot	Annual Salt Application	Ratios		
		K ₂ O/Na ₂ O	K ₂ O/Cl	Na ₂ O/Cl
Summer Pascal				
33 / 42	0	9.5	2.0	0.21
34	500	3.2	1.4	0.42
39	1000	2.4	1.2	0.48
36	778*	2.7	1.1	0.39
A and C Special 763				
33 / 42	0	9.0	2.1	0.24
34	500	1.8	1.2	0.63
39	1000	1.5	0.8	0.55
36	778*	1.6	0.9	0.55
Supreme Golden				
33 / 42	0	8.3	2.0	0.23
34	500	2.4	1.0	0.43
39	1000	1.8	0.8	0.48
36	778*	1.4	0.8	0.53
Superplume				
33 / 42	0	9.0	2.1	0.24
34	500	1.8	1.0	0.58
39	1000	1.3	0.7	0.54
36	778*	1.5	0.8	0.55

* 25% Carlsbad Potash containing 56% salt.

of the other three varieties were very similar.

Soda-Chloride---This ratio increases with the application of salt, but there is no consistent variation in the ratio with the different amounts of salt. With all four treatments Summer Pascal shows the narrowest ratio of soda to chloride. A & C Special 76Z and Superplume are the highest and Supreme Golden intermediate.

Sugar Beets

The data appearing in table 4 shows the effect of varying salt applications on the yield,* potash, chloride and soda* contents, both on a water-free and green bases, of the roots, tops, and tops and roots combined of three varieties of sugar beets.**

Yield

With increasing amounts of salt applied, Kuhn P and Schreibers S S responded with considerable yield in-

*The yield data presented in this thesis were obtained by Dr. Harmer and the Na_2O analysis by Dr. Benne and staff while the author was in military service. The data is used with their permission in making comparisons and drawing conclusions.

**The crowns were cut from the roots as is done on a commercial basis. Therefore the yields and analyses are of the roots (crowns removed) and of the leaves and crowns combined. The crowns and leaves were analyzed separately, but the results are combined in this data.

Table 4. Effects of applying salt to muck soil upon the content of potash, chloride, and soda in three varieties of sugar beet grown there-upon.

Plot	Annual Salt Application	Yield Tons per acre	Increase*	% Moisture	Percentage in Crop											
					Water-free Basis						Fresh Weight Basis					
					K ₂ O	Inc*	Cl	Inc*	Na ₂ O	Inc*	K ₂ O	Inc*	Cl	Inc*	Na ₂ O	Inc*
M S C Muck Beet (Roots)																
33	0	15.37	---	77.29	1.777	---	0.104	---	0.079	---	0.402	---	0.024	---	0.018	---
34	500	16.47	7.2	76.33	1.61	-8.8	0.143	37.5	0.206	160.8	0.382	-5.0	0.034	41.7	0.049	172.2
39	1000	16.08	4.6	76.08	1.51	-14.6	0.192	84.6	0.219	177.2	0.362	-10.0	0.046	91.7	0.053	194.4
Average	Increase	0.91	5.9	---	-0.21	-11.7	0.064	61.5	0.134	169.6	-0.030	-7.5	0.016	66.7	0.033	183.3
Kuhn P (Roots)																
33	0	10.21	---	79.84	1.95	---	0.174	---	0.155	---	0.393	---	0.035	---	0.032	---
34	500	12.56	23.0	79.02	1.72	-11.5	0.287	64.9	0.434	180.0	0.362	-7.9	0.060	71.4	0.091	184.4
39	1000	15.11	48.0	77.17	1.32	-32.3	0.345	98.3	0.393	153.6	0.301	-23.4	0.079	125.7	0.089	178.1
Average	Increase	3.62	35.5	---	-0.43	-21.9	0.142	81.6	0.258	166.4	-0.061	-15.5	0.034	97.1	0.058	181.2
Schreibers S S (Roots)																
33	0	9.27	---	80.74	1.78	---	0.159	---	0.195	---	0.342	---	0.031	---	0.038	---
34	500	12.24	32.0	80.00	1.87	5.2	0.339	113.2	0.580	197.4	0.374	9.4	0.068	119.4	0.116	205.3
39	1000	13.94	50.4	78.36	1.57	-11.5	0.386	142.8	0.493	152.8	0.340	-0.6	0.084	171.0	0.107	181.6
Average	Increase	3.82	41.2	---	-0.15	-8.3	0.204	128.3	0.342	175.4	0.015	4.4	0.045	145.2	0.074	194.7
M S C Muck Beet (Tops)																
33	0	15.76	---	83.30	4.38	---	1.82	---	0.62	---	0.732	---	0.303	---	0.104	---
34	500	16.69	5.9	81.59	3.85	-12.3	2.67	46.9	2.04	227.0	0.708	-3.3	0.491	62.0	0.375	260.6
39	1000	16.32	3.6	81.93	3.61	-17.7	2.61	98.8	1.90	205.6	0.652	-10.9	0.471	55.4	0.344	230.8
Average	Increase	0.74	4.7	---	-0.66	-15.0	1.32	72.9	1.35	215.4	-0.052	-7.1	0.178	58.8	0.256	246.2
Kuhn P (Tops)																
33	0	7.42	---	80.86	3.86	---	1.48	---	0.55	---	0.739	---	0.283	---	0.106	---
34	500	8.85	19.3	79.25	3.34	-14.3	1.95	31.9	1.52	174.0	0.693	-6.2	0.405	43.1	0.315	197.2
39	1000	9.72	31.0	80.63	3.35	-13.2	2.86	93.0	1.93	248.6	0.649	-12.2	0.553	95.4	0.374	252.8
Average	Increase	1.86	25.1	---	-0.53	-13.8	1.87	62.5	1.17	211.2	-0.068	-9.2	0.196	69.3	0.238	224.5
Schreibers S S (Tops)																
33	0	8.45	---	80.41	4.17	---	1.78	---	0.63	---	0.816	---	0.349	---	0.123	---
34	500	11.40	34.9	81.31	3.76	-9.8	2.53	42.0	2.01	219.4	0.702	-14.0	0.473	35.5	0.375	204.9
39	1000	13.24	56.7	82.46	3.67	-11.9	3.61	102.5	2.58	310.4	0.644	-21.1	0.633	81.4	0.452	267.5
Average	Increase	3.87	45.8	---	-0.45	-10.8	1.29	72.3	1.66	265.0	-0.143	-17.5	0.204	58.4	0.290	235.8
M S C Muck Beet (Total)																
33	0	31.13	---	80.33	2.89	---	0.84	---	0.32	---	0.569	---	0.165	---	0.062	---
34	500	33.16	6.5	78.98	2.60	-10.3	1.26	49.7	1.01	221.6	0.546	-4.0	0.264	60.0	0.213	243.6
39	1000	32.40	4.1	79.03	2.42	-16.3	1.24	47.8	0.95	202.9	0.508	-10.7	0.260	57.6	0.200	222.6
Average	Increase	1.65	5.3	---	-0.38	-13.3	0.41	48.8	0.67	212.1	-0.042	-7.4	0.097	58.8	0.144	232.3
Kuhn P (Total)																
33	0	17.63	---	80.27	2.73	---	0.70	---	0.32	---	0.539	---	0.139	---	0.063	---
34	500	21.41	21.4	79.11	2.39	-12.6	0.97	38.1	0.88	176.2	0.499	-7.4	0.203	46.0	0.184	192.1
39	1000	24.83	40.8	78.52	2.04	-25.5	1.23	75.3	0.94	193.4	0.437	-16.9	0.265	90.6	0.201	219.0
Average	Increase	5.49	31.1	---	-0.52	-19.0	0.40	56.7	0.59	185.0	-0.071	-13.2	0.095	68.3	0.130	206.4
Schreibers S S (Total)																
33	0	17.72	---	80.58	2.92	---	0.94	---	0.41	---	0.568	---	0.183	---	0.079	---
34	500	23.64	33.4	80.63	2.75	-6.1	1.36	44.2	1.24	205.6	0.532	-6.3	0.263	43.7	0.241	205.1
39	1000	27.18	53.4	80.36	2.48	-15.1	1.79	89.7	1.40	244.0	0.488	-14.1	0.351	91.8	0.275	248.1
Average	Increase	7.69	43.4	---	-0.31	-10.6	0.63	66.9	0.92	224.8	-0.058	-10.2	0.124	67.8	0.179	226.6

Percentage increase (+) or decrease (-) resulting from salt applications.

creases of both roots and tops. The MSC Muck Beet showed a yield increase with the 500-pound treatment, but the 1000-pound application resulted in a slight decrease in both root and top yield below that with the 500-pound application. Both the highest root and top yield were attained by this variety grown on areas receiving 500 pounds of salt. Schreibers S S produced the lowest root yield and Kuhn P the lowest yield of tops on those areas receiving no salt. The MSC Muck Beet showed the least yield response to the addition of salt and Schreibers S S the greatest response.

Chemical Composition

The analysis agree with those of Harmer and Benne (4) in that the roots contain the lowest percentage of the three constituents determined. Before combining the percentages found in the leaves and crowns, it was found that the latter were intermediate between leaves and roots in content of the different constituents.

Potash---With the single exception in the case of the Schreibers S S roots receiving 500 pounds of salt, both tops and roots of all three varieties showed a decrease in potash content with increase in salt application. When the entire plant is considered, Schreibers S S also shows this decrease. The greatest decrease as the result of the addition of salt is shown by Kuhn P and the

least by Schreibers S S.

Chloride---With the exception of the tops of the MSC Muck Beet, both roots and tops of all varieties showed a decided increase in chloride content with each increasing application of salt. The tops of the MSC Muck Beet showed a slight decrease with the 1000-pound below that of the 500-pound application. Most noteworthy is the fact that the roots of the MSC Muck Beet contained only about half as much chloride as did those of the other two varieties even though the chloride content of the tops of all varieties was somewhat similar.

Soda---The 1000-pound salt application produced slightly less soda than did the 500 pound application in the tops of the MSC Muck Beet and the roots of Kuhn P and Schreibers S S. On the other hand the roots of the MSC Muck Beet and the tops of Kuhn P and Schreibers S S showed an increasing amount of soda as the salt application was increased. Considering the entire plant, the highest increase in soda as the result of salt applications was shown by Schreibers S S and the least by Kuhn P. The most important difference in the composition of the three varieties is evident in the much lower content of soda in the roots of the MSC Muck Beet than in those of the other two varieties, even though the soda content of the tops is similar in all varieties.

Mineral Removal From Soil

Table 5 shows the effect of varying salt applications with three sugar beet varieties on the amount of potash, chloride, and soda removed from the soil. The percent of applied sodium recovered by the plant is also shown.

Potash---Kuhn P and Schreibers S S removed increasingly larger amounts of potash with increasing salt applications. The MSC Muck Beet removed slightly less potash from the area receiving 1000 pounds of salt than from the area receiving none, while the 500-pound salt application showed no appreciable effect on potash removal. All three treatments showed considerably more potash removed by both roots and tops of the MSC Muck Beet than by those of either of the other varieties. Considering the entire crop, Kuhn P removed the least potash. The greatest increase in the amount of potash removed as the result of salt applications was given by Schreibers S S while the MSC Muck Beet showed a slight decrease.

Chlorides---Schreibers S S and Kuhn P in both their roots and tops and the MSC Muck Beet in its roots removed more chloride with increasing salt applications. The MSC Muck Beet removed in its tops more chloride with the addition of salt, but less with the 1000 than with the 500-pound treatment. Without the salt application

the MSC Muck Beet removed considerably more chloride in the *tops* than did the other varieties but, with salt applied, the Schreibers S S showed the greatest increase in removal of chloride.

Soda---In general less soda was removed by the roots and more by the tops of the MSC Muck Beet than by the other varieties, whether or not salt was applied. Schreibers S S showed the greatest and the MSC Muck Beet the least increase in *Soda* removal resulting from the salt applications.

Proportion of Applied Sodium in Harvested Crop---Schreibers S S removed in the roots the highest percentage of the sodium applied in the salt from the area receiving the 500-pound treatment while the lowest percentage was removed from the plots receiving the 1000-pound application by the MSC Muck Beet. This last mentioned variety removed in its tops and in the entire plant the highest percentage of applied sodium from the 500-pound area, while the lowest percentage was removed from those plots receiving the greatest amount of salt by the tops and total plant of Luhn P.

Mineral Ratios

Table 6 presents the ratios of these three constituents found in the dried plant material.

Potash-Soda---Considering all three sugar beet var-

Table 5. Effect of applying salt to a muck soil upon the removal of potash, chlorides, and soda by three varieties of sugar beet and their variation in their ability to recover applied salt.

Plot	Annual Salt Application	Pounds Removed Per Acre					Inc*	% of Applied Sodium Removed
		K ₂ O	Inc*	Cl	Inc*	Na ₂ O		
M S C Muck Beet (Roots)								
33	0	123.6	---	7.4	---	5.5	---	---
34	500	125.8	1.8	11.2	51.4	16.1	191.9	4.0
39	1000	116.4	-5.8	14.8	99.9	17.0	208.1	2.2
Average	Increase	-2.5	-4.0	5.6	75.7	11.0	200.0	3.1
Kuhn P (Roots)								
33	0	80.2	---	7.2	---	6.5	---	---
34	500	90.9	13.3	15.1	110.8	22.9	250.1	6.2
39	1000	91.0	13.5	23.9	233.8	26.9	311.9	3.8
Average	Increase	10.8	13.4	12.3	172.3	18.4	281.0	5.0
Schreibers S S (Roots)								
33	0	63.4	---	5.8	---	7.0	---	---
34	500	91.6	44.4	16.6	189.6	28.4	303.4	8.1
39	1000	94.8	49.5	23.4	307.3	29.8	323.7	4.3
Average	Increase	29.8	46.9	14.2	248.3	22.1	313.6	6.2
M S C Muck Beet (Tops)								
33	0	230.7	---	95.5	---	32.8	---	---
34	500	236.3	2.4	163.9	71.6	125.2	281.7	34.4
39	1000	212.8	-7.8	153.7	60.9	112.3	242.4	15.0
Average	Increase	-6.2	-2.7	63.3	66.3	86.0	262.2	24.7
Kuhn P (Tops)								
33	0	109.7	---	42.0	---	15.7	---	---
34	500	122.7	11.8	71.7	70.7	55.8	255.4	15.1
39	1000	126.2	15.0	107.5	156.0	72.7	363.1	10.8
Average	Increase	14.8	13.5	47.6	113.3	48.6	309.6	13.0
Schreibers S S (Tops)								
33	0	137.9	---	59.0	---	20.8	---	---
34	500	160.0	16.0	107.8	82.1	85.5	311.1	24.4
39	1000	170.5	23.6	167.6	184.1	119.7	475.5	18.7
Average	Increase	27.4	19.9	68.8	116.6	81.8	393.3	21.6
M S C Muck Beet (Total)								
33	0	354.3	---	102.9	---	38.3	---	---
34	500	362.1	2.2	175.1	70.2	141.3	268.9	38.4
39	1000	329.2	-7.1	168.5	63.8	129.3	237.6	17.2
Average	Increase	-8.6	-2.4	68.9	67.0	97.0	253.3	27.8
Kuhn P (Total)								
33	0	190.0	---	49.2	---	22.2	---	---
34	500	213.6	12.4	86.8	76.4	78.7	254.0	21.3
39	1000	217.2	14.3	131.4	167.1	99.6	348.0	14.6
Average	Increase	25.4	13.4	59.9	121.8	67.0	301.0	17.0
Schreibers S S (Total)								
33	0	201.3	---	64.8	---	27.8	---	---
34	500	251.6	25.0	124.4	92.0	113.9	309.7	32.5
39	1000	265.3	31.8	191.0	194.8	149.5	437.8	23.0
Average	Increase	57.2	28.4	92.9	143.4	103.9	373.7	27.8

* Percentage increase (+) or decrease (-) resulting from salt applications.

ieties, the widest spread in potash to soda occurs in those plants grown without salt. This ratio decreases greatly as the salt application increases. There is a wider ratio in the roots than in the tops of each variety. Considering the entire plant the widest ratio of potash to soda occurs with the MSC Muck Beet while Schreibers S S has the narrowest.

Potash-Chloride---In all three sugar beet varieties the widest spread in potash to chloride occurs in plants from those areas receiving no salt. As the salt treatments increase, this ratio decreases. There is also a wider ratio in the roots than in the tops of each variety. Taking the entire plant Kuhn P has slightly the widest ratio and Schreibers S S the narrowest.

Soda-Chloride---In each variety the narrowest spread in soda to chloride occurs in those plants from the area receiving no salt. There is a wider ratio in the roots than in the tops. With each variety the ratio with the 500-pound salt application is slightly higher than with the 1000-pound treatment. Considering the entire plant, the ratios are almost identical.

Peas

No soda determinations were made on the peas. Since the dry weight of the straw was not determined, no figures as to the total amount of mineral constituents removed from the soil can be given.

Table 6. Ratio of contents of mineral constituents in three varieties of sugar beet grown on a muck soil receiving salt applications. (Water-free basis)

Plot	Annual Salt Application	Ratios		
		K ₂ O/Na ₂ O	K ₂ O/Cl	Na ₂ O/Cl
M S C Muck Beet (Roots)				
33	0	22.4	17.0	0.8
34	500	7.8	11.3	1.4
39	1000	6.9	7.9	1.1
Kuhn P (Roots)				
33	0	12.6	11.2	0.9
34	500	4.0	6.0	1.5
39	1000	3.4	3.8	1.1
Schreibers S S (Roots)				
33	0	9.1	11.2	1.2
34	500	3.2	5.5	1.7
39	1000	3.2	4.1	1.3
M S C Muck Beet (Tops)				
33	0	7.0	2.4	0.3
34	500	1.9	1.4	0.8
39	1000	1.9	1.4	0.7
Kuhn P(Tops)				
33	0	7.0	2.6	0.4
34	500	2.2	1.7	0.8
39	1000	1.7	1.2	0.7
Schreibers S S (Tops)				
33	0	6.6	2.3	0.4
34	500	1.9	1.5	0.8
39	1000	1.4	1.0	0.7
M S C Muck Beet (Total)				
33	0	9.2	3.4	0.4
34	500	2.6	2.1	0.8
39	1000	2.5	2.0	0.8
Kuhn P (Total)				
33	0	8.6	3.9	0.5
34	500	2.7	2.5	0.9
39	1000	2.2	1.7	0.8
Schreibers S S (Total)				
33	0	7.2	3.1	0.4
34	500	2.2	2.0	0.9
39	1000	1.8	1.4	0.8

Table 7 presents data showing the effect of varying salt applications on the yield,* potash, and chloride content on a water-free basis of the pea grain and straw.

Yield

The yields of both pea grain and straw were very erratic. The 1000-pound salt application resulted in a marked decline in the grain yield of all varieties and in the straw of every variety but Bliss Everbearing. The straw and grain yield from the Lincoln variety and the straw of Dwarf Telephone and Wisconsin Perfection decreased with all salt treatments. The straw yield of Bliss Everbearing increased with the application of salt although this increase showed no relation to the amount of added salt. The grain yields of Bliss Everbearing, Dwarf Telephone, and Wisconsin Perfection increased considerably with the 500-pound and mine-run potash treatments. The greatest decrease in yield as the result of the salt applications was shown by the grain of Lincoln and the straw of Wisconsin Perfection.

Chemical Composition

Potash---The potash content of the straw was more

*The yield data presented in this thesis were obtained by Dr. Harmer. The data is used with his permission in making comparisons and drawing conclusions.

Table 7. Effects of applying salt to muck soil upon the content of po-

tash and chloride in four varieties of peas grown thereupon.

Plot	Annual Salt Application	Yield Pounds per acre	Incl	Grain				Yield Tons per acre	Incl	Straw			
				Percentage in Crop ⁴						Percentage in Crop			
				K ₂ O	Incl	Cl	Incl			K ₂ O	Incl	Cl	Incl
Lincoln													
33 / 42	0	993.8	---	1.80	---	0.142	---	1.42	---	4.50	---	1.60	---
34	500	736.6	-25.8	1.94	8.3	0.260	83.1	1.21	-14.8	4.98	10.7	2.76	72.0
39	1000	654.2	-34.2	2.05	14.0	0.350	146.5	1.34	-5.6	4.07	-9.7	4.10	156.0
36	778 ³	959.9	-3.4	1.68	-6.6	0.190	23.8	0.98	-21.0	4.40	-2.2	3.04	89.5
Average increase		-210.2	-21.2	0.09	5.2	0.125	88.0	-0.24	-16.9	-0.02	-0.4	1.70	105.9
Bliss Everbearing													
33 / 42	0	1066.6	---	1.84	---	0.109	---	1.17	---	4.40	---	1.57	---
34	500	1248.6	17.1	1.96	6.9	0.188	72.5	1.32	12.8	4.08	-7.3	2.70	72.2
39	1000	825.4	-22.6	1.96	6.9	0.502	360.6	1.27	8.6	3.91	-11.2	4.86	210.0
36	778 ³	1316.3	23.4	1.82	-1.1	0.246	125.7	1.24	6.0	3.86	-12.3	3.76	140.3
Average increase		63.5	6.0	0.07	4.2	0.203	186.2	0.11	9.4	-0.45	-10.3	2.21	140.8
Dwarf Telephone													
33 / 42	0	859.7	---	1.80	---	0.132	---	1.32	---	4.45	---	1.43	---
34	500	1210.5	40.8	1.91	6.0	0.202	53.0	1.32 ²	---	4.24	-4.7	2.81	96.0
39	1000	677.6	-21.2	1.92	6.6	0.414	213.6	1.13	-14.4	3.66	-17.7	3.79	164.2
36	778 ³	1156.1	34.6	1.78	-1.1	0.222	68.2	0.97	-26.5	4.03	-9.6	3.52	145.2
Average increase		155.0	18.1	0.07	3.9	0.147	111.4	-0.27	-20.4	-0.47	-10.6	1.94	135.1
Wisconsin Perfection													
33 / 42	0	937.5	---	1.81	---	0.121	---	2.31	---	4.85	---	1.88	---
34	500	1192.6	27.2	1.91	5.7	0.306	152.9	1.98	-14.3	4.75	-1.9	2.92	54.9
39	1000	778.7	-16.9	2.22	23.0	0.611	405.0	2.06	-10.8	4.03	-16.8	3.90	107.3
36	778 ³	1349.0	43.9	1.98	9.7	0.219	81.0	1.44	-37.7	4.39	-9.3	3.31	75.9
Average increase		169.3	18.1	0.23	12.8	0.258	213.2	-0.48	-20.8	-0.46	-9.4	1.50	79.4

¹Percentage increase (+) or decrease (-) resulting from salt applica-

tions.

²This plot was lost at threshing time.³25% Carlsbad Potash containing 56% salt.⁴Determined on a water-free basis.

than twice as great as that of the grain. The percentage of potash in the grain of all varieties increased with the 500 and 1000-pound salt treatments and with the exception of Wisconsin Perfection decreased with the mine-run potash. Wisconsin Perfection showed a potash content increase with the mine-run potash. The potash content of the straw of all varieties but Lincoln decreased with the application of salt. Lincoln showed an increase with the 500-pound treatment and a decrease with the mine-run potash and the 1000-pound salt treatment. Wisconsin Perfection showed the highest increase in potash content of the grain as the result of applied salt while the increases in the other varieties were rather uniform.

Chlorides---The different pea straw varieties contained from 5 to 15 times as much chloride as did the grain. The percentage increased with increasing applications of salt in both straw and grain of all varieties. With both Lincoln and Wisconsin Perfection there was a slight decrease in the chloride content of the grain grown on the areas receiving mine-run potash below that grown on the plots receiving 500 pounds of salt. The least percentage increase of chlorides in the straw as the result of applied salt was given by Wisconsin Perfection and the greatest by Bliss Everbearing. The least increase of chlorides in the grain was given by Lincoln

and the greatest by Wisconsin Perfection.

Mineral Ratio

Table 8 presents the ratio of potash to chloride in the dried peas and straw. In each pea variety the widest spread in potash to chloride occurs in both the grain and straw of plants from those areas receiving no salt. The ratio in the straw is much more narrow than in the grain. With the straw of every variety and with the grain of all but Wisconsin Perfection and Lincoln, the ratio of potash to chloride decreases with each increasing salt application. These two varieties show a broader ratio with the mine-run potash than with the 500-pound salt application.

Immature Lincoln Peas

Table 9 presents on a water-free basis the percentage of potash, chloride, and soda* and the ratios of these constituents found in Lincoln peas harvested just as the peas were hardening. There is a decrease in the potash content with all applications of salt although this shows no relation to the amount of salt applied. Both the soda and chloride contents consistently increase as the amount of salt is increased. The potash-soda ratio is

*The Na_2O analysis were performed by Dr. Bonne and staff while the author was in military service. The data is used with their permission in making comparisons and drawing conclusions.

Table 8. Ratio of contents of potash to chloride in the grain and straw of four varieties of pea grown on a muck soil receiving salt applications.
(Water free basis)

Plot	Annual Salt Application	K ₂ O/Cl	
		Grain	Straw
Lincoln			
33 / 42	0	12.6	2.8
34	500	7.5	1.8
39	1000	5.8	1.0
36	778*	8.8	1.5
Bliss Everbearing			
33 / 42	0	16.8	2.8
34	500	10.5	1.5
39	1000	3.9	0.8
36	778*	7.4	1.0
Dwarf Telephone			
33 / 42	0	13.7	3.1
34	500	9.5	1.5
39	1000	4.6	1.0
36	778*	8.0	1.1
Wisconsin Perfection			
33 / 42	0	15.0	2.6
34	500	6.3	1.6
39	1000	3.6	1.0
36	778*	9.1	1.3

* 25% Carlsbad Potash containing 56% salt.

Table 9. Effects of applying salt to much soil on the percentage of mineral constituents and the ratio of these constituents found in immature Lincoln peas.

Plot	Annual Salt Application	Percentage Composition						Ratios		
		K ₂ O	Inc*	Cl	Inc*	Na ₂ O	Inc*	$\frac{K_2O}{Na_2O}$	$\frac{K_2O}{Cl}$	$\frac{Na_2O}{Cl}$
23 42	0	3.27	—	1.01	—	0.075	—	47.0	3.2	0.07
34	500	2.74	-15.2	1.44	43.2	0.164	118.7	16.7	1.9	0.11
39	1000	3.10	-4.2	2.66	162.5	0.415	457.3	7.3	1.1	0.16
36	778**	2.85	-11.7	1.44	43.2	0.166	121.7	17.2	2.0	0.12
Avrg.	Inc	-0.33	-10.4	0.84	83.0	0.280	271.1			

very high in that material grown on the area receiving no salt. With the 1000-pound treatment it is the narrowest but is slightly higher with the mine-run potash than with the ~~mine-run potash~~ than with the 500-pound application. The potash-chloride ratio varies similarly whereas there is slight change in the soda-chloride ratio.

* Percentage increase (+) or decrease (-) resulting from salt applications.

DISCUSSION

Celery and sugar beets have long been regarded as crops showing decided responses to salt applications in the presence of adequate supplies of potash. (5,6,9,12). The data in the preceding sections also show there is a considerable variation in the yield response of different varieties of each of these crops to salt applications. With the four celery varieties it is notable that the percentage composition of both soda and chloride are in the same order as their yield responses to the application of salt, the highest content contained by the variety showing the greatest yield response. The percentage of chloride absorbed was increased one-half to three-quarters by the salt application and the soda percentage three to four times. This further confirms the views of Harmer and Bonne (6) that soda is a plant nutrient for these crops.

Summer Pascal, a green variety of celery, showed somewhat less response to salt, as evidenced by yield increases, than did the other three, which were of the golden type of celery. This data confirms yield data with green and golden varieties secured by Harmer (4) in 1944. It would appear probable that this difference is correlated with the fact that Summer Pascal absorbed considerably less soda and slightly less chloride when salt was applied than did the three golden varieties.

It also contained a higher percentage of potash and removed more potash in the total crop than was removed by the golden celery.

The sugar beet variety, Schreibers S S, showing the greatest total yield increase as the result of salt applications, also contained the highest percentage of both soda and chloride. Here the percentage of chloride was increased by the salt application from 50 to 100 percent and the soda from approximately 200 to 250 percent. It seems safe to assume that those varieties of both celery and sugar beets which show the greatest yield response to applications of salt are more capable of utilizing these constituents in their metabolic activities.

The slight decrease in potash in the dried plant material as the result of salt applications, as shown in the foregoing data, has also been observed by past investigators (5,6,12). The total amount of potash removed from the soil is generally higher with salt applications. However, the celery varieties Supreme Golden and Superplume do show a slight decrease in the amount of potash removed from the soil with the addition of salt.

Harmer and Benne (5,6), in referring to the response of various crops to the application of salt, stated "that the narrower the potash-soda ratio, the greater the in-

crease in yield which may be expected from a salt application along with potash." This statement was applied to the varieties of each of these crops taking into consideration only the potash-soda ratio of the plant material grown upon the acres which received no salt. Their statement holds true for each variety of the sugar beets, but does not for the celery varieties as Supreme Golden is an exception since it has the lowest potash-soda ratio with a yield increase only slightly greater than Summer Pascal which has the highest ratio.

However, there is a direct relation with the yield increases as the result of salt application and the percentage of soda found in the plant and the amount removed from the soil. The higher the percentage of soda in the plant, the greater the yield increases and the more soda removed from the soil. This holds true for both the celery and the sugar beets.

Processors (1, 11), in the extraction of sugar from the sugar beet, have long held that the presence of excessive amounts of soda and chloride in the beets interfered with the extraction of sugar. In fact when salt was first recommended at Michigan State College for the fertilization of the sugar beet, opposition was voiced by representatives of the sugar beet industry because of the possibility of such interference in sugar extraction by the additional soda and chloride absorbed. In

this connection it is interesting to note that the MSC Muck Beet actually absorbs a somewhat smaller percentage of soda and chloride in the roots than does the other two varieties, although the percentage in the tops is fairly uniform in all three varieties.

Neither the potash-chloride ratio nor the percentage of chloride found in the plant material show any relation to yield response of the peas to salt. Further study with this crop, using disease-free seed is planned.

Van Itallie (9) in his comparison of the potassium and sodium contents of the complete plant of four varieties of fodder beets with that of Luhn P found the various types showed a large difference in the assimilation of these constituents, but the ratio of potassium to sodium in the dry matter was almost constant, ranging from 2.1 to 1.8. This is a spread of only 0.3. The varieties considered in this paper when receiving the same treatment exhibited a much wider range (2 to 0.5) in their potash to soda ratios.

Peas are not generally regarded as a crop benefited by the application of salt. In 1945 Harmer (4) found a response in yield of this crop directly proportional to the amount of applied salt. It is suggested that the relative response of the salt-responsive crops is correlated with the seasonal climate (5). This abnormally

droughty season of 1946 may have been one which would result in peas showing detrimental effects of salt. The fact that the crop was rather badly afflicted with mosaic and root rot also may be a contributing factor for the erratic results obtained.

SUMMARY

Four celery and three sugar beet varieties were produced in 1945 and four pea varieties in 1946 upon a muck soil which had received varying amounts of common salt in addition to the usual fertilization. Plant tissue from these crops was analyzed for potash, chloride, and soda for the purpose of determining the effects of these salt treatments on the intake of these constituents by the various varieties of crops.

This investigation showed that the application of salt produced the following results:

1. The yield of celery and sugar beets was increased.
2. The chemical composition of the crops were affected as follows:
 - (a) The potash content of celery and sugar beets and of straw of peas was decreased slightly.
 - (b) The percentage of soda and chloride in celery sugar beets, and peas was markedly increased.

3. The total removal of the chemical constituents were effected as follows:
 - (a) Slightly more potash was removed from the soil by the sugar beets.
 - (b) Much more chloride and soda were removed from the soil by celery and sugar beets.
4. Ratios between the different constituents varied as follows:
 - (a) The potash-soda and potash chloride ratios of the celery, sugar beets and peas decreased.
 - (b) The soda-chloride ratio of the celery, sugar beets, and peas increased.
5. The four celery varieties and three sugar beet varieties may be ranked in order of their yield increases from the applications of salt by the percentage of soda in their dried tissue, the higher percentage indicating the greatest yield response.
6. The three sugar beet varieties may also be ranked in order of their yield increases from salt applications by the potash-soda ratio, the most narrow ratio indicating the greatest response.
7. Summer Pascal, a green variety of celery, gave a lower yield response and absorbed less soda and chloride with the application of salt than did the three golden varieties.



6. The MSC Much Beet showed a notably smaller percentage of soda and chloride in the roots than did the other two sugar beet varieties.

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