THE EFFECT OF POTASSIUM AND SODIUM ON THE YIELD AND CHEMICAL COMPOSITION OF SUGAR BEETS AND TABLE BEETS GROWN ON FOUR ORGANIC SOILS

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L. M. Turk
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An ABSTRACT

Submitted to the School of Graduate Studies of Michigan
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ABSTRACT

The Effect of Potassium and Sodium on the Yield and Chemical Composition of Sugar Beets and Table Beets Grown on Four Organic Soils.

The study was initiated to investigate factors that might be associated with the differential yield response of sugar beets and table beets, grown on different organic soils, to sodium chloride applications.

Four organic soils were obtained from various locations in Michigan and treated with four levels of potassium and three levels of salt under greenhouse conditions.

On October 16, 1951, sugar beet seeds, commerical grade 215x216, were planted and the crop harvested on March 3, 1952. Fresh and oven dry weights of roots and leaves were recorded.

The untreated soils were analyzed for the following constituents: Exchangeable potassium and sodium, pH, exchangeable hydrogen, total exchange capacity, exchangeable cations, percent base saturation, and percent organic matter. The exchangeable potassium and sodium of the soils and the total potassium and sodium of beet leaves and roots were analyzed after harvest.

Table beets were sampled weekly, beginning July 29, up to harvest, September 24, 1951, from an experiment at the Muck Experimental Farm. The fertilizer treatments consisted of four levels of potassium and two levels of sodium chloride. Fresh and oven dry weights of leaves and roots were recorded and total potassium and sodium determinations were made of leaf and root tissue.

The yield responses of sugar beets grown in the greenhouse, on four soils, to applications of salt were not the same as reported under field conditions. The yield increases due to applications of salt, were not associated with the amount of exchangeable sodium before the salt was added.

Less exchangeable sodium was found in all soils, after cropping, at the lower level than at the higher levels of potassium applications; however, the exchangeable sodium content in all soils increased with increasing increments of salt.

In general, the exchangeable potassium contents of the soils treated with different amounts of potassium were proportional to the potassium applied with no observable change in exchangeable potassium as a result ofthe salt treatment.

The application of salt to soils 1 and 3 produced a significant yield increase of sugar beet roots and there was an increase in yield of roots observed in soils 2 and 4 when treated with the lower rate of potassium plus salt.

There was a higher percentage of potassium and sodium in the sugar beet and table beet leaves than in the roots with all treatments. The sodium content of the leaves increased with increasing increments of salt to the soil under greenhouse conditions and the sodium content was not influenced by the potassium levels in the soil. With the lower levels of potassium and with the addition of increments of salt, the concentration of potassium in the sugar beet leaves generally was reduced.

Where the concentration of potassium in the sugar beet leaf was 1.72 percent or higher and when salt was applied to the soil, no potassium deficiency symptoms appeared. However, in the absence of a salt application, potassium deficiency symptoms were evident when the percent of potassium was less than 1.77.

Under field conditions the concentration of sodium in the leaves of table beets, was not affected by the addition of salt at any level of potassium application, and as the table beet matured, the percent of potassium in the leaves decreased, but the percent of sodium remained fairly constant.

An apparent substitution of sodium for potassium, in the nutrition of the sugar beets, occurred on soils with a low initial exchangeable potassium content treated with the 10 percent potash fertilizer. In view of this observation, it would appear that the differential response of sugar beets to salt applications could be influenced by either initial low exchangeable potassium content of soils or by high levels of potassium applications.

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INTRODUCTION

Approximately ten percent of the sugar beet crop, plus an important part of the table beet acreage in the State of Michigan, is produced on organic soils. A general recommendation of five hundred pounds of salt (sodium chloride) per acre, is made in addition to the regular fertilizer applications for sugar beets and a number of other crops produced on these soils.

Field investigations show a considerable variation in the magnitude of response in yield of these crops to salt applications to soils at different locations.

Because of these differential yield responses the following study was instituted to investigate factors that might be associated with these differences. The objectives were as follows: first, to determine the relationship between the sodium and potassium contents of roots and leaves of sugar beets and table beets at varying levels of potassium and sodium; second, to compare chemical and physical characteristics of organic soils that are known to be responsive to salt applications in the field with those that have shown little or no response under similar field conditions.

REVIEW OF LITERATURE

Lehr (25) stated, "There is evidence that the application of sodium to beets produces an effect, especially on weakly buffered soils, that may equal or even exceed the reaction to nitrogen and potassium. Consequently, sodium is being regarded more and more as an essential element for the nutrition of the beet."

Sodium is now believed by many (4, 18, 21, 24, 26, 45) to have an independent function in plant metabolism, although Simon (41) in reviewing literature from Western Europe found investigators ascribing to the premise that sodium can partly replace potassium in plant nutrition.

Delemenchuk and Morozov (7) concluded that the favorable effect of sodium chloride on sugar beets could be attributed to the improvement by sodium of the assimilation of nitrogen and phosphorus.

The sodium along with potassium in plants, was found by Osterhout (33) to have some protective or balancing action in the presence of the antagonizing bivalent ions of calcium and magnesium.

Decoux, Vanderwaeren and Simon (6) reported for sufficiently rapid development of leaves, some sodium in the soil is necessary even with a sufficient supply of available potassium.

Harmer (12) observed that sugar beets receiving sodium chloride maintained a vigorous, healthy green foliage considerably later in growth and that the leaves of table beets retained their healthier green color instead of becoming prematurally purple as generally happened when ample potassium but no sodium was supplied. Van Schreven (46) noted that where the amount of potassium was small, addition of sodium chloride distinctly improved the growth of the plants, but the effect of sodium chloride diminished as the amount of potassium chloride was increased. This effect of sodium was ascribed to the establishment of more favorable ratio between bases and acids in the leaf.

Sayre and Vittum (37) studying sodium salts, did not find any toxic effect of sodium sulphate on beets and the sulphate salt proved equal to sodium chloride in increasing crop yields, indicating that it was sodium and not chlorine in the salt that stimulated the growth of table beets. Harmer (12) also reported that crops showed less damping-off in early growth, had less black rot later on, and exhibited more resistance to disease attacks when sodium chloride was applied in addition to potassium.

Andrlik and Urban (1) obtained results showing no increase in the sodium content of the beet root and therefore believed that the use of salt as a fertilizer would not influence the sugar content.

Harmer and Benne (16) pointed out that a narrow potassium/sodium ratio in plants indicated a probable sodium responsive crop and a wide ratio, a non-responsive crop. Hopkins (19) mentioned sodium as a macronutrient for certain crops, notably celery, mangolds, sugar beets and table beets, turnips and swiss chard, while maize, potatoes, soybeans, lettuce, onions, parsnips, spinach and peppermint had shown no significant growth response to sodium.

Van Itallie (45) observed that the consumption of sodium by beets depends to a great extent upon the potassium supply of the soil. On soils low in potassium, Chile saltpeter produced an increase in yield equal to that produced by 40% potassium salts, and he concluded that the addition of sodium was not important in the production of crops grown on soils high in potassium.

Lill, Byall and Hurst (27) indicated that the benefit derived from the application of sodium salt may be a measure of the needs of a certain type of fertilization and that if this fertilization was given directly, no benefit would be derived from additional applications of salt.

Sayre and Vittum (38) noted that for table beets, at all potash levels, the substitution of sodium chloride for 1/4 of the potash resulted in no reduction in yield and in most cases significantly increased the yield. With pot experiments, Dorph-Peterson and Steenbjerg (8) showed that sodium did not replace equivalent amounts of potassium in plants studied, and that two to three times as much sodium as potassium was required to produce an increase in yield.

Harmer and Benne (17) suggested, that with the greater purification of potash salts, fertilizer problems might arise on soils naturally low in sodium when sodium responsive crops are to be grown. Lehr (26) commented, "Sodium has the capacity either to prevent, or to defer for a long time, or to reduce considerably symptoms of potassium deficiency. Specific sodium deficiency might easily be over-looked in agricultural practice, both because its eventual symptoms will resemble much the known symptoms of potassium deficiency and because practice usually combats 'potassium deficiency' with sodium containing potash salts."

In addition to correcting the normal deficiency of potash, in most muck soils, additional potash may be required for normal crop development because of the fixation of potassium in the presence of a larger amount of organic matter (3). Pehelkin and Kozlova (35) were of the opinion that the addition of sodium chloride increased the fixation of potassium by the soil.

Besides the interactions of sodium and potassium in plant metabolism there are many soil phenomenona, observed by investigators, which are attributed to the presence of sodium.

Reports (17, 18, 30) indicated that sodium caused a reduction in evaporation and increased the water holding power of soils, while there was a tendency for sodium chloride to delay germination (41).

Scharer and Schreiber (39) found that sodium chloride decreased the availability of phosphorus in light, medium and heavy soils. Sokoloff's (42) conclusions, after treating aerated soils with the sulphates and chlorides of calcium and sodium, were: 1) the release of nitrate and total nitrogen as well as of the soluble and volatile forms of carbon was stimulated by sodium salts and depressed by the corresponding calcium salts regardless of aeration; 2) presaturation of the soil with sodium tended to emphasize the stimulating effects of the sodium salts; 3) the carbon/nitrogen ratio of the undissolved organic matter of the soil was lower in the sodium treated than in the calcium treated aerated soils. Harmer (13) indicated that with aging the rate of decomposition of muck soils was reduced and nitrogen deficiencies tended to develop in certain crops and necessitated nitrogen fertilization. Sokoloff's work may well apply to the situation which Harmer mentioned.

Franco (10) working with aerobic organisms, stated they were mostly found in soils where the nitrogen content was 0.05 to 0.15% and no microorganisms developed in soils where sodium chloride was found in quantities exceeding 0.2% or where sulphur was over 0.06%.

Van Itallie (44,45) mentioned that in addition to the potassium/sodium ratios found in plants, there also existed a similar ratio in soils. Decoux and Simon (5) found that the content of exchangeable potassium and sodium decreased with increasing depth from the soil surface and that the ratio of exchangeable potassium to sodium varied from 0.5 to 2.58.

Pehelkin and Kozlova (35) showed that potassium was more strongly absorbed as a bicarbonate than chloride, and that the addition of sodium chloride increased fixation of potassium. Joffee and Levine (20) observed that when potassium was fixed there was usually a decrease in the exchange capacity, but that the relationship was not equivalent. Sodium, calcium, magnesium, boron and strontium were not fixed by the soil.

Some investigators reported other observations dealing with organic soils. Pierre and Scarseth (36) suggested that it was probable that if a soil contained a large proportion of exchangeable sodium, it might through hydrolysis of the exchange complex show a lower degree of base saturation at the various pH values than would a similar soil containing a greater proportion of exchangeable calcium.

McGeorge (28) believed that as the carbonhydrates of the soil were decomposed the phenolic hydroxyl groups were rendered free to act and the exchange capacity of the complex increased accordingly. However, Mitchell (31) thought that lignin or a derivative of a very similar nature was responsible for the base exchange. Muller (32) concluded there apparently was no one substance wholly responsible for base exchange in organic materials.

Soils investigated by Pierre and Scarseth (36) failed to show any relationship between the percentage of organic matter and the percentage of base saturation of soils with like pH values.

PROCEDURE

Greenhouse Experiment: Four organic soils were obtained from the following locations in Michigan during the spring of 1951 from the upper twelve inches of the soil profile.

Soil 1 - Muck Experimental Farm (Clinton County)
2 - Scaffer Farm (Shiawasse County)
3 - Olsen Farm (Montcalm County)
4 - College Farm, Mt. Hope Rd. (Ingham County)

Sugar beets grown on two of these soils (2, 4) have shown an increase in yield from sodium chloride applications.

The soils were dried to an apparent optimum moisture content, sieved through a 1/4 inch screen, then uniformly mixed and a five gram sample was dried to a constant weight at 110°C to determine the moisture content.

Determinations of pH were made on triplicate samples of air-dried soil by the glass electrode method.

The fertilizer exclusive of sodium chloride, which was common table salt, was prepared from C.P. chemicals (ammonium sulphate, mono-potassium phosphate and potassium chloride). The treatments were as follows:

Fertilizer*	Sodium Chloride Pounds per acre
5-10-10	None
5-10-10	1000
5-10-10	2000
5-10-30	None
5-10-30	1000
5-10-30	2000
5-10-60	None
None	None

*Sufficient fertilizer carriers were added to each pot, to supply an equivalent of 2000 pounds per acre of the various fertilizer analyses indicated.

Ammonium nitrate was applied in solution at the rate of 200 pounds per acre once during the growing season.

Boron in the form of boric acid was also added, in solution at a rate equivalent to 40 pounds per acre of borax.

The soil and fertilizer, plus 40% chlordane, at the rate of 10 pounds per acre, were mixed thoroughly and placed in three and four gallon pots. The chlordane was added to the soil to control wire worms.

On October 16, 1951, sugar beet seed, commercial grade 215 x 216, were seeded 3/4 of an inch deep in potted soils.

Prior to seeding, the seeds received a treatment of "Arasan" as a preventive measure for control of soil borne organisms.

The beets were thinned, once after three weeks and again at six weeks, to two and three seedlings per 3 and 4 gallon pot respectively.

The soils were maintained at optimum moisture conditions by periodically bringing the pots up to weight with distilled water. Notes were recorded and photographs taken of the plants to show differences that developed.

The beets were harvested March 3, 1952 and fresh and dry weights of roots and leaves were recorded.

The untreated soils (air dried) were analyzed for exchangeable potassium and sodium. In addition the following properties were determined: pH, exchangeable hydrogen, total exchange capacity, exchangeable cations (total bases), per cent base saturation, and per cent organic matter.

Missing yield data was calculated by the following formula:

$$x = \frac{(t\ Tn) - (b\ Bn) - S}{(t-1)\ (b-1)}$$

Field Experiments: Table beets were sampled weekly beginning July 29, 1951, up to harvest time, September 24, 1951, from an expériment at the Muck Experimental Farm.

The fertilizer treatments, replicated four times were as follows:

Fertilizer*	Sodium Chloride Pounds per acre
0-10-10	None
0-10-10	500
0-10-20	None
0-10-20	500
0-10-30	None
0-10-30	500
0-10-60	None
0-10-60	500

*Sufficient fertilizer carriers were added to supply an equivalent of 1000 pounds per acre of the various fertilizer analyses indicated.

Fresh and oven dry weights of both leaves and roots were recorded. Total potassium and sodium determinations were made on oven-dried tissue, and exchangeable potassium and sodium determinations made from samples taken from plots, the day prior to harvest.

METHODS OF CHEMICAL ANALYSIS

Base Exchange Capacity Determination (34)

Weigh out 5 grams of air dry soil into a 250 ml. erlenmeyer flask and add 100 ml. of neutral N ammonium acetate solution. Shake flask for several minutes, and allow to stand overnight. Transfer contents into a Buchner funnel, fitted with moist 5.5 cm. Whatman No. 42 filter paper and apply gentle suction. Leach soil with an additional 400 ml. of N ammonium acetate, adding small portions at a time and using gentle suction, so leaching process will require not less than 1 hour. Save filtrate.

Wash out the excess ammonium acetate from the ammonium saturated soil with 200 ml. of 95% ethyl alcohol, using small portions at a time and draining well each time. Then leach soil with 450 ml. of acidified (.005 N HCl) 10 percent NaCl solution to extract adsorbed ammonium from soil adding small portions at a time and draining well between additions.

Transfer the sodium chloride extract to a kjeldahl flask, add 25 ml. of 1 N NaOH, and distill 200 ml. into 60 ml. of standard 0.2 N H_2SO_4. Titrate the excess acid with standard 0.1N NaOH, using methyl red as the indicator.

Note: To determine if all of the occluded ammonia has been removed by leaching with ethyl alcohol, add 1 drop of Nessler's reagent to 3 drops of the leachate. Compare color obtained against a color chart for ammonia. A very pale yellow color indicates approximately 1 part per million of ammonia present.

Determination of Total Bases (2)

The collected ammonium acetate filtrate is evaporated to dryness on a hot plate. Transfer the residue to a porcelain evaporating dish and gradually ignite at 550°C, for 30 minutes. After cooling, add a calculated excess of 0.2 N HCl, warm the solution and rub bottom of the dish with a rubber policeman. Add 5 drops of methyl orange indicator. The solutions should be red. Back titrate with 0.1 N NaOH. Calculate the milliequivalents of bases per 100 grams of soil.

Per Cent Base Saturation

From the base exchange capacity and total base determinations the per cent base saturation may be determined in the following manner:

$$\frac{\text{Total bases}}{\text{Base exchange capacity}} \times 100 = \text{per cent base saturation}$$

Exchangeable Hydrogen

From the base exchange capacity and the total bases in a soil, the exchangeable hydrogen may be calculated in the following manner:

Base exchange capacity - total bases = Exchangeable hydrogen

The Determination of Potassium and Sodium by the Flame Photometer (40)

Extraction and Determination of Exchangeable Sodium and Potassium in Soil

Place 5 grams of air dry, 20 mesh sieved soil, into a 250 ml. flask and add about 0.5 grams of ammonium oxalate crystals and 50 ml. (2 N ammonium acetate and 0.04 N ammonium oxalate) extracting solution. Shake flask intermittently for one-half hour. Filter suspension on a moist 5.5 cm. No. 42 Whatman filter paper in a Buchner funnel. Adjust the suction to a filtration rate of about two or three drops per second. Rinse flask three times with 15 ml. of extracting solution each time, and add rinsings to the funnel after previous additions have completely passed through.

Place filtrate in a 100 ml. volumetric flask; rinse suction flask with about 5 ml. of extracting solution and add rinsing to volumetric flask. Bring up to volume with extracting solution and determine concentrations of sodium and potassium with flame photometer.

Extraction and Determination of Sodium and Potassium in Plant Tissue

Place 1.0 grams of plant tissue ground to pass a sieve with 1 mm. openings, into a 250 ml. flask and add about 0.1 grams of ammonium oxalate crystals and 100 ml. (2 N ammonium acetate and 0.04N ammonium oxalate) extracting solution. Shake intermittently for 1 hour. Filter suspensions as done with soil extract. The extract is now ready for testing with flame photometer.

Determination and Calculation of Sodium or Potassium in Soils and Plant Tissue by Flame Photometer

Warm up the flame photometer for at least ten minutes. Locate the position of the sodium or potassium whichever is to be used first, wave length by using a standard solution. An internal standard of lithum chloride is not necessary.

For use in translating dial readings to parts per million sodium or potassium in solution, usually two graphs are needed, one for unknown solutions containing up to 100 p.p.m. of sodium or potassium, and the other for solutions containing from 100 to 500 p.p.m. These are prepared by taking dial readings for a series of standard solutions ranging in concentration from 0 to 100 and from 100 to 500 p.p.m. of sodium or potassium, and then plotting them against parts per million of the element in solution. The parts per million of sodium or potassium in the unknown solutions can then be read directly from the graph.

Pour unknown into the funnel of the flame photometer and record scale reading. By reading from the prepared graph p.p.m. can be determined. The percentage of potassium or sodium in plant tissue can be found in the following manner:

$$\%\text{ K or Na} = \frac{(\text{ml. of extract})\ (\text{p.p.m. K or Na in extract})\ (0.0001)}{\text{weight of sample}}$$

The milliequivalents of potassium or sodium per 100 grams of soil can be found in the following manner:

$$\text{Milliequivalents K or Na/100 gms. soil} = \frac{\text{mgms. K or Na/100 gms. soil}}{\text{meq. weight of K or Na}}$$

or to find pounds of exchangeable potassium or sodium per acre:

$$\text{Pounds per acre} = \frac{(\text{ml. extract})\ (\text{p.p.m. of standard})\ (\text{dial reading})\ (0.005)}{\text{weight of sample}}$$

Organic Matter and Total Ash

Place 5 grams of oven dry doil into a weighed flat bottomed fused silica dish of about 40 ml. capacity, which has previously been ignited. The dish with the sample is then placed in an electric muffle furnace and slowly ignited at 500-600°C overnight. Allow to cool in a desiccator and weigh. The loss in weight is due to the loss of volatile constituents, which in peat and muck analysis is taken as the organic matter content.

DISCUSSION OF EXPERIMENTAL RESULTS

Greenhouse Experiment: As shown by the data in Table 1, the four soils did not vary greatly in their exchangeable hydrogen content. Each soil was found to possess a high absorptive capacity for cations and contained a large amount of replaceable bases.

There was no relationship found between pH and total exchange capacity or exchangeable cations. However, there was an apparent direct relationship noted between pH and percent base saturation and an inverse relationship between pH and exchangeable hydrogen.

The total exchange capacity was highest in soil 1, 166.5 milliequivalents, and lowest in soil 4, 141.3 milliequivalents. The amount of exchangeable cations followed in the same order, soil 1 > soil 2 > soil 3 > soil 4, although the difference between soil 3 and 4 was negligable.

The percent base saturation ranged between 65.9 and 72.9, with soil 1 having the highest degree of saturation.

Table 1- Some chemical properties of four soils.

Soil	pH	Milliequivalents per 100 grams of air dry soil: Exchangeable hydrogen	Total exchange capacity	Exchangeable cations	Per cent base saturation
1	6.7	45.1	166.5	121.4	72.9
2	6.3	55.1	161.6	106.5	65.9
3	6.8	41.0	141.6	100.6	71.0
4	6.8	42.4	141.3	98.9	70.0

The organic matter contents, as shown in Table 2, of soils 1, 2, 3, and 4 were 82.6, 76.2, 75.6 and 69.6 percent respectively, with corresponding ash contents of 17.4, 23.9, 24.5, and 30.4 percent.

The potassium and sodium content of the soils varied greatly. McCool (29) working with fertilizer fixation of organic soils, noted, that when the ash content was 10 percent or less, the soils possessed a low capacity to take up potassium and phosphorus, and this capacity increased with an increasing mineral content or stage of decay. Staker and Jornlin (43) also found the lowest concentration of potassium in virgin profiles and the highest concentration of potassium in soils that had been cultivated over a long period.

The lowest exchangeable potassium was found in soil 1, which also contained the highest organic matter content. Soil 4, having the highest ash content, had the highest percentage of exchangeable potassium. It is believed that this situation, is the result of a recent fertilizer application and not due to a high potassium base saturation.

Soils 2 and 3 were similar with respect to their content of ash and exchangeable potassium.

The percent exchangeable sodium was highest in soil 3 and lowest in soil 1, yet sugar beets grown on these soils, as shown in Table 4 and 5, produced significant yield response from salt. Soils 2 and 4 had nearly the same concentration of exchangeable sodium but sugar beets grown on these soils did not give any significant increase in yield, under greenhouse conditions with the addition of salt. However, at the lower level of potassium (soil 2) and at both potassium levels (soil 4), higher yields were obtained as a result of salt applications.

As shown by these data, yield increases of sugar beets grown in the greenhouse, due to applications of salt, were not associated with the amount of exchangeable sodium.

Table 2- Exchangeable potassium and sodium, organic matter, and ash content of four soils.*

Soil	Per cent		Milliequivalents per 100 grams of air dry soil	
	Organic matter	Ash	K	Na
1.	82.6	17.4	0.22	0.09
2	76.2	23.9	0.51	0.17
3.	75.6	24.5	0.43	1.04
4	69.6	30.4	3.63	0.13

*Organic matter determined by igniting at 500-600° C.

The amount of exchangeable potassium and sodium found in the four soils after harvest of the sugar beets is shown in Table 3.

In general, the exchangeable potassium contents of the soils treated with different amounts of potassium were proportional to the potassium applied with no observable effect from salt applications. The exchangeable potassium content of the soils, receiving a 5-10-10 fertilizer, was approximately the same as that content found in the unfertilized soils.

There was less exchangeable sodium remaining in all soils at the lower level of potassium applications, indicating a higher absorption by the plants, of sodium, at the lower potassium levels.

It should be pointed out (Table 3) that soils 1 and 3 had lower concentrations of exchangeable potassium and sodium than soils 2 and 4 when the soils were fertilized with 5-10-30 plus salt, again supporting the idea that where potassium is limited in the soil, sodium is absorbed by plants in larger amounts. Data reported by Van Schreven (46) is in agreement with this observation.

The exchangeable sodium increased with increasing increments of salt in all soils.

Table 3- The effect of potassium and sodium levels on the sodium and potassium content of four soils after harvest of sugar beets, 1952.*

Treatment		Milliequivalents per grams of air dry soil							
		Potassium				Sodium			
	Pounds salt	Soil				Soil			
Fertilizer**	per acre	1	2	3	4	1	2	3	4
5-10-10	None	0.12	0.23	0.23	0.19	0.03	0.04	0.03	0.04
5-10-10	1000	0.17	0.30	0.18	0.25	0.05	0.06	0.14	0.09
5-10-10	2000	0.16	0.17	0.17	0.18	0.07	0.10	0.36	1.33
5-10-30	None	0.22	0.30	0.29	0.34	0.03	0.02	0.04	0.03
5-10-30	1000	0.21	0.48	0.31	0.42	0.15	0.47	0.18	0.35
5-10-30	2000	0.15	0.41	0.23	0.41	0.41	1.27	0.47	1.82
5-10-60	None	0.27	0.52	0.52	1.55	0.05	0.07	0.04	0.05
None	None	0.12	0.37	0.24	0.23	0.01	0.03	0.01	0.01

*Exchangeable potassium and sodium content expressed as K and Na.
**Fertilizer was applied at the rate of 2000 pounds per acre.

As shown by Table 4, on soil 1, a significant increase in yield of sugar beet roots (1% level) was obtained from pots treated with 5-10-10 fertilizer and 2000 pounds salt per acre over yields of pots treated with fertilizer alone. Yield increases (5% level) were also obtained from soil 1, treated with 5-10-30 fertilizer and 1000 pounds of salt per acre. Yields from pots treated with 5-10-60 fertilizer were the highest of any treatment, (Figure 1), but not significantly so.

With soil 2, similar trends as found with soil 1, were shown with the 5-10-10 fertilizer treatment, but due to the variability of data no significant differences were obtained between any treatments.

The yield of sugar beet roots, produced on soil 3 (Table 5) was significantly increased by the 5-10-10 plus salt treatment, and there was little further increase in yields of roots as a result of higher levels of potassium, with or without salt.

There was no significant yield increase of sugar beet roots grown on soil 4 with any treatment. There was a trend toward higher yields when increasing increments of salt with the 5-10-10 and 5-10-30 fertilizer treatments were applied. These yields were comparable to yields from pots treated with a 5-10-60 fertilizer.

An interesting observation was made (Figure 2) in which beet plants growing in pots treated with salt resisted wilting longer, than those plants grown in soils with no salt added. This phenomenon, occured in the greenhouse between temperature ranges of 90 to 102°F. Sayre and Vittum (37) reported that soil treated with salt produced table beets that were larger, stronger and had more erect leaves than plants grown on soil without salt.

Table 4- The effect of potassium and sodium levels on the yield of sugar beet roots grown in the greenhouse on soils 1 and 2, 1952.

Treatment		Yield (grams per pot)*									
	Pounds salt	Soil 1					Soil 2				
Fertilizer**	per acre	1	2	3	4	Mean	1	2	3	4	Mean
5-10-10	None	27.4	23.4	16.5	19.8	21.8	66.8	24.6	39.8	48.2	44.9
5-10-10	1000	27.9	29.8	45.2	45.6	37.1	34.8	58.6	34.8	59.1	46.8
5-10-10	2000	38.6	73.0	46.0	79.5	59.3	51.6	60.6	82.0	69.1	65.8
5-10-30	None	32.8	35.8	43.4	62.6	43.7	59.6	40.8	71.8	82.0	63.6
5-10-30	1000	68.0	56.2	77.0	51.4	63.2	64.0	48.2	74.4	47.9	58.6
5-10-30	2000	60.2	56.3	55.4	67.6	59.9	49.2	83.4	41.9	74.7	62.3
5-10-60	None	57.9	39.6	67.8	93.0	64.6	67.7	30.6	73.2	101.3	68.2
None	None	17.0	17.2	15.1	18.4	16.9	36.7	36.8	44.6	41.6	39.9
L.S.D.											
1% level						22.9					N.S.
5% level						16.8					N.S.

*Oven-dry weight at 90° C.
**Fertilizer was applied at the rate of 2000 pounds per acre.

Analysis of variance of yield data of sugar beet roots, soils 1 and 2.

Source of variance	Degrees of freedom	Sum of squares Soil 1	Sum of squares Soil 2	Mean square Soil 1	Mean square Soil 2	F Soil 1	F Soil 2
Total	31	14171.0	10479.6				
Replication	3	930.6	1301.3	310.2	433.8	2.07	1.54
Treatment	7	10099.0	3261.2	1442.7	465.9	9.64**	1.65
Error	21	3141.4	5917.1	149.6	281.8		

**Significant at 1% level.

Table 5- The effect of potassium and sodium levels on the yield of sugar beet roots grown in the greenhouse on soils 3 and 4, 1952.

Treatment		Yield (grams per pot)*							
	Pounds salt	Soil 3				Soil 4			
Fertilizer**	per acre	1	2	3	Mean	1	2	3	Mean
5-10-10	None	82.7	48.7	77.6	69.5	39.7	38.4	50.9	43.0
5-10-10	1000	106.1	86.7	107.8	100.2	43.8	50.7	56.2	50.2
5-10-10	2000	93.7	108.8	115.4	106.0	70.7	56.2	53.7	60.2
5-10-30	None	99.4	118.5	102.4	106.8	45.2	75.6	36.7	52.5
5-10-30	1000	128.6	80.4	118.2	109.1	48.6	63.3	78.7	63.5
5-10-30	2000	127.8	104.9	95.7	109.5	46.2	73.0	89.2	69.5
5-10-60	None	97.8	112.8	95.3	102.0	47.2	72.4	67.6	62.4
None	None	61.7	64.6	54.0#	60.1	56.8	41.2	48.5#	48.8
L.S.D.									
1% level					37.5				N.S.
5% level					27.0				N.S.

*Oven-dry weight at 90° C.
**Fertilizer was applied at the rate of 2000 pounds per acre.
#Missing values supplied by use of formula (see procedure).

Analysis of variance of yield data of sugar beet roots, soils 3 and 4.

Source of variance	Degrees of freedom	Sum of squares		Mean square		F	
		Soil 3	Soil 4	Soil 3	Soil 4	Soil 3	Soil 4
Total	22	11325.5	4738.9				
Replication	2	473.2	369.7	157.7	123.2	1.04	0.92
Treatment	7	7827.1	1686.0	1118.2	240.9	7.39**	1.80
Error	13	3025.2	2683.2	151.3	134.2		

**Significant at 1% level.

Table 6- The effect of potassium and sodium levels on the yield of sugar beet leaves grown in the greenhouse on four soils, 1952.

Treatment		Mean yield (grams per pot)*			
Fertilizer**	Pounds salt per acre	Soil 1	Soil 2	Soil 3	Soil 4
5-10-10	None	56.0	58.3	72.3	35.7
5-10-10	1000	71.1	58.3	77.2	38.2
5-10-10	2000	71.3	54.6	73.8	37.9
5-10-30	None	74.5	53.8	92.6	50.6
5-10-30	1000	68.4	53.9	71.8	45.8
5-10-30	2000	69.3	59.8	76.9	51.2
5-10-60	None	65.1	57.5	86.2	48.6
None	None	27.8	48.4	42.9	25.7

*Oven-dry weight 90°C.
**Fertilizer was applied at the rate of 2000 pounds per acre.

In general, more leaf growth was noted in the fertilized pots, as shown by the data in Table 6 and Figure 3. There was considerable loss of leaves throughout the growing period, which tended to mask treatment differences and increase the variability of the data.

At harvest, the various stages of potassium deficiencies were recorded and can be seen in Figure 4, Number 2. The first leaf on the left, shows a crinkling along the edges, with a slight browning and was termed "slightly deficient"; the middle leaf showed more advanced stages of breakdown, with necrotic areas appearing near the mid-rib and more pronounced browning of edges, and was termed, "moderately deficient"; and the last leaf on the right with severe necroses, was termed, "strongly deficient". The appearance of these symptoms was associated with the potassium content in the leaves and also with the sodium content in the soil. When the potassium content in the leaves (Table 7) was 1.72 percent or higher and when salt was applied to the soil, no potassium deficiency symptoms appeared. At lower potassium concentrations of the leaf, regardless of whether salt had been applied or not, potassium deficiency symptoms were evident.

These observations are in agreement with the data reported by Goodall and Gregory (11), whose summary of plant tissue analysis work of numerous invertigators, showed that when the concentration of potassium in the younger mature leaves of sugar beets was less than 2.00 percent, then the potassium supply in the soil was inadequate.

Applications of salt to the soil increased the sodium content of the sugar beet leaves, as shown in Table 7, and apparently the sodium content of the leaves was not influenced by the potassium levels in the soil. Hoffman (18) observed that sodium was found in greater abundance in the leaves, where it apparently had displaced a certain amount of potash, than in the roots of the sugar beet plant.

With soils 1 and 3, at the lower level of potassium, the percent of potassium in the leaves decreased with increasing increments of salt added to the soil. A similar situation was noted in soil 3, when

Table 7- The effect of potassium and sodium levels on the potassium and sodium content of sugar beet leaves grown on four soils in the greenhouse, 1952.*

Treatment		Potassium				Sodium			
	Pounds salt	Soil				Soil			
Fertilizer**	per acre	1	2	3	4	1	2	3	4
5-10-10	None	0.79#	3.13	1.02#	2.35	0.12	0.31	0.28	0.11
5-10-10	1000	0.76#	2.04	0.88#	2.55	1.14	1.57	1.59	2.17
5-10-10	2000	0.64#	2.96	0.79#	2.88	2.59	2.95	3.10	3.09
5-10-30	None	1.74	4.15	2.18	3.93	0.10	0.47	0.62	0.13
5-10-30	1000	1.72#	3.32	2.04	4.10	1.62	1.87	1.84	1.47
5-10-30	2000	2.29	4.29	1.77	4.21	3.47	2.95	3.03	2.17
5-10-60	None	4.11	5.19	3.89	5.08	0.13	0.21	0.54	0.13
None	None	0.65#	2.41	0.96#	2.54	0.20	0.25	0.25	0.10

*Total potassium and sodium content of oven-dried tissue expressed as percent K and Na.
**Fertilizer applied at the rate of 2000 pounds per acre.
#Potassium deficiency symptoms of leaves observed.

a 5-10-30 fertilizer was used. Results by Goodall and Gregory (11) support this view, that where the potassium levels are low, there would be lower limiting values for potassium when the sodium supply in the soil was high than when it was low.

According to the data in Table 8, there is a lower precent of potassium and sodium in the roots of sugar beets than in the leaves, with less variation due to treatments which indicates that the analysis of leaf tissue would be more indicative of variations in the amounts of potassium and salt applied to the soil.

Table 8- The effect of potassium and sodium levels on the potassium and sodium content of sugar beet roots grown on four soils in the greenhouse, 1952. *

Treatment		Potassium				Sodium			
	Pounds salt	Soil				Soil			
Fertilizer**	per acre	1	2	3	4	1	2	3	4
5-10-10	None	0.77	0.84	0.67	0.72	0.04	0.04	0.05	0.06
5-10-10	1000	0.38	0.80	0.58	0.72	0.17	0.51	0.13	0.13
5-10-10	2000	0.45	0.90	0.58	0.77	0.22	0.21	0.15	0.15
5-10-30	None	0.77	1.00	0.77	0.85	0.02	0.03	0.03	0.03
5-10-30	1000	0.73	0.87	0.68	0.86	0.06	0.10	0.05	0.10
5-10-30	2000	0.82	0.90	0.74	0.84	0.19	0.15	0.21	0.07
5-10-60	None	0.87	0.83	0.71	0.96	0.03	0.04	0.04	0.03
None	None	0.64	0.75	0.46	0.64	0.10	0.04	0.06	0.02

*Total potassium and sodium content of oven-dried tissue expressed as percent K and Na.

**Fertilizer applied at the rate of 2000 pounds per acre.

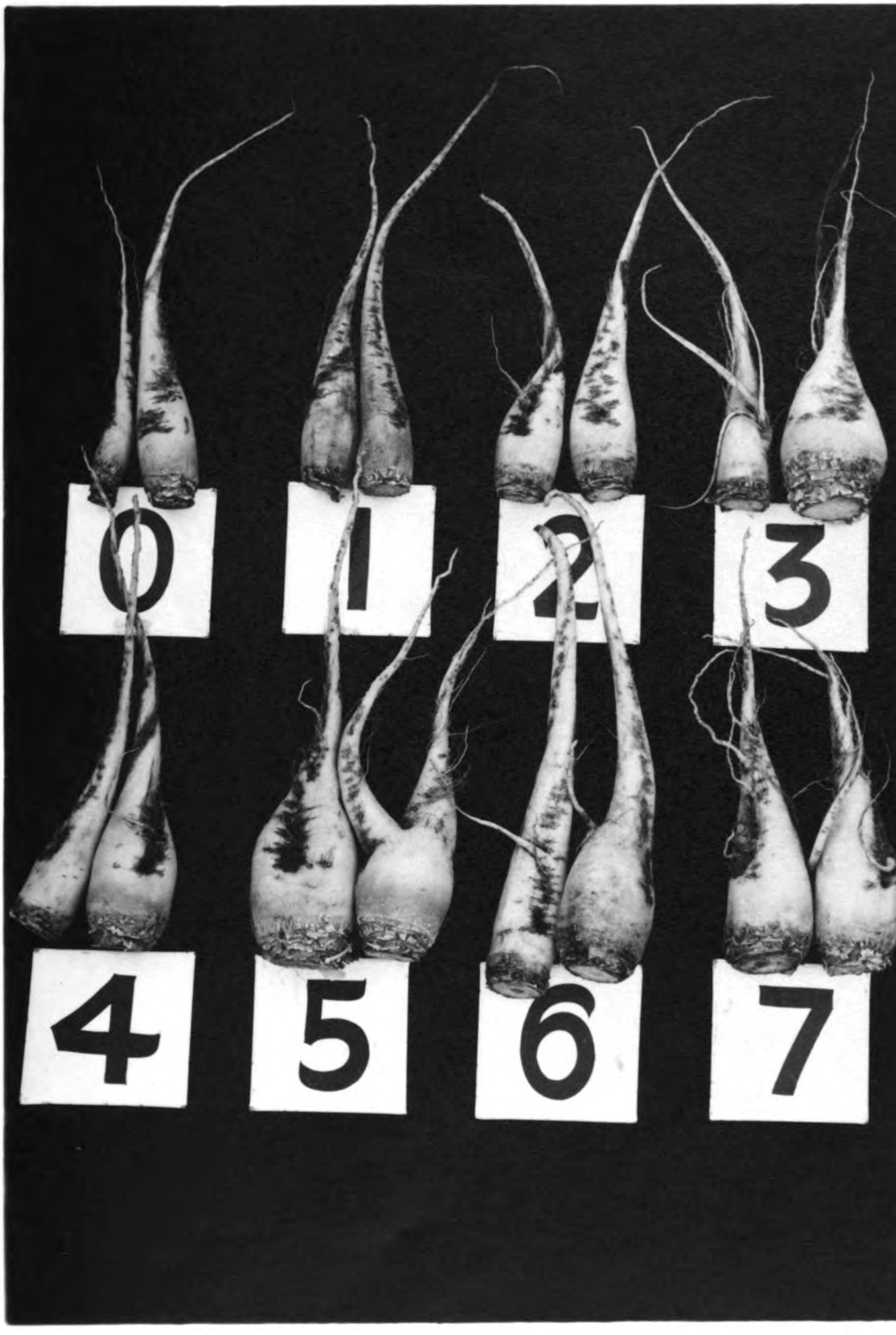

Fig. 1. The effect of potassium and sodium levels on the growth of sugar beet roots on soil 1. 0) no fertilizer or salt; 1) 5-10-10; 2) 5-10-10, 1000 pounds salt; 3) 5-10-10, 2000 pounds salt; 4) 5-10-30; 5) 5-10-30, 1000 pounds salt; 6) 5-10-30, 2000 pounds salt; 7) 5-10-60.

Fig. 2. The effect of sodium chloride on the ability of sugar beet plants to resist wilting at high temperatures (90 - 102° F.) on soil 3. 0) 5-10-30; 1) 5-10-30, 1000 pounds salt.

Fig. 3. The effect of fertilizer and sodium chloride on the growth of sugar beets on soil 1. Blank) no fertilizer or salt; 1) 5-10-10, 2000 pounds salt.

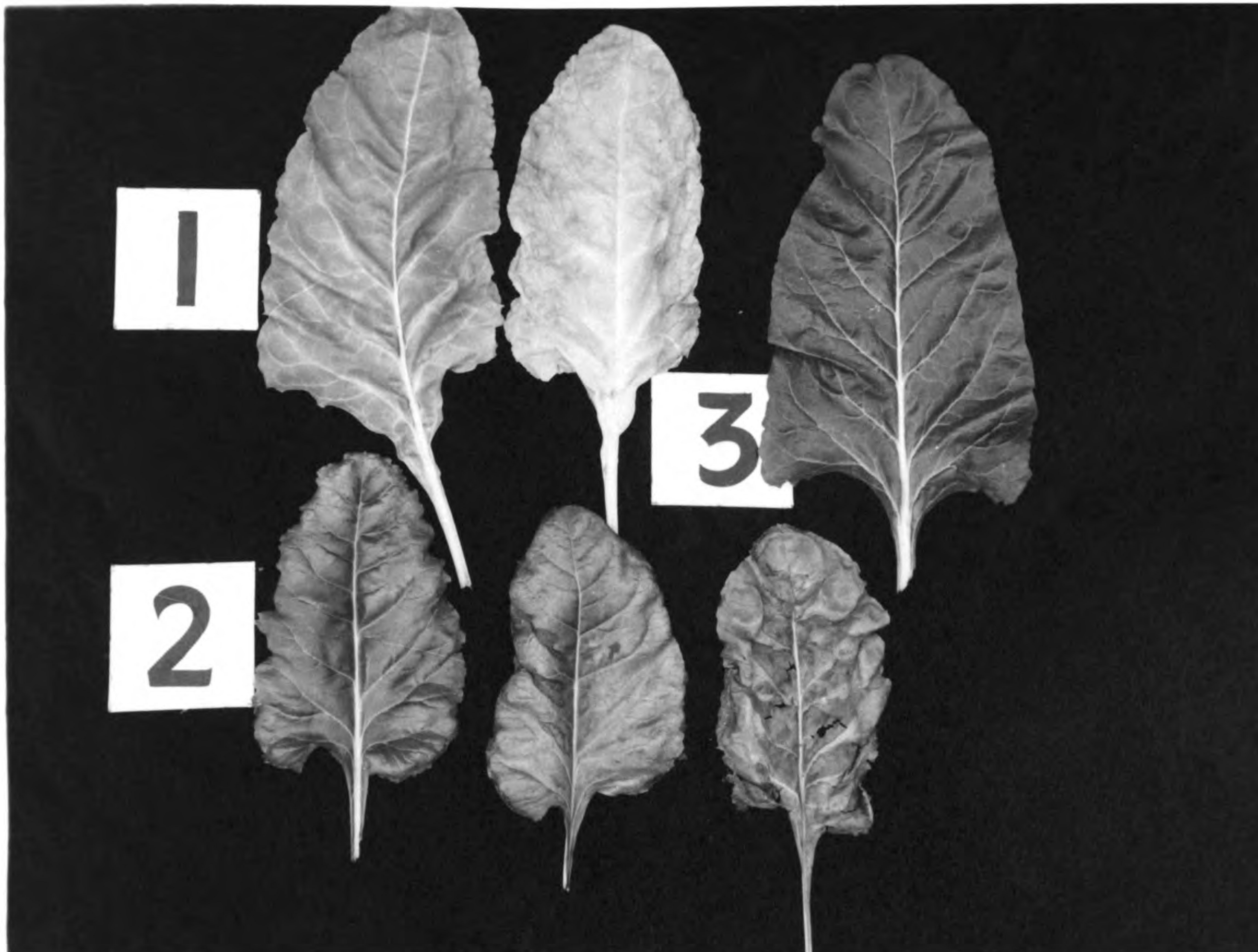

Fig. 4. Nutrient deficiency symptoms of sugar beet leaves. 1) nitrogen deficient; 2) potassium deficient; 3) normal.

Field Experiment: The data in Table 9 shows that as the table beets matured, the potassium content of the leaves, in general, decreased with some variation between sampling dates observed. The same trend occurred with sodium, with a greater variation between sampling dates.

The concentration of potassium in plants, grown on soil treated with 0-10-10 fertilizer, was lower than that found in plants growing on plots to which higher levels of potassium were applied.

The concentration of sodium in the leaves was not affected by the addition of 500 pounds of salt per acre at any level of potassium.

According to the data in Table 10, a lower percentage of potassium was found in the roots than in the leaves with very little variation due to seasonal fluctuation. Potassium levels of the soil did not affect the potassium and sodium content of the roots. In general a slightly higher sodium content of the roots was found in plants harvested from plots that had received salt.

As shown by data in Table 11, the exchangeable potassium of the soil increased with each increment of applied potassium and the exchangeable sodium content also increased when 500 pounds of salt per acre was added. The exchangeable sodium content was lower in plots treated with 0-10-10 than those plots treated with higher levels of potassium, which might indicate a partial substitution of sodium for potassium in the plants at lower levels of potassium.

There was no significant difference in either years, 1951 and 1952, in yield of table beets due to treatments, although the lowest average yield was obtained from plotstreated with 0-10-10 in 1952.

Table 9- The effect of potassium and sodium levels and dates of harvest on the potassium and sodium content of table beet leaves, Muck Experimental Farm, 1951.*

Date of harvest	Fertilizer**															
	0-10-10				0-10-20				0-10-30				0-10-60			
	No Salt		Salt		No Salt		Salt		No Salt		Salt		No Salt		Salt	
	K	Na	K	Na	K	Na	K	Na	K	Na	K	Na	K	Na	K	Na
July 29	7.62	1.40	7.50	1.70	7.20	1.10	7.20	1.65	8.30	1.20	8.90	1.00	8.90	1.30	8.20	1.75
Aug. 7	5.80	1.30	7.08	2.04	7.62	1.85	7.20	1.75	7.00	1.00	7.93	1.35	——	——	6.90	1.65
Aug. 15	4.14	1.75	3.29	1.70	6.90	1.50	5.80	2.00	5.40	1.05	5.53	1.70	6.38	1.60	7.78	1.64
Aug. 19	5.25	1.90	4.60	1.80	5.40	1.50	5.80	1.50	5.80	0.95	6.30	1.61	6.80	1.50	7.00	1.70
Aug. 23	4.00	1.60	5.25	2.04	5.98	1.60	5.80	1.75	6.50	1.30	7.00	1.35	5.80	1.40	7.34	1.80
Aug. 26	2.90	2.00	5.68	1.73	5.40	1.82	6.36	1.87	5.80	1.50	6.80	1.80	6.80	1.90	7.20	1.60
Sept. 2	4.98	1.60	4.28	1.58	5.80	1.80	5.80	1.70	7.20	1.45	4.30	1.58	6.20	1.50	6.50	1.82
Sept. 9	3.86	1.80	3.70	2.15	5.80	1.70	5.40	1.80	6.65	1.10	5.53	1.60	5.53	1.33	7.00	1.70
Sept.16	1.25	1.92	3.29	1.70	6.50	1.65	4.55	2.00	5.53	1.40	5.10	1.35	5.10	1.70	7.50	1.78
Sept.24	2.60	2.00	2.60	1.73	5.25	1.82	3.86	2.25	5.93	1.75	6.38	1.75	5.25	1.80	6.38	1.90

*Total potassium and sodium of oven-dried tissue, expressed as percent K and Na.
**Fertilizers and salt applied at the rate of 1000 and 500 pounds per acre respectively.

Table 10- The effect of potassium and sodium levels and dates of harvest on the potassium and sodium content of table beet roots, Muck Experimental Farm, 1951.*

Date of harvest	Fertilizer**															
	0-10-10				0-10-20				0-10-30				0-10-60			
	No Salt		Salt		No Salt		Salt		No Salt		Salt		No Salt		Salt	
	K	Na	K	Na	K	Na	K	Na	K	Na	K	Na	K	Na	K	Na
July 29	3.10	0.34	3.30	0.43	2.23	0.27	2.98	0.35	3.30	0.25	3.86	0.23	2.91	0.24	2.84	0.40
Aug. 7	2.18	0.35	2.60	0.48	3.10	0.23	3.40	0.40	3.45	0.27	3.04	0.27	2.47	0.32	3.15	0.29
Aug. 15	2.40	0.48	2.24	0.51	2.81	0.33	3.10	0.33	2.70	0.26	2.50	0.44	2.94	0.40	3.23	0.33
Aug. 19	2.70	0.44	2.60	0.43	2.63	0.29	2.90	0.35	3.14	0.20	2.70	0.22	2.75	0.29	2.84	0.30
Aug. 23	2.40	0.39	2.90	0.47	2.80	0.23	2.80	0.27	2.70	0.17	2.93	0.23	2.84	0.20	2.94	0.31
Aug. 26	2.30	0.38	2.65	0.27	2.70	0.34	2.75	0.35	2.75	0.20	2.80	0.26	2.80	0.23	3.10	0.35
Sept. 2	2.46	0.34	2.30	0.46	2.46	0.46	2.70	0.26	2.53	0.21	2.53	0.21	2.75	0.21	3.00	0.33
Sept. 9	2.32	0.45	2.70	0.48	2.54	0.30	2.63	0.29	2.94	0.17	2.90	0.27	2.94	0.21	3.10	0.54
Sept.16	2.24	0.51	2.63	0.40	2.75	0.33	2.43	0.36	2.65	0.15	2.90	0.29	3.04	0.27	2.94	0.28
Sept.24	2.63	0.40	2.75	0.52	2.60	0.42	2.93	0.45	2.80	0.21	2.93	0.22	2.75	0.29	3.10	0.31

*Total potassium and sodium of oven-dried tissue, expressed as percent K and Na.
**Fertilizers and salt applied at the rate of 1000 and 500 pounds per acre respectively.

Table 11- The effect of potassium and sodium levels on the yield of table beets and on the potassium and sodium content of the soil, Muck Experimental Farm, 1951 and 1952.*

Treatment		Soil*** Mean content		Mean yield**** Tons per acre	
Fertilizer**	Pounds salt per acre	K	Na	1951	1952
0-10-10	None	0.64	0.34	29.4	19.6
0-10-10	500	0.62	2.03	29.9	23.2
0-10-20	None	0.98	0.63	29.2	25.3
0-10-20	500	1.08	2.50	31.5	24.2
0-10-30	None	1.88	0.89	31.6	21.8
0-10-30	500	2.00	2.37	31.8	22.5
0-10-60	None	3.58	0.80	33.5	25.7
0-10-60	500	3.55	2.50	32.0	25.7

*Exchangeable potassium and sodium expressed as percent K and Na.
**Fertilizer applied at the rate of 1000 pounds per acre.
***For 1951
****Average of 4 replications.

Analysis of variance of yield data of table beets, Muck Experimental Farm, 1951 and 1952.

Source of variance	Degrees of freedom	Sum of squares 1951	Sum of squares 1952	Mean square 1951	Mean square 1952	F 1951	F 1952
Total	31	330.1	452.7				
Replication	3	70.6	29.9	23.5	10.0	1.56	0.65
Fertilizer	3	45.5	102.0	15.2	34.0	1.01	2.22
Error	9	135.8	137.9	15.1	15.3		
Salt	1	1.1	4.9	1.1	4.9	0.21	0.38
Fert. x salt	3	13.7	23.6	4.6	7.9	0.87	0.61
Error	12	63.4	154.4	5.3	12.9		

SUMMARY

The object of this study was to investigate factors that might be associated with the differential yield response of sugar beets and table beets grown on different organic soils, to sodium chloride applications.

Four organic soils were obtained from various locations in Michigan and treated with four levels of potassium and three levels of salt under greenhouse conditions. Sugar beet seeds were planted on October 16, 1951 and the crop harvested on March 3, 1952. Fresh and oven dry weights of roots and leaves were recorded.

The untreated soils were analyzed for the following: Exchangeable potassium and sodium, pH, exchangeable hydrogen, total exchange capacity, exchangeable cations, percent base saturation, and percent organic matter.

The exchangeable potassium and sodium of the soils and the total potassium and sodium of beet leaves and roots were analyzed after harvest.

Table beets were sampled weekly, beginning July 29, up to harvest, September 24, 1951, from an experiment at the Muck Experimental Farm. The fertilizer treatments consisted of four levels of potassium and two levels of sodium chloride.

Fresh and oven dry weights of leaves and roots were recorded and total potassium and sodium determinations were made on leaf and root tissue.

The following observations were made:

1. The yield responses of sugar beets grown on four soils to applications of salt were not the same in the greenhouse as reported under field conditions.

2. Yield increases of sugar beets grown in the greenhouse, due to applications of salt, were not associated with the amount of exchangeable sodium before the salt was added.

3. In general, the exchangeable potassium contents of the soils treated with different amounts of potassium were proportional to the potassium applied with no observable change in exchangeable potassium as a result of the salt treatment.

4. Less exchangeable sodium was found in all soils, after cropping, at the lower level than at the higher levels of potassium applications.

5. There was a significant yield difference of sugar beet roots obtained from the application of salt to soils 1 and 3, and while there was no significant yield difference observed in soils 2 and 4, there was an increase in yield of roots, on these two soils, when treated with the lower rate of potassium.

6. The exchangeable sodium content increased in all soils with increasing increments of salt.

7. Where the concentration of potassium in the sugar beet leaf was 1.72 percent or higher and when salt was applied to the soil, no potassium deficiency symptoms appeared. However, in absence of a salt application, potassium deficiency symptoms were evident when the per-

cent of potassium was less than 1.77.

8. The sodium content of the leaves increased with increasing increments of salt to the soil under greenhouse conditions and the sodium content was not influenced by the potassium levels in the soil.

9. With lower levels of potassium and with the addition of increments of salt, the concentration of potassium in the leaves generally was reduced.

10. There was a higher percentage of potassium and sodium in the sugar beet and table beet leaves than in the roots with all treatments.

11. As the table beet matured, the percent of potassium in the leaves decreased, but the percent of sodium remained fairly constant.

12. Under field conditions the concentration of sodium in the leaves of table beets, was not affected by the addition of salt at any level of potassium application.

13. An apparent substitution of sodium for potassium, in the nutrition of the sugar beets, occurred on soils with a low initial exchangeable potassium content treated with the 10 percent potash fertilizer. In view of this observation, it would appear that the differential response of sugar beets grown under field conditions could be influenced by either initial low exchangeable potassium content of soils or by high levels of potassium applications.

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