Yield, Quality, and Nutrient Content of Sugar Beets as Affected by Irrigation Regime and Fertilizers[1]

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The high cash investment required to grow the sugar beet crop makes it necessary for the grower to obtain high yields if he is to make a profit. Good quality is nearly as important as yield. Some of the many factors affecting the growth and quality of sugar beets behave one way under one set of conditions and in quite another manner under other conditions. In order for man to direct and control effectively the growth of plants to his advantage, he must not only know that a certain response will occur but also why it occurs.

The objective of this paper is to report some observations on factors affecting yield, quality, and nutrient content of sugar beets, which have been made in the course of an experimental study on a rotation of a number of crops including sugar beets.

Few crops are more sensitive or responsive to the quantity and quality of fertilizers provided for them, than sugar beets. It has been shown (2) (3)[3] that method of irrigation and soil moisture condition affect the availability of plant nutrients and in turn the yield and quality of this crop. There is some evidence (3) (4) that top : root ratio of sugar beets may indicate the proper balance of plant nutrients necessary for optimum yields. Chemical analyses of soils and plants have been made in profusion in an effort to determine optimum nutritional conditions. A number of these factors and their interrelations are discussed.

Experimental Materials and Methods

Sugar beets were grown in a crop rotation of canning peas, alfalfa, alfalfa, potatoes and sugar beets which were established at Logan, Utah, in 1949 on Millville loam. This is a deep, well-drained, highly calcareous soil low in soluble salts. Two methods of irrigation, sprinkler and furrow, with four soil moisture conditions superimposed on each method were studied (available soil moisture remaining in root zone allowed to approximate 90 (W_4), 70 (W_3), 40 (W_2), and 20 (W_1) percent between irrigations). Soil moisture plots were further subdivided for nitrogen and phosphorus fertilizer treatments. Nitrogen was broadcast and harrowed into the soil before planting at the rate

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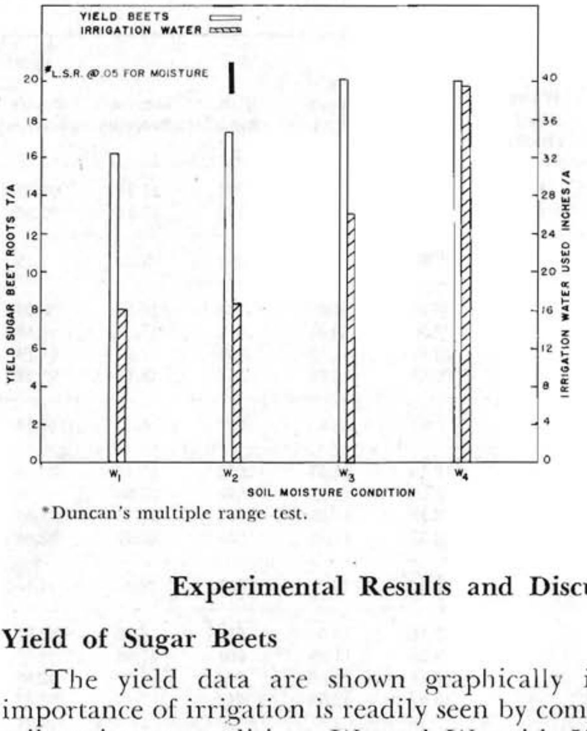
[3] Numbers in parenthesis refer to literature cited.

of 80 pounds N per acre as ammonium sulfate and phosphorus at the rate of 44 pounds of P per acre as treble super-phosphate. Nitrogen and phosphorus fertilizers were applied in 32 combinations to peas, potatoes, and sugar beets.

The Sachs-Le Docte (1, p. 363) cold digestion of rasped beet pulp was used as the basis for determining sucrose and purity. The method of Ulrich (6) was used for nitrate-nitrogen and phosphorus. Potassium, sodium and calcium were determined by means of the Perkin-Elmer flame photometer. Sodium bicarbonate-soluble soil phosphorus was determined by Olsen's (5) method.



*Duncan's multiple range test.

Figure 1.—Yield of sugar beets as related to soil moisture condition maintained and quantity of irrigation water used, 1956.

Experimental Results and Discussion

Yield of Sugar Beets

The yield data are shown graphically in Figure 1. The importance of irrigation is readily seen by comparing yields under soil moisture conditions W_1 and W_2 with W_3 and W_4. While yields are closely associated with quantity of irrigation water applied there appears to be no yield advantage for quantities greater than 25 inches (see Table 1 for information on quantity of water used).

The influence of nitrogen and phosphorus fertilizers on yield of sugar beets under sprinkle and furrow irrigation is illustrated in Figure 2. While nitrogen alone. was of little value it was significantly advantageous in the presence of added phosphorus. This was particularly true under furrow irrigation. Phosphorus appeared to be of more value under sprinkle than furrow irrigation. The reason for this differential response of sugar beets to fertilizers under the two methods of irrigation is undoubtedly related to the greater nitrogen losses by deep percolation under furrow irrigation. It has frequently been observed that nitrogen nutrition is better under sprinkle than furrow irrigation. This would account in part for the better phosphorus response and the lower nitrogen response under sprinkle than furrow methods.

Table 1.—Yield and Quality of Sugar Beets as Affected by Irrigation and Fertilization (1956).

Treatment				Yield Beets T/A	Yield Tops T/A	T/R Ratio	Sucrose (Percent)	Purity (Percent)
Symbol		Irrig. Interval (Days)	Water Used (Inch)					
Method of Irrigation	S	10	23	18.93	12.71	.692	17.35	92.75
	F	10	26	17.93	10.32	.589	17.55	93.34
*LSR at .05				N.S.	1.11	.044	N.S.	0.35
Soil Moisture Condition	W_1	19	16.1	16.19	11.87	.744	16.50	92.01
	W_2	13	16.6	17.32	12.01	.702	17.24	92.63
	W_3	5	25.7	20.14	11.19	.562	17.97	93.64
	W_4	2.7	40.1	20.07	10.98	.556	18.10	93.88
LSR at .05				1.67	N.S.	.067	0.39	0.54
Four year Residual Fertilizer	O			18.30	11.65	.652	17.47	92.98
	P			18.65	11.29	.617	17.38	93.25
	N			18.19	11.63	.657	17.48	93.01
	NP			18.57	11.48	.638	17.47	92.94
LSR at .05				N.S.	N.S.	.033	N.S.	N.S.
One Year Residual Fertilizer	O			17.58	10.95	.635	17.49	92.93
	P			19.28	11.28	.604	17.56	93.53
	N			17.18	11.45	.684	17.31	92.89
	NP			19.67	12.37	.642	17.45	92.83
LSR at .05				1.03	0.61	.033	0.20	0.41
Current Fertilizer	O			17.46	10.24	.597	17.42	93.50
	P			18.98	10.92	.585	17.61	93.57
	N			17.41	12.04	.721	17.42	92.58
	NP			19.87	12.85	.660	17.37	92.52
LSR at .05				1.03	0.61	.033	0.20	0.41

*Duncan's multiple range test.

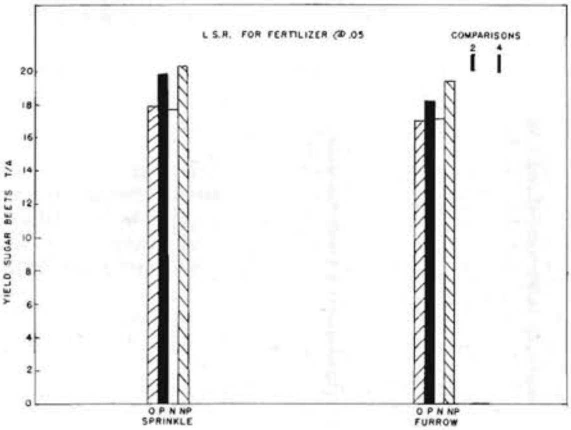


Figure 2.—Yield of sugar beets as affected by method of irrigation and current season fertilization, 1956.

The fact that yields of sugar beets were about 18 tons per acre without any added fertilizer indicates that the soil used in this study was not particularly deficient in available nitrogen and phosphorus. Nevertheless, 44 pounds of phosphorus per acre under sprinkle irrigation produced an additional yield of 1.8 to 2.6 tons per acre (see Figure 2). As will be seen subsequently 80 pounds of nitrogen also produced increased beet yields of about 1½ tons of beets under the moist conditions of treatments W_3 and W_4.

The question is frequently asked: How long will fertilizers remain effective after application? The answer depends on the fertility level and nature of the soil as well as the quantity of fertilizer added. Under the conditions of this experiment it appears that phosphorus applied to the soil the year previous to growing sugar beets is equally as effective in producing high yields as when applied the current season. It has been observed for a number of years that sugar beet yields have not only been higher when phosphorus was applied to the previous crop but better phosphorus nutrition was observed in beets from pre-fertilized soils than when phosphous was applied in the current season. The influence of nitrogen and phosphorus fertilizers on sugar beet yields when they are applied four years previous, one year previous, and directly to the sugar beet crop is shown in Figure 3. It is estimated that the four previous crops had removed 120 pounds nitrogen and 36 pounds of phosphorus per acre more than the additions through fertilizers, crop residues, and microbiological nitrogen-fixation. A yield stimulation would not be expected to result from 80 pounds of nitrogen and 44 pounds of phosphorus fertilizer under these circumstances.

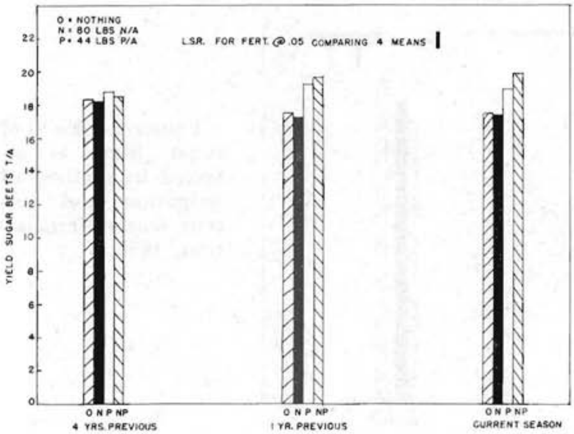


Figure 3.—Yield of sugar beets as affected by residual and currently applied nutrients, 1956.

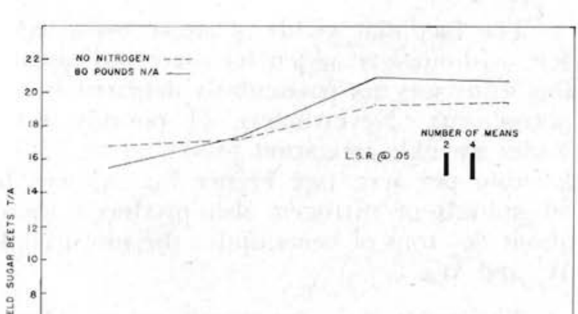


Figure 4.—Yield of sugar beets as affected by nitrogen under various soil moisture conditions, 1956.

One may be inclined to conclude from the data presented in Figures 2 and 3 that nitrogen is of no value under the conditions of this experiment. That such a conclusion is unsound is shown in Figure 4. It will be observed that under dry conditions (W_1) nitrogen is determined to high yields, and under moderately dry conditions (W_2) it is of no advantage. However, under moderately moist soil conditions (W_3) and moist soil (W_4) nitrogen is beneficial. This is a good illustration of important moisture fertilizer interactions which are too frequently overlooked. Since it was noted in Figure 1 that it is under soil moisture conditions W_3 and W_4 that yields are most satisfactory, one must conclude that both nitrogen and phosphorus fertilizers are needed if high yields are to be expected.

Yield of Sugar Beet Tops

The relation between top growth and sugar production is not well established. While it is recognized that top growth itself is not a good indication of sugar yields, it is not unrelated. Data on yield of tops are presented here for the purpose of indicating nutritional status of the sugar beet plant as related to cultural treatments.

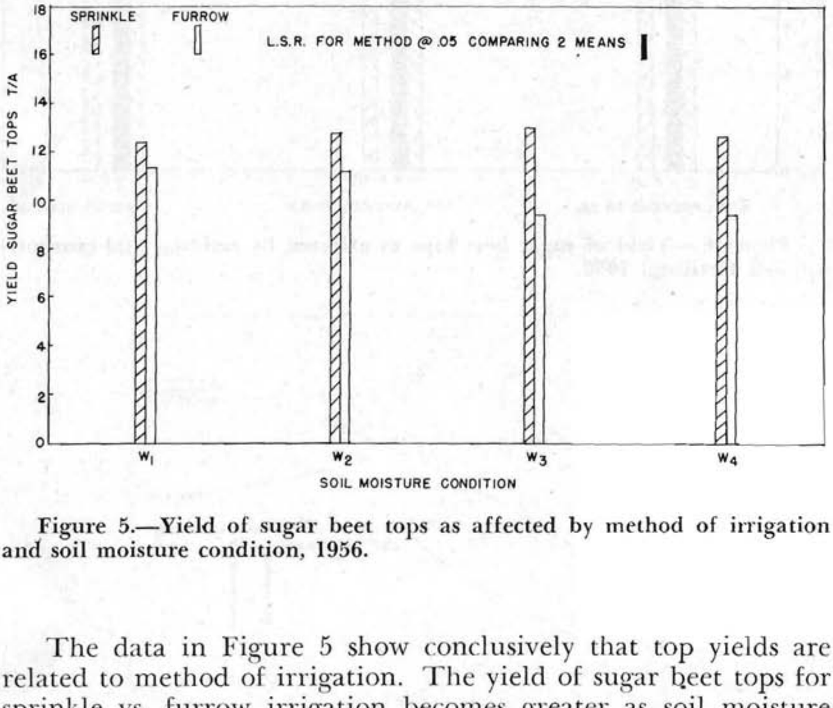


Figure 5.—Yield of sugar beet tops as affected by method of irrigation and soil moisture condition, 1956.

The data in Figure 5 show conclusively that top yields are related to method of irrigation. The yield of sugar beet tops for sprinkle vs. furrow irrigation becomes greater as soil moisture is increased. As will be seen when we examine the nitrogen content of plants grown on sprinkle and furrow irrigated plots, the increased yield of tops under sprinkle irrigation is probably a response to better nitrogen nutrition under sprinkle than furrow irrigation.

The yield of tops is affected by plant nutrients in quite a different manner than roots. Although top growth is stimulated by phosphorus under the conditions of this study it is affected to a much greater extent by nitrogen. This is illustrated in Figure 6. It may be of interest to compare the response in root yields to applied phosphorus as shown in Figure 3, to the response in top yields to applied nitrogen as shown in Figure 6.

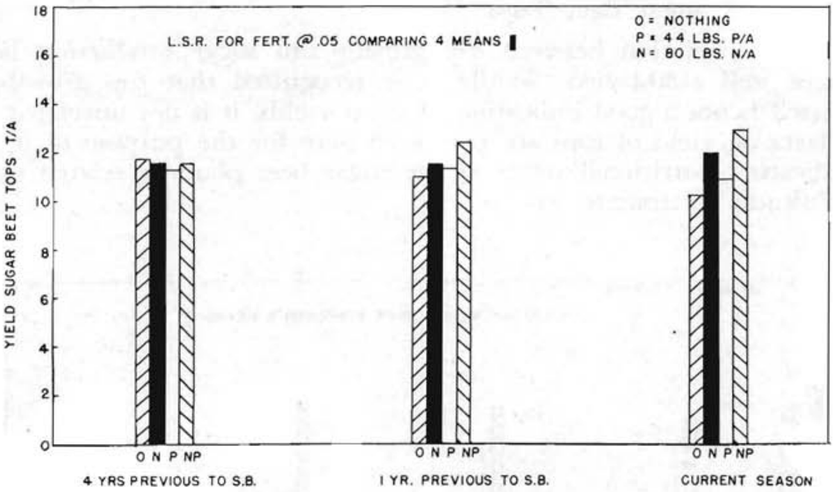


Figure 6.—Yield of sugar beet tops as affected by residual and currently applied fertilizer, 1956.

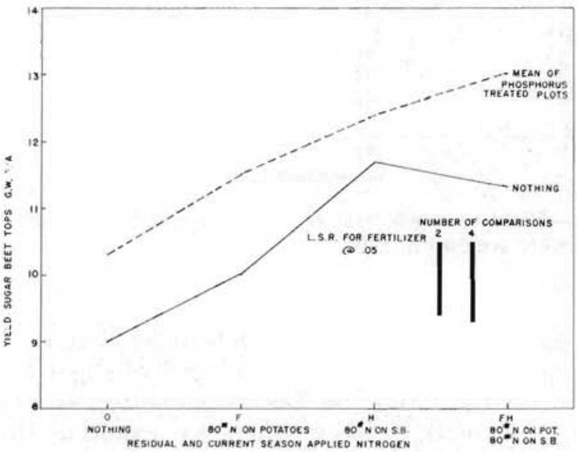


Figure 7.—Yield of sugar beet tops as affected by residual and currently applied fertilizer, 1956.

The data presented in Figure 7 show the effect of residual and currently applied nitrogen and phosphorus in various combinations on sugar beet top growth. While the graph is a little complex it can be readily understood if each line is first studied separately. Looking at the no treatment line one would conclude that without phosphorus 80 pounds of nitrogen per acre applied to potatoes (F) was effective towards increasing yields of green tops. Eighty pounds of nitrogen applied to the current sugar beet crop (H) was much more effective than when applied the previous season to potatoes. However, when 80 pounds of nitrogen was applied to the previous crop (potatoes) and also to the current sugar beet crop (FH) there was no top yield increase above that obtained when nitrogen was applied to the current sugar beet crop only. Actually the tendency was to depress top yields.

Forty-four pounds of phosphorus increased top yields significantly without and with nitrogen treatments. The greatest yield increase for phosphorus occurred when 80 pounds of nitrogen was applied to the potato crop and an additional 80 pounds was applied to the sugar beet crop (FH). There is no tendency for large applications of nitrogen to depress yield of sugar beet tops as long as the available soil phosphorus is in good supply.

Phosphorus stimulated top yield with and without nitrogen fertilizer. When phosphorus was present in the soil from residual or currently applied sources current season applied nitrogen resulted in greater top growth than residual nitrogen. Top growth was greatest when available phosphorus was kept high and available nitrogen was also high.

Some of the relations between cultural treatments and sugar beet root and top yields have been shown graphically in Figures 1 to 7. In order to conserve space and to facilitate comparisons between quality factors (sucrose and purity percentage) and nutrient composition of petioles (NO_3-N, P, K, Na, Ca) with yield of roots and tops, data are presented in Tables 1 and 2.

Effect of Cultural Practices on Top : Root Ratio

It will be observed in Table 1 that the top : root ratios show a small but significant range between treatments. The top : root ratio under sprinkle irrigation is higher than under furrow. Yields of tops and roots are likewise higher under sprinkle than furrow treatments. Dry plots produce beets with a higher top : root ratio than moist plots. Here the yield of tops is related positively and roots negatively to top : root ratios. Nitrogen-fertilized plots show a higher ratio than plots not treated with nitrogen. There appears to be no consistent relation between yield of roots and top : root ratios as affected by residual and current season applied fertilizers. These strong positive relations shown between current season applied nitrogen fertilizers and top : root ratios suggest that the higher top : root ratios noted in the comparison sprinkle versus furrow irrigation and dry versus moist soil conditions may result from increased nitrogen nutrition.

Table 2.—Chemical Composition of Sugar Beet Petioles as Affected by Irrigation and Fertilization 8/4/56.

Treatment		Soluble Constituents in Sugar Beet Petioles 8/4/56 (p.p.m.) NO_3-N	P	K	Na	Ca	NaHCO Sol. P. in Soil p.p.m.
Method of Irrigation	S	5803	1019	39,991	7884	2925	23.52
	F	2844	927	40,847	7337	2987	25.66
LSR at .05		1098	N.S.	N.S.	N.S.	N.S.	N.S.
Soil Moisture Condition	W_1	6132	576	41,841	9304	2922	28.36
	W_2	7578	867	41,824	8459	3348	28.51
	W_3	1863	1106	39,623	6727	2887	22.48
	W_4	1720	1344	38,388	5951	2669	19.01
LSR at .05		1677	235	N.S.	1334	N.S.	N.S.
Four year Residual Fertilizer	O	3859	940	40,292	7490	2888	23.87
	P	4921	1005	39,838	7855	3082	25.19
	N	4584	920	41,685	7520	2980	23.80
	NP	3930	1028	39,860	7576	2876	25.50
LSR at .05		N.S.	91	N.S.	N.S.	N.S.	1.73
One year Residual Fertilizer	O	5041	848	42,462	7637	3019	21.35
	P	3962	1121	37,603	7710	2919	27.09
	N	4730	831	42,662	7522	2973	21.69
	NP	3560	1092	38,388	7573	2915	28.24
LSR at .05		1204	91	2,065	N.S.	N.S.	1.73
Current Season Fertilizer	O	3034	875	41,945	7694	3013	21.66
	P	2429	1074	38,714	8385	2938	27.64
	N	6438	865	41,968	7009	2910	20.28
	NP	5392	1079	39,048	7452	2965	28.79
LSR at .05		1204	91	2,065	399	N.S.	1.73

Cultural Practices and Sucrose and Purity

It has been established that nitrogen content of plant tissue is inversely related to sucrose and purity percentages in sugar beet roots. In almost every instance when sucrose and purity are low, top : root ratios are high (see Table 1). The only exception is under conditions of four years residual fertilizers where the influence of nitrogen is small. The negative relation between sucrose and purity and nitrogen content of petioles will be emphasized subsequently.

Nitrate-Nitrogen Content of Petioles and Cultural Treatments

Suspicions that high soluble nitrate-nitrogen content of sugar beet petioles or high nitrogen nutrition is closely related if not responsible for high top : root ratios, high yield of tops, and low sucrose and purity percentages appears to be confirmed when we examine the column showing the nitrate-nitrogen content of sugar beet petioles in Table 2. Here we find high NO_3-N under sprinkle irrigation, high NO_3-N with dry soil moisture condition (W_1 and W_2), and high NO_3-N under conditions of current season nitrogen fertilization positively related to data in Table 1 showing yield of tops, and top : root ratio and negatively related to sucrose and purity percentages.

Cultural Treatments and Phosphorus Content of Petioles

Phosphorus composition of sugar beet petioles is positively related to yields of sugar beet roots under all treatments studied.

Cultural Treatments as Related to Soluble Potassium, Sodium and Calcium Content of Petioles

The relations of consequence shown in Table 2 are the negative ones between phosphorus application and potassium content of petioles, also phosphorus content of petioles and potassium content of petioles. These data indicate that fertilizer phosphorus has significantly depressed the potassium composition of beet petioles. Moist soil appears to have depressed sodium uptake, current season applied phosphorus appears to encourage the uptake of sodium, and current season applied nitrogen appears to depress sodium uptake. Soluble calcium composition seems to be unaffected by any of the treatments studied. Neither does it appear to be related to yield or quality.

Cultural Practices and $NaHCO_3$-Soluble Soil Phosphorus

Data showing sodium bicarbonate soluble soil phosphorus in Table 2 were obtained from soil samples taken in the spring of 1957 following the sugar beet crop in 1956. Although soluble soil phosphorus content is not significantly different between soil plots treated with sprinkle and furrow methods of irrigation (S and F) or between soils from dry and moist plots (W_1, W_2, W_3, W_4) yet there is a trend which suggests the larger the beet yields the lower the available phosphorus content of the soil for succeeding crops. This needs further study before any definite conclusions can be drawn.

The relations between yield of beet roots as shown in Table 1 and available soil phosphorus in Table 2 for four year residual, one year residual, and currently applied phosphorus appear consistent. Similarly, the relation between soluble phosphorus in sugar beet petioles and available soil phosphorus for these same treatments as shown in Table 2 are what one might well expect from the fertilizer treatments. These data appear to support the conclusion of the author that 22 p.p.m. or 50 pounds per acre six inches of soil, of sodium bicarbonate soluble *phosphorus* should be considered a minimum value for soils similar in behavior to Millville loam on which sugar beets are to be grown.

Summary

1. Under conditions of a rotation of crops including canning peas, alfalfa, alfalfa, potatoes, and sugar beets primary attention was directed to the effect of method of irrigation, soil moisture condition, and fertilizer treatments (both residual and currently applied) on yield, quality, and nutrition of sugar beets. An attempt was also made to show the relation between available soil phosphorus and yield and phosphorus content of sugar beet petioles.

2. Sprinkle irrigation increased the yield of sugar beet tops, top : root ratio, and nitrate-nitrogen content of petioles but decreased purity percentage when compared to furrow irrigation.

3. Increasing soil moisture condition favored high yield of roots, high sucrose, purity, and phosphorus content of petioles and decreased top growth, top : root ratios, nitrate-nitrogen, and sodium content of petioles.

4. One-year residual phosphorus fertilizer was as effective in increasing yield of roots, phosphorus content of petioles, and available soil phosphorus as currently applied phosphorus. Four-year residual phosphorus was effective in decreasing top : root ratio and in increasing the phosphorus content of petioles and available soil phosphorus.

5. A strong interaction was observed between current season nitrogen fertilization and soil moisture condition as these affect yield of sugar beet roots.

6. The yield of sugar beet tops appears to be negatively related to sucrose and purity percentages and positively related to nitrate-nitrogen content of sugar beet petioles.

7. While the data are not conclusive they lend tentative support to the use of 25 parts per million (50 pounds per acre six inches of soil) of sodium bicarbonate soluble phosphorus as a minimum level of available phosphorus for the growing of sugar beets on calcareous soils similar to Millville loam.

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