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THE USE OF SUGAR BEET PETIOLES AS INDICATORS OF SOIL FERTILITY NEEDS

By ROBERT GARDNER and D. W. ROBERTSON

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THE USE OF SUGAR BEET PETIOLES AS INDICATORS OF SOIL FERTILITY NEEDS

By ROBERT GARDNER and D. W. ROBERTSON

Soil investigators are continually confronted with the demand for rapid methods of determining fertility deficiencies of the soil. Many tests have been devised for this purpose. None have been entirely satisfactory under all soil conditions. The need for a reliable test for phosphate deficiency has been the most acute and has received the most attention. By far the greatest effort in the search for rapid tests has been centered on chemical analysis of the soil. A comparatively small number of investigators have studied the possibilities of using rapidly growing plants on soil samples in the laboratory or greenhouse as indicators of fertility needs. A much smaller number have studied the chemical composition of the plants growing in the field as a means of detecting soil deficiencies. Until recently, most of those who have attempted to determine fertility needs from plant composition have relied on total analyses and the results were not promising, due to the fact that there is not a wide difference in total composition between plants grown on soils of different productiveness. Recently, a number of investigators have studied the relationship of the inorganic constituents in the conducting tissues of the plants to soil fertility, and have found a high correlation.

A study of the plant as a measure of soil fertility offers, in many ways, a distinct advantage over a study of the soil. If the plant is able to maintain a high concentration of nutrients in its conducting tissues, there can be no doubt that the soil is comparatively well supplied with these nutrients in an available form. Any direct soil analysis, on the contrary, always involves an assumption that the amount of nutrients extracted, by whatever method used, is proportional to the amount the plant is able to withdraw. So little is known of the mechanism and forces which the plant uses in extracting plant food from the soil that very little can be predicted regarding the value of a soil test until it has been thoroughly tried out by comparing with fertilizer trials in the field.

A second serious weakness in the soil analysis, which the plant analysis avoids, is the question of proper sampling. There is no way of knowing what relative importance should be given to the surface and subsoil when taking soil samples. Neither surface nor subsoil represents the entire feeding zone of the plant. The plant samples represent the feeding zone without raising the question of its extent.

The theoretical considerations regarding the value of using the plants in the field as soil indicators are well supported by the results of several recent investigations. Work with a variety of crops has shown a very close agreement between the inorganic constituents in the plants and the supply of these constituents in an available form in the soil. Among the crops studied were corn, oats, tomatoes, lettuce and lemons. The works of Emmert (2, 3, 4, 5) of Kentucky, Pettinger (8, 11) of West Virginia, Thornton (9, 10, 11) of Indiana, and Chapman (1) of California, all strongly support the idea that the soluble material in the plant tissues reflects to a high degree the readily available supply of these constituents of the soil.

The use of commercial fertilizers is not yet extensive in Colorado, consequently, there is a lack of information on the economical use of them in this state. There is considerable evidence that phosphorus is a limiting growth factor on many farms, but the use of commercial phosphate does not give consistent results and often fails to give response where benefits are most expected. The soils are generally alkaline and highly calcareous. The soil tests which have given good indications with the neutral or acid soils of the East are not reliable under these conditions. A method involving an alkaline extract, reported by Hockensmith, et al (7), has been found to detect the soils distinctly high and distinctly deficient in available phosphorus with fair certainty, but the method will not detect small differences. This leaves many fields in a doubtful zone.

MATERIALS AND METHODS

The results presented in this bulletin were obtained in connection with two fertilizer experiments using sugar beets as the test crop. One of the experiments was a study of the effect of manure on the soil and crop; the other was a study of the tolerance of sugar beets to nitrates. The manure experiment included 12 treatments, replicated 4 times, or a total of 48 plats. The nitrate experiment included 13 treatments, also replicated 4 times. The treatments are given in Table 1.

SOIL AND PLANT SAMPLING.—Samples of the soil and samples of leaf petioles were taken periodically during the season. Each time the soil was sampled, 3 cores of soil were taken per plat to a depth of 3 feet by sections, as follows: First, 6 inches; second, 6 inches; third, 12 inches; and fourth, 12 inches. The samples for analysis were air-dried over a screen and ground in a hammer mill.

The plants were sampled by collecting ten leaf petioles from beets taken at random from each plat. Petioles from comparatively mature leaves were chosen and sections of 2 or 3 inches in length cut from about the middle portions. These were sealed in envelopes to reduce drying, taken to the laboratory and prepared for analysis as soon as possible.

Table 1.—Soil Treatments.

Series	Treatment No.	Material	Rate per acre	Time applied
Manure	1	Green manure (peas)		Fall 1933
Manure	2	Green manure (millet)		Fall 1933
Manure	3	Well-rotted manure	10 tons	Spring 1933
Manure	4	Well-rotted manure	10 tons	After barley 1933
Manure	5	Well-rotted manure	10 tons	Fall 1933
Manure	6	Well-rotted manure	10 tons	Spring 1934
Manure	7	Strawy manure	15 tons	Spring 1933
Manure	8	Strawy manure	15 tons	After barley 1933
Manure	9	Strawy manure	15 tons	Fall 1933
Manure	10	Strawy manure	15 tons	Spring 1934
Manure	11	No treatment		
Manure	12	Fallow 1933		
Nitrate	1	No treatment	None	
Nitrate	2	$CaCl_2$*	24,802 lb.	½ June 6, ½ June 30
Nitrate	3	$Ca(NO_3)_2$*	592 lb.	June 6
Nitrate	4	$Ca(NO_3)_2$*	1,794 lb.	June 6
Nitrate	5	$Ca(NO_3)_2$*	5,400 lb.	June 6
Nitrate	6	$Ca(NO_3)_2$*	16,183 lb.	June 6
Nitrate	7	$Ca(NO_3)_2$*	383 lb.	½ June 6, ½ June 30
Nitrate	8	$Ca(NO_3)_2$*	1,184 lb.	½ June 6, ½ June 30
Nitrate	9	$Ca(NO_3)_2$*	3,588 lb.	½ June 6, ½ June 30
Nitrate	10	$Ca(NO_3)_2$*	10,800 lb.	½ June 6, ½ June 30
Nitrate	11	$Ca(NO_3)_2$*	32,366 lb.	½ June 6, ½ June 30
Nitrate	12	{$Ca(NO_3)_2$*	5,400 lb.	
		{Treble superphosphate	5,226 lb.	June 6
Nitrate	13	Treble superphosphate	5,226 lb.	June 6

*Commercial grades.

SOIL ANALYSIS.—The soils were tested for available phosphorus by the potassium carbonate method of Hockensmith, et al (7), and for nitrate nitrogen by the diphenylamine method. The method of carrying out the nitrate test was to weigh 10 grams of soil into 20 cc. of 0.1 percent silver sulfate solution. The mixture was shaken 2 or 3 times at intervals and allowed to stand over night. One drop of the supernatant solution was placed on a spot plate and 4 drops of diphenylamine reagent added. The nitrate content was estimated from the color intensity. The reagent was prepared by dissolving 0.1 gram of diphenylamine in 50 cc. of concentrated sulfuric acid. The accuracy of the method is much higher than would be expected from this type of test. When the concentration of nitrate nitrogen in the solution is not greater than 12 or 15 p.p.m. a little experience enables the operator to estimate the nitrogen to within 1 or 2 p.p.m., which is near the limits of accuracy ordinarily obtained with the DeVarda's Alloy Method.

PLANT ANALYSIS.—Each sample of petioles was placed in a bunch on a block and enough thin cross-section slices shaved off to make a 2-gram sample. The sample was placed in 20 cc. of distilled water, shaken 2 or 3 times at intervals and allowed to stand 12 or 24 hours. For the phosphorus determination, 1 cc. of solution was drawn off and diluted sufficiently so that the color could be read in a Hellige Comparator. In most cases, 1 cc. of the solution to 20 cc. of water gave about the required dilution. The color was developed by adding 3 drops of molybdate solution, followed by 1 drop of stannous chloride solution. The reading was taken when the color approximated the maximum intensity, which was usually within 30 seconds. The molybdate solution was prepared by dissolving 25 grams of ammonium molybdate in 200 cc. of water at 60° C., and adding to 800 cc. of sulfuric acid prepared by diluting 28 cc. of arsenic and phosphorus free concentrated sulphuric acid. The volume finally was made up to 1000 cc.

The stannous chloride solution was prepared by dissolving 25 grams of $SnCl_2 \cdot 2H_20$ in 100 cc. of concentrated HCl and making up to 1000 cc.

Since the analyses reported in this bulletin were made, it has been found that better results are obtained if the molybdate reagent is prepared according to the method given by Zinzadze (12), using molybdic oxide instead of ammonium molybdate. The reagent is prepared by adding 6.02 grams of C. P. anhydrous MoO_3 to 120 cc. of concentrated H_2SO_4 (sp. gr. 1.84) and heating while stirring until dissolved. The volume is made up to 800 cc. with distilled water after cooling. The stannous chloride used with this reagent is prepared by adding 1.02 grams of $SnCl_2 \cdot 2H_2O$ and 5 cc. of concentrated HCl (sp. gr. 1.18) to 200 cc. of distilled water. In making the test 1 cc. of the molybdate reagent and 0.2 cc. of the stannous chloride solution are used. The stannous chloride solution must be discarded if it becomes cloudy or yellow. It will keep longer under a layer of mineral oil.

The nitrate and potash tests were made on portions of the extract diluted to the desired concentrations. The same procedure was followed for the nitrate determination as was described for the soil extract. Thornton's rapid procedure (10) was followed for the potash tests, using an aliquot of the extract as in the phosphate and nitrate tests.

ACCURACY OF THE METHODS AND ANALYSIS OF THE DATA.—Most methods of approximate analysis are subject to rather obvious sources of inaccuracy, and the above methods are no exception. There is always a very large sampling error in the field when collecting soil and crop samples. The final results, in spite of the laboratory precision, may be no more accurate than the accuracy of soil sampling. The most effective way of reducing the sampling error is to increase the number of samples. An estimate of the total error, including the error of field sampling and of laboratory analysis, was obtained from the statistical analysis of the data. This error which is high in both the soil and plant results probably could be lessened by increasing the number of samples and reducing the laboratory error.

Grinding rather than slicing the samples, no doubt, would give a more complete extraction of nutrients. However, it was found that grinding increased the organic material in the extract and interfered with the color development. Emmert's method (5) of grinding with charcoal, and filtering, probably would improve the color development. Allowing the solutions to stand 12 to 24 hours is a possible source of significant error, particularly in the case of nitrates, due to biological changes. However, we found that under the conditions prevailing the change was negligible.

The experiment was laid out in randomized blocks so that variance due to treatment and replications could be removed in calculating the standard error and Fisher's (6) "Z" values. The mean values of each treatment, the difference of each treatment from the check, the difference required to be significant by the 5 percent point, and the "Z" values for the experiment are given.

Table 2.—Estimated Error of Sampling and Analyzing Soil and Petioles.

Phosphorus					
Soil			Petioles		
No. Samples	Cores per sample	S. E. in percent	No. Samples	Petioles per sample	S. E. in percent
1	3	32.2	1	10	17.7
2	3	22.8	2	10	12.6
3	3	18.6	3	10	10.0
4	3	16.1	4	10	8.9
10	3	10.2	10	10	5.6
Nitrate Nitrogen					
Soil			Petioles		
No. Samples	Cores per sample	S. E. in percent	No. Samples	Petioles per sample	S. E. in percent
1	3	23.7	1	10	47.4
2	3	16.4	2	10	33.6
3	3	13.7	3	10	27.4
4	3	11.9	4	10	23.7
10	3	7.5	10	10	15.0

Table 2 gives the average standard error per plat and the estimated standard error which would have been obtained by increasing the number of samples. This was obtained by dividing the standard deviation by the square root of the number of samples.

EXPERIMENTAL RESULTS

The ability of the beet-petiole test to detect differences in available phosphorus is shown in Table 3. It can be seen from the "Z" values that each time the test was made during the season there were significant differences due to treatment. When all of the three tests made are included, the "Z" value is very high and all of the yard manure treatments except one are significantly higher than the check. The results are very striking when compared with the soil test which has a very low "Z" value. Even for the average of the season where 6 samplings in all or 72 borings for each plat were made, the "Z" value is below the 5 percent point. The table indicates that the soil test was unable to detect the small differences in available phosphorus found in the soils of the experiment. The differences were very readily detectable by the plant test.

Tables 3, 4 and 5 indicate that the soil-test values are not strictly proportional to the phosphates taken up by the plants. The soils of the two experiments before treatment were quite different in available phosphorus according to both tests. This is shown by the results from the check plats. The manure treatments increased the phosphates in the beets to a higher level than was found in the beets of the check plats on the nitrate series. However, the soil test indicated that there was much more available phosphorus in the untreated plats of the nitrate series. The phosphate in the petioles was apparently very much decreased by the nitrate treatments, probably due to the fact that the nitrate treatments greatly increased vegetative growth and resulted in a heavier drain on the soil. Phosphate in the petioles and yield of sugar were significantly lower than the no-treatment for the three highest nitrate plats. The average phosphate in the petioles from the manure-treated plats was very much higher than the average phosphate from the nitrate plats. The order was reversed in the soil. It is apparent that plants grown under generally favorable conditions may need a greater supply of available phosphorus than plants grown under unfavorable conditions. Testing the plants should give a measure of the relative supply of available nutrients compared to the plant needs and should furnish a means of detecting which particular nutrient is the limiting factor much more directly than soil analysis.

Usually tests for fertility needs are made for the purpose of determining whether or not to apply commercial fertilizer. It is natural to assume that if the test indicates a deficiency, the condition could be remedied by merely adding the deficient element in the form of a commercial fertilizer. The data in Tables 3 and 4 indicate that this assumption is not wholly justified. Treatments 12 and 13, Tables 4 and 5, consisted of more than 5,000 pounds of treble superphosphate

Table 3.—Water Soluble Phosphorus in Beet Petioles and Potassium Carbonate Soluble Phosphorus in the Soil of Manure-Treated Plats.

Treat-ment	Water Soluble P in Petioles (p.p.m.)								Potassium Carbonate Available P in Soil (average for season) (p.p.m.)							
	May 22		July 10		Sept. 6		Season		0″–6″		6″–12″		12″–24″		24″–36″	
	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D
1	147.5	–7.5	84.8	29.5	77.3	4.5	102.2	8.0	40.4	2.3	39.4	2.8	25.7	–0.6	25.1	–0.1
2	127.3	–27.7	63.0	7.7	84.5	11.7	91.5	–2.7	37.2	–0.9	31.0	–1.1	26.2	–0.1	24.1	–1.1
3	175.5	20.5	99.5	44.2	92.0	19.2	122.2	28.0	42.2	4.1	34.1	2.0	26.9	0.6	24.9	–0.3
4	185.0	30.0	98.3	43.0	100.2	27.4	128.0	33.8	40.5	2.4	36.2	4.1	25.1	–1.3	22.7	–2.5
5	187.3	32.3	99.0	43.7	83.8	11.0	123.0	28.8	42.0	3.9	35.8	3.7	25.4	–1.0	24.2	–1.0
6	152.5	–2.5	90.8	35.5	79.2	6.4	107.5	13.3	42.6	4.5	34.4	2.3	26.7	0.4	24.2	–1.0
7	172.8	17.8	106.3	51.0	79.0	6.2	124.0	29.8	43.6	5.5	33.1	1.0	26.0	–0.3	23.8	–2.0
8	211.0	56.0	107.3	52.0	112.0	39.2	143.2	49.0	47.5	9.4	37.8	5.7	25.9	–0.4	25.3	0.1
9	196.5	41.5	102.5	47.2	128.8	56.0	142.2	48.0	46.1	8.0	35.8	3.7	26.8	0.5	23.1	–2.1
10	174.0	19.0	88.5	33.2	104.8	32.0	122.5	28.3	45.0	6.9	36.6	4.5	26.4	0.1	23.0	–2.2
11	155.0	Ck.	55.3	Ck.	72.8	Ck.	94.2	Ck.	38.1	Ck.	32.1	Ck.	26.3	Ck.	25.2	Ck.
12	137.0	–18.0	66.3	11.0	79.5	6.7	94.2	0.0	38.3	0.2	33.9	1.8	26.1	–0.2	23.4	–1.8
	Z = .42		Z = .48		Z = .60		Z = .96		Z = .33		Z = –.10		Z = –.82		Z = –.24	
	Ds=37.4		Ds=30.9		Ds=26.4		Ds=22.2		Ds= 6.6		Ds= 6.1		Ds= 3.5		Ds= 3.2	

5 percent point= .4 (This applies to Tables 3-7)

Note: P =Phosphorus. D=Difference from no treatment plat. Z=Fisher's "Z" test for significance.
Ds=Difference for significance (2xS. E. of a difference). Ck.=No treatment.

Table 4.—Water Soluble Phosphorus in Beet Petioles in Nitrated and Phosphated Plats.

Treatment	Phosphate P				Nitrate N			
	June 20		Sept. 3		June 20		Sept. 3	
	P	D	P	D	N	D	N	D
1	138.5	Ck.	113.0	Ck.	945	Ck.	88	Ck.
2	100.5	-38.0	76.0	-37.0	578	-367	48	-40
3	136.3	-2.2	98.8	-14.2	1260	315	270	192
4	126.8	-11.7	89.8	-23.2	1418	473	283	195
5	92.0	-46.5	72.0	-41.0	1733	788	825	737
6	101.5	-37.0	71.3	-41.7	1733	788	660	572
7	103.0	-35.5	101.8	-11.2	1155	210	108	20
8	132.3	-6.2	90.0	-23.0	1470	525	318	230
9	128.0	-10.5	78.8	-34.2	1418	473	495	407
10	101.5	-37.0	64.5	-48.5	1733	788	770	682
11	114.5	-24.0	73.5	-39.5	1680	735	770	682
12	148.5	10.0	98.0	-15.0	1943	998	660	517
13	141.5	3.0	123.3	9.3	890	-105	40	-48
	Z = -.08 Ds=57.8		Z = .72 Ds=24.6		Z = 1.02 Ds=415.8		Z = 1.50 Ds=185.0	

Table 5.—Potassium Carbonate Soluble Phosphorus in the Soil of Nitrated and Phosphated Plats.

Treat-ment	June 28, 1934								August 24, 1934							
	0″–6″		6″–12″		12″–24″		24″–36″		0″–6″		6″–12″		12″–24″		24″–36″	
	P	D	P	D	P	D	P	D	P	D	P	D	P	D	P	D
1	80.5	Ck.	65.0	Ck.	49.5	Ck.	42.5	Ck.	60.8	Ck.	45.8	Ck.	36.3	Ck.	32.5	Ck.
2	83.0	2.5	73.8	8.8	57.0	7.5	42.0	-0.5	81.3	20.5	78.5	32.7	38.5	2.2	32.5	0.0
3	73.8	-6.7	53.0	-12.0	37.3	12.2	33.0	-9.5	127.3	66.5	95.3	49.5	52.0	15.7	37.0	4.5
4	92.0	11.5	73.8	8.8	54.8	5.3	41.8	-0.7	105.0	44.2	64.8	19.0	35.5	-0.8	32.5	0.0
5	75.0	-5.5	49.3	-15.7	37.3	-12.2	37.0	-5.5	66.3	5.5	51.8	6.0	35.3	-1.0	37.3	4.8
6	80.0	-0.5	64.0	-1.0	48.8	-0.7	38.8	-3.7	72.0	11.2	52.5	6.7	34.8	-1.5	30.5	-2.0
7	75.3	-5.2	57.3	-7.7	44.8	-4.7	45.5	3.0	105.3	44.5	70.0	24.2	44.8	8.5	39.0	6.5
8	85.5	5.0	60.0	-5.0	42.0	-7.5	39.5	-3.0	60.8	00.0	54.0	8.2	29.3	-7.0	26.8	-5.7
9	79.8	-0.7	64.3	-0.7	47.3	-2.2	37.5	-5.0	81.8	21.0	68.5	22.7	29.0	-7.3	36.5	4.0
10	86.3	5.8	57.5	-7.5	37.3	-12.2	37.5	-5.2	112.5	51.7	91.5	45.7	45.0	8.7	43.8	11.3
11	83.5	3.0	60.8	-4.2	52.0	2.5	39.3	-3.2	66.5	5.7	41.5	-4.3	32.5	-3.8	28.8	-3.7
12	186.0	105.5	110.5	45.5	67.3	17.8	47.0	4.5	134.5	73.7	64.8	19.0	37.3	1.0	31.8	-0.7
13	166.0	85.5	79.3	14.3	54.8	5.3	49.5	7.0	115.5	55.0	82.5	36.7	62.5	26.2	55.8	23.3
	Z = 1.21		Z = .37		Z = .20		Z = .12		Z = .08		Z = .09		Z = .36		Z = .29	
	Ds= 30.2		Ds=30.5		Ds=20.6		Ds=11.7		Ds=68.5		Ds=52.9		Ds=17.8		Ds=15.9	

per acre. The phosphate in the beet petioles was increased much less by this high treatment than by the manure treatments which contained in most cases less than 50 pounds of phosphorus per acre. The slight increase of phosphate in the plants due to this high phosphate treatment would indicate a very low availability of the treble superphosphate after being added to the soil. A higher availability might have been obtained by placing the fertilizer deeper in the soil, but the soil test showed that some of the phosphate had penetrated into the second foot.

NITRATES.—The soil tests for nitrates are much more accurate than the available phosphorus tests, since the nitrates are readily soluble and easily extracted. However, a low supply of nitrates in the soil does not necessarily indicate a shortage in the plants. The soil may show a low concentration when the plants are still abundantly supplied. This is shown in Tables 6 and 7. The soil was practically exhausted in nitrates by August 30, but there was still an abundant supply in the plants on September 6. The nitrates in the nitrate plats receiving treatments 3, 4, 7 and 8 were reduced so low in the soil by August 24 that they were not significantly higher than the no-treatment plats, but all of the treated plats except the one receiving the lowest treatment were much higher in the petioles than the check plats. The check plat gave a significantly lower yield of beets due to nitrate shortage than the other plats, even though the soil tests did not detect a difference. The shortage was clearly indicated in the plant test.

AVAILABLE POTASSIUM.—There is little evidence that potassium is a limiting factor in any of the Colorado soils. Potassium, however, is often high enough in beets to injure the quality of the crop. The rapid test described by Thornton (10) was applied to one set of

Table 6.—Soil Nitrates in Manure Plats 0″-36″.

	April 19		August 30		October 10		Season	
Treatment	N	D	N	D	N	D	N	D
1	8.3	0.7	3.6	0.3	3.8	1.2	7.0	-0.1
2	6.3	2.7	1.5	-1.8	2.8	0.2	4.3	-0.2
3	12.2	3.2	2.1	-1.2	2.2	-0.4	6.4	-0.7
4	8.4	0.6	2.6	-0.7	2.5	-0.1	5.9	-1.2
5	8.7	0.3	1.0	-2.3	3.8	1.2	6.8	-0.3
6	11.5	2.5	3.6	-0.3	3.3	0.7	7.5	0.4
7	11.1	2.1	2.0	-1.3	3.9	1.3	6.5	-0.5
8	10.6	1.6	2.2	-1.1	2.4	-0.2	6.8	-0.3
9	8.2	0.8	1.8	-1.5	2.9	0.3	5.8	-1.3
10	10.3	1.3	3.5	0.2	3.0	0.4	7.3	0.2
11	9.0	Ck.	3.3	Ck.	2.6	Ck.	7.1	Ck.
12	12.2	3.2	1.2	-2.1	3.2	0.6	7.2	0.1
	Z = .49		Z = .04		Z = .17		Z = .30	
	Ds=2.04		Ds=2.64		Ds=1.34		Ds=1.86	

Table 7.—Nitrate Nitrogen in Beet Petioles and Soil in Manure Plats.

Treatment	Nitrate Nitrogen in Petioles (p.p.m.)								Nitrate Nitrogen in Soil (Season) p.p.m.							
	May 22		July 10		Sept. 6		Season		0″–6″		6″–12″		12″–24″		24″–36″	
	N	D	N	D	N	D	N	D	N	D	N	D	N	D	N	D
1	1178	–82	1100	55	550	110	943	28	9.0	1.1	9.2	0.2	5.6	–0.5	6.1	–0.2
2	1123	–137	633	–414	330	–110	688	227	5.6	–2.3	5.2	–3.8	3.1	–3.4	4.2	–2.1
3	1205	–55	1017	–28	243	–197	839	–76	8.5	0.6	9.1	0.1	6.0	–0.5	6.4	0.1
4	1185	–75	825	–220	320	–120	779	–136	6.6	–1.3	8.7	–0.3	6.3	–0.2	5.7	–0.6
5	1125	–135	688	–357	288	–152	709	–206	8.0	0.1	8.2	–0.8	6.3	–0.2	5.9	–0.4
6	1125	–135	990	–55	495	55	868	–47	9.8	1.9	10.1	1.1	6.7	0.2	5.8	–0.5
7	1260	0.0	605	–440	468	28	778	–137	9.0	1.1	8.9	–0.1	5.1	1.4	5.3	–1.0
8	1335	75	715	–330	330	–100	803	–112	10.2	2.3	8.6	–0.4	5.7	–0.8	5.3	–1.0
9	1178	82	495	–550	258	–182	639	–276	9.0	1.1	7.9	–1.1	4.6	–1.9	4.1	–2.2
10	1043	217	605	–440	348	–92	659	–256	8.1	0.2	8.0	–1.0	7.1	0.6	6.1	–0.2
11	1260	Ck.	1045	Ck.	440	Ck.	915	Ck.	7.9	Ck.	9.0	Ck	6.5	Ck.	6.3	Ck.
12	1368	108	908	–137	413	–27	896	–19	10.3	2.4	9.3	0.3	6.9	0.4	5.5	–0.8
	Z = .05		Z = .61		Z = .13		Z = .35		Z = .15		Z = .34		Z = .49		Z = .03	
	Ds=253.		Ds=345.		Ds=213.		Ds=205.		Ds=3.38		Ds=2.48		Ds=1.96		Ds=2.06	

Table 8.—Nitrate Nitrogen in the Soil in Nitrated Series.

Treatment	June 28					August 24				
	0″–6″	6″–12″	12″–24″	24″–36″	0″–36″	0″–6″	6″–12″	12″–24″	24″–36″	0″–36″
1	14.8	12.8	7.3	7.5	10.0	7.8	4.0	2.5	2.5	3.7
2	24.0	21.5	5.5	3.0	11.7	13.5	9.0	8.5	8.3	9.5
3	24.1	14.0	13.3	6.5	12.9	5.5	4.3	4.5	3.8	4.4
4	66.0	41.0	13.3	9.5	21.2	8.3	3.5	3.3	5.3	4.8
5	113.0	89.5	20.5	18.5	46.3	46.0	38.3	68.0	26.0	45.4
6	687.5	225.5	72.2	50.2	189.3	277.0	176.0	259.5	243.0	242.9
7	11.5	10.3	5.0	3.5	6.5	11.3	6.0	6.0	4.3	6.4
8	41.5	16.0	9.3	6.8	15.0	7.0	4.3	3.5	4.8	4.7
9	111.0	32.0	13.5	8.5	32.0	9.0	39.0	54.5	12.5	30.3
10	317.5	115.0	25.0	17.3	92.0	118.5	102.0	231.0	138.0	159.7
11	642.5	210.5	40.0	28.5	165.0	160.0	163.0	302.0	378.0	280.5
12	275.0	93.5	15.0	10.3	71.5	106.0	42.3	34.5	18.5	44.1
13	6.5	4.5	5.0	3.3	4.6	3.8	3.0	2.0	2.8	3.4
Average	179.6	68.2	18.8	13.3	52.1	59.5	45.6	75.4	65.2	64.6

petioles taken in the late summer from each of the experiments. The test did not show any significant differences between treatments but did show a very large difference between the beets on the two experiments. The soluble potash was nearly twice as high on the manure series as on the nitrate series. The lowest test would be classed abundant by Thornton's standards. The results indicated that testing the plants is a practical method of estimating available potash.

THE LINE BETWEEN SUFFICIENT AND DEFICIENT SOILS.—The results indicate that 100 parts per million or less of either phosphate phosphorus or nitrate nitrogen in the petioles is below the optimum for sugar beets. The manure series of plats gave a significant phosphate increase in the petioles due to manure treatments which was highly correlated with beet yield. It is reasonable therefore to assume that the level of available phosphorus in that series is below the optimum, but the soil is very productive so there cannot be a great deficiency. Therefore, the level observed in the beets of the check plats on this series during the season probably is near the line between deficient and sufficient soil. There is a difference at the different dates of sampling. The test showed 155 p.p.m. at thinning time, May 22; 55.2, July 10; and 72.8, September 6; or an average of 94.3.

If these values were converted to milligrams P_2O_5 per cc. of cell sap, they would be close to the 0.2 milligrams of P_2O_5 per cc. of cell sap which Pettinger (8) gave as the approximate line between high and medium-yielding corn plats. Pettinger (8) gave 100 p.p.m. nitrate nitrogen in the cell sap as deficient and above 300 p.p.m. as sufficient. Our results indicate that these values would hold for sugar beets.

SUMMARY

A comparison of sugar beet petiole analysis with the potassium carbonate soil test in a sugar beet plat experiment showed the petiole test to be much more efficient in detecting the differences in available phosphorus due to the manure treatments than the potassium carbonate soil test.

The petiole test seemed to be sufficiently accurate to give a reliable indication of phosphate needs of the soil.

A comparison of the effects of applications of treble super-phosphate and manure on the composition of the plant extracts indicated that manure much more efficiently increased the available phosphorus.

The results of the experiment showed the test to be applicable in determining nitrate and potash needs.

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