Sugar Beet Petiole Tests as a Measure Of Soil Fertility

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The beet grower who owns his farm can maintain the fertility of the soil at a high point with no fear that money spent on surplus plant nutrients during one season will be lost. The tenant grower too often is in the position where the only certain returns he can see are in the current season. And therefore the tendency is merely to maintain such farms, at best, at the range of the dividing line between sufficiency and deficiency. The low level of the average beet yield indicates that a larger percentage of the farms are in this class. The growers in this class require that any fertilizer treatment produce an immediate response which repays for the treatment. Soil tests measure the available phosphate and potash with a satisfactory degree of accuracy, but give little useful information regarding nitrogen.

In the present discussion we have only slight interest in potash, since field trials on our soils, lowest in available potash, have not indicated a potash deficiency. Although soil tests measure the available phosphate with a high degree of accuracy, various factors, such as the variable requirement of the sugar beet for phosphate in different environments, make the interpretation of the results of the soil test unsatisfactory on a large percentage of soils. Too many soils fall in the doubtful classification. It appears logical that the plant itself which is the integration of all factors—soil nutrient status, climate, etc.—may be used to determine fertilization requirements. To be useful in the sugar beet crop it must be possible to gain the desired information sufficiently early in the season to permit of correction in the current crop.

Plant tissue tests are steadily becoming more popular as a measure of soil fertility. Investigators are not agreed as to which part of the plant should be tested, nor as to how 1ests should be made. One school favors tests on conducting tissue for non-assimilated plant nutrients. The other uses leaf tissue and analyzes for total content of those constituents. Various investigators have found that the sugar beet petiole is a good indicator of the supply of available nutrients, and the following presents results of petiole tests made in the Great Western Sugar Company area during recent years.

Petiole tests were made on cold water extracts of petiole matter ground in a mortar or food blender. All results are reported on the basis of parts per million of nitrate nitrogen and phosphate phos-

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phorus on original petiole matter. The earlier samples consisted of 10 to 12 petioles taken from as many randomly selected beets. In 1942 an accurate sampling technique was developed and since that date larger samples have been used.

Tn 1940 the primary interest was in phosphate, and periodic soil and petiole tests were made on samples from six widely scattered fields.

Results of individual petiole tests were very erratic. Below are given the results of the average petiole tests on three samplings during June, July, and August, compared with beet yields.

Table 1.—Petiole tests for phosphate and beet yields, 1940.

Field No.	p.p.m. of P in petioles	Root yield Tons per acre
1	138	10.9
2	134	16.3
3	84	13.4
4	82	19.0
5	63	22.3
6	60	22.0

Soil and petiole tests showed excellent correlation. 11 is curious that yield varies inversely with the phosphate test. There was no visual evidence that nitrogen was a controlling factor in these yields.

In 1941 periodic petiole tests were made on 66 commercial beet fields in the Colorado and Nebraska area of the Great Western Sugar Company. Results were very erratic and in table 2 are given average results of tests on 46 fields sampled during July, August, and September, grouped according to beet yield.

Table 2.—Periodic petiole tests, 1941. Average of petiole tests during July, August, and September.

Yield group	+20 tons	17 to 20 tons	14 to 10.9 tons	11 to 13.9 tons	Less than 11 tons
No. of fields in group	7	11	14	6	8
	p.p.m.—N	p.p.m.—N	p.p.m.—N	p.p.m.—N	p.p.m.—N
July	379	494	082	307	443
August	666	325	807	226	574
September	212	122	236	30	112
	p.p.m.—P	p.p.m.—P	p.p.m.—P	p.p.m.—P	p.p.m.—P
July	144	110	109	98	116
August	96	88	52	56	92
September	63	54	47	38	44

Some may be inclined to discount the significance of group averages, especially in the low-yield groups, since reciprocal relations of N and P are often observed. This is most common in the high-yield groups, when high yield associated with very low nitrate test is often accompanied by high phosphate test, and vice versa. Among the 14 fields comprising the two low-yield groups, only 2 gave results indieating that low phosphate was responsible for accumulation of nitrates and only 1 indicated that high phosphate accumulated as the result of low nitrates.

In 1942 petiole tests were made with the primary object of determining sampling requirements necessary to provide a petiole sample of known error limits. The results of this work were published in Soil Science, Vol. 56, p. 213 (Sept. 1943). Since that date the samples taken have consisted of a composite of single petioles from one of the group of youngest mature leaves from 72 to 75 randomly selected beets. This sample has an error limit of not over 20 percent at the 9 to 1 probability ratio. The 1942 work has little bearing on the present discussion, but it may be pointed out that the various fields sampled during this work showed almost complete loss of nitrates by the end of July.

Accurate samples were taken periodically from 10 fields in a single factory district in 1944. A summary of average results is given in table 3. The figures shown are averages of results from fields grouped according to yield. Figures on individual fields are of little value, and on averages of a small number of fields they are of doubtful value. Results from one field, far out of line, are not included in the averages.

Table 3.—Periodic petiole tests, 1944.

Yield group	+17 tons	17 to 10 tons	Minus l0 tons
Fields in group	2	4	3
	p. p. m.—N	p.p.m.—N	p.p.m.—N
July	669	434	253
August	300	343	105
September	226	189	33
	p.p.m.—P	p.p.m.—P	p. p. m.—P
July	93	87	101
August	89	91	90
September	54	55	36

One field which yielded 17.5 tons of beets showed practically no nitrates at any time during the season. The average phosphate test was 116 p.p.m.

The 1945 tests were made on five pairs of fields in five factory districts in Colorado and Nebraska, sampled periodically throughout the season. Each pair consisted of one fertile and one infertile field.

The average results of petiole tests on fields grouped according to yield are given in table 4.

Table 4.—Periodic petiole tests, 1045.

Yield group	+15 tons	15 to 10 tons	Minus 10 tons
Fields in group	3	4	3
	p.p.m.—N	p.p.m.—N	p.p.m.—N
July	683	986	848
August	195	296	356
September	135	190	109
	p.p.m.—P	p.p.m.—P	p.p.m.—P
July	85	108	60
August	84	94	58
September	78	79	40

Although the evidence as presented does not indicate it, 1941 and 1945 were years when nitrates held up generally high until late in the season, and 1942 and 1944 were seasons of early depletion of nitrates. In 1941 we had enough individuals in a group to give the averages definite significance. In 1945 two fields in the high-yield group were such that high yield was obtained with nitrate content of petioles at a low level. In 1944 one field in the medium-yield group gave petioles exceedingly low in phosphate and highest of all in September tests in nitrate, and thus upset the group average completely. In addition in 1944 an unknown source of interference with the nitrate test caused all low tests to be read falsely high.

Tn the following table the results of the 3 years are compared on the basis of yield produced per unit of N and P. For this purpose the July and August results are used. The average yield in each group is divided by 1he average petiole test of that group. The highest factor obtained on any group in 1941 is taken as 100 and all others are calculated proportionally.

Table 5— N mid P performance factors in 1941 1944. and 1945.

		1941			
Avg. yield of group	21.6	18.3	15.4	12.5	8.0
Fields in group	8	13	16	7	11
Performance:					
Nitrate	100	97	56	84	63
Phosphate	80	100	100	79	63
		1944			
Avg. yield of group		19.4	12.4	9.2	
Fields in group		2	4	3	
Performance:					
Nitrate		129	168	160	
Phosphate		116	70	48	
		1945			
Avg. yield of group		17.1	11.2	7.3	
Fields in group		3	4	3	
Performance:					
Nitrate		102	64	60	
Phosphate		109	68	71	

This table brings out a number of valuable points. If fertility level were the controlling factor in the low-yield fields, the highest performance factors for phosphate or nitrate or both should be found in those groups, since they never have an excess of at least one of the elements. Therefore our interest at. present turns to the medium- to high-yield groups. In 1941, a year of high nitrate levels and high average yield, phosphate appeared to control the yield except in the highest yield group where a slight excess probably existed and nitrate controlled.

Tn 1944, a year of early nitrate depletion, nitrate performance jumped up. as would be expected. Low phosphate performance would be expected. In two of the three groups it was demonstrated, and on one of the two high-yield fields it occurred also.

In 1945, a year of low yields and high nitrates, nitrate performance was low. The explanation of the 102 factor on the high-yield group is that the nitrate tests on two of the high-yield fields dropped to low values early in the season, yet the field produced high yields. In a high nitrate season, high phosphate performance might be expected. If one could explain why during 1945 the activities of the beet went toward developing tops rather than roots, he could probably explain why phosphate performance was low in 1945.

During the 1945 season a number of potash tests were run in an attempt to learn whether inter-relations of N, P, and K content of petioles might show something about fertility which tests for individual components do not indicate. The tests showed increasing potash content of petioles as the season progressed. On August 6 potash content of petioles ranged from 5,000 to 8,000 parts per million of K_2-O. Tests on high-yield fields averaged lower than tests on low-yield fields, but no inter-relation of N, P, and K could be worked out which was definitely associated with yields.

It has been necessary to condense the results we have obtained beyond a point where anyone examining those results can find just what has gone into them. The best that can be done is to point out what an examination of all results indicates.

If petiole samples are taken from various plots on the same field, differences in fertility will be reflected by differences in results of tests. But if a single petiole sample is taken from a field, interpretation of the results of the tests is questionable, unless the results are high.

While it appears that on the average a phosphate test of 100 p.p.m. or more is required to produce a sufficiency, it does not follow that applications of phosphate to a crop showing less than 100 p.p.m. will produce a response. Too many exceptions to the rule exist.

The average value for incipient nitrate deficiency appears to be about 400 p.p.m. during the third week of July. It appears that earlier than this date fields which will develop nitrate deficiency do not show it. And if tests are made later, results are known too late to permit of correction of the deficiency without delaying maturity unduly. Again, many exceptions to the rule are to be found.

As a measure of general fertility, where a large number of fields may be sampled and the results averaged, the sugar beet petiole test is very useful.

Many reports of successful application of petiole tests are to be found in the literature. However, the majority of references appear to be perennial crops, such as orchards. Thomas, in Social Science, Vol. 59, p. 353, reviews the subject of tissue analysis and finds analysis of leaf tissue for total components superior to analysis of conducting tissue for unassimilated components if the results are to be correlated with yields. The results we have obtained on analysis for total components have not been encouraging. In. 1941 complete analysis was made of total tops from 20 beet fields, 10 fields of high-yield history and 10 fields of low-yield history. Samples were taken twice during the season, first at about July 1 and the second at harvest time. The results show no clear-cut distinctions between tops from fertile and non-fertile fields. The maximum and minimum values are given in table 6.

Table 6.—Maximum and minimum nutrients in beet tops, percent total N, P', and K on dry matter.

	High-yield fields		Low-yield fields	
	Maximum	Minimum	Maximum	Minimum
	Early season samples			
% N	4.9	3.1	4.6	3.0
% P	0.44	0.23	0.40	0.21
% K	4.2	3.0	4.1	3.2
	At harvest time			
% N	3.3	1.8	3.0	1.4
% P	0.25	0.13	0.27	0.11
% K	4.2	1.7	4.9	2.2

Inspection of results on individual samples rarely reveals evidence of inter-relations of N, P, and K levels which may bear a relation to fertility or yields, and even the group averages show rather small differences.

Possibly we ask too much of plant tissue tests, but he demands upon us are severe. Will the field respond to application of fertilizer? We cannot today answer that question on the basis of results from a single sample, regardless of how accurately the sample represents the field, because unknown environmental factors, other than level of available soil nutrients, often control the level of nutrients in the tissue.