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James F. Harrington
Iowa Agricultural Experiment Station

THE TREND OF SOLUBLE NITRATE, PHOSPHATE AND POTASSIUM CONCENTRATE IN THE DEVELOPMENT OF THE SPINACH PETIOLE*

JAMES F. HARRINGTON

It is quite clear (Beeson, 1941) that factors other than the availability of a nutrient influence the concentration of that nutrient in the plant.

If the concentration in the plant of a given nutrient is to be used as a measure of the availability of that nutrient in the soil, then the other factors affecting the concentration must be evaluated so that correction factors can be established or else a method of sampling must be evolved in which the influence of the factors is negligible.

Previous work by several authors indicates that sampling error can be reduced if the morphologically same tissue is sampled each time. The author, (1944) found that an extract of the spinach petioles more clearly mirrored the change in availability of a particular nutrient than did an extract of the blades or roots. However, Brown (1943) found a wide difference in the concentration of nitrate nitrogen and soluble phosphorus between young and old petioles of suger beets harvested the same day from the same plants.

The present work is an effort to evaluate the effect of the age of the plant, the age of the petiole at a given harvest date and also whether the dry weight base is a more desirable base than the fresh weight base.

METHODS

Long Standing Bloomsdale spinach was grown on benches in a 60° to 70° greenhouse during the winter of 1944-45. (There were five replications for each sampling date.) In the first experiment the seed was planted October 4, 1944. The petioles were harvested weekly starting November 3 when there were five petioles per plant and continued for five weeks to Decembr 1, 1944, at which time they averaged twelve petioles and were at market maturity. In the second experiment the seed was planted at biweekly intervals beginning November 13, 1944 and extending to January 9, 1945. The sampling was also at biweekly intervals between January 30, 1945 and March 12,1945, samples being taken from two replicates of each of the five plantings.

All sampling was done between eight and ten in the morning. Even at ten the house had not heated much above 60° and the plants were receiving little direct sunlight. Thus the plants were still fully turgid and had carried on little if any photosynthesis. During the period of the experiment there were very few sunny days.

Twenty petioles each from a different plant were included in each

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sample. They were placed in a closed bottle to minimize evaporation, brought to the laboratory, sliced with a razor and mixed. One gram subsamples were immediately weighed out, one to determine dry weight and one for extracting.

The subsample to be extracted was placed in a Waring Blendor with 99 ml of "Universal" extracting solution (a sodium acetate-acetic acid solution buffered at pH 4.8, Morgan, 1941) and one-fourth gram of Darco G-60 charcoal. The solution was blended for three minutes and filtered. A clear, colorless extract was obtained. From this aliquots were taken for the chemical tests. The methods of Peech and English (1944) were used. In their methods nitrate nitrogon is determined by the colorimetric brucine test, phosphorus by the colorimetric molybdate test, and potassium by the cobaltinitrite test. In supplementary tests it was found tha the soluble organic compounds were never in great enough concentration to interfere with the brucine test and that the ammonium concentration was too low to interfere with the cobaltinitrite test. Every sample extract was analyzed on three successive days, and the mean values were used in data.

RESULTS

In Table I a summary is given of the data from Experiment I. The nitrate nitrogen concentration appeared to be at a maximum in the third and fourth oldest petioles. The concentration was less in the two older petioles, and there was a definite trend of decreasing concentration in the progressively younger petioles. On December 1, for example, the concentration rose from 1920 p.p.m. in the oldest leaf to 2700 p.p.m. in the third oldest, an increase of 41%. The concentration then decreased to 720 p.p.m. in the youngest, a decrease of 73%.

On the other hand the younger the petiole the greater the concentration of soluble phospohorus. On December 1 soluble phosphorus increased from 170 p.p.m. in the oldest petiole to 740 p.p.m. in the youngest petiole, an increase of 335%. These results are in close agreement with those obtained by Brown (1943). He found that nitrate-nitrogen increased from youngest to oldest petiole of sugar beet and soluble phosphorus decreased from youngest to oldest petiole.

The potassium concentration varied little with the age of the petiole although there was a tendency for the concentration to be lower in the younger petioles.

There is also a definite trend in the concentration of nitrate-nitrogen in a given petiole as it ages. The third petiole increased in nitrate concentration from 1270 p.p.m. on November 3 to 2700 p.p.m. on December 1, an increase of 112%. Every other petiole exhibited this same trend. It must be remembered that the spinach was growing during a period of increasingly cloudy and continually shorter days. It is possible that the nitrate-nitrogen was accumulating because of an increasing lack of carbohydrates for protein synthesis. The average dry weight was only 6.52% of the fresh weight. If the nitrate nitrogen is converted to percent of dry weight expressed as NO_3, the average concentration was 16.9% of the dry weight. The average potassium concentration was 16.7% of the dry weight. In other words, over one-third of the dry weight of the petiole was potassium nitrate.

The concentration of soluble phosphorus and potassium in a given petiole showed no definite trends as the petiole aged.

Tables II and III express the results of the second experiment. In Table II the results are expressed on a dry weight basis and in

TABLE I

The effect of petiole age and harvest date on the concentration of nitrate-nitrogen, phosphate-phosphorus and potassium in fresh spinach petiole.

Nitrate-Nitrogen in Parts per Million Fresh Weight

	Harvest Date				
Petiole	11-3	11-10	11-17	11-25	12-1
1	1460	1940	1600	1900	1920
2	1460	2000	1660	1950	1920
3	1270	2000	2040	2750	2700
4	1360	1940	1900	2650	2480
5	1290	1780	1890	2300	2640
6		1580	1290	2050	2400
7			1080	1700	2360
8			1020	1450	1680
9				800	1840
10					1560
11					1360
12					720

Phosphate Phosphorus in Parts per Million Fresh Weight

	Harvest Date				
Petiole	11-3	11-10	11-17	11-25	12-1
1	405	240	190	260	170
2	370	260	230	200	150
3	435	350	355	400	330
4	510	340	335	475	430
5	725	365	320	420	610
6		430	355	440	570
7			390	470	600
8			410	525	620
9				445	600
10					660
11					670
12					740

Potassium in Parts per Million Fresh Weight

	K				
Petiole	11-3	11-10	11-17	11-25	12-1
1	9400	8700	11700	12000	9300
2	9800	9300	10500	11400	9600
3	7600	8700	10200	11700	9300
4	8000	8100	10500	11700	10200
5	6400	8200	9300	11100	9900
6			9300	10200	10800
7			8700	9300	9900
8			9000	9600	9300
9				6600	8700
10					9600
11					9300
12					7200

TABLE II

The mean concentration of nitrate-nitrogen, phosphate-phosphorus and potassium on a dry weight basis at different plant ages, leaf ages, sample dates and replicates.

		NO_3-N %	PO_4-P %	K %
Plant Age	1	3.5	.55	17.3
	2	3.0	.53	17.3
	3	3.4	.51	18.1
	4	3.1	.51	17.2
	5	3.1	.51	16.5
Leaf Age	Old	3.8	.43	20.8
	Mature	3.6	.60	17.0
	Young	2.3	.58	13.1
Date	Jan. 30	3.2	.48	19.1
	Feb. 12	3.1	.51	18.2
	Feb. 26	3.2	.58	17.4
	Mar. 12	3.4	.54	16.2
Replicate	A	3.4	.53	17.5
	B	3.2	.54	17.2

TABLE III

The mean concentration of nitrate-nitrogen, phosphate-phosphorus and potassium on a fresh weight basis at different plant ages, leaf ages, sample dates and replicates.

		NO_3-N ppm	PO_4-P ppm	K ppm
Plant Age	1	1990	326	10,000
	2	1830	334	10,500
	3	1970	317	10,600
	4	1800	313	10,200
	5	1630	385	8,900
Leaf Age	Old	2090	231	11,300
	Mature	2110	352	10,600
	Young	1530	385	8,800
Date	Jan. 30	1720	301	10,200
	Feb. 12	1680	311	10,600
	Feb. 16	1890	352	10,200
	Mar. 12	2030	343	9,600
Replicate	A	1940	330	10,100
	B	1820	331	10,100

Table III on a fresh weight basis. Analysis of variance was used to analyze the date. The only variants that were significant at the 1% level were leaf age for all three nutrients tested and plant age for the soluble phosphorus concentration when expressed on a fresh weight basis.

A close examination of the data, comparing Tables II and III indicates that there is little difference between expressing the results on a fresh weight or a dry weight basis. The samples were always taken between eight and ten in the morning while the plants were still fully turgid. During the summer this would probably correspond to between six and eight in the morning or just after sun up although the presence of a dew would complicate sampling at that time. If the sampling were done at several and various times during the day, it is probable that the fresh weight results would be less reliable than the dry weight basis although both are probably less reliable than expressing the results on a per cell basis.

The replicates agree surprisingly well for biological material since there were only 120 samples in each replicate. The maximum difference was only 6% between replicates. That was in the nitrate-nitrogen tests expressed on a fresh weight basis.

Neither the date of harvest nor the age of the plant were significant variables.

There was a marked variation in the concentration of the nutrients in the petiole as a function of the leaf or petiole age. The immature petioles were significantly lower in nitrate nitrogen and potassium as compared to the old petioles and significantly higher than the old petioles in soluble phosphorus. This is in agreement with the first experiment. The petioles of fully mature but not old leaves were intermediate in concentration between those of the old and young leaves. A leaf was considered "old" when it began to show a lighter green shade.

SUMMARY

Spinach was grown in benches in a greenhouse during the winter of 1944-45. Samples of the petioles were analyzed for nitrate-nitrogen, soluble phosphorus and potassium.

The nitrate-nitrogen in spinach leaf petioles increased in concentration from the youngest to the oldest petiole of the plant on a given sampling date.

The soluble phosphorus in spinach leaf petioles decreased in concentration from the youngest to the oldest petiole of the plant on a given sampling date.

The potassium concentration tended to increase in concentration from the youngest to the oldest petiole of the spinach plant on a given sampling date.

Other factors being equal, the date of sampling and the age of the plant had little effect on the concentration of nitrate-nitrogen, soluble phosphorus and potassium in the spinach petiole.

If a fully turgid plant was sampled there was practically no difference between the concentration of nutrients determined whether expressed on a fresh weight or a dry weight basis.

The effect of petiole age could be reduced if care were taken to always sample those of about the same physiological age. It is suggested that the petioles from the youngest fully expanded leaf of a plant could most easily be distinguished and would at the same time

supply enough material that twenty of these petioles would supply an adequate sample.

VEGETABLE CROPS SUBSECTION
IOWA AGRICULTURAL EXPERIMENT STATION
AMES, IOWA

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