UNIVERSITY OF MINNESOTA EXTENSION

NUTRIENT MANAGEMENT

FO-3176-B (REVISED 2013)

Plant Analysis Sampling and Interpretation

Daniel E. Kaiser, John A. Lamb, and Carl Rosen

Over the past 25 to 30 years, the popularity of plant analysis or tissue testing has gone through several popularity cycles. This analytical tool is still important in modern agriculture. The reason for this importance, however, has changed.

When this diagnostic tool was introduced, it was intended to either help diagnose nutrient related problems or monitor the nutrient status of high-yielding crops. In today's agriculture, nutrient deficiencies are not common. Therefore, the use of plant analysis as a diagnostic tool has diminished. Nevertheless, the value of plant analysis as a monitoring tool remains.

Technologies and procedures used in the collection of plant samples vary with the intended purpose. Suggested procedures for the diagnosis and monitoring purposes are discussed separately.

SAMPLING THE RIGHT PLANT PART

Sampling the correct plant part at the correct time is critical to ensure accurate results. In addition, sampling multiple plants to form a single composite sample is crucial to ensure that the concentration number obtained from the lab is meaningful and represents a true average from the collection area. A summary of plant parts to sample is given in table 1. Samples can be air dried by placing them in a warm area with a fan blowing air across them. To lessen the risk of molding, samples should be stored in paper bags prior to drying or sending samples to the lab. **DO NOT** store plant samples in sealed plastic bags.

Table 1. Recommended plant parts to sample based on crop growth stage

CROP	STAGE	PART	#
Corn	< 12 inches	All above ground plant parts	10
	Silking	Leaf opposite and below ear	10
Soybean	< 12 inches	All above ground plant parts	10
	Mid to full bloom	Upper fully developed trifoliate	30
Alfalfa	Prior to 1/10 bloom	Upper 6 inches of the plant	10
Grass	Prior to heading	Top leaves	50
Potato	Tuber initiation to bulking	petioles	30-40
Small Grains	Boot Stage	All above ground plant parts	20
Sugarbeet	6-10 weeks	Developed leaf and/or petiole	15

*#, approximate minimum number of samples to suggested to take for a single composite sample

TAKING PLANT SAMPLES EARLY IN THE SEASON. An analysis of nutrient concentration only, is usually not effective in diagnosing many problems. Calculation of nutrient uptake is a better choice. Why? Nutrients, even though one or more may be deficient, are usually more concentrated in stunted plants. For example, the concentration of nitrogen may be greater in plants that are 12 inches in height compared to plants that are much taller. The nitrogen is simply diluted by carbohydrates in plants that are much taller. Calculation of nutrient

uptake is a better approach. In order to calculate nutrient uptake, it's necessary to:

1) dry the whole plants collected,
2) get an accurate weight, and
3) complete an analyses of the plant material.

Nutrient uptake is calculated by multiplying plant dry weight by nutrient concentration. Knowing the number of plants sampled, uptake for an individual plant can be determined.

To measure nutrient uptake there must be access to an oven that will dry a sample rapidly and a scale or electronic balance that can measure small differences in weight. So, some planning is needed if there is intent to calculate nutrient uptake.

In diagnostic situations, soil samples should be collected whenever and wherever plant samples are collected. Analysis of soil samples can often provide a good indication of nutrient deficiencies. By comparing the results of the analysis of soil samples collected, suspected nutrient deficiencies can be confirmed or rejected.

TAKING PLANT SAMPLES LATE IN THE SEASON.

When collecting samples late in the season there is less emphasis on total uptake of nutrients and more emphasis on sampling plant parts that, when the nutrient concentration is compared, correlate well to final crop yield. For corn it is recommended to sample leaves opposite and below the ear at silk emergence when pollen is falling. Timing of sample collection for corn is important. Samples should be collected before the silks turn brown. Nutrient concentrations decline substantially after this point in the life cycle and recognized standards cannot be used for comparison. For soybeans, a sample of the most recently matured trifoliates collected at early to mid-bloom is the standard.

Example of where to take sample from late season corn at 50% silking

PLANT SAMPLING AS A DIAGNOSTIC TOOL

When used as a **diagnostic tool** we expect plant analysis to identify a nutrient deficiency if one is expected or confirm a deficiency that is suspected. In these situations, we are usually faced with normal and stunted and/or off-colored plants in the same field. The normal tendency of individuals is to collect the stunted plants and conduct an analysis of the plant tissue. Plant sampling, however, is more complicated if we expect tissue analysis to be an effective diagnostic tool. Three samples are needed if a nutrient deficiency problem is to be effectively identified. One sample of whole plants should be collected from the stunted area. A second sample should consist of whole plants collected from a marginal area where there is a slight reduction in growth or where the plants are slightly stunted. Plants that are normal and healthy should be used for the third sample.

PLANT SAMPLING AS A MONITORING TOOL FOR CORN AND SOYBEAN

If intended as a **monitoring tool,** plant analysis is used to assess the nutrient statues of plants in relation to the fertilizer program used. If used for this purpose, techniques for sample collection are different. This discussion will focus on corn and soybeans.

Since the results of the plant analysis will be compared to known standards, parts of plants should be sampled at a certain stage of development. The results of the analysis of these tissue samples are compared to standards that are summarized in Tables 2 and 3.

Plant analysis, if used correctly, can be a useful management tool in modern agriculture. To get good information, stop and think before sample collection. Are samples being collected to diagnose a problem or to monitor the results of a fertilizer program?

Table 2. Expected range in nutrient concentrations for corn ear leaves collected at 50% silk

NUTRIENT		EXPECTED RANGE
Nitrogen (N)	%	2.70 to 3.50
Phosphorus (P)	%	0.20 to 0.40
Potassium (K)	%	1.70 to 2.50
Sulfur (S)	%	0.10 to 0.30
Calcium (Ca)	%	0.40 to 1.00
Magnesium (Mg)	%	0.20 to 0.40
Boron (B)	ppm	4 to 15
Copper (Cu)	ppm	3 to 15
Iron (Fe)	ppm	50 to 200
Manganese (Mn)	ppm	20 to 250
Zinc (Zn)	ppm	20-70

Data summarized from J. Benton Jones Jr., 1991 "PLANT ANALYSIS HANDBOOK"

Table 3. Expected range in nutrient concentrations for soybean trifoliate samples at early to mid bloom.

NUTRIENT		EXPECTED RANGE
Nitrogen (N)	%	4.01 to 5.50
Phosphorus (P)	%	0.26 to 0.50
Potassium (K)	%	1.71 to 2.50
Sulfur (S)	%	0.21 to 0.40
Calcium (Ca)	%	0.36 to 2.00
Magnesium (Mg)	%	0.26 to 1.00
Boron (B)	ppm	21 to 55
Copper (Cu)	ppm	10 to 30
Iron (Fe)	ppm	51 to 350
Manganese (Mn)	ppm	21 to 100
Zinc (Zn)	ppm	20 to 50

Data summarized from J. Benton Jones Jr., 1991 "PLANT ANALYSIS HANDBOOK"

TISSUE ANALYSIS FOR POTATO

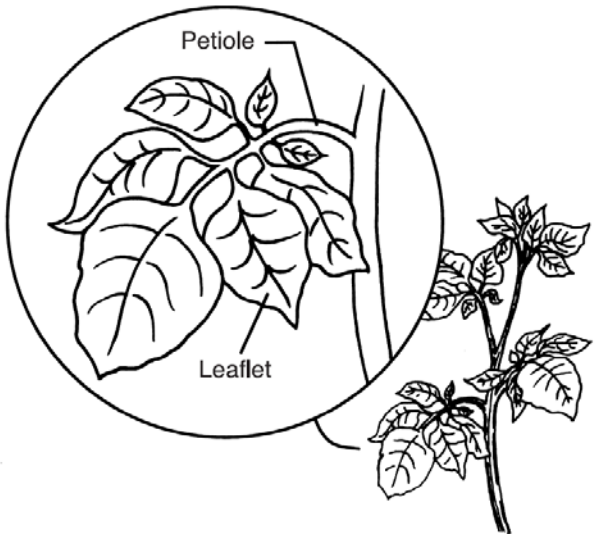

Figure 1. Potato leaf consisting of leaflets and petiole.

The recommended tissue used for nutrient analysis in potato is the petiole (leaf stem and midrib) of the fourth leaf from the shoot tip (Figure 1). It is critical that this tissue stage is collected because younger or older tissue will have different nutrient

concentrations and can lead to erroneous interpretations.

For sampling, approximately 30-40 leaves from randomly selected plants within a field should be collected and the leaflets stripped off and discarded. Most diagnostic criteria for tissue analysis are based on a sample taken during the tuber initiation through the tuber bulking stage. Samples taken too early in the season or soon after a fertilizer application may not accurately reflect the true or potential nutritional status of the crop if uptake of applied fertilizer by roots has not yet occurred.

For irrigated potato, tissue analysis should begin when rows are about ¾ closed and at least four days after a fertigation and then continue at 10 to 14 day intervals through the bulking stage. If petiole nitrate-N falls below the suggested range, then 10- 20 lbs N/A should be applied through the irrigation system. Higher rates of N applied during tuber bulking may cause misshapen tubers and hollow heart in some varieties like Russet Burbank.

Table 4. Suggested nutrient concentration sufficiency ranges in whole leaf potato tissue (leaflets plus petioles collected from the 4th leaf from the top of the shoot during the tuber bulking stage.

NUTRIENT		EXPECTED RANGE
Total Nitrogen (N)	%	3.50 to 4.50
Phosphorus (P)	%	0.25 to 0.50
Potassium (K)	%	4.00 to 6.00
Sulfur (S)	%	0.30 to 0.45
Calcium (Ca)	%	0.50 to 0.90
Magnesium (Mg)	%	0.25 to 0.50
Boron (B)	ppm	20 to 40
Copper (Cu)	ppm	5 to 20
Iron (Fe)	ppm	30 to 150
Manganese (Mn)	ppm	20 to 450
Zinc (Zn)	ppm	20 to 40

Table 5. Suggested nutrient concentration sufficiency ranges in potato petioles collected from the 4th leaf from the top of the shoot during the tuber bulking stage and for petiole nitrate-N at three growth stages.

NUTRIENT		EXPECTED RANGE
Nitrate-Nitrogen		
--Tuber Initiation	%	1.70 to 2.20
--Tuber Bulking	%	1.10 to 1.50
--Maturation	%	0.60 to 0.90
Phosphorus (P)	%	0.22 to 0.40
Potassium (K)	%	8.0 to 10.0
Sulfur (S)	%	0.20 to 0.35
Calcium (Ca)	%	0.60 to 1.00
Magnesium (Mg)	%	0.30 to 0.55
Boron (B)	ppm	20 to 60
Copper (Cu)	ppm	4 to 20
Iron (Fe)	ppm	50 to 200
Manganese (Mn)	ppm	30 to 300
Zinc (Zn)	ppm	20 to 40

Whole leaves can also be used for analysis; however, different diagnostic criteria need to be used for interpretations. Petioles are generally preferred as the tissue to use for predictive purposes, because they more accurately reflect the immediate nutritional status of the plants and whether they are currently taking up sufficient nutrients. Nutrients are ultimately transported from the petiole to the leaflets and the whole leaf provides a more integrated nutrient status since nutrients tend to accumulate in the leaflets. Therefore, leaves are better indicators of the cumulative nutritional status of plants and whether nutrient uptake has been adequate up to the present point in time.

A comparison of nutrient sufficiency ranges for petioles vs. whole leaves is provided in

Tables 4 and 5. Note that K requirements are much greater in petioles compared with whole leaves. Also note that total N is used for whole leaves, while nitrate-N is used for petioles. Most N in petioles is in the nitrate form and measurement of nitrate-N is a more straightforward procedure than total N; however, there is less nitrate-N in leaflets and total N provides a more accurate measurement of N status for whole leaves.

THE BASAL STALK NITRATE TEST FOR CORN

Minnesota corn growers are becoming more interested in fine tuning rates of fertilizer N used for corn production. This increased interest is fueled by higher prices for fertilizer N and concerns for environmental quality. Therefore, many are searching for diagnostic tools that can be used to improve the management of fertilizer N. The basal stalk nitrate test is one of these tools.

This analytical test was developed and refined by faculty at Iowa State University. It is a diagnostic--not a predictive--test. It was not intended to and cannot predict the amount of fertilizer N needed for the next time that corn is in the rotation. However, its use does allow for a closer evaluation of the rate of fertilizer N used in the year that the corn was grown.

WHAT'S MEASURED? In this analytical test, a 6-inch section of the corn stalk starting at 6 to 8 inches above the soil surface is analyzed for NO_3-N. Leaves are not included. The results are compared to standards developed from field research. For best results, the sample should be collected after formation of black layer in the kernel. Waiting until after harvest to collect the sample could easily lead to inaccurate results.

WHAT'S IN THE SAMPLE? The base of the corn stalk is used for this test. The base is considered to be that section of stalk that is 6 inches long and starts 6 to 8 inches above the said surface. This section of stalk should include the bottom node of the plant. Only stalk, not leaf or sheath tissue, is submitted for the sample. Any other tissue should be removed before the sample is submitted. A representative sample should include at least 15 stalks from the area of interest. Some advisors have worked with farmers to compare the impact of various rates of nitrogen fertilizer across the landscape. For these comparisons, this test, in addition to yield, would be an added feature in the evaluation of nitrogen rates. This test could also be used in the evaluation of management zones.

HANDLING THE SAMPLE. Once the sample is collected, it should be split vertically parallel to the length of the corn stalk. Splitting each stalk into four sections would be ideal. Splitting into two sections is absolutely necessary. The splitting is necessary to assure rapid drying.

Once split, the sections should be dried as rapidly as possible. Use of an oven or placing in front of a fan blowing warm air is suggested for rapid drying. Once dried, the

samples can be submitted to the laboratory. Accurate results depend on rapid drying of the samples.

Table 6. Interpretation of the stalk nitrate test for corn.

NO_3-N		INTERPRETATION
ppm		
0 to 250	Low	nitrogen was probably deficient during the growing season
250 to 700	Marginal	, it is possible that nitrogen shortage limited yield
700 to 2000	Adequate	yield was not limited by a shortage of nitrogen
2000+	Excessive	nitrogen rate was too high or some production factor caused a yield reduction

SUGGESTED INTERPRETATION OF THE RESULTS.

As mentioned, this is a diagnostic, not predictive, test. Interpretation of the results is given in Table 6.

When interpreting the basal stalk nitrate values, it's important to remember that factors other than excessive use of N fertilizer can lead to high values. Anything that can cause a severe reduction in yield such as hail damage or drought can lead to high values.

Table 7. Summary of basal stalk nitrate averages for multiple nitrogen rates at two locations in Minnesota.

Nitrogen Rate	SITE 1	SITE 2
lbs. N/acre	ppm	ppm
0	10	10
120	12	595*
200	2100	3263
300	4711	4548

*Data for individual replications for this value are given in Table 8.

Table 8. Summary of individual replication data for basal stalk samples collected at Site 2 in Table 7 for the 120 lb N application rate.

	NITRATE NITROGEN
	ppm
Rep 1	7
Rep 2	9
Rep 3	468
Rep 4	1896

CONCERNS

1. The results of this test are diagnostic and not predictive. Do not make a management change base only on the test results.
2. The results from different samples can be quite variable. See Table 7 and Table 8. The results from the sample area in a field managed the same way have a range of values from 7.4 to 1896 ppm.
3. Choosing the representative location to sample in a field may be difficult at best
4. Any stress, such as drought, can cause the test results to be greater than expected and thus effect the interpretation.

The Laboratories: The University of Minnesota Soil Testing Laboratory as well as some commercial laboratories will analyze these stalk samples. All use the same analytical procedure. Submit the samples in paper, not plastic, bags. Get the samples to the laboratory as soon after collection as possible. Speed in getting the sample to the laboratory will help to insure accuracy of analysis.

SUMMARY

Remember, as with taking any plant sample proper planning is crucial for obtaining the best results. In addition, samples represent only a single point in time. Stress on plants can significantly affect nutrient uptake and results obtained. There is no guarantee plants will not recover and resume normal growth for the rest of the season. With any plant tissue test there are no fertilizer recommendations associated with the results given. Fertilizer recommendations should be made based on soil samples since these tests are correlated to crop response and calibrated to aid in making decisions on rates of fertilizer to apply.

Additional Publications

BU-06240-S – Fertilizer Guidelines for Agronomic Crops in Minnesota
BU-5668-E – Nutrient Management for Commercial Fruit and Vegetable Crops in Minnesota
FO-03814-C - Fertilizing Alfalfa in Minnesota
FO-3773-B - Fertilizing Barley in Minnesota
FO-3790-C - Fertilizing Corn in Minnesota
WW-05672-G - Fertilizing Edible Bean in Minnesota
FO-03813-C - Fertilizing Soybean in Minnesota
FO-07715-C Fertilizing Sugar Beet in Minnesota and North Dakota
FO-3814-S – Fertilizing Sugar Beet in Southern Minnesota
FO-3772-C - Fertilizing Wheat in Minnesota

Minnesota's Agricultural Fertilizer
Research & Education Council

Funding for printing this publication is provided by Minnesota's Agricultural Fertilizer Research and Education Council (AFREC).

UNIVERSITY OF MINNESOTA | EXTENSION