Midwest Laboratories

PLANT TISSUE SAMPLING & ANALYSIS

Spring 2020 Edition

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Midwest Laboratories®

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This publication provides general information on how to best utilize plant tissue analysis. We focus on combining the information gained from plant analysis with soil analysis data to make better decisions regarding soil and plant nutrients. For additional information about taking plant tissue samples and getting them to Midwest Laboratories refer to our "Sampling Guide for Plant Tissue Analysis." This resource can be found in our website library: ***Sampling Guide for Plant Tissue***

Introduction

Plant tissue nutrient analysis has been used for decades to diagnose plant health issues, identify visual nutrient deficiencies, find "hidden hunger," and to evaluate the effectiveness of fertilizer materials and soil amendments. While soil nutrient analysis is well accepted as a foundational source of information when making fertilizer and soil amendment recommendations, plant tissue analysis has a much more limited acceptance.

Much of the lack of acceptance is due to the lack of strong correlation between plant leaf nutrient levels and yield. Without the establishment of strong correlation data, there has been limited work on calibration of leaf nutrient levels to fertilizer recommendations. This is appropriate. In the United States correlation/calibration data is usually generated by Land Grant Universities. These studies consist of sampling done for specific crops across many soil types and soil fertility levels.

There is a large body of this research that has shown low or inconsistent correlation between plant nutrient concentration and crop yield. Much of the existing correlation between leaf nutrient concentration and yield is only at extremely low test levels. These very low plant nutrient concentrations are uncommon. For all of these reasons, caution should be used when making fertilizer decisions based on plant tissue analysis.

Using Plant Tissue Analysis to Diagnose Visual Symptoms

A common and well-accepted use of plant tissue nutrient analysis is to confirm or identify existing visual symptoms. Many nutrient deficiency symptoms in specific crops are very similar to other nutrient deficiencies. If the crop advisor is not often exposed to these visual symptoms it is recommended that they confirm visual symptoms, with laboratory analysis. A nutrient deficiency may also be confused with herbicide injury or pest damage. Laboratory testing can confirm suspected nutrient deficiency or tell the crop advisor to look at other possible causes if nutrients are not considered deficient in the leaf tissue.

When pulling leaf or plant samples for nutrient analysis, it is often advised to take at least two samples: one from the bad area and one from a good area with the same hybrid and soil type. Taking a soil sample along with the tissue sample is recommended as well. The grower may have data for that field from previous soil sampling events but a new sample taken in the areas the leaf samples are pulled from helps make sure you have soil data that correlates to the leaf samples. We recommend pulling a soil core from the root area of the plants being sampled.

Take a soil core at your normal sampling depth (usually 6 to 8 inches) near each plant you are pulling leaves from and composite those cores in a clean plastic bucket. Run a complete (S3C) soil test on those

samples to look at all possible deficiencies and match this information to the nutrient data the lab will provide for the plant tissue samples.

A good resource to have with you when looking at potential nutrient deficiencies is a tablet app or booklet showing visual symptoms of nutrient deficiencies in crops common in your area. One such resource is available from the International Plant Nutrition Institute (IPNI). Search **NUTRIENT DEFICIENCY PHOTOS** in the iTunes app store to download. The app includes a collection of photos showing a range of nutrient deficiency examples from 93 prominent crops. Text and diagrammatic descriptions are also provided.

Another step to take while out in the field is to dig up some plant roots in both the good and poor areas to compare. It is possible that damage from some sort of pest or limited root growth caused by soil conditions (saturated, dry, compaction, etc.) will explain the symptoms you see in the crop.

This may also be a good time to take a sample for nematode analysis if nematode feeding is suspected. Your regular soil sample can be used for soybean cyst nematode analysis. For plant parasitic nematode analysis, a separate sample that is protected from heat or freezing and accompanied by a couple of root balls in a separate bag is preferred. Additional information on sampling for nematodes can be found on our website: **Cyst Nematodes Egg Count and Live Plant Parasitic Nematode Determination**

When you get your soil and tissue analysis data back from the laboratory, your initial focus should be on the nutrients most likely indicated by the visual symptoms you observed when collecting samples. Compare the plant tissue results to the soil test results to determine if the deficiency is related to soil test levels or a problem with the plants' ability to take up the nutrient. Here is where taking the time to dig up some plants and look at their root systems while you are in the field will help you relate the lab analysis to what is going on in the field.

Another thing to consider in when looking at your laboratory data is the possibility of an excessive level of one nutrient interfering with the plant uptake of another nutrient causing the symptoms you are observing.

Sampling Plant Tissue for Disease vs. Nutrient Analysis

While you are in the field looking at visual symptoms you may decide that a plant disease or pest of some sort may be responsible for or compounding the symptoms you are observing. In this case, you will want to submit a sample to a laboratory that can diagnose plant diseases or insect damage. Midwest Laboratories does not offer this service. Your local land grant university is likely your best source for this type of service. Check with them for specific instructions for submitting samples.

In general, most diagnostic labs will want fresh plant material shipped in a plastic bag to limit desiccation. This is different than shipping plants to Midwest Laboratories for nutrient analysis. We prefer plant tissue to be shipped in ventilated paper bags to speed drying, limit mold growth, and even limit leaf respiration. Plant diagnostic labs will often ask for field history and a description of the pattern of the damage in the field. Photos or videos of the affected plants are often welcome as well.

Plant Tissue Nutrient Analysis to Find Hidden Hunger

Over the years land grant universities have done a lot of studies to find correlations between nutrient levels in plant leaf tissues and grain yield. For the most part the correlations have only been well established at very low test levels. Without a strong correlation between leaf tissue nutrient levels and yield there is no reason to perform calibration studies to make in-season fertilizer recommendations based on plant tissue analysis. This issue is complicated by the wide range of specialty fertilizer products available to apply either in-season to the soil or directly to plant tissue intended for uptake through the leaf.

There is also a lack of correlation and calibration for soil analysis of micronutrients in most commodity crops such as corn, soybeans, wheat, and alfalfa. This is often true of manganese (Mn), boron (B), copper (Cu), and iron (Fe). Some universities have built recommendations at very low test levels for some of these nutrients in some crops. Many universities do have soil-test-based recommendations for sulfur and zinc. This lack of good soil-test-based correlation and calibration data for Cu, Mn, Fe, and B can make the plant tissue analysis a helpful tool in deciding whether to apply one of these nutrients to correct a suspected deficiency in the soil.

Even though most land grant university-based research has not found a consistent economic benefit to plant-tissue-based fertilizer recommendations or foliar applied fertilizers, many agricultural

fertilizer suppliers and growers participating in state and national yield contests have found this analysis and subsequent product application to be beneficial to yield. Unlike soil testing which looks at extractable nutrients using a specific extract solution and laboratory process; plant tissue analysis looks at the total amount of nutrients in the plant. The plant itself performs the extraction from the soil.

Midwest Laboratories provides laboratory analysis of plant tissue nutrient levels but does not provide tissue sample based fertilizer recommendations. The lack of correlation and calibration data combined with the wide variety of fertilizer products made for in-season application leaves the laboratory unable to make generic fertilizer recommendations with a high degree of confidence. Midwest Laboratories does make soil test based fertilizer recommendations for micronutrients such as Mn, Cu, Fe, and B. It is often difficult to predict if these recommendations will provide economic benefit for a specific crop due to the lack of correlation and calibration data for these micronutrients in many field crops. A plant leaf analysis can assist with the decision to apply or not apply one of these nutrients called for in a soil-test-based recommendation. If both the leaf tissue and the soil analysis show low test levels it seems more likely that an application of that nutrient would be beneficial. If the soil test shows medium to high levels for a specific nutrient but the plant tissue analysis is low, you should think about plant growth or root uptake issues that might lead to lower plant analysis when soil nutrient levels appear to be more than sufficient.

There are several soil characteristics or management practices that often add value to a plant-tissue-based testing program. Here are some to consider:

1. Low organic matter soil has limited ability to mineralize additional nutrients during the growing season.
2. Soils with no history of manure application and little past micronutrient application.
3. Sandy textured soils with lower cation exchange capacity.
4. Very high yield environments where soils may be taxed to provide all needed nutrients especially during times of rapid plant growth.
5. High plant populations where root area is limited by interplant competition.
6. Compacted soils where root growth is limited making soil nutrients less available to the plant.

When should I sample plant tissues for nutrient deficiency?

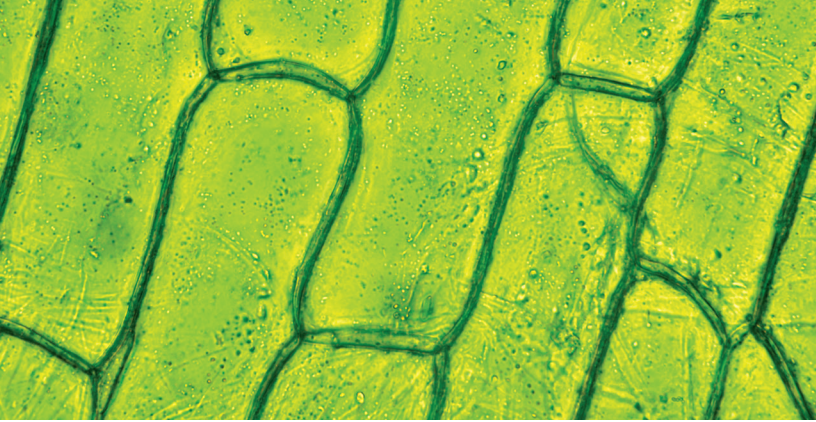
The answer to this question depends on the crop, the time of season when the grower prefers to make in-season application, and whether the grower is trying to impact the yield of this year's crop or is using plant tissue analysis as a way to identify potential areas for improvement in the yield of future crops.

Many plants receive the majority of the nutrients needed for early growth directly from the seed. Measuring plant tissue nutrient levels at these very early stages of growth may have little value. Later growth stages sampled after the plant has completed more of its vegetative growth is probably a better assessment of the plant's ability to find the nutrients it needs from the soil. Unfortunately, later sampling may provide test results too late to impact current year yield or to make a fertilizer application. Multiple tissue samplings throughout the growing season will show the grower variation in the plant's ability to take up nutrients necessary to match vegetative growth, but this can be labor intensive.

Suggestions for Using Plant Tissue Analysis to Assess Plant Nutrient Needs

NITROGEN: A very difficult nutrient to manage. Recommendations are normally made for crops that do not have a symbiotic relationship with nitrogen fixing bacteria. The nitrogen recommendation is often the application most likely to affect yield in any given season. Nitrogen is mobile in the soil in nitrate form. It also has strong interactions with soil microbial life often cycling multiple times in a given season from organic forms unavailable to crops to mineral forms that are plant available. Measuring soil nitrogen for crop production has normally been focused on the nitrate form but this has been complicated in recent years by the increased use of nitrification inhibitors that limit bacterial conversion of ammonium to nitrate and keep nitrogen in the ammonium form later into the growing season.

In-season nitrogen assessment can be made with tools like the pre-sidedress nitrate test (PSNT). This test is calibrated based on a specific growth stage window for corn and is not appropriate for use outside of that window. Several nitrogen modeling tools such as Encirca by Dupont, Climate Pro by Climate Corporation, and Adapt-N by Agronomic Technology Corp & Cornell University are currently in use to model nitrogen behavior in the soil. These tools estimate nitrogen mineralization, crop uptake, early season losses, and current crop needs. The models also attempt to estimate future losses based on past weather patterns.



The plant tissue test can be used to supplement these tools by looking at the current nitrogen levels in the leaf and comparing it to norms for that plant species at similar growth stages. Other in-season assessments are in-field chlorophyll meters, remote imaging such as normalized difference vegetation index (NDVI), and active crop canopy sensors.

The only test Midwest Laboratories uses to make in-season nitrogen recommendations is the 12 inch depth soil nitrate based PSNT. We will also measure soil ammonium levels when requested. Applied fertilizer may remain in the ammonium form due to naturally slow conversion to nitrate or the use of nitrification inhibitors. Plant tissue testing combined with in season soil N testing is a good way to differentiate between the lack of soil nitrogen and plant uptake issues.

PHOSPHORUS: Midwest Laboratories measures soil phosphorus (P) using the P1 Bray method and supplements that measurement with the P2 Bray test. We normally run the Olson Bicarbonate method when working with high pH soils (greater than 7.5 pH) that are suspected of neutralizing the P1 Bray extract (this assessment can be made by comparing the P1 Bray and P2 Bray results). We will also run the Mehlich 3, Morgan Extract, or water-soluble extraction on request. The P1 Bray, Mehlich 3, and Olson P test methods are all well correlated to crop yield and calibrated to P application rates. There is little reason to adjust recommendations based on plant tissue results. Plant tissue testing may be used to assess plant uptake and possibly adjust future placement methods or timing to maximize uptake at specific growth stages such as starter or pop up fertilizers.

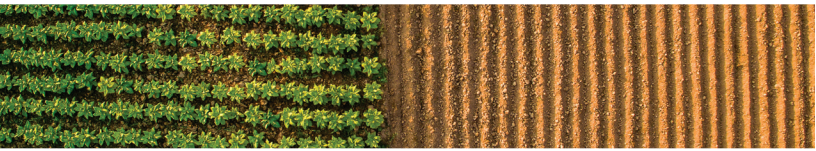
POTASSIUM: Midwest Laboratories measures soil potassium (K) using ammonium acetate extraction and ICP measurement. The Mehlich 3 or water soluble extraction may also be requested. The ammonium acetate extraction method is correlated to plant yield and calibrated for K application. There is slightly less confidence in this correlation and calibration than what exists for phosphorus test methods. Because of the interaction of potassium with other cations in the soil, soil moisture, and other factors, plant uptake may not match soil test K levels. The leaf K test is appropriate to supplement the K soil test but little correlation or calibration data exists to give guidance in combining the two measurements into one recommendation. It will be up to the end user of the data to decide how to best use this information. Two possible uses would be adding in-season K when the plant tissue test shows low levels or adding K for next season's crop

based on low current year plant tissue levels even though soil test K would normally not call for additional K application. The possibility of additional yield must be balanced with the cost of additional fertilizer that may not be needed.

SULFUR: Midwest laboratories use soil test sulfur levels to make sulfur (S) recommendations. Other Agronomists may use organic matter levels to make S recommendations since organic matter is a good source of in-season sulfur. The soil test for sulfur is not well correlated to yield in many crops. Because of this lack of correlation, plant tissue analysis for S may be very useful in adjusting in-season recommendations or deciding to add S for next year's crop. A reduction in industrial sources of sulfur common in air pollution has made sulfur less available in many areas.

ZINC: Some of the best correlation/calibration data to support soil test based recommendations of any of the micronutrients for field crops. This relationship of the soil test level of Zn to yield is still weak compared to phosphorus or potassium. The plant tissue test may be useful for confirming a suspected soil deficiency. Zinc is considered to be critical in early development of corn and other crops. Because of this, a later vegetative growth stage test may be most useful for choosing to make starter fertilizer Zn application in future corn crops.

MANGANESE: A micronutrient with limited correlation and calibration data for most field crops. A plant tissue test may be used to supplement soil test data when making long-term Mn decisions. Plant tissue data is also often used to assess current year Mn levels for possible in-season application. Some herbicides have been suspected of chelating Mn in the plant leaving it unavailable for normal plant functions. If the mineral makes it into the tissue sampled and sent to the laboratory, the acid digestion and ICP measurement will break the chelation and detect the manganese. Soil aeration is a key component in Mn availability. Wet and poorly aerated soils tend to have larger amounts of available Mn due to the increased availability of the nutrient in its reduced form.



BORON: Often suspected of being yield-limiting in some crops such as alfalfa. There are only limited correlation and calibration data available to substantiate the relationship of soil test B levels to yield and to make appropriate recommendations. Care should be exercised when making boron application. Boron is normally toxic to germinating seeds. It can also be toxic when applied in high concentration such as banding an amount that was meant to be broadcast. Here again, the plant tissue test can add credibility to a soil based fertilizer recommendation. The most benefit is likely to be in a plant that is considered responsive to B.

IRON: Plant deficiencies of iron (Fe) are often highly related to high soil pH. Soil pH is difficult to lower. Iron fertilizers applied to high pH soils are likely to be tied up in the soil. Lack of Fe in the soil is seldom the problem. It is the compounds Fe forms in high pH soils that limit the plant's ability to take-up the nutrient. The soil test will often show low levels in high pH soils. Often growers who experience Fe deficient soils will choose hybrids or varieties that have shown resistance to iron deficiency chlorosis (IDC). The leaf test can be used to confirm IDC and to help with the decision for treatment or variety adjustment. Poor drainage will increase Fe availability. The lack of oxygen in the soil leads to a larger amount of Fe in its reduced form, which is more plant available.

COPPER: Deficiencies are fairly rare in field crops but not unheard of. Deficiencies in small grains especially in very high organic matter soils are sometimes observed. The soil test correlation to yield is limited outside of organic soils. The leaf tissue analysis may be helpful in deciding if Cu might be a limiting factor in your crop.

SODIUM: Not considered an essential nutrient for crop growth or reproduction. High Na can, however, be a limiting factor to yield especially in high sodium soils (sodic). If the tissue test shows high Na levels, a soil test should also be checked for high Na levels. If soil Na levels are high, remediation with gypsum and improved drainage are often recommended. Elemental sulfur can be used in place of gypsum if the soil is high in calcium. If the field is irrigated, irrigation water should be analyzed for Na levels and sodium absorption ratio (SAR).

A suggested soil and plant tissue sampling program to maximize yield

The appropriate sampling program and nutrient priorities are going to vary by crop species. In this example, we will consider corn. Similar programs can be developed to other crops but adjustments based on research and grower experience should be made.

In this example we assume that the grower is trying to maximize yield:

STEP 1: A dense geo-referenced soil-sampling program using 2.5 acre or smaller grids. This sampling is done shortly after harvest of the previous crop or even in late spring the crop before the target crop. All nutrients should be analyzed including all micronutrients. Nitrate should be assessed to a 2-foot depth. Recommendations should be requested from the laboratory based on highest yield expectations.

These recommendations should be followed with Lime, P, K, at least ½ of S and most micronutrients being applied in the fall before the target crop to allow freeze/thaw cycle to alleviate compaction caused by the application. At least a few of

these samples in the trial area should be checked for parasitic nematodes. Some micronutrients may be applied in a starter fertilizer that supplements what is broadcast.

STEP 2: N application should be made according to local custom but an in-season application of at least 25% of annual N needs should be planned. The in-season application can be supplemented with in-season sulfur and possibly other nutrients depending on mixing compatibility and crop needs.

STEP 3: V5-V6: Use either the soil-based late spring soil nitrate test (PSNT) or a nitrogen modeling tool to make an in-season recommendation and application of N. Pull a plant leaf sample to analyze for additional nutrients. If the grower is using a liquid coulter to sidedress nitrogen some of these other nutrients can be added at this time. This may be more difficult with a dry top dress. Sulfur should be part of this application with the nitrogen.

STEP 4: V8-V10: A second leaf tissue sample is taken and additional nutrients are planned with a fungicide application.

STEP 5: VT-R1: A third leaf tissue sample is taken and foliar or irrigation nutrient application is considered based on leaf test results.

STEP 6: R4-R5: A final leaf tissue sample is taken. If the leaf normally used is very desiccated use a leaf higher in the plant. This sample is only used as an autopsy to adjust application for next season's crop or the next time corn is grown in the field.

STEP 7: Stalk nitrate test: This test assesses the effectiveness of the overall N program and may call for adjustments in future years. It also helps calibrate N modeling or PSNT based decisions. Keep in mind that late season N application may skew the stalk nitrate test to higher levels.

STEP 8: Bring all test results together along with weather data and crop yield and scouting information. This information will allow the grower to make adjustments for the next year's program. It will usually take multiple years of this work to get the most benefit from the data. Weather variation as well as other factors (insects, population, planting date, etc.) will have a major impact on what the factors limiting yield might be in any given year. The above program will make it very unlikely that soil fertility is a limiting factor for more than the first couple of years.

A more intense program would include weekly tissue sampling from V4 to maturity. A spreadsheet or other program should be used to graph each plant nutrient against the laboratory norms. These graphs can be used to assess performance at the end of the growing season and for comparison for future crop years and nutrient applications.

Complications and issues to consider with plant tissue sampling & testing:

1. SOIL SPLASH: Rainfall or irrigation-caused soil splash can lead to significant overstating of nutrient levels especially for iron and manganese. This is most often the case in smaller plants that are closer to the soil surface and do not protect the soil from direct rainfall. Bare soil from tillage makes this phenomenon more common. Wiping dirty or dusty tissues with a damp rag may remove some of this contamination. A gentle washing of the leaf with distilled water might be needed as well. When submitting whole corn plants, check the whorl and leaf sheath/collar areas for soil accumulation.

2. RAPID GROWTH: Periods of rapid growth caused by warm temperatures and sunlight following cool, wet periods can cause leaf tissue nutrient levels to be lower than normal.

3. TIME OF DAY: The time of day the plant tissue sample is taken can cause some variation in nutrient results for some nutrients in some crops. This variation is usually quite small and should have limited effect on any fertilizer decisions. Midwest Laboratories participated in three recent studies looking at this issue. The results were largely inconclusive but indicated additional research may be needed in this area. The publication covering this research is listed below.

4. RECENT FERTILIZER APPLICATION: Similar to soil splash, plant tissue analysis will show nutrients on- the-leaf as well as in-the-leaf if these nutrients not yet absorbed are not removed before analysis. Care should be taken when sampling plants receiving recent foliar applied fertilizer products.

Summary

Plant tissue nutrient analysis can be a valuable tool. Correlation of plant nutrient levels to yield and calibration to fertilizer recommendations is not as well established as it is for soil nutrient analysis. The value of plant nutrient analysis is maximized when it is used to diagnose visual symptoms and/or used in conjunction with a soil analysis to understand plant uptake vs. soil test levels. Growers trying to maximize yield should look at using plant tissue analysis to supplement the knowledge gained from soil testing. Using this information they can fine-tune fertilizer decisions concerning nutrients needed, amounts to apply, and application timing.

Additional reading suggestions:

Plant Analysis Handbook J. Benton Jones, Jr. and Harry A Mills Revised 1996 MicroMacro Publishing Athens, GA.

Sampling guide for plant tissue analysis Midwest Laboratories

Nitrogen Fertilizer Recommendations for Corn in Iowa PM1714 May 1997 A.M. Blackmer, R.D. Voss, and A.P. Mallarino.

Time of Day Effect on Foliar Nutrient Concentrations in Corn and Soybean. Journal of Plant Nutrition Issue 14 2015. Tim Mundorf, Charles Wortmann, Charles Shapiro, and Ellen Paparozzi

PLANT TISSUE ANALYSIS

The Increasing Need

Modern agriculture demands top yields and quality yields. Additionally, you demand profitable yields. In satisfying these demands, plant tissue analysis has become a valuable crop production tool.

Top quality and profitable yields, unfortunately, don't just happen. Many factors need to be considered ... like adequate moisture and fertility, proper plant population, adapted variety, disease and insect resistance and control ... the list goes on.

One of the more important factors affecting crop yields is the nutrient status of the plant... or the flow of nutrients to plant tissues during the growing season. Nutrient status is an "unseen" factor in plant growth, except when deficiencies become so acute that visual deficiency symptoms appear on the plant.

Plant populations can be counted, and a variety of names or numbers can be read on the label. Rainfall can be measured with gauges. However, the determination of the nutrient status of plants requires precision laboratory analysis of a plant tissue sample during the growing season.

How Can a Tissue Analysis Help?

A plant tissue analysis will show the nutrient status of the plants during the growing season and detect unseen, hidden hunger. Plant tissue analysis can also supply information to confirm visual deficiency symptoms. Though usually used as a diagnostic tool for future correction of nutrient problems, a plant tissue analysis from young plants will allow for a corrective fertilizer application that same season. Combined with data from a soil analysis, tissue analysis is an important tool in determining proper fertilizer applications to balance the nutrient availability in the soil and the nutrient requirements of the crop.

A complete plant tissue analysis will identify the nutrient status of the following elements:

Tissue Sample Mailing Kits are Available

- Nitrogen
- Phosphorus
- Potassium
- Magensium
- Calcium
- Sulfur
- Sodium
- Iron
- Manganese
- Boron
- Copper
- Zinc

Collection & Preparation of the Sample

When gathering the tissue sample in the field, be sure to use a clean container. A plastic pail or a paper bag work best. Never use a metal container to gather the sample as the metal may contaminate the sample.

To ensure proper sample amount on young plants, collect approximately one pint of lightly packed material.

If the plant samples have soil, fertilizer, dust or spray residues on them, they will need to be cleaned. A dry brush works well. For stubborn residues, wipe the samples with a damp cloth or wash the samples with distilled or deionized water'. However, do not prolong the washing.

Air-dry the samples. Clean paper bags or envelopes work best to avoid contamination when mailing the samples to the laboratory.

Never place fresh samples In a plastic bag or include roots with samples submitted for nutrient analysis.

Midwest Laboratories will provide sample bags suitable for plant tissue samples and plant sample submittal forms. These forms should be filled out accurately and completely. If complete information is submitted with the sample, the interpretation of the plant tissue analysis will be more meaningful. Ship the sample directly to Midwest Laboratories, Inc. 13611 B Street. Omaha, NE 68144

TISSUE SAMPLING TECHNIQUES - FIELD CROPS

CROP	WHEN TO SAMPLE
Alfalfa	At 1/10 bloom stage or before
Canola	prior to seed set
Cereal Grains (including rice}	Seeding stage or prior to heading
Clover	prior to bloom
Corn	Seeding stage or prior to tasseling or from tasseling to silking
Cotton	Prior to or at first bloom or when first squares appear
Flax	Seeding stage or prior to heading
Hay, Forage, or Pasture Grasses	Before seed head emergence or at the stage for best quality
Milo-Sorghum	Before or at heading
Peanuts	Before or at bloom stage
Soybeans	Seeding stage or Prior to or during initial flowering
Sugar Beets	Mid-season
Sugar Cane	Up to 4 months old
Sunflowers	Prior to Heading
Tobacco	Before bloom

PART OF PLANT TO SAMPLE	PLANTS PER SAMPLE
Mature leaf blades about 1/3 of the way down the plant.	45-55
Fully developed leaves from top of plant.	60-70
All the above-ground portion.	50-75
Four uppermost blades from top of plant.	30-40
Mature leaf blades about 1/3 of the way down the plant.	50-60
All the above-ground portion.	25-30
The first fully developed leaves from the top.	15-20
The leaves below and opposite the ear.	15-20
The youngest fully mature leaves on the main stem.	30-35
Above ground portion or youngest, mature leaves.	50-60
The four uppermost leaf blades.	50-60
Second leaf from top of plant.	20-25
Fully developed leaves from the top of the plant.	45-50
All the above-ground portion.	20-30
The first fully developed leaves from the top.	20-30
Fully mature leaves midway between the younger center leaves and the oldest leaf whorl on the outside.	30-35
Fourth fully developed leaf from the top.	25-30
Mature leaves from top of plant.	25-30
Top fully developed leaf.	8-12

ORNAMENTALS & FLOWERS

CROP	WHEN TO SAMPLE
Carnations	Unpinched plants
Chrysanthemums	Pinched plants
Ornamental	Before or during early flowering
Trees and Shrubs	Current year's growth. Before or during early flowering
Poinsettias	Current year's growth. Before or during early flowering
Roses	During flowering
Turf	During growing season

FRUIT & NUT CROPS

CROP	WHEN TO SAMPLE
Apple, Apricot, Almond, Cherry, Peach, Pear, Plum	Mid-season
Blueberries	Mid-season or 2-4 weeks before harvest
Grapes	End of bloom period
Lemon, Lime	Mid-season
Orange	Mid-season
Pecan	6-8 weeks after bloom
Raspberry	Mid-season
Strawberry	Mid-season
Walnut	6-8 weeks after bloom

PART OF PLANT TO SAMPLE	PLANTS PER SAMPLE
4th or 5th lead pair from base of plant	20-30
5th or 6th leaf pair from top of primary laterals	20-30
Top leaves on flowering stem	20-30
Fully mature leaves	30-75
Most recently mature fully expanded leaf	15-20
Upper leaves on the flowering stem	25-30
Leaf blades; avoid soil contamination	2 cups of material

PART OF PLANT TO SAMPLE	PLANTS PER SAMPLE
Leaves near base of current year's growth	75-100
Youngest fully expanded mature leaves	75-100
Petioles from leaves adjacent to fruit clusters	75-100
Mature leaves from last flush of growth on non-fruiting terminals	30-40
Spring cycle leaves, 4 to 7 months old from non-fruiting terminals	25-30
Leaves from terminal shoot, taking the pairs from the middle of the leaf	30-45
Take youngest mature leaves on laterals of primocanes	25-40
Youngest fully expanded mature leaves	50-70
Middle leaflet pairs from mature shoots	30-40

VEGETABLE CROPS SAMPLE

CROP	WHEN TO SAMPLE
Beans	Seeding stage or Prior to or during initial flowering
Cabbage, etc. (Head Crops)	Before heading
Celery	Mid-growth cycle
Cucumber	Before fruit set
Leaf Crop (Lettuce, Spinach, etc.)	Mid-growth
Melons	Prior to fruit set
Peas	Before or during initial flowering
Potato	Before or during early bloom
Root Crops (Carrots, Beets, Onions, etc.)	Before root or bulb enlargement
Sweet Corn	Before tasseling or at tasseling
Tomato (field)	Before or during early bloom stage
Tomato (greenhouse)	Before or during fruit set

PART OF PLANT TO SAMPLE	PLANTS PER SAMPLE
Entire above ground portion	25-30
Two or three mature leaves at the top of the plant	25-30
First mature leaves from center of whorl	10-20
Petiole of youngest mature leaf	20-30
Mature leaves near the base of the main stem	20-25
Youngest mature leaf	30-50
	20-30
Mature leaves near base of main stem	20-30
Leaves from the third node down from the top of the plant	30-50
Third to sixth leaf from growing tip	20-30
Center mature leaves	25-35
The entire fully mature leaf below the whorl	20-25
The entire leaf at the ear node	20-25
Third or fourth leaf from growing tip	20-25
Young plants: leaves from 2nd and 3rd clusters	
Older plants: leaves from 4th to 6th clusters	20-25

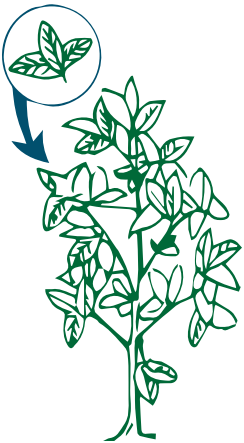
DESIRED SAMPLE LOCATION FROM COMMON CROPS

Corn - before tasseling

Collect the first fully developed leaves from the top of 15 to 20 plants. (If the plant is less than 12 inches tall, collect all of the above ground portions).

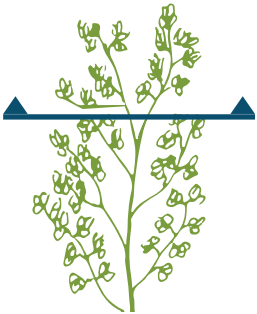
Corn - from tasseling to silking

Collect the leaves below and opposite from the ear of 15 to 20 plants.



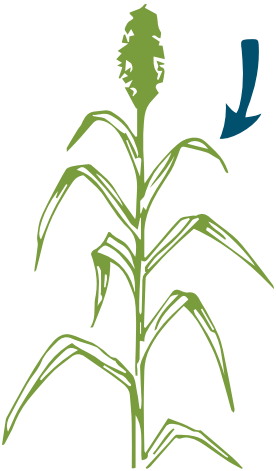
Soybeans

Collect the youngest mature trifoliate leaves from the top of 20 to 25 plants prior to or during flowering. (In the seedling stage, collect all of the above ground portions).



Alfalfa

Collect mature leaf blades and petioles about one-third of the way down the stem at one-tenth bloom stage or before.

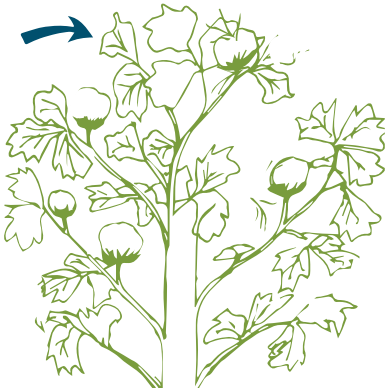


Sorghum

Collect the second leaf from the top of 15 to 20 plants before or at heading.

Wheat, Oats, & Grass

Collect the four uppermost leaf blades from the top of 30 to 35 plants. (In the seedling stage, collect all of the above ground portions). Sample should equal two cups.



Cotton

Collect the youngest fully mature leaves on the main stem from 30 to 35 plants selected at random prior to or at first bloom.

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