GETTING FULL VALUE FROM TISSUE TESTING

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Tissue testing is the quantitative measurement of the essential elements in plant tissue. Plants require 17 elements for normal vegetative growth and reproduction. These elements fulfill a variety of functions in plants and are required at varying levels by different plant species. Carbon, hydrogen and oxygen are not analyzed because they come from the air or water and virtually are never limiting to plant growth. Of the remaining 13 elements that come from the soil, chlorine is normally not analyzed because it is always sufficient under Wisconsin conditions. As a result, tissue testing or plant analysis, usually refers to the analysis for nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), iron (Fe), manganese (Mn), copper (Cu), zinc (Zn), boron (B), and molybdenum (Mo). Aluminum (Al) and sodium (Na) are normally included even though they are not essential elements. Aluminum can be toxic in acid soils, and sodium improves the quality of some crops.

Results of tissue testing along with a soil test can provide a valuable guide to more efficient crop production. Soil tests provide a good estimate of lime and general fertilizer needs. By adding tissue analysis data, the user is able to better evaluate fertilizer and management practices more accurately by providing a thorough nutritional view of the crop. Several key uses of plant analysis include: evaluation of fertilizer efficiency, determination of availability of elements for which reliable soil tests are not available, and the ability to evaluate the interaction among plant nutrients. In a healthy plant, all essential elements are present at appropriate levels and in proper proportions relative to each other. Plant growth is restricted when: not enough of one or more elements is present; too much of one or more elements is present, including toxic levels of nonessential elements such as aluminum, arsenic, selenium, or sodium; or the levels of one or more elements is adequate but out of balance with other elements.

Typically, the first result of nutrient deficiency, toxicity or imbalance is a reduction in the growth of the plant. If the condition worsens, visible deficiency symptoms appear and plant yield is further reduced. Severe deficiencies or toxicities can kill plants or weaken them to the point that they are more vulnerable to other stresses, such as disease or insect attack.

Sampling

Collecting a proper sample is critical for plant tissue analysis as plant nutrient composition varies with age, the portion of the plant sampled, and many other factors. Mistakes or carelessness in selecting, collecting, handling, preparing, or shipping plant tissue for analysis can result in unreliable data, which may lead to incorrect interpretations and recommendations. The standards against which the samples are evaluated, have been selected to represent the plant part and time of sampling that best define the relationship between nutrient composition and plant growth. Deviating from the prescribed protocol severely limits the ability to interpret results. Therefore, it is critical to follow a standard sampling procedure.

Table 1 lists the proper stage of growth, plant part, and number of plants to sample for some key agronomic and horticultural crops. If the tissue sample is collected at any other time in

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the growing season, it may not be possible to interpret the results properly. However, when plant analysis is being used to confirm a suspected nutrient deficiency, the samples should be taken as early in the season as possible so that the deficiency can be corrected and minimize the potential yield loss. Plants showing abnormalities usually continue to accumulate nutrients even if growth is impaired by some limiting factor. Samples should not be taken from plants that obviously have been stressed from causes other than nutrients. Do not take samples from plants that; 1) are dead or insect damaged, 2) are mechanically or chemically injured, 3) have been stressed by too much or too little moisture, or 4) have been stressed by abnormally high or abnormally low temperature.

When a nutrient deficiency is suspected, or there is a need to compare different areas in a field, it is recommended that similar plant parts be collected separately from both the affected plants and adjacent normal plants that are at the same stage of growth. In this way, a better evaluation can be made between the nutritional status of healthy and abnormal plants of the same variety grown under the same conditions.

Tissue Sample Handling

After a plant sample has been collected, it should be prepared for shipment or delivery to the laboratory. Roots or foreign material attached to the sample should be removed and discarded. Plant tissue must then be dusted off to remove soil particles. Tissue samples should never be washed since soluble nutrients will be leached out of the sample. If a tissue sample is to be mailed, the sample should be air dried at least one day to avoid mold formation during shipment. Never mail samples late in the week, since the tissue will deteriorate in the post office over the weekend. Place the plant sample in a large paper envelope for shipment. Do not place tissue samples in plastic or polyethylene bags since plant tissue molds more rapidly in these air-tight types of bags. Plant samples that are delivered to the lab do not need to be air dried if they are delivered within one day of collection.

Soil Sampling

Soil test results for pH, organic matter, phosphorus and potassium can be useful for helping to correlate tissue analysis results to nutrient deficiency or toxicity. A soil sample consisting of 10 or more cores should be collected from the same area where the plant sample was taken. For row crops, such as corn, avoid the fertilizer band by sampling in the middle of the row. Label the soil sample with the same field and sample number as that assigned to the tissue sample. Package corresponding plant and soil samples together, making sure that the bags are properly closed so that they will not open in transit and allow the soil to contaminate the tissue sample.

Interpretation of Tissue Analysis Values

Depending on the crop, plant part and stage of growth sampled, there are a number of ways in which tissue analysis data is reported and interpreted. The UW Soil and Plant Analysis Laboratory uses three approaches for interpreting tissue analysis results. These include the use of a sufficiency range approach (SR), the diagnosis and recommendation integrated system approach (DRIS), and the plant analysis with standardized scores (PASS) system. Essentially, the SR approach looks at one element at a time using critical levels for that element. The DRIS system uses two or more elements at a time to develop an index. PASS attempts to combine the fixed and variable features of the SR and DRIS systems.

The SR system uses the critical level approach in which the critical level corresponds to 90 to 100% of maximum yield on a yield vs. nutrient concentration graph. The sufficiency approach interprets the plant nutrient levels as being in a range considered to be adequate (sufficient) or below (deficient) or above that range (high). The advantages of this approach include that it is simple to determine and interpret and the values are independent as the level of one nutrient does not affect the classification of another nutrient. Some disadvantages include the fact that there are too few categories to adequately distinguish a low from a very low for example, it does not rank the nutrients to determine which is most limiting, it is very sensitive to plant maturity and plant part sampled. The following crops can be interpreting by SPAL using the sufficiency approach. Alfalfa; apple; asparagus; barley; bean, dry; bean, lima; bean, snap; beet, red; black oak; blueberry; bluegrass; broccoli; brome grass; brussel sprouts; buckwheat; cabbage; canola; carrot; cauliflower; celery; cherry; cranberry; cucumber; fescue, fine; field corn; ginseng; grape; lettuce; lupine; millet; mint; muskmelon; oat; onion; orchard grass; pea, canning; pea, chick; pepper; post oak; potato; pumpkin; raspberry; red clover; red clover hay; rye; sorghum, grain; sorghum-sudan; soybean; spinach; squash; strawberry; sugar beet; sunflower; sweet corn; tobacco; tomato; trefoil; triticale; vetch, crown; watermelon; and wheat.

The DRIS system is based on taking the ratio of all possible pairs of nutrients. These sample ratios are compared with ratios that are normal for high-yielding crops using a relatively complicated standardization formula. The standard scores for each nutrient are averaged to get one index per nutrient. Zero is the optimum, while negative index values indicate that the nutrient level is below optimum and the more negative the index the more deficient the nutrient. Similarly, the more positive the index, the more excessive the nutrient is above normal. The advantages of DRIS include that the nutrients are ranked from most deficient to most excessive and the scale is continuous and easily interpreted. Disadvantages include that the computations are complicated and the indices are not independent. Because of this, the level of one nutrient can have a marked effect on the other indices. DRIS interpretations can be made by SPAL for alfalfa; apple; field corn; lettuce; and soybeans.

The PASS system is a hybrid system that has two components. One is based on the independent nutrient index approach as in the SR system, and the other based on a dependent nutrient index approach as in the DRIS system. In Wisconsin, data is available to perform PASS analysis on alfalfa; field corn; and soybeans.

Summary of Sufficiency Range Results

The results for tissue analyses performed at the UW Soil and Plant Analysis Laboratory in the past four years are summarized in Tables 2 to 7. Only the results of plant materials that were tested at least 25 times or more are included in these tables. Since plant analysis is used as the primary guide for making nutrient application recommendations for fruit crops, it is not surprising to see many of the most commonly grown fruit crops on this list. In addition, the dominant agronomic crops for the state are also represented as tissue testing is used to help diagnose nutrient deficiencies or imbalances for these crops under certain circumstances.

Since most crops require significant amounts of nitrogen, and N does not normally carry over to any significant extent from one growing season to another, it might be expected that plant analysis may often show N levels to be below the sufficiency range. The results do indicate that N is the most commonly deficient element if the median lab values are compared to the sufficiency level for various crops. Also, the very low minimum values found in Table 2, indicate that N can be very limiting to crop production under certain conditions as some of these values are extremely low when compared to the level required for sufficiency. The median value

for tissue N is below the sufficiency range for field corn, grape, strawberries, and soybeans. Since soybean is a legume, the lower than expected N levels are probably related to poor nodulation or other factors limiting growth. In looking at the other macro-nutrients, secondary and micro-nutrients, S and Zn are the two that show the greatest frequency of the median value for tested samples falling into the deficient range. A number of crops show tissue levels of Fe and Cu below what is considered to be sufficient, but this is likely related to other issues as these nutrients are not commonly applied as fertilizer amendments under Wisconsin conditions.

Summary

The use of plant tissue testing as a tool in helping to more efficiently manage crop production in Wisconsin is relatively limited. In general, tissue testing is most common on relatively high value horticultural crops, such as cranberries and apples and much less common on traditional agronomic crops such as alfalfa and corn. The use of the technology also differs as tissue testing is used routinely to guide nutrient applications on horticultural and fruit crops, but when used on more traditional agronomic crops such as corn or alfalfa, it is normally to help diagnose a plant production problem. Of the three methods of interpreting results, the use of the sufficiency range is by far the most common as DRIS and PASS norms are only available for a small number of crops. When sampled properly, a tissue sample can be an extremely valuable tool to diagnose plant nutrient problems that would not be apparent with soil testing alone. Even if no SR norms are available for a crop, tissue testing can be used by comparing plants with normal and abnormal growth when sampled and tested separately.

The key to tissue testing is to take a good, representative sample from the proper part of the plant, at the correct stage of growth, and handle the sample properly. Remember to include a soil sample to aid in the interpretation of the results and the diagnosis of the problem, if one exists.

References

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Table 1. Recommended stage of growth, plant part and sample size for tissue testing.

	Stage or growth	Plant part	No. of plants
Field crop			to sample
alfalfa	bud to first flower	top 6 inches	35
alfalfa	harvest	whole plant	25
barley	prior to heading	newest fully developed leaf	50
bluegrass	prior to heading	newest fully developed leaf	50
bromegrass	prior to heading	newest fully developed leaf	50
corn, field	12 inches tall	whole plant	20
corn, field	pre-tassel	leaf below whorl	15
corn, field	tassel to silk	ear leaf	15
pea, canning	prior to or at initial flower	newest fully developed leaf	25
potato	prior to or at initial flower	4th petiole and leaflet	40
potato	tuber bulking	4th petiole and leaflet	40
red clover	bud to first flower	top 6 inches	35
soybean	prior to or at initial flower	newest fully developed leaf	25
wheat	tillering - prior to heading	newest fully developed leaf	50
Veg crop			
beet, red	mid-season	youngest mature leaves	20
cabbage	mid-season	wrapper leaves	20
carrot	mid-season	youngest mature leaves	20
ginseng	mid-season	youngest mature leaves	35
onions	mid-season	tops, no white portion	20
squash	prior to or at early fruit development	newest fully developed leaf	25
tomato	mid-season	newest fully developed leaf	40
Fruit crop			
apple	current season shoots (July 1-15)	fully developed leaf at mid-point of new shoots	4 lvs
blueberry	new summer growth	fully developed leaf	35
cherry, sour	current season shoots (July 1-15)	fully developed leaf at mid-point of new shoots	4 lvs
cranberry	Aug 15 - Sept 15	current season growth above berries	200 uprights
grape	full bloom	newest fully developed petiole	5 from each of 10 vines
raspberry	Aug 10- Sept 4	6th and 12th leaf blade and petiole from tip	2-3 lvs from 10 canes
strawberry	at renovation before mowing	fully developed leaflets and petioles	40

The units for the numbers in Tables 2-4 are percent (%); the units for Tables 5-7 are parts per million (ppm)

Table 2.

	Nitrogen				Phosphorus			
Crop	Min	Max	Median	Sufficiency range	Min	Max	Median	Sufficiency range
Cranberry	0.04	2.80	0.90	0.9 - 1.1	0.08	1.17	0.14	0.1 - 0.2
Apple	0.93	3.22	2.06	1.9 - 2.2	0.12	2.24	0.19	0.20 - 0.21
Field corn-tassel	0.46	3.66	2.61	2.50 - 3.33	0.10	1.17	0.33	0.25 - 0.34
Field corn- 12" tall	1.24	5.26	2.98	3.5 - 5.0	0.14	0.87	0.42	0.3 - 0.5
Alfalfa	0.07	5.85	3.31	2.5 - 4.0	0.14	0.75	0.40	0.25 - 0.45
Soybean	0.48	6.26	3.75	4.2 - 5.4	0.08	2.11	0.40	0.3 - 0.7
Field corn	0.76	4.09	2.97	3.0 - 3.5	0.21	3.04	0.41	0.25 - 0.45
Grape	0.45	3.42	0.74	0.85 - 1.25	0.03	0.69	0.28	0.14 - 0.30
Strawberry	1.10	2.88	1.73	2.1 - 2.9	0.18	0.45	0.26	0.24 - 0.30
Blueberry	0.91	2.15	1.66	1.7 - 2.1	0.07	0.80	0.11	0.1 - 0.4
Cherry	1.80	3.81	2.42	2.1 - 2.6	0.12	0.28	0.21	0.20 - 0.25

Table 3.

	Potassium				Calcium			
Crop	Min	Max	Median	Sufficiency range	Min	Max	Median	Sufficiency range
Cranberry	0.31	1.90	0.52	0.4 - 0.75	0.15	9.91	0.83	0.3 - 0.8
Apple	0.43	10.3	1.18	1.0 - 1.6	0.42	9.96	1.12	0.6 - 1.0
Field corn	0.35	4.27	2.01	1.75 - 2.63	0.16	0.96	0.51	0.30 - 0.55
Field corn	0.38	5.45	2.87	2.5 - 4.0	0.04	1.61	0.43	0.3 - 0.7
Alfalfa	0.38	4.19	2.49	2.25 - 3.5	0.60	3.65	1.36	0.7 - 2.5
Soybean	0.37	3.87	2.30	2.15 - 3.25	0.34	2.99	1.10	0.8 - 1.3
Field corn	0.19	5.21	2.70	2.0 - 2.5	0.11	1.06	0.41	0.25 - 0.50
Grape	0.23	4.47	1.22	1.2 - 2.5	0.15	2.81	1.56	1.2 - 2.5
Strawberry	1.00	2.17	1.63	1.2 - 1.7	0.46	1.54	0.89	0.6 - 1.0
Blueberry	0.34	1.31	0.56	0.4 - 0.7	0.28	0.66	0.45	0.35 - 0.80
Cherry	0.60	2.30	1.61	1.0 - 1.6	0.91	2.44	1.66	0.6 - 1.0

Table 4.

	Magnesium				Sulfur			
Crop	Min	Max	Median	Sufficiency range	Min	Max	Median	Sufficiency range
Cranberry	0.09	0.40	0.22	0.15 - 0.25	0.05	1.12	0.12	0.08 - 0.25
Apple	0.16	0.94	0.34	0.3 - 0.5	0.08	0.22	0.15	0.14 - 0.18
Field corn	0.06	1.27	0.27	0.16 - 0.34	0.10	0.39	0.20	0.16 - 0.25
Field corn	0.06	1.68	0.30	0.15 - 0.45	0.08	0.90	0.20	0.15 - 0.50
Alfalfa	0.16	1.20	0.40	0.25 - 0.70	0.09	0.55	0.31	0.25 - 0.50
Soybean	0.19	1.54	0.49	0.23 - 0.55	0.08	0.41	0.27	0.38 - 0.50
Field corn	0.11	1.66	0.28	0.13 - 0.30	0.10	39.7	0.23	0.15 - 0.50
Grape	0.10	1.95	0.89	0.3 - 0.5	0.05	0.27	0.12	0.15 - 0.25
Strawberry	0.24	0.53	0.34	0.3 - 0.5	0.08	0.92	0.12	0.14 - 0.18
Blueberry	0.11	0.24	0.15	0.12 - 0.25	0.11	0.61	0.14	0.12 - 0.30
Cherry	0.33	0.87	0.62	0.3 - 0.5	0.12	0.19	0.14	0.14 - 0.18

Table 5.

	Zinc				Boron			
Crop	Min	Max	Median	Sufficiency range	Min	Max	Median	Sufficiency range
Cranberry	4	171	24	15 - 30	2.3	188	52.0	15 - 60
Apple	6	261	19	25 - 35	0.2	69	32.0	30 - 40
Field corn	10	109	25	19 - 34	0.2	223	11.0	6 - 13
Field corn	11	132	29	20 - 60	0.1	99	8.0	5 - 25
Alfalfa	14	129	29	20 - 60	0.1	103	39.0	25 - 60
Soybean	11	795	43	25 - 88	0.2	116	37.4	27 - 224
Field corn	11	222	29	15 - 60	0.1	108	13.8	4 - 25
Grape	13	132	62	30 - 50	0.2	52	37.1	25 - 50
Strawberry	8	28	17	25 - 35	0.1	245	34.0	30 - 40
Blueberry	6	21	11	9 - 30	18.8	68	46.5	25 - 70
Cherry	10	21	14	25 - 35	24.4	254	37.8	30 - 40

Table 6.

	Manganese				Iron			
Crop	Min	Max	Median	Sufficiency range	Min	Max	Median	Sufficiency range
Cranberry	19	1173	279	10 - 200	2	2486	83	20 - 300
Apple	8	353	41	30 - 50	2	766	49	90 - 120
Field corn	5	576	51	19 - 68	30	614	92	21 - 170
Field corn	6	1368	67	20 - 300	55	5933	244	50 - 250
Alfalfa	4	1781	42	20 - 100	34	1965	86	30 - 250
Soybean	2	3601	63	54 - 300	53	1429	135	50 - 300
Field corn	6	297	52	15 - 300	18	1643	109	10 - 200
Grape	10	577	95	30 - 1000	16	332	25	30 - 100
Strawberry	28	239	63	30 - 50	22	1112	118	90 - 120
Blueberry	90	812	365	50 - 60	41	99	62	70 - 200
Cherry	9	48	19	30 - 50	42	95	58	90 - 120

Table 7.

	Copper			
Crop	Min	Max	Median	Sufficiency range
Cranberry	0.6	495	3.9	4 - 10
Apple	3.4	218	6.2	7 - 10
Field corn	0.7	92	8.9	3 - 7.5
Field corn	2.0	182	7.0	5 - 20
Alfalfa	3.0	20.0	8.0	3 - 30
Soybean	1.7	16.0	8.8	6 - 15
Field corn	1.8	76.3	8.9	3 - 15
Grape	3.8	15.0	6.7	5 - 15
Strawberry	2.8	8.1	5.0	7 - 10
Blueberry	1.8	7.9	4.0	5 - 10
Cherry	5.3	10.0	7.0	7 - 10