PLANT TISSUE TESTING IN WISCONSIN: WHAT'S NEW?

John B. Peters[1] and Carrie A. M. Laboski[2]

Interest in plant tissue testing as a tool to help diagnose the plant nutrient status of crops has increased greatly in the past few years. 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.

Plant Analysis in the Midwest

Of the twelve states making up the North Central region, eight maintain some form of public soil and plant analysis laboratory. All of these states provide plant analysis services to research and in many cases commercial clients as well (Table 1). Of these states, two provide only raw data to clients while the others provide an interpretation of sufficiency levels based on in-state research results in combination with interpretations derived from the literature.

Table 1. Status of plant tissue analysis in the North Central Region.

State	Data Only	Interpretation from literature + local data	Field research ongoing
Iowa	X		Yes
Kansas		X	Yes
Michigan		X	Yes
Minnesota		X	Yes
Missouri		X	No
North Dakota	X		Yes
South Dakota		X	Yes
Wisconsin		X	Yes

Nearly all states have some active research ongoing to help refine and update the interpretation levels used in their state. Most states are gathering data on corn, soybeans and wheat but many are also working on specialty crops where little previous data had existed.

[1] Director, UW Soil Testing Laboratories, Department of Soil Science, UW-Madison.
[2] Associate Professor & Extension Soil Scientist, Department of Soil Science, UW-Madison.

Sampling Guidelines for Wisconsin

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. 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 2 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 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.

Table 2. Recommended stage of growth, plant part and sample size for tissue testing

	Stage or growth	Plant part	No. of plants to sample
Field crop			
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

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.

Interpretation of Tissue Analysis Values for Wisconsin

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 90-100% 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 eleven years are summarized in tables 3-8. Only the results of plant materials that were tested at least 100 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.

Table 3.	**Nitrogen (%)**				**Phosphorus (%)**			
Crop	**Min**	**Max**	**Median**	**Sufficiency Range**	**Min**	**Max**	**Median**	**Sufficiency Range**
Cranberry	0.04	9.7	0.91	0.9 - 1.1	0.04	1.17	0.15	0.10 - 0.20
Apple	0.61	3.22	1.96	1.9 - 2.2	0.09	2.24	0.19	0.20 - 0.21
Field corn-tassel to silk	0.35	5.23	2.46	2.5 - 3.33	0.10	1.17	0.31	0.25 - 0.34
Field corn-12" tall	0.97	6.59	3.43	3.5 – 5.0	0.09	4.00	0.41	0.30 - 0.50
Alfalfa	0.07	6.16	3.46	2.5 – 4.0	0.12	0.86	0.40	0.25 - 0.45
Soybean	0.35	6.37	3.94	4.2 - 5.4	0.08	2.11	0.43	0.30 - 0.70
Field corn-pre-tassel	0.76	5.09	3.04	3.0 - 3.5	0.14	1.12	0.35	0.25 - 0.45
Grape	0.45	4.71	0.92	0.85 - 1.25	0.03	1.03	0.29	0.14 - 0.30
Strawberry	0.88	2.95	1.53	2.1 - 2.9	0.08	0.45	0.26	0.24 - 0.30
Blueberry	0.91	2.57	1.58	1.7 - 2.1	0.07	0.80	0.10	0.10 - 0.40
Cherry	1.64	3.81	2.33	2.1 - 2.6	0.07	0.42	0.18	0.20 - 0.25

Table 4.	Potassium (%)				Calcium (%)			
Crop	**Min**	**Max**	**Median**	**Sufficiency Range**	**Min**	**Max**	**Median**	**Sufficiency Range**
Cranberry	0.11	1.75	0.59	0.4 - 0.75	0.10	9.91	0.76	0.3 - 0.8
Apple	0.30	10.3	1.22	1.0 - 1.6	0.40	9.96	1.11	0.6 – 1.0
Field corn-tassel to silk	0.03	4.79	1.83	1.75 - 2.63	0.03	2.16	0.49	0.3 - 0.55
Field corn-12" tall	0.30	10.6	3.26	2.5 – 4.0	0.04	3.00	0.48	0.3 - 0.7
Alfalfa	0.38	4.99	2.30	2.25 - 3.5	0.45	3.65	1.43	0.7 - 2.5
Soybean	0.26	5.35	2.45	2.15 - 3.25	0.14	2.99	1.05	0.8 - 1.3
Field corn-pre-tassel	0.19	5.21	2.57	2.0 - 2.5	0.10	1.47	0.38	0.25 - 0.5
Grape	0.23	7.48	1.73	1.2 - 2.5	0.53	2.94	1.36	1.2 - 2.5
Strawberry	0.32	2.17	1.50	1.2 - 1.7	0.45	1.90	0.92	0.6 – 1.0
Blueberry	0.33	1.50	0.54	0.4 - 0.7	0.17	1.27	0.47	0.35 - 0.8
Cherry	0.60	2.72	1.57	1.0 - 1.6	0.56	2.44	1.41	0.6 – 1.0

Table 5.	Magnesium (%)				Sulfur (%)			
Crop	**Min**	**Max**	**Median**	**Sufficiency Range**	**Min**	**Max**	**Median**	**Sufficiency Range**
Cranberry	0.01	0.40	0.20	0.15 - 0.25	0.03	1.12	0.12	0.08 - 0.25
Apple	0.12	0.94	0.31	0.30 - 0.50	0.05	0.22	0.15	0.14 - 0.18
Field corn-tassel to silk	0.03	1.27	0.26	0.16 - 0.34	0.02	0.39	0.18	0.16 - 0.25
Field corn-12" tall	0.03	5.00	0.29	0.15 - 0.45	0.06	7.00	0.25	0.15 - 0.50
Alfalfa	0.12	1.20	0.37	0.25 - 0.70	0.01	0.67	0.27	0.25 - 0.50
Soybean	0.11	1.54	0.46	0.23 - 0.55	0.08	0.46	0.27	0.38 - 0.50
Field corn-pre-tassel	0.03	1.66	0.24	0.13 - 0.30	0.08	0.71	0.22	0.15 - 0.50
Grape	0.08	1.95	0.71	0.30 - 0.50	0.04	0.36	0.13	0.15 - 0.25
Strawberry	0.24	0.65	0.34	0.30 - 0.50	0.04	0.92	0.11	0.14 - 0.18
Blueberry	0.06	0.40	0.14	0.12 - 0.25	0.10	0.61	0.14	0.12 - 0.30
Cherry	0.21	0.96	0.51	0.30 - 0.50	0.10	0.20	0.14	0.14 - 0.18

Table 6.	Zinc (ppm)				Boron (ppm)			
Crop	**Min**	**Max**	**Median**	**Sufficiency Range**	**Min**	**Max**	**Median**	**Sufficiency Range**
Cranberry	4.0	171	27.1	15-30	2.3	188	46.0	15-60
Apple	4.6	8084	16.1	25-35	0.2	115	32.5	30-40
Field corn-tassel to silk	7.0	256	23.6	19-34	0.2	223	10.7	6-13
Field corn-12" tall	4.0	2930	34.3	20-60	0.05	152	8.1	5-25
Alfalfa	7.4	328	29.7	20-60	0.06	103	37.1	25-60
Soybean	10.9	795	40.7	25-88	0.2	116	34.3	27-224
Field corn-pre-tassel	8.9	959	25.4	15-60	0.06	108	9.3	4-25
Grape	5.6	229	50.1	30-50	0.2	183	35.0	25-50
Strawberry	7.8	78	15.7	25-35	0.06	245	34.6	30-40
Blueberry	5.4	33	10.3	9-30	17.5	152	45.0	25-70
Cherry	4.1	36	12.7	25-35	13.1	254	27.7	30-40

Table 7.	Manganese (ppm)				Iron (ppm)			
Crop	**Min**	**Max**	**Median**	**Sufficiency Range**	**Min**	**Max**	**Median**	**Sufficiency Range**
Cranberry	8.9	1340	282	10 - 200	2.0	4309	113	20 - 300
Apple	8.0	385	39.9	30 - 50	2.0	1896	50.9	90 - 120
Field corn-tassel to silk	4.9	576	42.0	19 - 68	17.9	3524	86.8	21 - 170
Field corn-12" tall	4.0	1368	59.4	20 - 300	5.0	7465	222	50 - 250
Alfalfa	4.0	1781	36.2	20 - 100	12.6	12385	78.8	30 - 250
Soybean	2.0	3601	57.6	54 - 300	19.6	4576	115	50 - 300
Field corn-pre-tassel	4.0	1259	51.2	15 - 300	18.0	5265	120	10 - 200
Grape	9.9	2468	116	30 - 1000	0.1	3936	21.8	30 - 100
Strawberry	27.2	890	74.2	30 - 50	20.6	20032	55.9	90 - 120
Blueberry	40.5	812	285	50 - 60	23.1	231	56.7	70 - 200
Cherry	6.9	80	15.0	30 - 50	32.9	1210	50.2	90 - 120

Table 8.

Crop	Copper (ppm) Min	Max	Median	Sufficiency Range
Cranberry	0.04	1050	3.2	4 - 10
Apple	0.49	218	5.3	7 - 10
Field corn-tassel to silk	0.49	187	7.5	3 - 7.5
Field corn- 12" tall	0.40	182	7.0	5 - 20
Alfalfa	0.49	20	8.0	3 - 30
Soybean	0.49	18	6.9	6 - 15
Field corn-pre-tassel	0.40	76	7.0	3 - 15
Grape	0.49	233	5.9	5 - 15
Strawberry	0.49	14	4.2	7 - 10
Blueberry	0.49	7.9	3.2	5 - 10
Cherry	1.71	358	7.7	7 - 10

Summary

There are a number of limitations to the use of plant tissue testing as a tool to manage crop production in Wisconsin. In general, tissue testing is most common on relatively high value horticultural crops, such as cranberries and apples and relative to the acreage of these crops 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.

Field research is ongoing in Wisconsin and many other Midwestern states in an attempt to update the database that is being used to interpret plant tissue results. Much of the data is relatively old and may not reflect modern crop genetics or the changes that have occurred in production practices. Even if no or outdated plant tissue norms are available for a crop, tissue testing can be used effectively by comparing plants with normal and abnormal growth when sampled and tested separately.

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IMPORTANCE OF POTASSIUM FOR WISCONSIN CROPPING SYSTEMS

Carrie A.M. Laboski[1]

Potassium is important for crop production in Wisconsin particularly in rotations with alfalfa and corn silage. Unfortunately when potash prices increased dramatically in 2008 many growers chose not to apply potash or apply less than recommended rates. Recently, soil test K levels have been decreasing throughout much of Wisconsin even before potash prices increased (Fig. 1). Though changes in soil test K over time vary by county (Fig. 2).

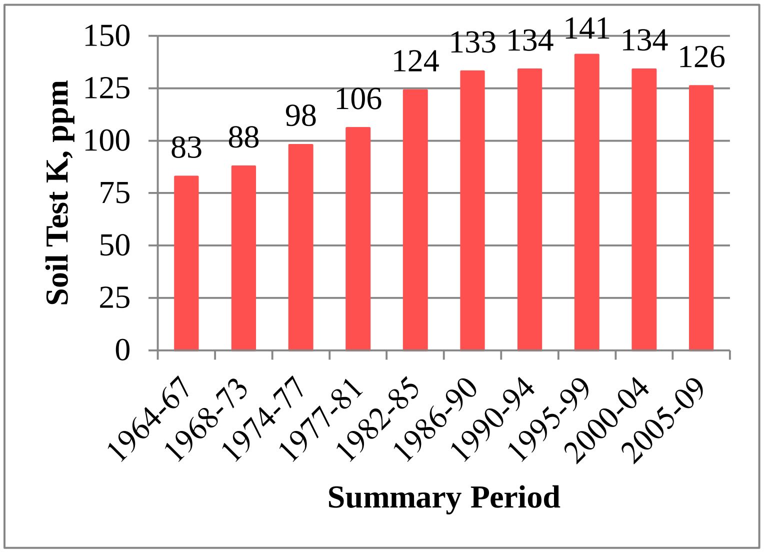

Figure 1. Average Wisconsin soil test K values from 1964 through 2009. Summary of all soils analyzed by Wisconsin Department of Agriculture, Trade, and Consumer Protection certified laboratories.

A few case studies highlight the need to pay attention to soil test K levels and apply recommended rates of potash. The first case study is from a soybean field in 2005. The soybeans exhibited potassium deficiency symptoms in linear patterns spaced about 30 inches apart with half of the field exhibiting the symptomology more strongly (Fig. 3). The field was planted to corn in 2004 and half of the field was harvested for grain and the other half for silage. Where silage was harvested in 2004, K deficiency on soybean was much more apparent. Starter fertilizer was applied to the corn in 2004. It was hypothesized that the more normal looking soybeans were growing over the old starter bands and the soil test K levels would be higher where the soybeans exhibited no deficiency symptoms. Soil sample results confirmed this hypothesis. Within the corn row, soil test K was 57, 71 and 52 ppm (average 60 ppm) and between the rows soil test K was 48, 62, 54 ppm (average 55 ppm). Less deficiency was observed where corn grain was harvested the previous years because some K taken up by the corn would have been recycled back into the soil as the residue aged and rainfall leached K from the residue into the soil. On medium- and fine-textured (loamy) soils like this one, soil test K levels below 90 ppm are considered very low for rotations, which contain alfalfa, corn silage, and wheat; while soil test K less than 70 ppm is considered very low in corn grain and soybean rotations (Table 1). It is very interesting that K deficiency symptomology was so much greater soil test K

[1] Associate Professor, Dept. of Soil Science, 1525 Observatory Dr., Univ. of Wisconsin-Madison, Madison, WI 53706.