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Plant Tissue Testing

Soil testing can provide an estimate of plant nutrient availability in a soil. However, soil testing cannot predict the quantity of nutrients a plant or crop will actually use because many factors other than soil fertility levels are involved in plant nutrition. Only through plant tissue analysis can we assess the plant's nutritional status and determine how well the soil is supplying the plant's nutritional requirements. Plant tissue analysis cannot replace a good soil testing program; however, plant tissue analysis can provide additional information on plant nutrient status not obtained from soil analysis.

In theory, plant tissue testing is quite simple. Plant samples from a field are collected and the nutrient levels determined after the plant tissue has been digested or extracted in a solution. Generally, only those plant portions growing above ground are sampled, although underground parts are sometimes sampled. Frequently, only specific plant parts (leaves or petioles, for example) are sampled. After nutrient levels are measured, the plant's nutritional status can be determined by comparing the measured levels with standard levels that have been previously determined through field research. Alternatively, when a field contains both healthy and unhealthy plants, samples can be taken from both and a comparison of nutritional levels can be made. Nutritional problems frequently can be identified by this process.

In reality, there are a number of factors that make plant tissue testing far more complicated than suggested. Plant nutrient concentrations are affected by plant age, plant part and sometimes by variety even in a healthy plant. These influences must be taken into consideration.

As a plant ages, the proportions of the various types of structures change. Young plants are very succulent, with a high proportion of water in the tissues. When the plant gets older, water content decreases, the proportion of cell walls increases and the plant may become woody. The different plant structures vary in plant nutrient content. Concentrations of some nutrients (N, P, K, Cu, Zn) tend to decrease as plants age, while the concentrations of others (Ca and Mn) often increase. Unfortunately, the rates in which these tissues change are difficult to quantify. Therefore, it is extremely important to know the plant's growth stage (or age) when sampled if the composition is to be compared to "standardized" levels. There are commonly recommended growth stages for sampling and standard nutrient stages. Samples taken from plants at different growth stages are not easily evaluated.

Just as plants of various ages differ in nutrient content, different plant parts may contain varying levels of plant nutrients. For example, the wood and the leaves of a tree contain very different nutrient levels. Similarly, stems, leaves, roots and fruits of non–woody plants may have distinct nutrient concentrations. Therefore, it is critical when taking a plant tissue sample that the plant structure collected is the one for which standard values are known. In small plants, the whole above–ground portion of the plant is usually sampled. In older plants, the most common sampling method is to collect the youngest fully expanded (grown to its full size) leaf, or to take the petioles (leaf stems) associated with those leaves. For plants requiring leaf sampling, the petiole is usually not included. Petioles are often used for sampling water–soluble (nitrate and phosphate) rather than total nutrients because

the petiole is the conducting tissue where nutrients travel from the stem to the leaf. The recommended plant part for sampling should be determined for each specific plant (see Table 1.)

If a field contains both healthy and unhealthy plants, these sampling guidelines are less critical. One can remove a sample from both healthy and unhealthy plants, making sure that the same plant part is taken in both. The healthy plant can be used as the standard value to compare against the unhealthy plant. This type of comparison may be less ideal than it appears because the physiological age of the two plant groups differ. It is not uncommon for an unhealthy plant to mature at a different rate than a healthy one. For example, an unhealthy plant may bloom much earlier than its healthy counterpart. Therefore, although two plants may have been planted at the same time in the same field, their physiological age, or stage of development, may not be the same. This can make direct comparison difficult. It is helpful if soil samples are collected from healthy and unhealthy areas when tissue samples are collected.

Plant tissue samples should be taken from plants representative of the sampling area. Dead or damaged plants, those with insect or disease problems, those at the end of rows or in edge rows, or plants that differ significantly from those in the rest of the planting should not be sampled. Plants that have been recently sprayed with foliar fertilizers should be avoided. It is important that at least the recommended number of plants is sampled to ensure that a representative sample is obtained. If the recommended sample size is 25 mature leaves, all leaves should be taken from separate plants. In addition, the sampled plants should be randomly selected from a field, not concentrated in one area.

Try to sample clean leaves. Plants analyzed for iron or aluminum should first be washed quickly in a mild (2 percent) detergent solution. Fresh tissue samples must be dried rapidly at 150° to 175°F until all water is removed (a kitchen oven on the warm setting will suffice). Drying at higher temperatures may destroy plant tissues; drying at lower temperatures will not stop biological activity. Tissue samples will dry best in open containers, cloth bags or opened paper bags. Samples should be dried immediately following sampling. If this is not possible, samples may be refrigerated for short periods of time prior to drying.

Tissue samples are ground to powder in the laboratory, then put into a liquid form for analysis. One of several methods may be used. Often plant tissues are digested in acid solutions. The tissue may be directly digested in boiling acid or it may be ashed in a furnace prior to acid digestion. Sometimes soluble nutrients are extracted from plant tissue in water or in salt or dilute acid solutions. Selection of appropriate methodology depends on the specific analysis to be conducted.

Results from analyses are most frequently compared directly to previously determined standard values. Standards are established for nutrient concentration ranges adequate for healthy plant growth; these are called sufficiency ranges. By comparing the results of a plant tissue analysis with these standards, the nutritional status of the test crop can be established. Sufficient nutrient concentration ranges for most crops grown in Alaska are presented in Table 2.

In some cases, the levels of soluble nutrients in petiole tissues provide more sensitive parameters for nutritional diagnoses than leaf analyses. Diagnostic values for petiole nutrient levels are given in Table 3.

Table 1. Recommended plant part and growth stage for selected crop plants.

Crop	Number of Plants Sampled	Plant Part	Stage of Growth
Alfalfa	12	Top 6 inches	Prior to bloom
Barley	25	Whole top1	Emergence of head from boot
Beets	20	Most recently mature leaf 2	At maturity
Bluegrass		Clippings	4–6 weeks after last cut
Broccoli	12	Most recently mature leaf	At heading
Bromegrass	25	First mature stem w/leaves	At maturity
Brussels sprouts	12	Most recently mature leaf	At maturity
Cabbage	15	Whole tops	2–6 weeks old
Cabbage	12	Wrapper leaf	2–3 months old
Canola	20	First fully mature leaves	At flowering
Carrot	15	Most recently mature leaf	Mid–season
Carrot	15	Oldest leaf	At maturity
Cauliflower	12	Most recently mature leaf	At heading
Celery	12	Most recently mature leaf	Half–grown
Chinese cabbage	12	First fully developed leaf	8–leaf stage
Chinese cabbage	12	First fully developed leaf	At maturity
Clover, red	15	Whole top	Prior to bloom
Clover, alsike	20	Whole top	At first flower
Clover, white	50	Leaves	Prior to bloom
Romaine lettuce	12	Wrapper leaf	At maturity
Head lettuce	12	Wrapper leaf	Heads half–size
Oats	25	Whole top	Emergence of head from boot
Potato	25	Most recently mature leaf	Plant 12 inches tall
Potato	25	Most recently mature leaf	Tubers half–grown
Raspberry	50	Most recently mature whole leaves	Flower bud start
Strawberry	25	Most recently mature whole leaves	At flowering
Tall fescue	20	Clipping	5–6 weeks after last cut
Timothy	25	Whole top	Early bloom
Turnip	12	Most recently mature leaf	Mid–growth

1 Whole top is the entire above ground portion of the plant.

2 Most recently mature leaf is the youngest fully developed leaf.

Table 2. Nutrient sufficiency ranges for selected crop plants.[1]

Nutrient	Alfalfa	Barley	Beets	Bluegrass	Broccoli
			%		
Nitrogen	2.95–5.00	1.75–3.00	4.00–5.50	2.60–3.50	3.20–5.50
Phosphorus	0.24–0.70	0.20–0.50	0.25–0.50	0.28–0.40	0.30–0.75
Potassium	2.00–3.50	1.50–3.00	2.00–4.50	2.00–3.00	2.00–4.00
Calcium	1.20–3.00	0.30–1.20	2.50–3.50	———	1.00–2.50
Magnesium	0.16–1.00	0.15–0.50	0.30–1.00	0.40–0.48	0.23–0.75
Sulfur	0.23–0.50	0.15–0.40	—	0.16–0.24	0.30–0.75
			ppm		
Boron	20–80	—	30–85	—	0–100
Copper	6–30	4.25	5–15	—	5–15
Iron	31–250	—	50–200	—	70–300
Manganese	21–200	18–100	50–250	—	25–200
Molybdenum	1.0–5.0	0.11–0.18			
Zinc	20–70	20–70	15–200	—	35–200

Nutrient	Brome grass	Brussels sprouts	Cabbage 2–6 wks	Cabbage 2–3 months	Canola
			%		
Nitrogen	2.00–3.50	2.20–5.50	3.00–5.00	3.00–5.00	2.50–4.00
Phosphorus	0.25–0.35	0.26–0.75	0.35–0.75	0.30–0.75	0.25–0.50
Potassium	2.00–3.50	2.00–4.00	3.50–6.00	3.00–5.00	1.50–2.50
Calcium	0.25–0.40	0.30–2.50	3.00–4.50	1.10–3.50	0.50–4.00
Magnesium	0.14–0.30	0.23–0.75	0.50–2.00	0.24–0.75	0.20–1.50
Sulfur	0.17–0.30	0.30–0.75	—	0.30–0.75	0.25–0.50
			ppm		
Boron	10–20	30–100	25–75	25–75	30–80
Copper	5–10	5–15	5–15	5–15	2.7–20
Iron	50–100	60–300	30–200	30–200	20–200
Manganese	40–80	25–200	50–200	25–200	15–100
Molybdenum	—	0.25–1.00	—	0.4–0.7	—
Zinc	20–50	25–200	25–200	20–200	15–70

Nutrient	Carrots mid-season	Carrots mature	Cauliflower	Celery	Chinese Cabbage
			%		
Nitrogen	1.80–3.50	3.00–3.50	3.00–4.50	2.50–3.50	4.50–5.50
Phosphorus	0.20–0.50	0.20–0.40	0.33–0.80	0.30–0.50	0.50–0.60
Potassium	2.00–4.30	2.90–3.50	2.60–4.20	4.00–7.00	7.50–9.00
Calcium	1.40–3.00	1.00–2.00	0.70–3.50	0.60–3.00	3.00–5.50
Magnesium	0.30–0.53	0.25–0.60	0.24–0.50	0.20–0.50	0.35–0.50
			ppm		
Boron	29–100	30–75	30–100	30–50	23–75
Copper	4.5–15	5–15	4–15	5–8	5–25
Iron	50–300	50–300	30–200	20–40	31–200
Manganese	60–200	60–200	25–250	200–300	25–200
Molybdenum	0.5–1.5	0.5–1.4	0.5–0.8	—	—
Zinc	20–250	20–250	20–250	20–50	30–200

Nutrient	Alsike Clover	Red Clover	White Clover	Romaine Lettuce	Head Lettuce
			%		
Nitrogen		3.00–4.50	4.5–5.0	3.50–4.50	3.50–5.00
Phosphorus	0.25–0.50	0.20–0.60	0.36–0.45	0.45–0.80	0.40–0.60
Potassium	1.50–3.00	2.20–3.00	2.00–2.50	5.50–6.20	6.00–9.60
Calcium	1.00–1.80	2.00–2.60	0.50–1.00	2.00–2.80	1.40–2.25
Magnesium	0.30–0.60	0.21–0.60	0.20–0.30	0.60–0.80	0.36–0.70
Sulfur	—	0.26–0.30	0.25–0.50	—	—
			ppm		
Boron	15–50	30–80	25–50	25–60	23–50
Copper	3–15	8–15	5–8	5–25	7–25
Iron	50–100	30–250	25–100	40–100	50–175
Manganese	40–100	30–120	25–100	11–250	20–250
Molybdenum	—	0.50–1.00	0.15–0.25	—	—
Zinc	15–80	18–80	15–25	20–250	25–250

Nutrient	Oats	Potatoes 12-in. plants	Potatoes tubers ½ grown	Raspberry plants
			%	
Nitrogen	2.00–3.00	4.50–6.50	3.00–4.00	2.20–4.00
Phosphorus	0.20–0.50	0.29–0.50	0.25–0.40	0.30–0.50
Potassium	1.50–3.00	2.40–3.90	3.20–4.10	1.40–3.00
Calcium	0.20–0.50	0.76–1.00	1.50–2.50	0.80–1.50
Magnesium	0.15–0.50	0.36–0.49	0.49–0.54	>0.30
Sulfur	0.15–0.40	—	—	—
			ppm	
Boron	—	25–50	40–70	25–75
Copper	5–25	7–20	7–20	3–50
Iron	40–150	50–100	40–100	
Manganese	22–100	30–250	30–250	30–250
Molybdenum	0.2–0.3	—	—	—
Zinc	15–70	45–250	30–200	25–100

Nutrient	Strawberry plants	Tall Fescue	Timothy	Turnips
			%	
Nitrogen	2.50–4.00	3.20–3.80	0.53–1.68	3.50–5.00
Phosphorus	0.21–1.00	0.34–0.45	0.11–0.18	0.33–0.60
Potassium	1.30–3.00	2.80–4.00	1.14–1.70	3.50–5.00
Calcium	1.00–2.50	—	0.09–0.35	1.50–4.00
Magnesium	0.25–1.00	—	0.06–0.25	0.30–1.00
Sulfur	—	>0.15	—	—
			ppm	
Boron	23–50	—	1–10	30–100
Copper	6–50	—	7–45	6–25
Iron	50–200	—	22–54	40–300
Manganese	70–200	—	11–35	40–250
Zinc	20–200	—	24–62	20–250

[1]Standard values are for plant parts and growth stages specified in Table 1.

Table 3. Sufficiency levels for nitrate, phosphate, and potassium in petioles and leaf midribs of selected crop plants.

Crop	Stage of Growth	Plant part	Nitrate– N (ppm)	Phosphate– P (ppm)	Potassium (%)
Broccoli	Mid–growth	Midrib of YML[1]	>9000	>4000	>5.0
	First buds		>7000	>4000	>4.0
Brussels sprouts	Mid–growth		>9000	>3500	>5.0
	Late growth	Midrib of YML	>7000	>3000	>4.0
Chinese Cabbage	Heading	Midrib of wrapper leaf	>9000	>3500	>4.0
Carrot	Mid–growth	Petiole of YML	>10000	>4000	>6.0
Cauliflower	Head forming	Midrib of YML	>9000	>5000	>4.0
Celery	Mid–growth	Petiole of YML	>9000	>5000	>6.0
	Near mature		>6000	>3000	>5.0
Head Lettuce	Heading	Midrib of	>8000	>4000	>4.0
	Harvest	wrapper leaf	>6000	>2500	>2.5
Potato	Early–season	Petiole of fourth	>19000	>2000	>12.0
	Mid–season	leaf from the	>15000	>1600	>9.0
	Late season	growing tip	>8000	>1000	>6.0

[1] YML – youngest mature (fully expanded) leaf.

Nutritional diagnoses can give important information about the condition of a crop; however in the case of an annual crop, it may be too late to effectively remedy nutritional problems. Nevertheless, even when irreparable damage has been done, diagnostic nutritional information can be extremely valuable. If tissue analyses reveal shortages of nutrients routinely applied in a fertilization program (nitrogen, phosphorus or potassium), this may be an indication that the fertilization regime being used is inadequate for that crop. The next time the crop is grown at that location, fertilizer application rates should be adjusted. If tissue analyses reveal shortages of secondary or micronutrients, soil test information should be consulted and consideration should be given to various means of correcting the problem before the field is planted again. When dealing with perennial crops, adjusting fertilization practices can be made at almost any time. Action taken late in the season may not improve that season's yield, but performance in subsequent years should be enhanced.

Information from plant tissue tests cannot replace that from soil tests; the two practices provide complementary data. By combining information from the two sources, one gets a clearer picture of the ability of a soil to provide adequate nutrition and of the crop to use nutrients. Both should be considered integral parts of a complete nutrient monitoring program.

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Steven Seefeldt, Extension Faculty, Agriculture and Horticulture. This publication was originally prepared by James L. Walworth, former Soil Scientist, University of Alaska Agriculture and Forestry Experiment Station, Palmer.

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