Zinc (Zn): Deficiency—Short internodes may cause rosetting appearance in trees. Younger leaves usually affected first and may show signs of yellowing between the veins. High levels of phosphorus fertilizer may induce zinc deficiency. Can occur on high pH soils or acid sandy soils. **Excess**—May induce iron deficiency.

Plant Analysis for Fruit and Vegetable Production

Plant analysis is a powerful tool growers can use to help diagnose nutrient disorders that may occur during the growing season. Plant analysis can also be used to help fine-tune the efficiency of a fertilizer program before nutrient deficiency symptoms appear and is especially useful for perennial crops. The technique involves determining the elemental composition of plant tissue during the growing season and then comparing these values with those already established for a normal, healthy plant. From this comparison, nutrient deficiencies or excesses can be determined.

It should be recognized that plant analysis is not a substitute for a routine soil test. Soil testing provides information on lime and fertilizer needs prior to planting and is particularly well calibrated for nutrients such as phosphorus, potassium, magnesium, calcium, sulfur, boron, and zinc. Soil tests for nutrients such as nitrogen (eastern Minnesota), iron, manganese, copper (mineral soils), and molybdenum are often not reliable for predicting fertilizer needs. Therefore, when used in conjunction with soil testing, plant analysis can provide additional information related to crop nutrition and the effectiveness of a particular fertilizer program.

What and When to Sample

The basis behind plant analysis is that maximum yields are associated with an optimum range of nutrients in the leaf or tissue sampled. Usually the leaf plus petiole or just the petiole alone is sampled for nutrient determination. If the level of a nutrient falls outside this range, then corrective measures should be taken. These optimum nutrient ranges are based on samples collected at a particular growth stage and tissue maturity. Samples collected too early or late in the growing season may not be interpreted accurately using the established sufficiency values. The proper time and plant part to sample are presented in **Table 45**.

When troubleshooting suspected nutrient deficiency or toxicity symptoms, it may not be possible to collect the samples at the recommended time. For these situations, samples should be collected from plants showing a problem and then compared to those collected from both healthy plants and plants only showing minor symptoms. Comparing nutrient levels in these samples as well as looking at soil test results can help determine whether the problem is nutritional.

Sampling and Handling Procedures

The following instructions may be used as a guide for proper sampling and handling procedures:

1. Refer to **Table 45** for proper times to sample and the plant part to collect.
2. Obtain a representative composite sample from a uniform area. Areas of different soil type should be sampled separately. Each sample should not represent more than 10 acres even in uniform areas. Refer to **Table 45** for the number of plants or leaves required for each sample. Samples should consist of tissue collected over the entire area. Leaves showing insect, disease, or mechanical damage should not be selected for sampling. Do not sample if foliar fertilizers have been recently applied unless you are only interested in nutrients other than those applied.
3. Avoid sampling dirty or dusty leaves. Consult your tissue testing laboratory for specific information on how to handle and send in the samples. Some general guidelines for handling dirty samples are as follows. If leaves are dirty or dusty, they should be rinsed quickly in distilled or demineralized water. A mild non-phosphate detergent may be added if necessary. Do not let the leaves soak in water as the nutrients can leach out. Particulate matter may be removed with a clean cloth dampened with distilled or demineralized water. Dried tissue should not be rinsed. Samples should be dried as rapidly as possible. Forced air drying at 150-170° F is preferred, but air drying is also permissible. Transport the samples to the laboratory in loose fitting, clean paper or cloth bags. Do not use plastic bags unless the samples have been previously dried or are transported to the laboratory within a few hours.
4. The University of Minnesota Research Analytical Laboratory (phone: 612-625-3101) offers tissue testing services for a fee. An information sheet along with current prices can be found at the following web site: http://ral.coafes.umn.edu/Forms/DIAGNOSTIC%20PLANT2003a.pdf

   A number of private laboratories also offer tissue testing services. Contact your Extension Office or fertilizer dealer for information about commercial laboratories in your area or look in the Yellow Pages under "laboratories."

Interpretations

The established sufficiency levels for a healthy crop are presented in **Table 46**. Even though many of these levels have been determined from research conducted outside of Minnesota, they do provide a starting point for interpretation.

Table 45. Procedures for sampling plant tissue.

Crop	Stage of Growth	Plant Part Sampled	Approximate Number of Plants or Leaves to Sample
Apples	July 15-Aug. 15	Leaf from middle of current terminal shoot	60
Asparagus	Mature fern (August)	Fern from 17 to 35 inches up	20
Beans, snap	Initial flowering	Young mature trifoliate	50
Beets, table	Mature	Young mature leaf	20
Blueberries	First week of harvest	Young mature leaf	50
Broccoli	Heading	Young mature leaf	15
Brussels sprouts	Maturity	Young mature leaf	15
Cabbage	Heads, half-grown	Young wrapper leaf	15
Cantaloupe	Early fruiting	Fifth leaf from tip	25
Carrots	Midgrowth	Young mature leaf	25
Cauliflower	Buttoning	Young mature leaf	15
Celery	Half-grown	Young mature leaf	20
Cucumbers	Early fruiting	Fifth leaf from tip	20
Eggplant	Early fruiting	Young mature leaf	15
Garlic	Bulbing	Young mature leaf	25
Grapes	Full bloom	Petiole from leaf opposite basal fruit cluster	75
Lettuce	Heads, half-size	Wrapper leaf	20
Onions	Midgrowth	Top, no white portions	25
Peas	First bloom	Recently mature leaflet	50
Peppers	Early fruiting	Young mature leaf	20
Potatoes	40-50 days after emergence	Fourth leaf from tip	20
Potatoes	40-50 days after emergence	Petiole from fourth leaf from tip	40
Pumpkin/Squash	Early fruiting	Young mature leaf	15
Radishes	Midgrowth to harvest	Young mature leaf	40
Raspberries	First week in August	Leaf 18 inches from tip	50
Spinach	30-50 days old	Young mature leaf	35
Strawberries	Mid-August	Young mature leaf	20
Sweet corn	Tasseling to silk	Ear leaf	10
Tomatoes	First mature fruit	Young mature leaf	20
Watermelons	Midgrowth	Young mature leaf	15

Table 46. *Nutrient concentration sufficiency ranges for fruit and vegetable crops.*[1]

	Nutrient Concentration Ranges											
Crop	**N**	**P**	**K**	**Ca**	**Mg**	**S**	**Fe**	**B**	**Cu**	**Zn**	**Mn**	**Mo**
	%						ppm					
Apples	1.9-2.3	0.09-0.40	1.2-1.8	0.8-1.6	0.25-0.45	0.20-0.40	50-200	30-50	6-12	20-50	25-135	>0.1
Asparagus	2.4-3.8	0.25-0.50	1.5-2.4	0.4-1.0	0.25-0.30	—	40-250	40-100	5-25	20-60	25-160	—
Bean, snap	5.0-6.0	0.25-0.75	2.2-4.0	1.5-3.0	0.25-0.70	—	50-300	20-60	7-30	20-60	50-300	>0.4
Beets, table	3.5-5.0	0.25-0.50	3.0-4.5	2.5-3.5	0.30-1.00	—	50-200	30-80	5-15	15-30	70-200	—
Blueberries	1.7-2.1	0.10-0.40	0.4-0.7	0.35-0.8	0.12-0.25	0.12-0.30	70-200	25-70	5-20	9-30	50-600	—
Broccoli	3.2-5.5	0.30-0.70	2.0-4.0	1.2-2.5	0.23-0.40	0.30-0.75	50-150	30-100	4-10	20-80	25-150	0.3-0.5
Brussels sprouts	3.1-5.5	0.30-0.75	2.0-4.0	1.0-2.5	0.25-0.75	0.30-0.75	60-300	30-100	5-15	25-200	25-200	0.25-1.0
Cabbage	3.6-5.0	0.33-0.75	3.0-5.0	1.1-3.0	0.40-0.75	0.3-0.75	30-200	25-75	5-15	20-200	25-200	0.4-0.7
Cantaloupe	4.5-5.5	0.30-0.80	4.0-5.0	2.3-3.0	0.35-0.80	0.25-1.0	40	50-300	25-60	7-30	20-200	50-250
Carrots	2.5-3.5	0.20-0.30	2.8-4.3	1.4-3.0	0.30-0.50	—	50-300	30-100	5-15	25-250	60-200	0.5-1.5
Cauliflower	3.3-4.5	0.33-0.80	2.6-4.2	2.0-3.5	0.27-0.50	—	30-200	30-100	4-15	20-250	25-250	0.5-0.8
Celery	2.5-3.5	0.30-0.50	4.0-7.0	0.6-3.0	0.20-0.50	—	30-70	30-60	5-8	20-70	100-300	—
Cucumbers	4.5-6.0	0.30-1.25	3.5-5.0	1.0-3.5	0.30-1.00	0.30-0.70	50-300	25-60	5-20	25-100	50-300	—
Eggplant	4.2-5.0	0.45-0.60	5.7-6.5	1.7-2.2	0.25-0.35	—	—	20-30	4-6	30-50	15-100	—
Garlic	3.4-4.5	0.28-0.50	3.0-4.5	1.0-1.8	0.23-0.30	—	—	—	—	—	—	—
Grapes	1.2-2.2	0.15-0.46	1.5-2.5	1.2-2.5	0.30-0.50	—	40-180	30-50	7-15	25-100	25-150	0.2-0.4
Lettuce	2.5-4.0	0.40-0.60	6.0-8.0	1.4-2.0	0.50-0.70	—	50-500	30-100	7-10	26-100	30-90	>0.1
Onions	5.0-6.0	0.35-0.50	4.0-5.5	1.5-3.5	0.30-0.50	0.50-1.0	60-300	30-45	5-10	20-55	50-65	—
Peas	4.0-6.0	0.30-0.80	2.0-3.5	1.2-2.0	0.30-0.70	0.20-0.40	50-300	25-60	5-10	25-100	30-400	>0.6
Peppers	3.5-4.5	0.30-0.70	4.0-5.4	0.4-0.6	0.30-1.50	—	60-300	30-100	10-20	30-100	26-300	—
Potatoes (leaf)	3.5-4.5	0.25-0.50	4.0-6.0	0.5-0.9	0.25-0.50	0.19-0.35	30-150	20-40	5-20	20-40	20-450	—
Potatoes (petiole)	—	0.22-0.40	8.0-10.0	0.6-1.0	0.30-0.55	0.20-0.35	50-200	20-40	4-20	20-40	30-300	—
Pumpkin/ Squash	4.0-6.0	0.35-1.00	4.0-6.0	1.0-2.5	0.30-1.00	—	60-300	25-75	6-25	20-200	50-250	—
Radishes	3.0-6.0	0.30-0.70	4.0-7.5	3.0-4.5	0.50-1.20	0.20-0.40	50-200	30-50	6-12	20-50	25-130	—
Raspberries	2.2-3.5	0.20-0.50	1.1-3.0	0.6-2.5	0.25-0.80	0.20-0.30	50-200	25-300	4-20	15-60	25-300	—
Spinach	4.2-5.2	0.30-0.60	5.0-8.0	0.6-1.2	0.60-1.00	—	60-200	25-60	5-25	25-100	30-250	>0.5
Strawberries	2.1-2.9	0.20-0.35	1.1-2.5	0.6-1.8	0.25-0.70	0.20-0.30	90-150	25-60	6-20	20-50	30-100	—
Sweet corn	2.8-3.5	0.25-0.40	1.8-3.0	0.6-1.1	0.20-0.50	0.20-0.75	50-300	8-25	5-25	20-100	30-300	0.9-1.0
Tomato	4.0-6.0	0.25-0.80	2.9-5.0	1.0-3.0	0.40-0.60	0.40-1.2	40-200	25-60	5-20	20-50	40-250	—
Watermelon	2.0-3.0	0.20-0.30	2.5-3.5	2.5-3.5	0.60-0.80	—	100-300	30-80	4-8	20-60	60-240	—

[1] *Portions of this table were adapted from* Plant Analysis Handbook *by J.B.Jones, Jr., B. Wolf, and H.A. Mills. MicroMacro Publishing, Inc., 1991.*