TAKING AND INTERPRETING SOIL AND TISSUE SAMPLES

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In addition to water, sunlight, and carbon dioxide from the air, plants require 13 mineral nutrients that are typically derived from the soil. The macronutrients nitrogen (N), phosphorus (P), potassium (K) are needed by plants in relatively large amounts and often have to be added to the soil. Intermediate amounts of secondary nutrients magnesium (Mg), calcium (Ca), and sulfur (S) are needed by plants. Trace or micronutrients [boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn)] are needed in small amounts and are seldom deficient in Wisconsin soils.

In a healthy plant the essential mineral elements are present in adequate levels and in correct proportion to other elements. Plant productivity or fruit quality is reduced if:

- one or more of the required elements is not present in sufficient quantity (deficiency);
- one or more elements is present in too great a quantity (toxicity);

These nutrients perform a variety of functions in plants ranging from being structural components of cell walls and membranes to activating enzyme systems. About 95% of the dry weight of a typical plant is made up of carbon, oxygen and hydrogen. The soil supplied minerals make up only 5% of a plants total dry weight.

The nutrition of plants and animals is very different. While animals need proteins, carbohydrates, vitamins and minerals to be healthy, plants need only water, air, sunlight and the 13 essential mineral nutrients. No scientific evidence supports the use of vitamins or other similar supplements for plant growth. Plants don't need to be "fed". They simply need adequate supplies of water, air, sunlight and minerals.

While fertilizers can be added to soils to supplement less than adequate nutrient supply, the best plan is to establish plantings on an appropriate soil. The soil pH should be between 4.5 and 5.5 for optimum production. Soils can either be peat or sand based.

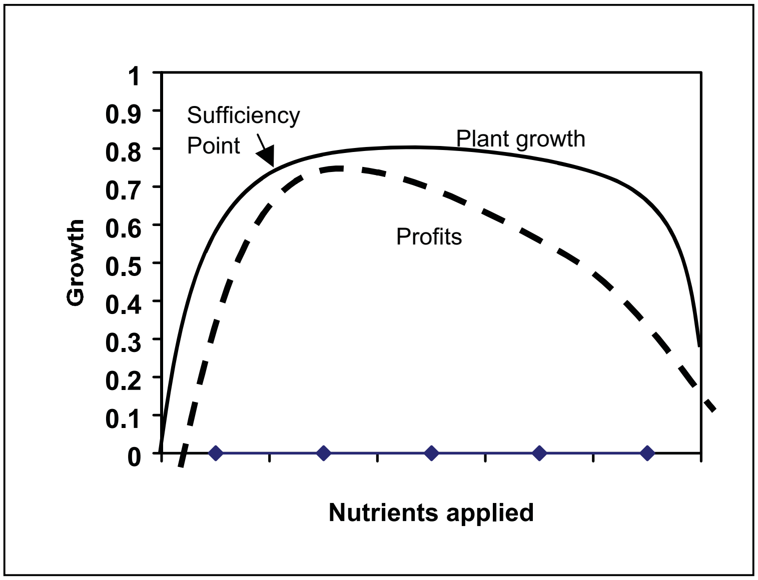
Plant response and soil fertility

Soil fertility can be thought of as the ability of the soil to supply nutrients needed for optimum plant growth. A soil test is the most practical way of measuring the nutrient supplying power of the soil and telling if fertilizer and/or pH adjustment are needed before planting.

Fertilizers are applied to supply essential nutrients that may be in short supply or unavailable to plants from the soil. Plants absorb nutrients from the soil and use them to produce new growth or fruit. The application of agricultural fertilizers has greatly increased crop yields over the past 50 years by eliminating nutrients as a major limitation to yield.

When a particular nutrient is in short supply, application of additional nutrient will increase growth and yields (Fig. 1). Initially this may be a linear response where yield increases one unit per unit of fertilizer added. At some point the response levels out and yield increases become less pronounced as additional fertilizer is applied. For cranberry, this is followed by a decline where yield is reduced with additional applications of nutrients (especially nitrogen) as rank vine growth ensues. Sometimes, plants may continue to absorb nutrients without having a corresponding increase in plant growth. This is known as luxury consumption. At the far end of the figure there is a point where excessive nutrient levels, especially micronutrients, may become toxic to plants and will further reduce yields. The goal in applying fertilizer is to supply enough nutrients to provide optimal plant growth without supplying too much fertilizer.

Figure 1. Plant and profit response



Diagnosing the mineral nutrition status of fruit crops

Fruit growers have three main tools to use in evaluating the mineral nutrition status of their plantings. These are:

- examine visual symptoms exhibited by leaves, stems, and fruit;
- analyzing leaf tissue and;
- testing the soil.

Used together properly these are powerful tools that can be used to prevent nutrient deficiencies or toxicities as well as to assess current fertility management practices.

Because cranberry vines are perennial, not all nutrients to support a crop must come from the soil each year. The amount of nutrient removed with the crop each year is also not a good approach for recommending fertilizer. A crop of 200 bbl/A would remove about 7 lbs N, 2 lbs P, and 18 lbs K, yet fertilizer in excess of these amounts are needed for adequate yields.

Visual Symptoms

Visual symptoms have been used for many years to diagnose deficiencies of certain elements. Color photographs of various deficiency symptoms have been published as diagnostic tools. However, there are at least two disadvantages associated with this approach as the primary method for estimating nutrient need. First, once the visual symptoms have appeared the crop quality and yield have likely already been reduced. Second, some visual deficiency symptoms look similar while others may be confused with disease, insect or environmental stress symptoms. Further confusion arises when the symptoms from more than one deficient element is confounded by a deficiency or toxicity of another.

Tissue Analysis

Tissue analysis is a powerful tool in assessing mineral nutrition of crops. Chemically analyzing the concentration of nutrients in the leaves of growing crops can more precisely define the nutrient status than an examination of deficiency symptoms. This fact is particularly true for perennial fruit crops. This method is based on collecting samples of tissue in the field and measuring the amounts of mineral elements in the tissue. Tissue analysis provides a "snapshot" picture of the nutrient status of a crop at a particular point in time resulting from all factors that affect plant growth. In addition to confirming suspected deficiencies, plant analysis can also detect toxicities or hidden deficiencies before visual symptoms appear. Experimentation has shown the amounts of the various minerals that should be present in plants to provide optimal growth. These amounts are different for each crop species.

Collecting a sample

The most important part of tissue analysis is taking a proper sample. The sample must be taken at the right time, the correct plant part must be sampled and the sample must be representative of the planting. If an improper sample is collected it will be impossible to draw correct conclusions from the analysis.

Sample at the right time. Plants must be sampled at the proper stage of maturity in order to correctly interpret the results. Nitrogen, for example, is relatively high in new leaves in the spring, levels off in midseason and then declines in the late summer and fall before the leaves dormancy. Interpretations are based on knowing the relationship between nutrient levels in a particular part of a "standard" tissue in a specific time in the growing season. A leaf sample taken in the spring could show excess nitrogen compared to late summer standards and a sample taken in the late fall could show a deficiency even if it were adequate in late summer. Samples taken at a time during the season different than the "standards" used for nutrient interpretation will likely show erroneous results or will at least be “uninterpretable”.

Sample the correct plant part. Sampling a different plant part than the "standards" will also lead to incorrect interpretations of the analysis. For example, the nitrogen content of one-year-old leaves is lower than for current season leaves. If one-year-old leaves are included in a sample a nitrogen deficiency may be indicated, while if only current season leaves are sampled an adequate amount or an excess may be shown. Table 1 shows the correct plant part to sample.

Take a representative sample. The sample should be representative of the planting because the results of the test can be no better than the sample sent in for analysis. The amount of tissue the lab actually tests is less than a teaspoon, so it is very important that the sample be characteristic of the bed. Take samples throughout each bed to be sampled. Begin at one corner and take samples as you walk to the opposite corner or walk a zig-zag pattern in the bed. Don’t sample just along one edge or only in the corners. This won’t provide a representative sample. Don't sample diseased, damaged, insect infested or abnormal tissue. If you suspect a nutrient related disorder, sample early in the growing season. Submit a sample of abnormal appearing tissue along with a sample not showing the symptoms that is collected on the same day. By doing so a comparison of the two samples can be made and a better evaluation can be made between the nutritional status of healthy and abnormal plants.

Include a soil sample with your plant analysis sample. Take soil samples at about the same locations as tissue samples. Soil test results for pH, organic matter, and available P and K can be useful when interpreting the plant tissue results. At the UWEX lab, a routine soil analysis is included as part of the plant analysis program at no additional cost.

Submitting a sample

Once the tissue sample has been collected, it should be prepared for shipment or delivery to the lab. Any soil or foreign material should be dusted off the sample. DO NOT WASH the leaves as this will remove soluble nutrients. Don't separate leaves from stems, but do remove any fruit. If the sample is to be mailed, allow the sample to air dry for one day to prevent mold from forming during shipment. Place the dry sample in a paper envelope for shipping. Do not use plastic or cellophane bags since these retain moisture and promote molding. Try to ship samples early in the week (Wednesday at the latest) to avoid samples deteriorating in warm post offices over the weekend. Plant samples that are delivered to the lab do not need to be air dried if they are delivered within a day after sampling. Please submit an information sheet describing the crop type, date sampled, and other information necessary to make the best interpretations of lab results. Plant analysis information sheets are available from the laboratory or your County Extension office.

Table 1. Proper cranberry sampling for diagnostic plant analysis.

Crop	Stage of Growth	Plant Part	#Plants to sample
Cranberry	Late August to early September	Current season uprights. Include fruiting uprights, but remove any fruit.	6-10 handfuls per sampled bed. About 200 uprights.

Soil analysis

Soil testing is a means of measuring soil pH and estimating the supply of nutrients available for plant growth. There is a poor relationship between soil and plant nutrient levels in perennial fruit crops including cranberry. When plant tissue levels (from tissue analysis) are compared to corresponding soil nutrient contents (from soil analysis), no correlation is found. Therefore, soil testing alone will not provide enough information to make accurate fertilizer decisions for perennial fruit crops.

Reliable commercial soil tests have not been developed for nitrogen, copper or iron. The need for these elements can best be evaluated by plant analysis. Deficiencies of minor elements can better be identified by plant analysis too. Because cranberries grow under acidic soil conditions, some fertility problems are best diagnosed by both soil and tissue tests.

Soil testing

Soil samples should be taken from the same areas as the tissue samples. Take individual samples with a trowel, soil probe, or small shovel. A good sample consists of about 8-10 subsamples, taken to 6 inches, per area. Mix the subsamples and place about 1 cup of soil in a soil bag or pint plastic bag. Identify the bag with the same sample number as the corresponding tissue sample. Submit the soil sample along with the tissue sample for analysis to the lab of your choice. Be sure the bags are sealed tightly so the tissue samples cannot be contaminated with soil. No fee is assessed for routine soil analysis corresponding with a tissue sample at the UWEX lab.

A soil analysis should always be a part of preparing the site before planting. Because cranberries are long lived it makes sense to amend the soil ***prior to planting***. Take soil samples from the site after the beds are formed and the sand lift, if any, is installed. Phosphorus and potassium can be applied before planting and lightly incorporated. A soil test will indicate if preplant pH adjustment is needed.

Interpreting the report

About two weeks after samples have been submitted you will receive a report showing the concentrations of various nutrients in the tissue and soil. Beside each number is a letter designation indicating that the concentration is deficient, low, sufficient, high or in excess for that nutrient. This interpretation is provided only if the plant was sampled at the proper stage of maturity. Soil pH, organic matter and an estimate of plant available phosphorus and potassium will also be reported if a soil sample was submitted. If soil was not sampled, interpretations of plant tissue results will be based on an assumption of optimum soil test results.

The indication that the tissue nutrient concentration is deficient, low, adequate, high or excessive will tell you whether changes in your fertilizer program is warranted. They cannot tell you exactly how much fertilizer to add as that is based on the soil, vigor of the vines, crop load, weather, etc.

Tissue testing can also help determine if a fertilizer program is working. For example, a previous tissue test showed a deficiency of a micronutrient and you had applied this micronutrient in your fertilizer program. However, a later test still showed a deficiency in this micronutrient. Comparing these results suggests that a change in your fertilizer formulation, applications method, timing, or rates is warranted.

Because soil concentration and nutrient uptake are independent, there is no relationship between soil P or K and tissue P or K. Elevated soil concentrations will not necessarily lead to elevated tissue levels.

Long experience and experimentation has shown what concentrations of each required element should be found in plant tissues. These concentrations are listed for cranberry in Table 2. Interpretation of the results with these standards is possible only if the correct plant part was sampled at the proper stage of maturity. *No valid interpretation is possible if the wrong part was sampled or the plants are sampled at other times in the season.*

Table 2. Fertility status of cranberries in relation to nutrient content in leaves.

Nutrient	Normal concentration +
Nitrogen (N)	0.9-1.1 %
Phosphorus (P)	0.10-0.20 %
Potassium (K)	0.40-0.75 %
Calcium (Ca)	0.30-0.80 %
Magnesium (Mg)	0.15-0.25 %
Sulfur (S)	0.08-0.25 %
Concentration of (ppm)	
Zinc (Zn)	15-30
Boron (B)	15-60
Manganese (Mn) *	>10
Copper (Cu)	4-10
Iron (Fe) *	>20

\+ Normal levels are based on samples taken between August 15 and September 15.

* Cranberry researchers have not established a normal range for Fe and Mn.

Fertilizer application

Fertilizers are materials that contain nutrients required by plants. In some cases, organic materials such as manures and plant residues can supply some or all the nutrients required by plants. However, plants cannot differentiate between nutrients from organic, inorganic, liquid or granular sources. All nutrients are absorbed by plant roots as ions and all ions of a given element are identical regardless of the source.

Fertilizers can be applied to the soil and taken up by the roots or applied to the plant as a liquid for uptake by the leaves, stems or fruit (foliar application). Each method has advantages. Soil application is usually less expensive and is better suited for large application rates of the major nutrients and for pre-plant application. For the most part, soil applications by broadcasting are the most economical and efficient.

Foliar application is best for correcting micronutrient deficiencies or for increasing the concentration of immobile elements to specific tissues. Liquid fertilizers that are foliar applied are more expensive per unit of nutrient. In many cases the liquid fertilizer runs off, or is washed off leaves onto the soil where it is later taken up by the roots. In this case it would have been much less expensive to apply a granular fertilizer to the soil. The expense of foliar applications of nutrients may be decreased if they can be mixed with pesticides in a spray. However, the nutrients may interact with pesticides, spray adjuvants or surfactants and reduce the pesticide efficacy. Mixing foliar nutrients and pesticides, in general, is not a good practice. Fertilizers commonly used on cranberry are described below.

Fertilizers

A soil and/or plant tissue analysis are the most reliable methods to determine nutrient need. Nutrients of most common concern to Wisconsin cranberry growers include nitrogen, phosphorus, potassium, calcium, boron and zinc.

Fertilizers can be blended, complete, or single nutrient. While cranberry growers use all three types, blended is probably the most common.

Nitrogen

Nitrogen is the nutrient most commonly applied to cranberry. Cranberry prefers nitrogen in the ammonium form, although cranberry vines will take up nitrate when ammonium is also present. However, the nitrate is not utilized in plant metabolism. Because nitrate will leach and is a potential contaminant, the commercial practice is to use only ammonium nitrogen sources. At pH 5.5 and above nitrification will occur in cranberry soils, but at a much lower rate than in other agricultural soils. Research studies have shown that at pH 5.5 nitrification began about 20 days after application to the soil.

The amount of nitrogen to apply in a given year depends on a number of factors and cannot be completely discussed here. Actual nitrogen application rates vary by soil type (peat vs. sand), age of vines, vigor of the vines, and crop load. An average rate of N application for bearing cranberries in Wisconsin is about 20 pounds of actual N per acre. Too little N application results in weak vine growth, pale foliage and reduced yields. Too much N results in vine overgrowth, substantial runnering, "bud blasting", poor fruit color and reduced yields.

Nitrogen is applied in split applications throughout the growing season. Recent research suggests that an application of 20 lbs actual N/a split equally between budbreak, peak bloom, fruit set, bud set and preharvest produced the highest yield and best fruit quality. Further, research has shown that N applications have little, if any, influence on yield during the year of application, even for sites that are N deficient regardless of the date of application. Thus, growers cannot increase yield through current season N applications and N application should be a long term practice.

Most growers are using blended fertilizers to obtain their nitrogen. Common formulations are 6-24-24 and 10-20-20. Some will also use ammonium sulfate (21-0-0) or urea (46-0-0). The characteristics of common nitrogen containing fertilizers are shown in Table 3.

Table 3. Characteristics of common nitrogen containing fertilizers.

Fertilizer	%N	lbs material per 1 lb actual N	Soil Reaction
Urea	46	2.22	acidic
Ammonia, Aqua	20	5	acidic
Ammonium nitrate*	33	3	acidic
Ammonium sulfate	20.5	4.88	acidic
Diammonium phosphate	17	5.5	acidic
Monoammonium phosphate	11	9.1	acidic

* *For reference only. Not recommended for use in cranberry.*

Phosphate

Wisconsin soils typically contain enough phosphate to supply plant needs. An average crop of cranberries (fruit + vine growth) would take up only about 20 pounds of phosphate per acre per year. Cranberry growers typically apply more P fertilizer than this per year. This is largely a result of the acidic environment in which cranberries grow. Acid soils "fix" more phosphorus than neutral soils. As phosphate is added to soils it is converted from a soluble form into insoluble forms. The phosphate ion ($H_2PO_4^-$) reacts strongly with iron, aluminum and manganese ions in acid soils to create insoluble phosphate precipitates.

All commonly used phosphate fertilizers presently sold in Wisconsin (except rock phosphate) contain at least 85% water soluble phosphorus. Rock phosphate is insoluble, but research has shown that it can be an effective phosphorus source for cranberries since cranberry soils are acidic.

The common practice is to make multiple light applications of phosphorus per year so that soluble, or at least plant available, phosphate is present throughout the season. However, spring applications are usually not necessary as warming soils release some phosphorus. Fall applications are not a good idea as the soils will soon be flooded. Critical application times are from hook to fruit set when demand is high and availability is low.

High levels of soil test phosphate do not correlate with high levels of tissue phosphate. It is unusual for phosphorus to leave cranberry beds since it binds tightly to the soil. Usually P moves only as soil erodes and moves.

Table 4. Characteristics of common phosphate containing fertilizers.

Fertilizer	Analysis*
Triple superphosphate	0-45-0
Diammonium phosphate	18-46-0
Monoammonium phosphate	11-48-0
Ordinary superphosphate	0-20-0
Rock Phosphate	variable

* refers to the % of P_2O_5 contained in the material.

There is no evidence that different soluble phosphorus sources are superior to each other. When applied at identical rates each of the P sources produced similar crop yields. Research shows no yield response to phosphorus fertilizer beyond 45 lbs P_2O_5 per acre per year. As phosphorus can be an environmental contaminant, growers are urged to apply no more that 45 lbs P_2O_5 per acre per year. Doing so should help keep phosphorus out of both ground and surface waters.