

Using Nitrate-N Petiole Sap-Testing For Better Nitrogen Management in Vegetable Crops

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Introduction

Vegetables have a relatively high nitrogen requirement and at times growers apply too much fertilizer-N that contributes to ground and surface water pollution. Fertilization can be made more efficient by plant analysis. Plant tissue (petiole) nitrate testing is a way of monitoring the nitrogen condition of the crop during the growing season. This is an especially useful method as the petiole is a very good indicator of current N supply and management practices such as fertigation allow for corrective measures when deficiencies are found.

The limiting factors of plant tissue testing are the amount of time required in drying the samples, sending samples to a commercial lab, and receiving the results, all of which can take several days to a week or more. While plant tissue nitrate analysis gives the grower information about current plant nitrate-N, the information may be received too late to be useful. The development of a quick method for on-site analysis would improve the application of plant tissue testing. The grower could then make quick decisions about adjustments to fertigation programs.

Various nitrate test kits for vegetable plant sap-testing are available for use on vegetables. The goal is to find a system that growers can use in the field to help manage nitrogen fertilization. The following guidelines should help growers who are interested in using a quick method for on-site petiole sap-testing. Most of these guidelines have been developed through research on the eastern seaboard and are based on field experience.

Nitrogen in the soil

To better understand nitrate testing results a basic understanding of how nitrogen reacts in the soil is required. Nitrogen is a very mobile element which goes through many transformations. Nitrogen is added to the soil in several different ways such as commercial fertilizer, crop residue, cover crops and manures. Nitrogen is also removed from the soil in the harvested portion of crops, by leaching and by atmospheric loss. In addition to these results, nitrogen undergoes many alterations while in the soil. The most important of these are immobilization and mineralization. Nitrogen that is immobilized is unavailable to plants because it is held in the tissues of microorganisms or because it has been changed into complex organic forms (chelating) that resist being broken down.

Mineralization is the reverse process where nitrogen in complex organic form is broken down into simpler molecules that can be absorbed by plants.

The majority of the nitrogen in the soil is in the organic form, with less than 10% of the nitrogen being mineralized to plant available forms during the growing season. The rate at which these complex structures are broken down into plant available forms is constantly changing, controlled by a series of interactions of crop residue, soil, microbes, and soil moisture and temperature. When plant residues that are low in nitrogen are incorporated into the soil, it may reduce the amount of nitrogen available to the plants by immobilization by microbes. When high nitrogen containing residues are turned under, succeeding crops can draw a substantial (~ 50%) portion of the nitrogen they need from the organic matter in the soil.

The two forms of nitrogen taken up by plants are ammonium and nitrate ions. The ammonium ion (NH_4^+) has a positive charge and is held by the soil particles (soil particles are negatively charged) and is resistant to leaching. Nitrate (NO_3^-) has a negative charge and moves freely in the soil solution and is readily lost by leaching. When soil organic matter is broken down it is converted into ammonium and later into nitrate. When ammonium fertilizers are applied, the ammonium is converted to nitrate through nitrification. Since ammonium tends to be converted to nitrate, soils usually contain higher levels of nitrate than ammonium.

Crop nitrogen needs and fertilization

Vegetable crops differ widely in how much nitrogen they need for proper growth and high yields. Crops also differ in their pattern of uptake over the growing season. Fruiting crops such as tomatoes and peppers require relatively little nitrogen until flowering begins, and then increase their nitrogen uptake, reaching a peak during fruit set and early fruit bulking period. As fruits mature, N demand drops again. Non-fruiting crops like celery and lettuce show slow nitrogen uptake through the first half of the season, with nitrogen needs increasing rapidly as harvest approaches. As they grow vegetables exhibit distinct changes in nitrate levels within the plant. Highest values are seen during early vegetative growth, with declining nitrate concentrations thereafter. The decline is particularly sharp for fruiting crops; as fruits begin to set and grow, they form a sink into which the plant pumps large amounts of nitrogen, limiting the amount of nitrate stored in leaf petioles.

Plant tissue testing

While plants take up nitrogen in both the ammonium and nitrate forms, nitrate is usually more abundant than ammonium so nitrogen tests measure nitrate rather than ammonium. Under conventional fertilizer practices, plant tissue contains high levels of nitrate which is a good indicator of the nutrient status of the plant. However, once the nitrate reaches the leaf it becomes incorporated into other compounds, and the rate of this metabolism may affect the levels of nitrate in the petioles. Therefore, environmental factors that affect plant metabolism may affect the nitrate levels in the petioles and thus influence the

plant tissue test. In addition to environmental factors affecting readings, measuring nitrate levels in organic fields or fields fertilized entirely with organic material may not work as well since the plants tend to take up more of their nitrogen in the ammonium form.

Fresh Sap Nitrate-N Testing

One misunderstood part of fresh sap testing is the confusion between nitrate and nitrate-N. Nitrate (NO_3), contains both nitrogen and oxygen. The term nitrate-N refers only to the nitrogen portion of the nitrate molecule. The nitrate molecule contains 1 nitrogen atom and 3 oxygen atoms. It is often necessary to convert values between nitrate and nitrate-N. The conversion can be accomplished by the following formulas: $\text{PPM NO}_3 \times 0.226 = \text{PPM of NO}_3\text{-N}$ or $\text{PPM NO}_3\text{-N} \times 4.43 = \text{PPM NO}_3$. In most agricultural uses, the term nitrate-N is usually used. However, many instruments used to measure nitrate give readings in nitrate that should be converted to nitrate-N for comparison to most published crop values.

Cardy test

The easiest way to measure nitrate in fresh sap is with a specific-ion electrode meter. One such meter is the Cardy meter, which is readily available. Although there are other meters that could be used (this publication is not endorsing this particular product nor is criticism implied of similar products not mentioned). The usefulness of fresh sap analysis is strengthened when it is used on a regular basis following the trend of nitrate concentration over the season. Not only does this provide information on the nitrogen dynamics of the crop, it also allows identifying a suspect value, which needs retesting. Although it can be used in the field, the Cardy meter is better suited for use indoors. It is sensitive to temperature changes, so frequent recalibration is necessary through the day if used in the field. Also, readings tend to drift for the first few minutes after it is turned on. From the standpoint of accuracy and efficiency, it is better to collect a number of petiole samples and bring them to a central location indoors for analysis.

Sampling

As a general rule twenty petioles from different plants throughout a management unit are required for a representative sample. Where there are differences in fertility within a field, separate samples should be collected and analyzed. Collect samples from areas in the field where the stand is uniform. The nitrate level in the plant can vary somewhat throughout the day. My results from testing over a 12-hour period show that the most consistent outcomes were obtained by collecting samples between 11 am and 2 pm (as long as weather conditions were not extreme—see below). This also has been shown to be the time when nitrate-N levels peak in the petioles of many plants. Do not collect samples after a rainfall or an irrigation of 1 inch or more in the past 24 hours or when there are high temperatures ($>95^{\circ}\text{F}$) and humidity's ($>90\% \text{RH}$) for several days as this will cause inconsistent readings. At collection, leaves should be stripped away and petiole sap should be squeezed into vials and analyzed within 1-2 hours. To ensure accuracy as much sap as possible should be collected from the petioles in the sample. Petioles should be placed in the garlic press and squeezed into a funnel that is sitting in a vial or collecting jar.

2006 Study

This study was conducted to test the feasibility of accurately testing the $\text{NO}_3\text{-N}$ concentration (ppm) in the leaf petiole of several major vegetable crops; tomato, pepper, watermelon and cantaloupe.

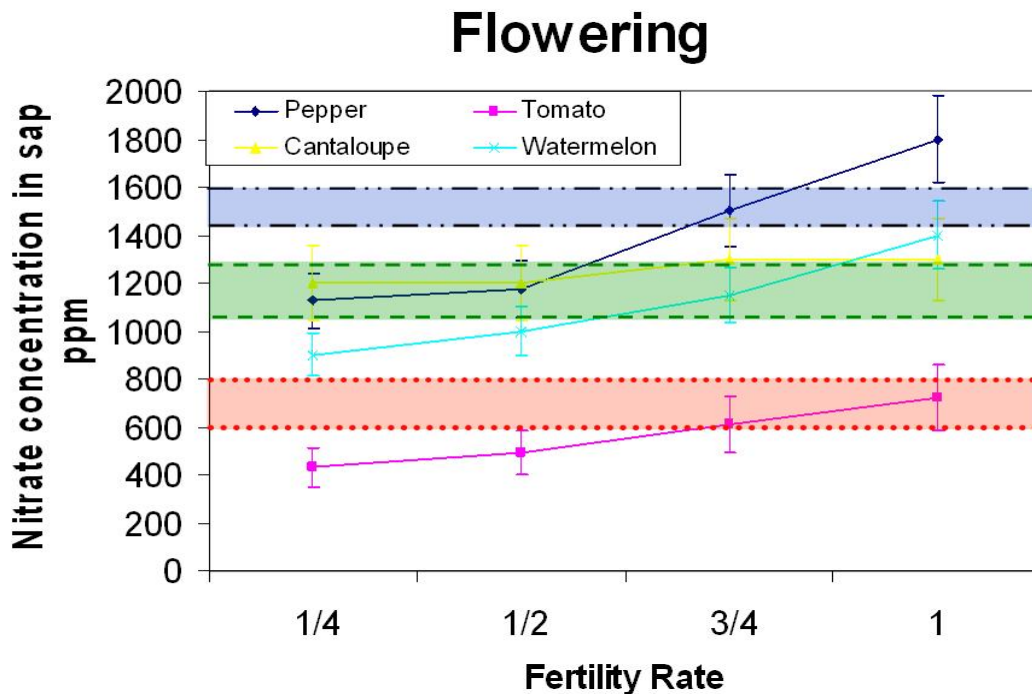
Methods

Four replications with 6 plants of each vegetable variety were used in a plasticulture/drip irrigation system. Four fertility levels were used, a full rate (200lbs of N), $\frac{3}{4}$ rate (150 lbs. of N), $\frac{1}{2}$ rate (100 lbs of N) and a $\frac{1}{4}$ rate (75 lbs of N). Plots were fertilized and plastic mulch and drip irrigation were laid on top of 6 inch beds. All transplants were set out June 24 for each fertility level for each vegetable crop used.

During the season petiole sap samples were taken 3 times from all plants in each fertility level. The sampling times were: at first flower, at small fruit size, at first harvest. Petioles were squeezed and their sap was placed into vials and taken back to the lab after all fertility levels for a vegetable crop were completed (about 15 mins from start to finish). Samples were then opened and a dropper of fluid was taken from the top portion of a vial and placed on the Cardy meter so that enough liquid covered the well and was read. Standards were used before and after each fertility sample was read.

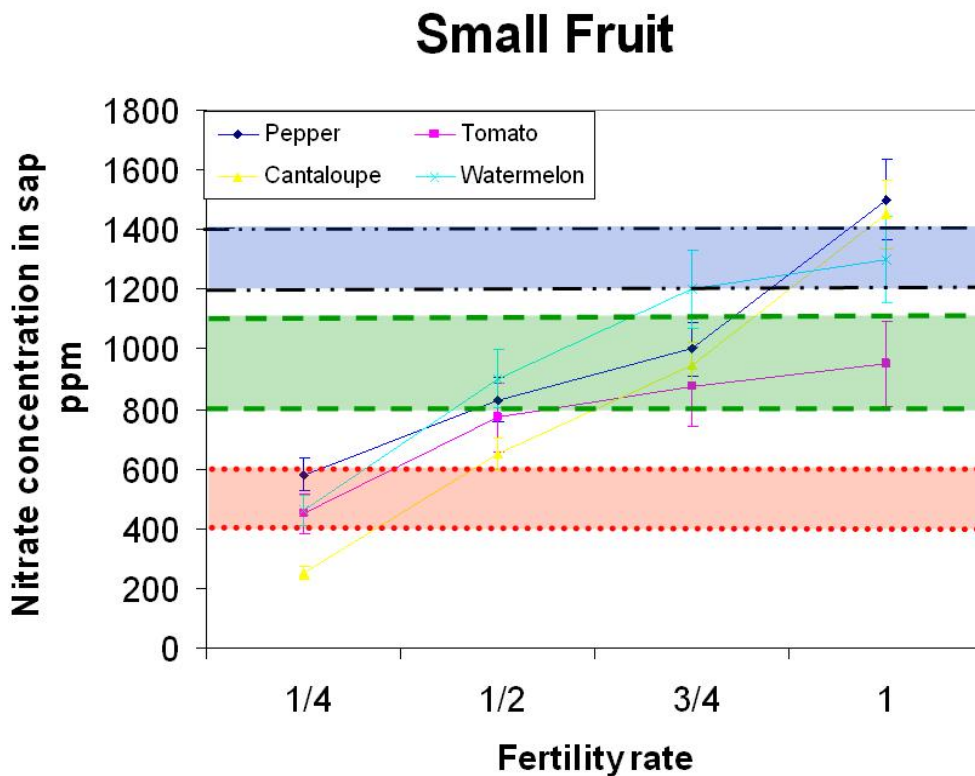
Results

Figure 1 below shows the results of the first petiole sampling period taken during first flowering.



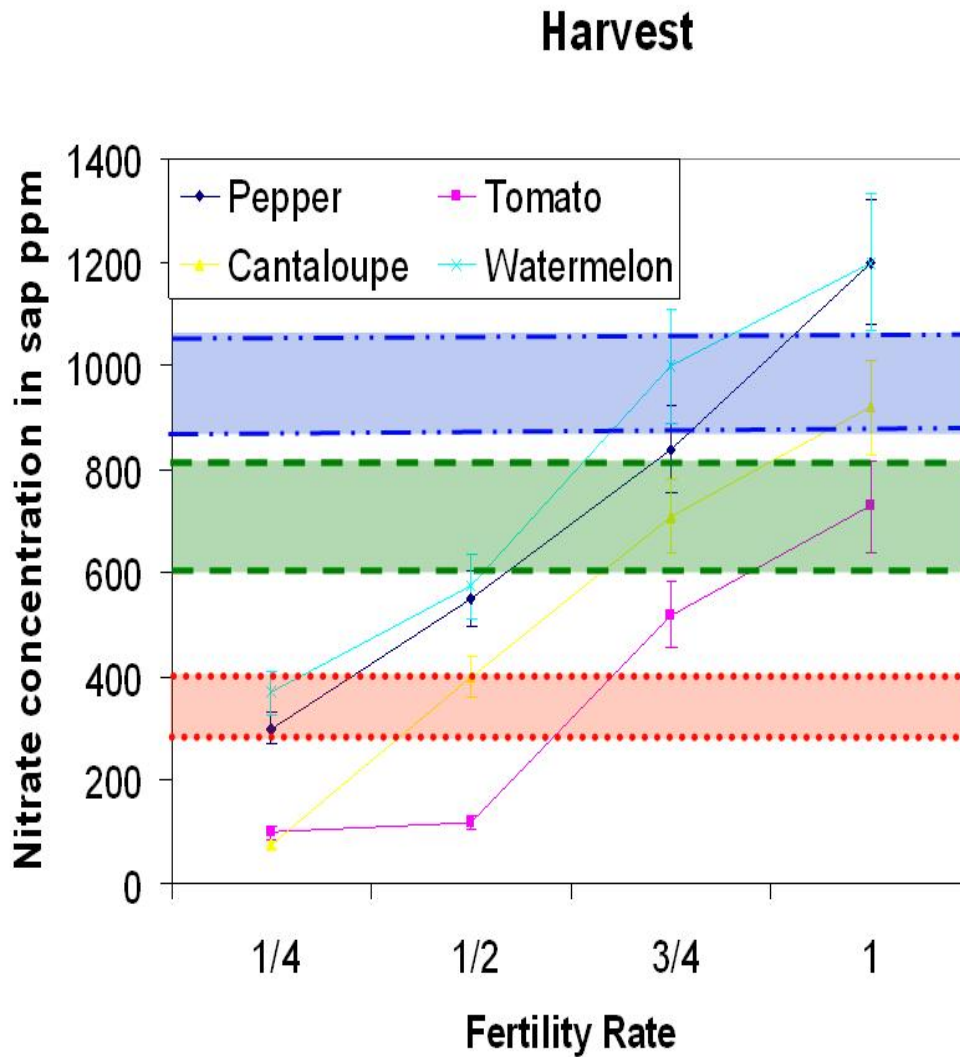
The colored bars across the figure show the recommended range of NO₃-N ppm in petiole sap for each vegetable for each phenological stage. The green area is for watermelon and cantaloupe, the red is for tomato and the blue is for pepper. Therefore each vegetable line showing the levels of NO₃-N in petiole sap should be compared only with its corresponding recommendation range. As an example, pepper results (blue line representing actual petiole sap nitrate-N in ppm taken from test plot pepper plants) should be compared only with the blue area (representing the recommended range of nitrate concentration in petiole sap). For the ¼ and ½ rates NO₃-N ppm are below the range recommended for tomato, watermelon and pepper, but for cantaloupe all fertility rates result in NO₃-N readings within the recommended range. Nitrate levels in the petiole sap were above recommended levels when a full rate of nitrogen was used.

The second sampling period was taken when small fruit was present (Fig. 2 below).



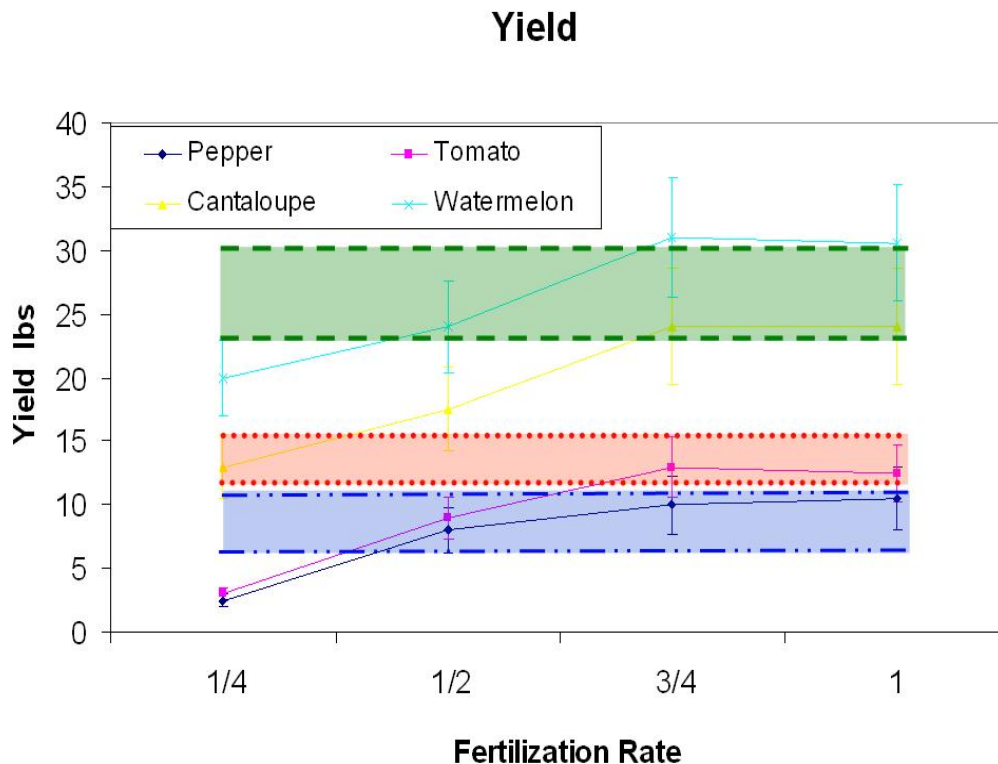
At just a ½ rate of fertilization, nitrate levels in tomato and watermelon are within or above recommended levels. Even at a ¼ rate of fertilization tomato nitrate-N petiole-sap levels fall within the recommended level (400-600ppm). Cantaloupe however, only falls within needed nitrate levels at the ¾ fertility rate and much above needed levels at the full rate. Pepper is below needed rates at the ¾ rate of fertility, but above the recommended amounts when a full rate of fertilizer is applied.

Figure 3 below demonstrates nitrate levels in plant petiole sap at first harvest.



All nitrate levels for each of the four vegetables are at or above recommended amounts when a 3/4 or full rate of fertilizer is used. Using only a half or a 1/4 rate of fertilizer resulted in levels of nitrate-N in plant petiole-sap that were well below the recommended quantity.

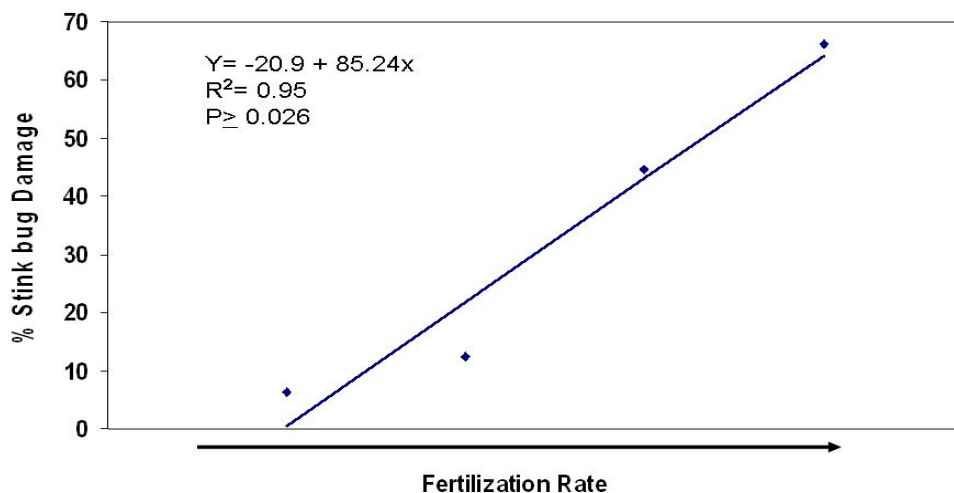
Figure 4 below shows the yield response for each of the four vegetables in the test.



Each of the ranges of nitrate-N for each vegetable crop at harvest is represented in the figure. This shows that a $\frac{3}{4}$ and a full rate of fertilizer give the best yields compared with $\frac{1}{4}$ and $\frac{1}{2}$ rates. However, pepper shows that even at a $\frac{1}{2}$ rate of fertilizer yields are not different from $\frac{3}{4}$ or full rates. This is probably due to errors in the sampling program. The amount of sap retrieved from pepper was always a minimal amount and at times was deficient even with over 20 petioles sampled. This inability in obtaining enough sap to measure consistent nitrate levels makes pepper a poor candidate at this time for petiole sampling. Petiole sampling for watermelon, cantaloupe and tomato all show a strong correlation between nitrate levels measured in the sap across the season and resulting yields that with some tweaking (watermelon nitrate needs may need to be increased for best yields as the nitrate levels measured in watermelon plant sap almost always ran above recommended levels and yet yields were equal to one another only at the $\frac{3}{4}$ and full rates and significantly greater than when $\frac{1}{2}$ rates were used). This does not mean that all areas of the state would need to be recommended the same nitrate levels as the present research only applies to the Lower eastern Shore Research and Education Center fields and only to the variety of watermelon used in the study-*Crimson sweet*. More petiole sap testing over several areas of the state and under different environmental and varietal parameters will have to be done before guidelines can be recommended.

The figure below shows the relationship between the fertility rate and the amount of stink bug damage to tomatoes. As tomatoes were being harvested it was apparent that there was a difference in the amount of damage, i.e., cloudy spot, stinkbugs had caused to the tomato fruit. Other research has shown that high levels of nitrogen can result in a preference of some insect pests such as aphids or Colorado potato beetle feeding on high nitrogen fertilized plants and causing an increase in damage. Fertilization rates at the $\frac{3}{4}$ and full amounts resulted in significantly greater stink bug feeding than at $\frac{1}{4}$ and $\frac{1}{2}$ fertilizer rates. It is not being recommended that nitrogen rates be reduced to reduce pest damage, simply that any excess nitrogen will not only be wasted in a fertility program (i.e., not result in greater yields), but also can lead to unnecessary pest damage and environmental pollution.

% Stinkbug Damage in Relationship to Fertilizer Rate



SUMMARY

The nitrate meter enables growers to quickly measure nitrogen-N levels in the plant. The results are interpreted by using guidelines to consign the readings into low, adequate or high values. These nitrogen-monitoring techniques enable growers to apply nitrogen fertilizer at the right time, helping to ensure high yields without making unnecessary applications that could adversely affect the environment or possibly increase some pest damage. This also can save farmers money. The principal advantage to these techniques is the ability to get immediate results. Other advantages are that the equipment is portable and easily available through catalogs. There are several disadvantages to using the meter. First, the results, though close, are not as accurate as measurements from an analytical laboratory. Second, the instruments are sensitive to environmental conditions and can

give inaccurate or inconsistent readings if exposed to heat, direct sunlight, water, sand and dirt. Therefore testing of sap should take place indoors under controlled environmental conditions and the reader should be kept clean and dry. The environmental conditions also include those that directly affect the plant, which include excessive rain or irrigation at time of testing, i.e., 1 inch of water in the last 24 hrs., very hot or stressful conditions during the summer and very dry conditions.

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