1-800-346-9140
ATTRA
Appropriate Technology Transfer for Rural Areas
www.attra.ncat.org

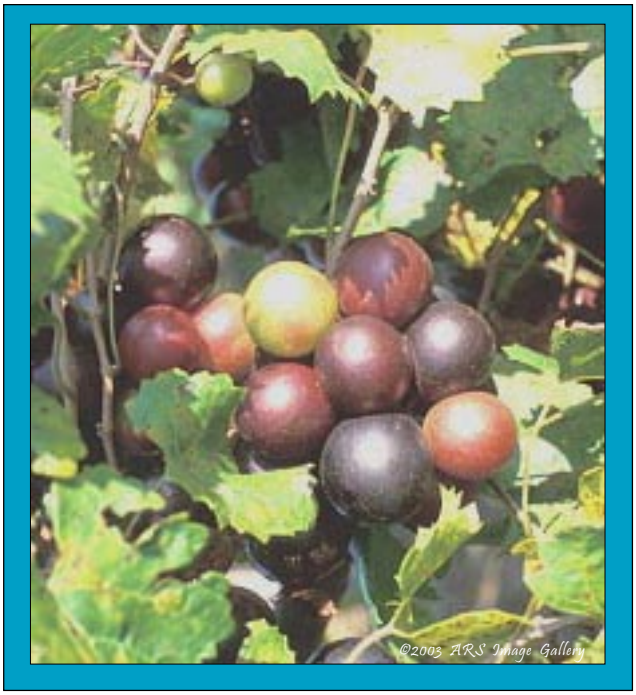
FOLIAR FERTILIZATION

CURRENT TOPIC

George Kuepper
NCAT Agriculture Specialist
March 2003

Introduction

Foliar fertilization (or foliar feeding) entails the application—via spraying—of nutrients to plant leaves and stems and their absorption at those sites. Used in both conventional and alternative production systems, it is a viable (though somewhat controversial) means of enhancing crop nutrition. Because information on conventional applications of foliar feeding is usually available through Cooperative Extension and the general farm press, this publication will stress applications in sustainable and organic agricultural systems. For more detail on what is meant by "sustainable" and "organic" agriculture, request ATTRA's *Sustainable Agriculture: An Introduction* and *Overview of Organic Crop Production*.



Background

Foliar feeding has been used as a means of supplying supplemental doses of minor and major nutrients, plant hormones, stimulants, and other beneficial substances. Observed effects of foliar fertilization have included yield increases, resistance to diseases and insect pests, improved drought tolerance, and enhanced crop quality. Plant response is dependent on species, fertilizer form, concentration, and frequency of application, as well as the stage of plant growth.

Foliar applications are often timed to coincide with specific vegetative or fruiting stages of growth, and the fertilizer formula is adjusted accordingly. Applications may also be used to aid plants in recovery from transplant shock, hail damage, or the results of other weather extremes.

In terms of nutrient absorption, foliar fertilization can be from 8 to 20 times as efficient as ground application (1). However, this efficiency is not always achieved in actual practice. Often, failures result from inattention to the principles of foliar feeding (see "Basics of Foliar Feeding" below). Other causes of failure include application of the wrong spray mix, or of the right mix at the wrong time. Judging what foliar materials to apply and at what plant stage to spray them appears to be as much art as science.

Because of the variability in research results and practical field experience with foliar feeding, opinions on its usefulness vary in both conventional and alternative agriculture circles. There is

ATTRA is the national sustainable agriculture information service operated by the National Center for Appropriate Technology, through a grant from the Rural Business-Cooperative Service, U.S. Department of Agriculture. These organizations do not recommend or endorse products, companies, or individuals. NCAT has offices in Fayetteville, Arkansas (P.O. Box 3657, Fayetteville, AR 72702), Butte, Montana, and Davis, California.

NCAT

general consensus, however, that foliar fertilization should not be considered a substitute for a sound soil-fertility program. For operations seeking to farm more sustainably, this includes some combination of compost, livestock manure, green manure, cover crops, soil-applied rock minerals, and well-planned crop rotations that include legumes.

One of the touted benefits of foliar fertilization is the increased uptake of nutrients from the soil. This notion is based on the belief that foliar fertilization causes the plant to pump more sugars and other exudates from its roots into the rhizosphere. Beneficial microbial populations in the root zone are stimulated by the increased availability of these exudates. In turn, this enhanced biological activity increases the availability of nutrients, disease-suppressive biochemicals, vitamins, and other factors beneficial to the plant. It is this rationale, in good part, that reinforces the use of foliar fertilization in organic agriculture, where the philosophy of "feed the soil, not the plant" prevails.

While foliar fertilization is being used on a wide variety of crops, its economic value is generally deemed greater for horticultural than for agronomic crops. This is because horticultural crops are of higher value and their nutrient status is more carefully monitored. At present, for example, foliar sprays are commonly recommended to correct zinc deficiencies in grapes (2), to control bitter pit and cork spot in apples (3), and for general supplementary nutrition in strawberries (4).

Overall, the economics of foliar fertilization is dependent, first, on how successful applications are and, second, on whether or not the same nutrition might have been supplied more economically through another means. Because weather can be a factor and because circumstances differ widely among farms and farm managers, there is no simple determination. The individual grower must decide based on need, and monitor for indicators of success.

Foliar Fertilization and Pest Resistance

It is a basic tenet of organic agriculture that properly nourished crops will exhibit a natural resistance to insect pests and disease organisms. While traditionally most practitioners try to achieve optimum nutrition through direct soil management, many consider foliar fertilization the final key to making some form of "induced resistance" a practical reality.

There are several schools of thought regarding pest resistance and crop nutrition. Some suggest that well-nourished plants certainly have a better ability to tolerate pests and disease, but that there is no induced resistance; others deny any relationship at all between crop nutrition and the incidence of pests.

Some connections between pest problems and nutrient imbalances are documented. The presence of excessive soluble nitrogen in soils, for example, increases the nitrate and water content of plant cells. This is especially attractive to aphids, which thrive on plant sap (5).

Among the more popular theories is that plant sap with a higher level of soluble solids—measured as °Brix—is unsuitable food for plant-eating insects. Research on this theory is limited and far from conclusive. One California study, for example, failed to find a relationship between the °Brix of sap in commercial grape plantings and the presence of leafhoppers (6). See the section

"Formulating Foliar Sprays" for details on how foliar feeding is used to increase soluble solids in plant sap.

Some proponents of foliar fertilization consider it an especially effective means of stimulating the natural defense mechanisms of plants. Studies to date are rather limited but have shown some positive results. Israeli research on corn using foliar sprays of phosphate and of trace nutrients demonstrated induced resistance to several diseases (7).

For a good overview of the research and theory relating pest infestations to fertility, Gary Zimmer's *Crop Pests and Fertilizers—Is There a Connection?* is recommended (8).

The Basics of Foliar Feeding

For foliar fertilization to work effectively, certain guidelines must be followed:

- To be efficient and to avoid crop damage, very dilute solutions of nutrient formulations are suggested. Sometimes as little as one cup to two quarts per acre of an active ingredient is all that is required to obtain the desired response (1). Highly concentrated sprays, especially those bearing inorganic salt-based fertilizers, have the potential to "burn" plant foliage. This is especially true of chloride salts (e.g., potassium chloride).

  Spray-solution pH should remain in the near-neutral range (5.5-8.5). If pH adjustment is required, vinegar can be used to increase acidity, and baking soda to decrease it.
- In addition to pH, some other qualities of spray-water should be considered:
  - *Cleanliness*. Small undissolved particles can quickly clog nozzles—even those well-equipped with strainers can be plugged if enough suspended matter is present.
  - *Chemical and disease contaminants*. Some water sources are contaminated and should not be used at all for foliar feeding. If there is concern specifically about disease organisms, the water can be treated effectively with a small amount of hydrogen peroxide.
  - *Chlorine*. Chlorination of water removes harmful bacteria, but it can also kill beneficial organisms, which may be included in some foliar sprays. Allowing water to stand in an open tank overnight generally renders chlorinated water harmless to beneficial microbial mixtures.
- Best effect is achieved when foliar sprays are finely atomized. This can be managed by increasing sprayer pressure or by using a mist blower. Some advantage can be gained on boom-type sprayers by tilting the nozzles back to a 45° angle to allow the spray to drift onto the plants.
- Spray when wind is minimal. This is especially important with finely atomized sprays because they drift readily.
- Absorption is increased when sprays also reach and coat the undersides of leaves. This is where most of the plant's stomates are located.
- Always delay foliar fertilization until air temperatures drop to 80°F or below. Absorption at higher temperatures is very poor because plant stomates are closed. Some of the most effective foliar feeding is done late in the evening or in the early dawn, when temperatures are right and wind is minimal.
- Absorption is further enhanced when weather conditions are humid and moist. The presence of heavy dew on the leaves facilitates foliar feeding.
- Addition of a surfactant to the solution decreases surface tension on the leaf and may increase absorption.
- Take note of possible chemical interactions among foliar fertilizers. Some materials are incompatible and should not be mixed together. They may create precipitates that tie up the nutrients and clog nozzles. Many product labels warn of incompatibilities. If there is no information, mix relative quantities of the materials and water in a jar and shake it. If there is no precipitate, there should be no problem.
- For convenience and cost savings, foliar fertilization can sometimes be combined with a pes-

ticide application. However, timing conflicts and material incompatibilities can make combining sprays unwise. Be certain to read all product labels and do the jar test if uncertain.

Further Application Technologies

Two technologies that appear especially applicable to foliar fertilization deserve to be mentioned. The first is the use of electrostatic sprayers, which impart a charge to the spray particles and cause them to adhere more readily to plants. The second technology, known as Sonic Bloom™, uses sound to increase the leaves' absorption of nutrients. For more information on electrostatic sprayers, contact the manufacturers (such as Electrostatic Spraying Systems Inc. at 706-769-0025). For more information on Sonic Bloom, contact ATTRA.

Formulating Foliar Sprays

Unfortunately, foliar fertilization is often attempted without clear objectives. Sometimes the grower has been convinced—perhaps by a salesperson—that spraying a particular product will be good for the crop. Sometimes it is simply a matter of faith.

Foliar fertilization need not be undertaken in such a haphazard manner. There are several methods for determining need, possible benefits, and what materials to apply. These methods range from conventional analytical approaches to some that are best described as metaphysical. The most common farmer-friendly approaches are discussed here.

Deficiency History or Symptoms

In areas where crop production has continued for some time and where the interactions of particular crops and soils have been well studied, certain nutrient deficiencies are predictable. Where these deficiencies involve secondary nutrients and micronutrients, foliar feeding often becomes the preferred means of correction. For example, foliar feeding is routinely used in some regions to manage zinc deficiencies on pecan crops. Likewise, calcium sprays have often been recommended as one means to prevent blossom-end rot in tomatoes. The decision to spray in such cases is basically the result of past experience, often bolstered with soil test information and/or observation of symptoms in the field.

Plant Tissue Tests

Tissue nutrient tests are much more reliable than past history, plant symptoms, or soil tests for establishing whether nutrient deficiencies exist. They can, however, work hand-in-hand with any or all of these. In most high-value horticultural crops on large acreage (commercial pecans and tomatoes included), tissue testing is routine. This is perhaps the most commonly accepted means of identifying nutrient deficiencies. The suitability of foliar feeding as a corrective agent usually depends on the deficient nutrient. For example, it is more common to use foliar feeding if a micronutrient is needed than if nitrogen, phosphate, or potash are deficient.

Many soil testing services also offer tissue testing. The same is true of many state-run laboratories. The University of Arkansas, for example, has a program specializing in the foliar analysis of blueberries—a crop of significant value in the state. ATTRA's *Alternative Soil Testing Laboratories* publication lists a large number of independent testing facilities, many of which also provide tissue analysis services.

Be aware that accurate foliar analysis depends on good sampling and handling procedures. While instructions should be obtained from each laboratory or consulting service in advance, some good general advice is provided in the enclosure entitled *Leaf/Petiole (Stem) Sampling*.

Refractometers

An instrument that some growers find useful in combination with foliar feeding is the refractometer. Refractometers are low-cost hand-held tools that measure the dissolved solids (mostly sugars) in plant sap, by observing the bending (refraction) of light as it passes through the liquid. The higher the percentage of dissolved solids present, the better nourished the plant. As indicated earlier, many proponents of foliar fertilization associate higher °Brix readings with pest resistance.

The process for using the refractometer to guide foliar feeding is relatively simple. Begin by extracting a sample of sap from one or more crop plants. This is accomplished by squeezing the leaves or stems with a garlic press or some other tool. Place the extracted sap in the refractometer to measure and record the reading. Then, use a spray bottle to mist a small sample of a foliar spray blend onto the plants. After a short time, extract and measure another sap sample. If the °Brix has increased, foliar feeding with that specific blend is advisable. By testing several possible blends using several spray bottles, you can determine the best spray to use. Of course, a control spray of water should be tested at the same time to discount any changes not caused by the fertilizer.

Use of the refractometer in this manner is common among proponents of Reams Biologic Ionization Theory, as well as others within the alternative agriculture movement. It is not, however, a widely accepted practice nor, as indicated earlier, is it especially well-researched as yet. For more information on refractometers and their use for foliar feeding and crop management, chapters 14 and 15 in *The Non-Toxic Farming Handbook* by Wheeler and Ward (9) are recommended, as are chapter 16 and appendices 1 and 3 in Andersen's *Science In Agriculture* (10). A good online resource is "Using a Refractometer to Test the Quality of Fruits and Vegetables" (11). Note also that some promotional literature from Agri-Mart is included, which provides a drawing of a refractometer and the refractive indices (°Brix) recommended for specific crops. Also enclosed is a brief article by Gary Zimmer entitled "Can Health be Measured?"

Radionic/Radiesthetic Analysis

Radionics and radiesthesia (dowsing) are metaphysical approaches to determining the need for foliar fertilization and formulating the fertilizer sprays to be used. Despite the pseudoscientific nature of these modalities, they apparently are used with significant success by a surprising number of farmers. This writer had exceptional results using radionics to guide foliar feeding of commercial blueberries and blackberries in the late 1980s. For more general information on radionics in agriculture see chapter 6 in *The Non-Toxic Farming Handbook* (9) and chapter 22 in *Science In Agriculture* (10). (The authors use the term "electronic scanner" to describe a radionic device.) For how-to information on using radionics for plant culture, the book *Plants, Soils, Earth Energy & Radionics* is recommended (12).

Component Fertilizers for Foliar Fertilization

Synthetic Fertilizers

Most soluble conventional fertilizer materials can be used for foliar fertilization. Hot mix liquid and dry soluble formulations (e.g., Miracle-Gro™ products) are usually preferred, as they are designed to be dissolved in water and contain few contaminants. Fertilizers containing significant amounts of chlorine, however, should be avoided to reduce the chances of plant damage. Note that synthetic fertilizer materials are not permitted in organic production.

Organic Fertilizers

Fish-based fertilizers (fish emulsion or fish powder) and seaweed (soluble seaweed powder or seaweed extract) are among the most common foliar feeds in organic farming, applied either separately or in combination. Information on these fertilizers is available, as both have been in general use for many decades. The *Non-Toxic Farming Handbook* (9) provides information on using fish-based fertilizers for both foliar and soil applications. Various books by Lee Fryer, such as *The Bio-Gardener's Bible* (13), are also good sources of advice on the use of fish fertilizers. Details and references on kelp as a fertilizer are available from ATTRA.

Compost tea has become popular as a foliar spray material because of its nutrient content and disease-suppressive characteristics. For further information on the production of compost teas, *Compost Tea Manual* by Ingham is suggested (14). Also see the ATTRA publication *Notes on Compost Teas*.

Other soluble organic materials and those from which extracts are easily made include spray-dried blood, bat guano, worm castings, manure teas, humates, molasses, milk, B vitamins, and herbal extracts of plants like stinging nettle and horsetail. Several enclosures are provided that give further detail on these and other organic foliar fertilizer components. Take particular note of Cantisano's "What to use for foliar feeding," a very enlightening and informative article that contains specific product references and commonly recommended rates.

Additional articles on homemade foliar fertilizers are also enclosed, with particular emphasis on teas made from weeds. Information on this subject matter is often difficult to find. Some of it, the reader will note, comes from the Biodynamic™ school—a metaphysics-based approach to organics. ATTRA's publication *Biodynamic Farming and Compost Preparation* is recommended for further reading on this subject.

Foliar Fertilization for Organic Farming

Organic growers should be cautious when purchasing commercial foliar feeding products. Not all are cleared for certified production. Some have been blended with conventional fertilizer materials. Certain stimulants, biocatalysts, and other materials are also prohibited, often because they contain or are derived from genetically engineered organisms.

Organic producers must be cautious when using manure- or guano-based teas. Federal regulations limit the time between application and harvest of food crops. Compost teas, from compost produced according to USDA requirements, may or may not be restricted in the same way. It is important to consult your certifier in advance. For further information, request ATTRA's *Manures for Organic Crop Production*.

Crop Manipulation through Foliar Fertilization

Fertilization strategies can influence flowering, fruit set, fruit size, the amount of vegetative growth, and other plant characteristics. By carefully choosing the components of a foliar or sidedress fertilizer, the grower can "nudge" a crop toward earlier, heavier fruit set, or discourage fruiting—an advantage when producing greens or a forage crop. This concept is fairly well recognized in the conventional agricultural community. Many citrus growers, for example, are known to foliar feed with fertilizer blends dominated by potassium and nitrate—vegetative-growth-enhancing nutrients—to increase fruit size after the crop is well set. Generally speaking, fertilizer blends dominated by potassium, nitrate nitrogen, calcium, and chlorine tend to promote vegetative growth and fruit

size. Blends dominated by ammonium nitrogen, phosphorus, sulfur, and manganese encourage the setting of fruit and seed.

While this knowledge gives the farmer more management options, one should not assume too much when trying to manipulate crop performance. All crops—but especially fruit crops—will need certain amounts of both growth- and fruit-enhancing nutrients throughout the season. Imprecise timing, or attempts to tip the balance too far, can yield disappointing and costly results. Note, too, that these manipulations can be especially difficult for certified organic producers to attempt with the smaller array of soluble fertilizer materials available for their use.

For more detail on how fertilization can be used to influence crop growth in this manner, chapter 13 in *The Non-Toxic Farm Handbook* (9) and chapter 11 in *Science In Agriculture* (10) are recommended. The authors of both these texts are heavily influenced by Cary Reams's *Biological Ionization Theory*. Their explanations might appear confusing at first. Thorough reading of the books may be necessary for a good understanding.

Further Resources

Anon. No date. Manure tea. Golden Herb. <http://www.lanningpages.com/golden_herb/tea.html.

Anon. 1995. Foliar nutrition. Acres U.S.A. July. p. 64-65.

Donelan, Peter. 1988. Foliar feeding. Mother Earth News. May-June. p. 58, 60-61.

Goble, Ron. 2001. Foliar feeding inputs can determine wine quality. The Fruit Growers News. September. p. 20, 25.

Koepf, H.H. No date. Biodynamic Sprays. 16 p.

Available for $9 (shipping & handling included) from:
The Biodynamic Farming and Gardening Association, Inc.
P.O. Box 29135
San Francisco, CA 94129-0135
415-561-7797
888-561-7796
Fax: 415-561-7796
E-mail: biodynamic@aol.com
http://www.biodynamics.com/

Kuepper, George. 1992. Experiences with Electronic Scanning and Foliar Feeding in Commercial Small Fruits. GAIA, Goshen, AR. 2 p.

Available free of charge. Send SASE to:
GAIA
POB 151
Goshen, AR 72735

References

1) Anonymous. 1985. TNA Principles of Foliar Feeding. TransNational Agronomy, Grand Rapids, MI. 2 p.

2) Williams, Greg and Pat Williams. 1986. Zinc foliar sprays needn't be fancy, at least not for grapes. HortIdeas. March. p. 32.

3) Greene, George M. and Rob Crassweller. 1995. Correct calcium disorders. Fruit Grower. October. p. 19–20.

4) Deremiens, Janice. 1995. Foliar feeding strawberries. Northland Berry News. June. p. 8–9.

5) Cantisano, Amigo. 2000. Aphid outbreaks: Why they happen and what to do about them. Growing for Market. August. p. 6–8.

6) Mayse, Mark. 1996. Leaf sap brix and leafhoppers in vineyards. OFRF Information Bulletin. Fall. p. 6–7.

7) Williams, Greg, and Pat Williams. 1998. Plant therapy. Plants & Gardens News. Winter. p. 2.

8) Zimmer, Gary. No date. Crop Pests and Fertilizer Is There a Connection? Midwestern Bio-Ag, Blue Mounds, WI. 30 p. Available for $6 p&h included from: Midwestern Bio-Ag 10851 HWY ID, Box 160 Blue Mounds, WI 53517. Fax: 1-608-437-4441. Email: bioag@mhtc.net. Website: <http://www.midwesternbioag.com>.

9) Wheeler, Philip A., and Ronald B. Ward. 1998. The Non-Toxic Farming Handbook. Acres USA, Metairie, LA. 236 p. Available for $28 p&h included from: Acres U.S.A., P.O. Box 91299, Austin, TX 78709-1299. Tel: 800-355-5313. Fax: 512-892-4448. E-mail: <orders@acresusa.com>. Web site: http://www.acresusa.com

10) Andersen, Arden. 1992. Science In Agriculture. Acres USA, Kansas City, MO. 370 p. Available for $29 p&h included from: Acres U.S.A., P.O. Box 91299, Austin, TX 78709-1299 Tel: 800-355-5313 Fax: 512-892-4448 E-mail: <orders@acresusa.com>. Website: <http://www.acresusa.com>.

11) Harrill, Rex. 1998. Using a Refractometer to Test the Quality of Fruits and Vegetables. Pineknoll Publishing, Keedysville, MD. <http://www.crossroads.ws/brixbook/BBook.htm>.

12) Kuepper, George. 1998. Plants, Soils, Earth Energy & Radionics. GAIA, Goshen, AR. 212 p. For price and availability, send SASE to: GAIA, P.O. Box 151 Goshen, AR 72735.

13) Fryer, Lee. 1982. The Bio-Gardener's Bible. Chilton Book Co., Radnor, PA. 240 p. Available for $14 p&h included from: Acres U.S.A., P.O. Box 91299, Austin, TX 78709-1299. Tel: 800-355-5313. Fax: 512-892-4448. E-mail: <orders@acresusa.com> Website: <http://www.acresusa.com>

14) Ingham, Elaine R. 1999. Compost Tea Manual. Soil Foodweb, Inc./Growing Solutions, Inc./Ardeo, Inc. Corvallis, OR. 42 p. For price and availability, contact: The Soil Foodweb, Inc., 1128 NE 2nd St., Suite 120 , Corvallis, OR 97330. Tel: 541-752-5066. Fax: 541-752-5142. E-mail: <info@soilfoodweb.com>. Website: <http://www.soilfoodweb.com/>.

Enclosures

Anon. No date. Refractometer & Refractive Index of Crop Juices Calibrated in % Sucrose or °Brix. Agri-Mart, Inc. Hudson, FL. 4 p.

Anon. No date. Sprays for Pest Control. Organic UK. 3 p. Formulas credited to: Lacey, Roy. 1988. Organic Gardening. David & Charles (publishers), London.

Cantisano, Amigo. 2000. What to use for foliar feeding. Growing for Market. July. p. 4–6.

Eddy, David. 2000. A future for foliars. American Vegetable Grower. January. p. 46–47.

Eddy, David. 1999. Application and micronutrients. American Fruit Grower. February. p. 30–32.

Faulkner, S.P. 1999. Foliar feeding when your plants need it fast. The Growing Edge. May-June. p. 42-43, 47.

Faust, R.H. 1996. Why foliar fertilization works. <http://www.humic.com/fol-fert.html >. 3 p.

Franck, Gertrud. 1983. Companion Planting. Thorsons Publishing Group, Great Britain. p. 62–66.

Klocek, Dennis. 1983. A Biodynamic Book of Moons. Bio-dynamic Literature, Wyoming, RI. p. 64–72.

Raman, P. Sundara. 1999. Organic manure for crops. Honey Bee. October-December. p. 7.

Stone, Pat. 2000. Homebrewed solutions. Country Journal. July-August. p. 62–64. Texas Soil & Plant Lab. 2000. Leaf/petiole (stem) sampling. Acres USA. November. p. 29.

Tsuda, Hideaki. 2000. Homemade soil microorganisms. Organic Farms, Folks & Foods. Mid-Winter. p. 18.

Zimmer, Gary. 2000. Can health be measured? Acres USA. November. p. 29.

By George Kuepper
NCAT Agriculture Specialist

Edited by Richard Earles and David Zodrow
Formatted by Ashley Hill

The electronic version of **Foliar Fertilization** is located at:
PDF
http://attra.ncat.org/attra-pub/PDF/foliar.pdf
HTML
http://attra.ncat.org/attra-pub/foliar.html