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Foliar Feeding Revisited David Trinklein

Foliar feeding has been the subject of much debate in recent years. The practice involves applying water-based fertilizers to the leaves of plants to enhance their nutritional status. Claims of yield increases up to 20 percent have been made based on the assumption that leaves are more efficient at taking up nutrients than are roots. This rationale dates back to research conducted at Michigan State University in the 1950's using radio-isotopes of certain essential mineral elements.

Opponents of foliar feeding are quick to point out that the leaves of plants are not designed to take up nutrients. The roots are. It has been estimated that only 15 to 20 percent of the nutrients applied to leaves actually are taken in. Additionally, the translocation of nutrients to other parts of the plant is much less efficient when taken in through the leaves versus when absorbed by the roots.

The mode-of-entry of essential elements into the leaves when applied as a foliar fertilizer still is under debate. Conventional theory is that foliar feeding is effective because plants can take in essential minerals in liquid form through pores in their leaf cuticle called stomata. The latter serve as points-of-entry for air laden with carbon dioxide used by the plant during photosynthesis.

Research has revealed, however, nutrients are more likely to be taken in through the leaf cuticle. The latter contains a pathway of extremely minute pores (< 1 nm in diameter) with a density of about ten billion pores per cm^3 of leaf surface area. These micro-pores are lined with negative charges which tend to attract (when in ionic form) positively charged elements such as calcium (Ca^{++}), magnesium (Mg^{++}), potassium (K^{+}), ammonium-form nitrogen (NH^{+}), etc. Movement through the cuticle is dependent upon a number of factors including, nutrient concentration, molecule size, organic vs. inorganic, etc.

Conversely, negatively charged essential elements in ionic form such as phosphorous (HPO_4^{-2}), sulfur (SO_4^{-2}) and nitrate-form nitrogen (NO_3^{-1}) find leaf entry through the cuticle more challenging. Whereas opposite charges attract, like charges repel one another.

As alluded to above, another consideration when foliar feeding is the fate of the nutrients after they enter the leaf. Smaller molecules or those with a lesser positive charge are more readily transported in the vascular system where they are translocated to other parts of the plant. Examples of the latter include ammonium (NH^{+}), potassium (K^{+}) and urea (NH_2CONH_2).

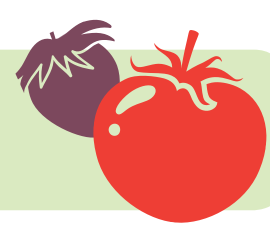
On the other hand, larger molecules and ions with greater positive charges tend to stay fairly close to their point-of-entry as they adhere to the negatively-charged cell walls. Examples of fairly tightly held (immobile) nutrients include calcium (Ca^{++}), iron (Fe^{++}), manganese (Mn^{++}), zinc (Zn^{++}), and copper (Cu^{++}). Therefore, when applied as foliar fertilizers, elements with strong positive charges such as calcium do not move much upon entering the leaf. Accordingly, elements such as phosphorous which are negatively charged are slow to enter the leaf. Both are relatively immobile after gaining entry.

Additional research demonstrated that species vary greatly relative to their ability to take in nutrients through their leaves. Differences in cuticle thickness, stomata number and resistance as well as genetic and environmental factors all influence the ability of a species to taken in foliar-applied nutrients. If spray concentrations are increased to offset the restricted ability of a plant to take up foliar-applied nutrients, leaf burn can be a serious problem. The latter also can occur when applying the macro-nutrients (e.g. N, P, and K) which are needed in large amounts by the plant, making concentrated solutions a necessity.

If practiced, foliar feeding should be considered a supplement to a sound, well-designed soil fertility program, and not a substitute for the latter. However, given proper circumstances, foliar feeding can be helpful in managing the nutritional well-being of a crop, especially when it comes to correcting micro-nutrient deficiencies.

(continued on page 2)

Also In This Issue



The following is a list of plant nutrients and rates that are effective as foliar applications, according to Dr. Gordon Johnson, Extension Vegetable & Fruit Specialist at the University of Delaware in his publication titled ***Foliar Fertilization of Vegetable Crops***:

- Foliar applications of nitrogen (N) can benefit most vegetables if the plant is low in N. Urea forms of N are the most effective; methylene urea (urea formaldehyde) and triazoles ($C_2H_3N_3$) are effective with less injury potential; and ammonium sulfate is also effective. Recommended rates are 1 to 10 lbs./acre.
- Foliar potassium (K) is used on fruiting vegetables such as tomatoes and melons. Best sources are potassium sulfate or potassium nitrate. Recommended rate is 4 lbs./acre of K.
- Foliar magnesium (Mg) is used on tomatoes, melons, and beans commonly. The best source is magnesium sulfate and recommended rates are 0.5 to 2 lbs./acre of Mg.
- Foliar calcium is often recommended, but because it moves very little, it must be applied at proper growth stages to be effective. For example, for reducing blossom-end rot in tomato or pepper fruits, foliar calcium must be applied when fruits are very small. Best sources for foliar calcium are calcium nitrate (10 to 15 lbs./acre), calcium chloride (5 to 8 lbs./acre) and some chelated Ca products (manufacturers recommendations).
- Iron (Fe), manganese (Mn), or zinc (Zn) are best applied as foliar feeds in as sulfate forms. Rates are: Fe, Mn, 1 to 2 lbs./acre, and Zn ¼ lb./acre. While these metal micronutrients are not mobile, foliar applications are very effective at correcting local deficiencies in leaves.
- The other micronutrient that can be effective as a foliar application is boron. Boron in the Solubor® form is often recommended at 0.1 to 0.25 lbs./acre for mustard family crops such as cabbage as a foliar application. Boron is very toxic to plants if applied in excess so applying at correct rates is critical.

(Please note: an average greenhouse or high tunnel is about 3,000 sq ft which constitutes about 0.06 acres of cropped area. Conveniently one ounce is about 0.06 pounds, thus for each pound per acre, it would be one ounce for 3,000 sq ft)

Additional points to consider when foliar feeding crops include:

- Foliar feeding the micro-nutrients appears to be much more effective than the macro-nutrients.
- If practiced, foliar feeding should be done when the air is relatively cool (around 72ºF). For most summer crops this dictates early morning or late evening application.
- Do not apply foliar fertilizer to the point that droplets form on leaf surfaces—this encourages leaf burn.
- It is better to apply weaker concentrations of foliar feed more frequently than stronger concentrations less frequently.
- As with any new cultural practice, initiate foliar feeding on a trial basis first.

In short, foliar feeding is usually not the most cost effective method of supplying nutrients to plants. However, it has proven to be an effective method of treating certain nutrient deficiencies and (perhaps) boosting plant growth in times of stress. Growers wishing to initiate a foliar feeding program should research the subject well before proceeding.

Low Tunnel Benefits and Opportunities for Specialty Crops in Missouri

Ramón Arancibia

Sustainable intensification of the specialty crops industry and urban agriculture involves the application of modern technologies to improve profitability, environmental stewardship, and social wellbeing. To improve productivity of specialty crops, farmers in Missouri and throughout the country use intensive production systems such as black plastic mulch, floating row covers, low and high tunnels, and heated greenhouses to increase temperature and extend the production season of high value crops. Low tunnels are easy to assemble and disassemble with each crop, which offers an advantage over high tunnels of been readily movable, allowing for rotations with cover crops or other cash crops to maintain soil health and the system use efficiency. Here we discuss some of the benefits of low tunnels that can improve productivity and sustainability of the production system.

Low tunnels covered with spun-bonded row cover over wire hoops.

Low tunnels are temporary structures comprised of a set of hoops (2 to 4ft tall) aligned over one or several rows and covered with a material that fits the purpose. The supporting hoops can be wire (No. 6 or 9), PVC, metal pipe, or other supporting material. Wire hoops are the most economical, but PVC and metal pipes work better for tall tunnels and windy conditions. For season extension, low tunnels are covered with slit or perforated transparent polyethylene film and semitransparent spun-bonded plastic fabrics of various thicknesses. Spun-bonded fabrics are also used as floating blankets directly over the crop. The use of plastic films is limited as row cover because of water condensation in the inner side of the film, which results in suffocation and decay of the foliage in contact with the water. This problem is rare with spun-bonded fabrics because they are permeable and allow air flow with little condensation, which dissipates rapidly after sunrise. Spun-bonded fabrics are available in various thicknesses: 0.5 to 3 oz/yd2. The thickness influences the level of protection against cold temperatures and mild freezes/frosts, but the strength of the material depends on its thickness. Heavier fabrics are stronger and can maintain warmer temperatures under the tunnel in a freezing or near freezing event, but cost more. Lightweight fabrics are less expensive, but the level of protection against low temperatures is less and rip easily, so careful handling during installation and removal is necessary for reuse. Manufacturer specifications may indicate the expected temperature differences (2°F to 12°F) between the inside and outside the material can offer, but environmental conditions may also play a role in their performance. Tight and secured ends and sides are critical to avoid wind getting underneath and blow the cover away. Many farmers use sand or gravel bags, but shoveling soil makes a good tight closure as well.


Floating blanket over strawberries.

Row covers modify the microenvironment under the tunnel into more favorable growing conditions that reduce overall plant stress. Low tunnels effectively increase air and soil temperatures, protect crops against cold temperatures and mild freezes, and promote vegetative growth. Studies with cucurbitaceous, solanaceous and other specialty crops throughout the country have shown that low tunnels covered with spun-bonded fabrics enhance vegetative growth, which it has been attributed to the increased temperature. Micro-environmental conditions indicate that in addition to the increased temperatures, the cover reduces light intensity and blocks wind resulting in less evapotranspiration (the sum of evaporation from the soil and evaporation from plants). This reduced water stress in the peak hours of sunny and/or windy days promotes vegetative growth resulting in larger plants, similar to growing in greenhouses. In the case of cucumber, peppers, and okra, the enhanced vegetative growth by the time of cover removal sustains more fruits and therefore, yield increases in comparison to open field. Timing for cover removal, however, is critical in crops that require insects for pollination such as cucurbits. In addition, the reduced evapotranspiration results in less water requirements, so irrigation is reduced under low tunnels despite the increased in temperature.


Enhanced vegetative growth in spring watermelon under low tunnels covered with spun-bonded row cover over wire hoops.

Cool season crops that can withstand freezing temperature also benefits when grown under low tunnels in early spring and late fall. In fact, farmers use low tunnels inside high tunnels as an additional protection layer against extreme cold temperatures in northern states to promote growth of cool season crops. The enhanced vegetative growth of leafy vegetables grown under low tunnels shorten the growth period between planting and harvest. In addition to early harvests, decreasing the time to harvest allows additional harvest events and/or crop cycles within the season, which may increase profitability and land use efficiency.


Puerto Rican sweet pepper under low tunnels covered with spun-bonded row cover over PVC hoops for taller plants.

Spun-bonded row covers and insect nets are physical barriers against insect pests as well as viral diseases transmitted by insects. Coarse insect nets (small mesh or large gaps) exclude large insects such as butterflies and moths, bugs, beetles, and others from reaching the crop and reduce feeding injury. However, most virus-transmitting insects are small. Aphids, whiteflies and thrips transmit the most common viruses affecting specialty crops. Row covers and fine insect nets of large mesh (small gaps) can effectively exclude small insects and reduce the direct feeding injury as well as the incidence of viral diseases transmitted by these vectors. Therefore, tunnels covered with spun-bonded fabrics and insect nets can reduce the use of insecticides, benefiting conventional as well as organic producers of specialty crops.


Fall cilantro under low tunnels covered with spun-bonded row cover over metal hoops for wider beds and windy conditions.

In conclusion, there are opportunities for specialty crops farmers and urban agriculture in Missouri to improve their operation sustainability by using low tunnels. Since low tunnels increase yield and profitability, and considering that low tunnels are more affordable than high tunnels in the short term, they can very well improve the economic sustainability of specialty crops farmers. Low tunnels reduce insecticide applications, which improves environmental sustainability. Low tunnels also reduce the time to harvest and increase crop cycles, so land and/or roof top use efficiency improves significantly, which is particularly important for small-sized specialty crops operations and urban agriculture.

Additional articles

Arancibia, R.A. 2018. Low tunnels in vegetable crops: beyond season extension. Virginia Cooperative Extension publication Hort-291. https://www.pubs.ext.vt.edu/HORT/HORT-291/HORT-291.html

Arancibia, R.A. and C.E. Motsenbocker. 2008. Differential Watermelon Fruit Size Distribution in Response to Plastic Mulch and Spunbonded Polyester Rowcover. HortTechnology 18:45-52

Announcements

The Food Safety Modernization Act (FSMA) trainings

The Food Safety Modernization Act (FSMA) trainings were held in and around a number of Amish and Mennonite communities these last several months. Below are the number of individuals who took the training (**in bold**). Some trainings were hosted by a grower in the community, in a farm building or their house. We appreciated their assistance. It was also a great way for growers to engage with representatives from Missouri Department of Agriculture.

Lamar on October 29th, **20**
Windsor on November 7th, **12**
Morgan County Seeds on December 13th, **24**
Seymour on December 21st, **23**
St. Joseph on January 10th, **25** (Missourians)
Clark on January 16th, **31**
Dixon on April 24th, **TBD**

At some of these FSMA trainings, ways to increase the number of water samples was explored. In several instances, certain individuals stepped forward to coordinate the pick-up and delivery of water samples to the Kansas State University lab. We applaud the efforts of both the cooperating growers and those individuals (Missouri Department of Ag and MU Specialists). As water sampling has increased, questions have arisen on how best to take a sample. An insert has been included with this newsletter edition to help with those questions. Let an MU Specialist or a Missouri Department of Ag representative know if you need further assistance with this matter. A number of you will have an opportunity to do so when taking part in On Farm Readiness Reviews.

The 2019 Missouri Tomato School

The 2019 Missouri Tomato School is scheduled for May 30-31 at Lincoln University's Carver Farm in Jefferson City. The Missouri Tomato School is in its third year, and features information on all aspects of commercial field, high tunnel and greenhouse tomato production. Speakers will include nationally known tomato specialists Dr. Rick Snyder of Mississippi State University and Dr. Joe Kemble of Auburn University, as well as tomato experts (Extension and farmers) from across Missouri.

Day 1 of the school will focus on tomato production – greenhouse/high tunnel/field management, pest control, nutrition, harvest and postharvest handling, and marketing. The second day of the school will include farm visits and hands-on discussions of tomato production practices on the farm and in the greenhouse/high tunnel.

Information on the Missouri Tomato School, including registration, is available at the Webb City Farmers Market growers training website http://www.webbcityfarmersmarket.com/grower-training.html. In addition to Webb City Farmers Market, sponsors of the Missouri Tomato School include MU Extension, LU Extension, and the Missouri Department of Agriculture Specialty Crop Block Grant program.

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