BY DANIELLE CLADE AND BRIAN WHIPKER

Culinary herb BMPs

Learn how to manage nutrient disorders of cilantro for a more profitable crop.

This is the **first of an eight-part series** focused on nutrient deficiencies, post-harvest shelf life, disease management, food safety and marketing of CEA culinary herbs.

CEA HERB Controlled Environment Agriculture Herb Extension & Research Base

Figure 1. Nitrogen deficiency of cilantro plants causes stunted growth, chlorotic and light-green foliage, and death of the older leaves.

PHOTOS COURTESY OF THE AUTHORS

The Controlled Environment Agriculture Herb Extension & Research Base (CEA HERB) project team received a grant from the USDA to develop science-based information relevant to greenhouse and indoor production and economics of potted and fresh-cut culinary herbs produced in controlled environments. The team is led by Dr. Roberto Lopez at Michigan State University (MSU) and consists of faculty, researchers and graduate students at MSU, the University of Tennessee, North Carolina State University, Iowa State University, Texas Tech University and the USDA Agricultural Research Service.

The project objectives are to: 1. increase the demand and marketability of culinary herbs; 2. increase growth, quality, shelf life, disease management and food safety of herbs through environmental control and cultural practices; and 3. develop effective marketing, production, plant protection, technology adoption, post-harvest and food safety guidelines for CEA herb growers. More information and project updates are available online at **scri-ceaherb.org**.

Why herbs? First, consumer demand for fresh herbs has increased in the last decade. This has stimulated production in controlled environments to meet year-round demand, especially for holidays such as Thanksgiving. Second, little research-based information exists on these crops, at least partly because (until recently) they were a small production niche. Third, there are fewer pesticides labeled for herbs, which creates added challenge to manage diseases, insect pests and crop height. Finally, since culinary herbs are meant for consumption, food safety protocols are essential.

This article is the first of eight to appear in *Produce Grower* in 2025 and 2026. A complementary six-part series of articles will also be published in sister publication *Greenhouse Management* (**greenhousemag.com**) throughout the year. In total, these 14 articles will provide research-based information on a variety of production, marketing and food safety topics focused on culinary herbs.

Here, we delve into our research at NC State University focusing on nutrient disorders of culinary herbs.

Hydroponic crop production involves monitoring myriad factors: temperature, light, nutrient solution pH, electrical conductivity (EC) and more. While these factors are crucial for achieving maximum yields and maintaining healthy, marketable plants, visually monitoring plants and interpreting the results is equally as important. This is especially important in recirculating irrigation systems, where nutrient imbalances can quickly occur as the plants absorb and utilize nutrients. While plants can't talk, their leaves can say a lot about their health and nutrient status and can aid in diagnosing nutrient disorders.

Experiment protocol

Herbs were grown hydroponically in silica sand using a custom blend of fertilizer salts. For each treatment, a single nutrient was omitted

Figure 2. Sulfur deficiency in cilantro causes chlorosis of the newest growth.

Figure 3. Phosphorus deficiency in cilantro plants causes purpling of the older leaves, starting at the margin and enveloping the entire leaf if deficiency persists.

from the nutrient solution while all other nutrients were held constant, allowing us to induce specific nutrient disorders and document the corresponding symptomology. We teamed up with Dr. Jennifer Boldt at the USDA-ARS facility in Toledo, Ohio, to analyze leaf tissue for critical concentrations.

Location matters: To understand the visual symptoms of nutrient deficiencies in plants, it's helpful to categorize the essential macronutrients into two categories: mobile and immobile.

Mobile nutrients can be relocated within a plant, and when deficient, they are redirected from the older foliage to support the newest growth. As a result, symptoms of mobile nutrient deficiencies are initially observed in the older foliage. The major mobile elements of nitrogen, phosphorus, potassium and magnesium are the ones that appear most frequently.

Immobile nutrients, on the other hand, cannot be relocated within the plant tissue. This results in deficiency symptoms of immobile nutrients developing on the newest growth. The primary immobile elements which commonly develop deficiencies are calcium, boron and iron.

Cilantro disorders: Cilantro (*Coriandrum sativum*) is a popular annual herb that can be grown for leaves or seeds. Our research indicates that, when grown in a controlled environment, cilantro is most prone to nutrient deficiencies of nitrogen, phosphorus, sulfur and calcium. Each nutrient plays a critical role in plant growth, so imbalances can significantly impact yield and marketability.

Nitrogen is required in the largest quantity to support healthy plant growth and is the most common nutrient deficiency to occur in plants. Due to nitrogen being a mobile nutrient, deficiency symptoms will initially be seen in the older leaves of the plants. In cilantro, the most prevalent symptom of nitrogen deficiency is stunted growth and chlorotic or light-green foliage (**Figure 1**). Extremely deficient plants will become entirely chlorotic and may exhibit a slight reddening of the leaf margins, and older leaves will eventually die altogether.

At first glance, sulfur deficiency can easily be confused with nitrogen deficiency in cilantro plants. Both deficiencies cause light-green and chlorotic foliage, but unlike nitrogen, sulfur is partially immobile in plant tissue. As a result, symptoms of sulfur deficiency will initially develop on the newest growth, which exhibits interveinal chlorosis and a light green-yellow coloration (**Figure 2**), similar to what is seen in nitrogen-deficient plants.

To differentiate between the two disorders, it is essential to distinguish between the location of where the symptoms appear. Given the rosette growth pattern of cilantro, the newest leaves are located in the center of the plant, while the oldest leaves are located on the outer edges. If yellowing is initially occurring on the outer, older leaves, then the problem is most likely due to a lack of nitrogen. On the other hand, symptoms that appear on the inner, newer growth of cilantro plants are likely due to a sulfur deficiency.

Nitrogen deficiencies are more likely to occur due to the large quantity of the element utilized by plants, while sulfur deficiencies are less common. Sulfur deficiencies are most likely to occur when a Cal-Mag fertilizer formulation, which contains magnesium nitrate instead of magnesium sulfate, is used.

Figure 4. Calcium deficiency in cilantro plants causes death of the growing points and cupped leaves.

Phosphorus is another essential mobile nutrient needed in higher quantities to support healthy, vigorous plants. With inadequate phosphorus uptake, cilantro plants begin developing faint purple margins of the lower leaves as phosphorus is redirected to newer growth (**Figure 3**). As symptoms progress, this purpling becomes more prominent, eventually enveloping the older leaves entirely. If deficiency persists, growth is considerably stunted.

Calcium is an immobile element needed for proper development of plant cell walls and membranes, so deficiency

symptoms are seen on newly expanding leaves. When cilantro plants receive inadequate calcium supply, the leaves and growing points are unable to properly develop. This results in cupped leaves, where the leaves appear to be curled downward, unable to fully unfurl (**Figure 4**). The tips and margins of these leaves will also become necrotic. As symptoms progress, the growing points of the plant, which are in the center of cilantro plants, will also become necrotic and die.

Calcium deficiency is less likely to occur in regions overlying limestone bedrock, where highly alkaline water (i.e., "hard" water) naturally contains calcium and magnesium. In regions not over limestone deposits, calcium deficiencies are more likely to occur.

In some cases, adequate calcium may be supplied to cilantro plants, and deficiency symptoms may still appear. Because calcium uptake is highly affected by transpiration rates, low transpiration rates can induce acute calcium deficiency. This is especially common in crops like cilantro, where the growing point is lower in the plant canopy and may receive less airflow. Overcrowding or poor ventilation can further decrease the transpiration rate of the growing points, limiting calcium transport to young leaves.

Visually monitoring cilantro plants and recognizing the symptoms of common nutrient disorders can help diagnose problems as they arise. Since some deficiencies (such as sulfur and nitrogen) can mimic one another, tissue analysis may be necessary to confirm a diagnosis.

While inadequate fertilization can cause nutrient deficiencies in cilantro, other factors should also be considered. Nutrient disorders can also be induced by a pH imbalance, environmental conditions and nutrient interactions. Evaluating the EC of the nutrient solution is a useful place to start, but sending a sample of nutrient solution for analysis can help pinpoint any depleted or excessive nutrients. An imbalance in nutrients can lead to antagonistic effects, where certain nutrients can inhibit the uptake of others, resulting in deficiencies despite adequate fertilization.

By combining visual monitoring and routine testing, growers can maintain healthy crops and minimize nutrient imbalances to optimize yield and quality of cilantro plants grown in controlled environments. **pg**

Danielle Clade is a graduate research assistant and Brian Whipker is a professor and extension specialist in the Department of Horticultural Science at North Carolina State University. Contact Whipker at **bwhipker@ncsu.edu**. The authors would like to thank the USDA Specialty Crops Research Initiative award 2022-51181-38331 for funding.