an Association of Floriculture Professionals

January/February 2006 • Number 894

Temperature Effects on Floriculture Crops and Energy Consumption

by Erik Runkle

The high cost of energy this spring is forcing many greenhouse growers in colder climates to re-evaluate different aspects of their production strategies. When we had a surge in fuel prices in 2000-01, *Greenhouse Grower* magazine surveyed growers about what they did differently in response to the increased fuel costs. According to their September 2001 issue, the highest percentage (22%) of respondents lowered their growing temperature. Other growers increased the insulation of their greenhouses (15%), started production later (13%), and consolidated production (12%).

Based on this data, about one-third of the greenhouse operations in the United States either lowered their greenhouse temperature, delayed the start of their production, or both. How do those actions influence crop timing? Did the growers actually save energy? And, as a result of those changes, did growers meet their target marketing and shipping dates? This article will discuss these concepts and provide insight into the answers to these questions.

Continued on page 5

Geranium Nutrient Deficiencies: A Visual Primer for Grower Diagnosis & Correction

by Jonathan Frantz, James Locke, and Dharmalingam Pitchay

The genus *Pelargonium*, which is native to South Africa, is a popular floriculture crop because of its use as a bedding plant, potted crop, or in hanging baskets (USDA Ag Statistics, 2004). A wide range of species and varieties have been bred and introduced, with more than 500 types available in 2004 (M. Taylor and P. Nelson, personal communication). In spite of their popularity and diversity, only the most general nutritional guidelines are available for this crop. Therefore, a key to avoiding nutritional deficiency issues is to recognize the various tell tale signs and combine that knowledge with information gathered from water, media, and tissue testing.

Many patterns of visible nutrient deficiency symptoms are common to many crops, and by learning the role of the different nutrients within the plant, it is possible to predict how a deficiency symptom may show up in different crops. Once the general patterns are known, crop-specific symptoms can be used to fine-tune diagnoses. It is important to remember that not all deficiency symptoms that appear to be nutrient related can be addressed by adding that specific nutrient. Rather, there are times when other management practices

Continued on page 9

Inside this Edition...

ofa Grower

Geranium Nutrient Deficiencies

Continued from page 1

(i.e., over watering, pH control, root pathogens) can be changed to eliminate particular symptoms (i.e., iron chlorosis). Once identified, it is possible to salvage the plants from the nutritional disorder if immediate action is taken prior to necrotic lesions or developmental effects are observed that could negatively impact plant quality.

In this article, we summarize the role of each nutrient within plants in general, describe the specific deficiency symptoms observed for geranium, and accompany this text with color photos of typical symptoms for that nutrient deficiency. Finally, Table 1 provides a diagnostic key of nutrients to aid in recognition of geranium-specific deficiency symptoms.

Nitrogen

Protein is essential for all living organisms and is required for growth and development. Nitrogen is one of the main elements in protein. Nitrogen is also a component of nucleic acid, DNA, RNA, genes, chromosomes, enzymes, chlorophyll, secondary metabolites (alkaloids), and amino acids. As a result of its importance in plants, nitrogen deficiency slows down the growth and development of plants. The plants appear stunted with light green lower leaves, while the upper leaves remain green. With

Table 1. Unique symptoms for geranium (*Pelargonium*χ*hortorum*) nutrient deficiencies.

Primary Symptom	Secondary Symptom	Element
Uniform Yellowing	• Older leaves develop chlorosis from the leaf margins and slowly progress inward. In some geranium cultivars, **reddish to pinkish pigmentation** develops instead of chlorosis.	Nitrogen
	• Entire plants including petioles and stems, regardless of age, turns chlorotic.	Sulfur
	• Young leaves develop chlorosis within the **distinct zonal band**; developing leaves enlarge with slight marginal cupping.	Zinc
	• Mild chlorosis appears at the base of the leaves and progresses outward to leaf margins.	Copper
Interveinal yellowing	• **Young leaves** develop interveinal chlorosis.	Iron
	• **Older leaves** develop interveinal chlorosis.	Magnesium
Lack of leaf sheen	• **Dullness** starts at the leaf margins and progresses inward towards the petioles.	Copper
Speckles of chlorosis	• Maturing leaves develop **speckles** of chlorosis across the leaves.	Manganese
Leaf necrosis before discoloration	• **Necrosis** develops along the margins of old leaves **without prior chlorotic symptoms;** potassium deficiency symptom is delayed relative to many other greenhouse crops.	Potassium
	• Necrotic spots develop along the veins, and they coalesce and enlarge as the symptoms progress.	Boron
Leaf Wilt	• Lower leaves wilt; geranium is a highly drought tolerant plant, so symptoms in the shoots are minimal, even after the root system dies.	Calcium
Root tissue differences	• **Roots develop light bronze to cream coloration** with numerous, short primary roots.	Zinc
	• Significant reduction in primary and secondary root development.	Copper
	• **Swollen, blackened root tips** with numerous lateral roots closer to the primary roots creating **witches' broom-like** symptoms.	Boron
	• Root system rapidly becomes brown to black and sloughs off.	Calcium
	• Root system becomes **dull, and rust colored.**	Iron
	• **White, healthy roots, but primary roots elongate** much more rapidly compared to control roots.	Phosphorus
Deeper green than normal	• Leaves appear **darker green** at the early stage of deficiency, followed by the development of **necrosis along the margins of older leaves** at advanced stage.	Potassium
	• Leaves appear **darker green** at the early stage of deficiency, followed by the development of **pink to purple pigmentation** along the margins of older leaves.	Phosphorus

Continued on page 10

Geranium Nutrient Deficiencies

Continued from page 9

prolonged nitrogen deficiency, yellowing (chlorosis) or reddish pigmentation of older or lower leaves occurs, depending on cultivars. This is followed by browning and death (necrosis) of leaf margins. Figures 1, 2, and 3 exhibit the visual signs of nitrogen deficiency of two different zonal geranium cultivars.

Figure 1. *At first, the lower leaves develop yellowish-green, uniform chlorosis that slowly progresses from the leaf margins to the mid-leaf. As the chlorotic symptoms progress inward, a greenish-yellow gradient pigmentation follows.*

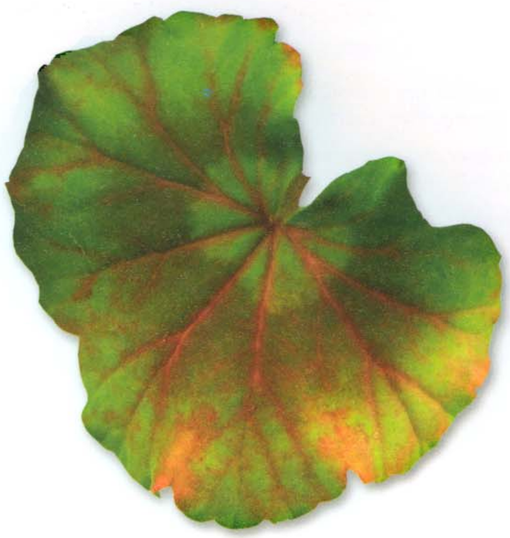

Figure 2. *Some geranium cultivars develop reddish pigmentation instead of yellow chlorotic symptoms. The red pigmentation progresses to upper maturing tissue.*

Figure 3. *Flowering is earlier and greatly reduced compared to normal plants.*

Phosphorus

Phosphorus is also a component of protein, DNA, RNA, and cell membranes, and is a component of stored energy in plants. In early phosphorus deficiency, plants appear darker green than normal with reduced growth. As the deficiency progresses, the older, lower leaves develop irregular spots of red or purple pigmentation along the leaf margins, which eventually turn brown to dark brown and die. In most cases, lack of phosphorus delays flowering in plants. Figure 4 shows phosphorus deficiency symptoms in zonal geranium.

Figure 4. *Initially, lower matured leaves appear darker green than normal leaves. Then, the initiation of chlorosis develops along the margins and progresses inward toward the acropetal area, while upper mature leaves appear normal.*

Potassium

Potassium is important for movement of sugars and starch formation, pH stabilization, drought tolerance, cell turgor, enzyme activation, and regulation of stomata opening and closing. The leaves of potassium-deficient plants are small and darker green than normal plants. These symptoms are followed by a sudden development of irregular necrotic tissues along the margins and tips of lower, older leaves. The browning eventually covers the whole leaf, giving the leaf a scored appearance. Geranium leaves can be potassium deficient for several weeks before necrotic symptoms develop. Figure 5 shows potassium deficiency symptoms in zonal geranium.

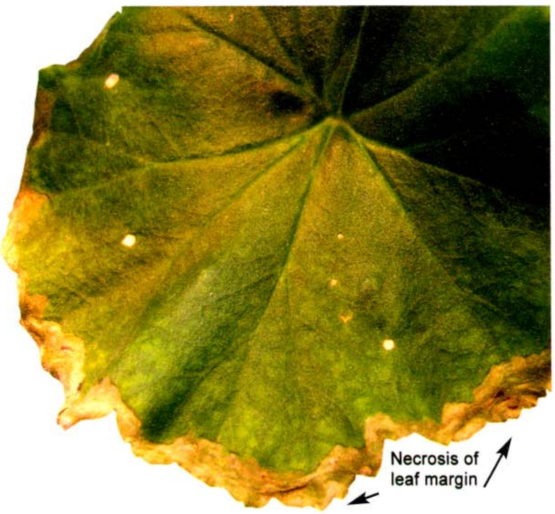

Figure 5*. Semicircular blackish-gray necrotic spots suddenly develop (like sudden trauma) along the margins of lower matured leaves, without prior chlorotic symptoms. These spots enlarge and spread inward from the leaf edge.*

Calcium

Calcium is required for cell wall structure and cellular signaling and is important in cell division and expansion, building of cell walls, stomatal regulation, and cold tolerance. Unlike other macronutrients, lack of calcium generally affects the growing points. The symptoms first appear on the root tips as a black necrosis (indication of cell death). When deficiency is severe, cell death occurs on the entire primary and secondary roots. The wilting of lower leaves occurs as a result of root death, even though geranium is a normally highly drought-tolerant plant.

Magnesium

Magnesium is a core constituent of chlorophyll (required for photosynthesis). Magnesium is also important in enzyme and cofactor reactions within cells. It is involved in the metabolism and movement of carbohydrate and stabilizing cell membranes. Normally, magnesium deficiency symptoms appear in lower, older leaves with greenish-yellow to yellowish-green chlorosis developing along the leaf margins and tips, which progresses inward between the leaf veins. As the deficiency persists, necrosis develops between the veins and the leaves curl downward. Figure 6 shows magnesium deficiency symptoms in zonal geranium.

Figure 6*. Interveinal chlorotic symptoms on older leaves, especially in the zonal region for which geraniums are known.*

Sulfur

Sulfur is essential in protein synthesis since it is a constituent of the essential amino acids such as cystine and methionine. Sulfur is also involved in plant photosynthesis and respiration. Initially, uniform light greenish-yellow chlorosis develops on young and/or mature leaves, but rarely on lower, older leaves. As the symptoms advance, uniform chlorosis spreads to the rest of the leaves. Figure 7 shows sulfur deficiency symptoms

Figure 7*. Recently matured leaves turn lightly and uniformly chlorotic across the leaf. Eventually, the entire plant, except the lower-most matured leaves, appear uniformly chlorotic.*

Continued on page 12

Geranium Nutrient Deficiencies

Continued from page 11

Iron

Iron is an important component of heme and sulfur proteins. DNA and RNA synthesis is restricted in iron-deficient environments. Iron is also involved in chlorophyll formation because iron is an immobile element in the plant. Iron deficiency symptoms develop on young leaves and shoots. Generally, young leaves develop interveinal chlorosis from the base, but in some species it develops from the tips. Over time, the chlorosis intensifies and the pattern becomes less interveinal. Even the stems appear chlorotic. At this point, the chlorotic symptoms are irreversible even if corrective measures are taken. Eventually, yellow gives way to white. Figures 8 and 9 highlight iron deficiency symptoms in zonal geranium.

Manganese

Manganese plays a significant role in photosynthesis. The formation of free oxygen radicals during the water splitting process and ultimately the release of oxygen is not possible in manganese-free environments. Manganese is the only element that can contribute the necessary electrons for this biochemical process. Young and recently matured leaves develop chlorosis followed by a necrotic stippling on recently matured and matured leaves. Drastic reduction of shoot and root growth is common. Flowering is strongly inhibited. Figure 10 shows manganese deficiency symptoms in zonal geranium.

Figure 8. *Pronounced interveinal chlorosis on new leaves.*

Figure 9. *The edges of the flower petals lose pigmentation and appear bleached-white.*

Figure 10. *Chlorosis is a spotty, speckled pattern across the entire leaf on recently matured to mature leaves.*

Copper

Copper plays an important role in quenching the radicals produced during biochemical processes. It is also a component of proteins and enzymes that are critical to producing chemical energy. Copper is required for lignification, especially xylem formation, and it is moderately mobile to immobile within the plant. Initially, young and maturing leaves appear stunted and misshapen with pointed margins. Overall, the plants appear "Bonsai-like." This is followed by impaired flower development that includes reduced size, premature abscission, or abortion. Sudden death of tissue, with symptoms similar to localized tissue dehydration, develops on recently matured leaves as a result of poor xylem tissue development. Figures 11, 12, and 13 highlight copper deficiency symptoms in zonal geranium.

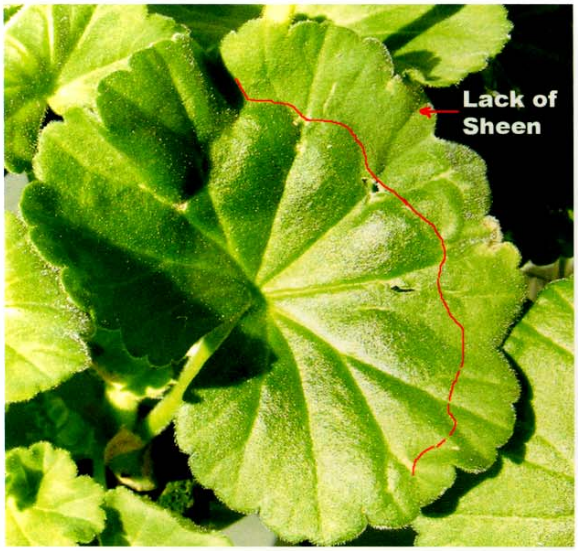

Figure 11. Maturing leaves are smaller with dull green appearance (lacks luster or shine) that progresses inward from the leaf edge.

Figure 13. The flower petals are pleached at the edges and begin to wilt earlier, starting at the petal edges.

Figure 12. After losing luster, chlorosis progresses from the leaf base outward toward the leaf margins.

Zinc

Zinc is an integral component of protein. So far, more than 80 zinc-containing proteins have been reported. One of them, referred to as 'Zinc Fingers', is actively involved in DNA transcription. This means protein synthesis will be affected. As a result, zinc deficiency severely affects plant growth. Young and recently matured leaves develop marginal cupping, veinal chlorosis, and necrosis. Some plants develop purple/pinkish pigmentation. Shoot and root growth is reduced. Figures 14, 15, and 16 show zinc deficiency symptoms in zonal geranium.

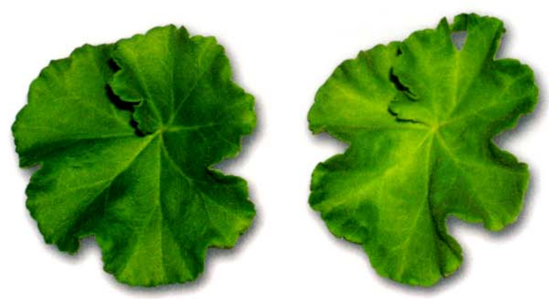

Figure 14. Young leaves develop veinal chlorosis from the leaf base.

Figure 15. The veinal chlorosis spreads to adjacent tissue until the entire leaf appears chlorotic. Pink-to-orange pigmentation develops interveinally.

Continued on page 14

Geranium Nutrient Deficiencies

Continued from page 13

Figure 16. Flowers are smaller with gaps between the petals. The petals are spoon-shaped and light colored.

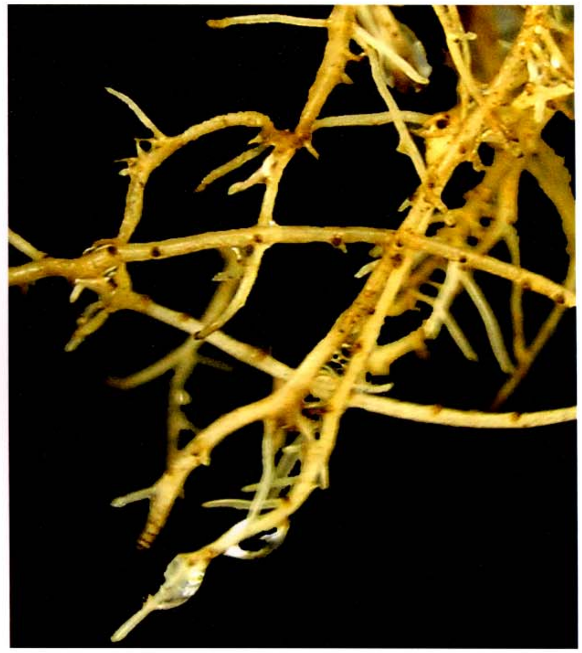

Figure 17. Initially, symptoms develop on the roots rather than the shoots. Primary and secondary roots are short, stiff, thick and stubby with necrotic tips and halted growth. Secondary roots are short and stubby, and are located in close proximity to the tips of the primary roots, giving the appearance of a witch's broom.

Boron

Boron is an essential element in plants for cell division, cell wall formation and stabilization, lignification, xylem differentiation, membrane integrity, auxin activity, and inhibition of callose formation, nucleic acid metabolism, pollination, and reproduction. Like calcium, boron disorders develop on the shoot and root meristem and on young leaves. The symptoms first develop on the roots three to four days earlier than the shoots. Overall, the roots are thick and short. Primary roots develop thick, swollen root tips with numerous short, secondary roots developing close to the tips, resembling witches' broom-like growth. Meanwhile, foliage becomes darker and glossy. Young and recently matured leaves become thick, leathery, and brittle with severe distortions. Loss of apical dominance is a common symptom in the roots and shoots. Figures 17 and 18 feature boron deficiency symptoms in zonal geranium.

Causes of Deficiencies

Lack of the nutrient in the media or fertilizer, excessive leaching and watering, low or high pH, and elevated EC can all lead to nutrient management problems. Be aware of competition between nutrients (i.e., cations can inhibit other cations) and the role your water quality and media type may play in delivering nutrients to your plants (ozonation systems, copper injectors, fine particle size, etc.). Container size and geometry also can influence deficiency symptoms through potential water and nutrient holding capacities.

Figure 18. The leaves are thick and brittle. Primary veins appear chlorotic (yellowish), and necrotic spots (corky tissue) develop close to the veins in the basipetal area. Small, water-soaked necrotic spots appear on the bottom of the leaves of maturing leaves adjacent to the veins.

The length of time to get obvious foliar deficiency symptoms relates to the sensitivity of geranium to a particular element (Table 2). In this case, geranium is more sensitive to nitrogen, calcium, and boron, and less sensitive to potassium.

Table 2. Length of time to get obvious foliar deficiency symptoms.				
2 to 3 weeks	3 to 4 weeks	4 to 5 weeks	5 to 6 weeks	More than 6 weeks
Nitrogen	Magnesium	Phosphorus	Manganese	Potassium
Calcium	Iron	Sulfur	Copper	
Boron		Zinc		

More information

We've only had room to touch on some issues related to plant nutrition. For more information, try these websites and books that have been useful to us:

- aggie-horticulture.tamu.edu/greenhouse/nursery/guides/index.html
- muextension.missouri.edu/explore/agguides/hort/index.htm
- www.ashs.org/resources.html
- www.ces.ncsu.edu/depts/hort/floriculture/def/
- www.unce.unr.edu/publications/FS02/FS0265.pdf
- www.utextension.utk.edu/publications/horticulture/default.asp#greenhouses
- Epstein, E. and A.J. Bloom. 2005. Mineral nutrition of plants: principles and perspectives. 2nd edition Sinauer Associates, Inc. Sunderland, MA
- Handreck, K and N. Black. 2002. Growing media for ornamental plants and turf. 3rd edition. UNSW Press, Sydney, Australia
- Marschner, H. 1995. Mineral Nutrition of Higher Plants. 2nd edition. Academic Press, Cambridge, UK
- Mengel, K. and E. A. Kirkby. 2001. Principles of plant nutrition. 5th edition. Kluwer Academic Publishers. Dordrecht, The Netherlands
- Mills, H.A. and J.B. Jones, Jr. 1996. Plant Analysis Handbook II. MicroMacro Publishing, Inc., Athens, GA
- Nelson, P.V. 1998. Greenhouse Operation and Management. 5th edition. Prentice Hall, Upper Saddle River, NJ
- Pitchay, D.S., J.M. Frantz, J.C. Locke, C. Krause. 2005. Towards a Healthy Plant. Available by request from Ohio State and Michigan State Extension Services
- Reed, D.W. 1996. Water, media, and nutrition for greenhouse crops. Ball Publishing, Batavia, IL
- White, J.W. 1993. Geraniums IV. Ball Publishing, Batavia, IL

Disclaimer

Mention of a trademark, proprietary product, or vendor does not constitute a guarantee or warranty of the product by the USDA, and does not imply its approval to the exclusion of other products or vendors that also may be suitable.

Jonathan Frantz
USDA-ARS
2427 Hempstead
Toledo, OH 43606
419-530-1531
Fax: 419-530-1599
Jonathan.frantz@utoledo.edu

James Locke
USDA ARS ATRU
University of Toledo
Mail Box #604
2801 W Bancroft St
Toledo, OH 43606
419-530-1595
Fax: 419-530-1599
James.locke@utoledo.edu

Dharmalingam Pitchay
University of Toledo
Mail Box #604
2801 W Bancroft St
Toledo, OH 43606
419-530-1576
Fax: 419-530-1539
ldelp@utnet.utoledo.edu