Towards a Healthy Plant

A “symptom” is the combined external and internal reactions or alterations of a plant in response to it being unhealthy. Such conditions can be initiated by either biotic (living) or abiotic (non-living) causes. Since symptoms are the plant’s response to some “stress”, there are many commonalities in response to differing causes. For example, root discoloration from white to brown or black can be the result of root pathogens, nutritional problems, or a symptom of other physical production problems. Determining the cause requires investigating the suite of symptoms and other clues (i.e. water quality, spray history, nutrient analysis, etc.) before proper corrective action can be taken.

Herein, the suite of visual symptoms related to specific nutritional deficiencies for geranium are described. While useful as a starting point to diagnosing production problems, keep in mind that multiple nutritional disorders often occur simultaneously.

DS Pitchay	JM Frantz	JC Locke	CR Krause
University of Toledo	USDA-ARS	USDA-ARS	USDA-ARS

Nitrogen (N)

Why do plants need 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. Nitrogen accounts for about 1 to 6 % of plant dry matter, depending on the species.

What happens when Nitrogen is not available to plants?

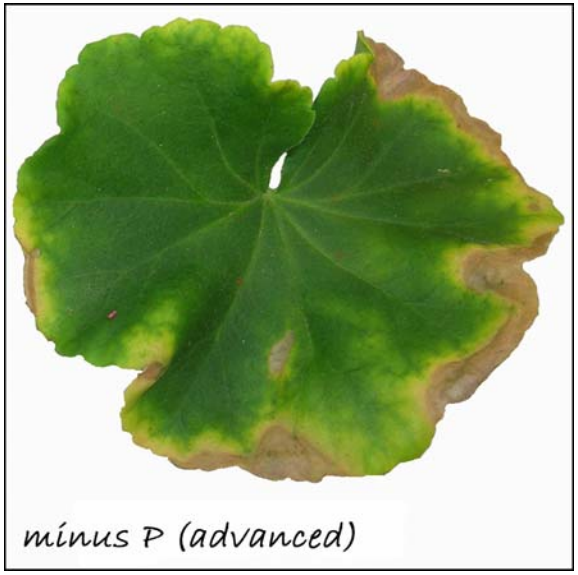
Nitrogen deficiency slows down the growth and development of plants. The plants appear stunted with light green lower leaves, while the upper leaves remain green. With prolonged N deficiency, yellowing (chlorosis) of older or lower leaves occurs. This is followed by leaf tip death and leaf margins developing a brown discoloration (necrosis). In some instances the leaves fall off. The plant stems become woody.

Source of Nitrogen Fertilizers

NAME	RATE	COMMENTS
Ammonium Nitrate	200 – 300 ppm	Single N (33%) source; lowers substrate pH
Ammonium Sulfate	200 – 300 ppm	Excellent source of N (21%) and S (24%)
Ammonium Chloride	200 – 300 ppm	Source of N (25 %) and Cl^-(66%); high concentration may cause foliar injury
Potassium Nitrate	200 – 300 ppm	Source of N (13%) and K (44%)
Monoammonium Phosphate	200 – 300 ppm	Source of N (10%) and P (50-52%)
Diammonium Phosphate	200 – 300 ppm	Source of N (19%) and P (46-53%)
Urea	200 – 300 ppm	Single source of N (45%); cheap, but will lower substrate pH
Calcium Nitrate	200 – 300 ppm	Source of N (15%) and Ca (22%); will increase the substrate pH

notes

Phosphorous (P)



Why do plants need Phosphorous?

Phosphorus provides energy in the form of ATP and NADPH for plant metabolism (photosynthesis and respiration). Additionally, it is a component of DNA, RNA, nucleotides and cell membrane.

What happens when Phosphorous is not available to plants?

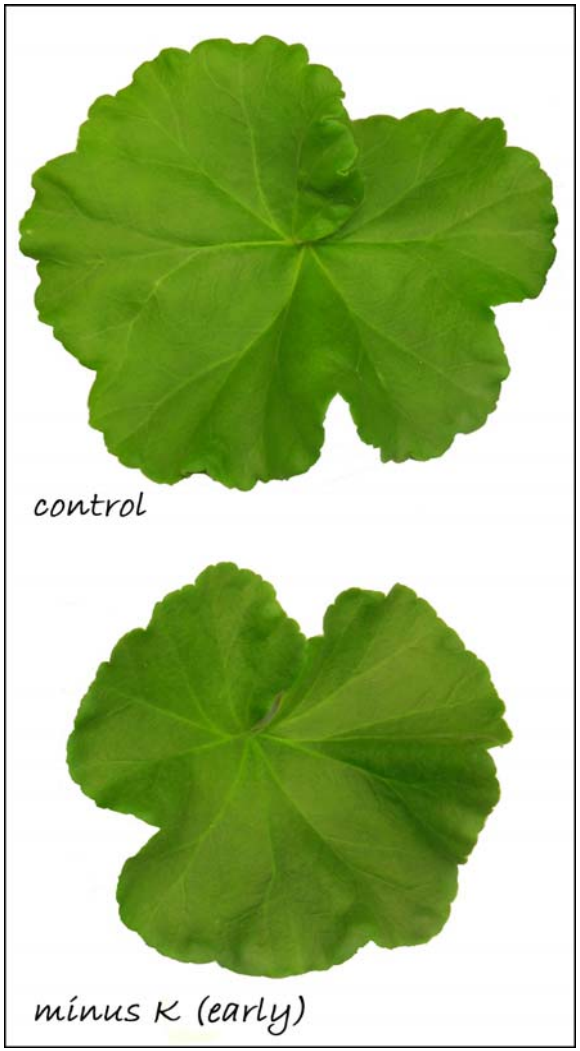
Initially, plants appear darker green with reduced growth affecting the leaf size and stem thickness. As the deficiency continues, the older, lower leaves develop irregular spots of brown to dark brown dead tissue. In some plants, reddish to purple pigmentation may appear on the under or upper surface of leaf margins, lower leaves, and stems. Eventually, leaf death of older leaves may occur. In most cases, lack of phosphorus delays flowering in plants.

Source of Phosphorous Fertilizers

NAME	RATE	COMMENTS
Monoammonium Phosphate	30 ppm	Source of N (10%) and P (50-52%)
Diammonium Phospate	30 ppm	Source of N (19%) and P (46-53%)
Monobasicpotassium phosphate	30 ppm	P (23%) K (28%)
Dibasicpotassium phosphate	30 ppm	P (18%) K (45%)
Phosphoric acid	10 ppm	Single P source (P_2O_5 -54%)

notes

Potassium (K)



Why do plants need Potassium?

Unlike nitrogen and phosphorus, potassium is not a component of plant organic matter. Potassium is important for movement of sugars, starch formation, pH stabilization, drought tolerance, cell turgor, enzyme activation, and regulation of stomata opening and closing.

What happens when Potassium is not available to plants?

The leaves of potassium deficient plants are small and dark green. The plants have short internodes resulting in compact plant appearance. These symptoms are followed by a sudden development of irregular necrotic tissues along the leaf margins and tips of lower, older leaves and eventually covering whole leaves, making the leaves appear scorched. Also, leaves curl downwards.

Source of Potassium Fertilizers

NAME	RATE	COMMENTS
Potassium chloride	200 ppm	Source of K (60%) and Cl
Potassium nitrate	200 ppm	Source of K (44%) and N (13%)
Potassium sulfate	100 ppm	Source of K (50%) and S (18%)
Potassium hydroxide	50 ppm	Single source of K (75%)
Potassium thiosulfate	200 ppm	Source of K (25%) and S (17%)
Monobasic potassium phosphate	200 ppm	Source of K (28%) and P (23%)
Dibasic potassium phosphate	100 ppm	Source of K (45%) and P (18%)

notes

Calcium (Ca)

Why do plants need Calcium?

Calcium is required for cell wall structure and cellular signaling. Calcium is important in cell division, cell expansion, building of cell walls, stomatal regulation, and cold tolerance.

What happens when Calcium is not available to plants?

Unlike other nutrients, lack of calcium generally affects the growing points and young leaves of the plants. The young leaves are often twisted or wrinkled. The growth is reduced with tiny black spots appearing around the mid-leaf area of young leaves and on the tips of very young leaves. In some cases, these black spots appear on the growing points. Abortion of flowers or flower buds is common if calcium is unavailable during flowering. During fruiting, lack of calcium can result in fruit cracking, water soaked tissues or blossom end rot (tomato).

Source of Calcium Fertilizers

NAME	RATE	COMMENTS
Calcium nitrate	200 ppm	Calcium source 22%
Calcium chloride	200 ppm	Calcium source 36%
Calcitic limestone	3 g per liter of substrate	Calcium source 32%
Dolomitic limestone	3 g per liter of substrate	Calcium source 22%
Hydrated lime	1.5 g per liter of substrate	Calcium source 46%
Gypsum	3 g per liter of substrate	Calcium source 23%

notes

Magnesium (Mg)


minus Mg

Why do plants need magnesium?

Magnesium is a core component of chlorophyll (pigment of photosynthesis). Magnesium is also important in enzyme and cofactor reactions. It is involved in the metabolism and movement of carbohydrates and stabilizing cell membranes.

What happens when magnesium is not available to plants?

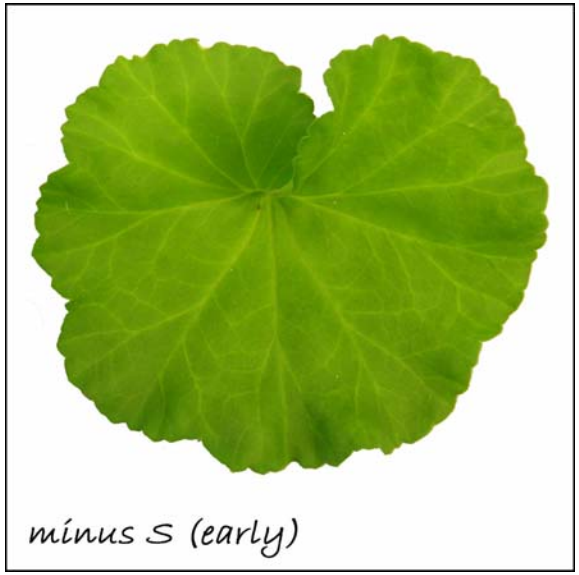
Normally magnesium deficiency symptoms appear in lower, older leaves with chlorosis of greenish yellow to yellowish green developing along the leaf margins and tips, which progresses inward between the leaf veins. As the deficiency prolongs, necrosis develops between the veins and the leaves curl downwards. Eventually, leaf and plant death may occur if the magnesium deficiency continues.

Source of magnesium Fertilizers

NAME	RATE	COMMENTS
Magnesium nitrate	50 ppm	Magnesium source 9%
Magnesium sulfate	50 ppm	Magnesium source 10%
Magnesium chloride	50 ppm	Magnesium source 25%
Potassium magnesium sulfate	25ppm	Magnesium source 11%
Dolomite	3 g per liter	Magnesium source 8-20%
Magnesium oxide	1 g per liter	Magnesium source 50-55%

notes

Sulfur (S)



minus S (early)

Why do plants need sulfur?

Sulfur is essential in protein synthesis since it is a constituent of some essential amino acids such as cystine and methionine. Sulfur is also involved in plant photosynthesis and respiration.

What happens when sulfur is not available to plants?

Initially, uniform chlorosis of light greenish yellow pigmentation develops anywhere between the young and mature leaves, but rarely on lower, older leaves. As the symptoms advance, uniform chlorosis spreads to the rest of the leaf area.

Source of sulfur Fertilizers

NAME	RATE	COMMENTS
Ammonium sulfate	60 ppm	Sulfur source 24%
Potassium sulfate	60 ppm	Sulfur source 18%
Magnesium sulfate	60ppm	Sulfur source 13%
Calcium sulfate	3 g per liter of substrate	Sulfur source 18%
Sulfuric acid	30 ppm	Sulfur source 33%
Elemental Sulfur	1.5 g per of substrate	Sulfur source 30-99%
Potassium thiosulfate	30 ppm	Sulfur source 17%

notes

Iron (Fe)


minus Fe

Why do plants need iron?

Iron is an important component of heme and sulfur proteins. DNA and RNA synthesis is restricted under iron deficient environment. Iron is also involved in chlorophyll formation. Iron is considered an immobile element in the plant, and as a result, iron deficiency symptoms develop on young leaves and shoots.

What happens when iron is not available to plants?

Generally young leaves develop interveinal chlorosis, from the base, but in some species from the tip. Over time, interveinal chlorosis intensifies and the pattern becomes less interveinal. Even the stems appear chlorotic. At this point, the chlorotic symptoms are irreversible even if correctional measures are taken. Eventually, yellow gives way to white. The bioavailability of Fe is pH dependent; the lower the pH, the higher the solubility and hence the availability of iron to plants.

Source of iron Fertilizers

NAME	RATE	COMMENTS
Fe - EDTA	4 ppm	Iron source 9-12%
Fe - DTPA	4 ppm	Iron source 10%
Fe - EDDHA	4 ppm	Iron source 6%
Fe - HEDTA	4 ppm	Iron source 5-9%
Iron sulfate	4 ppm	Iron source 20%
Ferrous ammonium sulfate	4 ppm	Iron source 14%

notes

Manganese (Mn)

Why do plants need manganese?

Manganese plays a significant role in photosynthesis. The formation of free oxygen radicals during water splitting and ultimately the release of oxygen is not possible under Mn-free environments. Mn is the only element that can contribute the necessary electrons for this biochemical process.

What happens when manganese is not available to plants?

The young and recently matured leaves develop chlorosis followed by stippling of necrosis on recently matured leaves. Drastic reduction of shoot and root growth is common. Flowering is strongly inhibited. Environmental factors such as sunny summer months, greenhouses built close to traffic areas and ozonated water used in irrigation/fertigation may contribute to manganese deficiency.

Source of manganese Fertilizers

NAME	RATE	COMMENTS
Manganese chloride	10 ppm	Manganese source 58%
Manganese sulfate	20 ppm	Manganese source 24%
Manganese EDTA	30 ppm	Manganese source 9-12%

notes

Copper (Cu)

minus Cu

Why do plants need 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 in producing ATP the “Biological Currency’. Copper is required for lignification, especially xylem formation, and its mobility is moderate to immobile within the plant.

What happens when copper is not available to plants?

Initially, the young and maturing leaves appear stunted. In some species a tinge of bluish-green appears, especially over the veins. 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 mature leaves as a result of poor xylem tissue development. Chlorosis is generally not a distinguishing feature. Substrate with high pH or alkaline water may contribute to Cu deficiency. Symptoms appear initially at the base of the leaf and spread toward the margins.

Source of copper Fertilizers

NAME	RATE	COMMENTS
Copper EDTA	15 ppm	Copper source 9-13%
Copper HEDTA	15 ppm	Copper source 9%
Copper chloride	6 ppm	Copper source 47%
Copper sulfate monohydrate	7 ppm	Copper source 35%
Copper sulfate pentahydrate	9 ppm	Copper source 25%
Cuprous oxide	3 ppm	Copper source 89%

notes

Zinc (Zn)

Why do plants need zinc?

Zinc is an integral component of protein; so far, over 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 requires Zinc.

What happens when zinc is not available to plants?

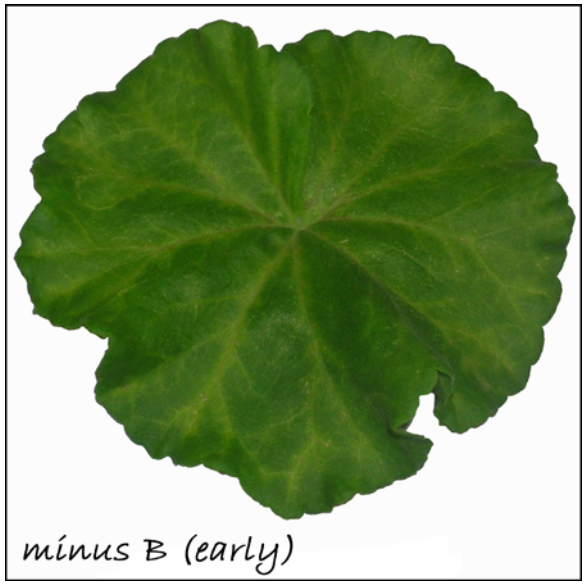
Young and recently matured leaves develop puckering, veinal chlorosis, and necrosis. Some plants develop purple pigmentation. Shoot and root growth is reduced. A high level of P in the substrate induces Zn deficiency. Zn availability is reduced by high pH and bicarbonates (HCO_3^-).

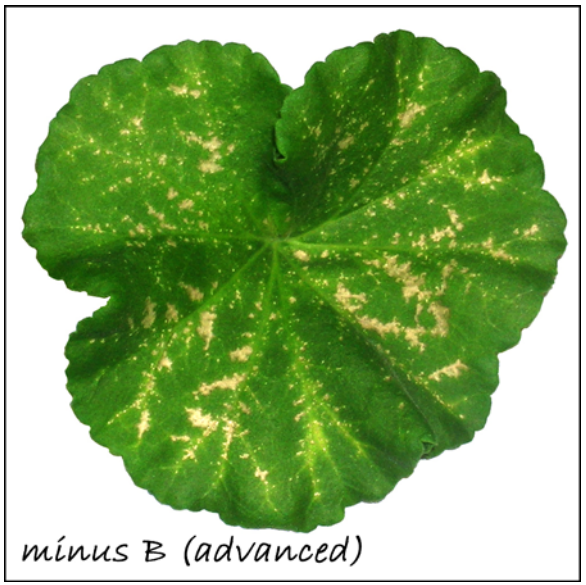
Source of zinc Fertilizers

NAME	RATE	COMMENTS
Zinc Sulfate monohydrate	13 ppm	Zinc source 36%
Zinc Sulfate heptahydrate	10 ppm	Zinc source 21%
Zinc Chloride	13 ppm	Zinc source 27%
Zinc nitrate	6 ppm	Zinc source 49%
Zinc EDTA	15 ppm	Zinc source 9-14%
Zinc HEDTA	15 ppm	Zinc source 9%

notes

Boron (B)


minus B (early)


minus B (advanced)

Why do plants need boron?

Boron is required in plants for cell division, cell wall formation and stabilization, lignification, xylem differentiation, membrane integrity, auxin activity, inhibition of callose formation, nucleic acid metabolism, apical meristem function, pollination and reproduction, and counteracting the toxic effects of Aluminum. The critical B concentration varies among species, and B requirement during the developmental stage is greater than vegetative stage. Almost 90% of plant B is contained in the cell wall.


flower:
control (L)
minus B (R)

What happens when boron is not available to plants?

Like Ca, B disorders develop on the shoot and root meristem, and on young leaves. The symptoms develop on the roots 3 to 4 days earlier than the shoot. Overall, the roots are thick and short while primary roots develop thick swollen root tips with numerous short secondary roots developing close to the tip giving a “witch’s broom” symptom. 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 root and shoots. At this point, it is too late to take any correctional measures.


root:
minus B

Source of boron Fertilizers

NAME	RATE	COMMENTS
Boric acid	6 ppm	Boron source 18%
Borax	6 ppm	Boron source 15%
Solubor	6 ppm	Boron source 15%

notes

Molybdenum (Mo)

Why do plants need molybdenum?

The requirement of Molybdenum for healthy plant is only 0.1 ppm in the form of Mo(VI) and is available only at high pH (> 6.8). It is involved in the initial step of inorganic nitrate (NO_3) assimilation. Therefore, Mo is critical when nitrate is supplied rather than ammoniacal (NH_4- N) N. It is important in the biosynthesis of the phytohormone abscisic acid, which is required in drought conditions.

What happens when molybdenum is not available to plants?

Generally, the symptoms appear on the middle and older leaves with interveinal mottling and marginal chlorosis. Eventually, the symptoms progress to upward curling and necrosis of leaf margins. The symptoms are accentuated whenever nitrate-nitrogen (NO_3-N) is the sole source of N, and under such conditions, the symptoms of Mo deficiency are similar to N deficiency.

Source of molybdenum Fertilizers

NAME	RATE	COMMENTS
Ammonium molybdate	0.7 ppm	Molybdenum source 54%
Sodium molybdate	0.7 ppm	Molybdenum source 39%
Molybdic acid	0.7 ppm	Molybdenum source 53%

notes