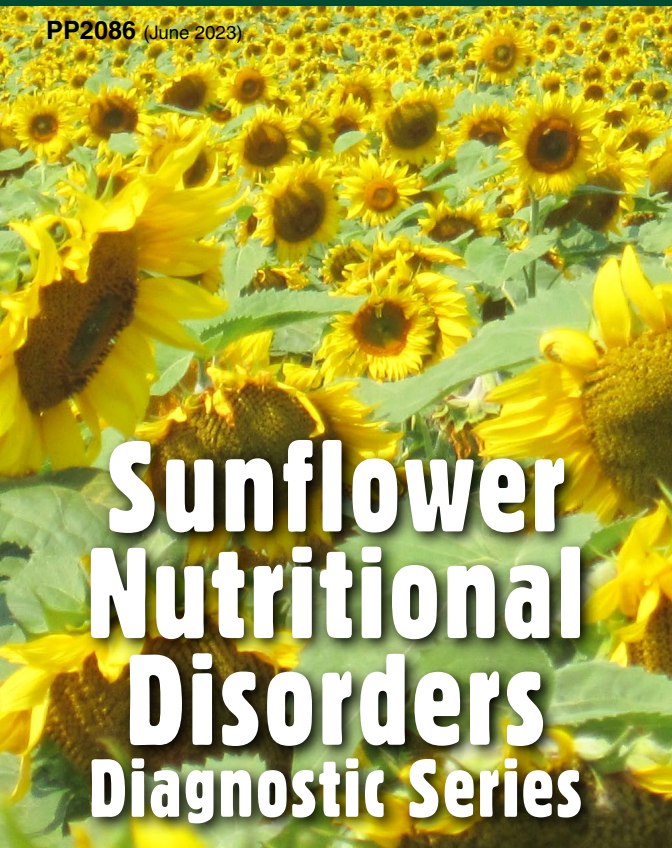
PP2086 (June 2023)



Sunflower Nutritional Disorders Diagnostic Series

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This publication was made possible by the Sunflower Pathology Working Group, and is/was supported by the USDA National Institute of Food and Agriculture, Crop Protection and Pest Management Program through the North Central IPM Center (2018-70006-28883).

This publication represents an interdisciplinary and international effort between scientists in the United States and Australia to deliver information to sunflower growers across the world. Please note, not all disorders are known to be common or occur in all growing regions or countries.

Aluminum (Al) toxicity

Figure 1

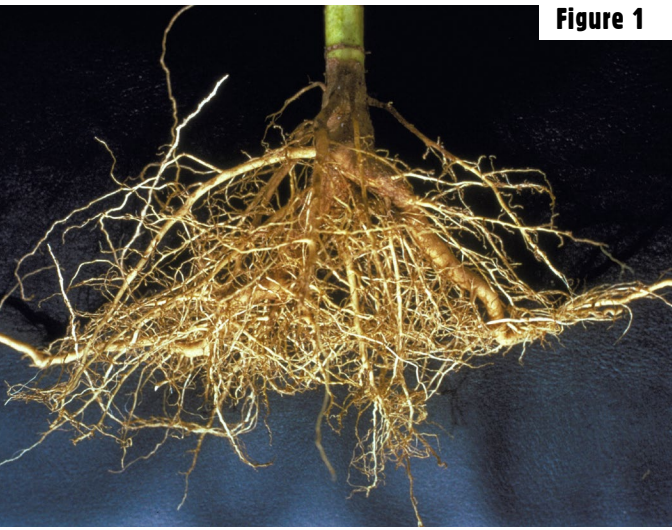

Figure 2

Aluminum (Al) toxicity

SYMPTOMS

- **Sunflower is very sensitive to high aluminum.**
- **Al toxicity may manifest itself first as patches of stunted/dead plants in a field.**
- **Emergence is poor and plants are stunted.**
- **Affected roots are short, thickened and distorted.**
- **Poor root growth decreases uptake of essential plant nutrients resulting in various deficiency symptoms, especially phosphorus (e.g., death of lower leaves).**

FIGURE 1 - Soil with high soluble Al decreases root proliferation.

FIGURE 2 - Low pH soil (foreground) with high Al. Decreased root growth results in stunted and dead plants. Dead lower leaves of remaining plants indicate P deficiency.

FACTORS FAVORING DEVELOPMENT

- Toxicity occurs on acid (< pH 5.0), highly weathered soils, and soils acidified by long-term nitrogen (N) fertilizer use.
- Toxicity occurs in both temperate and tropical regions.

IMPORTANT FACTS

- Sunflower is more sensitive to Al than many other crops.

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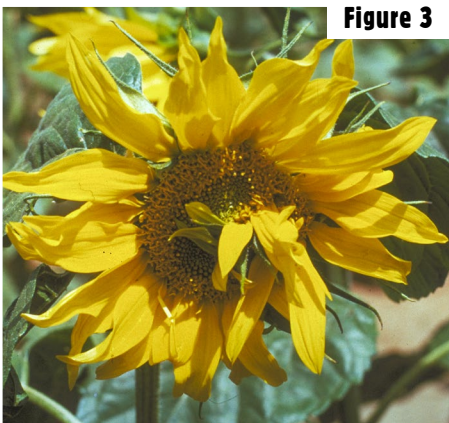
Boron (B) deficiency

Figure 1

Figure 2

Figure 3



Boron (B) deficiency

SYMPTOMS

- **B-deficient plants are initially darker green and stunted.**
- **Leaves progressively become smaller, and upper leaves become puckered and deformed.**
- **Grey-brown streaks may develop on upper stems and capitula.**
- **Buds may abort, or heads will display hypertrophy (petals forming in center of head), resulting in poor and uneven seed set.**
- **Stems may snap off just below head.**

FIGURE 1 - Leaf puckering/distortion evident on young plants

FIGURE 2 - Discoloration of stem below a head

FIGURE 3 - B-deficient plants have petals in center of heads

FACTORS FAVORING DEVELOPMENT

- Boron deficiency is most likely on leached acid soils.
- Dry conditions favor the appearance of symptoms, which may disappear after rain.

IMPORTANT FACTS

- B deficiency is a common micronutrient deficiency.
- Symptomatic sunflower plants are indicators of boron deficient soils.
- Borax is a useful treatment for B-deficient potted sunflower plants.
- B fertilization where B is not needed can reduce yield.
- Can be confused with Tobacco Streak Virus.

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Boron (B) toxicity

Figure 1

Figure 2

Boron (B) toxicity

SYMPTOMS

- **Excess boron causes chlorosis and necrosis of marginal and interveinal areas of older leaves.**

FIGURE 1 - High B supply in the root environment initially results in distinct marginal chlorosis and necrosis (left) that spread with increasing severity to the interveinal areas (right).

FIGURE 2 - Spraying with a solution of B can result in a distinct pale brown necrosis.

FACTORS FAVORING DEVELOPMENT

- Sunflower is relatively tolerant of high B in the root environment but may suffer from B toxicity in situations where excess B fertilizer has been applied.
- Attempts to overcome B deficiency with a B foliar spray may result in leaf burning.

IMPORTANT FACTS

- Sunflower is unlikely to suffer from B toxicity.
- There is a fine line between meeting B requirements and B toxicity in sunflower.
- B is not mobile in plants, so tissue analysis should come from upper leaves.
- Because B is mobile in the soil, plants can recover from B toxicity with rainfall or irrigation.

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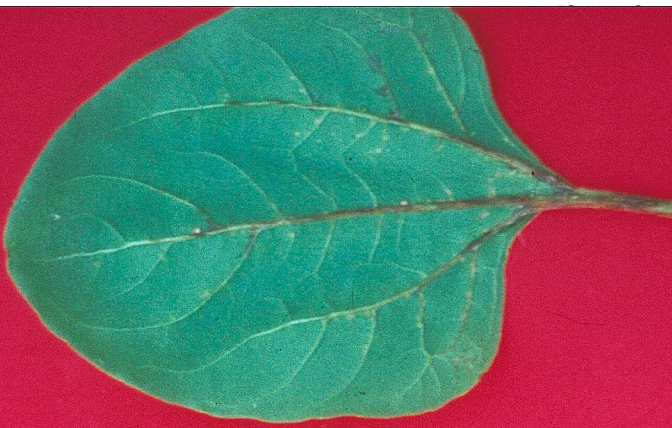
Calcium (Ca) deficiency

Figure 1

Figure 2



Calcium (Ca) deficiency

SYMPTOMS

- **Symptoms appear on both younger and older leaves.**
- **Ca deficiency slows expansion of young leaves which appear crinkled or wilted.**
- **Darkened areas of petioles and major veins on underside of older leaves.**

FIGURE 1 - A deficiency of Ca limits the expansion of young leaves that appear crinkled.

FIGURE 2 - Young leaves are small and wilted with upward cupping and bronzing.

FIGURE 3 - Low Ca in older leaves results in darkened areas of petioles and major veins.

FACTORS FAVORING -DEVELOPMENT

- Ca deficiency limits plant growth in acid soils, especially those that are sandy and highly leached.

IMPORTANT FACTS

- Acid soils are often low in Ca, plus magnesium (Mg) and potassium (K), resulting in poor plant growth.
- Addition of magnesium (Mg) or potassium (K) may induce Ca deficiency.

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Copper (Cu) deficiency

Figure 1

Copper (Cu) deficiency

SYMPTOMS

- **Cu deficiency causes a reduction in stem elongation.**
- **Fully expanded, older leaves remain dark green and shiny and become cupped.**
- **Emerging young leaves are severely crinkled, thickened and are grey-green.**
- **The roots of potted plants become excessively branched.**

FIGURE 1 - Severe crinkling and thickening of newly-emerged leaves

FACTORS FAVOURING DEVELOPMENT

- Cu is immobile in soil and can become unavailable for plant uptake in dry soils.
- Heavy applications of lime or nitrogen (N) can induce Cu deficiency.
- Coarse-textured, low organic matter soils can produce Cu deficiency.

IMPORTANT FACTS

- Cu deficiency is very rare in sunflowers.
- Consider Cu deficiency as being possible if it shows up in more sensitive crops, such as wheat.

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Iron (Fe) deficiency

Figure 1

Figure 2

Iron (Fe) deficiency

SYMPTOMS

- **Symptoms seldom occur in the field, but may be seen in plants grown in liquid solution culture.**
- **Initial symptoms appear in young leaves as a pale yellow, interveinal chlorosis.**
- **Severe Fe deficiency results in leaf distortion and leaf necrosis.**

FIGURE 1 - Older leaves remain green while young leaves exhibit increasing chlorosis.

FIGURE 2 - Young leaves of older plants show a pale interveinal chlorosis.

FACTORS FAVORING DEVELOPMENT

- Sunflower has the ability to decrease soil pH, i.e., increase acidity, thereby increasing the solubility of Fe oxides to improve plant availability.
- Some hybrids/breeding lines are more prone to Fe deficiency than others.

IMPORTANT FACTS

- Fe deficiency is unlikely in field-grown plants
- FeEDDHA or FeHBED are the preferred iron fertilizers for soil application in the field.
- The addition of Fe chelates can correct Fe deficiency in potted plants.

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Magnesium (Mg) deficiency

Figure 1

Figure 2

Figure 3

Magnesium (Mg) deficiency

SYMPTOMS

- **Initial symptoms include a mild mottled chlorosis, followed by bronzing and downward cupping of older leaves.**
- **Symptoms are more severe on older than younger leaves.**
- **As Mg deficiency increases, older leaves often develop marked interveinal chlorosis and necrotic margins.**

FIGURE 1 - Severity of Mg deficiency (interveinal chlorosis and necrotic margins) is most severe on older/lower leaves.

FIGURE 2 - A pale mottled chlorosis is visible between the major veins during the early stages of Mg deficiency.

FIGURE 3 - Bronzing and cupping of older leaves is a symptom of severe Mg deficiency.

FACTORS FAVORING DEVELOPMENT

- Mg deficiency is most likely on acid infertile soils and soils overfertilized with calcium (Ca) or phosphorus (P).

IMPORTANT FACTS

- Mg deficiency is prevented by use of Mg fertilizers or liming with dolomitic limestone.

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Manganese (Mn) deficiency

Figure 1

Manganese (Mn) deficiency

SYMPTOMS

- **Mn-deficient plants usually have thin, spindly stems.**
- **Initially, younger leaves of plants with Mn deficiency have small chlorotic spots that do not coalesce (merge).**
- **With increasing severity, the small chlorotic spots turn into pale brown necrotic spots surrounded by a yellow ring/halo.**
- **Young and recently matured leaves also develop an upward curling of the leaf margins.**

FIGURE 1 - Small chlorotic spots develop on younger leaves of plants with Mn deficiency and become necrotic surrounded by chlorotic areas.

FACTORS FAVORING DEVELOPMENT

- High pH decreases plant-available Mn in soils.

IMPORTANT FACTS

- A deficiency of Mn is likely in alkaline soils, even though there may be high Mn levels in the soil.
- Iron fertilizers like FeEDDHA can reduce Mn uptake when Mn supply is marginal.

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Manganese (Mn) toxicity

Figure 1

Figure 2

Figure 3

Figure 4

Manganese (Mn) toxicity

SYMPTOMS

- **Excess Mn uptake causes stunting along with marginal chlorosis and distortion of older and younger leaves.**
- **Severe Mn toxicity results in marked leaf crinkling and mottled chlorosis and pale brown necrosis.**
- **Minute dark spots develop initially on lower leaves, petioles and stems.**

FIGURE 1 - Chlorosis around the major veins and leaf distortion are symptoms of Mn toxicity.

FIGURE 2 - Small dark spots on stems are signs of Mn accumulation.

FIGURE 3 - Severe Mn toxicity.

FIGURE 4 - Small dark spots on lower leaves, stem and petioles are a sign of high Mn accumulation.

FACTORS FAVORING DEVELOPMENT

- Although many soils contain large amounts of oxidized Mn, it is not directly available to plants.
- However, if soils become acidic or waterlogged, Mn oxides are converted to high concentrations of plant-available Mn that may be toxic.

IMPORTANT FACTS

- Sunflower is moderately tolerant of high Mn in the root environment.
- The small dark spots in sunflower may be used as an indicator of high Mn availability in soil.

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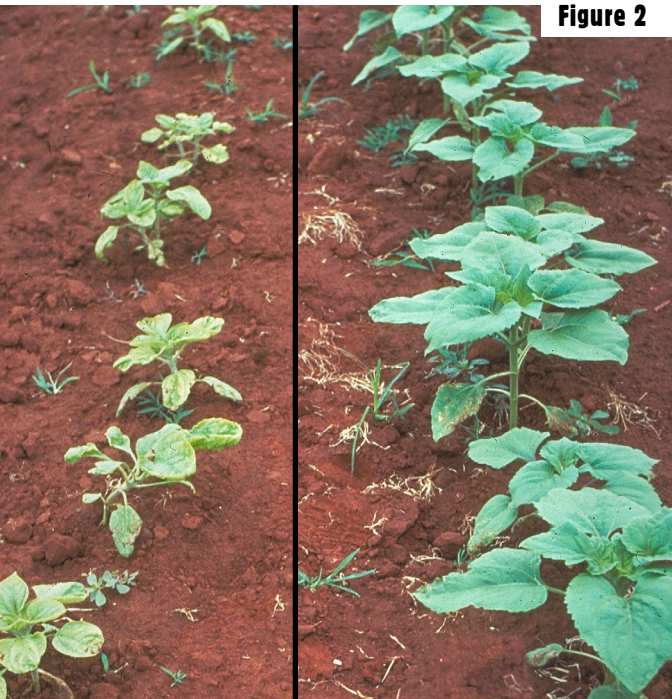
Molybdenum (Mo) deficiency

Figure 1

Figure 2



Molybdenum (Mo) deficiency

SYMPTOMS

- **Symptoms occur in young seedlings, often within a few days of emergence.**
- **Seedlings have upward cupped leaves that are chlorotic, especially between the major veins.**
- **In severe instances, leaf margins turn necrotic.**
- **Mo is easily translocated and symptoms are seen on the entire plant.**

FIGURE 1 - Mo-deficient young plant with leaves that cup upwards and have severe interveinal chlorosis

FIGURE 2 - Poor growth and chlorosis in Mo-deficient seedlings (left) compared to those with sufficient Mo (right)

FACTORS FAVORING DEVELOPMENT

- Acid soils may have low plant-available Mo, resulting in seedlings with Mo deficiency.

IMPORTANT FACTS

- Seeds produced from plants low in Mo may have insufficient Mo to produce healthy seedlings when grown on acid soils.
- Seedlings deficient in Mo may recover through increased root proliferation that enhances Mo absorption.
- Mo is associated with nitrogen (N) metabolism in the plant, so Mo-deficient plants exhibit symptoms of N deficiency.

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Nitrogen (N) deficiency

Figure 1

Figure 2

Nitrogen (N) deficiency

SYMPTOMS

- **N deficiency may occur in plants of all ages.**
- **A general chlorosis of leaves is the most characteristic symptom of N deficiency.**
- **Older leaves often become increasingly yellow and develop a marginal pale-yellow to light-brown necrosis.**
- **N deficiency may result in young seedlings with thin, elongated stems and small, pale leaves.**

FIGURE 1 - Chlorosis increases due to a more severe N deficiency in the root environment with the lower leaves especially affected.

FIGURE 2 - Chlorosis and marginal necrosis are most severe on the older/lower leaves.

FACTORS FAVORING DEVELOPMENT

- N deficiency is a common limitation to plant growth in most field crops.
- Low N supply is often the most limiting factor for plant growth.
- Prolonged waterlogging, or leaching, can induce N deficiency.

IMPORTANT FACTS

- Early N deficiency results in low seed set and yield, even if adequate N fertilizer is applied after symptoms appear.

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Phosphorus (P) deficiency

Figure 1

Figure 2

Figure 3

Phosphorus (P) deficiency

SYMPTOMS

- **Localized and dark gray necrosis of older leaves is the most characteristic symptom.**
- **Older leaves die as P deficiency increases in severity.**
- **P-deficient plants are stunted and heads are smaller.**

FIGURE 1 - P deficiency (foreground) compared to applied P fertilizer (background) may result initially in poor growth with no other visible symptoms.

FIGURE 2 - Increased P demand as the plants mature results in necrosis on older leaves.

FIGURE 3 - Stunted, P-deficient plants (left) and healthy plants

FACTORS FAVORING DEVELOPMENT

- P deficiency is a common limitation to plant growth in most field crops.

IMPORTANT FACTS

- Aluminum (Al) toxicity in acid soils decreases root growth that may result in visible P deficiency symptoms.
- Necrotic lesions on leaves can look like Alternaria leaf spot and Septoria leaf spot.

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Phosphorus (P) toxicity

Figure 1

Phosphorus (P) toxicity

SYMPTOMS

- **Older leaves develop a pale brown necrosis in the interveinal areas of older leaves when there is excess P in solution.**

FIGURE 1 - High P in solution results in distinct necrosis (but no chlorosis) between the major veins while the remainder of the leaf remains healthy

FACTORS FAVORING DEVELOPMENT

- Sunflower is relatively tolerant of high P in the root environment but may suffer from boron (B) toxicity in situations where excess P fertilizer has been applied.

IMPORTANT FACTS

- Sunflower plants are only likely to show symptoms of P toxicity when grown in pots and/or under glasshouse conditions when excess P fertilizer has been added.

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Potassium (K) deficiency

Figure 1

Figure 2

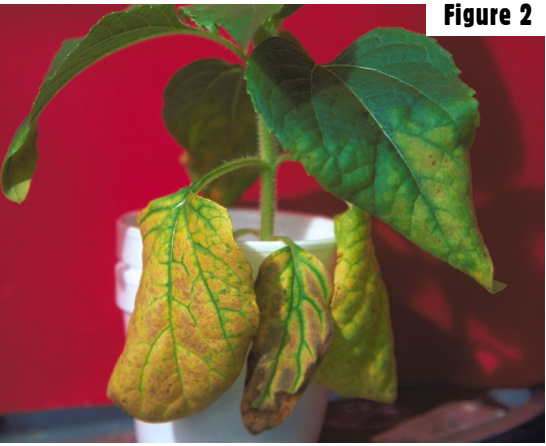

Figure 3

Potassium (K) deficiency

SYMPTOMS

- **Early symptoms appear as interveinal chlorosis on edges of older leaves.**
- **Results in chlorosis spreading between major veins towards the midrib.**
- **Pale brown necrosis follows marginal chlorosis.**
- **Younger leaves remain healthy even with severe K deficiency.**
- **Affected plants are stunted.**

FIGURE 1 - Inadequate K supply greatly decreases plant growth with marginal chlorosis evident on older leaves (left) compared to a healthy plant (right).

FIGURE 2 - Interveinal chlorosis and marginal necrosis of older leaves.

FIGURE 3 - Severe interveinal chlorosis.

FACTORS FAVORING DEVELOPMENT

- K deficiency is a common limitation to plants grown on infertile soils.
- K is readily leached from sandy soils in regions of high rainfall.

IMPORTANT FACTS

- Plants require a high supply of K for healthy growth.

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Salinity – Sodium Chloride (NaCl)

Figure 1

Figure 2

Salinity – Sodium Chloride (NaCl)

SYMPTOMS

- **Initial symptoms of high NaCl include poor growth and upward cupping of leaves.**
- **In older seedlings, high salinity in the root environment results in marginal necrosis especially on older leaves.**

FIGURE 1 - Response of sunflower seedlings (left to right) to increasing application of NaCl (0, 1, 2, 4, 8 and 16 t/ha) to a Vertosol soil.

FIGURE 2 - High NaCl in the root environment results in a light brown marginal necrosis and mild interveinal chlorosis especially on older leaves.

FACTORS FAVORING DEVELOPMENT

- Adverse effects of high salinity are likely to occur in regions of low rainfall and in alkaline soils of high pH.

IMPORTANT FACTS

- The numerous individual factors that cause detrimental salinity effects include high sodium (Na), magnesium (Mg), calcium (Ca) and chloride (Cl).
- Sunflower is more tolerant of high saline soils than most other field crops.
- Sodicity is caused by high levels of Na, which can cause the degradation of soil structure.

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Salinity – High Sodium Sulfate (Na_2SO_4)

Figure 1

Figure 2

Salinity – High Sodium Sulfate (Na_2SO_4)

SYMPTOMS

- **In older seedlings, high Na_2SO_4 in the root environment results in chlorosis and a pale brown necrosis of interveinal areas especially on older leaves.**

FIGURE 1 - Response of sunflower seedlings (left to right) to increasing application of Na_2SO_4 (0, 1, 2, 4, 8 and 16 t/ha) to a Vertosol soil.

FIGURE 2 - High Na_2SO_4 in the root environment results in leaf distortion along with interveinal chlorosis and a light brown necrosis especially on older leaves.

FACTORS FAVORING DEVELOPMENT

- Adverse effects of high salinity are likely to occur in regions of low rainfall and in alkaline soils of high pH.

IMPORTANT FACTS

- The numerous individual factors that cause detrimental salinity effects include high sodium (Na), magnesium (Mg), calcium (Ca) and chloride (Cl).
- Sunflower is more tolerant of high saline soils than most other field crops.
- Sodicity is caused by high levels of Na which can cause the degradation of soil structure.

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Sulfur (S) deficiency

Figure 1

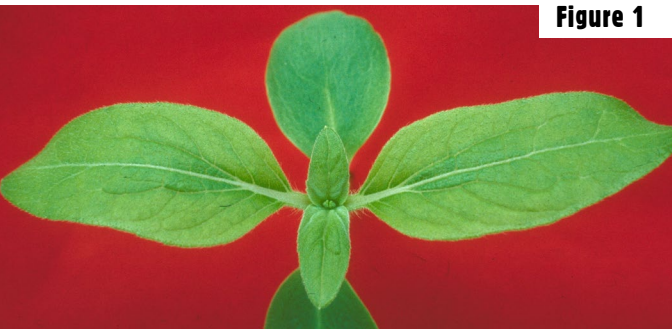

Figure 2

Sulfur (S) deficiency

SYMPTOMS

- **S deficiency occurs in plants of all ages.**
- **In seedlings, the main symptom is an interveinal chlorosis of young leaves with no leaf distortion.**
- **In older plants, S deficiency causes stunting and spindly growth, and leaves are chlorotic with necrotic leaf margins.**

FIGURE 1 - A pale general chlorosis of the first true leaves is visible during the early stages of S deficiency in a young seedling.

FIGURE 2 - S deficiency (left) results in a stunted, chlorotic plant compared to a plant with adequate S (right).

FACTORS FAVORING DEVELOPMENT

- S deficiency occurs in soils with low organic matter and sulfur-leached soils.

IMPORTANT FACTS

- S deficiency is difficult to diagnose because the mild chlorosis which occurs across the field may be caused by other abiotic factors.
- If uncertain, a plant tissue analysis can differentiate between nitrogen (N) and S deficiency.

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Zinc (Zn) deficiency

Figure 1

Figure 2

Zinc (Zn) deficiency

SYMPTOMS

- **Initial symptoms are small, thin leaves that otherwise appear healthy at the growing point.**
- **Chlorosis of youngest leaves may occur as Zn deficiency intensifies, followed by sudden wilting and bronzing.**

FIGURE 1 - Zn deficiency initially results in small thin leaves at the growing point.

FIGURE 2 - Sudden wilting and bronzing of younger leaves occurs with increasingly severe Zn deficiency.

FACTORS FAVORING DEVELOPMENT

- High pH decreases plant available Zn in soils.

IMPORTANT FACTS

- A deficiency of Zn is likely in alkaline soils even though they may be high in total Zn.
- High applications of lime to acid soils may induce Zn deficiency.

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Diagnostic Key

A key to the diagnosis of symptoms on leaves and stems of nutritional disorders in sunflower.

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SYMPTOMS	DISORDER
SYMPTOMS ON LOWER LEAVES	
Chlorosis (yellowing)	
Leaves generally pale-green to yellow, marginal, pale necrosis; upper leaves may be pale-green	Nitrogen (N) deficiency
Interveinal chlorosis evident especially near margins, upward and downward, leaf cupping, later necrosis of chlorotic areas; upper leaves dark green	Potassium (K) deficiency
Pale interveinal chlorosis with area beside veins remaining green, some mottled chlorosis, downward leaf cupping, necrosis between major veins	Magnesium (Mg) deficiency
Marginal necrosis of lower leaves, some chlorosis between major veins	Salinity - Sodium chloride (NaCl)
No chlorosis, or chlorosis not prominent	
Plant growth reduced, interveinal grey necrosis follows appearance of water-soaked areas, mimics biotic disease infection, some chlorosis may be present	Phosphorus (P) deficiency
Marginal and later interveinal indistinct chlorosis which becomes necrotic, necrotic areas are dark grey surrounded by darker (almost black) border, leaves dark green	Boron (B) toxicity
Interveinal, straw-colored to light-brown necrosis	Phosphorus (P) toxicity

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SYMPTOMS	DISORDER
SYMPTOMS ON UPPER LEAVES	
Chlorosis (yellowing)	
Chlorosis pale, almost white, veins green, straw-colored to brown necrosis, leaves distorted	Iron (Fe) deficiency
Yellow chlorosis, veins green, necrosis at the point of petiole attachment to stem	Zinc (Zn) toxicity
General chlorosis with small, pale chlorotic spots, small necrotic spots which generally do not coalesce	Manganese (Mn) deficiency
No chlorosis, or chlorosis not prominent	
Leaves hard and leathery, dark-brown necrosis, stems corky and brittle, capitula deformed, irregular seed set	Manganese (Mn) deficiency
Very youngest leaves distorted and highly pubescent, slightly older leaves shiny and cupped upwards	Boron (B) deficiency
Reduced leaf width, margin wavy, wilting, brown necrotic areas	Copper (Cu) deficiency
SYMPTOMS ON BOTH UPPER AND LOWER LEAVES	
Chlorosis (yellowing)	
Pale, general chlorosis of all leaves, some mottled chlorosis, no necrosis, upper leaves may be more affected	Sulfur (S) deficiency
Pale, general chlorosis of seedlings, leaves cupped upwards, seedling death	Molybdenum (Mo) deficiency
Veinal chlorosis (strikingly yellow) and distortion of expanding leaves, small black spots on trichomes of lower leaf blades and petioles and of the lower stem; dark, angular necrosis on lower leaves	Manganese (Mn) toxicity
No chlorosis, or chlorosis not prominent	
Pale necrosis of interveinal area of upper leaves, upper leaves distorted, pale marginal necrosis of lower leaves, some chlorosis may be present	Salinity - Sodium sulfate (Na_2SO_4)
Crinkling accompanied by wilting and a bronzed necrosis of recently expanded leaves, dark brown to black necrosis on petioles and major veins of lower leaves	Calcium (Ca) deficiency