

Nutrient	Plant Response to Nutrient	Deficiency Conditions in the Environment	Deficiency Symptoms of the Plant	Toxicity in the Plant and Environment
<b>Nitrogen (N)</b>	<ul style="list-style-type: none"> <li>• Influences color, shoot growth, shoot density, root growth, rhizome and stolon growth, carbohydrate reserves, high temperature stress, cold tolerance, drought resistance, wear tolerance, thatch accumulation, disease susceptibility and recuperative potential</li> </ul>	<ul style="list-style-type: none"> <li>• Sandy soils</li> <li>• High leaching conditions from rainfall or irrigation</li> <li>• Low organic matter</li> <li>• Clipping removal</li> <li>• Loss by denitrification under anaerobic conditions</li> <li>• Low soil pH</li> <li>• Infertile soils</li> </ul>	<ul style="list-style-type: none"> <li>• Loss of green color (appears first on older leaves)</li> <li>• All leaves become chlorotic</li> <li>• Stunted growth</li> <li>• Lack of vigor</li> <li>• Gradual loss of leaves, tillers and eventually the entire plant</li> <li>• Thinning of turf stand</li> <li>• Decreased recuperative potential</li> <li>• Susceptible to diseases (dollar spot, anthracnose, red thread)</li> </ul>	<ul style="list-style-type: none"> <li>• Excessive growth</li> <li>• Turf is susceptible to disease and weeds</li> <li>• Prone to insect attack</li> <li>• Poor recuperative potential</li> <li>• High thatch</li> <li>• Reduced root, rhizome, tiller and stolon growth</li> <li>• Reduced heat and drought tolerance</li> </ul>
<b>Phosphorus (P)</b>	<ul style="list-style-type: none"> <li>• Involved in transfer and storage of energy for metabolic processes in turf</li> <li>• Affects seedling development, maturation, root growth and seed production</li> <li>• Needed during establishment</li> </ul>	<ul style="list-style-type: none"> <li>• Sandy, low CEC, irrigated soil</li> <li>• Acidic pH</li> <li>• High pH</li> <li>• Cold soils</li> <li>• Soil low in P content or available P</li> </ul>	<ul style="list-style-type: none"> <li>• Reduced shoot growth</li> <li>• Dark green color</li> <li>• Eventually reduced root growth</li> <li>• Reddish or purple coloration after dark green</li> <li>• Leaves become narrow and have a tendency to curl</li> </ul>	<ul style="list-style-type: none"> <li>• Toxicity is uncommon</li> </ul>
<b>Potassium (K)</b>	<ul style="list-style-type: none"> <li>• Involved in photosynthesis</li> <li>• Important in the regulation of stomates and internal water management</li> </ul>	<ul style="list-style-type: none"> <li>• High rainfall or irrigation</li> <li>• Sandy or low CEC soils</li> <li>• Acidic soil</li> <li>• High inputs of Ca, Mg, or Na</li> </ul>	<ul style="list-style-type: none"> <li>• Interveinal yellowing of older leaves</li> <li>• Dieback at leaf tip</li> <li>• Scorching or firing of margins</li> <li>• Total yellowing of leaf blade</li> </ul>	<ul style="list-style-type: none"> <li>• Excess K can cause salinity</li> <li>• High K can suppress Mg, Ca, or Mn uptake</li> <li>• Excess K can cause fertilizer burn</li> </ul>

	<ul style="list-style-type: none"> <li>• Maintain turgor pressure in plants</li> <li>• Affect root growth, heat, cold and drought tolerance, wear tolerance, disease susceptibility, and environmental stress resistance</li> </ul>	<ul style="list-style-type: none"> <li>• Clipping removal</li> <li>• High N fertilization</li> </ul>	<ul style="list-style-type: none"> <li>• Plant may appear weak and spindly</li> <li>• Stomatal control mechanism becomes less efficient and evapotranspiration increases</li> <li>• Increased potential for low temperature injury</li> <li>• Poor tolerance to traffic, high and low temperature extremes, stress, drought, and disease</li> </ul>	
<b>Calcium (Ca)</b>	<ul style="list-style-type: none"> <li>• Aids in cell wall structure and new cell formation</li> <li>• Stimulates root and leaf development</li> </ul>	<ul style="list-style-type: none"> <li>• Acidic pH on low CEC soils with high leaching</li> <li>• High sodium levels</li> </ul>	<ul style="list-style-type: none"> <li>• Very rare to be deficient</li> <li>• Distorted appearance of new leaves</li> <li>• Reddish brown to rose leaf blades</li> <li>• Leaf tips and margins may wither and die</li> <li>• Roots may be stunted and discolored</li> <li>• Reduction in cell wall formation and stability</li> <li>• Influences disease susceptibility</li> </ul>	<ul style="list-style-type: none"> <li>• High soil Ca may cause Mg, K, Mn, or Fe deficiencies</li> </ul>
<b>Magnesium (Mg)</b>	<ul style="list-style-type: none"> <li>• Involved in formation of proteins</li> <li>• Found in chlorophyll molecule</li> <li>• Improves P uptake from soil</li> <li>• Aids in plant respiration</li> </ul>	<ul style="list-style-type: none"> <li>• Acidic pH on low CEC soils</li> <li>• Soil subject to leaching</li> <li>• High addition of Ca</li> <li>• High addition of Na and soils with naturally high Na</li> <li>• High K fertilization</li> </ul>	<ul style="list-style-type: none"> <li>• Deficiencies are uncommon</li> <li>• Loss of green color on older leaves</li> <li>• Color goes from pale green to cherry red</li> <li>• Leaf margins blotchy red</li> <li>• Leaf veins remain green and some light yellow striping</li> </ul>	<ul style="list-style-type: none"> <li>• High Mg can induce K, Mn, or Ca deficiencies</li> </ul>

		<ul style="list-style-type: none"> <li>• High leaching condition</li> </ul>	<p>may occur between veins</p> <ul style="list-style-type: none"> <li>• Leaves start to die</li> </ul>	
<b>Sulfur (S)</b>	<ul style="list-style-type: none"> <li>• Involved with formation of proteins</li> <li>• Helps with turf growth, green color, shoot growth and density, root growth, carbohydrate reserves, and disease susceptibility</li> </ul>	<ul style="list-style-type: none"> <li>• Sandy soils subject to leaching</li> <li>• High rainfall and leaching conditions</li> <li>• Areas not receiving atmospheric S</li> <li>• Associated with high N use and removal of clippings</li> <li>• Low soil OM content</li> </ul>	<ul style="list-style-type: none"> <li>• Reduced shoot growth rate</li> <li>• Yellowing of new leaves with tip and margins showing symptoms first</li> <li>• In older leaves, chlorosis in the interveinal areas</li> <li>• High N makes turf more susceptible to S deficiency</li> <li>• Greater susceptibility to wear damage because of reduced growth</li> </ul>	<ul style="list-style-type: none"> <li>• High foliar or granular rates of S lead to foliar burn</li> <li>• Excessive acidity</li> <li>• Excess S can lead to black layer and anaerobic conditions</li> </ul>
<b>Iron (Fe)</b>	<ul style="list-style-type: none"> <li>• Improves color, shoot growth and density, root growth, carbohydrate reserves, heat, cold and drought hardiness, and wear tolerance</li> <li>• Darker leaf color without stimulating growth like N</li> <li>• Improved frost resistance</li> <li>• Reduced dehydration in winter</li> </ul>	<ul style="list-style-type: none"> <li>• Cultivars susceptible to Fe deficiency</li> <li>• More likely at a high pH</li> <li>• Poor rooting or root viability</li> <li>• Excess thatch</li> <li>• Cold, wet soils</li> <li>• Presence of high P especially at high pH's</li> <li>• High pH calcareous soils in arid regions</li> <li>• Low OM soils</li> </ul>	<ul style="list-style-type: none"> <li>• Immobile in plant and can be seen in young leaves</li> <li>• Leaves turn pale yellow to white</li> <li>• Thin, spindly growth</li> <li>• Older leaves exhibit chlorosis</li> </ul>	<ul style="list-style-type: none"> <li>• High Fe can blacken leaves</li> <li>• Some grasses are sensitive to iron</li> <li>• High iron can cause Mn deficiency</li> <li>• Acidic poorly drained soils can produce toxic levels of Fe</li> <li>• Poorly drained or anaerobic soil conditions and Fe reacts with S to cause black layer</li> </ul>
<b>Manganese (Mn)</b>	<ul style="list-style-type: none"> <li>• Required for formation of chlorophyll</li> <li>• Influences photosynthesis and rate</li> </ul>	<ul style="list-style-type: none"> <li>• High pH soils and calcareous soils</li> <li>• Acid, heavily leached sand or peat soils</li> </ul>	<ul style="list-style-type: none"> <li>• Decrease in photosynthesis, chlorophyll content, shoot/root growth</li> <li>• Small distinct greenish-gray</li> </ul>	<ul style="list-style-type: none"> <li>• Acid soils</li> <li>• Anaerobic soils</li> <li>• High Mn can cause Fe, Mg, or Ca</li> </ul>

	<ul style="list-style-type: none"> <li>of growth</li> <li>Helps with resistance to some diseases</li> </ul>	<ul style="list-style-type: none"> <li>Dry, warm weather</li> </ul>	<ul style="list-style-type: none"> <li>spots on leaves</li> <li>Chlorosis on younger leaves because Mn is immobile in the plant</li> <li>Interveinal yellowing with veins green to light green</li> <li>Leaf tips can turn white and exhibit drooping or withering</li> <li>Turf stand may appear mottled and not respond to N fertilization</li> </ul>	<ul style="list-style-type: none"> <li>deficiencies</li> <li>Plants may tolerate Mn toxicity at high temperatures</li> </ul>
<b>Zinc (Zn)</b>	<ul style="list-style-type: none"> <li>Enzyme activation</li> <li>Protein synthesis</li> <li>Carbohydrate metabolism</li> </ul>	<ul style="list-style-type: none"> <li>Alkaline soils</li> <li>High levels of Fe, Cu, Mn, P, N</li> <li>High soil moisture</li> <li>Cool, wet weather and low light intensity</li> <li>Highly weathered, acid, coarse textured soils</li> </ul>	<ul style="list-style-type: none"> <li>Rarely deficient</li> <li>Chlorotic leaves with some mottling</li> <li>Stunted leaves</li> <li>Leaf margins may roll or appear crinkled</li> <li>Symptoms first appear on young leaves</li> </ul>	<ul style="list-style-type: none"> <li>Mine spoils and municipal waste may be high in Zn</li> <li>Cause chlorosis by inducing Fe or Mg deficiencies</li> </ul>
<b>Copper (Cu)</b>	<ul style="list-style-type: none"> <li>Needed in photosynthesis</li> <li>Involved in respiration</li> </ul>	<ul style="list-style-type: none"> <li>Organic soils</li> <li>Heavily leached sands</li> <li>High levels of Fe, Mn, Zn, P, and N</li> <li>High pH</li> </ul>	<ul style="list-style-type: none"> <li>Appear on youngest to middle leaves</li> <li>Yellowing and chlorosis of leaf margins</li> <li>Bluish leaf tips that will turn yellow and die</li> <li>Stunted growth with leaves rolling or twisting</li> </ul>	<ul style="list-style-type: none"> <li>Sewage, industrial sludges, mine spoils, pig/poultry manure</li> <li>High Cu materials</li> </ul>
<b>Boron (B)</b>	<ul style="list-style-type: none"> <li>Used in cell walls and plasma membrane</li> <li>Affect root cell elongation</li> </ul>	<ul style="list-style-type: none"> <li>High pH</li> <li>Leached, calcareous, sandy soils</li> <li>High Ca can restrict B availability</li> </ul>	<ul style="list-style-type: none"> <li>Slowed growth</li> <li>Younger leaves have leaf tip chlorosis</li> <li>Interveinal chlorosis of young and older leaves and curling</li> </ul>	<ul style="list-style-type: none"> <li>More likely toxicity than deficiency</li> <li>Irrigation water</li> <li>Soils naturally high in B</li> </ul>

		<ul style="list-style-type: none"> <li>• Dry soils</li> <li>• High K may increase B deficiency on low B soils</li> </ul>	<ul style="list-style-type: none"> <li>• of leaves</li> <li>• Roots may be stunted and thickened</li> <li>• Plants are stunted and appear bushy or as a rosette</li> <li>• Accumulated in leaf tips</li> </ul>	<ul style="list-style-type: none"> <li>• Overapplication of B</li> <li>• Compost amendments</li> </ul>
<b>Molybdenum (Mb)</b>	<ul style="list-style-type: none"> <li>• Required for structural functions</li> </ul>	<ul style="list-style-type: none"> <li>• Acid, sandy soils</li> <li>• Acid soils high in Fe and Al oxides</li> <li>• High levels of Cu, Mn, Fe, S suppress uptake</li> </ul>	<ul style="list-style-type: none"> <li>• Mobile in plant</li> <li>• Similar to N deficiency - chlorosis of older leaves and stunted growth</li> </ul>	<ul style="list-style-type: none"> <li>• High pH soils</li> <li>• Wet soils</li> </ul>
<b>Chlorine (Cl)</b>	<ul style="list-style-type: none"> <li>• Stimulates photosynthesis</li> <li>• Involved in nutrient balance in plant cells</li> </ul>	<ul style="list-style-type: none"> <li>• Suppressed by high NO<sub>3</sub> and SO<sub>4</sub></li> </ul>	<ul style="list-style-type: none"> <li>• Rarely deficient</li> <li>• Chlorosis of new leaves</li> <li>• Wilting (especially at leaf margins)</li> <li>• Leaf curling and eventually necrosis</li> <li>• Stunted shoot and root growth</li> </ul>	<ul style="list-style-type: none"> <li>• Can be directly toxic to leaf tissues and roots because it's a salt</li> <li>• Reduces water availability by enhancing total salinity</li> </ul>
<b>Nickel (Ni)</b>	<ul style="list-style-type: none"> <li>• Part of enzymes</li> </ul>	<ul style="list-style-type: none"> <li>• Not clear because it is very rare</li> </ul>	<ul style="list-style-type: none"> <li>• Chlorosis as interveinal yellowing and eventually necrosis</li> <li>• Failure of leaf tip to unfold</li> </ul>	<ul style="list-style-type: none"> <li>• Use of high Ni industrial or sewage sludge</li> </ul>