Nutrient	Plant Response to Nutrient	Deficiency Conditions in the Environment	Deficiency Symptoms of the Plant	Toxicity in the Plant and Environment
Nitrogen (N)	• 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	• Sandy soils • High leaching conditions from rainfall or irrigation • Low organic matter • Clipping removal • Loss by denitrification under anaerobic conditions • Low soil pH • Infertile soils	• Loss of green color (appears first on older leaves) • All leaves become chlorotic • Stunted growth • Lack of vigor • Gradual loss of leaves, tillers and eventually the entire plant • Thinning of turf stand • Decreased recuperative potential • Susceptible to diseases (dollar spot, anthracnose, red thread)	• Excessive growth • Turf is susceptible to disease and weeds • Prone to insect attack • Poor recuperative potential • High thatch • Reduced root, rhizome, tiller and stolon growth • Reduced heat and drought tolerance
Phosphorus (P)	• Involved in transfer and storage of energy for metabolic processes in turf • Affects seedling development, maturation, root growth and seed production • Needed during establishment	• Sandy, low CEC, irrigated soil • Acidic pH • High pH • Cold soils • Soil low in P content or available P	• Reduced shoot growth • Dark green color • Eventually reduced root growth • Reddish or purple coloration after dark green • Leaves become narrow and have a tendency to curl	• Toxicity is uncommon
Potassium (K)	• Involved in photosynthesis • Important in the regulation of stomates and internal water management	• High rainfall or irrigation • Sandy or low CEC soils • Acidic soil • High inputs of Ca, Mg, or Na	• Interveinal yellowing of older leaves • Dieback at leaf tip • Scorching or firing of margins • Total yellowing of leaf blade	• Excess K can cause salinity • High K can suppress Mg, Ca, or Mn uptake • Excess K can cause fertilizer burn

	• Maintain turgor pressure in plants • Affect root growth, heat, cold and drought tolerance, wear tolerance, disease susceptibility, and environmental stress resistance	• Clipping removal • High N fertilization	• Plant may appear weak and spindly • Stomatal control mechanism becomes less efficient and evapotranspiration increases • Increased potential for low temperature injury • Poor tolerance to traffic, high and low temperature extremes, stress, drought, and disease	
Calcium (Ca)	• Aids in cell wall structure and new cell formation • Stimulates root and leaf development	• Acidic pH on low CEC soils with high leaching • High sodium levels	• Very rare to be deficient • Distorted appearance of new leaves • Reddish brown to rose leaf blades • Leaf tips and margins may wither and die • Roots may be stunted and discolored • Reduction in cell wall formation and stability • Influences disease susceptibility	• High soil Ca may cause Mg, K, Mn, or Fe deficiencies
Magnesium (Mg)	• Involved in formation of proteins • Found in chlorophyll molecule • Improves P uptake from soil • Aids in plant respiration	• Acidic pH on low CEC soils • Soil subject to leaching • High addition of Ca • High addition of Na and soils with naturally high Na • High K fertilization	• Deficiencies are uncommon • Loss of green color on older leaves • Color goes from pale green to cherry red • Leaf margins blotchy red • Leaf veins remain green and some light yellow striping	• High Mg can induce K, Mn, or Ca deficiencies

		• High leaching condition	may occur between veins • Leaves start to die	
Sulfur (S)	• Involved with formation of proteins • Helps with turf growth, green color, shoot growth and density, root growth, carbohydrate reserves, and disease susceptibility	• Sandy soils subject to leaching • High rainfall and leaching conditions • Areas not receiving atmospheric S • Associated with high N use and removal of clippings • Low soil OM content	• Reduced shoot growth rate • Yellowing of new leaves with tip and margins showing symptoms first • In older leaves, chlorosis in the interveinal areas • High N makes turf more susceptible to S deficiency • Greater susceptibility to wear damage because of reduced growth	• High foliar or granular rates of S lead to foliar burn • Excessive acidity • Excess S can lead to black layer and anaerobic conditions
Iron (Fe)	• Improves color, shoot growth and density, root growth, carbohydrate reserves, heat, cold and drought hardiness, and wear tolerance • Darker leaf color without stimulating growth like N • Improved frost resistance • Reduced dehydration in winter	• Cultivars susceptible to Fe deficiency • More likely at a high pH • Poor rooting or root viability • Excess thatch • Cold, wet soils • Presence of high P especially at high pH's • High pH calcareous soils in arid regions • Low OM soils	• Immobile in plant and can be seen in young leaves • Leaves turn pale yellow to white • Thin, spindly growth • Older leaves exhibit chlorosis	• High Fe can blacken leaves • Some grasses are sensitive to iron • High iron can cause Mn deficiency • Acidic poorly drained soils can produce toxic levels of Fe • Poorly drained or anaerobic soil conditions and Fe reacts with S to cause black layer
Manganese (Mn)	• Required for formation of chlorophyll • Influences photosynthesis and rate	• High pH soils and calcareous soils • Acid, heavily leached sand or peat soils	• Decrease in photosynthesis, chlorophyll content, shoot/root growth • Small distinct greenish-gray	• Acid soils • Anaerobic soils • High Mn can cause Fe, Mg, or Ca

	of growth • Helps with resistance to some diseases	• Dry, warm weather	spots on leaves • Chlorosis on younger leaves because Mn is immobile in the plant • Interveinal yellowing with veins green to light green • Leaf tips can turn white and exhibit drooping or withering • Turf stand may appear mottled and not respond to N fertilization	deficiencies • Plants may tolerate Mn toxicity at high temperatures
Zinc (Zn)	• Enzyme activation • Protein synthesis • Carbohydrate metabolism	• Alkaline soils • High levels of Fe, Cu, Mn, P, N • High soil moisture • Cool, wet weather and low light intensity • Highly weathered, acid, coarse textured soils	• Rarely deficient • Chlorotic leaves with some mottling • Stunted leaves • Leaf margins may roll or appear crinkled • Symptoms first appear on young leaves	• Mine spoils and municipal waste may be high in Zn • Cause chlorosis by inducing Fe or Mg deficiencies
Copper (Cu)	• Needed in photosynthesis • Involved in respiration	• Organic soils • Heavily leached sands • High levels of Fe, Mn, Zn, P, and N • High pH	• Appear on youngest to middle leaves • Yellowing and chlorosis of leaf margins • Bluish leaf tips that will turn yellow and die • Stunted growth with leaves rolling or twisting	• Sewage, industrial sludges, mine spoils, pig/poultry manure • High Cu materials
Boron (B)	• Used in cell walls and plasma membrane • Affect root cell elongation	• High pH • Leached, calcareous, sandy soils • High Ca can restrict B availability	• Slowed growth • Younger leaves have leaf tip chlorosis • Interveinal chlorosis of young and older leaves and curling	• More likely toxicity than deficiency • Irrigation water • Soils naturally high in B

		• Dry soils • High K may increase B deficiency on low B soils	of leaves • Roots may be stunted and thickened • Plants are stunted and appear bushy or as a rosette • Accumulated in leaf tips	• Overapplication of B • Compost amendments
Molybdenum (Mb)	• Required for structural functions	• Acid, sandy soils • Acid soils high in Fe and Al oxides • High levels of Cu, Mn, Fe, S suppress uptake	• Mobile in plant • Similar to N deficiency - chlorosis of older leaves and stunted growth	• High pH soils • Wet soils
Chlorine (Cl)	• Stimulates photosynthesis • Involved in nutrient balance in plant cells	• Suppressed by high NO3 and SO4	• Rarely deficient • Chlorosis of new leaves • Wilting (especially at leaf margins) • Leaf curling and eventually necrosis • Stunted shoot and root growth	• Can be directly toxic to leaf tissues and roots because it's a salt • Reduces water availability by enhancing total salinity
Nickel (Ni)	• Part of enzymes	• Not clear because it is very rare	• Chlorosis as interveinal yellowing and eventually necrosis • Failure of leaf tip to unfold	• Use of high Ni industrial or sewage sludge