Environmental, Nonparasitic Injuries

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Bad weather, air pollution, growth regulators, and the deficiencies or excesses of minerals in the soil can cause a group of diseases of plants that we classify as environmental and nonparasitic.

They are related closely to diseases brought about by parasitic organisms. Often we can regulate plant growth so as to control them and thereby control somewhat the diseases attributed to parasites. Symptoms associated with nonparasitic diseases frequently are confused with those caused by fungi, bacteria, and viruses. Often the injury from nonparasitic disturbances permits fungi, bacteria, or viruses to enter and damage the plant.

The severity and type of injury vary with the plant, its stage of maturity when the disturbance occurs, and the part of the plant involved.

LIGHTNING, hail, wind-blown rain, drowning, frost, and drought are among the elements of weather that may harm plants.

Lightning may tear large trees apart or it may only injure a few limbs. It may kill the stem tissue of annual plants, such as tobacco, so that the leaves get a shrunken, dark midrib. Damage to plants by lightning is local and usually not extensive.

Hail may cause only small holes in a few leaves or complete defoliation and destruction of plants. A striking instance of hail damage is the destruction of an entire field of shade-grown tobacco and the shade cloth over it. Usually hail does damage in limited areas only.

Heavy rains may break young, tender leaves or puncture holes in them. Wind-blown rain also causes water soaking of the intercellular spaces of the leaves. Sometimes, if micro-organisms are present, the damage may be severe. Plants blow over; leaves and grain in contact with the soil may rot; it might be impossible to use machinery to harvest the crop.

Most crop plants grow well on relatively well-drained soil that may be subject to leaching or temporary flooding, but most plants will not survive persistent flooding, which drowns and destroys the root system. If a part of the root system is damaged, growth is reduced and micro-organisms may invade the tissues. Temporary wilting is often evident. In sandy soils the rapid loss of water by percolation—leaching—causes the loss of soluble plant foods, particularly nitrogen and possibly magnesium.

Not uncommonly are plants injured on days of high temperature and bright sunshine. Sunscald is the permanent wilting of young leaves. Another type of injury results in a drying of the lower or older leaves. Such conditions are more common with temporary shortages of water. Corn, for example, first shows rolling of leaves; if the drought continues it may suffer to the degree that the upper part of the plant, including the staminate inflorescence, dries up and fertilization cannot take place. In extreme droughts trees and other plants may die.

In cold weather growth may be delayed so that parasites develop. Losses from late spring and early fall freezes are an ever-present threat in most of the Temperate Zone. Small grains, corn, and other crops often fail to reach proper maturity before being killed by freezes in some seasons in northern latitudes. Following frost and freezing injury, plants may suffer death of twigs and branches, splitting of trunks, and the loss of fruit crops when flowers are killed.

FACTORIES may release concentrations of gases that are toxic to plant growth. Sulfur dioxide is an example. In many places the vegetation around industrial establishments—such as factories that make sulfuric acid or smelters of sulfide ores—has been almost entirely wiped out. Smoke from coal sometimes contains sulfur dioxide in amounts that may injure plants if it is not dissipated by wind.

Fluorine, as hydrofluoric acid gas, is injurious to plants near chemical works that release it into the air. The injury often appears only as marginal lesions or necrosis, but sometimes the entire leaf dies prematurely. Low concentrations of fluorine often cause leaves to turn yellow.

Smog is a still, heavy mixture of fog and various contaminants, such as sulfur oxides, ammonia, fluorides, filterable oils, gaseous hydrocarbons, oxides of nitrogen, and hydrogen sulfide. It is not known for certain which one of those gases is the culprit or whether two or more act simultaneously to injure plants. In the south coastal area of California, for example, Romaine lettuce, endive, and spinach suffer extreme injury from smog; beet, celery, oats, Swiss chard, and alfalfa suffer moderate injury. Barley, onion, parsley, radish, tomato, turnip, and rhubarb suffer slight injury. Cabbage, cantaloup, carrot, cauliflower, cucumber, pumpkin, squash, and broccoli suffer no injury. Bleaching and scorching sometimes are evident.

INSECTICIDES may injure plants. Arsenicals used improperly may cause shedding of leaves. The effect of arsenicals, particularly lead arsenate, may be cumulative and in time may kill fruit trees. Calcium arsenate, as used on cotton, may temporarily sterilize the soil. Oil sprays may damage fruit trees. Parathion and some of the other newer synthetic insecticides may cause the russeting of some varieties of apples. Benzene hexachloride may cause the formation of strap-leaf and off-flavors, particularly in potatoes.

All parts of plants, notably orchard trees, might be injured by bordeaux sprays and dusts. The leaves may show burning, shot holing, spotting, discoloration, and defoliation. The blossoms may be injured so that no fruit is set. The fruit may show spotting, russeting, malformation, cracking, and shedding. The twigs may have injuries of various kinds, or the entire tree may die if damage is unusually severe. Lime-sulfur also might cause lesions on foliage or fruit and premature fruit drop. The most common injury is a dull-brown spotting of the leaves or burning of margins and tips.

Many injuries have followed the extensive use of the growth-regulator herbicides, especially 2,4–D. Minute amounts of them are enough to produce ill effects on plants—even the tiny residue in a sprayer that has not been cleaned thoroughly with plenty of hot water and ammonia. Injury also may occur from the drift of herbicide spray when the wind is blowing. Leaf malformations occur in sensitive species around factories that prepare 2,4–D. The injury may be only a slight rat-tail type of growth of the leaves or the death of trees.

A DEFICIENCY of any one of the chemical elements necessary for plant growth may reduce total growth of plants. To distinguish the effect of one element from that of another, one must examine closely the affected plant. For example, it is not enough to say that a leaf is chlorotic; a detailed description of the chlorotic pattern is necessary and the age of the leaf must be known. A shortage of any one of the elements—boron, calcium, copper, iron, magnesium, manganese, molybdenum, nitrogen, phosphorus, potassium, sulfur, and zinc—may produce malnutritional diseases of plants.

A shortage of boron in the soil results in poor growth of tops and roots. Top sickness in tobacco, heart and dry rot of sugar beets, internal cork of apples, internal browning of cauliflower (which first occurs as small, concentric, water-soaked areas in the stem and central branches of the curd), and cracked stem of celery are boron-deficiency diseases. Poor growth, yellowing of the terminal growth, and death of the terminal buds are typical symptoms in most plants. The affected terminal growth becomes brittle, breaks easily, and shows discoloration of vascular tissues.

A deficiency of calcium shows up first near the growing point on the young leaves. The growing point dies and the young leaves often are severely distorted and show a hooked tip. When later growth takes place, the margins are irregular because of the failure in early development. The leaf petioles of many plants collapse when the growing points die. The floral parts, including corolla and calyx, may show abnormalities. Shedding and little or no seed set may follow. Tobacco, tomato, and potato plants show distinctive deficiency effects. Tomatoes show pronounced dieback of stems, leaves, and fruiting branches and blossom-end rot of fruits. Potatoes form few tubers, show bushy vines, and develop leaflets near the shoot tips that are small, chlorotic, and roll inward toward the midveins. Beans, peas, clovers, and other legumes have pale-green leaves with necrotic margins. The stems may collapse near growing points, petioles, and pedicels. Pods and seeds are few and poorly developed. The growing points of sugar beet, carrot, parsnip, and other root crops may die. The tree fruits undergo death of the terminal shoots. The tip leaves have a scorched and ragged appearance, and the margins roll inward. Calcium deficiency in most plants results in breakdown of the meristematic tissues in stem, root, or any part of the plant where the deficiency occurs. Extreme shortages of calcium commonly mean the early death of the plant.

Years ago growers learned that the dieback, or exanthema, of citrus trees in Florida could be corrected by the use of copper compounds, although the ailment was not recognized at first as due to a copper deficiency.

Apple, pear, and plum trees show much the same symptoms when they lack copper. Tobacco plants deficient in copper suffer a breakdown of older leaves and wilting of younger leaves. When the shortage of copper operates after flowering, the seed head cannot stand erect and the seed stalk bends to one side. The cereals show much the same symptoms—withering of tips of the younger leaves, wilting of the foliage, dwarfing, distorting of seed heads, and less formation of grain. The lower leaves and tillers on such plants tend to remain green. Copper is essential for normal color and growth of lettuce and onions, particularly when they are grown on peat soils.

The first deficiency disease of plants to be recognized was the one caused by too little iron. It was first reported in France, and the remedy was iron salts. Yellowing of the young growth is the first sign of the disease. Some necrosis may occur. In extreme cases the young leaves may become almost white. In milder cases there is a mottled pattern; the primary and secondary veins tend to retain the green color. Sometimes there is drying or scorching of leaf tips and margins. In extreme cases dieback of twigs may extend to large branches of trees. Fruit and shade trees are often more commonly affected than field or vegetable crops. The typical chlorosis due to iron deficiency often occurs on soils of high lime content and has been termed "lime-induced." The typical chlorosis of pineapples in Hawaii occurs on soils high in manganese and has been corrected by the use of sprays that contain iron.

Magnesium deficiency causes a chlorosis that first affects the older leaves. Magnesium is a component of chlorophyll. Sand drown, the distinctive chlorosis of tobacco, is caused by magnesium deficiency. The lowermost leaves of the plant first lose their normal green color at the tips and margins and between the veins. The primary and secondary veins and the nearby tissue tend to retain the normal green color long after the remaining leaf tissue has become pale green or almost white. The deficiency rarely occurs until the plants have attained considerable size. It is called sand drown because it is more prevalent in deep, sandy soils and during seasons of excessive rainfall. Corn has streaks on the lower leaves when magnesium is deficient. The cotton plant shows chlorosis, and a purplish-red color develops in the yellow areas. Leaves of vegetables turn yellow and die. Citrus trees develop a chlorosis known as bronzing. Leaves of deficient apple trees turn yellow and unhealthy and drop if the shortage is acute.

Chlorosis and necrosis of young leaves are early symptoms of manganese deficiency. Tomato plants growing in calcareous soils in Florida showed retarded growth, failure to blossom, chlorosis, and a necrotic spotting of the younger leaves until manganese was supplied. The gray speck disease of oats is due to too little manganese. The first seedling leaves of the oat plant are of a normal green; later leaves are faintly yellow and develop necrotic spots. "Pahala blight" of sugarcane arises from too little manganese. Snap beans show a chlorosis of the young leaves; each new leaf shows more chlorosis, and affected plants finally die. Young leaves of an ailing tobacco plant lose color in even the smallest veins; the contrast between the green and yellow places gives a checkered effect to the leaf. Chlorotic leaves develop small lifeless spots, which may enlarge and fall out. The spots are distributed over the leaf—not only at the tip and margin, as with potassium deficiency. The acidity or alkalinity of the soil on which the plant grows appears to dominate manganese absorption, as most instances of deficiency of manganese have been reported on neutral or alkaline soils.

The effect of molybdenum deficiency was first mentioned as a cause of the whiptail disease of cauliflower in New Zealand and Australia. The disease restricts the development of the leaf lamina, so that sometimes the midribs are left bare. In extreme cases the growing point dies. The effects of a shortage of molybdenum on tobacco and tomatoes has been reported for plants grown in nutrient solutions. The tomato plant shows a mottling of the lower leaves, followed by necrosis and crinkling. The fruit set is poor because most of the blossoms shed. Tobacco shows much the same symptoms when molybdenum is deficient; the shedding of flower buds leads to a reduction in amount of seed. Various crops, particularly legumes, have responded favorably to the addition of molybdenum on serpentine and ironstone soils in some areas.

Shortage of nitrogen, perhaps the most common of the deficiencies, shows up at any time from the seedling stage to maturity. First the plant loses its normal green color. The growth rate slows down. Then lemon, orange, red, or purple tints develop and the older leaves dry or drop. Leaves that develop later when nitrogen is transferred to them from the older leaves are small; the production of fruit or seed is correspondingly reduced. The growth of nitrogen-deficient plants is sparse, spindly, and erect. The roots may be long and little branched; the twigs of trees are short and small. Small grains show a marked reduction in number of tillers and consequently yield poorly. Not all effects of nitrogen deficiency are bad, however. The growth of broadleaved plants, such as tobacco, can be regulated by withholding nitrogen to produce leaf of a certain type, such as the bright lemon-colored leaf known as the flue-cured type. Fruit trees on nitrogen-deficient soil may produce highly colored fruits that store well.

Shortages of phosphorus lower plant growth markedly. The symptoms are not always clearly defined. Usually the leaves are small and erect, the lateral buds are few, and the roots may be sparsely branched. But most of the effects of phosphorus deficiency apparently are more general. The leaves usually are dark green, but in later stages or in extreme cases they may be dull green and may show purplish tints. Sometimes necrosis is evident. When the older leaves dry up or shed they are dark brown to almost black. The cereals often show purpling on older leaves. Tobacco leaves are a dark gray green and maturity is delayed. Production of fruit and seed is reduced and slow.

Chlorosis, commonly beginning on the older leaves at their tips and margins, is typical of potassium deficiency. Necrosis follows, first as small areas that gradually enlarge and merge. The dead areas may fall out so the leaves get a ragged appearance. Grasses, when potassium is deficient, show a yellowish streaking which, on older leaves, may develop into scorching. The stalks on such plants are short, roots are poor, and the ears are poorly filled at the tip. The tobacco plant becomes bluish green, mottled, and chlorotic. Generally the lower leaves show the first symptoms, but if the shortage operates during later growth stages of the plant, when growth is rapid, the upper leaves may show the first symptoms. Mottling is followed quickly by necrotic spotting at the leaf tips and margins between the veins. Tomato and the potato plants show much the same symptoms as tobacco. Tomato fruits fail to ripen evenly; often greenish-yellow patches are intermingled with the red of the red-fruited varieties. Cotton and the sweetpotato develop chlorosis and necrosis of the older leaves and some leaf shedding. Cotton rust is associated with potassium deficiency. Foliage of deciduous fruit trees becomes bluish green; intervein chlorosis, necrosis, and marginal scorch occur on older leaves; extreme cases involve dieback of shoots and branches and fruits of poor quality. Citrus fruits display small leaves, fluting or tucking along the midrib, small and poor fruit, and dieback in serious disorders.

The effects of sulfur deficiency on plant growth generally resemble those caused by shortage of nitrogen. The younger leaves display a pronounced yellowing with little or no drying of older leaves. While nitrogen shortage is accentuated and sometimes brought about by excessive rainfall, sulfur shortage is often more apparent during dry periods and in dry areas, since sulfur dioxide, a common air contaminant, is brought down by rainfall. Grasses lose their normal green color when sulfur is withheld. Leaves of legumes become yellow and develop brown spots; the plants are less succulent and have thin stems. The tobacco plant first shows light-green leaves; veins and the tissue between the veins lose their green color when sulfur is deficient. Much the same symptoms have been reported for the tomato. The tobacco plant recovers quickly from sulfur deficiency in times of adequate rainfall. Citrus trees show a marked yellowing of the younger leaves in the early stages of the deficiency. Some dieback of the twigs may occur later. A disease known as tea yellows is caused by sulfur deficiency. The initial stages of sulfur deficiency generally are marked by a yellowing of the younger leaves. When the condition becomes acute and lasting, the older leaves may turn yellow. Leaves of citrus and the tea bush may die back.

The initial effects of zinc deficiency, most evident on the older leaves of many plants, are chlorosis, necrosis, shedding of leaves, and, in extreme cases, dieback of twigs in trees. Pecan rosette, citrus mottling, littleleaf, and citrus rosette are due to zinc deficiency. The corn plant shows yellow streaks on the older leaves when zinc is deficient. The streaks later become necrotic; the young leaves unfolding in the bud may be white or yellow and produce the white-bud disease. Sugar beet and potato develop leaf spots on the older leaves. The leaves of the potato are thickened and curled. Tobacco grown in purified, zinc-free sand or solutions in the greenhouse has shown deficiency symptoms—first a faint chlorosis on the older leaves at the leaf tip and margins between the veins. Necrosis soon develops as small areas that rapidly enlarge to involve the veins or the entire leaf. The leaves are thick, internodes are short, and the corolla appears to be shortened.

It is not possible to distinguish clearly between the disorders that are due to a deficiency as such and the disorders that are due to too much of another element. A deficient supply of one element implies an excess of other elements. A mass-action effect may arise as when too much of one element may interfere with the solubility, absorption, and utilization of another element to the extent of developing acute deficiency effects. The effects often may result from the acidity or alkalinity of the culture medium.

Many of the nutrient elements in excess may cause symptoms of toxicity. For example, boron in any considerable amounts results in a marginal necrosis of the older leaves followed often by stunting and death. Those symptoms often have been seen following the use of irrigation water that carried toxic amounts of boron. The use of potash salts in fertilizers containing excessive amounts of boron has caused serious losses.

Calcium, if present in amounts that cause alkalinity of the soils when the levels of iron, manganese, boron, or zinc are low, often results in deficiency symptoms previously described as typical for the deficiency of each of those elements.

An excess of copper causes necrosis, wilting, reduced growth, and death of plants.

Too much iron may induce a deficiency of phosphorus or manganese.

Magnesium present in large amounts may accentuate potassium deficiency if the potassium supply is low. An excess of magnesium may operate in much the same manner for calcium and show the calcium-deficiency symptoms.

Manganese when present in excess may bring about iron deficiency. Manganese is often present in acid soils in amounts sufficient to reduce plant growth. Low calcium is often associated with this condition so that plant growth will be improved by liming to neutralize soil acidity.

Excess amounts of nitrogen stimulate excessive growth and frequently may cause a deficiency of another element that is present in small amount. Often the other element is potassium; then the plant is commonly more susceptible to rusts (in the case of the small grains and cotton) and to leaf spots (tobacco). Sulfur often is added to acidify alkali soil to improve plant growth. Sometimes the continued use of ammonium sulfate and other sulfates brings about a low pH, which often is unfavorable to plant growth. Excess sulfates bring into solution the extra manganese and aluminum that may be present in the soil and thus injure plant growth.

Actually, most effects associated with soil reaction are related to solubility of nutrient or toxic ions rather than injuries associated with the hydrogen ion. Since the acidity or alkalinity of soils in humid areas may range between pH 4.0 and 8.0, most plants can grow successfully at that range if there are no complications in regard to availability and toxicity of the ions present. The so-called alkali soils show a much higher pH and present a different problem.

Salinity is a serious problem in many arid areas and in places where ocean spray or salt water floods agricultural soils. Excessive fertilization with soluble salts sometimes causes much the same kind of injury. The effect may vary according to the plants in question and the salts and concentrations that are involved. Sometimes the effect is merely one of concentration of soluble salts, but again, if alkali salts are present in excess, the soils are said to be alkali. The actual salts present may vary, but the three common ones are sodium chloride (table salt), sodium sulfate (Glauber's salt), and sodium carbonate (sal soda). Various other salts of sodium, calcium, magnesium, and potassium may also be present.

Most of our common crop plants are sensitive to salts. Seed germination may be retarded or prevented. Young seedlings may die. When the plants do survive, the growth rate commonly is slow, the plant wilts, and the leaves burn at the tips and margins. Fruit or shade trees may survive for a time on saline soils and show chlorosis, possibly caused by induced shortages of iron brought about by alkaline soil conditions. Their growth is reduced, leaves drop, and eventually the trees die. If conditions are not too severe, the more resistant types of plants may have drought-resistant characteristics. The leaves are small and have a thicker cuticle. Waxy coatings are more developed and the breathing pores are sunken below the outer surface, so that evaporation or transpiration are reduced.

Among the crop plants, sugar beets, Rhodes grass, and Bermuda-grass have the strongest tolerance to saline conditions. Those with medium-strong tolerance to saline conditions are alfalfa, cotton, kale, barley as a hay crop, rape, and sorgo. The crops with medium tolerance include onions, squash, flax, Ladino clover, sunflowers, rice, and rye as a grain crop. Those with the weakest tolerance include red clover, snap beans, navy beans, vetch, and wheat as a grain crop.

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The Effects of Soil Fertility

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Many farmers and gardeners have observed that plant diseases have become more prevalent and soils less fertile than they used to be. Some have argued that the two phenomena are related and that diseases are more destructive because the plants have been weakened by poor mineral nutrition. A few have even maintained that there would be no serious disease problems if plants were grown in properly conditioned soil, but evidence obtained in hundreds of experiments throughout the world does not uphold this extreme viewpoint.

Soil fertility does affect the prevalence and severity of some plant diseases, but it is only one of several factors that predispose plants to infection by fungi, bacteria, viruses, and nematodes. We can make no sweeping generalizations about the effect of fertilizers on diseases because of the extreme differences in crop plants, their special nutritional requirements, the soil types upon which they are grown, and the diversity of the pathogens that attack them. Some diseases are severe on weakened, undernourished plants. Many others are most destructive when plants are growing vigorously.

If wheat on a moderately fertile soil, for example, is given an extra supply of nitrogen it probably will escape seedling diseases more readily, be more subject to pythium root rot, suffer less from take-all disease, and