Soil Aeration Prime Factor in Development of Turf

By THEODORE T. KOZLOWSKI

Head of Department of Botany, University of Massachusetts

In order to maintain healthy grass it is necessary to have oxygen continuously supplied to roots in adequate amounts. This, however, is only one of the factors of the environment which enter into the complex of all the factors which influence growth of plants.

In a real sense the growth of grass, as of other plants, is determined by interacting genetic characters and a great array of environmental factors. A number of internal physiological processes and conditions in plants are affected by the environment and changes in rates of these processes result in turn in growth differences. The manufacture of plant foods (carbohydrates, fats and proteins), permeability and extensibility of cell walls, digestion and translocation of foods, respiration, absorption of mineral salts, and intake of water as well as loss of water by transpiration might be listed as being among the more important physiological processes involved.

Environmental factors which have a profound effect on growth of plants include the climatic factors (temperature, light, precipitation, humidity, wind, gases), the soil or edaphic factors (origin and classification, minerals, temperature, aeration, pH, organisms, texture and structure, organic materials, etc.) and the biotic factors (insects, cultivation, birds, grazing animals, fungi, pollination, etc.).

Improper Aeration

On the golf course improper soil aeration is generally the result of incorrect watering or compaction. Too much water without proper drainage will result in air spaces being occupied so aeration is inadequate. Compaction at or near the soil surface also means that water cannot move through such a layer and the very necessary exchange of gases between the soil and the atmosphere is prevented. Among direct causes of compaction are player traffic, proper and improper use of equipment, precipitation, and artificial watering. Aggravating causes of compaction include soils of too heavy texture, soils low in organic matter, overwatering, poor drainage, too acid soils (usually pH 5 and below resulting from residual action of ammonium sulfate), too alkaline soils (usually pH 8 and above resulting from residual action of sodium nitrate), and necessary eradication of earthworms and soil insects.

Indicator Plants

Compaction will finally result in poor root growth, thatching, hard greens which will not hold pitch shots, anaerobic soil conditions which influence beneficial bacteria and the nitrogen cycle, hard greens which will not absorb rain water or artificial water since it will simply run off the compacted ground, and the prevalence of weed species. Compaction can be relieved by disc harrowing with a disc set straight, spiking, tyning, forking, terferating, aerifying, using "night crawler" machinery or by fertilizing judiciously, liming, or increasing the organic matter content of soil. Under certain field conditions, indicator plants may give some idea of the degree to which turf areas have become compacted. Presence of clover indicates moderate compaction, plantain indicates medium to heavy compaction, and knotweed warns of heavy compaction.

Two of the most important physiological processes of plants which influence growth are photosynthesis and respiration. Photosynthesis is the process in which simple carbohydrates are synthesized from carbon dioxide and water by the green leaves of living plants in the presence of light, and oxygen is released as a by-product. The process is generally rated as the most important biological reaction since it is a basis of production of food materials. Carbon dioxide gas from the atmosphere diffuses into leaf tissue through stomatal pores and the reaction takes place. Food formed in this process is used for leaf development, and the excess is transported and used for growth of stem tissues and root tissues. The process can be summarized by the following balanced chemical reaction:

$$\underset{\text{Carbon Dioxide}}{6\ CO_2} + \underset{\text{Water}}{6\ H_2O} + \text{Energy of Sunlight} \longrightarrow \underset{\substack{\text{Simple Sugar} \\ \text{(i.e. glucose)}}}{C_6H_{12}O_6} + \underset{\text{Oxygen}}{6\ O_2}$$

$\square Ca^{++}$	+	$2\ K^+$	+	$2\ Cl^-$	$\rightleftharpoons$	$\square\ \begin{matrix} K^+ \\ K^+ \end{matrix}$	+	Ca^{++}	+	$2\ Cl^-$
Negatively charged clay particle and bound calcium ion		**Potassium ion**		**Chloride ion**		**Negatively charged clay particle and bound potassium ion**		**Released calcium ion**		**Chloride ion**

Respiration is defined as the oxidation of foods in living cells resulting in the release of energy. In a sense respiration is the opposite of photosynthesis and the process could be summarized by simply turning the arrow around in the summary equation above. It would then be the case that a simple sugar is oxidized and the products of the reaction are carbon dioxide, water, and energy. This energy which is released is of great importance to plants for carrying on a number of other necessary physiological processes. Energy released in respiration is necessary for synthesis of fats, amino acids, and metabolic products. It is necessary for migration of chromosomes and translocation of other cell constituents during cell division. Respiration energy is also necessary for streaming of protoplasm, growth of stems, growth of root tips, and accumulation of ions or molecules. Although photosynthesis is carried on during the daytime only and by green cells exclusively, the process of respiration is carried on by all living plant cells and goes on during the day and night.

Respiration of Roots

Respiration of roots is especially important but in order for this process to go on at a favorable rate, a continuous supply of oxygen must be made available to roots. Unless rates of processes are in proper balance, there will be metabolic disturbances which will result in poor growth. Root respiration may be either aerobic or anaerobic. Aerobic respiration takes place when atmospheric oxygen is available while anaerobic respiration takes place in the absence of atmospheric oxygen. Most roots must carry on aerobic respiration. When they are forced to substitute anaerobic for aerobic respiration, the rate of energy release is not great enough to maintain cell processes and bad effects are soon produced on plant tissues. This is essentially what happens when soil is flooded for too long a time or when soil layers are impermeable because of severe compaction.

With only a few exceptions all the mineral elements which enter into plant composition come from the soil. A normal rate of aerobic root respiration is required for intake of such nutrients. Clay particles of soil are generally negatively charged and tie up certain positive ions so they are not available to plants. Consider the case where calcium ions are tied up with negatively charged clay particles. If a solution of potassium chloride is added to such a soil some of the added potassium ions replace the calcium ions and render them available for plants. The calcium ions would be available only after such release. This type of exchange, called base exchange or cation exchange, could be represented as shown above.

Each clay particle may have a number of such ions tied up with it and some other positive ion must be added to replace those tied up with the clay. When root respiration is normal the carbon dioxide which is released into the soil combines with water to form carbonic acid. From the carbonic acid (H_2Co_3) the H^+ ion is available to displace ions tied up with the clay and therefore such ions are released and made available to plants. When respiration is inhibited by poor watering or compaction this kind of ion exchange does not take place properly and chlorosis results.

Reduced aeration of soil results in a number of morphological and physiological effects on turf grasses and other plants. Reduced aeration results in cell walls in roots that remain abnormally thin. Root hair formation is usually suppressed as a result of reduced aeration and this generally results in an inability of the plant concerned to take in enough moisture. Root branching is less complex and roots are less numerous. Poor aeration will result in decreasing the production of dry weight of roots and the roots are shorter and occupy less space. Leaf areas and the number of chloroplasts may also be reduced. A pronounced chlorosis may develop which will be correlated with decreased intake of ions as previously considered.

Results of Reduced Aeration

A number of adverse physiological effects may also result from reduced aeration. Roots quite often change from aerobic to anaerobic respiration, at least in part, with a consequent accumulation of by-products. By-products of anaerobic respiration are quite toxic to plants when present in significant proportions. Carbon dioxide and alcohol are regular products of anaerobic respiration and such respiration is essentially identical with alcoholic fermentation when carbohydrates are present. Under certain conditions it approaches other types of fermentation and the following

(Continued on page 85)

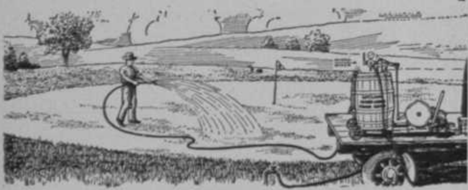
What Asst. Should Learn to Become a Good Professional;" Ed Rankin, pres., Walter Hagen Div., with a talk on "Pro Line Merchandising" and G. T. McCarthy, sales mgr., Golf Ball Dept., U. S. Rubber Co., who will show pictures and give commentary on the manufacture of golf balls.

Jimmy Thomson, Johnny Revolta and Ed Vines will put on the teaching clinic at 4:00 followed by the membership dinner at 6:00 and business meeting at 7:30.

SOIL AERATION

(Continued from page 49)

products may be formed: acetic, formic, and lactic acids; amyl, butyl, and ethyl alcohols; acetic, butyric, citric, formic, lactic, oxalic, propionic, and valerianic acids; acid aldehyde and acetone. Decomposition products include ammonia, fatty amido acids, leucin, skatol, tyrosin, sulphureted hydrogen, mercaptan and others. Under conditions of aerobic respiration these products do not form. Other effects of poor aeration are a decrease in permeability of cell membranes, decline in pH of cell sap,



reduction in the rate of absorption of water and nutrients, reduction in rate of transpiration, discoloration of foliage together with root degeneration, decrease in carbohydrate content, delay or suppression of reproductive processes, and premature falling of reproductive structures that have been initiated. Under anaerobic conditions compounds of calcium, magnesium, and iron are not very available to plants and nutrient deficiency results. Also sulfur exists as sulfides rather than sulfates and nitrogen as ammonium rather than nitrates. When the oxygen content drops below the critical level certain bacteria begin to reduce nitrates to nitrites in order to obtain oxygen and thereby further deplete the nitrogen fertility.

Microorganisms in soil do not function to the advantage of grass if soil is poorly aerated and lacks oxygen. Grass is dependent on a continuous supply of nutrients and some of these are released by microorganisms. Dr. Hogan at California showed that plants lacking adequate oxygen were not able to absorb potash. A weak solution of muriate of potash was sprayed on the greens and the grass recovered in a matter of a few days.

The composition of the atmosphere above the ground is considerably different from that below the ground level. The above ground atmosphere contains approximately 21 percent oxygen, 78 percent nitrogen, and only 0.03 percent carbon dioxide or about three parts in ten thousand. Since basic responses of protoplasm are more or less identical it would be expected that free oxygen from the air must get down into the soil for root respiration. The amount of carbon dioxide normally increases with depth of soil. It has been found that the oxygen content decreases in soils and may go down to a fraction of one percent at a five foot depth. Carbon dioxide content increases from 0.03 percent at the soil surface to over 15 percent at a five foot depth under some conditions. There are also marked seasonal differences in composition of soil air. Soil air is richest in carbon dioxide in summer, less in autumn, still less in spring, and least in winter. Organic matter and manure greatly increase the amount of carbon dioxide and decrease the amount of oxygen in soil. Microscopic fungi, molds, bacteria, and algae together with soil animals from amoebae to rodents all increase the carbon dioxide content of soils.

Water has only about six cubic centimeters of oxygen per liter when saturated during the growing season. Therefore, the water content and air content in soils are in inverse relation. The greater the water content, the smaller the air content and the amount of available oxygen. Dry soils contain large amounts of air and wet soils small amounts regardless of fineness. Under the same rainfall porous soils have larger air content than fine or compact ones, and this is true even when they approach saturation, owing to the ready movement of water in them. Air capacity of heavy soils can be increased by the addition of organic matter, cinders, or sand. A very serious effect of deterioration of structure of surface soil is a decrease in air capacity. This decrease of non-capillary pores is responsible for poor aeration, reduced bacterial activity, and lower infilltration capacity for precipitated water. When soil is wet and excessively packed, the air capacity may be reduced to almost zero. It has been shown that frequent trampling of greenhouse soils between rows of plants has been found to lower air capacity from 16 percent to 2 percent. It has also been reported that earthworm burrows raised the air capacity of a loam soil from 8.9 percent to 31.2 percent.

Beneath the surface of the soil oxygen is usually suboptimal in concentration. Roots usually do not begin to show definite injury until the oxygen content of the soil atmosphere drops as low as 10 percent. Ordinarily the oxygen content of the upper levels of drained loams lies somewhere between the lower critical value of 10 percent and the 21 percent characteristic of free air. A reduction of soil oxygen to about 3 percent practically stops root growth in most plants. Because the oxygen content of the soil drops abruptly to about one percent just above the water table, the roots of most land plants are restricted to soil horizons above this level.

In a recent consideration of the aeration problem, Dr. Fred Grau, Director of the Greens Section, USGA, emphasized that soil compaction resulting from years of play and equipment traffic and inadequate drainage posed one of the most important barriers to natural turf development. This is largely true because of the improper aeration that roots are subjected to in a compacted soil.