abundantly and branch more profusely, but they also fail to penetrate as far into the deeper soil.

On the other hand, the presence of an abundance of phosphates has been shown to increase root development strikingly. If phosphorous is deficient in soil, its application in an available form may be expected to greatly stimulate root length and branching.

Soil Acidity

Soil acidity and a lack of lime may also limit root penetration. The tolerance of turf grasses to soil acidity varies with the species, but all are injured to some extent by strong acidity. In some cases it may be found that the roots will penetrate only as deeply as the soil is freed of active acids. Soil acidity may affect absorption of nutrients and water even before it modifies root extent. This is due to the fact that root hairs are injured or destroyed by excessive acidity, just as they are killed by the presence of poisons in the soil water.

The extent of the root system can be considerably influenced during the period of its development by the height and frequency of cutting. Plants cut very short are able to manufacture only a limited quantity of food in the leaves. If the supply of nitrogen is abundant or excessive at this period, the tendency will be to produce luxuriant top growth without a corresponding root development. On the other hand, plants that are cut less closely may utilize considerably greater amounts of nitrogen without hampering the development of the root system. The critical point seems to be the ratio of carbohydrate food present in the plant to the supply of available nitrogen. An overabundance of nitrogen favors top growth and retards root growth. This relation is probably most important in early spring when roots are actively growing.

Dr. Sprague concluded by giving details and results of the studies made at New Brunswick, N. J., on which the preceding remarks were based. The study data will be found in March GOLFDOM.

Bacteria in the Growing of Turf

By DR. J. G. LIPMAN
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PLANTS commonly used in greens are the specialized and selected representatives of their class, expected to thrive and to survive under conditions that would be fatal to most plants. Frequent, close cutting, stimulation and over-stimulation of root development, compacting the soil, and frequently abnormal moisture, temperature and aeration conditions represent an environment that is not normal. It is evident that this abnormal environment would weaken and ultimately destroy the most hardy of the turf grasses except as special devices and treatments be used toward offsetting the weakening effects of the treatment. Such devices and treatments must reckon with the presence and activities of bacteria.

Factors which affect the growth and vigor of turf grasses may be grouped under the heads of environment and in connection with the food supply of plants. Amount, character and distribution of organic matter is of major importance. Amount of organic matter directly affects the circulation of air and water in the soil, and, to some extent, its temperature. Everything being equal, the more organic matter in the soil, the greater the amount of water absorbed and held. It is possible, therefore, to create a supply of organic matter so large as to interfere with optimum root development. The quality of the organic matter is also of direct significance in that its composition and physical nature may favorably or unfavorably influence root growth and the activities of soil bacteria. Distribution of the organic matter is also a factor of importance, since the amount of it at different depths of the soil and subsoil control the circulation of water and air and, through these, the feeding of the plants.

Everything being equal, the deeper the root zone the more vigorous the plants and the greater their resistance to unfavorable changes in their soil and climatic environment.

Carbon's Part Important

Approximately 50% of the dry weight of grasses, and of other plants, is carbon, the element which makes up all but a small proportion of the entire weight of coal or charcoal. There is only about .03% of carbon dioxide in moisture-free air. Areas on which vegetation is flourishing draw heavily and repeatedly on this relatively small supply. Had it not been for the constant movement of air above the land surface the gases overlying any area on which forests, cultivated crops or grasses grow vigorously would become depleted of their carbon dioxide supply to a point where plant growth would be checked. It is fortunate that there is not only the circulation of air, but also the replenishment of carbon dioxide from the soil itself.

Actively developing plant tissues contain only 5 to 10% dry matter. The rest is water. Without adequate water supply growth of both roots and tops is retarded. It is not merely a question of the amount of water supplied by rain or artificially, but also of the circulation of water in the soil, its ability to lift water from lower depths, and its ability to allow water to move downward and laterally. Together with water supply, we must consider air supply, for, in so far as the space not occupied by soil particles or roots is filled with water, it is not occupied by air or vice versa. When the soil is saturated and water stands at the surface, there is no air in it except for the small amounts of air gases dissolved in the water itself.

Preventing Plant Poisoning

For the best growth of plants there must be an optimum relation between water and air in the pore space. Growing roots take something out of the soil water and something out of the soil air. The latter must move about freely enough to prevent such changes in the composition of the soil air as would be inimical to the activities of soil bacteria. When such inimical or unfavorable conditions arise, substances more or less poisonous to the plants may be formed. Types of bacteria, fungi, protozoa and algae objectionable to the greenkeeper might, under such conditions, become unduly prominent. They might interfere with the functioning of the roots of turf grasses and of the kinds of bacteria that are important in providing for a satisfactory supply of certain plant ingredients.

In the soil available plant food is both manufactured and dispensed, so that there is a more or less constant transformation of raw materials into finished products that plants can use, and there is also a transformation into material made unavailable. The manufacturing processes in the soil are carried on largely by bacteria and other micro-organisms. One of the plant nutrients prominent in promoting growth of tops and roots is nitrogen. Nearly all nitrogen in soils is present in combination with carbon, hydrogen, sulphur and other elements in the so-called organic matter. This, as is well known, consists of residues of plants, the cells of micro-organisms and of the remains of insects, worms and other soil-inhabiting organisms. They must be broken down and the nitrogen released in the form of ammonia and nitrates.

Make Plant Food Available

Bacteria and other soil micro-organisms are the living agency on which we depend for breaking down soil organic matter and for manufacturing ammonia, nitrates, sulphates, phosphates and other essential plant nutrients. Everything else being equal, the warmer the soil and the more favorable the conditions as to water and air supply, the greater the number of soil bacteria, the more intense their multiplication and activities and the greater the rate of plant growth. Soil organic matter which contains too large a proportion of carbon does not favor a large supply of ammonia and nitrates to growing plants. In soils of this character bacteria actively compete with the higher plants and interfere with their growth in so far as the supply of available nitrogen is concerned. The ammonia and nitrates of the soil solution are so rapidly taken up by bacteria and changed back into unavailable organic matter as to deprive plant roots of a sufficient supply of this important plant nutrient. To a lesser extent this will apply also to sulphate, phosphates, lime and magnesia. The greenkeeper, if he succeeds, so tunes up the biological machinery in the soil as to create optimum growing conditions for the plants in which he is interested.

Balance in Soil

Examination of the plant roots may show that they do not penetrate deeply enough, nor are they more or less symmetrically distributed. The fault may lie in the texture of the soil and subsoil. In that case, artificial drainage must be provided for. Otherwise, the use of chemical fertilizers may hinder rather than favor normal and vigorous root development. The greenkeeper must bear in mind that, in applying chemical fertilizers, he inriches the soil solution which bathes the plant roots. He may make this solution so rich as to corrode the root hairs and the fine rootlets. He may also swing the biological balance in the soil toward types of bacteria and fungi that would be detrimental rather than helpful. In his anxiety to maintain a sufficient supply of organic matter he may resort to the use of peat, which has valuable as well as objectionable characteristics. It is true that any organic matter, including peat, will open up heavy soil and make more compact loose, sandy soil. It will increase the water-holding power of the soil and improve the circulation of air in fine textured material. At the same time, the organic matter of peat is not readily usable as a source of food for bacteria. Hence, peat is less desirable than good compost for stimulating soil bacterial activities. There is another factor in the use of composts that should not be overlooked. In one sense, good compost is like yeast in that it inoculates the soil, supplies it with billions of bacteria and sets up fermentation of organic matter that results in liberating a more adequate supply of available plant nutrients. The question of soil inoculation for greens is one that has not received much study. It is not necessary to use composts for the purpose. It is conceivable that, in the course of time, we shall develop artificial inoculants that can be applied to greens as a means of accomplishing the various improvements that an active soil bacterial flora may make possible.

Stimulating Bacteria

The greenkeeper must remember that, when he uses sulphate of ammonia, urea, nitrate of soda or various mixed chemical fertilizers, he supplies raw material containing an important and essential constituent of plant food. But, whatever the kinds and amounts of these nitrogen salts that may be used for stimulating root development and top growth, we should not forget that bacteria, also, are stimulated by having these substances placed at their disposal. Being so stimulated, they effect a whole chain of transformations and changes that become evident in the rate of growth of the plants themselves.

The greenkeeper may overlook the fact that the various chemicals employed may tend to make the soil more acid or less acid; that he may deepen the root zone or make it more shallow. Overemphasis has been laid in the past on the desirability of using such chemicals as would make the soil strongly acid; in consequence, there are many greens where lime or other materials possessing the same corrective action is needed. But, there are different kinds of lime and there are differences as to the amounts of lime that need to be used in establishing optimum conditions in the soil both for the bacteria and the plants. A uniform procedure cannot be recommended because conditions afield are not uniform. The best we can do is to acquaint ourselves with certain fundamental facts which hold true under all conditions. If these fundamental facts are well understood, practice may be so adjusted as to meet the needs of any particular place and time.

Rebuilding and Resodding Greens and Tees

By JOS. WILLIAMSON

HASTILY and inexpertly built greens in which there is faulty general construction or lack of drainage, Mr. Williamson blames for many apparently mysterious turf troubles. Before rebuilding he advises greenkeeper to learn past history of old green and why it did not function properly. Greenkeeper should satisfy himself about reasons of the green's failure so he may profit by mistakes that have been made.

Williamson expressed belief that life of a putting green is far overestimated, stating:

When we stop to consider what a green goes through during the years of its use and what we have done to it, it is only reasonable to admit that its life is gone and we must renew the soil which has become wornout, poisoned, and lifeless. So under these conditions it is only natural after a few years the old green should be torn up and rebuilt."

In rebuilding, select soil on which grasses will grow and thrive mostly from soil itself instead of by irrational use of high-powered fertilizers, Williamson counseled. He strongly championed good compost pile as greens maintenance necessity. Lack of care in soil selection and preparation and excessive fertilization he held responsible for much greens trouble. For proper greens soil, he advised thoroughly mixing approximately one-third loamy, fibrous topsoil, one-third sharp sand that will not pack, and one-third humus such as old, rotted stable manure and peat moss or leaf mold with a little wood ashes. If sub-soil is heavy clay, he advised plowing it up and mixing in a few loads of clean fine cinders or common sand, then rough grading to approximate contour.

Emphasizing correct drainage, he advised following procedure:

Most greens as a rule are built sloping slightly to the approach, and in this case the drains should be laid crosswise of the green, the trenches dug about 18 or 20 inches deep at the start with a gradual fall to the main which would be on one side of the green, falling to the lowest corner and the most convenient outlet. The trenches should be on an average of 12 to 15 ft. apart and either 3- or 4-in. drain tile used and placed close together in a straight line making connections to the main with tees which are made for this purpose, and should be back-filled with 1½ in. crushed rock to within 10 or 12 ins. of the finished surface of the topsoil.

After the drains have been filled with the rock, the subsoil should be rough graded between the drain trenches and sloped a little from the center to the line of tile, taking care that there are no low pockets lying between the drains in the subsoil. However, I would suggest not to cover the rock with the subsoil, but to leave it open and let it be covered with the topsoil when you are filling the surface. This will give perfect drainage of the subsoil to the trenches, and the topsoil on the rock will assure a complete porosity from the finished surface to the drains below.

Next is the filling in of the topsoil. This is done by wheelbarrows on plank boards, taking care that the grade of the subsoil