previously discussed, fungi benefit greatly as a result of this moisture.

Spiking, aeration, aerothatching, and rebuilding greens are often done in an effort to reduce this organic layer and thus effect cultural disease control. Basic soil consistency is a consideration here and was discussed under moisture.

CONCLUSION

All turf management practices are either directly or indirectly associated with incidence of disease. As can be seen, chemical control and cultural control of disease-causing fungi are intrinsically interwoven. Cultural control goes a long way in keeping turfgrass disease free (or disease reduced) and unless proper management practices are pursued, even the best chemical controls often fail to stop disease spread. On the other hand, chemical control measures are frequently and regularly necessary especially during periods when adverse environmental conditions prevail, even though the best known cultural practices are followed.

The frustrating aspects of disease control mentioned earlier arise primarily as a result of the lack of basic knowledge. As examples, why will a green, even though located in a similar area or adjacent to other greens, be constantly susceptible to disease while its neighbors remain relatively disease free. The author has seen examples of courses located in the same general area; one course receives the best possible management known, yet disease is a problem even though fungicides are regularly and frequently used. The other course receives far inferior management and less frequent and regular fungicide applications, yet diseases are much less of a problem and in general, turf is healthier. Of course, these are exceptions. Nonetheless, they exist.

COMING EVENTS

February 26-March 1
Cornell Turfgrass Conference
Cornell University
Ithaca, N. Y.

March 5-6-7
Midwest Regional Turfgrass Conference
Memorial Center, Purdue University
Lafayette, Indiana

March 8-9
Massachusetts Turfgrass Conference
University of Massachusetts
Amherst, Mass.

March 13-14-15
Iowa Turfgrass Conference
Memorial Union Building
Iowa State University
Ames, Iowa

March 22-23
Michigan Turfgrass Conference
Michigan State University
East Lansing, Mich.

Potassium — That Mysterious Macronutrient

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Of the various soil minerals known to be essential to plant growth, potassium was among the first to be recognized. One of the first observations of potassium-plant relationships was that potassium is required in relatively large quantities by plants. Yet, since those early observations, progress has been slow in understanding the specific part potassium plays in plant growth and development. Through scientific investigations and practical observations we have learned that plant uptake of potassium is often higher than any other mineral and that a deficiency of potassium will give a very marked decrease in growth and, if the potassium level is low enough, even death of the plant. Since the beginning of the 20th century, emphasis on quality of crop production, especially in turf management, has increased to a prime factor. Here, too, potassium and plant quality are very closely related. It seems only profitable, then, to survey briefly what is known of the potassium-plant relationships.

Function of Potassium in Plants

Voluminous amounts of investigations on potassium-plant relationships have clearly indicated that unlike nitrogen, phosphorus, calcium, and magnesium, potassium is not a permanent component of any organic compound or structural part of plants. Its total apparent existence is in the form of soluble inorganic and organic salts, the greater portion being the inorganic forms.

Recent investigations have indicated that potassium affects the metabolic activities of plants in several ways, most of which appear to be enzymatic. Lawton and Cook report that evidence now available shows that potassium affects the following processes: (1) synthesis of carbohydrates, (2) translocation of carbohydrates, (3) reduction of nitrates and synthesis of proteins, particularly in meristem tissues, and (4) normal cell division. It is also suggested that potassium plays a part in maintaining turgor in plant cells as well as increasing disease resistance. Research further indicates to some investigators that potassium may affect photosynthesis through its influence on chlorophyll.

Concerning carbohydrate synthesis, it has been reported that a decrease in available potassium is associated with a decrease in carbohydrate content of the plant and that high potassium content is necessary for high carbohydrate synthesis. It has been suggested that potassium may play a major part in the formation of more complex sugars and starches from the simple sugars in plants—a lack of potassium appeared to cause an increase in simple sugars as compared to total carbohydrate.

Practically coupled with potassium-carbohydrate studies has been the investigations of potassium as related to the structure of stems and cell walls. It is generally held that adequate supplies of potassium are necessary for the formation of stiff straw or stalk. Researchers have reported that when carbohydrates are present in high amounts, stem structures are likely to be strongest. Such a report strongly supports the potassium-stiff straw relationship. But if carbohydrates are used up in protein synthesis as when high amounts of available nitrogen are present, stems and plant tissue may not be stiff even though there is an abundant amount of potassium present in the plant.

There are a few workers who have suggested that the presence of potassium and calcium in the plant sap increases the uptake of nitrate nitrogen. These same investigators state further that such activity does not seem to hold true with all species of plants.

There is considerable belief, however, that potassium definitely influences the synthesis of proteins in plants. Some investigators believe there is a direct relationship between potassium and protein synthesis while others hold that the relationship is an indirect one. The overall effect agreed upon is that potassium-deficient plants are generally lower than normal in protein content. Along this same line it is suggested that with high nitrogen supply and deficiency of potassium there may result a toxic condition to plants from a too high accumulation of ammonia in the plant.

A number of reports have been made that potassium is in some way associated with cell division and actively growing plant tissues. Often it has been found that in potassium deficient plants the potassium is moved from older tissues to the actively dividing cells of the meristematic tissues. The effects of this phenomenon are observed in grasses by a yellowing of the margins and tips of grass blades. In such a case the potassium, being deficient in the plant, has migrated to the base of the leaves where intercalary meristematic tissues exist. There is still a great deal of doubt as to the function of potassium in cell division, but the feeling is that it is associated with protein synthesis.

Adequate levels of potassium in the plant have been reported to maintain and in some cases increase disease resistence in the plant. Here again just how potassium causes this effect is not known. A general belief is that it is brought about by the ability of potassium to regulate chemical reactions in the cells of the plant. When potassium is deficient, there usually exists excess nitrate and phosphorus, thinner cell walls in epidermal tissues, reduced production of amino acids because nitrate reduction is suppressed, a marked decrease or halt in the accumulation of carbohydrates, a failure to produce new cells for want of essential amino acids for the protoplasm, and slower growth of meristematic tissues that would permit replacement of diseased tissues. Under such conditions caused by potassium deficiency, disease organisms can more easily enter the thin cell walls, obtain the abundantly available nitrogen necessary for their growth, and more easily damage plant tissues which the plant is unable to replace at a competitive rate.

Potassium is also given partial credit for the maintenance of proper turgor in plant cells. Turgor is the state of living cells being plump and swollen as a result of internal water pressure. In this respect it is reported that potassium affects the cell sap and helps to regulate the degree of swelling and the water economy of cells.

Concerning potassium and photosynthesis, some workers suggest that potassium has an indirect effect. It is known that photosynthesis takes place in the chlorophyll molecule, and that CO2 as well as water and light are needed for the process. Some scientists feel that potassium enables the chlorophyll molecule to accept CO2 more readily, which in turn affects the photosynthesis process—the process from which plant food is derived. It is also thought that potassium, perhaps by way of activating enzymes, plays a definite role in the manufacture of the chlorophyll molecule.

A. G. Kennelly has been quoted as summarizing the role of potassium in plants as follows: "Potassium is important in the general health of the plant, particularly in developing sturdiness and disease resistance. It helps to promote the growth of woody tissues and usually improves texture, color, and quality."

Supply of Potassium to the Plant

The plant receives its potassium from the soil. It is generally known that heavy soils or soils high in clay content have the ability to hold more available potassium than light soils or those high in sand content. The available potassium is supplied to the soil from the weathering of potassium minerals, which contain unavailable potassium. Generally the unavailable potassium makes up approximately 99% of the total potassium in the soil. In many cases the amount of such minerals in the soil and the rate of weathering of these minerals is great enough to supply adequate amounts of available potassium to the plant. However, when the weathering of enough minerals is too slow or the available potassium is lost at too rapid a rate by plant removel, leaching, and erosion, potassium must be added to the soil in the form of fertilizer.

The available potassium is taken into the plant by the root. There is widespread belief that the root cells immediately associated with the uptake of potassium and other minerals as well must exert a considerable amount of energy in order to absorb the potassium.

It has been well recognized that soil aeration is necessary for normal root growth and nutrient absorption by roots. And it has been observed that poor aeration apparently has more pronounced inhibitory effects on potassium than on any other elements. The effects of aeration on potassium absorption are primarily on the plant roots and not on the status of potassium in the soil. The effects of a lack or adequate aeration are due to either a lack of oxygen to the roots, or a toxic effect of too much carbon dioxide on the roots, or both. This point still remains a mystery. Excess soil moisture and soil compaction affect the absorption of potassium in that they limit soil aeration. Unless a soil can be adequately drained and relieved of compaction, areation will be limited.

A number of investigators have found that very low soil moisture considerably reduces the absorption of potassium by the plant. This effect is a result of both the dehydration of the plant and a reduced availability of the soil potassium.

Most workers have concluded that mineral nutrient absorption is reduced under low environmental temperatures. It has been found that within the range of 50° F. and 77° F. potassium absorption changed directly as the temperature changed.

Potassium Fertilization of Turfgrass Areas

There are a number of potassium fertilizer materials. The most widely used material, however, is potassium chloride, commonly called muriate of potash, which contains from 50 to 60 per cent

K2O. This fertilizer can be applied alone or in a fertilizer mixture with phosphorus and/or nitrogen materials.

The amount of potassium fertilizer to apply and the time to apply it will depend on several factors. These factors are: (1) The amount of available potassium in the soil. If, at any time during the growing period of the turf the available potassium is not sufficient, potassium will need to be added in a quantity high enough to adequately raise the potassium level. (2) The kind and amount of clay in the soil. Some types of clays hold more potassium than others, and some clay types hold potassium in a more available form than others. If a soil is high in clay, it will be able to hold more potassium than a soil which is primarily sandy. A sandy soil will need small but frequent applications of potassium whereas a soil high in clay may be able to provide sufficient potassium with larger but less frequent potassium applications. (3) The type of watering program. Where the watering program is heavy, potassium will tend to leach out of the soil more readily than where the watering program is light. (4) Whether or not clippings are removed. Grass clippings contain a considerable amount of nitrogen, phosphorus, and potassium. O. J. Noer has reported that clippings removed from a golf green in Memphis, Tennessee contained nitrogen, phosphoric acid, and potash in the approximate ratio of 3-1-2, respectively. If the clippings are removed instead of being allowed to remain on the turf, potassium will be depleted more rapidly. (5) The kind of grass grown. All turfgrass species and varieties need available supplies of essential nutrients. However, some turfgrasses are cool season types and others are warm season types, and because of this difference the various types require greater amounts of nutrients at different times of the year. (6) The particular management of the turf. In general a turf that is mowed close and frequently will need more potash than one that is mowed higher and less frequently. A turf area that is designed to be kept in an active growing state the year round by either overseeding warm season grasses or by the use of permanent cool season grasses will more than likely need to be fertilized with potash more frequently and with an overall increase in amount of potash. On the other hand a turf area that is allowed to go dormant or partially so in the winter will not need an addition of potassium during the winter. In many cases the winter dormant period gives the potassium minerals time to weather, the result of which is at least a partial replenishment of the available potassium in the soil. If such weathering is inadequate to supply all the needed available potassium for the following growing season, applications of potassium will need to be made in the spring and anytime thereafter if the available potassium supply becomes short. It is also a good policy to have sufficient quantities of available potassium in the soil in the fall in order that the turf can become "hardened" for the cold winter temperatures. It is felt that plants well supplied in potassium and not overly tender due to high applications of nitrogen in the fall will be more capable of surviving freezing temperatures of the winter. There is also the possibility of getting too much available potassium in the soil. Plants are apparently unable to regulate the uptake of potassium; and if the soil supply is high enough, a so called luxury consumption may result. Under such conditions, the high potassium content in the grass plant may cause an excessive amount of stiffness in the stems and leaves as well as other undesirable or harmful effects. (7) The general weather conditions of the area. If there is a great amount of rainfall there is apt to be a need for more available potassium in the soil to replace that lost by leaching.

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