favorable balance in the motor so temperature, rainfall, and many other conditions influence the balance in plant growth. Fortunately the soil with its various chemicals and microorganisms tends to keep the balance favorable in many cases. Under the extremely artificial soil conditions on most golf courses, however, it is easily possible to seriously upset the desired balance. For example, the more rapidly the plant absorbs nitrogen from the soil, the greater is the need for an increased supply of other elements, such as phosphorus, potash, and calcium.

Moisture also is an essential factor in the growth of plants. The limits of moisture are rather definitely fixed. When too little moisture is present in the soil the plants begin to wilt, and when there is too much moisture the roots are injured. Many crops are injured by an unbalanced water supply. The damage caused by excessive water is due to the replacing of air in the soil with water, leading to a deficiency of oxygen, which is essential for healthy root growth. Excessive water may also leach essential elements from the soil. A deficiency of water on the other hand may lead to too great a concentration of salts.

Light and a favorable temperature also are important factors in the growth of plants. Long cloudy periods and shading cause a yellowing and a weakened condition. After a period of shading, sudden exposure to bright sunlight is likely to be injurious. Changes in temperature may weaken the growth of plants. There are points above and below which plants can not live and there is an optimum temperature at which they grow best. The limits are rather wide for some plants, but near either extreme injury is apt to occur. The condition of the plant determines to a large extent the amount of injury which occurs from extreme temperatures. For instance, when a heavy frost occurs after plants have begun to grow in the spring and they are in a tender state, injury may often result.

Still other nonparasitic diseases result from direct injury to plants. An important example is burning the turf with chemicals, which frequently occurs on golf courses where insufficient care is taken in applying chemicals. Plants which are in a tender condition will not stand nearly as heavy applications of chemicals as when they are more hardy. Plants are more subject to injury from chemical burns in the summer, during the hot periods.

HISTORY OF DISEASE CONTROL

Since the dawn of history when men first noticed the occurrence of diseases in plants they have taken measures to alleviate or to prevent them. Blight and mildew were known in Biblical times. Aristotle discussed wheat rust in 350 B. C. At that time the causes of diseases were unknown and accordingly many superstitious explanations were offered. A variety of measures were taken to prevent or control diseases without any understanding of their true causes. Plant diseases were at first thought to be punishments inflicted upon the people by angry gods or malicious demons; accordingly prayers were offered and complex rituals performed to appease the gods or to frighten away the demons. These were probably the first attempts at plant-disease control.

Later treatments attempted during the early historic period were of a more practical nature. These were the results of trial-and-error methods, which in most cases were not effective. Some of these early

treatments included sowing seed in the dark of the moon and "in God's name," mixing powdered lime with seed, soaking seed in salt water, running seed through burning straw, treating seed with lime and lye, and treating seed with a mixture of salt, saltpeter, lime, and wood ashes. Many of these practices were adhered to for a great many years after they had proved valueless. Even today in many parts of the world futile practices handed down through countless generations are still in use. A common example is the sowing of seed only in a particular phase of the moon, a practice based wholly upon superstition.

Only occasional practices for plant-disease control used in early days have value today and most of these are cultural practices. Some of the early practices of fertilization and crop rotation still have some value. More important is the removal of diseased plants, which is still practiced in controlling some diseases. In a diseased group of plants there is a natural selection or thinning of the stand, because the most susceptible individuals succumb first and produce no progeny. This tends toward improvement without the interference of man.

Not until the seventeenth century were concerted efforts made to control diseases by spreading various concoctions on the plants themselves, although as early as 470 B. C. Pliny had recommended the sprinkling of pure amurca of olives for prevention of plant blight. The cause of plant diseases was not understood even in the seventeenth century, when experiments were made with many mixtures of materials. Some of the mixtures contained a half-dozen or more materials, which were usually the most evil-smelling that were obtainable, the theory being that if the mixture was offensive to human beings it would also be offensive to the cause of the disease.

The following are the directions given in 1790 for making a mixture "to cure diseases, defects and injuries to plants." "Take one bushel fresh cow dung, one-half bushel lime rubbish from old buildings, one-half bushel wood ashes, one-sixteenth bushel pit or river sand. The last three are to be sifted fine before they are mixed. Then work them well together with a spade and afterward with a wooden beater until the stuff is very smooth like fine plaster used on ceilings of rooms." The mixture was made to the consistency of plaster or paint with soapsuds or urine, and after its application it was dusted with "dry powder of wood ashes mixed with the sixth part of the same quantity of burnt bones." A formula such as this seems ridiculous to us in the present knowledge of plant-disease control, but it is probably no more ridiculous than some of the theories and methods of which we occasionally hear for the control of brownpatch. During this early century, however, these experiments with mixtures and compounds were forerunners of the successful experimentation that has resulted in the control of many plant diseases.

Early in the nineteenth century the first successful chemical control measures for fungus or parasitic diseases were discovered. The use of copper sulphate (bluestone) for the treatment of cereal seeds to control smut was discovered in 1807. In 1821 sulphur was sprayed on plants to control mildew. This chemical is still used in a modified way against mildew. In 1833 lime-sulphur was first used to treat various diseases. These discoveries of chemicals to control diseases successfully stimulated a great deal of experimentation with chemicals during the last half of the nineteenth century. This increase in ex-

perimentation was also stimulated by the increased importance of plant diseases such as late blight of potato and powdery mildew on grape, occasioned by an intensification of agriculture which occurred at that time when cities were growing larger and greater food supplies were needed to supply the demands of increased population. Further impetus was added to the activity of the experimenters by the discovery in 1853 of the true cause of plant diseases, at which time proof of the parasitism of fungi was demonstrated.

About 1860 the foundations for the science of bacteriology were laid and soon afterwards the development of pure culture methods made it possible to cultivate parasitic bacteria and fungi which aided considerably in the study of disease organisms and their control. In 1869 the results of the first study of diseases were published in America, and about 1873 the subject began to be taught in American universities. The organization of a section in the United States Department of Agriculture for the study of plant diseases took place in 1885, and in 1888 the State Agricultural Stations were organized. During the time of these developments many of our common fungicides were discovered. Later, in the twentieth century, the study of plant diseases and their control with various fungicides has been continued intensively until a great many of the diseases can now be effectively controlled. During this century there has also been a study of the effects of cultural practices on plant diseases which has developed certain improvements that have greatly reduced the severity, or even the occurrence of disease. The control of plant diseases by production of resistant varieties by breeding and selection has given promising results in reducing losses from some diseases.

Plant Quarantines

Increased commerce between various parts of the world has resulted in the spread of plant diseases from one country to another. Thus the late blight of potato was introduced into Europe from South America about 1830, and caused the potato famine in Ireland in 1848. Powdery mildew on grape was introduced from the United States into France in 1845, and became so serious there that it threatened the grape-growing industry. Examples of diseases introduced into the United States from other countries are hollyhock rust from Europe in 1886, asparagus rust in 1896, white pine blister rust from Germany in 1906, and chestnut-bark disease from the Orient in 1904. It has been found that when a disease or an insect is introduced into a new country it often becomes much more serious than it was in the country where it originated. This is due to several reasons, one of which is that in the absence of their natural enemies, the organisms thrive more vigorously. The varieties of host plants in the old country are often very resistant, because of the many years of natural selection that have taken place. This was particularly the case with the American and French varieties of grape; the American varieties were resistant and the French varieties were very susceptible.

To check the spread of plant diseases and insects into the United States from other countries the plant quarantine laws were passed in 1912. These laws impose restrictions on the shipment of plants into the United States from parts of the world where serious diseases or insect pests are known to exist. All plants and plant materials are subjected to rigid inspection upon entry into the United States.

Methods of Golf Turf Disease Control

With the increasing demand for better turf by the golfing public, particularly on putting greens, the greenkeeper is compelled to stimulate an artificial growth of grass with its attendant increase in severity of disease. Each disease has distinct symptoms, and the greenkeeper should learn to know these symptoms in order that he may choose the proper method of control. The aim of plant-disease control is not to cure plants, or parts of plants already diseased, but to prevent the spread of disease to parts or entire plants that are still healthy.

When large numbers of plants of the same species or variety are grown close together the opportunities for the spread of disease from one favorable host plant to another are enhanced. When plants are stimulated by intensive culture and abundant fertilizer they become better mediums for many fungus growths and thus more susceptible to serious damage from diseases. Therefore diseases often occur more frequently and more seriously on good turf than on poor, neglected turf. Intensive culture of plants also tends to increase the danger from several nonparasitic diseases, because some of the daily practices used in maintaining putting green turf may have a harmful cumulative effect on the grass.

The control of turf diseases essentially involves three principles of plant-disease control: the use of disease-resistant grasses, the employment of correct cultural practices, and the judicious use of fungicides.

DISEASE CONTROL WITH RESISTANT VARIETIES

It has been observed for generations that there are different degrees of resistance to disease in many species of plants, but this phase of the subject has only recently been studied extensively. Theophrastus, in 286 B. C., recognized a difference in resistance of grains to rust, but no attempts at artificial selection were made to improve the plants cultivated, such as have been made so successfully in modern times.

There are many degrees of disease resistance in plants. A resistant plant is one which is not attacked by a fungus except under conditions which are unusually favorable to the fungus and unfavorable to the plant. A plant which is never attacked by a fungus, even under favorable conditions, is said to be immune. Varieties of plants have often been considered immune to a disease because no attacks had been observed, but when the plants were grown under conditions more favorable for the attack the disease caused slight damage. Such varieties of plants are considered highly resistant but are not classed as immune.

There are two ways in which disease-resistant plants are obtained; by selection and by breeding. By selection, a search is first made for naturally-resistant individual plants, and propogation is made solely from these, excluding seeds or cuttings from any plants susceptible to the disease. Several seasons may be required to develop a resistant plant. In selecting resistant plants it is important to select not only for resistance but for desirable types. The second way, breeding, consists essentially in creating new varieties by crossing disease-resistant plants with other plants. It often happens that disease-resistant plants are of poor type, and it may be necessary to cross them with