## Introduction to the Chemistry of Fertilizers

The past 10 or 15 years have witnessed some remarkable changes in the manufacture and use of fertilizers, and naturally golf courses have been affected by these changes. Not many years ago farms and golf courses depended almost entirely for their fertilizers on animal manures. The motorization of farms as well as industry, together with the improvements in the manufacture of commercial fertilizers, have revolutionized fertilizing practices. Many of the men in charge of the maintenance of golf courses refer back to the methods of fertilization which were practiced in their boyhood days on the farms they left years ago. Such individuals seldom stop to think that if they were to return to the farms of today they would find that fertilizing practices there are by no means the same as they were years ago, for farming practices have made much progress in different lines since many members of green committees were boys.

The general use of worn-out soils for golf courses and the modern demands for better turf have greatly increased the demands for fertilizers to keep grass growing vigorously. The demands for continuous play on golf courses have made it necessary to use some form of fertilizer that would not clutter up the course with bulky manures such as were used years ago. The realization that plant food can be applied to turf in a concentrated and convenient form has led clubs to use more modern methods for obtaining the desired results with the minimum of inconvenience to play.

The improvements in fertilizers, as in other modern developments, have presented complicated problems at the same time that they have been adding to our conveniences. In the early days the question of fertilizers was very largely merely a matter of how many loads of manure to apply. In recent years, however, it is not only a matter of how much to apply but which to choose from a great assortment of the fertilizer materials of merit which are available.

The fertilizer trade has a language almost of its own, with the result that when greenkeepers and members of green committees attempt to make fertilizing plans for their courses they frequently become confused with the large number of terms and symbols which to them present all the difficulties of a foreign language. Much of the language of the fertilizer trade is elementary chemistry, and simple enough if one wishes to devote sufficient time to understand the fundamental principles involved; yet one does not need any mastery of even elementary chemistry to have a working knowledge of modern fertilizers. In this and the following (April) number of the Bulletin will be presented material which should serve to acquaint those in charge of golf courses with chemistry and trade terms which will be found useful in understanding and discussing intelligently fertilizing problems of golf courses.

Golf course fertilization on altogether too many courses is simply done by the old method of trial and error. This method is essentially sparing of mental effort but is usually extremely wasteful of funds. The increasing interest in fundamentals of fertilizers that is evident in the management of golf clubs is such that the Green Section feels that there is a real demand for accurate published information on the subject. It is obviously impossible to give in a few numbers of the Bulletin sufficient information to cover all questions that arise in considering golf course fertilizing programs. No attempt will be made in these two numbers of the Bulletin to give specific information for all purposes. The purpose of these numbers is merely to give general information in such a form that it will serve for ready reference in the future.

The whole fertilizing problem is one which involves chemistry; therefore in discussion of the subject we must employ chemical terms. In order to understand the nature and behavior of the various fertilizers a few of the essential facts about chemistry must first be understood. All substances may be divided chemically into two general classes—organic and inorganic. This division is roughly made on the basis of the animal kingdom and mineral kingdom. Years ago it was generally believed that all chemicals which were products of the animal kingdom were the result of some vital force within the living organism. The chemicals which were supposed to be products of these living organisms were classified as organic to distinguish them from chemicals of a mineral nature, which were designated as inorganic. Later, however, it was discovered that it was possible in the laboratory without any vital force to manufacture many of the chemical compounds that were classified as organic. The term organic now stands, however, regardless of whether the material was formed in the body of the living organism or manufactured by some artificial means.

Inorganic chemicals may be divided into three general classes: acids, bases (alkalies), and salts. Acids are formed by the combination of non-metallic elements (nitrogen, sulphur, chlorine, and others) with hydrogen or a combination of hydrogen and oxygen. They have a sour taste and turn blue litmus paper red. Bases are formed by the combination of metallic elements (calcium, sodium, potassium, and others) with hydrogen and oxygen. Ammonia also is a base, but instead of being a single metallic element it is composed of a combination of the elements nitrogen and hydrogen ($NH_3$) acting in the rôle of a metal. Salts are formed when an acid and a base unite. Certain bases containing soda, potash, lime, or ammonia, which are more violent in their action than are the weaker bases, such as iron and aluminum, are referred to as alkalies.

Chemists have divided matter into its simplest components, which are called elements. Thus an element can not be divided or broken down into simpler substances. They have designated each element by a convenient symbol consisting of one or two letters. The more common elements, entering into materials now in use on golf courses, are the following: aluminum, Al; arsenic, As; calcium, Ca; carbon, C; chlorine, Cl; copper, Cu; hydrogen, H; iron, Fe; lead, Pb; magnesium, Mg; manganese, Mn; mercury, Hg; nitrogen, N; oxygen, O; phosphorus, P; potassium, K; silicon, Si: sodium, Na; sulphur, S. These elements seldom occur in nature alone, but in combination. The proportion of each element or combination of elements in a substance is designated by numbers. A complex substance accordingly has a complex symbol. While familiarity with the chemical symbol of a substance is not a necessity in the intelligent purchase and use of the substance, yet it is indispensable to the chemist and will be found to be a material aid to anyone interested in knowing the structure of the substance he is using. There is accordingly presented on the following page the chemical symbols of the more common combinations of elements which occur as fertilizers or as parts of fertilizers.

Plants and animals use elements in various forms as food, converting them into complex substances by means of certain physiological processes. All of the chemicals used by plants are absorbed by means of the roots. Most plants require for growth at least the following elements: carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, iron, sulphur, boron, copper, and manganese. Carbon is obtained from the carbon dioxide in the air, oxygen from air and water, and hydrogen chiefly from water. The three plant-food elements most frequently deficient in soils are nitrogen, phosphorus, and potassium, and it is chiefly to supply the deficiencies in these three elements that fertilizers are used. Fertilizers are rated according to their ability to supply plants with these three elements. Soils frequently need calcium and magnesium in the form of lime, but since lime acts to neutralize harmful acids in the soil and otherwise modifies certain unfavorable soil conditions, it is regarded primarily as a soil conditioner rather than as a fertilizer. There are other elements which are frequently needed in certain soils, and they are therefore added to fertilizers for special purposes.

| *Fertilizer substance* | *Chemical symbol* |
|---|---|
| Ammonia | $NH_3$ |
| Calcium carbonate (limestone) | $CaCO_3$ |
| Calcium phosphate (bone phosphate) | $Ca_3(PO_4)_2$ |
| Carbonate | $CO_3$ |
| Muriate of potash (postassium chloride) | KCl |
| Nitrate | $NO_3$ |
| Nitrate of soda | $NaNO_3$ |
| Phosphate | $PO_4$ |
| Phosphoric acid (as fertilizer) | $P_2O_5$ |
| Potash (as fertilizer) | $K_2O$ |
| Sulphate | $SO_4$ |
| Sulphate of ammonia | $(NH_4)_2SO_4$ |
| Water | $H_2O$ |

There are many technical expressions that are used in the fertilizer trade, and one must be familiar with these terms in order to understand any discussion of fertilizers. As plants take up food through their roots, any fertilizer material to be of use to plants must be in such a condition that it may be taken in by the roots; that is, in solution. A large piece of bone, for instance, may contain quantities of fertilizer, but a plant can not use any of it except that which is on the outside of the bone, where the roots can get in contact with it. On the other hand, if this piece of bone is finely ground and applied to soil, the fine roots of plants may get in contact with practically all of the material, and it can be used as food. Certain fertilizer materials may be in such a chemical combination that plants can not use them even though they are ground into a fine powder. The fertilizer trade designates the plant food in the soil or in a fertilizer which is in a form that plants can use, as "available" plant food, as distinguished from the plant food which can not be used by plants, which is designated as "unavailable" plant food. Available plant foods are soluble in water or weak acids, and when they are in solution the roots can absorb them. Certain fertilizers are applied to soil in a form that is not immediately usable by plants, but when acted on by chemicals or living organisms in the soil they are converted into forms which are available. Such materials are referred to as being slowly available, and include such fertilizers as bone meal, animal manures, sewage sludge, and waste products. Some of the fertilizers which are classified as unavailable or very slowly available can be made readily available by certain chemical treatments which are used in the fertilizer trade; thus phosphate rock or leather scrap may be treated with sulphuric acid and the fertilizer contained may be made available by the action of the acid. Since fertilizers are applied to furnish plant food, only that which can be classified as available is regarded as of value as an ingredient in fertilizers. The plant food in fertilizers is expressed in terms of nitrogen (N) or ammonia ($NH_3$), phosphoric acid ($P_2O_5$), and potash ($K_2O$). For a number of years the nitrogen content of fertilizers has been expressed in terms of both nitrogen and ammonia. Such designation is a duplication, and practically all states have recently agreed to have the nitrogen content of fertilizers expressed in terms of nitrogen only. The fertilizer trade has chosen to express the content of phosphorus and potassium in terms of phosphoric acid and potash, respecspectively. It is acknowledged that these fertilizer elements do not occur in fertilizers as free nitrogen, phosphoric acid, or potash, but these designations are used in order that there may be a common ground for comparing fertilizer values. In some instances the phosphorus which can be used by plants is designated as bone phosphate instead of phosphoric acid. The bone phosphate content is roughly twice that of the phosphoric acid content, so that when the bone phosphate figure is given one can convert it to approximate terms of phosphoric acid simply by dividing by two. Many of the other terms of the fertilizer trade will be found in the April number of the Bulletin.

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## Some Suggestions on the Selecting of Fertilizers

The question is frequently asked why fertilizers are needed when nature has provided abundantly for plant growth under natural conditions. Plants have decidedly different food requirements, and in the wild state soil which is deficient in one or more fertilizer elements supports only those plants which can get along without the particular fertilizer that is lacking in a particular soil. Since grasses on golf courses are growing under decidedly artificial conditions, it is necessary to use artificial methods for providing the necessary plant food. The plant food in much of the soil used for golf courses has been depleted by poor farming practices which had been used on the land for perhaps many years before it was taken over for golf course purposes. The deficiencies of a run-down farm soil must be replenished. Much plant food collects in the leaves and stems of plants; therefore old leaves and stems left to rot in a natural state add fertilizer to the soil. On golf courses where grass is clipped frequently and either removed immediately or left to be washed down hillsides by heavy rains there is a constant loss of plant food through the removal of these clippings from the soil, and such losses must be compensated by some fertilizing program. Much plant food is also dissolved by rain and washed down through the soil beyond the reach of the grass roots. Certain chemical changes are constantly taking place in the