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Contents

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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.

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 soil, and together with the decomposition of organic material in the soil these changes account for a loss of certain plant foods which must be replaced to provide for a vigorous growth of grass.

	Nitrogen (N) Per cent	Phosphoric acid (P_2O_5) Per cent	Potash (K_2O) Per cent
Activated sludge	4-6.5	2.5-3	....
*Ammo-phos 13-48	10.5	48	....
*Ammo-phos 20-20	16	20	....
*Basic slag	....	10-25	....
Blood, dried	8-14	....	....
Bone meal, raw ground	2-6	14-27	....
Bone meal, steamed	2-4	16-40	....
Castor pomace	4.5-6	1.5-2	.5-3
Commercial 6-12-4	6	12	4
Commercial 12-6-4	12	6	4
Compost of good quality	1-2	.5-1	1-1.5
Cottonseed meal	3-8	2-3	1.5-2
Fish scrap	3-10	5-20	....
Manure, farm, fresh	.5-1	trace-1.5	.5-1
Manure, farm, well rotted	.5-1.5	trace-1	.5-1.5
Manure, poultry, pulverized	2-6	1-3	1-1.5
Manure, sheep, pulverized	2-4	1.5-2.5	1-3
Meat meal	10-11.5	1-5	....
*Muriate of potash	....	....	48-53
Mushroom soil	.5-1.5	trace-1	.5-1.5
*Nitrate of ammonia	35	....	....
*Nitrate of potash	12	....	44
*Nitrate of soda	15	....	....
Poultry manure tankage	6-7	3	1.5
Soybean meal	6.5-7.5	1-2	1.5-2
*Sulphate of ammonia	20.5	....	....
*Sulphate of potash	....	....	48
*Superphosphate	....	14-20	....
*Superphosphate, double	....	40-48	....
*Superphosphate, treble	....	40-48	....
Tankage	1-11	trace-23.5	trace-1.5
Tobacco dust	1-5	.5-1	.5-10
Urea	46	....	....
*Wood ashes, unleached	....	....	trace-14

Table giving percentage range of nitrogen, phosphoric acid, and potash contained in various fertilizers. Those marked with an asterisk (*) are inorganic

In the diagram on the following page a comparison is given of the more common fertilizers on a nitrogen basis. Those familiar with the use of any one fertilizer for golf turf purposes can readily determine from the diagram the approximate amount of some other fertilizer that will be necessary to supply an equal quantity of nitrogen. An application of 2 pounds of sulphate of ammonia, for example, is equivalent to an application of 2½ pounds of nitrate of soda to supply the same quantity of nitrogen to the same area. Results will however vary slightly when the organic fertilizers are used, since the nitrogen in organic fertilizers is somewhat slower in becoming available to the plant. With the least concentrated organic fertilizers (fresh farm manure, well-rotted farm manure, mushroom soil, and good compost) it is customary to apply two or three times their equivalence with sulphate of ammonia as shown in the diagram. Since however the nitrogen in these least concentrated organic fertilizers is more slowly available than the nitrogen in the more concentrated organic fertilizers or the nitrogen in the inorganic fertilizers, the former are as a rule applied less frequently.

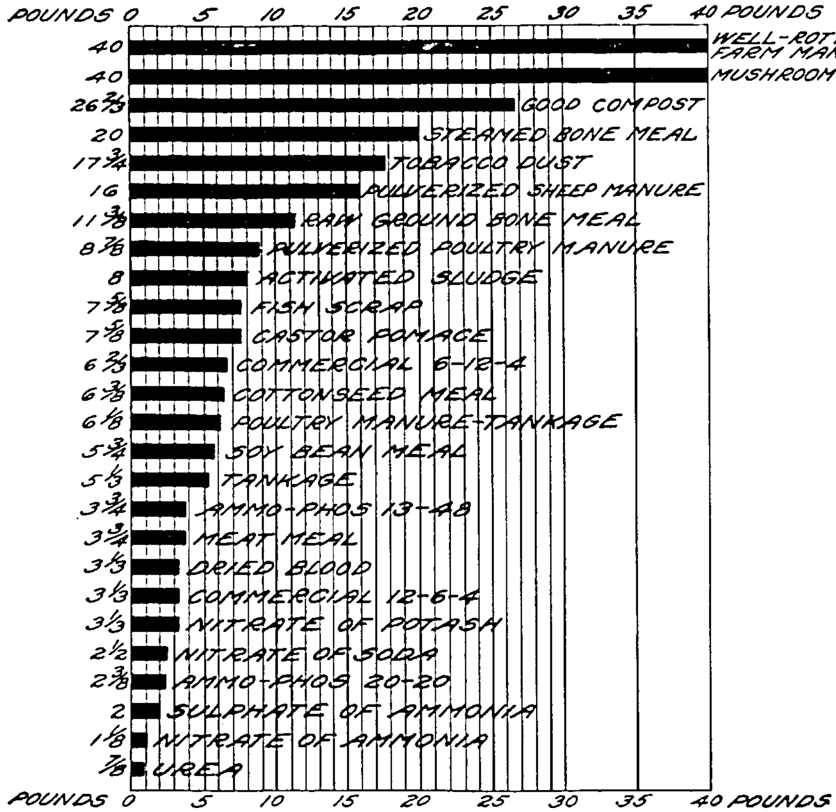


Diagram showing the number of pounds of an average grade of various fertilizers required to supply the same amount of nitrogen

No simple and definite fertilizing program can be recommended for all golf courses, since the use of fertilizer on any golf course is influenced by the demands of the various types of soil, the financial circumstances of the club, the kind of grass composing the turf, and many other conditions that can not be standardized. Lack of any definite fixed program for all purposes, however, does not imply lack of definite information as to general principles involved in fertilizing golf course turf. The absence of understanding of general principles of fertilization is responsible for much waste of funds on golf courses due to the attempt to follow some programs that have been successful on other courses under wholly different conditions. The kind, the rate, and the time of application of fertilizers must be determined individually for each golf course and for different parts of the same golf course. To be effective, however, this final determination should be based on an understanding of fertilization rather than on the hit-and-miss methods that prevail on the majority of golf courses today. It is of great importance in selecting fertilizers to know what they contain that may be useful to plants and also how soon plants may be able to use this food. When fertilizer is used primarily to improve the growth of grass over a long period, such as is the case in construction work and fairway improvement, it may have a large proportion of plant food in a form that is only slowly available to plants. On the other hand, when putting greens are being fertilized to produce a quick growth to put the turf in prime condition for a tournament, it is necessary to have plant food in a form that is immediately available to the grass. In much of the golf course fertilizing work it is desirable to have both quickly available and slowly available fertilizers in the soil.

The cost of a fertilizer is always an important consideration in selecting fertilizers. In the case of too many golf courses the cost of fertilizer is compared on a ton basis; that is, a fertilizer that costs $20 a ton is considered cheaper than one that costs $60 a ton. Such a comparison is, however, often ridiculous, for a fertilizer that costs $80 a ton may be actually cheaper than one that costs only $8 a ton. The *value* of a fertilizer should be judged primarily on the amount and character of the plant foods it contains. The present tendency in the fertilizer trade is to produce fertilizers in which the plant foods are extremely concentrated. Fertilizers of this type are more economical than less concentrated fertilizers in the cost of handling, bagging, storing, and distributing. Yet the *cost* of a fertilizer can not be rated entirely on the total amount of plant food it contains. The cost of a unit of nitrogen is much greater than the cost of a unit of phosphoric acid or potash; therefore any fertilizer that contains a higher proportion of nitrogen than phosphoric acid or potash, demands a higher price than mixtures containing a small amount of nitrogen even though the proportion of its total of plant food may be higher. Two different complete fertilizers, for example a 12-6-4 and a 6-12-4, may contain the same amount of total plant food; but due to the difference in the proportion of nitrogen, a ton of 12-6-4 fertilizer is worth more than a ton of 6-12-4 fertilizer. The differences in the values of nitrogen, phosphoric acid, and potash are given in the table near the bottom of page 69 of this number of the Bulletin.

The utilization of wastes and by-products in the manufacture of many fertilizers tends to lessen the price of fertilizers. In recent years there has been a tendency in industry to utilize many of the waste products which formerly were discarded. Much of the waste of the industrial plants is now taken care of by the fertilizer trade, and frequently wastes with much fertilizer value are available at a relatively low cost to clubs in the vicinity of industrial plants where such wastes accumulate. Sometimes this material may be obtained merely for the cost of hauling, and when composted it provides a cheap source of plant foods for turf. Usually these waste products are of only local value because of the limited amounts available and the cost of hauling. Golf clubs should, however, give consideration to the available local supplies that may contain sufficient plant food to be of value. A number of examples of analyses of such waste products will be given in the April number of the Bulletin.

The cost of some fertilizers is influenced largely by their demand for other purposes. Cottonseed meal and other materials that are used as feed for cattle can be used economically as a fertilizer only in years when the supply is too great to meet the demands for cattle feeding, which results in a reduction in the price that brings them within the range of an economical fertilizer. Such fluctuations in price mean that one year cottonseed meal may be generally recommended as a golf course fertilizer while possibly the next year the price would make it entirely out of the question for such use.

At the present time there are a large number of commercial mixed fertilizers on the market, a few of which will be referred to by name in the April number. Many of these commercial mixed fertilizers are excellent fertilizers for turf and are sold at prices in conformity with the amount of plant food contained. However, in many instances the mixtures are much more suitable for the production of many farm crops than for the best development of golf course turf, or else the price is out of proportion to the value of the fertilizers contained. Because of the great variety of commercial mixed fertilizers it is well to consider every product separately both as to plant food constituents and price. At the present time there is no law to make a manufacturer use the same materials from year to year in a fertilizer of a given formula. He may, according to the price of the materials, change from year to year the kind and amount of materials he uses, provided the total comes up to the minimum analysis which he guarantees. A mixed fertilizer sold under a special name may one year contain large quantities of cottonseed meal, for instance, and the next year, because of the difference in price of cottonseed meal, this same brand of fertilizer may contain none of this material; therefore a greenkeeper who has obtained favorable results from the use of a certain commercial fertilizer one year does not necessarily get the same fertilizer for his course the next year even though he uses the same brand of fertilizer. Commercial mixed fertilizers frequently offer an outlet for fertilizing materials of inferior quality. Care should therefore be exercised in selecting commercial mixed fertilizers. Many of the fertilizer companies gladly give not only the minimum analysis of a fertilizer which is required by law, but also furnish information as to what materials are used in making up the mixture. Such information is of much value, provided the purchaser has a sufficient knowledge of the principles of fertilizers to understand the terms that are used. If a golf club has some one in its employ who has some fundamental information on principles of turf fertilization it may well consider the method of preparing on the golf course its own mixed fertilizers for putting greens and fairways from standard fertilizer ingredients of known quality. This method is simple and requires no particular skill and no unusual amount of information. It usually can be done at a great saving to the club. Detailed information on the preparing of mixed fertilizers on the golf course has been kindly presented by Dr. C. C. Fletcher, of the United States Department of Agriculture, in his article on the subject in the current number of the Bulletin.

Farmers and all others who use fertilizers may take advantage of the provisions made by national and state organizations supported by laws to prevent fraud in the sale of fertilizer materials. The true value of fertilizers can be readily detected by chemical analysis and carefully controlled experimental work, but since very few of those who use fertilizers have the training or facilities for such determinations the national and state governments have provided certain fundamental information and regulations for the fertilizer trade. Many of the reliable fertilizer manufacturers of the country have themselves urged such regulations in order to protect the trade. The Association of Official Agricultural Chemists of North Amreica is an organization composed of analytical chemists connected with the United States Department of Agriculture and with any state, provincial, or national agricultural experiment station or agricultural college, or other institutional body in North America, charged with the official control of fertilizers, soils, cattle feed, dairy products, human foods, medicinal plants, and other materials connected with agricultural industry. This organization includes associate membership of chemists connected with municipal laboratories charged with the control of any of the above-mentioned materials. It was formed to provide uniformity and accuracy in the statement of analyses of the above materials and to afford opportunity for a distribution of information that would be made useful to those who are charged with this work. The organization has already done much to bring about uniformity in the various state and national fertilizer regulations. Golf clubs, like farmers, can profit by the work of this association and the various chemical laboratories handling fertilizer material, provided those who purchase fertilizer for the clubs avail themselves of the information placed at their disposal by these various organizations.

The laws of most states require that a statement of analysis be placed on all fertilizer bags or containers. Such statements are of no value to golf clubs if those who purchase fertilizers for the clubs pay no attention to the statements or plead ignorance of their significance. These statements are simple and are for the protection of all who use fertilizers; and there is really no excuse for anyone with a reasonable amount of intelligence failing to understand the practical significance of the analyses required by law. The significance of these statements is explained in the Bulletin for June, 1928, and further information on this subject will be found in the April, 1931, number. Many state agricultural experiment stations from time to time publish reports of analyses of fertilizers sold within their states. These analyses indicate how closely many of the fertilizer manufacturers conform to the requirements of the fertilizer laws. Every golf club purchasing fertilizer should request of its state agricultural experiment station a copy of its latest report of the analyses of fertilizers sold within the state.

Impressive bunkers placed about a mashie-shot hole often lend an intensive mental hazard to the hole and make it much more interesting. With a hole so short, a mental hazard is generally the only real hazard possible.

Preparing Mixed Fertilizers on the Golf Course

By C. C. Fletcher
Division of Soil Fertility, United States Department of Agriculture

Commercial fertilizers are usually mixtures of materials containing nitrogen, phosphoric acid, and potash. These so-called complete fertilizers may be bought ready mixed or their ingredients may be bought and mixed on the golf course. The fertilizer industry in the United States is based largely on factory-mixed goods, but the practice of home mixing has always had its advocates. A list of the common fertilizers adapted for golf course use, with their approximate analyses, will be found on page 58 of this number of the Bulletin.

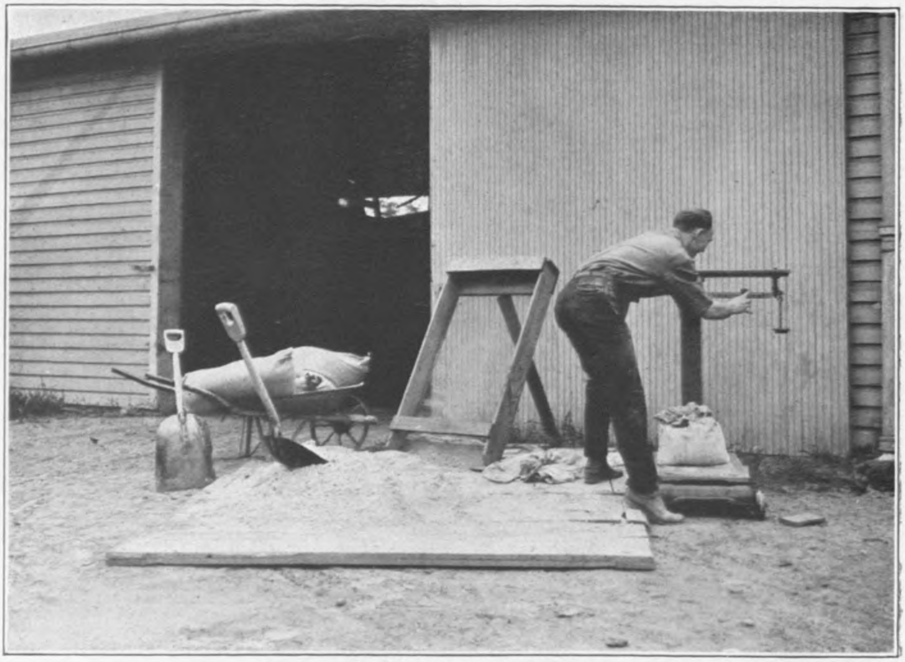
Mixing fertilizers on the golf course is a simple process and requires no great amount of labor

For one thing, home mixing is often more economical and affords the greenkeeper an opportunity to prepare fertilizer mixtures adapted to special needs. He thus not only learns more about fertilizer materials but can select them himself. In many cases it is important to know what form of nitrogen to use. For example, in some cases a large proportion of a quick-acting nitrogen carrier is essential; for others, a more slowly acting one, which allows the nitrogen to become available gradually throughout the season, is desirable. The greenkeeper can, for example, purchase sulphate of ammonia or nitrate of soda and be certain that he is obtaining high-grade materials.

In some localities there is an opportunity to buy so-called open-formula* mixed fertilizers. The company states plainly the ingredients used in making the fertilizer and the pounds of each ingredient in a ton of the mixed product. This system of selling takes away one

*The Association of Official Agricultural Chemists has given the following definitions of terms used in this article: (1) Fertilizer formula: The term formula shall be interpreted as expressing the quantity and grade of the crude stock materials used in making a fertilizer mixture. For example, 800 pounds of 16-per-cent superphosphate, 800 pounds of 9-20 tankage, and 400 pounds of sulphate of potash-magnesia. (2) Analysis: The word analysis, as applied to fertilizers, shall designate the percentage composition of the product expressed in terms of nitrogen or ammonia, phosphoric acid, and potash in their various forms. (3) Unit: A unit of plant food is 20 pounds, or 1 per cent of a ton.

of the reasons for preferring to do home mixing. Undoubtedly home mixing is a good thing for many individuals, both financially and educationally, and should be considered where economy is necessary or desirable. It has proved satisfactory in many parts of the country.



When materials in bulk or in bags of various weights are to be used, scales become necessary in the home mixing of fertilizers. With care in weighing out the ingredients, especially when the usual fertilizer materials are employed, it is possible on the golf course practically to duplicate any of the standard fertilizer mixtures

In the purchase of fertilizer materials good business judgment should be used. Wide competition should be sought and prices procured not only from local merchants but from large fertilizer firms in the home state and adjoining states. Lists of firms may be obtained from the state agricultural experiment stations, the United States Department of Agriculture, and golf association service bureaus. Advice should be sought from local green sections or the United States Golf Association Green Section. Best prices can be obtained for cash. Materials should be bought well in advance, as this not only insures a better price but allows the use of labor in the winter when it is often not occupied profitably. Mixing may be done when the weather is too inclement for outside work.

The mixing of the materials is comparatively simple. Any tight floor or a wagon box may be used, and tools at hand may be employed. The materials are spread in layers, usually the most bulky first, and are thoroughly shoveled together. The mixture is passed through a screen, and any lumps present are broken up with a tamper or the back of a shovel. The writer has found a very large long-handled mortar hoe a convenient tool for mixing, but its purchase especially for this purpose is not necessary. Where large amounts are to be mixed it would probably pay to buy a rotary mixer, such as is sold for concrete mixing. The stirring should be continued until the materials are uniformly mixed and show no streaks of color, after which the product may be bagged and stored in a dry place until applied.

To avoid caking and losses of plant-food elements, certain ingredients should not be used together in a mixture. The accompanying diagram shows materials which may and may not be safely combined.

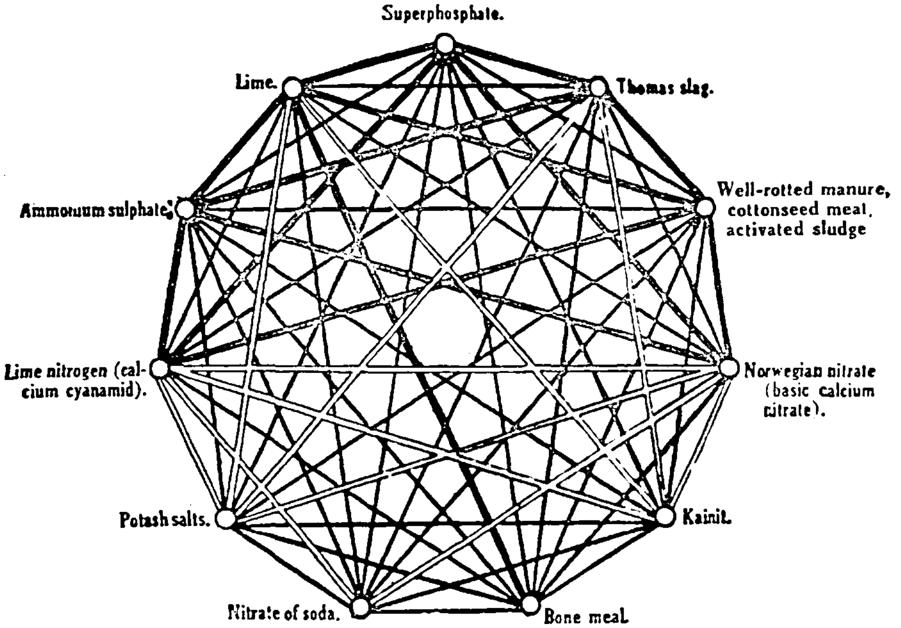


Diagram indicating what fertilizer materials may and may not be safely mixed. The heavy lines unite materials which should never be mixed, the double lines those which should be applied immediately after mixing, and the narrow single lines those which may be mixed at any time

When making high-analysis mixtures with concentrated materials it is well to include at least 100 to 200 pounds, per ton of the mixture, of some organic material, such as fish scrap, animal tankage, activated sludge, or cottonseed meal, as a conditioner. This holds good especially when the mixture is to be stored.

One of the easiest ways to start home mixing is to duplicate a formula already in use. A beginner should select a mixture which he has used successfully on his course, get a price on the mixed goods, and then find out what a home mixture of similar analysis will cost.

In making up fertilizer formulas it is well first to decide what percentages are required and then what materials shall be used. Start with the phosphoric acid (P_2O_5). Superphosphate is almost universally used as a source of the phosphoric acid in ordinary-strength fertilizers. With 16-per-cent goods, if 8 per cent of phosphoric acid is desired in the mixture, the procedure would be as follows: If the whole mixture were superphosphate, it would contain 16 per cent of phosphoric acid; as 8 per cent is desired, make 8/16 (½), or 1,000 pounds to a ton, of the mixture superphosphate; if 6 per cent is wanted, 6/16, or 750 pounds to a ton, would consist of this material. Similarly with nitrogen, if sulphate of ammonia contains 20 per cent of nitrogen and 2 per cent of nitrogen is desired, 2/20 (1/10) of the mixture, or 200 pounds in a ton, will be needed. Similarly also with potash, if muriate of potash (potassium chloride) containing 50 per cent of potash is used and 5 per cent of potash is desired, 5/50 (1/10) of a ton (200 pounds) of muriate of potash is needed.

Any other material may be used in a similar manner. It is not necessary for the greenkeeper to be exact down to the fraction of a per cent, as fertilizer application is not an exact science and a slight variation in the calculation will not materially alter the value of the mixture.

Fertilizer materials are often used to advantage also without mixing. Examples are superphosphate, basic slag, sulphate of ammonia, and nitrate of soda.

The following table will be of help in calculating home mixtures. In making ton lots, to get 1 per cent use amounts shown in the first column, for 2 per cent use those in the second column, and so on:

Quantities of Fertilizer Ingredients to be Used to Give Definite Percentages in a Ton of Mixture*

Ingredient	1% Lbs.	2% Lbs.	3% Lbs.	4% Lbs.	5% Lbs.	6% Lbs.	7% Lbs.	8% Lbs.	9% Lbs.	10% Lbs.
Carriers of nitrogen (N):										
Nitrate of soda (15% N)	133	266	400	532	666	800	933	1,066	1,200	1,333
Sulphate of ammonia (20% N)	100	200	300	400	500	600	700	800	900	1,000
Cottonseed meal (7% N)	285	571	856	1,142	1,428	1,714	2,000	.....	.....	.....
Dried blood (10% N)	200	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000
Fish scrap (8% N)	250	500	750	1,000	1,250	1,500	1,750	2,000	.....	.....
Activated sludge (5½% N)	364	727	1,093	1,455	1,818	.....	.....	.....	.....	.....
Carriers of phosphoric acid (P_2O_5):										
Superphosphate (16% P_2O_5)	125	250	375	500	625	750	875	1,000	1,125	1,250
Superphosphate (20% P_2O_5)	100	200	300	400	500	600	700	800	900	1,000
Double superphosphate (40% P_2O_5)	50	100	150	200	250	300	350	400	450	500
Ground bone† (23% P_2O_5)	87	174	261	348	435	522	609	696	783	869
Carriers of potash (K_2O):										
Sulphate of potash (50% K_2O)	40	80	120	160	200	240	280	320	360	400
Muriate of potash (50% K_2O)	40	80	120	160	200	240	280	320	360	400
Kainit (12½% K_2O)	160	320	480	640	800	960	1,120	1,280	1,440	1,600
Manure salts (20% K_2O)	100	200	300	400	500	600	700	800	900	1,000

To make up a ton of a 4-8-4 mixture in which the nitrogen is two-thirds in the form of sulphate of ammonia and one-third in organic form from cottonseed meal, the phosphoric acid is from 16-per-cent superphosphate, and the potash is from 50-per-cent muriate of potash (potassium chloride), the following materials would be used:

	Pounds
Sulphate of ammonia	268
Cottonseed meal	380
Superphosphate (16 per cent)	1,000
Muriate of potash	160
Filler (ground dried peat)	192
Total	2,000

Since the fertilizer materials add up to 1,808 pounds, 192 pounds of a filler is added. This filler may be a conditioner as well, and often has some fertilizer value in itself. Dried peat, ground phosphate rock, ground limestone, or even sand may be used. The total is so near 2,000 pounds that it may be considered unnecessary to bother with a filler. When the total of the mixture is appreciably less than 2,000 pounds, it may be perfectly satisfactory to use a smaller quantity of fertilizer to the acre rather than to dilute with filler. Thus, if you are making

*Where the combined materials do not total 2,000 pounds a filler may be used to bring up the mixture to that weight.

† Ground bone also carries nitrogen.

a ton of 4-8-4 mixture, in which the sum of the materials used is 1,500 pounds without filler, by using three-fourths of the normal application the filler can be omitted.

The mixture just given is a good general fertilizer. Its nitrogen is in different degrees of availability. The cottonseed meal in this mixture, besides its fertilizer value, is an excellent conditioner. A mixture such as this will spread well, and when properly stored should remain several months in good condition for applying. It is possible to make other mixtures which would have the same ratio of nitrogen, phosphoric acid, and potash, such as 5-10-5, 8-16-8, 10-20-10, and even 15-30-15. As the number of units increases, however, the difficulty of keeping the mixture in condition and of distributing it evenly in the soil or on the turf may increase.

A 7-6-5 mixture may be made of the following materials:

	Pounds
Sulphate of ammonia	400
Nitrate of soda	270
Cottonseed meal	285
Superphosphate	750
Muriate of potash	200
Filler and conditioner (ground dried peat and such)	95
Total	2,000

This mixture is high in quickly available nitrogen.

Fertilizer mixtures may be readily modified to suit various needs. Suppose a greenkeeper can purchase to advantage a concentrated fertilizer analyzing 15-30-15 but desires to use a fertilizer distributer which he thinks more suited to a lower-grade mixture. He also prefers, for local conditions, a greater proportion of nitrogen. He may combine 1 ton of the 15-30-15 analysis commercial fertilizer, 1,500 pounds of sulphate of ammonia, and 2,500 pounds of inert material, such as sand or sandy soil, and thus have 3 tons of approximately 10-10-5 goods. Other concentrated mixtures may be used in a similar manner.

Following is a 12-6-4 mixture made up in two different ways, one with the nitrogen partly in organic form and the other in inorganic form:

12-6-4 Mixture With Organic Base

	Pounds
Urea (46 per cent N)	180
Meat meal (10 per cent N)	300
Cottonseed meal (7 per cent N)	1,027
Phosphate of ammonia (13 per cent N and 48 per cent P_2O_5)	333
Muriate of potash (50 per cent K_2O)	160
Total	2,000

12-6-4 Inorganic Mixture*

	Pounds
Sulphate of ammonia	1,200
20-per-cent superphosphate	640
Muriate of potash	160
Total	2,000

*This mixture should be used soon after mixing as it may become lumpy.

Following are two simple but useful golf course mixtures:

12-8-4 Mixture With Organic Base

	Pounds
Sulphate of ammonia	1,040
Raw ground bone meal (4 per cent N)	800
Muriate of potash	160
Total	2,000

6-12-4 Inorganic Mixture*

	Pounds
Sulphate of ammonia	600
20-per-cent superphosphate	1,240
Muriate of potash	160
Total	2,000

Usually the mixing of fertilizers on the golf course will show a profit, but the greenkeeper will have to investigate and determine what the materials and mixed goods cost in his community and then make his decision. The United States Golf Association Green Section is in a position to help the greenkeeper regarding proper mixtures for his turf and is always pleased to be of assistance.

Fertilizer Production, Consumption, and Costs

Circular 129, published in January, 1931, by the United States Department of Agriculture, entitled "Survey of the Fertilizer Industry," contains information of value to all who are concerned with the use of fertilizers. Some of the more interesting facts and figures contained in the circular are herewith presented.

WORLD PRODUCTION OF INORGANIC NITROGEN (NET TONS)

	1909	1913	1917	June 1, 1923, to May 31, 1924	June 1, 1928, to May 31, 1929
By-product ammonia	233,200	377,300	400,400	346,400	469,700
Chilean nitrate	330,000	429,000	431,200	372,200	539,000
Air fixation	6,050	93,500	374,000	444,500	1,315,600

The modern fertilizer industry, the circular states, is only 80 years old. Although various waste materials have been used from earliest times, without special treatment, to improve the productivity of the soil, the production of commercial fertilizer as it is known today dates back only to about 1850, the year in which superphosphate was first made in the United States. Before that, in 1830, Chile commenced to export nitrate of soda, a natural product requiring little special treatment. In 1840 the acid treatment of insoluble phosphate rock to render it soluble and thus available for use as fertilizer, was invented in Europe. The by-product coke oven, rendering po- sible the recovery of nitrogen as sulphate of ammonia as a by-- of the coke industry, was introduced into the Unite- - Europe in 1893. Later, as the concentration o- industry into large units led to the gen--

*This mixture should be used soon after mix--

products, dried blood and tankage became important fertilizer materials. Simultaneously cottonseed meal came into use as a by-product of cottonseed-oil mills. Fisheries furnished fish scrap, and many other organic materials became available. The latest and most prominent step in the development of the fertilizer industry has been the fixation of atmospheric nitrogen.

FERTILIZER CONSUMPTION (NET TONS) 1928

	Nitrogen	Phosphoric acid	Potash	Total
Germany	450,000	566,000	818,000	1,834,000
United States	345,000	800,000	343,000	1,488,000
France	160,000	583,000	210,000	953,000
All other countries	946,000	1,787,000	655,500	3,388,500

Of the total world production of nitrogen by air fixation, about 87 per cent is consumed in agriculture and the remaining 13 per cent is required for such industrial uses as refrigeration and the manufacture of explosives, nitric acid, and nitrogen salts. Although the low prices of recent years have greatly increased the agricultural consumption of nitrogen, there seems to have been no material increase in the consumption for other purposes.

NUMBER AND ANNUAL NET TON CAPACITY OF NITROGEN-FIXATION PLANTS AT THE END OF 1929

	Number of Plants	Capacity
Germany	14	938,500
United States	9	195,600
England	2	175,000
France	28	168,300
All other countries	68	726,500

The United States, with about 6 per cent of the world's population, uses approximately 19 per cent of the total output of commercial fertilizer, ranking second to Germany as a consumer.

ILLUSTRATION OF ITEMS OF COST ENTERING INTO A TON OF 4-8-4 MIXED FERTILIZER

Nitrogen, 4 units, at $2.60	$10.40	
Phosphoric acid, 8 units, at 50 cents	4.00	
Potash, 4 units, at 80 cents	3.20	
Total plant food		$17.60
Factory and general expense		5.00
Sales expense		2.50
Freight		3.00
Profit to manufacturer		1.50
Total		$29.60

The average plant-food content of commercial fertilizer produced in the United States has increased apparently from 12 or 13 per cent in 1914 to more than 17 per cent in 1928. This result has been accomplished largely by the elimination of worthless filler, by the substitution of better grades of potash salts, and by the substitution of inorganic nitrogen materials for organics of low nitrogen content, and also to a less extent by the use of concentrated materials such as double superphosphate. Freight is an important item in the cost of fertilizer to the consumer, and the possible reduction in this item is a strong recommendation for a concentrated product. It is estimated that the total saving in freight costs for 1928 amounts to $9,900,000 over freight costs for 1914 on a basis of like consumption for the two years. In 1929 there were 832 fertilizer plants in the United States, mostly in the East and South.

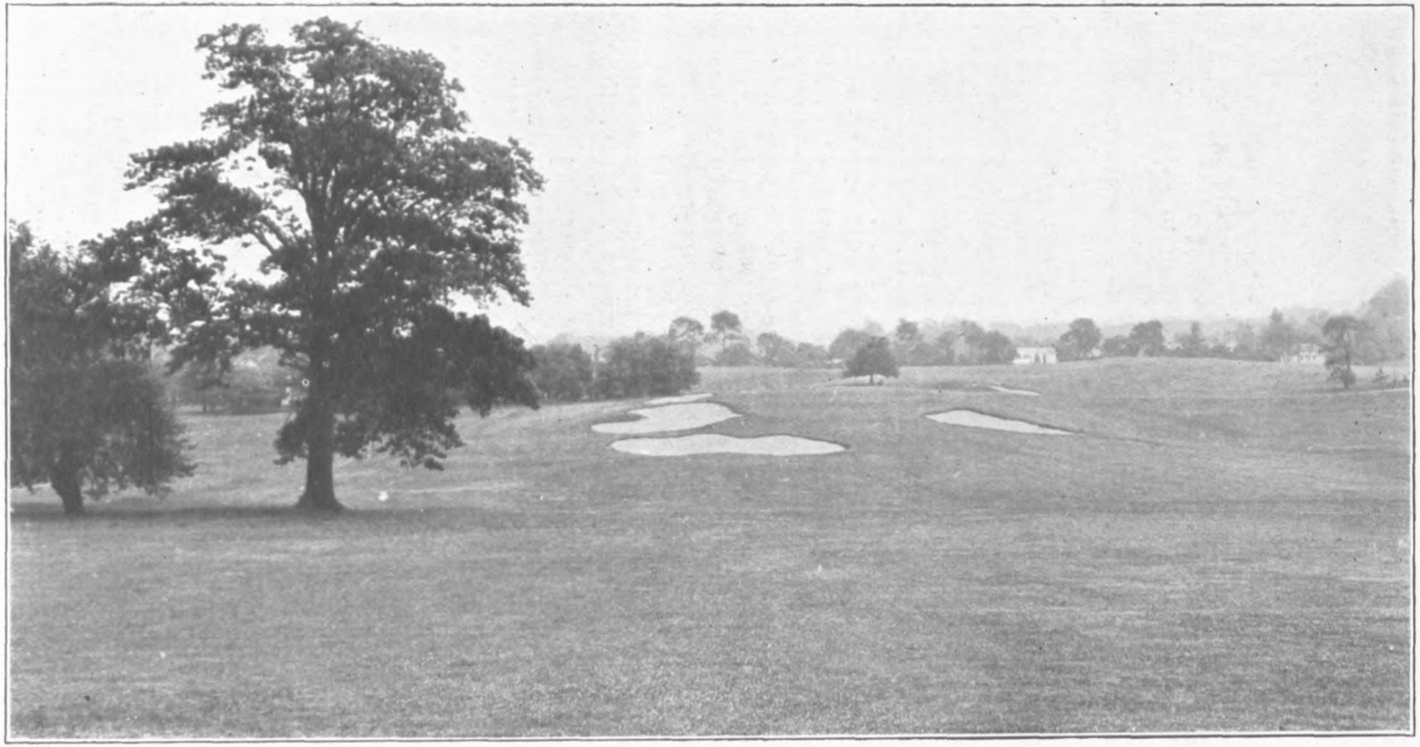
The United States is well supplied with raw materials required in the production of phosphate fertilizer, but is largely dependent on imports for potash. At the present rate of use it is estimated that the total reserve of phosphate rock known to exist in the United States will last some 2,000 years.

It is hopeless to expect to obtain a cheap fertilizer containing any considerable quantity of organic nitrogen. A great saving might possibly be expected in filling nitrogen requirements by such a radical change in practice as the direct application to the soil of aqua ammonia (ammonia in water solution).

Questions and Answers

Preventing injury to bent greens from brown-patch.—In September of last year we planted four of our greens with bent stolons and the remaining five with bent seed. Neither the stolons nor the seed have shown proper development, and it has occurred to us that possibly we are too far south for the proper growing of bent grass. Our soil is a sandy loam and as a rule we have early springs and mild autumns. Do you think we would get better results with Bermuda grass? (West Virginia)

ANSWER.—We do not think you are too far south for success with bent greens, as these are proving satisfactory as far south as points in North Carolina. It would, of course, be possible for you to have fine Bermuda greens during summer, but this grass can not be compared with bent grass for putting purpose, and has the disadvantage of becoming dormant after the first frost in the fall. Located where you are, there is no reason why you can not have success with bent grass. Your trouble is probably due to the brown-patch disease, which is particularly damaging to turf from June to late September. During these months it is necessary to apply fungicides to bent grass to save it from injury. The fungicide with which we get most success is a mixture of 1 part of corrosive sublimate to 2 parts of calomel, applied to putting greens at the rate of 3 ounces to 1,000 square feet, for the first application. The application should be repeated as soon as a fresh attack of brown-patch is noticed, at which time the rate may be reduced to 2 ounces to 1,000 square feet. If the applications have to be made within a week of each other, 1 ounce to 1,000 square feet is sufficient. It must be remembered that the application of a fungicide simply kills the fungus causing the disease and hence merely temporarily checks the disease. Therefore areas that have been allowed to become injured do not become green again until the injured grass has recovered new growth. In hot, muggy weather, when the conditions are particularly favorable for the growth of fungus, applications of fungicides may have to be made every week or so. Further information on brown-patch and its control is contained in the Bulletin for December, 1927.



Seventh hole (225 yards), Women's National Golf and Tennis Club, Glen Head, L. I.

Modern civilization rests upon physical science, for it is physical science that makes intelligence and moral energy stronger than brute force. The whole of modern thought is steeped in science. It has made its way into the works of our best poets, and even the mere man of letters, who affects to ignore and despise science, is unconsciously impregnated with her spirit and indebted for his best products to her methods. She is teaching the world that the ultimate court of appeal is observation and experience, not authority. She is creating a firm and living faith in the existence of immutable moral and physical laws, perfect obedience to which is the highest possible aim of an intelligent being.

Thomas Huxley