Commercial Fertilizer

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The commercial fertilizer industry has been built on the Liebig theory of manures. Briefly stated, that theory is essentially as follows: Given chemical analyses of both the soil and the crop to be grown, all the fertilization necessary is to add to the soil the constituents shown to be lacking; or, in other words, to supply the soil with the mineral elements which the difference between the two analyses indicates are needed. This theory has been exploded time after time. A chemical analysis, except in extreme and very rare cases, does not show which fertilizers will give the best crop production. But while this theory was in vogue (and it still holds sway in certain quarters, especially among city agriculturists), farmers learned by experience that chemical fertilizers are an efficient aid to increase production. The practice of using them has persisted and the commercial fertilizer business has grown to enormous proportions.

CUT AND TRY WITH FERTILIZERS

There is still much of the haphazard in connection with the use of fertilizers. Chemists have never been able to approximate or measure the reactions which under natural conditions take place in the soil. Perhaps they never will. These reactions are complex owing to the large number of factors involved, and they differ with each individual soil. The only way to find out what fertilizer is needed is to try them out, leaving an untreated area as a check for comparison. Literally thousands of such tests have been conducted, and from the mass of data collected some fairly definite and other less definite conclusions may be drawn. Unfortunately for the subject at hand—that is, growing fine turf—we have very few definite data. Most of the fertilizer tests with grass have been conducted on seedings of the coarse forage types used for hay. It has not been shown that fine turf grasses require the same kind of fertilizer, for best results, as would be used for a hay crop. We know now that different grasses vary widely in the way they respond to applications of fertilizers. There is great need for many more definite tests of fertilizers on fine turf. It will be to the interests of golf in general, and a money-saving expedient to the clubs conducting such experiments, if tests, well planned and carefully carried out, are made of the standard fertilizing materials to be found on the market. In most putting-green construction there are so many things done that it is often impossible to know what causes the results, good or bad, as the case may be. So it is unwise to attribute too much value to a certain fertilizer unless there is an untreated piece of turf under the same conditions to be used as a check for comparison.

NO MYSTERY ABOUT FERTILIZERS

In the early days of the fertilizer industry manufacturers endeavored to cover their business with a fog of mystery. Farmers, not being chemists, were supposed to be incapable of understanding the technique of fertilizer composition. Most outrageous frauds were perpetrated. Scores of brands with high-sounding names and for which most extravagant claims were made were offered for sale. Many of these different brands were of the same identical composition and frequently were taken from the same bulk lot.

Low-grade stuff, sometimes almost devoid of plant food, was sold in direct competition and not uncommonly at a higher price than first-class, honest goods. The chemists of the agricultural experiment stations exposed these frauds and are responsible for the various State laws which now govern the sale of fertilizing materials. They punctured the veil of mystery so full of holes that any man of ordinary intelligence can readily understand all the known facts in regard to the manufacture and use of fertilizers.

Plant Food

Chemists have found that most plants are made up of thirteen elements, an element being a substance, as iron or sulfur, which has never been divided into two or more other substances. Of these thirteen elements, three—sodium, chlorine, and silicon—are not essential to normal growth of most plants, though they are often present in the plant and probably under certain conditions perform some service. The remaining ten elements are absolutely essential. In the absence of any one of the ten the plant does not make a normal growth. Four of the ten essential elements are derived either directly or indirectly from air and water; these are carbon, hydrogen, oxygen, and nitrogen. These four elements constitute from 90 to 99 per cent by weight of all ordinary plant material. Young grass, with which the golfer is concerned, is about 98 per cent of carbon, hydrogen and oxygen, derived from air and water. Of course, these do not exist in plant tissues as free carbon, free hydrogen, etc., but are chemically combined with each other, or with some of the other elements, into various compounds. Of these three elements, carbon is always present in abundance in the air in the form of carbonic acid gas. The chemist refers to this gas as carbon dioxide, or more easily by the symbol CO_2. This is given off from the lungs of animals, and is produced by the burning of wood or other vegetable material. In plant growth it is absorbed by the leaves from the air.

Hydrogen and oxygen, in the proportion of two parts hydrogen to one of oxygen, when chemically combined, constitute water. Plants demand a great deal more water than what is needed to supply the hydrogen and oxygen required in building up their tissues. In order to transport the material, for every pound of dry matter produced in plant growth around 500 to 600 pounds of water has to enter the plant roots, pass up to the leaves, and be evaporated. Water is also the carrying agent for moving the starch, sugar, and fiber elaborated in the leaves, to the stems and roots.

Nitrogen

Nitrogen, which costs the golf clubs a liberal-sized fortune every year, constitutes four-fifths of the air we breathe. There are approximately 37,000 tons of nitrogen over every acre of the earth's surface. When free, as it is in the air, nitrogen is one of the most inert materials known. Unless it is stirred up and goes on a rampage in the form of a tornado it is entirely harmless. But get it chemically combined with some other elements and it quickly loses its pacific tendencies. Nitrogen enters into the composition of the most violent explosives, as guncotton, T. N. T., dynamite, etc., it is a constituent of the most deadly poisons, as hydrocyanic gas; and nitricacid is a powerful solvent. Nitrogen is also essential to the growth of animals, and is present in large amounts in lean meat, eggs, and milk. What makes nitrogen expensive is the energy that it takes to get it combined with other elements, especially oxygen. The lightning flash accomplishes this combination, and it has been done commercially where powerful electric currents are available. The Muscle Shoals plant in Alabama was projjected for the purpose of making combined nitrogen.

The cheapest way to combine nitrogen with oxygen is performed in nature by a species of bacteria which live in the live root-tissues of the legume family of plants, such as clovers, beans, peas, vetch, alfalfa, etc. Unfortunately none of the legumes so far tried make fine turf suitable to golfing purposes, so the green-keeper is dependent on manure and commercial forms of this material to keep up the supply of combined nitrogen for his grass.

A Warning.—For the reason given above none of the commercial cultures for inoculating legumes are of any value for use on a golf course. Some companies are now advertising inoculating cultures, and making claims not warranted by experience, in order to sell their dope. It should be clearly understood that these cultures have no effect whatever on the true grasses.

Purpose Served by Nitrogen

Nitrogen aids greatly in the formation of leaves. A deficiency of this element results in a stunted, yellow, sickly growth of grass. As the nitrates are quickly washed out of the soil if not taken up by growing plants, they should be applied as a top-dressing to growing grass rather than before seeding. Nitrogen is usually reported in fertilizer analysis as the number of pounds of the pure element in one hundred pounds of the fertilizer. Sometimes it is reported as ammonia. Of course this element does not occur in fertilizer either as free nitrogen or free ammonia, so it does not matter which form is used so long as it is understood that ammounia is only 14-17 nitrogen—that is, 14 pounds of nitrogen is equivalent to 17 pounds of ammonia. Many manufacturers prefer to use the term ammonia instead of nitrogen, as they can accompany it with a larger number, which gives a better appearance on the bag. The chemical symbol for nitrogen is N, and for ammonia NH_3.

Nitrogenous Fertilizers

Ammonium sulfate.—This is a bi-product in the distillation of coal in the manufacture of coke and illuminating gas. The usual commercial grades have about 20 per cent nitrogen; but as some of this nitrogen does not become available to plants, ammonium sulfate is generally considered of equal value, weight for weight, with nitrate of soda. Ammonium sulfate is highly soluble and quickly available to plants. Its continued use tends to sour land, and is detrimental to the growth of clover and many weeds, such as buttercups, dandelions, plantains, and crabgrass. There is no evidence of injury to the bents and fescues even after many years of use. Ammonium sulfate should never be mixed with strong alkalies, such as lime, ashes, potash, etc., as the ammonia is easily driven off in the air by these substances.*

Nitrate of soda.—This is mined in Chile, South America, and is sometimes called Chile saltpeter. The commercial grades carry about 16 per

* See "Ammonium Sulphate," in No. 3 (p. 31) of this Bulletin.

cent nitrogen. It is soluble in water and readily available to plants. It tends to form an alkaline condition of the soil, due to the absorption of the nitrogen by plants, leaving sodium, a strong alkali, in the soil. The effects from nitrate of soda on grass in good growing weather are remarkable. The grass turns to a deep green and grows rapidly.

Fish-scrap.—The refuse, heads, offal, etc., from fish canneries is dried and sold on the market for fertilizers. Many unedible fish are also caught and used in the same way. Fish fertilizers vary greatly in their chemical composition, but frequently carry about 8 per cent nitrogen and 8 per cent phosphoric acid. Fish decay quickly in the soil and the plant food which they contain is soon available. As might be expected, they have a very disagreeable odor; otherwise there is no objection to their use on fine turf. The use of fish-scrap is confined quite largely to the coast country, where its merit is fully recognized.

Cotton-seed meal.—There are several concentrated vegetable substances which are highly valuable as fertilizers; among these, cotton-seed meal is the most widely used. This material becomes available quickly, and its effects on growing grass are almost as quickly noticeable as are those from such soluble salts as nitrate of soda. Cotton-seed meal contains from 6 to 7 per cent nitrogen, about 2 per cent of phosphoric acid, and 2 per cent potash. From a theoretical standpoint, backed up by considerable experience, cotton-seed meal is an ideal complete fertilizer for growing fine turf. It is best applied mixed with a top-dressing of sand, compost, etc., but can be spread alone. Soy-bean meal, of which there has been a little offered for sale, is still richer than cotton-seed meal in fertilizing ingredients and may be used whenever it can be obtained. Both cotton-seed meal and soy-bean meal are valuable stock feeds, which keeps the price above their relative values for fertilizers.

Dried blood.—This by-product from slaughter-houses is a quick-acting fertilizer. If pure it has from 12 to 14 per cent nitrogen, but if other refuse is mixed with the blood it may analyze as low as 10 per cent nitrogen, but usually in that case will have also 3 or 4 per cent phosphoric acid. The limited supply and demand for dried blood for feeding poultry usually makes the price high in comparison with nitrate of soda or ammonium sulphate.

Calcium cyanamid.—This compound is manufactured by passing nitrogen into a closed retort over superheated calcium carbide. The composition of the calcium cyanamid on the market varies considerably. The nitrogen content varies from 15 to 23 per cent. This fertilizer is so new and its effects on plants under some conditions so peculiar that its general use can not be recommended at this time; but it offers a fine opportunity for experimental work on turf grasses in order to find the reaction of insect pests, weeds, diseases, etc., to its use.

Elements from the Soil

The six other essential elements—calcium, magnesium, potassium, phosphorus, iron, and sulfur—are derived from the solid material of the soil. These are sometimes spoken of as the mineral elements of a plant. They constitute the ash when vegetable substances are completely burned. While these materials are present in very small quantities in plant tissue, they are absolutely necessary. As stated before, normal growth can not take place if any one of them is entirely lacking. Of these six elements, magnesium, iron, and unsually sulfur, are present in every soil in sufficient quantities to answer all requirements for plant food. In a few tests recently conducted, sulfur has been beneficial on some crops, as alfalfa in certain locations, but for all practical purposes the green-keeper need not worry at all about magnesium, iron, or sulfur; his soil will have all of these in ample quantities for growing grass.

Calcium.—This is the basic substance in the various lime materials. The use and abuse of lime was thoroughly discussed in No. 3, page 43, of this current volume of THE BULLETIN, so that part of the subject need not be repeated here.

There are three grades of lime (burned lime, hydrated lime, and ground limestone) on the market. While the results of lime experiments are not all in harmony, the weight of the evidence indicates that it does not make any difference which one of these three forms is used provided the same amount of calcium is added to the soil in each case.

Ground limestone is just what its name implies. In most cases only a high grade of calcium carbonate is used for grinding. There is much ground limestone on the market which analyzes above 93 per cent calcium carbonate. Some forms of limestone carry magnesium as well as calcium. If the magnesium is not present in excessive amounts it does no harm. Marble and oyster shells are also composed of calcium carbonate and are frequently ground for agricultural purposes and are of equal value for the same degree of purity as ground limestone.

When calcium carbonate is burned at a high temperature it gives off carbonic acid gas and water, leaving calcium oxide, or, as it is known commercially, quicklime or burned lime. One hundred pounds of pure limestone, when thoroughly burned, gives 56 pounds of quicklime.

If to the 56 pounds of quicklime just 18 pounds of water are added, the lime slakes to a fine, dry powder; this is known on the market as hydrated lime. If this 74 pounds of hydrated lime is exposed to the air for a few weeks it will take up carbonic acid gas, increasing in volume, and will return to its original weight of 100 pounds; this is known as air-slaked lime. These figures give the relative value of the three grades of lime; that is, 56 pounds of burned lime equals 74 pounds of hydrated lime or 100 pounds of air-slaked lime or ground limestone. Approximately one ton of quicklime is equivalent to two tons of limestone.

Quicklime should be thoroughly slaked before being applied to living grass or when seeding. The caustic nature of quicklime, especially in the ground form, is very irritating to the skin and disagreeable to handle. Horses hauling it should be protected with blankets. In the hydrate form, much of the caustic property is gone, and the ground limestone is free from it entirely.

There is still one other form of lime used agriculturally; that is, calcium sulfate, known variously as gypsum, land-plaster, and plaster of Paris. It has a remarkably stimulating effect on the growth of clover when applied to fairly fertile land. The use of land-plaster has greatly declined in late years. It is doubtful if it has any value in growing fine turf.

Phosphorus.—There is much variation in the phosphorus requirements of different plants. Plants which produce seeds, as wheat or other grain, require relatively a large amount of this element. It is also highly important in the growing of tobacco, potatoes, and many vegetables. For grass growing it takes a secondary position to nitrogen; but it must be remembered that phosphorus is an essential element and nature has no way of restoring it to the soil once the supply becomes exhausted. The tendency has been of late years to forego the use of phosphates on fine turf, and depend almost entirely on the use of nitrates in order to keep up the growth of the grasses. This in some instances has been undoubtedly carried too far, and on some putting-greens an application of phosphatic fertilizers would likely be beneficial. Unlike nitrates, which are quickly leached out of the soil, phosphates become fixed until used by plants. Phosphates have markedly beneficial effect on bluegrass, and the famous bluegrass regions are all righ in this element. One characteristic result from phosphorus should be noted: it hastens the maturity of plants to which it is applied. This is especially noticeable in leafy plants, such as tobacco, as well as those grown for seed. For this reason it should, when applied to turf grass, be used in moderate amounts, as the desire in the latter case is to postpone maturity as much as possible.

Phosphorus is usually reported in fertilizer analysis as phosphoric acid, a compound of two parts of phosphorus and five of oxygen. In some states the manufacturers are required to give the composition as phosphorus alone; less than half of the phosphoric acid is phosphorus. To be exact, 31 pounds of phosphorus is equivalent to 71 pounds of phosphoric acid. The chemical symbol for phosphorus is P, and for phosphoric acid P_2O_5.

Phosphatic Fertilizers

Acid-phosphate.—When a ton of ground phosphate rock (mined in Tennessee, South Carolina, and Florida) is treated with an equal weight of sulphuric acid, the resulting product is two tons of acid phosphate. If the original rock has 32 per cent phosphoric acid, the acid-phosphate will have just half as much, or 16 per cent. The reason for this acid treatment is to change the chemical form of the phosphate from an insoluble to a soluble form. At the same time quite a large amount of land-plaster or calcium sulfate is produced. Each ton of acid-phosphate has from 1,000 to 1,200 pounds of sulfate of lime. As previously stated, sulfate of lime promotes the growth of clover, and top-dressings with acid-phosphate on bluegrass pastures have greatly increased the stand of white clover. For that reason acid-phosphate should be used moderately on putting-greens. Much of the white clover trouble may be attributed to the use of too much of this fertilizer.

Bone-meal.—Long before plant food was called "pabulum," farmers learned that bones and other animal refuse nourished and increased the size of plants. This class of materials is still one of the most popular forms of fertilizers. It has proved especially efficient in increasing the production of meadows and pastures. Three of the characteristics of bone-meal which appeal to farmers are (1) that there are no deleterious effects, no matter how abundantly or carelessly applied; (2) that the action is slower than some other phosphates; and (3) that the effects are noticeable for several years after using.

While bone-meal is generally classed as a phosphatic fertilizer, raw bones contain about 4 per cent of nitrogen in addition to 22 per cent of phosphoric acid. The form most generally used for fertilizer is steamed bone-meal—that is, bones which have been heated in live steam to extract the fat and gelatinous matter. In steamed bones the nitrogen content is reduced to about 1½ per cent, and the phosphoric acid increased in some cases to 28 and 30 per cent. The steamed bone-meal is more readily available, on account of the absence of fat, which retards decay, and is the form to be preferred by green-keepers. Bone-black (or animal charcoal), which is made by heating bones until all volatile matter is driven off, is used to clarify sugar. After it has served its purpose in refining sugar, it is sold for fertilizer. Bone-black, together with the impurities it has absorbed, will contain from 32 to 36 per cent of phosphoric acid. The absence of sulfate of lime in bone-meal makes it one of the most desirable forms of phosphate for putting-greens.

Basic slag.—In the smelting of ores which contain phosphorus, a high grade of fertilizer is obtained in the slag. This is known as basic slag, also as Thomas phosphate. Good slag should have 18 per cent phosphoric acid. It carries, however, a large amount of lime in the carbonate form. This promotes the growth of clovers, dandelions, crab-grass and other noxious weeds. The use of basic slag should be avoided by the green-keeper.

Potash

The term potash when used in connection with fertilizers means the oxide of potassium in the proportion of two parts potassium to one of oxygen. Potassium plays a very peculiar role in plant growth. It appears to be more of an aid to growth than an intimate constituent of plant tissue itself. In a crop like wheat there is more potassium present when the crop is just heading out than when it is mature, indicating that part of the potassium had served its purpose and was discarded. Most soils carry sufficient potash for growing grass. But to be sure that there is enough present it is advisable to give a light application at least once a year. Potash does not leach out of the soil, so it may be applied at any time without danger of losing it. The experiments which have been conducted with potash on grass indicate that heavy applications promote the growth of clovers, which are not desirable. On the other hand, withholding completely all potash gives the grass a stunted appearance, showing that it is suffering from malnutrition.

In fertilizer analyses, potassium is usually given in per cent of potash. If the analysis is given for potassium, one should know that 39 pounds of potassium equals 47 pounds of potash. The chemical symbol for potassium is K, and for potash K_2O.

There were two forms of potash on the market prior to the war, each of which contained approximately the equivalent of 50 per cent of oxide of potassium; these were the muriate and sulfate, obtained from large deposits in Europe. The muriate of potash (or chloride of potassium, as known by chemists) was usually cheaper and fully as efficient as the sulfate for increasing plant growth. The potash industry was badly demoralized by the war and has not as yet returned to normal. It is now possible, however, to get muriate of potash and that is the form which is best to use on fine grass. This is a high-grade material and is frequently applied in too large amounts. One hundred pounds of muriate of potassium carries as much potash as a ton of mixed fertilizer analyzing 2½ per cent of this ingredient. *Do not use too much potash.*

Mixed Fertilizers

A mixed fertilizer, as the name implies, consists of two or more materials mixed together, and usually carry nitrogen, phosphorus, and potash in various proportions. Sometimes one of these three elements may be lacking. The fertilizer manufacturers always claim that the different ingredients in their goods are complete and properly balanced for the particular use desired, etc. There is something in the matter of balancing a fertilizer where large amounts are applied to special crops, such as potatoes and tobacco; but the green-keeper is not concerned in this subject, and the matter of whether the fertilizer is balanced or not, in the light of present knowledge, need not be considered in turf work.

What the green-keeper is vitally concerned about is whether the plant food in the fertilizer is readily available or not. The fertilizer companies are compelled by law in most states to give the percentage composition of their fertilizers, showing how much of nitrogen, how much phosphoric acid, and how much potash they contain. In some states the kind of material used in the mixture must also be given. Two fertilizers may have exactly the same composition and yet differ widely in their value. Leather waste, hoofs, horns, and hair carry a high percentage of nitrogen, yet unless treated to render them soluble are nearly worthless for fertilizer because they are so slow in decaying. It should be remembered that plants absorb all of their food which they get from the soil in liquid form. Until a fertilizer goes into solution it can not benefit a growing plant. Some materials which are insoluble decay quickly and form soluble compounds when exposed in the soil.

Many of the large fertilizer companies have practically discarded the use of brand-names and designate their fertilizers by their composition, as 3-8-3 or 3-6-8 goods. These numbers mean the parts in a hundred by weight of the three substances, nitrogen, phosphoric acid and potash, and in this order. In some localities it is customary to give the phosphoric acid first, as 8-3-3, or 6-3-8. If this order is used it can usually be readily detected, as potash is always given last place in the series and the phosphoric acid is almost always a much larger number than that for nitrogen.

A ton of 3-8-3 goods carries 60 pounds of nitrogen, 160 pounds of phosphoric acid, and 60 pounds of potash. If this fertilizer is composed of the standard materials (nitrate of soda, acid phosphate, and muriate of potash) the amounts of these to the ton would be as follows:

Nitrate of soda with 16%	$N = 60 \div 16 \times 100 =$	375 lbs.
Acid-phosphate with 16%	$P_2O_5 = 160 \div 16 \times 100 =$	1,000 "
Muriate of potash with 50%	$K_2O = 60 \div 50 \times 100 =$	120 "
Total		1,495 "

There are many other fertilizing materials from which this grade of fertilizer might be made, but in buying a ton of 3-8-3 goods one gets 1,495 pounds of fertilizing materials and 505 pounds of filler. This explains why sand-banks are at a premium when located near a fertilizer factory. It also explains why it is better and cheaper to buy unmixed goods, know what you are buying, and save freight and hauling on this filler. The consensus of opinion of green-keepers in late years has been to steer shy of Bunkum's Grass Special of unknown composition and buy standard unmixed goods of known purity. There is no more need to be swindled in buying nitrate of soda or ammonium sulfate than there is in buying granulated sugar or table salt.

Buy by Composition

The analysis of any fertilizing material should be ascertained and the price compared with the prices of similar grades before purchasing.

While the chemical analysis is far from being a perfect guide, it is the only means available for telling anything whatever about the value of a fertilizer before using it, and it is by far better to buy by analysis than by trade-name.

Some companies still try to befog the issue by including so many different things in the statement of composition that their fertilizer analysis looks like the advertisement of a mineral spring. They still like to drag in by the hair of the head high-sounding terms, as "bone phosphate of lime," although the phosphorous in the fertilizer may all be derived from southern phosphate-rock. The inference is plain; bone-meal has long been favorably known as a fertilizer.

Rate of Application

The following recommendations for fertiliziing putting-greens are given for those who have not had much experience in the matter of the use of these materials. It is not claimed to be a perfect combination for all soils, but it is safe and sane. The proportions should be changed when experiments indicate such change is desirable.

For a complete fertilizer to be used once a year, preferably in the spring (or the phosphate and potash may be applied in the fall and the nitrate withheld until spring), the following is suggested:

Ammonium sulfate	250 pounds
Bone-meal	500 "
Muriate of potash	100 "

This mixture should be applied at a rate not to exceed 20 pounds to 1,000 square feet of surface. During the summer two or three applications of ammonium sulfate may be made at the rate of not to exceed 6 pounds to 1,000 square feet. If desired, nitrate of soda may be substituted for ammonium sulfate by using the same quantities.

Burning from Fertilizers

Everyone who has done much fertilizing of grass with high-grade fertilizers is familiar with the burning effects which are produced when too much is applied or when the fertilizer is in large lumps.

Such materials as nitrate of soda, ammonium sulfate, calcium cyanamid, and other highly soluble materials, should never be applied at a heavier rate than one ounce to ten square feet, or six pounds to 1,000 square feet of surface. Such materials cause a concentration of dissolved material in the soil water and give a greater density than the sap within the plant. As a result the juices are drawn out of the plant instead of more moisture entering, as is necessary to keep the grass alive.

The same effect can be produced with liquid manure if it is in too strong a solution. The remedy is to dilute with water. We have several reports of burning of grass from the use of cotton-seed meal in too liberal quantities. While the writer has never been able to produce this effect even with very heavy applications, he does not doubt the accuracy of these reports. When conditions are right for the rapid fermentation and decay of the meal, burning will undoubtedly take place if too much is used. But two ounces to ten square feet or 12 pounds to 1,000 square feet will probably never cause any trouble. In applying any of these fertilizers, it is advisable to work them down to the soil with a broom, and, if possible, follow immediately with a good watering.