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FERTILISERS & MANURES

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FERTILISERS AND MANURES

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FERTILISERS AND MANURES

THEIR MANUFACTURE
COMPOSITION AND USES

BY

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PREFACE

THE present volume is a sequel to the author's *The Soil and the Plant*. It has been written for a wide circle of readers. Besides students in colleges and farm institutes, gardeners professional and amateur, market gardeners, farmers and fertiliser merchants should have a knowledge of those substances which are used to assist the growth of plants. Some small knowledge of chemistry is essential in order to understand the methods of manufacture and also the nature of the different fertilisers. Armed with that knowledge, fewer mistakes will be made in their application.

The aim has been to give to readers, as briefly as possible, a clear account of the nature of the various substances. The industrial side has grown enormously in the last two decades. Chapters on the preparation of compound fertilisers and on the Fertilisers and Feeding Stuffs Act have therefore been included.

The author is grateful to the Royal Horticultural Society for permission to include the details of the method of making composts. He wishes also to acknowledge his debt to the papers of Drs. Ogg and Nicol and also to that of Sir Alfred Howard.

E. V.

MORLAIS,
BISHOPSTEIGNTON, DEVON

March 1947

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CHAPTER I

NITROGENOUS FERTILISERS

THE requirements for the adequate growth of plants are air and water, light and warmth, food, and the defeat of enemies. The elements required in greatest amounts are nitrogen, potassium, phosphorus, and calcium. These elements are taken in by the plant by means of the fine root hairs. For this to be possible, the elements must be in a state of solution or liquid condition.

Most soils do not supply the first three of these elements in a state of solution quickly enough for maximum growth. It is therefore necessary to assist the plant by supplying the elements in a more soluble form. The substances thus supplied are called fertilisers.

The term manures is usually applied to such substances as the excreta of animals — for example, farmyard manure, poultry manure — also to bone manures and fish guano. The choice of terms is, however, not rigidly kept and both terms are used in describing substances which assist growth. It will be evident that the fertilisers required will be nitrogenous, potassic, phosphatic, and the various forms of calcium or lime compounds.

The following is a list of the nitrogen-containing fertilisers in common use :

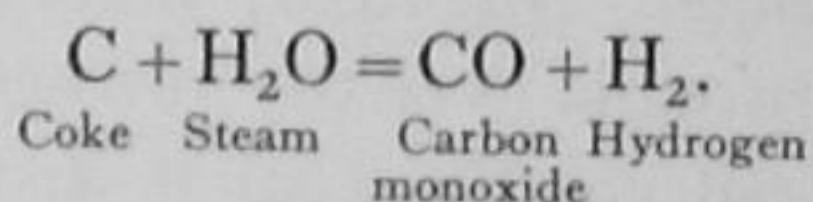
Sulphate of ammonia : $(\text{NH}_4)_2\text{SO}_4$.

Nitrate of soda : NaNO_3 .

Calcium cyanamide : CaCN_2 .

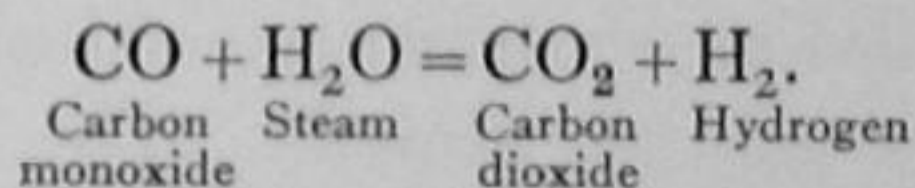
solved the problem. There is, or should be, an abundance of combined nitrogen available for food production. Unfortunately, much of it has had to be diverted to manufacture explosives. Chemists have been able to combine the two gases nitrogen and hydrogen to form ammonia. They can also combine nitrogen with oxygen and water and so produce nitric acid and nitrates.

Manufacture of Ammonia.—Starting with coal, coke, and water, by passing steam over red-hot coke, water-gas is produced. This is a mixture of carbon monoxide and hydrogen :



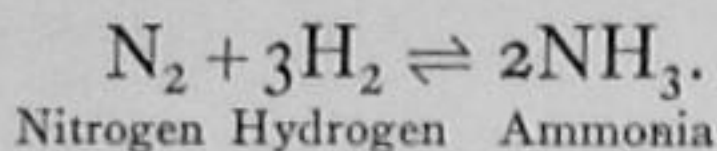
By heating coal and coke in a special type of furnace known as a "producer", in which the supply of air can be carefully regulated, producer gas is obtained. This is a mixture of carbon monoxide, carbon dioxide, and nitrogen. The water-gas and the producer gases are mixed. The next step is to remove the oxides of carbon and so leave the two gases hydrogen and nitrogen.

It has been found that steam and carbon monoxide will react in the presence of a catalyst or accelerator as follows :



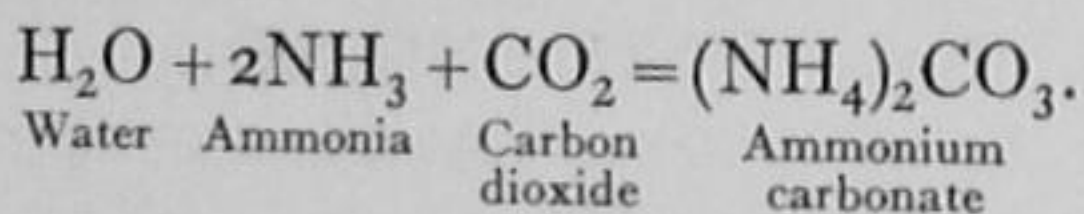
The monoxide has been converted into the dioxide and more hydrogen formed. The dioxide can now be removed by compression into water. Any monoxide remaining can be removed by absorption in copper liquor, a solution of cuprous chloride, leaving the pure gases nitrogen and hydrogen. These two gases can be combined to produce ammonia. The best conditions have been worked out.

Satisfactory yields are obtained when working with the gases compressed to two hundred atmospheres, that is, about 2800 lb. per square inch, and at a temperature of 500° C. in the presence of a catalyst such as iron and molybdenum. The ammonia gas so produced is immediately cooled and so liquefied.

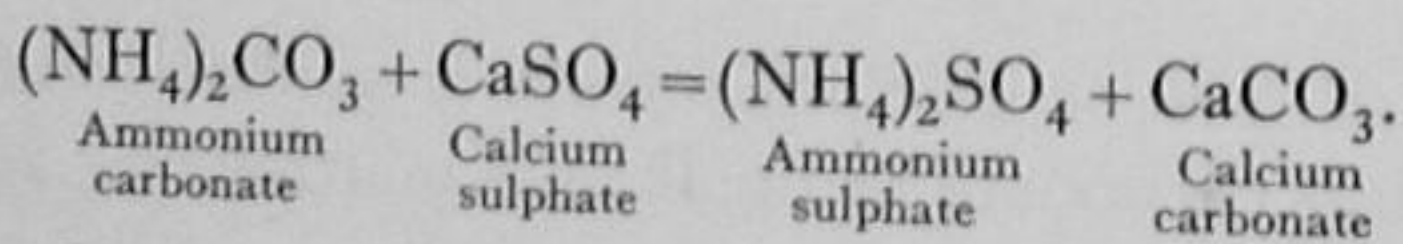


Having obtained ammonia, it can now be made into a number of valuable products.

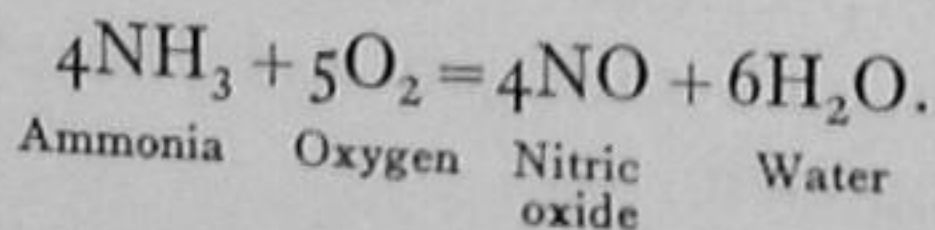
Sulphate of Ammonia.—The ammonia is combined with the carbon dioxide previously removed, so forming ammonium carbonate :



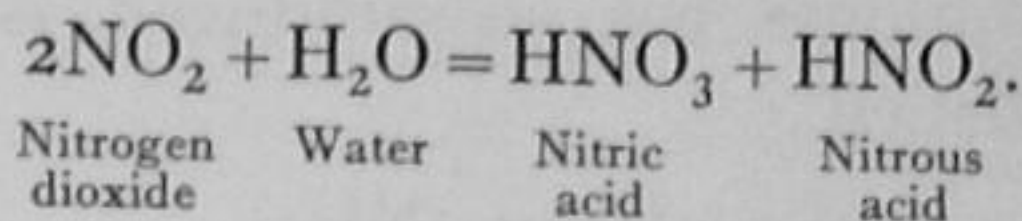
This ammonium carbonate is now made to react with anhydrite, a cheap form of calcium sulphate. Ammonium sulphate and chalk or calcium carbonate are produced. The former can be dissolved out with water, concentrated, and crystallised, and practically pure ammonium sulphate is obtained :



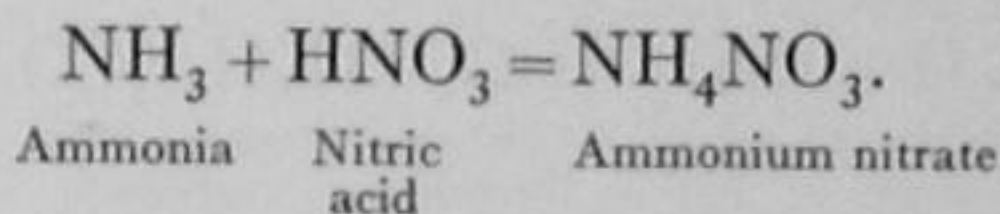
Nitric Acid from Ammonia.—In ammonia the element nitrogen is combined with hydrogen. In nitric acid and nitrates it is combined with oxygen. The change can be brought about by oxidation of the ammonia. This happens when a mixture of air and ammonia is passed over hot platinum gauze as a catalyst :



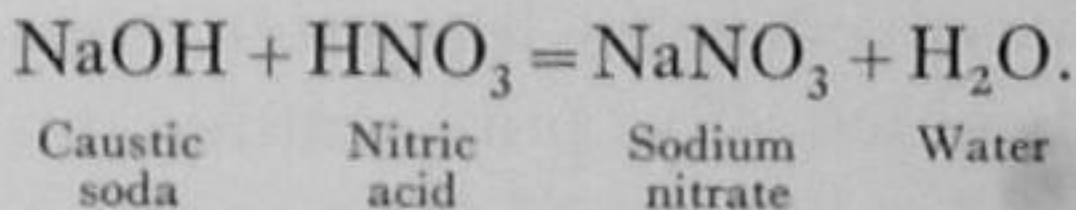
The nitric oxide (NO) so obtained readily combines with more oxygen from the air, forming a brown gas, nitrogen dioxide (NO₂). This is readily soluble in water, producing a mixture of nitric and nitrous acids :



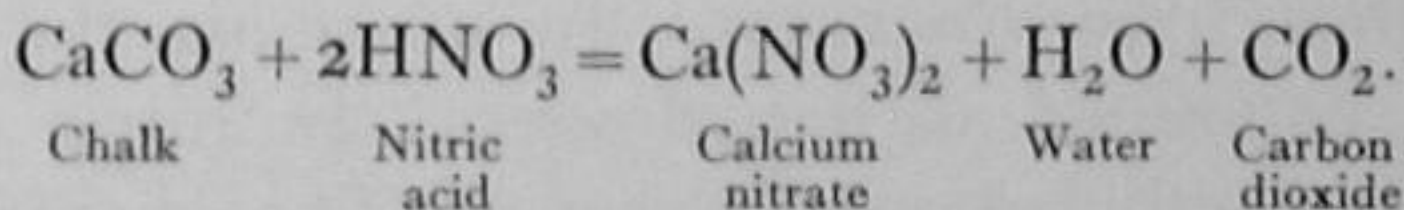
Nitrates from Nitric Acid.—The acid can be neutralised with ammonia to yield ammonium nitrate. This is an explosive substance. Any danger in its use is removed by mixing with chalk. The mixture is called *nitro-chalk*. It contains both ammoniacal and nitrate nitrogen :



Nitrate of soda can be obtained by neutralising nitric acid with sodium carbonate or with caustic soda :

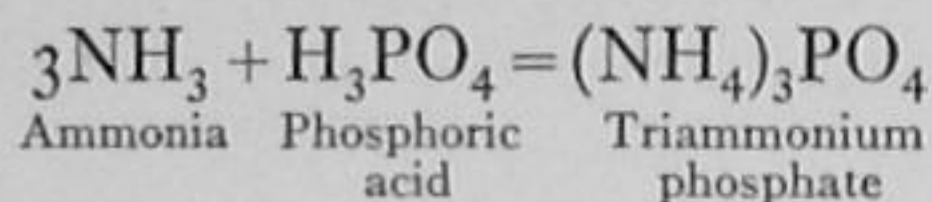
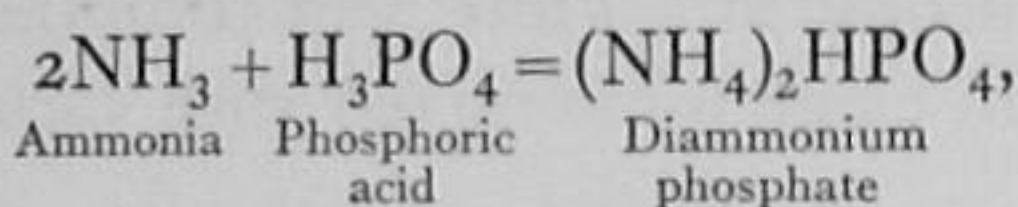
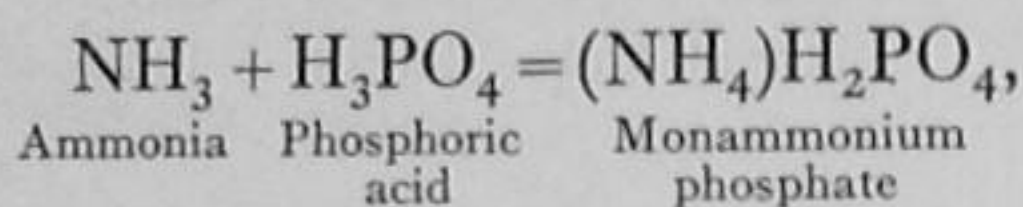


Nitrate of lime or calcium nitrate is similarly formed by using calcium carbonate or chalk as a neutralising agent :



Ammonium Phosphates.—By substituting phosphoric acid for nitric acid, and neutralising it with ammonia, ammonium phosphates can be prepared. They are of special interest since they contain both nitrogen and phosphorus, both of which are fertilising elements.

Three ammonium phosphates are known. This is seen from the following equations :

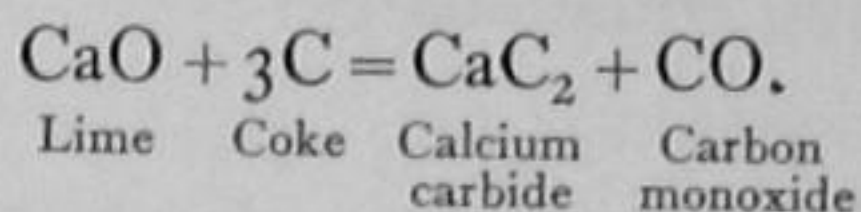


They are known as monammonium phosphate, diammonium phosphate, and triammonium phosphate. The percentage of nitrogen increases as we pass from the first to the third and the percentage of phosphoric acid diminishes.

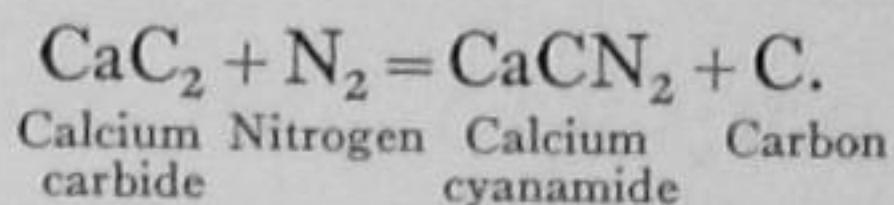
Nitrate of Soda.—It has been mentioned that this substance can be made from nitric acid and sodium carbonate. The nitric acid was obtained by the oxidation of ammonia. In countries where water-power was available to produce cheap electrical energy it was possible to combine the nitrogen and oxygen in the air by passing the gases through a large electric arc. Nitric oxide (NO) was formed in small quantity. By quickly cooling and combining with more oxygen, the dioxide was produced and then nitric acid, as already described. From this, nitrates of lime and soda were made. Nitrate of soda is, however, found below the soil in Chile in South America. In fact it is often called Chile saltpetre. The raw material called *caliche* is loosened by blasting, mined, carted to crystallising vats, where it is dissolved, concentrated, and crystallised. It is dried and bagged.

Calcium Cyanamide : CaCN_2 .—This fertiliser is also made by fixing atmospheric nitrogen. Electrical energy is again necessary. Lime and coke are heated in an electric

furnace, when calcium carbide is formed :



This calcium carbide at a white heat combines with nitrogen, forming calcium cyanamide mixed with carbon :



The other nitrogenous fertilisers are all white crystalline substances readily soluble in water. Calcium cyanamide is a greyish-black dusty substance mixed with carbon. It contains combined nitrogen and has proved to be a valuable fertiliser.

CHAPTER II

EFFECTS OF NITROGENOUS FERTILISERS ON THE PLANT AND THE SOIL

THE manner in which the nitrogen is combined has a great effect on the solubility and therefore on the rapidity of action of the fertiliser. In ammonium compounds the nitrogen is combined with hydrogen; in nitrates it is combined with oxygen; while in calcium cyanamide half the nitrogen is combined with carbon and the other half with calcium. In organic manures such as bone meal, the nitrogen is present in an exceedingly complex compound, namely, an albuminoid or protein. Nitrates have the most rapid effect on the plant, then ammonium compounds, then calcium cyanamide. The organic manures are generally very slow in action.

The extremely rapid effect of such fertilisers as nitrates has caused them to be regarded as stimulants. Obviously these fertilisers must be used with caution and only in small quantities at a time. Their effect is to promote rapid leaf development. Too much will result in the growth of soft sappy leaves which are readily attacked by pests, such as insects and fungi. Plants absorb nutrients from the soil with extreme slowness; growth is slow; consequently growers usually prefer a fertiliser or manure which gives a steady continuous supply of nourishment. Manures like bone meal, farmyard manure, hoof and horn meal, and shoddy supply nitrogen slowly. Where a quick result is wanted then nitrates, ammonium salts, and cyanamide can be profitably employed.

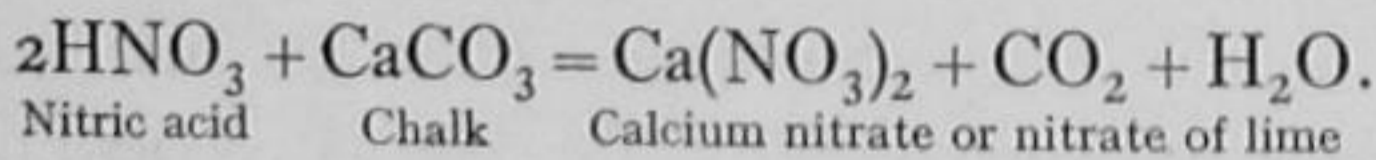
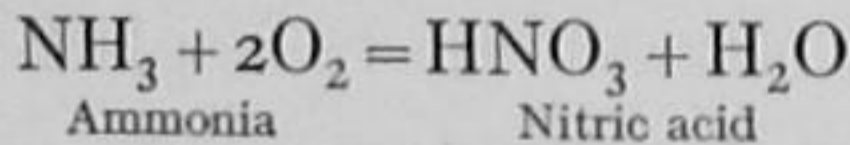
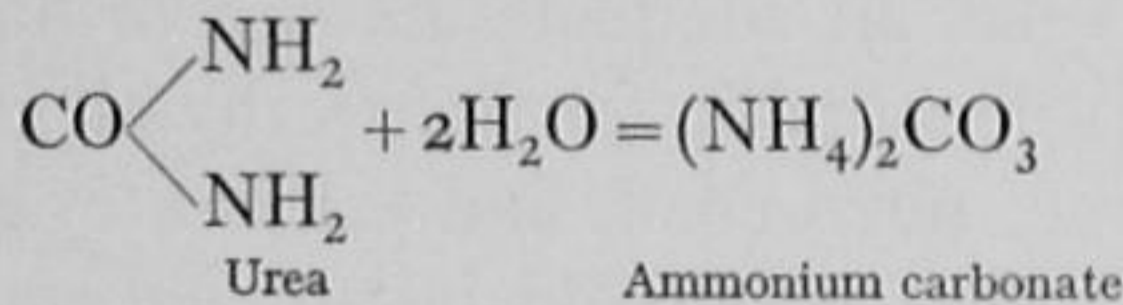
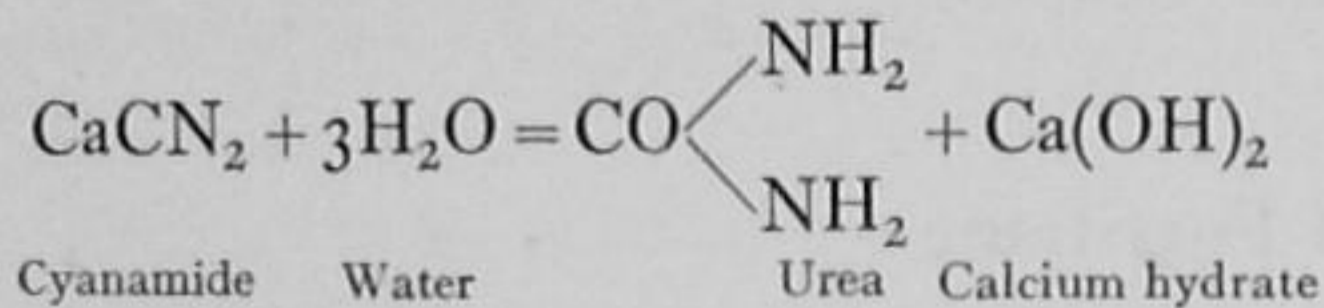
Effect of Nitrogenous Fertilisers on the Soil

Sulphate of Ammonia.—In ammonium sulphate the ammonium is the basic or positive part and the sulphate the acid or negative part. When this salt is applied to the soil and dissolved by the rain, the ammonium part is absorbed by the soil colloids or clay and humus particles and another base or bases given up in exchange. The base turned out is usually calcium. This forms calcium sulphate which becomes soluble and so passes from the soil into the drainage water. Ammonium compounds such as sulphate of ammonia therefore increase the rate of loss of lime from the soil. After absorption of the ammonium by the clay particles it becomes oxidised or nitrified and converted into nitrate, through the agency of the nitrifying organisms in the soil. This nitrate is absorbed by the plant roots. Any excess passes into the drainage water. Ammonium salts may be absorbed by the roots without previous nitrification, but this latter process is usually rapid in soils. The removal of basic elements from the soil may gradually produce acidity in the soil. At Rothamsted Experimental Station, one of the permanent grass plots has been continually treated with sulphate of ammonia and the soil has become distinctly acid. Acids cause the clay particles to collect together to form aggregates or, in other words, to become flocculated, so sulphate of ammonia will tend to cause flocculation and improve the texture of the soil.

Nitrate of Soda.—The soda in this substance is strongly basic and when applied to the soil it will release other bases, including potash, for the plant. The clay particles are adversely affected, being deflocculated. Unless the nitrate is taken up by the crop it is soon washed down to lower depths by the rain and eventually passes to the drainage

water. The soda base itself is not strongly retained.

Calcium Nitrate and Calcium Cyanamide.—Both these contain lime and leave residues of lime in the soil; they therefore cause flocculation of soil particles. The nitrate is immediately available to the plant. The cyanamide undergoes various chemical changes but ultimately is converted to nitrate, as indicated by the following equations :



The Purchase of Nitrogenous Manures

The grower buys these for the nitrogen in them. He must know the percentage of nitrogen present. In commercial nitrate of soda there is 15.5 per cent of nitrogen, so a ton of this fertiliser will contain

$$\frac{15.5 \times 2240}{100} \text{ lb. of nitrogen,}$$

or

$$15.5 \times 22.4 \text{ or } 15\frac{1}{2} \text{ times } 22.4 \text{ lb. of nitrogen.}$$

22.4 lb. or $\frac{1}{100}$ th of a ton is the unit in the purchase of fertilisers. So nitrate of soda has 15.5 units of nitrogen in a ton.

Similarly sulphate of ammonia with 20·6 per cent nitrogen has 20·6 units of nitrogen in a ton.

The value of the unit, that is, of 22·4 lb. of nitrogen, will be the price per ton divided by the number of units present. So the value of the same weight of nitrogen can be compared in the different fertilisers. These unit values are usually published weekly in the trade journals and it is easy to see which is the cheapest.

Choice of Fertiliser

If the soil has an adequate amount of lime, sulphate of ammonia will be suitable for practically all crops. On soils lacking in lime, nitro-chalk and calcium cyanamide will be satisfactory. The last should be applied some time before sowing the seed. Nitrates can be applied when a very rapid effect is wanted. The quantities usually are from one to two cwts. per acre. These fertilisers only last one season; that part which is not removed by the crop is washed out into the drainage water. It must always be remembered that nitrogenous fertilisers should be applied cautiously — a little at a time. Some of these fertilisers are almost pure chemical substances: in particular, sulphate of ammonia and nitrate of soda.

How pure are the commercial articles? From the chemical formula it can be seen that sulphate of ammonia of molecular weight 132 contains 28 parts of nitrogen: $(\text{NH}_4)_2\text{SO}_4 = 132$. The percentage of nitrogen in pure sulphate of ammonia will be $28 \times 100/132$, or 21·2 per cent. The commercial article contains 20·6 per cent of nitrogen. Its purity is therefore $20·6 \times 100/21·2$, that is, 97·1 per cent. *Nitrate of soda* has the formula NaNO_3 . Its molecular weight is $23 + 14 + 48$, or 85. There are 14 parts by weight of

nitrogen in 85 parts by weight of nitrate of soda. A hundred parts will therefore contain $14 \times 100/85$, or 16.47 per cent of nitrogen. The commercial nitrate of soda is guaranteed to contain 15.5 per cent. Its purity is therefore $15.5 \times 100/16.47$, or 94.1 per cent.

CHAPTER III

PHOSPHATIC FERTILISERS : MINERAL PHOSPHATES AND SUPERPHOSPHATE

THE element phosphorus supplied to the plant in the form of soluble phosphates promotes a vigorous root development. When phosphates are given in addition to a supply of available nitrogen, which promotes growth of leaves, more extensive growth will follow.

The chief phosphatic fertilisers are :

Mineral or rock phosphates.

Superphosphate of lime.

Basic slags.

Bone manures.

Mineral Phosphates

These are found in various parts of the earth. North African phosphates come from Tunisia where immense deposits are found at Gafsa. Deposits are found in Florida, U.S.A. ; in the Pacific isles of Nauru and Christmas ; in Egypt and in the West Indies. These phosphates are the fossilised deposits of birds ; the nitrogen and potash compounds have been lost by leaching. Nearly all these mineral phosphates consist chiefly of tricalcium phosphate ($\text{Ca}_3(\text{PO}_4)_2$) together with a variable amount of calcium carbonate. The North African phosphates are more available than those from other parts of the world. They are found to be more soluble in weak acids.

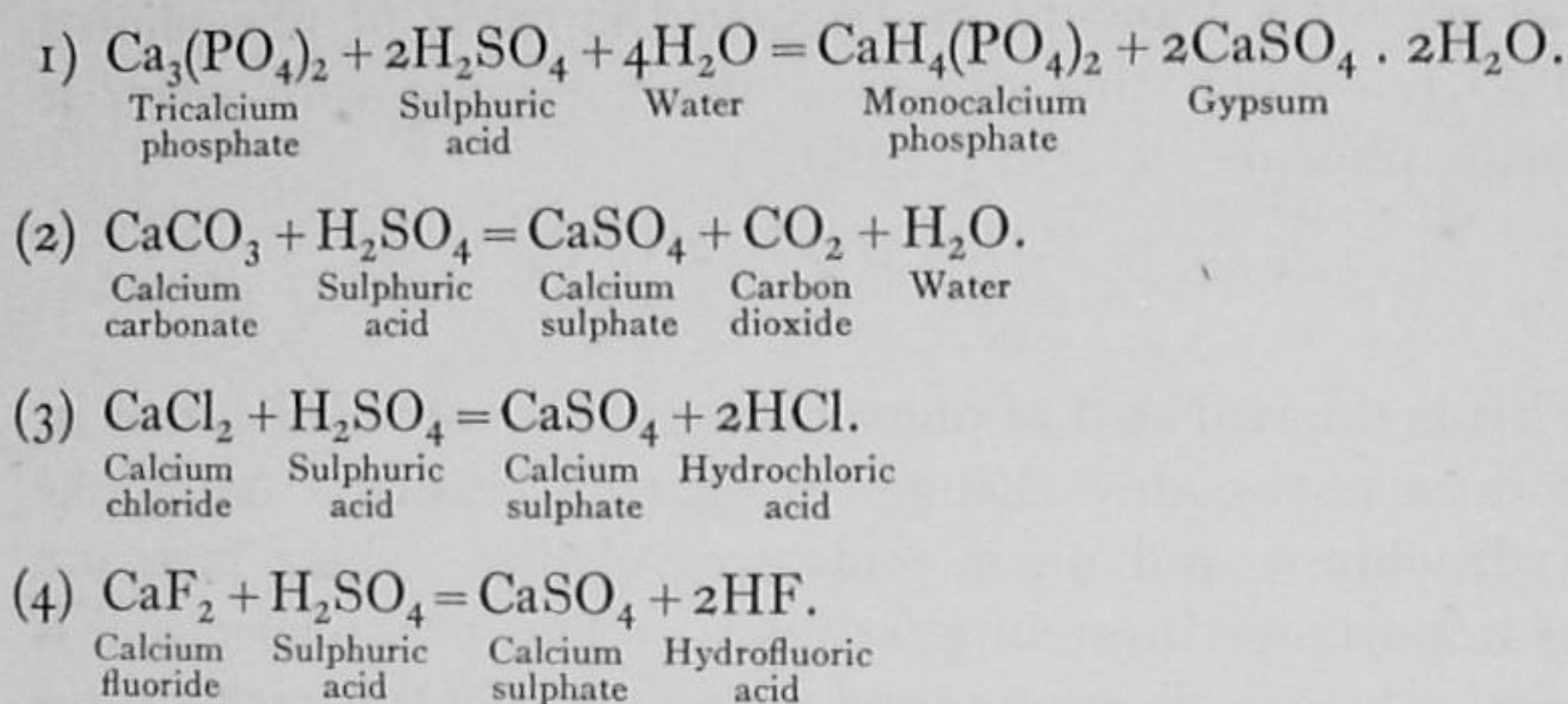
So it is seen that 62 parts of phosphorus will produce 142 parts of phosphoric acid, and from that 310 parts of phosphate of lime can be obtained. Therefore 1 part of phosphorus will produce 2.29 parts of phosphoric acid and that will produce 5 parts of phosphate of lime, and **1 part of phosphoric acid** will produce $5/2.29$, or **2.18 parts of phosphate of lime**. A seller of Gafsa North African phosphate would state that it contained 26 per cent of phosphoric acid equivalent to 26×2.18 ; that is, 56.7 per cent of phosphate of lime. He would also state its fineness; that is, the percentage that would be fine enough to pass through a prescribed sieve. The availability of slowly-acting fertilisers like mineral phosphates depends to some extent on the fineness of division. Incidentally, this fineness does not reach that degree possessed by the clay particles of the soil. It is much nearer to the "fine sand" fraction in mechanical analysis of soils.

Superphosphate

This is a water-soluble phosphate manufactured from the mineral or rock phosphate. Consequently it is immediately available to the plant. Immense quantities are now produced in most countries.

Manufacture.—The rock phosphate is crushed and discharged into a large lead-lined vat. Sufficient sulphuric acid (about 60 per cent strength) is run in to convert the tricalcium phosphate to a monocalcium phosphate; that is, to remove two-thirds of the calcium from combination with the phosphoric acid, and also to convert other calcium compounds — such as the carbonate, chloride, and fluoride — into calcium sulphate. The quantity of sulphuric acid required is calculated from the analysis of the mineral phosphates.

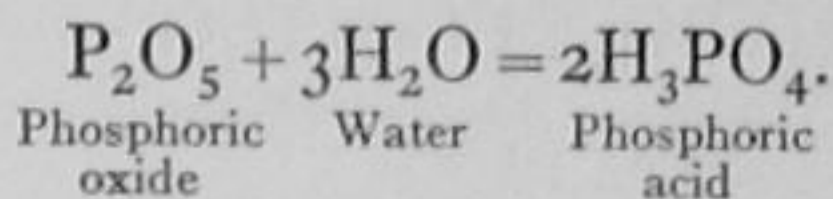
The reactions taking place are as follows :



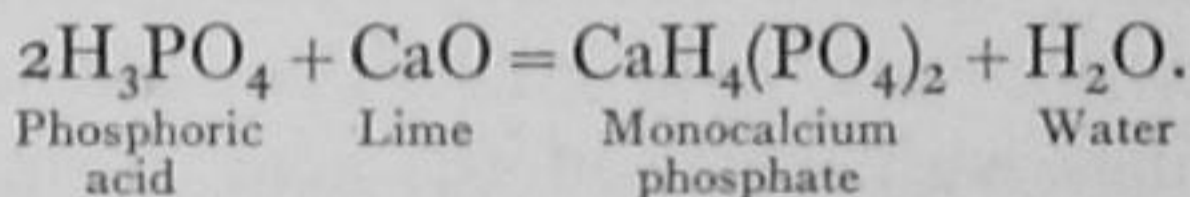
The mineral phosphate and the acid are well mixed by means of the paddle or agitator ; much heat is evolved ; poisonous gases — carbon dioxide, hydrochloric acid, and hydrofluoric acid — are evolved. The calcium sulphate formed combines with water in the acid, forming gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). When the reaction is over, the whole mass is removed, usually to a lower chamber or silo. Here it soon dries to a fairly coarse grey powder. It is a mixture of monocalcium phosphate ($\text{CaH}_4(\text{PO}_4)_2$) and gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). The amount of phosphoric acid is usually about 18 per cent. The remaining 82 per cent consists of about 7·1 per cent of lime combined with the phosphoric acid and $4\frac{1}{2}$ per cent of water, also combined with the phosphoric acid. This accounts for a further 11·6 per cent. The balance, 70·4 per cent, is almost entirely sulphate of lime or gypsum ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$). A buyer of superphosphate, therefore, purchases mostly gypsum and only 18 per cent of phosphoric acid. The seller is obliged to state the percentage of water-soluble phosphoric acid present.

Two phosphates of lime — namely, tricalcium phosphate and monocalcium phosphate — have been mentioned. The

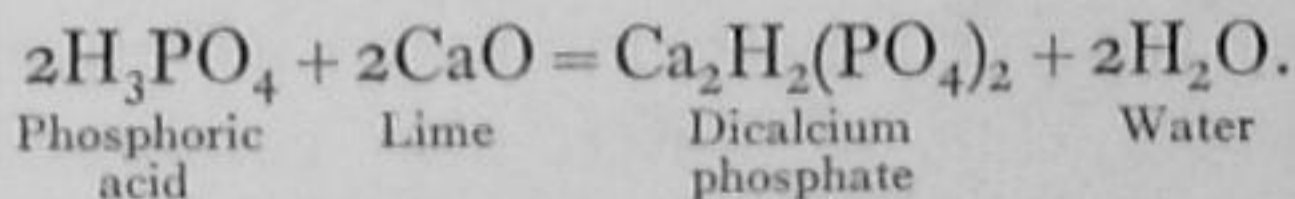
student may find difficulties in differentiating between them. Let us for a moment go back to the oxide of phosphorus (P_2O_5). When this dissolves and combines with water it forms phosphoric acid (H_3PO_4):



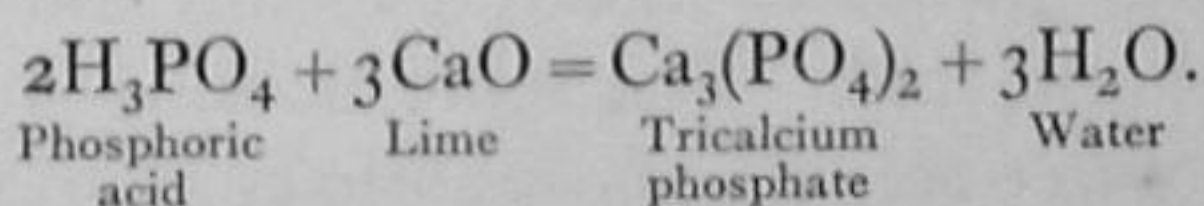
This is the real acid of phosphorus. It is not volatile, that is, it does not readily change to a gas on heating. Acids like hydrochloric and nitric acids are volatile. These facts are of importance in mixing fertilisers. This phosphoric acid is very soluble. When treated with lime (CaO) it yields three different phosphates, differing in solubility. If given one part of lime, the compound formed is the monocalcium phosphate, which is water-soluble:



The phosphoric acid has not been completely neutralised, so monocalcium phosphate is an *acid* phosphate which can still combine with bases. When phosphoric acid is treated with two parts of lime, a dicalcium phosphate is formed. This is not soluble in water but it still possesses acid properties.



When phosphoric acid is treated with three parts of lime, it is completely neutralised and tricalcium phosphate is formed. This, also, is insoluble in water.

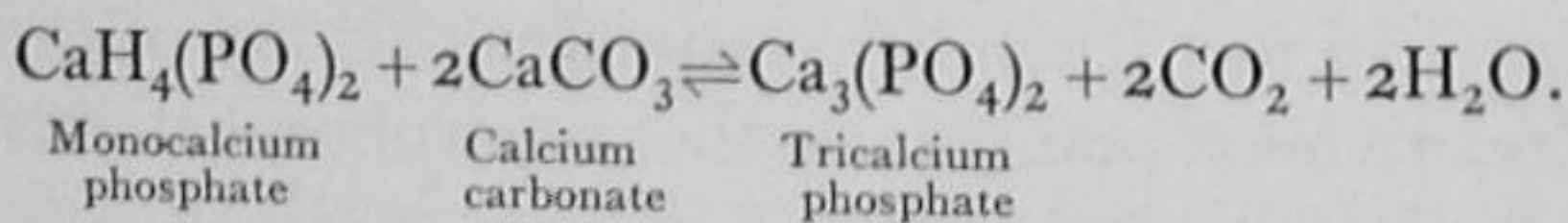
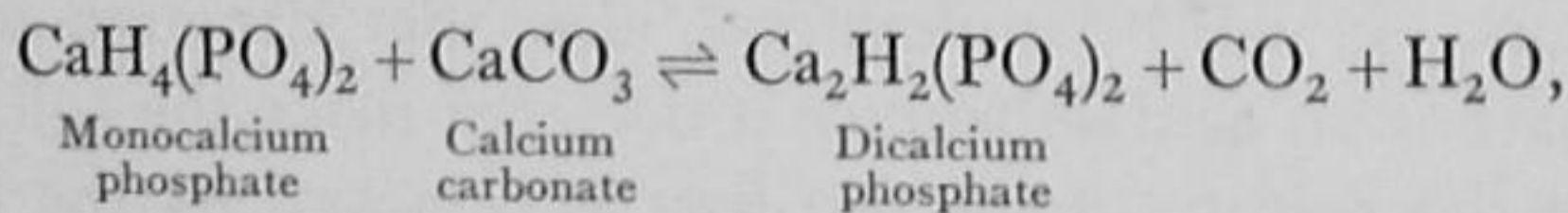


Thus we have two acid phosphates of lime, one of which is soluble.

CHAPTER IV

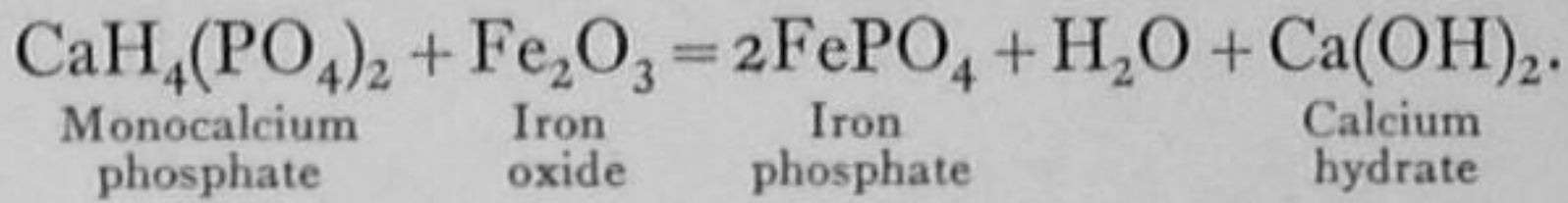
CHANGES IN SUPERPHOSPHATE BY THE SOIL

WE should now be able to understand the changes that superphosphate undergoes when applied to the soil. Being still acid, it will combine with the bases in the soil. The chief base present is calcium carbonate, and others are the oxides of iron and aluminium. The acid phosphate or monocalcium phosphate combines with the calcium carbonate, forming the insoluble di- and tri- calcium phosphates :



It would appear that the object achieved in the manufacture of a water-soluble phosphate has now been reversed. This is true to a great extent, but not completely. The phosphates now formed are finely divided and well distributed and the reverse reactions can occur, so a gradual supply of available phosphate will pass into the root hairs of the plant. We have seen that this process is always a remarkably slow one. If the amount of calcium carbonate in the soil is inadequate, then the acid phosphate in the superphosphate will combine with the other bases, namely,

the oxides of iron and aluminium :



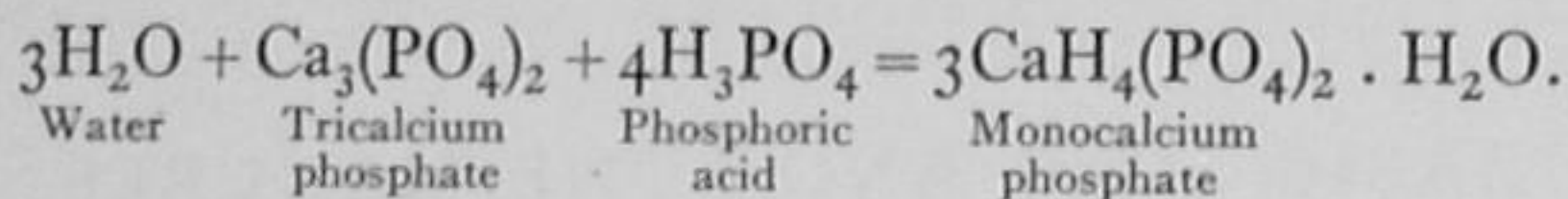
So phosphates of iron and aluminium will be formed. These are much less soluble in the soil water, so the *reversion* is more permanent and much of the superphosphate is made unavailable. It will remain so until the soil is limed, and until the added lime has been able to convert iron and aluminium phosphates into calcium phosphate.

Thus we see that chemical changes cause superphosphate to be made insoluble and fixed in the soil. As a rule only about 25 per cent of the water-soluble phosphate supplied is available in the first year. The remainder is not lost nor is it washed out ; it remains in the soil and gradually becomes available to succeeding crops. To minimise fixation of the phosphate, the fertiliser is now prepared in a granular condition. It will be understood, also, that although superphosphate is an acid substance it does not make the soil acid, because the acidity of the fertiliser is removed by the bases in the soil. In fact it tends to reduce the acidity of the soil. It has already been pointed out that superphosphate consists largely of calcium sulphate.

What effect has this substance on the soil? It is a soluble sulphate of lime and so brings about "base exchange" — that is, the calcium enters into the clay and humus colloids and, in exchange, bases like magnesium and sodium are set free. Potassium is not made available. Thus the calcium content of the colloids is increased and there is less loss of this valuable base.

Superphosphate has no ill effect on soil tilth. If anything it will flocculate the colloidal particles and so improve the texture.

Triple Superphosphate.—By treatment of the mineral phosphate with phosphoric acid, instead of with sulphuric acid, a much more concentrated phosphatic fertiliser is produced :

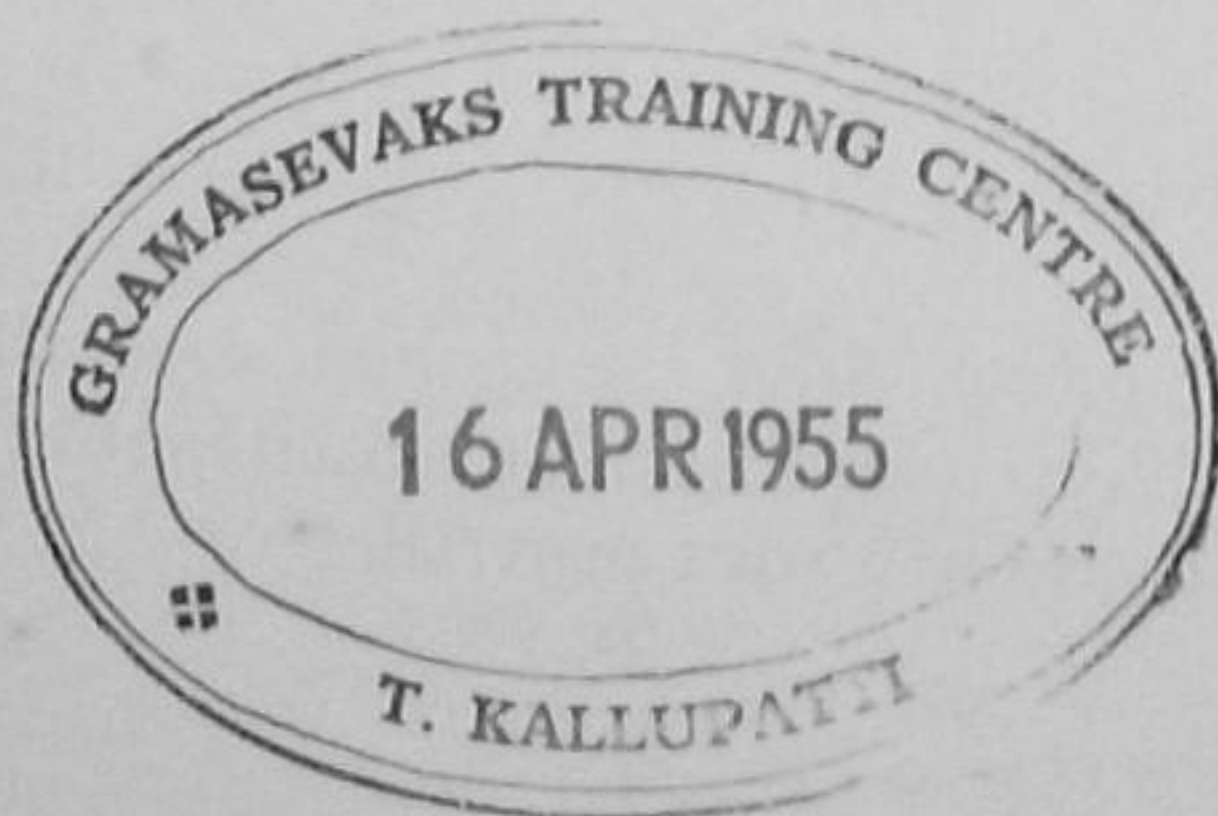


The product consists entirely of monocalcium phosphate and contains about 48 per cent of soluble phosphoric acid (P_2O_5).

Purchase of Superphosphate.—The buyer will wish to know the value of one unit of phosphoric acid (P_2O_5) — the unit is $\frac{1}{100}$ of a ton, or 22.4 lb. of phosphoric acid. Its value is found by dividing the price per ton by the percentage of phosphoric acid in the fertiliser; thus, if superphosphate with 18 per cent phosphoric acid is sold at £3 a ton, then the value of 22.4 lb., or 1 unit of phosphoric acid, is :

$$\frac{3 \times 20}{18} \text{ shillings, or 3s. 4d.}$$

Basic Superphosphate.—This is the name given to the mixture of superphosphate with lime. It may be dicalcium phosphate with calcium sulphate, or tricalcium phosphate and calcium sulphate according to the amount of lime added, as shown by the equations on page 5.



CHAPTER V

BASIC SLAG AND BONE MANURES

Basic Slag

This is a phosphatic fertiliser obtained as a by-product in the manufacture of steel. Steel is made from cast iron. The cast iron is made by smelting iron ore with coal in a blast furnace. The iron ore contains a high percentage of oxide of iron (Fe_2O_3) or carbonate of iron, associated with earthy matter. Through the centuries the bones of animals and human beings have become intermingled with the soil, so the iron ore contains small quantities of phosphate of lime.

Manufacture of Cast Iron.—In the smelting process in the blast furnace, iron ore and coal are fed into the furnace at the top and a blast of hot air is forced into the bottom. The reducing gases, chiefly carbon monoxide, from the burning of the coal reduce the oxide of iron to the metal. The molten iron thus formed flows to the bottom or well of the furnace. Compounds of silicon, of phosphorus, and of sulphur are also reduced, and the elements silicon, phosphorus, and sulphur, together with about 3 per cent of carbon, are found in the cast iron. As a result cast iron has a crystalline structure. It is also brittle and easily broken.

Above the molten iron the molten slag collects. This slag has no value as a fertiliser. It is used in the manufacture of cement and also as a road material.

Fertilisers and Manures

<i>Analysis of Cast Iron</i>	<i>Analysis of Blast Furnace Slag,</i>
<i>%</i>	<i>%.</i>
C = 3.13	SiO ₂ = 29.92
Si = 1.72	Al ₂ O ₃ = 21.70
Mn = 0.54	FeO = 0.32
P = 0.68	MnO = 0.80
S = 0.04	CaO = 38.72
Fe = 93.89	MgO = 6.10
	P ₂ O ₅ = 0.07
	S = 1.61

Manufacture of Steel and Basic Slag.—To convert cast iron into steel, about half of the carbon must be removed and practically all of the silicon, phosphorus, and sulphur. The oxides of these elements are all acidic oxides. If, therefore, the elements are oxidised in the presence of a basic substance, the oxides will combine with the base and so be removed from combination with the iron. The iron will still contain some carbon, but it will no longer be brittle but of great tensile strength. It will now be steel. Steel is made either by the *Bessemer Process* or by the *Open Hearth Process*.

In the Bessemer Process the molten cast iron is transferred to a Bessemer converter. This converter is a huge furnace rather like a great hollow egg of metal mounted on an axis. The inside is lined with dolomite or limestone and a blast of hot air forced in at the base. In less than half an hour the elements carbon, sulphur, phosphorus, and silicon are oxidised. Some of the carbon, therefore, is removed as carbon monoxide gas and some sulphur as sulphur dioxide. Some carbon still remains in the steel. The oxides of phosphorus and silicon combine with the lime and pass into the slag. The slag can be tapped off, cooled, and ground. Owing to the large amount of lime that goes to make this slag, it is basic. It contains phosphates of lime, also silicate of lime,

and a little sulphide of lime together with oxides of iron.

The amount of phosphorus to be removed from the cast iron is very small and the amount of lime added is very large, being more than sufficient to form the neutral phosphate ($\text{Ca}_3(\text{PO}_4)_2$) tricalcium phosphate, so a phosphate with more lime is formed, a tetra-calcium phosphate ($\text{Ca}_4\text{P}_2\text{O}_9$) or ($4\text{CaO} \cdot \text{P}_2\text{O}_5$), and another of the composition ($5\text{CaO} \cdot \text{P}_2\text{O}_5 \cdot \text{SiO}_2$), that, is a silico-phosphate. Both of these are basic phosphates and so distinguished from acidic phosphates, such as that in superphosphate, or neutral phosphate, such as tricalcium phosphate.

The slag thus obtained is a dark-grey, heavy powder. It contains about 18 per cent phosphoric acid (P_2O_5) and about 40 per cent of lime. This lime is not free but is combined as phosphate and silicate. The phosphate in basic slag is not soluble in water. It is, however, readily soluble in water containing carbon dioxide, or in dilute solutions of weak acids such as citric acid.

Slags in which the phosphate is readily soluble in a solution of citric acid of strength 2 per cent are more readily available than those having a low solubility.

The Open Hearth Process.—In this process ingots of cast iron or pig iron are melted on the hearth of a furnace and to this is added more iron ore and limestone. The chemical reactions are much the same as in the Bessemer Process, except that the oxygen now comes from the iron ore. Carbon, sulphur, phosphorus, and silicon are oxidised. Oxides of phosphorus and silicon pass into the slag, while those of carbon and sulphur mostly escape. The slag is tapped off, cooled, and ground.

Open Hearth slag is similar in composition but contains rather less phosphorus, usually about 14 per cent phosphoric acid.

Fertilisers and Manures

ANALYSIS OF A BASIC SLAG

	%		%
CaO	= 41.6	FeO	= 13.6
MgO	= 6.1	MnO	= 3.8
Al ₂ O ₃	= 2.8	SiO ₂	= 7.4
Fe ₂ O ₃	= 8.1	P ₂ O ₅	= 14.4

Basic slags have proved exceedingly valuable on grass-land. The lime, present as silicate of lime, neutralises the acidity and the phosphate dissolves in the soil water. Wild white clover, with its roots spreading just below the surface, develops with great rapidity, especially on clay soils treated with basic slag. The effect is cumulative because the clover fixes atmospheric nitrogen and so the soil becomes more fertile.

The clover and grasses also have a higher percentage of lime and phosphorus and more flesh-forming protein. They are more nutritious. The pastures are thus able to carry more stock and the health of the stock is improved.

In the period between the two World Wars, British pastures had been to a large extent treated with phosphates. The effect was seen in the good harvests when these pastures were ploughed and corn grown. The phosphates in basic slag are not washed out of the soil. This fertiliser lasts for some years. The basis for compensation, that is, the allowance to the outgoing tenant of a farm for residues of phosphatic fertilisers, is shown in the table at top of page 25.

From this table it is seen that the nitrogenous fertiliser, sulphate of ammonia, is considered to be completely removed by a single crop, whereas basic slag and mineral phosphates will last three years on arable land and as long as seven years on grass-land. In practice each case is considered by the valuer on its merits; the table serves as a guide in making allowances for unexhausted residues.

	ARABLE LAND			GRASS-LAND						
	After 1st Crop	After 2nd Crop	After 3rd Crop	After 1st Crop	After 2nd Crop	After 3rd Crop	After 4th Crop	After 5th Crop	After 6th Crop	After 7th Crop
Superphosphate	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{6}$	—	—	—	—
Basic slag	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
Mineral phosphate	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{7}{8}$	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
Steamed bone flour	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{6}$	—	—	—
Dissolved bone	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{7}$	$\frac{1}{2}$	$\frac{1}{4}$	$\frac{1}{3}$	—	—	—	—
Sulphate of ammonia	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Kainit	$\frac{1}{2}$	$\frac{1}{4}$	—	$\frac{1}{2}$	$\frac{1}{4}$	—	—	—	—	—
Potash salts	$\frac{1}{2}$	$\frac{1}{4}$	—	$\frac{1}{2}$	$\frac{1}{4}$	—	—	—	—	—

Bone Manures

Fresh bones are tough and not easily crushed. After treatment with steam much of the collagen or connective tissue permeating the mineral framework of the bone is removed. This collagen is used for making glue and gelatine. Fat is at the same time removed. This is sent to the soap factory. The bone can now be crushed. It forms a coarse powder and is called "bone meal". It still contains some collagen but the greater part consists of the neutral tri-calcium phosphate. As a rule bone meal contains from 3.5 to 5 per cent of nitrogen in a slow-acting condition, and from 20 to 25 per cent of phosphoric acid (P_2O_5). The collagen will slowly decompose in the soil and yield up its nitrogen, while the phosphate will slowly become soluble in the soil water.

It thus provides a steady supply of two of the chief fertilising elements. As a result it is in great demand by horticulturists. The finer it is ground the more available it becomes. In order to be able to grind the bones to a fine powder more of the collagen must be removed. This is

accomplished by a further treatment with superheated steam. The product now obtained by grinding is called "steamed bone flour". This material contains from 1 to 2 per cent of nitrogen and from 25 to 32 per cent of phosphoric acid. It is almost too costly to use as a fertiliser as it is also required as a mineral supplement in cattle foods.

Dissolved Bone.—This material is chemically much the same as superphosphate. In fact it was called "bone superphosphate". It is made by treating bones or bone meal with sulphuric acid. Since both bones and mineral phosphate contain tricalcium phosphate, the chemical reactions with sulphuric acid will be similar and will result in the formation of a water-soluble phosphate. Treatment of bones with the acid does not, however, remove the nitrogen. A part of this may be available, but most of it will gradually become available as the nitrogen compounds undergo further decomposition. Dissolved bone usually contains from 2 to 3 per cent of nitrogen and from 15 to 16 per cent of soluble phosphoric acid as well as some insoluble phosphoric acid.

Fish Guano.—The waste parts of fish are dried or dehydrated and ground to a fine powder. This material contains from 7 to 9 per cent of nitrogen in the form of complex protein compounds and also from 7 to 9 per cent of phosphoric acid insoluble in water. Both nitrogen and phosphoric will become slowly and steadily available.

CHAPTER VI

POTASSIC FERTILISERS

It has been stated that nitrogenous fertilisers produce strong leafy growth. The green colouring matter or chlorophyll in the leaf, in the presence of sunlight, converts the simple substances carbon dioxide and water into sugar, and later this is transformed to starch and cellulose. Potash is essential for this process, so to produce the bulk of the plant both nitrogen and potash play most important parts. The potash or potassic fertilisers used are :

Sulphate of potash (K_2SO_4) — with 48·6 per cent potash (K_2O)
Muriate or Chloride of

potash (KCl)	50·4	”	”	”
Kainit	14·0	”	”	”
Potash salts	30·0	”	”	”
” ” (lower grade)	20·0	”	”	”

Manufacture of Potassic Fertilisers.—The chief sources of potash are the deposits at Stassfurt, and the salts obtained from the Dead Sea in Palestine. Considerable quantities have also been obtained from sea-water. In the Dead Sea evaporation has gone on in a district of very low rainfall, with the result that the quantity of salts in solution is much greater than in ordinary sea-water. By evaporation the water is driven off and the salts obtained. A complicated process of fractionation of these salts has been perfected and potash salts obtained. The Stassfurt deposits were formed by the

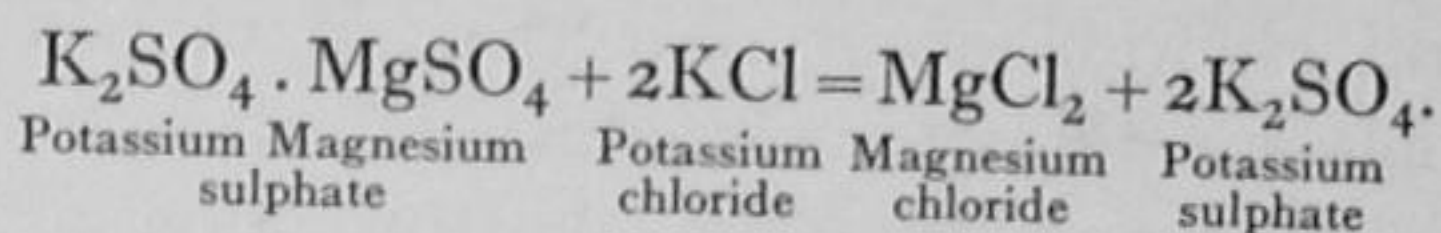
evaporation of a former inland sea. The substance that is least soluble would separate first and the very soluble substances last. This is shown in the deposits, since at lower depths are found the sparingly soluble calcium sulphate or anhydrite and rock salt, while the very soluble magnesium sulphate and chloride occur near the top of the deposit. The materials are mined, analysed, dissolved in water, and evaporated. The conditions for the formation of salts of definite composition have been worked out.

Manufacture of Chloride of Potash from Carnallite ($\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$).—Among the many compounds mined at Stassfurt are carnallite and kainit. Carnallite contains 16 per cent potassium chloride. It is dissolved in the liquid left after crystallising out other salts. When as much carnallite as possible has dissolved in the liquid at a temperature of 115°C ., the solution is run off into clearing vats, where it is kept hot and allowed to stand for about two hours. The clarified liquid is run into crystallising vats and allowed to cool slowly, and to crystallise. This takes two or three days. The crystals obtained contain 80 to 85 per cent of potassium chloride. By washing with water or weak liquid the percentage is brought to 90. The liquid left on further evaporation yields more carnallite ($\text{KCl} \cdot \text{MgCl}_2 \cdot 6\text{H}_2\text{O}$). This is dissolved in the washing liquid and crystallised. The final product after washing and drying contains about 80 per cent of potassium chloride.

Manufacture of Sulphate of Potash from Kainit.—Kainit is a complex mixture containing sulphates and chlorides of potassium and magnesium. When ground up with water and allowed to stand, the double sulphate of magnesium and potassium ($\text{K}_2\text{SO}_4 \cdot \text{MgSO}_4 \cdot \text{H}_2\text{O}$) crystallises and magnesium chloride remains in solution, or if the kainit is heated with a saturated solution of salt under a pressure of 2 to 4

atmospheres the same double sulphate is formed. It is separated, dried at 100° , and after washing is pure.

This salt is macerated with a solution of potassium chloride of specific gravity 1.142, when potassium sulphate separates as a crystalline mass :



After washing and drying it contains 96 per cent sulphate of potash.

These two fertilisers, sulphate and muriate of potash, are almost pure chemical compounds. Potassium sulphate (K_2SO_4) of molecular weight 174 contains 94 parts by weight of potash (K_2O). The pure sulphate therefore contains $94 \times 100/174$, that is, 54 per cent of potash. The commercial article is guaranteed to contain 48.6 per cent of potash. The purity of the fertiliser thus sold is therefore $48.6 \times 100/54$, or 90 per cent.

Strictly speaking, muriate or chloride of potash contains no potash (K_2O) since it contains no oxygen. The statement that it contains 50 per cent potash means that it contains an amount of potassium which would yield or be equivalent to 50 per cent of potash.

Its formula is KCl , so it takes two molecules of KCl to yield one of K_2O . 2KCl or $2(39 + 35.5)$ parts by weight of potassium chloride yield $(2 \times 39) + 16$ parts of potassium oxide or potash. That is, 149 parts of muriate of potash would produce 94 parts of potash, and 100 parts of muriate would produce $94 \times 100/149$ parts, or 63 per cent of potash from pure muriate of potash. The commercial article is guaranteed to contain 50.4 per cent potash. Its purity is therefore $50.4 \times 100/63$, that is, 80 per cent.

Besides the sulphate and muriate of potash there are

three other fertilisers, namely, kainit, potash salts with 20 per cent potash, and potash salts with 30 per cent potash. These are mixtures of muriate of potash with large amounts of common salt, or sodium chloride. This is seen from the following table :

	Kainit	Potash Salt 20 %	Potash Salt 30 %
	%	%	%
Muriate of potash .	23·5	33·7	49·1
Salt	52·5	47·0	25·6
Magnesium sulphate	10·4	6·0	5·1
Percentage potash guaranteed	14·0	20·0	30·0

Effect of Potash Fertilisers on the Soil.—All potash fertilisers are soluble salts. When applied to the soil, soluble salts bring about “base exchange”. In the case of potassium salts the base is potassium. The colloidal particles of clay and humus in the soil have a remarkable power of absorbing this potassium from solutions of potassium salts, so that it becomes insoluble in water and is therefore retained by the soil. At the same time as the potassium is absorbed, the clay and humus particles give up an equivalent amount of another base or bases. The base present in greatest amount is calcium, so this element leaves the colloidal particles and passes to the drainage water. The elements magnesium and sodium may also be replaced or exchanged in this way. The quantities taking part in this exchange are in the proportions of the chemical equivalents; thus 39 parts of potassium will replace 20 parts of calcium or 12 parts of magnesium or 23 parts of sodium. The 39 parts of potassium cannot replace 20 parts of calcium and 23 parts

of sodium, but it might replace 10 parts of calcium and 11.5 parts of sodium. The potassium that is absorbed is gradually given up to the plant.

On a clay soil an excess of potash will result in the colloidal particles having an excess of potassium, so producing a potash clay with an alkaline reaction. This condition leads to a dispersal of the particles or "deflocculation", causing stickiness or a deterioration in the tilth. Root crops and also crops of the cabbage variety require larger amounts of potash than of any other fertiliser. Some of this returns to the soil when the leaves break away. Fruit trees, too, make a heavy demand on the potash in the soil. It is estimated that about half of the potash taken up by apple trees returns to the soil with the leaf fall.

CHAPTER VII

LIME AND LIME COMPOUNDS

Lime or Calcium Compounds.—With the exception of grasses and clovers and crops like cabbage, broccoli, and brussels sprouts, plants do not require much calcium as a nutrient. An acre of potatoes removes less than 10 lb. of calcium oxide or lime, while an acre of broccoli will remove more than 100 lb. Lime compounds must be applied to soils to maintain the correct reaction, that is, to prevent too much acidity. Soils lose more lime than any other constituent, and the use of fertilisers, such as sulphate of ammonia and potash salts, increases the rate of removal, hence lime should be applied when required. The Regional Advisory Chemist can always inform any farmer or grower whether lime is required and in what quantity.

Kinds of Lime Compounds.—The following are the common substances applied :

Ground limestone : CaCO_3 .

Ground chalk : CaCO_3 .

Burnt lime or quicklime : CaO .

Hydrated lime : Ca(OH)_2 .

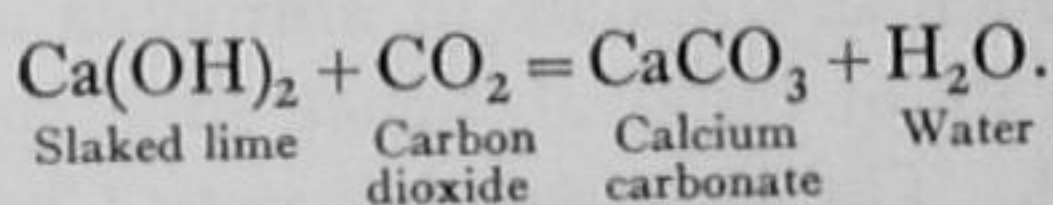
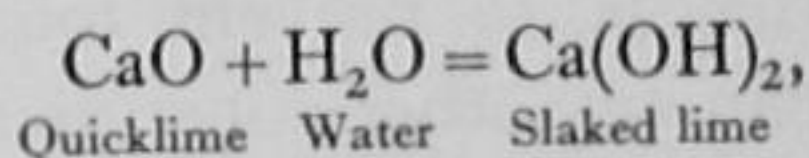
Gas lime : CaO together with sulphide of lime.

Waste lime from tanneries : Ca(OH)_2 .

Ground Limestone and Ground Chalk (CaCO_3).—These are forms of carbonate of lime and are the cheapest forms of lime. They will serve to correct acidity in soils but will not possess any caustic or burning effect and so will not destroy

insect pests or bring about partial sterilisation. They could be used with advantage to a much greater extent on both grass and arable land.

Burnt Lime or Quicklime (CaO).—This is the caustic form of lime. It is made by burning lumps of limestone in a kiln with coal and comes from the kiln in similar lumps : $\text{CaCO}_3 = \text{CaO} + \text{CO}_2$. These are often placed in heaps in a field and left to slake by the rain or by the moisture in the soil. Much heat is developed in the process and the soil beneath will be partially sterilised and insects destroyed. The lime is then spread and mixed with the soil. It is doubtful whether this method is much superior to treatment with ground limestone. The slaked lime soon changes back to the carbonate form by absorbing the carbonic acid from the air and the soil.



The advantage, such as it is, depends on whether the slaking has resulted in a much finer product than the ground limestone. That this is so has been disputed. Where the quicklime coming from the kiln has been ground and then distributed, the above objection does not hold, and this method had distinct advantages. Ground quicklime should not be stored, as it will soon slake or become hydrated, with such increase in bulk as to burst the bags.

Hydrated Lime.—This is quicklime, that has been slaked with water. It is a dry bulky powder, which can be kept, although it will gradually form chalk when it is in contact with the air. It is easy to distribute and soon becomes carbonated in the soil.

Gas Lime.—This contains harmful sulphides and should

be exposed to the air for some time before application to the soil. It is waste material from the gasworks which was used for removing the sulphur from the coal gas.

Waste lime from tanneries is generally wet and requires to be dried before use. It will, by that time, be mostly chalk.

CHAPTER VIII

FARMYARD MANURE

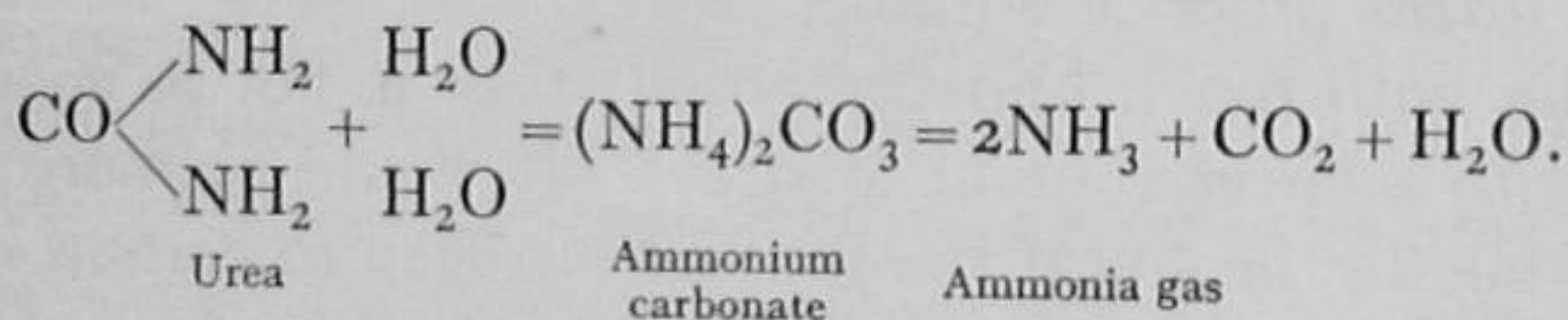
FOR centuries the excreta of animals have been used as manures. The farmyard manure of to-day is a mixture of the solid and liquid excreta of cattle and horses, and sometimes pigs, with an absorbent material, usually straw. It is regarded as of great value by farmers and horticulturists. The valuable plant nutrients in it come from the foods eaten by the animals. Different foods contain different amounts of nitrogen, phosphoric acid, and potash. When the foods are eaten, most of these nutrients are not retained by the animal but pass out in the excreta, the nitrogen and potash mainly in the liquid urine and the phosphoric acid in the solid faeces or dung.

The amounts retained by the animal which do not pass to the manure vary with the age and nature of the animal. Considering the nitrogen in the food first, this is present as a flesh-forming substance (protein or albuminoid), a very complex compound. In passing through the animal during the process of digestion, it is changed into simpler compounds and most of it appears in the urine as urea, hippuric and uric acids. If the animal is of mature age, all the nitrogen in the food is excreted. If the animal is young, part of it is retained to form flesh in the growing animal. If the animal is a dairy cow, part is used to form flesh and part of it passes into the milk, and the remainder to the urine and faeces.

It will therefore be understood that the dung obtained

from stall-fed oxen will contain more nitrogen than that from young stock or from dairy cows, also that the dung from animals receiving food rich in nitrogen, such as cattle cakes, will also be rich in nitrogen. Thus, it is seen that the plant nutrients in foods pass through the animal and should find their way to the dung-heap and eventually back to the soil.

Unfortunately losses occur. Urea readily changes into ammonium carbonate by the agency of bacteria. Ammonium carbonate is volatile (it is one of the constituents of smelling salts), so if the dung-heap is disturbed nitrogen is lost in the form of ammonia gas.



If the dung-heap is exposed to rain, soluble nitrogen and potassium compounds are lost. The dark-brown liquid seen escaping at the bottom of the heap is alkaline, containing ammonium and potassium carbonates, which have some of the humus in solution.

Changes in the Dung-heap.—If the air is allowed to enter, the ammonium compounds are oxidised to nitrate by the nitrifying organisms; that is, nitrification will take place as it does in the soil. Then nitrates may be washed out or they may undergo denitrification; that is, certain bacteria may change the ammonia back into free nitrogen gas which passes into the air. The conditions for this process are present, namely, a large amount of organic matter, presence of nitrates and of the denitrifying organisms.

It should be noted that in the absence of air or under anaerobic conditions these changes will not occur. Nitrifica-

tion will not take place ; there will be no formation of nitrates and therefore no denitrification. Other changes will proceed ; the nitrogen compounds will be used by bacteria to build up their own substance, that is, the nitrogen will be changed into the more complex albuminoid or protein form and become less available. The longer the dung is kept the less available is the nitrogen.

A dung-heap gradually loses bulk on keeping. The straw present gets less and less. This is due to the change in the cellulose of the straw brought about by bacteria. The more easily decomposed forms of cellulose are slowly burned away to carbon dioxide, but the more resistant or harder forms produce humus.

Dung with much undecomposed straw is not so good as dung with a lower content of straw. It would be more like the humus in the soil if the ratio of nitrogen to carbon is as 1 to 10. Under these conditions nitrates will be formed but not when the proportion of carbon is much higher, that is, when the straw has not decomposed. The preference for well-rotted dung can thus find an explanation. This mixture of straw and dung saturated with urine readily undergoes fermentation and decomposition. Consequently it gets hot and is used in that condition for hot-beds in frames. The longer the manure is kept the less bulky it becomes, changing from what is known as long dung to short ; at the same time the nitrogen becomes less available.

The Chemical Composition of Farmyard Manure.—It has already been stated that the fertilising constituents of farmyard manure come from the foods eaten by the animal. Farm crops are not rich in nitrogen, potash, or phosphoric acid, so the quantities present in the dung and urine will therefore be small.

For various reasons already mentioned, the composition

will vary, so only average figures for the composition can be stated :

Manure	Nitrogen	Phosphoric Acid	Potash
	%	%	%
Bullock . . .	0.62	0.26	0.72
Cow . . .	0.40	0.20	0.44
Horse . . .	0.54	0.23	0.54
Pig . . .	0.45	0.19	0.60
Sheep . . .	0.83	0.23	0.67
Liquid manures	0.20	0.08	0.50

Suppose we take as the average composition, nitrogen 0.5 per cent, phosphoric acid (P_2O_5) 0.2 per cent, potash (K_2O) 0.5 per cent; then one ton of the manure will contain 22.4×0.5 lb. of nitrogen and potash, 22.4×0.2 lb. of phosphoric acid or 11.2 lb. of nitrogen and of potash, and 4.48 lb. of phosphoric acid. Sulphate of ammonia has 20.4 per cent of nitrogen. 100 lb. will supply 20.4 lb. of nitrogen, and therefore $100/20.4 \times 11.2$ lb. of sulphate of ammonia, *i.e.* about 55 lb., will provide as much nitrogen as a ton of dung. Similarly, 28 lb. of superphosphate will give the same amount of phosphoric acid as a ton of dung. Again, 48.6 lb. of potash are supplied by 100 lb. of sulphate of potash; 11.2 lb. of potash will be supplied by $100/48.6 \times 11.2$, or 24 lb.

The fertilising constituents, nitrogen, potash, and phosphoric acid, in a ton of average farmyard manure can be supplied by a mixture of 55 lb. of sulphate of ammonia, 28 lb. of superphosphate with 16 per cent phosphoric acid, 24 lb. of sulphate of potash with 48.4 per cent of potash.

Before the introduction of such chemical fertilisers as these, manuring was mainly a matter of large dressings of dung, such as 100 tons per acre, and lime at intervals, which would prevent acidity and assist in more rapid decomposition of humus. Nowadays such heavy dressings are not possible and about 15 tons are applied to the root crops, and this is supplemented by suitable quantities of chemical fertilisers.

Advantages of Farmyard Manure.—Its great value lies in the fact that it adds humus to the soil and in its capacity to absorb water. Water is the chief factor in the growth of plants. In considering the requirements of plants it was stated that these were light and warmth, air and sunshine, food, and the conquest of enemies.

Farmyard manure brings warmth by the chemical and bacterial decomposition of the straw; it adds moisture (about 80 per cent of its weight is due to water) — it also assists in retaining moisture; then it keeps air in the soil, especially long dung; and it supplies food. Farmyard manure is very lasting; its effects are seen for several years. Part of the nitrogen is in the form of complex compounds which decompose very slowly, but some of the nitrogen is in a readily available form as ammonium compounds.

The potash also is readily available. The phosphoric acid is found in the solid excrement of animals and is less available. The quantity present is about half the amount of the other constituents. Thus it is seen that farmyard manure has all the essentials for fertility and its slowness in action supplies nutrients gradually and continuously to the plant. The only disadvantage is found to be the large number of weed seeds often present, which later are carried to the soil. Horse and sheep manures are more concentrated and drier

than that obtained from cows and pigs. This is seen in the following table :

Manure		Water	N	P ₂ O ₅	K ₂ O
		%	%	%	%
Horse	{ Dung . . .	75	0·6	0·3	0·4
	{ Urine . . .	90	1·5	—	0·6
Cow	{ Dung . . .	86	0·4	0·1	0·1
	{ Urine . . .	91	1·0	—	0·4
Sheep	{ Dung . . .	58	0·7	0·4	0·15
	{ Urine . . .	86	1·3	0·01	2·2
Pig	{ Dung . . .	76	0·5	0·4	0·13
	{ Urine . . .	98	0·5	0·1	0·80
Poultry : Hen . . .		60	1·1	0·85	0·56

CHAPTER IX

SUBSTITUTES FOR FARMYARD MANURE : COMPOSTS

THE difficulty in obtaining sufficient farmyard manure, especially in the case of market gardens, and the necessity of maintaining the supply of organic manure in the soil to keep it fertile, has compelled growers to find means for its replacement. The practice of green manuring, or growing such crops as mustard and ploughing them in, is one method of maintaining the humus or organic matter. Near the coasts much use is made of seaweed. The broccoli-growers of Brittany use very large quantities, which they collect and allow to rot, adding nitrogenous material to accelerate the process. In this country the decomposition of straw has been investigated and a process of making artificial farmyard manure from it has been developed. In the hot climate of India the fermentation of waste vegetable matter is very rapid. Good results have followed the use of composts made by the "Indore" process. This has been described by Sir Alfred Howard. The practice of making composts from waste garden materials, such as weeds and leaves, which will prove of value as organic manures, has greatly increased, and almost every garden now has a compost heap which can be used instead of, or to supplement, stable manure.

Details of various processes will now be considered.

Manures from Straw

Straw is not so easily rotted as material like lawn clippings. The latter readily yields a manure resembling stable manure,

because it has a high nitrogen and water content, and therefore ferments easily. Straw is not so easily wetted, and, moreover, it contains very little nitrogen. To make it decay it must be chaffed, sulphate of ammonia added, and sufficient water sprayed on. Chalk and mineral phosphate are also added and a culture of cellulose decomposing organisms, as in the "Adco" process. In this way it is possible to decompose the straw and produce a product resembling farmyard manure.

Manure from Waste Vegetable Matter

THE INDORE PROCESS.—All available vegetable material is collected and stacked. Any hard material is crushed. Fresh green materials are withered before stacking, well mixed, and packed. The material is placed in a pit and dung or poultry manure added. All wood ashes are also collected.

Charging the Pit.—First, a layer of plant residues, 3 feet deep, is sprinkled with wood ashes and a 2-inch layer of dung is added. This is moistened with water; then another layer, 3 inches thick, of plant residues is put on, followed by another 2-inch layer of dung. This is watered, and so on until the heap is $2\frac{1}{2}$ feet high. Water is added morning and evening. To start the intense fermentation the water is added in three stages. All materials should be packed lightly. The level of the pit is at first above the level of the ground, but it soon shrinks. Too much wood ashes should not be added. Later, water should be sprayed on once a week, and also at the first, second, and third turns. By keeping the heap moist and not wet, a high temperature will be obtained which will destroy any weed seeds which may be present.

Turning the Heap.—The heap is first turned when ten to fourteen days old. Half of the pit is dug out and put on the half not dug, and then watered. The second turn is made fourteen days later and the heap is turned into the empty half after watering. The third and last turn is made when the heap is two months old. The whole heap is removed, watered, stacked, and left for a month, when it is ready for use. Seeds of weeds are destroyed by the vigorous fermentations that occur.

BRITISH PROCESS.—The same principles are involved in the process of compost-making in this country, but the fermentations will be much slower owing to the colder climatic conditions. Sufficient water and nitrogenous matter must be present and sufficient air must enter the heap. The method recommended by the Royal Horticultural Society in their booklet *The Vegetable Garden Displayed* is as follows :

Mark out a plot of level ground about 9 feet by 4 feet. Make it firm by treading and beating with the back of a spade. Put all waste vegetable matter onto this — weeds, outside leaves of cabbages, broccoli, and lettuces, pea haulms, soft hedge clippings, lawn mowings, even waste straw and paper, dead leaves in the autumn, but keep out thick stuff like cabbage stalks.

If you can get any stable manure or horse-droppings, spread that with the rubbish. Tread from time to time. When the heap is about 6 inches thick, sprinkle it with sulphate of ammonia and superphosphate, half an ounce of each to the square yard, *i.e.* 2 ounces of each for a 9 feet by 4 feet plot, together with any ashes from a *wood* fire you can get, not coal ashes. Sprinkle with 4 gallons of water. If basic slag is obtainable it may be used instead of superphosphate. (Proprietary articles are obtainable which may be used in place of the above mixture.) Throw soil about an

inch thick over the whole. When you have more rubbish, build up another layer on the top, and when it is 6 or 8 inches thick, again sprinkle over the sulphate of ammonia and superphosphate, followed by watering and a layer of soil. Go on building up layer after layer until the heap is about 4 feet high. After that it is better to begin another heap. In dry summer weather water every week. Turn the heap right over after a month in summer weather, and water again if it is dry. In cool weather and in the autumn, it may not be ready to turn until after six weeks. After turning, top up with soil and leave it until you are ready to dig it in.

CHAPTER X

ORGANIC MANURES AND CHEMICAL FERTILISERS

THE COMPOSITION OF SOME ORGANIC MANURES

	Water	Organic Matter	Nitrogen	Potash	Phosphoric Acid
	%	%	%	%	%
Seaweed * { Fresh	79	16	0.3	1.5	—
{ Dried	—	70	1.3	7.8	—
Sewage sludge † .	50-80	10-30	0.5-1	0.03-0.3	0.1-0.5
Horn and hoof meal	—	—	12-14	—	2.5
Fish guano	—	—	7-9	—	7-9
Farmyard manure	—	—	0.6	0.6	0.3

* Potash in the ash from 12 to 28 per cent.

† It has approximately two-thirds the value of dung.

The controversy between the supporters of the so-called "natural" manures is strongly reminiscent of the antagonism with which Pasteur had to contend against those who favoured the idea of spontaneous generation of life or the production of living matter from dead material. At one time also there were chemists who claimed that the substances of vegetable matter differed from those of minerals because, so they said, some vital force was necessary in the production of the former. To-day there are people who oppose the use

of artificial fertilisers. The subject is well discussed in a paper on "Balanced Manuring" in the *Scottish Journal of Agriculture*, vol. xxv, No. 2, January 1945, by Dr. W. G. Ogg, Director of the Rothamsted Experimental Station and the Imperial Bureau of Soil Science, and Dr. Hugh Nicol of the same Bureau. They point out that the term "artificial" is misleading. A better term would be "chemical" fertilisers. They also show that many of the practices in modern agriculture are artificial rather than natural, for example, the drilling of corn.

The opponents of chemical fertilisers have their likes and dislikes. Some like basic slag but dislike superphosphate. They claim that fertilisers poison the soil, bring about erosion, injure the quality of crops, and lower the ability of plants to resist disease. They also hold that animals and human beings consuming these crops are particularly susceptible to many diseases. There is no justification for these claims. Heavy dressings of chemical fertilisers have been given to soils for many years without ill effects. There is no evidence of fertilisers causing erosion. In fact, their use in growing covering crops is a means to prevent it. There is no evidence that fertilisers adversely affect soil bacteria. There will be greater numbers of bacteria in soils with much organic matter. Fertilisers do not reduce the number of earth-worms in ordinary soil. They are less in acid soil. There is no sound evidence that fertilisers increase susceptibility of crops to insect, fungus, and virus attacks. Work is proceeding all the time on the study of such attacks. It may be that the use of dung will spread virus diseases more quickly than if it were not used. When the fertilisers added to plants are fairly well balanced, that is (in particular), when there is no large excess of nitrogen, but nitrogen, potash, and phosphate in quantities suited to

the particular crop, then there is no bad effect on the composition and quality. The vitamin content is not lower in plants given chemical fertilisers.

In recent years it has been shown that the pasture grass in many parts of this country and other parts of the world is deficient in lime and phosphoric acid. The health of the stock has been considerably improved by applying these substances to the pastures. In other pastures certain other elements are deficient, and the cause of disease, while in others they are in excess, and cause trouble on that account. Generally speaking, organic manures are foolproof; they act so slowly that the veriest novice can use them. Tons of seaweed can be carted and ploughed in. It rots and supplies the nitrogen, potash, and phosphate. At the same time it holds water, and for every ton applied about four-fifths of a ton of water is carted on to the land. On a sandy soil this would have a great effect in producing a good yield of a crop like mangolds. Even the salt in it would be valuable. On such a light soil, chemical fertilisers such as superphosphate, sulphate of ammonia, and sulphate of potash would give a poorer yield, because the main factor in plant growth, namely, water, is not sufficient. If the seaweed were supplemented by superphosphate, potash, and sulphate of ammonia in suitable amounts, then a greater yield would be obtained than from seaweed alone. The preference by growers for bone meal and hoof and horn meal is to be attributed to the steady supply of nitrogen and phosphate they yield whereas if nitrate of soda or sulphate of ammonia were used, the effect would be too rapid at the outset.

The supply of humus in soils must be kept up to maintain fertility. Without it the soil is simply powdered rock, unable to retain water and lacking in bacteria, but the proper use of fertilisers will greatly increase the yield of crops. More

knowledge is needed to use fertilisers. The writer overheard a discussion between two farmers as to which was the better manure, sulphate of ammonia or basic slag. This showed great ignorance, since, as we have seen, nitrogenous manures are particularly suited to leaf development and phosphates for root growth. On another occasion a merchant who sold superphosphate of lime wanted to know whether it contained 35 per cent lime or 35 per cent phosphate. Such mistakes were excusable in the past but ought not to be made in the future. In these days crops are grown in water, in sand, in clinkers, without any organic matter and grown to perfection, provided the necessary chemical substances for plant growth are present.

In ordinary agriculture and horticulture both organic manures from dung, composts, seaweed, green manuring, and also chemical or inorganic fertilisers are needed. More and more knowledge is wanted as to the best way to balance the fertilisers for particular crops. This will be treated in a later chapter.

CHAPTER XI

COMPOUND OR MIXED FERTILISERS

CERTAIN fertilisers cannot be mixed without loss of valuable nutrients. Others may be mixed if they are then applied to the soil, while others may be mixed and the mixture stored for a considerable period. There are two underlying chemical facts governing the mixing of fertilisers: firstly, ammonia is a volatile alkali or alkaline gas; secondly, superphosphate is a non-volatile or non-gaseous acid substance. An alkali such as lime is not volatile and will expel the volatile alkali ammonia from ammonium compounds, therefore lime, or fertilisers containing lime, should never be mixed with sulphate of ammonia. This means that the following should not be mixed with sulphate of ammonia: lime, basic slag, mineral phosphates, nitrate of lime, nitro-chalk.

Superphosphate is an acid substance like sulphuric acid. It is not volatile, and it will expel volatile acids such as nitric acid and hydrochloric acid from nitrates and chlorides. Superphosphate should therefore not be mixed with fertilisers containing nitrates and chlorides. This means that nitrates of soda, potash and lime, nitro-chalk, muriate or chloride of potash, kainit, and potash salts should not be mixed with superphosphate or with dissolved bone. If the mixture is to be used immediately, then it is possible to mix nitrate of soda with superphosphate and potash fertilisers. The commonest mixture which can be stored is made from superphosphate, sulphate of ammonia, and sulphate of potash.

and for potash :

$$= \frac{\% \text{ of } K_2O \text{ in mixture} \times \text{cwts. of mixture}}{\% \text{ of } K_2O \text{ in sulphate of potash}}$$

$$= \frac{6 \times 20}{48.4} = \frac{120}{48.4} = 2.48 \text{ cwts.}$$

So a mixture with 4 per cent N, 10 per cent P_2O_5 , and 6 per cent K_2O could be made with

4	cwts.	of	sulphate	of	ammonia
$12\frac{1}{2}$,,		superphosphate		
$2\frac{1}{2}$,,		sulphate	of	potash
<hr style="width: 50%; margin: 0 auto;"/>					
Total	<u>19</u>				<u>cwts.</u>

It is seen that this makes only 19 cwts. and fine sand or some suitable filler is added to make the additional weight. Had 8 cwts. only been required, the quantities could be worked out by the same method by substituting 8 for 20.

Then the amount of sulphate of ammonia required would be :

$$\frac{4}{20.4} \times 8 \text{ cwts.} = \frac{32}{20.4} = 1.57 \text{ cwts.}$$

The amount of superphosphate :

$$\frac{10 \times 8}{16} = 5 \text{ cwts.}$$

The amount of sulphate of potash :

$$\frac{6 \times 8}{48.4} = \frac{48}{48.4} = 1 \text{ cwt. approx.}$$

The total weight would be $1\frac{1}{2} + 5 + 1 = 7\frac{1}{2}$ cwts., so $\frac{1}{2}$ cwt. of filler would be necessary.

Often the opposite information is required ; that is, when we know the quantities mixed, what will be the

percentage composition? Suppose, for example, there were mixed together

1½ cwts. of sulphate of ammonia
 5 „ superphosphate
 1 cwt. of sulphate of potash.

Then the percentage of nitrogen present is given by

$$\frac{\text{Weight of sulphate of ammonia} \times 20.4}{\text{Total weight}} = \frac{1\frac{1}{2} \times 20.4}{7\frac{1}{2}}$$

$$= \frac{3 \times 20.4}{15} = \mathbf{4.08 \text{ per cent nitrogen.}}$$

The percentage of phosphoric acid will be

$$\frac{\text{Weight of superphosphate} \times 16}{\text{Total weight}} = \frac{5 \times 16}{7\frac{1}{2}}$$

$$= \frac{80}{7\frac{1}{2}} = \mathbf{10.66 \text{ per cent } P_2O_5.}$$

The percentage of potash will be

$$\frac{\text{Weight of sulphate of potash} \times 48.4}{\text{Total weight}}$$

$$= \frac{1 \times 48.4}{7\frac{1}{2}} = \mathbf{6.45 \text{ per cent potash.}}$$

The formula can be written

$$\frac{\text{Weight of fertiliser} \times \% \text{ of } N, P_2O_5, \text{ or } K_2O \text{ in the fertiliser}}{\text{Total weight}}$$

The student will note that when the weights to be mixed are required, they are given by the ratio of the percentages in the mixture and in the particular fertiliser, multiplied by the total weight: whereas when the percentages of the constituents are wanted, then the ratio of the weight of the fertiliser to the total weight is multiplied by the percentage

percentage composition? Suppose, for example, there were mixed together

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The percentage of nitrogen supplied by this weight of diammonium phosphate will be

$$\frac{5.95}{20} \times 21.21, \text{ that is, } \frac{126.2}{20}, \text{ or } 6.31.$$

But 9 per cent nitrogen is required. The balance, $9 - 6.31$ or 2.69 per cent, will be supplied by $2.69/20.6 \times 20$ cwts. of sulphate of ammonia; that is, by 2.61 cwts. of sulphate of ammonia.

To supply 15 per cent potash the weight of sulphate of potash required will be

$$\frac{15}{48} \text{ of } 20 \text{ cwts.}, \text{ or } 6.25 \text{ cwts.}$$

So the mixture will contain

	5.95	cwts.	of diammonium phosphate
	2.61	,,	sulphate of ammonia
	6.25	,,	sulphate of potash
Total	14.81	cwts.	

requiring 5.19 cwts. of filler to make up the ton.

Instead of the diammonium phosphate, the monammonium phosphate ($(\text{NH}_4)\text{H}_2\text{PO}_4$), containing 12.17 per cent of nitrogen and 61.7 per cent of phosphoric acid, could have been used.

To supply 16 per cent of phosphoric acid the weight of monammonium phosphate required would be

$$\frac{16}{61.7} \times 20 \text{ cwts.} = 5.18 \text{ cwts.}$$

The percentage of nitrogen supplied by 5.18 cwts. of

monammonium phosphate containing 12·17 per cent of nitrogen will be

$$\frac{5\cdot18}{20} \times 12\cdot17, \text{ that is, } 3\cdot15.$$

But 9 per cent nitrogen is required. The balance, $9 - 3\cdot15$ or 5·85 per cent, will be supplied by

$$\frac{5\cdot85}{20\cdot6} \times 20 \text{ cwts. of sulphate of ammonia,}$$

that is, by 5·68 cwts. of sulphate of ammonia.

As before, 15 per cent of potash will be supplied by 6·25 cwts. of sulphate of potash. So the mixture will contain

5·18	cwts.	of monammonium phosphate
5·68	„	sulphate of ammonia
6·25	„	sulphate of potash
Total		
17·11	cwts.	

requiring 2·89 cwts. of filler to make up the ton.

Valuation of Fertilisers

If a fertiliser is made up of the three constituents mentioned, namely, sulphate of ammonia, superphosphate, and sulphate of potash, and if it contains 4 per cent nitrogen, 10 per cent phosphoric acid, and 6 per cent potash, what is its cash value? Mention has been made of the unit in the valuation of fertilisers. It is $\frac{1}{100}$ of a ton, or 22·4 lb. It was also stated that the value of this unit is published regularly in the trade journals.

Suppose the unit value of nitrogen in sulphate
of ammonia 10s.

Suppose the unit value of phosphoric acid in superphosphate	3s. 6d.
Suppose the unit value of potash in sulphate of potash	4s.

This means that 22.4 lb. of nitrogen are worth 10s.

4 per cent nitrogen means $\frac{4}{100}$ ton or 4 units, and this will be worth $4 \times 10s.$, or £2.

Similarly 10 per cent phosphoric acid means 10 units in a ton and will be worth $10 \times 3s. 6d.$, or £1 : 15s.

And 6 per cent potash means 6 units in a ton and will be worth $6 \times 4s.$, or £1 : 4s.

So that a ton of this mixture would be worth £2 + £1 : 15s. + £1 : 4s. = £4 : 19s.

An addition is made for cost of bagging and mixing. This was about 10s. a ton in 1939.

CHAPTER XII

FERTILISERS FOR AGRICULTURAL CROPS

THE kinds and quantities of fertilisers required will depend on what rotation of crops is practised. In crop rotations the aims will be to conserve the humus or organic matter and to take advantage of the increased fertility brought about in the soil by the growth of leguminous crops such as peas, beans, clover, and vetches. The inclusion of a temporary ley in the rotation brings about both of these desirable effects, Root crops and such green crops as cabbage, brussels sprouts, and broccoli require particularly heavy manuring.

In the following table a general guide to the manuring of various agricultural crops is given. It shows the amounts of each of the three principal fertilising constituents added in the manure and also the amounts removed by an average crop. Larger crops will, of course, remove proportionately more. How much is actually available to the crop will depend on the particular crop grown, on the extent of its root system, on how the manure is incorporated in the soil, and on the rainfall and hours of sunshine during the period of growth.

It is useful to note the following :

- 1 cwt. sulphate of ammonia (20·6 per cent) supplies 23 lb. nitrogen.
- 1 cwt. nitro-chalk (15·5 per cent) supplies 17·3 lb. nitrogen.
- 1 cwt. superphosphate (18 per cent) supplies 20 lb. phosphoric acid.
- 1 cwt. basic slag (14 per cent) supplies 16 lb. phosphoric acid.

1 cwt. sulphate of potash (48 per cent) supplies 54 lb. potash.
1 cwt. muriate of potash (50 per cent) supplies 56 lb. potash.

FERTILISERS FOR AGRICULTURAL CROPS (In cwts. per acre)

N = Nitrogen ; P_2O_5 = Phosphoric acid ; K_2O = Potash

Crop	Sulphate of Ammonia	Super-phosphate	Muriate of Potash	Supplied			Removed			
				N	P_2O_5	K_2O	N	P_2O_5	K_2O	CaO
Winter wheat . . .	1-1½	—	—	23-24	—	—	60	20	30	10
Spring wheat . . .	1	—	—	23	—	—	—	—	—	—
Oats	1-1½	—	—	23-24	—	—	50	20	45	12
Barley	1	—	—	23	—	—	50	20	35	10
Beans	—	3	1	—	54	56	100	30	70	30
Peas	1	3	1	23	54	56	—	—	—	—
Potatoes	2	4	3	46	72	168	46	22	75	3
Mangolds	2	3	1	45	54	56	150	53	300	43
Swedes	2	4	1	45	72	56	40	33	150	75
Turnip	1	4	1	23	72	56	140	33	150	75
Sugar beet	3	4	1½	69	72	84	—	—	—	—
Brussels sprouts	2	5	4	46	90	224	190	65	170	144
Broccoli	1	4	4	23	72	224	220	80	250	120
Hay	1½	2	1	34	36	56	100	25	90	90

Mangolds and sugar beet should also receive 2 to 3 cwts. of salt. Kale and cabbage are given the same quantities of fertilisers as mangolds. For mangolds, swedes, potatoes, kale, cabbage, brussels sprouts, and broccoli about 10 tons of dung should also be applied. This will supply about 130 lb. of nitrogen and potash and about 60 lb. of phosphoric acid. Much of the nitrogen and phosphoric acid will not, however, be available for the first crop.

Applications of potash and phosphoric acid can be made in the drills or before sowing. They are not washed out of the soil but firmly fixed. Nitrogenous fertilisers are readily removed.

Many farmers and market gardeners buy complete ready-mixed fertilisers. Thus a main-crop potato fertiliser is

stated to contain 2.5 per cent nitrogen, 8.24 per cent phosphoric acid, 4 per cent potash. At a glance it is not possible to realise the significance of these figures. If they are multiplied by ten we shall see how many pounds of nitrogen, phosphoric acid, and potash are supplied by 1000 lb. or approximately 9 cwts. of the fertiliser. The amounts are: 25 lb. of nitrogen, 82 lb. of phosphoric acid, 40 lb. of potash. These amounts would be supplied by about 1 cwt. of sulphate of ammonia, $4\frac{1}{2}$ cwts. of superphosphate, and $\frac{3}{4}$ cwt. of muriate of potash.

The following is another example: A mangold manure is stated to contain 4.75 per cent N, 7.4 per cent K_2O , 11 per cent P_2O_5 . Ten times these quantities, namely, $47\frac{1}{2}$ lb. N, 74 lb. K_2O , and 110 lb. P_2O_5 , will be contained in 1000 lb. of fertiliser, or approximately 9 cwts. This is equivalent to 2 cwts. of sulphate of ammonia, $1\frac{1}{2}$ cwts. of muriate of potash, 5 cwts. of superphosphate.

CHAPTER XIII

GENERAL PRINCIPLES OF MANURING AGRICULTURAL CROPS

AN examination of the quantities recommended for the various crops reveals the following facts :

- (1) Where dung is applied, it is in such large amounts that considerable quantities of nitrogen, phosphoric acid, and potash are supplied. Only small amounts of the nitrogen and phosphoric acid will, however, be available.
- (2) For most crops 3 to 4 cwts. of superphosphate is sufficient. Of this about 30 per cent will be available in the first year and the remainder will be useful for subsequent crops.
- (3) Potash is supplied in comparatively small amounts unless dung is present. In this case more would be given if more could be obtained. In future years, when supplies have increased, it will be an advantage to supply more potash. It will not be harmful and any potash not taken up by a crop will serve for those that follow.
- (4) Sulphate of ammonia is usually applied at the rate of 1 cwt. per acre. More care must be taken with this fertiliser to avoid profusion of leaf. It is as a rule best applied as a top dressing.

Grass-land

An immense amount of experimental work has been carried out on the manuring of grass-land. The results

following the application of basic slag and mineral phosphates to pastures on heavy clay soils led to the conclusion that this was the best method of improving grass-land and that by this means more meat and more milk could be obtained. On meadow-land also more hay was obtained.

The use of nitrogenous fertilisers produced coarse grasses and depressed the clovers and in consequence was not recommended. Later experiments have shown that this is exactly what would occur with one-sided manuring of that kind. When a complete fertiliser is applied, then both yield and composition of herbage is improved and therefore the feeding value. Much of the grass-land was too sour to benefit by fertilisers until the acidity had been corrected by liming. When that had been done and a basal dressing of phosphates and potash applied, followed by application of nitrogenous fertilisers, then the clovers were not depressed, the grasses were more leafy, and the herbage more bulky and more nutritious.

The work of Sir George Stapledon has shown the value of temporary leys, when such leys are sown with strains of leafy grasses of high feeding value. This has led to the advocacy of ley farming and the carrying of the plough round the farm, that is, to the ploughing of each field in succession and following with a rotation which includes one or two years of grass. In this way the humus is restored and the fertility maintained. Many acres of poor grass-land have been improved by correct mechanical treatment and the application of phosphates or of lime and phosphates. In many cases these cannot act until the "mat" has been opened up by somewhat violent mechanical treatment.

The quality of grass and hay varies considerably in different parts of the country and in different countries. By quality is meant its chemical composition and its feeding

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The quality of grass and hay varies considerably in different parts of the country and in different countries. By quality is meant its chemical composition and its feeding

value. Nearly all farm crops are deficient in lime. The bones of animals consist mainly of phosphates of lime. The chief source of lime for bone formation is found in the grass and hay. It is evidently a matter of great importance in maintaining healthy stock for the farmer to see that the grassland is adequately supplied with lime and phosphates.

The improvement of pastures involves experienced and proper management as well as correct manuring. For increasing the hay crop the following mixture will be found of value :

- 1½ cwts. of sulphate of ammonia
- 2 „ superphosphate
- 1 cwt. of sulphate or muriate of potash.

It is common practice to spread dung, and this certainly increases the bulk, but it also increases the proportion of weeds.

CHAPTER XIV

FERTILISERS FOR HORTICULTURAL CROPS

IN horticultural practice, cultivations, cropping, and manuring are on a much more intensive scale. Plant nutrients are removed from the soil in much greater quantities. Since most of the crops are sold, the plant nutrients thus removed must be returned in the form of fertilisers, if fertility is to be maintained.

Intensive cropping also means that vast quantities of water are required for growth purposes. The soil must therefore be well supplied with organic matter. Moreover, this organic matter must be constantly renewed because there are two factors that hasten its removal: first, the frequency and efficiency of the cultivations which admit air into the soil and slowly burn up or oxidise the organic matter; and second, the continued application of lime which accelerates the oxidation or burning process. Horticultural crops require a steady, continuous supply of nitrogen, which they can only obtain from organic manures, such as dung, seaweed, bone meal, shoddy, or guano.

Owing to the frequency of liming, horticultural soils differ markedly from agricultural soils in their reaction or intensity of acidity. Whereas most agricultural soils are somewhat acid with a pH varying from 5 to 6.5, horticultural soils are more often alkaline with a pH greater than 7. This will result in the phosphate in the latter soils being more available, but it may also result in less availability of other elements such as iron, boron, and manganese.

Crop	Sulphate of Ammonia	Super-phosphate	Sulphate or Muriate of Potash
	Oz.	Oz.	Oz.
Cabbage (autumn sown)	1	3	1
Broccoli . . .	$\frac{1}{2}$	2	1
Brussels sprouts . . .	1	3	2
Kale	1	3	1
Cauliflower	$\frac{1}{2}$	1	1
Onions	$\frac{1}{2}$	3	1
Carrots	$\frac{1}{2}$	1	$\frac{1}{2}$
Swedes	1	3	$\frac{1}{2}$
Turnip	—	1	1
Potatoes	2	2	1
Peas	1	3	1
Broad beans	—	2	1
Runner beans	—	2	1
Kidney beans	—	2	1
Lettuce	$\frac{1}{2}$	2	1
Parsnip	1	2	1
Tomatoes	Bone meal	3	1
Beet root	1	2	1
Celery	$\frac{1}{2}$	1	$\frac{1}{2}$
Spinach	—	2	1
Apples :			
Young trees	2	4	4
Old trees	4	1 lb.	1 lb. per tree
Pears :			
Young (weak)	8	—	8
If too much wood	—	4	8
Apricots and peaches	—	4	1
Fruiting	4	—	—
Gooseberries	1 (April)	4 (October)	1 (October)
Raspberries	2	8	2
Cherries	1 (after fruit has set)	2	1
Strawberries	Bone meal in autumn	2	1

From what has been stated it will be evident that larger quantities of fertilisers will be applied in horticultural practice. In agricultural practice it is usual to apply about 4 cwts. per acre of superphosphate. In horticultural practice the quantities are better stated in ounces per square yard.

It may be useful to remember that 1 cwt. per acre is equivalent to 0.37 oz. per square yard, or rather more than a third of an ounce.

An ounce of any of the following is approximately a heaped tablespoonful: sulphate of ammonia, nitro-chalk, superphosphate, muriate of potash, sulphate of potash, nitrate of soda, and potash salts.

An ounce of basic slag is approximately a heaped dessert-spoonful.

As a general guide to the manuring of horticultural crops the table on page 64 has been compiled. The quantities of fertilisers are stated in ounces per square yard. For crops such as cabbage, broccoli, brussels sprouts, cauliflower, potatoes, and celery, an organic manure such as dung or compost should be applied also at the rate of half a barrowful per square yard. As a rule this should be dug in in the autumn.

CHAPTER XV

CONTROL AND DISTRIBUTION OF FERTILISERS (1944-5)

At the present time permits are necessary in order to purchase phosphatic and potassic fertilisers but not for fertilisers containing only nitrogen. The following are the standard dressings authorised by the Ministry of Agriculture. As supplies increase now that the war is over, it should soon be possible to purchase all fertilisers without permits.

The table will serve to remind users how short was the supply during the war years.

[See table on facing page —

Crop : Autumn and Spring Sown	Rate of Phosphoric Acid per Acre	Super-phosphate required	Rate of Potash per Acre	Muriate of Potash required
Cereals . . .	0.1 cwt., or 11.2 lb.	62 lb.	Nil	Nil
Swedes for stock	0.7 cwt., or 78.4 lb.	434 lb.	Nil	Nil
Mangolds for stock	0.5 cwt., or 56 lb.	310 lb.	0.3 cwt.	56 lb.
Other root and green crops	0.5 cwt., or 56 lb.	310 lb.	—	—
Peas for stock .	0.5 cwt., or 56 lb.	310 lb.	—	—
Beans for stock	0.5 cwt., or 56 lb.	310 lb.	—	—
Sugar beet . .	0.5 cwt., or 56 lb.	310 lb.	0.3 cwt.	56 lb.
Flax for fibre .	0.1 cwt., or 11.2 lb.	62 lb.	0.6 cwt.	1 cwt.
Potatoes . . .	0.7 cwt., or 78.4 lb.	434 lb.	1.2 cwts.	2 cwts.
Roots and vegetables for seed	0.5 cwt., or 56 lb.	310 lb.	0.6 cwt.	2 cwts.
Market garden crops for human consumption	0.7 cwt., or 78.4 lb.	434 lb.	0.3 cwt.	1 cwt.
Tomatoes in open	0.7 cwt., or 78.4 lb.	434 lb.	1.2 cwts.	2 cwts.
Tomatoes under glass	3.0 cwts., or 336 lb.	1860 lb.	—	6 cwts.
Black currants .	0.3 cwt., or 33.6 lb.	186 lb.	0.3 cwt.	56 lb.
Other small fruits	0.3 cwt., or 33.6 lb.	186 lb.	Nil	Nil
Grass and clover seeds—				
1-year ley .	0.1 cwt., or 11.2 lb.	62 lb.	—	—
2-year ley .	0.5 cwt., or 56 lb.	310 lb.	Nil	Nil
7-year grass ploughed since 1939	0.1 cwt., or 11.2 lb.	62 lb.	Nil	Nil

CHAPTER XVI

FERTILISERS AND FEEDING STUFFS ACT, 1926

THIS Act, the latest of many, was designed to protect purchasers of fertilisers and feeding stuffs from fraudulent practices. By the terms of this Act, to all purchasers of fertilisers a statement in writing or statutory statement must be given, giving particulars of the article as specified in the First and Second Schedules of the Act. For example: If the article was basic slag, then the percentage of phosphoric acid must be stated and also the amount that will pass through a sieve of prescribed dimensions. No statutory statement need be given when two or more articles are mixed at the request of the purchaser. Again, no statutory statement need be given when a half-hundredweight or less is taken in the presence of the purchaser from a large amount which is plainly labelled with the necessary particulars. Vendors of fertilisers must keep a register in which must be entered the necessary particulars as to percentages of constituents.

Inspectors appointed by Local Authorities and the Ministry of Agriculture are empowered to enter premises where articles in the First Schedule prepared for sale or consignment are to be found. They may take samples in a prescribed manner.

The various articles in the First and Second Schedules and the particulars which must be contained in the statutory statement are shown on pages 69 and 70.

FIRST SCHEDULE

<i>Article</i>	<i>Particulars</i>
Basic slag	Amount of phosphoric acid. Amount of the article that will pass through a prescribed sieve.
Basic superphosphate.	Amount of phosphoric acid.
Bone meal, or other product (excluding dissolved or vitriolised bone) obtained by grinding or otherwise treating bone used for fertilising purposes.	Amounts of nitrogen and phosphoric acid.
Dissolved or vitriolised bone.	Amounts of nitrogen, soluble phosphoric acid, and insoluble phosphoric acid respectively.
Fish residues or other product obtained by drying and grinding or otherwise treating fish or fish waste used for fertilising purposes.	Amounts of nitrogen and phosphoric acid respectively.
Guano, including Peruvian and other raw guanos.	Amounts of nitrogen, phosphoric acid, and potash respectively.
Hoofs.	Amount of nitrogen.
Hoofs and horns.	Amount of nitrogen.
Horns.	Amount of nitrogen.
Meat and bone residues or any product not specifically mentioned elsewhere in this part of this Schedule, obtained by drying and grinding or otherwise treating bone, flesh, flesh fibre (including whale	Amounts of nitrogen and phosphoric acid respectively.

meat), and other slaughtered residues used for fertilising purposes.	
Nitrate of lime.	Amount of nitrogen.
Nitrate of soda.	Amount of nitrogen.
Oil-seed fertilisers including castor meal, mowrah meal, rape meal, or any residue which is obtained by the removal of oil from seeds.	Amount of nitrogen.
Potassium salts used as fertilisers, including kainit, extra kainit, sylvinit, potash manure salt, muriate of potash, sulphate of potash, and sulphate of potash-magnesia.	Amount of potash.
Sulphate of ammonia.	Amount of nitrogen.
Superphosphate.	Amount of soluble phosphoric acid.

SECOND SCHEDULE

<i>Article</i>	<i>Particulars</i>
Calcium hydrate. } Calcium hydroxide. } Slaked lime. } Chalk, ground.	Amount of calcium hydroxide and equivalent of calcium oxide. Amount of calcium carbonate and equivalent of calcium oxide.
Dried blood for fertilising purposes.	Amount of nitrogen.
Dried carbonate of lime not otherwise specifically mentioned in this Schedule.	Amount of calcium carbonate and equivalent of calcium oxide.
Lime, ground.	Amount of calcium carbonate and equivalent of calcium

oxide. Amount that will pass through a prescribed sieve.

Precipitated bone.

Amount of phosphoric acid.

Quicklime, ground or otherwise.

Amount of calcium oxide.

Shoddy.

None.

Fertilisers and Feeding Stuffs Act

Sampling.—A purchaser of fertilisers who has doubt about the quality and who wishes to have analysed any materials which he has purchased, must not take a sample or samples himself, but he must call in the Official Sampler.

This official is usually the official Agricultural Analyst. The taking of a representative sample, that is, obtaining from a large bulk of material a small quantity which shall be truly representative of the whole, is not so easy as it may at first sight appear.

Details of the methods employed are prescribed in the Act. A few examples are given below.

When the fertiliser is delivered in bags or packages :

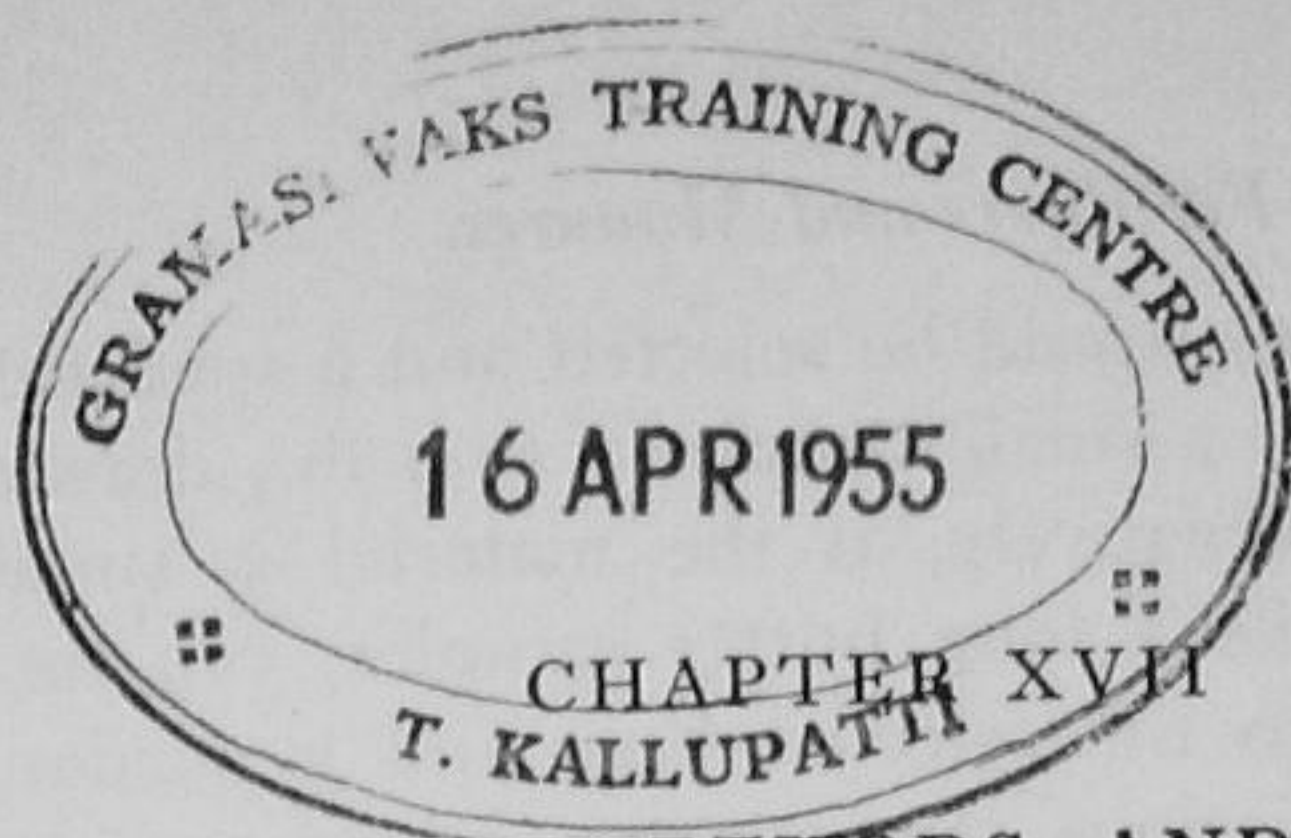
Quantity	% which must be sampled	Not fewer than
2-20 packages .	20	2 packages
21-60 " .	10	4 "
61-200 " .	7½	6 "
201-500 " .	5	15 "
501-1000 " .	4	25 "
Above 1000 " .	3	40 "

Selected bags may be emptied on a clean floor, a spadeful of each taken, set aside and mixed, and a sample of 2 to 4 lb. drawn from the mixture ; for example, if there were 50 bags

of basic slag, 5 bags would be selected and a spadeful from each mixed. Then a small sample, 2 to 4 lb., drawn from the mixture. Alternatively, if the material is suitable, a sampling spear, like a long butter sampler, can be used. This is placed into the selected bags and a portion then withdrawn; the various portions are mixed to form the sample for analysis. If the material consists of lumps such as burnt lime, 4 spadefuls from each ton are taken at random from different parts, crushed at once, and passed through a sieve with meshes $1\frac{1}{4}$ inches square; lumps and stones present are broken and mixed and 4 to 6 lb. drawn. If the materials can change in the air as burnt lime and nitrate of lime, the sample is taken as quickly as possible and placed in an air-tight container. In the case of materials like shoddy and wool refuse, portions are selected at random, matted parts teased out, and the whole mixed and a sample drawn.

The Act also prescribes the methods of analysis and the limits of variations are stated. The limit of variation in the case of sulphate of ammonia is 0.3 per cent of nitrogen. Suppose a seller of fertilisers states the percentage of nitrogen in the sulphate of ammonia he has sold to be 20.6 and the analyst finds 20.3, this is within the permissible error, whereas if 20.2 or less had been found it would have been greater than the limit allowed. For basic slag the limit is 1 per cent of phosphoric acid, and for mineral phosphate one-twentieth of the amount of phosphoric acid stated. The reason for allowing for any variation in composition of fertiliser is the possibility that in some cases slight differences may exist in different parts of the same sample. The sample may not have the same composition throughout and the mixing may have been incomplete.

For further details the Act itself must be consulted. Here it has only been possible to deal with a few of the important points.



EXPERIMENTAL METHODS, AND CONCLUSION

Experimental Methods of determining the relative Efficiency of Fertilisers

From the preceding chapters the reader should now understand that only fertilisers of the same type or class should be compared. The effect of sulphate of ammonia in increasing the yield of a particular crop could be compared with any of the following nitrogenous fertilisers — nitrate of soda, calcium cyanamide, or nitro-chalk. It would be absurd to try to compare sulphate of ammonia with basic slag, that is, a nitrogenous with a phosphatic fertiliser, since they have very different effects on the plant. Basic slag should be compared with superphosphate or with a mineral phosphate.

In manurial trials, plots of equal area are selected in the same field and equal amounts of the particular nutrient supplied. Thus, in comparing the effect of sulphate of ammonia with that of nitrate of soda, equal amounts of nitrogen would be applied to the selected plots. If one of the plots was given 1 cwt. of sulphate of ammonia, having 20.6 per cent of nitrogen, the plot would receive 23 lb. of nitrogen. To supply 23 lb. of nitrogen from nitrate of soda which has 15.5 per cent nitrogen, 148 lb. of nitrate of soda would be required. Owing to variations in the soil in the same field, an experiment which used one plot only for sulphate of ammonia and one plot only for nitrate of soda

would not be likely to yield any satisfactory and conclusive result. It might even happen, and indeed has often occurred in field trials, that the plot which received no fertiliser at all would give a greater yield than the plots which had been manured.

It has therefore been found necessary to have a large number of plots, such as five plots without fertiliser, five plots with one of the fertilisers, and five plots with the other. Various arrangements of the plots have been tried. From the records of the crop yields by this method it is possible to determine the error of the experiment and to draw reliable conclusions. Obviously such replication of plots involves considerable labour and expense, but such is necessary or the experiments will prove valueless.

Often pot experiments similarly conducted are also carried out, that is, replicated pot experiments in which the soil in several pots receives similar treatment. Here the conditions are different from field trials, since they are more artificial and the soil is not in the same condition as in the field. Moreover, the pots receive water whenever it is required.

It will be realised that only by close co-operation between farmers and advisers can field trials prove successful. Such co-operation is on the increase and the results will add considerably to our knowledge of the value of fertilisers for crop production.

Conclusion

The application of compounds to supply trace elements for fertilising purposes has not been considered. Such trace elements as boron, cobalt, copper, iodine, zinc, and manganese are rarely absent from soils. The amounts necessary for

plants are so small that it is best to seek the free services of the Regional Advisory Chemist when symptoms of deficiency appear in crops. The most economical use of fertilisers is obtained by the rotation of crops so as to have the advantage of the residues from the preceding crop. These residues will consist of the potash and phosphoric acid in excess of the requirements of the former crop or which for the time has become unavailable. The soil has the power of retaining strongly the potash and phosphoric acid but not the nitrogen nor the lime compounds. Nitrogenous fertilisers are best applied when growth is well started, but phosphatic and potassic fertilisers can be put in with the seed. The rotation should always include a leguminous crop, so as to secure nitrogen indirectly from the atmosphere and to promote desirable bacterial activities in the soil.

It is hoped that the reader has obtained some knowledge of the methods of manufacture and also of the properties or characteristics of the different fertilisers, also that something has been learned of the effects of each on the soil and the plant. He should now be able to study the information obtained from actual field trials. Such information can be obtained in the Bulletins issued by the Ministry of Agriculture and Fisheries — in particular the very valuable and interesting Bulletin No. 28, written by Sir E. John Russell. As the years pass and knowledge of fertilisers grows, so we shall understand more and more about those now in use and new fertilisers that will appear. It is certain that there will be much greater production and use, because at the present time the necessity for increasing the food supply of the world is so great and so urgent.

Of their value there can be no doubt. Enormous sums of money are spent on them annually, and this will continue and will increase. The human race can control and improve

the soil and so enlarge the production of food that hunger can be prevented in any part of the world. At the moment millions are suffering. Even in Britain there is much malnutrition. By the combination of scientific knowledge of agriculture and its technical application by producers, by the spread of that knowledge, the world can be made a happier place for all, a world in which famines will have no place.

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