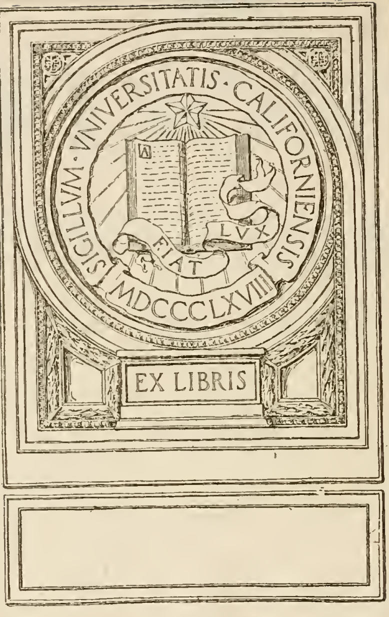
THE MANUAL OF MANURES

HENRY VENDELMANS

S'

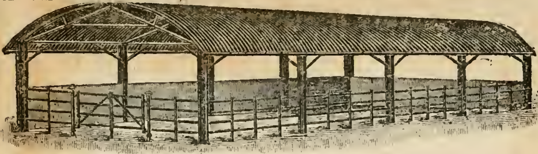
S



J(LTD.,
are rtilizers
in ised all
ove

ally to
me ps and
hav

ley has
on won by
the ds and
hur ... Cups and
Prizes have been gained by Grain, Roots, Potatoes, Hops, Vegetables, and Fruit grown by their aid.



THE INCREASED PRODUCTIVITY SERIES

GENERAL EDITOR: P. ANDERSON GRAHAM

COUNTRY

C L

LIFE

THE MANUAL OF MANURES

THE MANUAL OF MANURES

BY

HENRY VENDELMANS

ING. AGRI. (BELGIQUE)

LONDON:
PUBLISHED AT THE OFFICES OF "COUNTRY LIFE,"
20, TAVISTOCK STREET, COVENT GARDEN, W.C., AND BY
GEORGE NEWNES, LTD., 8-11, SOUTHAMPTON STREET,
STRAND, W.C., NEW YORK: CHARLES SCRIBNER'S SONS

MCMXVI

PREFATORIAL NOTE

THIS little book was projected in order to help those engaged in cultivating the soil to increase their returns. It will tell little to the highly successful grower. The other day one who probably sends more food stuffs to market than anybody else in Great Britain, told me his account with a single firm of chemical manure manufacturers averaged about £8000 annually, and he never lays out money without seeing how he will get it back. There is no reason why every one who cultivates the tiniest garden plot should not share in his knowledge and its advantages. It is the aim of this book to enable him to achieve this. Mr. Vendelmans, the author, writes not only from "the book," but from his experience as a highly successful cultivator. In simple terms that he who runs may read he has described the nature and constitution of manures of every type, explaining the manner of their application and to what crops and at what seasons of the year. Any one who habitually uses the volume for reference and advice will, if he be working for a livelihood, be enabled to add to his gains. If an amateur, he will have the satisfaction of an abundant and first-class crop instead of only a moderate one. Within brief compass the fruits are given of long study and experience of practical growing. It is intended to supplement this manual with another book to be called "Exportation and Restitution"—the aim of which will be to show exactly what each crop takes away from the soil and what therefore the grower should put back in the shape of manure. The two together will form an invaluable help to cultivation.

In conclusion let me quote what was so well said in a notice recently issued from the Board of Agriculture and Fisheries, "Lord Selborne confidently hopes that farmers will this year greatly increase their demands for fertilisers of all descriptions, so as to stimulate as far as practicable the production from the land, and thus reduce the importation of foodstuffs." The wise reader, however, will add after "this year" three more words "and every year."

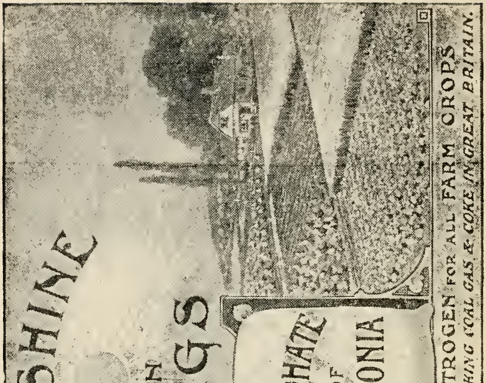
P. A. G.

CONTENTS

Contents

Contents

Contents


SUNSHINE
IN
BAGS
SULPHATE
OF
AMMONIA
THE BEST SOURCE OF NITROGEN FOR ALL FARM CROPS
PRODUCED DURING THE PROCESS OF MAKING COAL GAS & COKE IN GREAT BRITAIN.

THE MANUAL OF MANURES

CHAPTER I

Introduction

THE question of manures is of paramount importance to-day, and unfortunately it is not very well understood; yet on its comprehension depends the future of agriculture on which, as the great war has shown, our existence as a nation must depend.

To be in a position to pay the high wages demanded in these times of scarcity of labour, the farmer must modernise his methods. And if, on the one hand, he tries to reduce the cost of cultivation by the use of labour-saving machinery, he ought, on the other hand, to increase his profits by the employment of artificial manures, as well as that of the farmyard.

But manures increase productiveness only when they are intelligently and judiciously used. It is of no use to apply a lot of manure when the increase in production is worth less than the price of that manure. It is useless to spend a great deal of money on artificial manures, if they are applied at seasons when they will be washed away in the drainage. If they are applied to crops which cannot profit economically by them, not given in the right proportions, or with the right kinds in association, or, above all, if by buying without knowledge the usual price is paid for inferior products, a loss is entailed at the starting point.

Whatever the method of cultivation may be, the quantity and quality of the results obtained will depend chiefly on the influence of manure. Other conditions being equal, the difference in results ought to be attributed entirely to the manures, and this difference is sometimes enormous.

In some cases proper manuring may mean a two-fold increase ; in others it will enable us to cultivate soils which otherwise could not have been touched.

We know, too, that between the price of manures and the extra value of crops obtained, thanks to their use, there is a large margin of profit ; but this profit ought to be derived from the judicious use of these manures, and to be able to utilise them judiciously we must understand them.

There are actually on the market such a variety of artificial manures, and they are introduced with so much skill, that it is very easy to be led astray as to their value and the use one should make of them. It is not wisdom either, on the part of the buyer, to rely solely and completely on the seller for advice as to what is useful or necessary for his purpose. He ought to know and be able to judge for himself.

" A Manual of Manures " will be not only useful, but essential to the farmer, and he ought always to keep it handy.

He ought to know what elements these manures bring to the soil, under what forms, and in what proportions. He ought to know what kinds of manure he should employ and to be able to calculate the quantities that should be applied to various crops and the seasons favourable for their application, so that they will be most profitable to the plants for which they are intended, and not be merely washed away.

He ought to know what manures can be combined without fear of loss ; how to store them for a length of time without appreciable loss ; how to fix their value on the basis of the units of the fertilising elements which they contain, and the more or less favourable form in which these elements are present. He must not blindly believe in the virtue of manures, or listen to advertising recommendations. He must demand a *written guarantee* of the number of units of fertilising matter and the forms in which they are presented, confirming these facts by analyses, so as to pay a price, based on the price of the day, corresponding to these units. He ought to know the principal adulterations to which these manures are liable, so as to be forewarned, and exercise care so as to buy well and cheaply.

Knowledge of the subject will prevent him from paying too much for some manures much in demand, which for this reason alone have attained a price much beyond their real value.

Finally, he ought to be able to account to himself for the produce which he has obtained per unit of fertilising matter at the most advantageous price at the farm, not forgetting the price of transport, which, in the poorest manures, will be proportionally higher to the unit.

Introduction

All this knowledge is necessary to enable the farmer to handle manures, and having it, he should be able to estimate the exact results obtainable instead of only waiting to see what will come of the employment of haphazard methods.

It is from lack of knowledge that many people are obliged to resort to compound manures and mixtures of all sorts, in which the unit of fertilising matter is always sold at too high a price, a price often comparable to that of the "Aqua Pompae" of old apothecaries, or the alcohol in sedative waters.

We shall say something on the subject of farm-yard manure, its formation, its preservation, and its employment, and we should like to call attention to the enormous waste of it which takes place.

We shall make allusion also to green manures, without dwelling on them, however, in order not to increase the size of the book.

Not only farmers, but every one who possesses land or even a garden ought to learn about manures, especially, we think, teachers in country schools, both male and female.

We have intentionally put on one side everything that is difficult in the subject, and everything that could impede easy comprehension. The few unusual terms employed will be explained in a way to make them quite intelligible.

It is the popularisation of the knowledge of manures on which we are intent, convinced that in this direction we can be of some service.

CHAPTER II

Manures in General

The Necessity of Manures.

Plants, like all living things, require that ten elements should be put at their disposal under fixed conditions, but to give crops they do not require equal quantities of each of these elements. They show a greater need for some than for others.

Thus, among these ten necessary elements, seven are generally found in sufficient quantities in the soil and in the air.

They are Hydrogen [H], Oxygen [O], Carbon [C], Calcium [Ca], Magnesia [Mg], Iron [Fe], and Sulphur [S].

Three others exist universally and generally, in insufficient quantities to give good crops, and plants require them in relatively large quantities. They are Phosphor [P], Nitrogen [N], and Potash [K]. These are the elements which are universally regarded as manures. In certain cases the magnesia and calcium associated with these manures have also given favourable results, which seems to prove that in these particular cases there was too little magnesia and calcium in the soil, and that therefore they also became manures. But these elements are present in many manures besides, without being counted as such themselves. The movement which has been attempted in the agricultural world to popularise the use of magnesium as manure can perhaps be considered as coming from an interested source, desirous of raising the price of certain manures by the value attributed to magnesium (Stasfurt salts of potash).

Lime applied separately ought to be regarded as an improvement, and it is for this purpose and to this end that it is especially applied to the soil. It has been noticed, however, that the simple application of lime has been sufficient to render certain soils fertile. It is apparently true that magnesia will constitute a manure in future time if the soil is not regularly reinforced.

Manure, then, is all matter applied to the soil for the purpose of augmenting the quantity of plant food utilisable by the crops. The necessity for artificial manures need no longer be discussed. It has been a recognised fact for so long, and to such an extent, that any one who does not employ them can only be regarded as retrogressive.

Fertile Land.

By fertile land we mean that which contains in a form relatively assimilable, and in addition to a certain quantity of humus, up to a thousand of the chief fertilising elements. One might say that Western Europe contains practically no fertile land. The crops raised there for many ages have taken the fertilising elements from the soil in ever increasing quantities, and they have not been restored completely by farmyard manure. Therefore it is necessary to import them.

Exportation.

A more or less important part of the crops produced on the farm does not return to the soil—thus a portion of the wheat, oats, barley, potatoes, etc., grown is sold as such. These cereals and roots contain nitrogen, phosphates, potash, and lime extracted from the soil by the plants. Therefore the total quantity of fertilising elements which these products contain are taken from the farm.

Hay and straw are also sold sometimes, and all this represents an exportation of fertilising matter. On dairy and breeding farms the crops obtained are consumed on the spot. But then they are exported in the animals sold—in the shape of meat, skins and blood, bones, or in the sale of milk—and, further, there is the loss in fertilising matter between the consumption of produce by the animal and its restoration in the form of manure. These losses which are considerable, as we shall see further on, especially in nitrogen and potash, are caused by exposure to air, by fermentation, by dilution, by rain water, and by the loss of urine. The loss of fertilising elements in the air and by drainage is considerable. Those in the drains are carried to the sea and irretrievably lost.

All these depletions, by sale and loss, going on practically for hundreds of years on some soils, have ended by impoverishing them to a point where the usual restitution is not sufficient to maintain their fertility, and sometimes even to the point of ruining the land.

Restitution.

It is necessary to give back to the soil those fertilising elements which the crops have taken from it, and of which there are not enough reserves in the soils, in the form of manure.

This is usually done by means of farmyard manure. But, even under the most favourable conditions of formation and preservation, farmyard manure contains and gives back far less than the total quantity of the elements which the crops have taken from the ground, and so the latter is incapable of maintaining its fertility. Besides, simple restitution, even when complete, is no longer sufficient for our progressive agriculture. We want to get very large crops very economically. To supply the deficit of the ordinary restitution, and to increase the productivity of the soil we must have recourse to

Importation.

This means that we must turn to outside fertilising matters to restore or retain the fertility of the soil, and to increase its capacity. This importation is usually made in two different ways :

1. By concentrated foods (cake, meal, etc.) which are given to the cattle.

2. By bought manures. This second way is preferable because it is more economical.

From the manurial point of view the first way is not advisable because the units of nutritive matter, which are the same as those of the manure, but in another form, are dearer than those in the manure. This means converting a product of higher value into one of lower value without counting the losses which arise in the process of transformation.

Improvements.

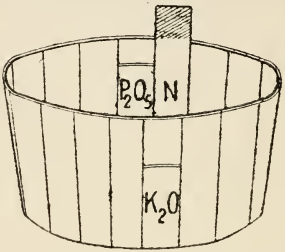
All modifications applied to the soil, whether physical, physiological or chemical, are classed as improvements, which, without being regarded as manures, help to ameliorate and correct the soil from an agricultural point of view. These improvements are practically as necessary as the manures.

Thus certain soils, poor in fertilising elements, have gradually lost their humus as well, because of an insufficient supply of farmyard manure. Cultural operations, aided by bacteriological influence, and natural oxydisation stimulated in most cases by the use of lime, have impoverished the soil in humus to such a degree that chemical manures alone cannot make it fertile. Humus is of great importance. Indeed, it is of such absolute necessity to the soil that it must be considered as seriously as manures. It does not constitute a manure in itself, but soil in which it is lacking is practically sterile, and it is chiefly in these soils that green manures are of the greatest service.

The Law of the Minimum.

The importation of manure is regulated by the Law of the Minimum. *In point of fact, the crops are proportionate—all conditions being equal—to the amount of manure that the soil contains in the* *least quantity.* For to obtain the whole of the effect of the given manure, the other manures must be present in the soil in the right proportions. If any one manure is lacking, the addition of other manures, no matter in what quantity, will be incapable of increasing the productivity.

Let us make this clear by means of an example.



Imagine any kind of crop. The liquid in the tub illustrated represents the crop. The tub full represents the capacity of the soil. The planks of the tub represent the manures. The planks are of different sizes, because different quantities of each manure are required ; but the height represents the proportions, which ought to be equal. The plank of nitrogen [N] is of the necessary height, but the planks of potash [K_2O] and phosphoric acid [P_2O_5] are too low, the plank of P_2O_5 coming higher than that of K_2O. The quantity of K_2O, represented by the size of the plank, is, however, larger than the quantity of P_2O_5 present and of nitrogen [N] necessary. The proportion of these elements, therefore, is not good.

Now, in order to increase the crop, it will be of no use to raise the nitrogen plank, or the height of the water in the tub, because the crop is regulated by the height of the plank of K_2O. But, raise the plank of K_2O and immediately the crop will be increased in proportion to that rise. Adding to the plank of nitrogen would not increase the crop at all. One would merely have spent money uselessly.

But from the moment that the plank of K_2O has passed the plank of P_2O_5, the increase of K_2O, as far as the level of the capacity of the soil will not further increase the crop, because the P_2O_5 is not in the requisite proportion. This plank also must be raised to the height of the capacity of the soil. It is at this stage that the best results can be expected under the given conditions. It is the strict application of the Law of the Minimum which enables us to put waste lands into cultivation economically.

Each kind of crop has different needs and demands different quantities of manure. Therefore, knowing the requirements of a crop and the elements which are lacking in the soil, one can easily determine the respective quantities of the various manures to use, and give them in the necessary quantities when the requisite proportions have been decided. But there is a limit to the

Possibilities of the Soil.

Manures cannot be applied indefinitely in the hope of getting a corresponding increase in crops. In spite of using good proportions, there would come a time when an increase of manure would not give a similar increase of production, and the practical limit is when the addition of manure ceases to give good extra value in the produce. In reality one would never push the practice as far as the point where the production did not do more than pay for the manures, though in theory it can sometimes be justified—say by the production of the most nourishment on a given site, thus making a larger head of stock possible.

It is often written and more often said that "basic slag or superphosphate" (of good quality, be it understood) "do not answer." Such a statement proves that the manure has not been given a sufficient trial, and, moreover, that the experimenter is not familiar with the use of chemical manures. One thing is certain. The soil lacks phosphoric acid: the exceptions to this rule are too rare to make one believe anything to the contrary. If basic slag and superphosphates do not respond, it means that they have not been given their proper complement—they cannot respond. They must be given in combination with potash or nitrogen, sometimes with both, and then they will answer. The Law of the Minimum must be satisfied.

The Selection of Manures.

It only remains to decide what manures must be used to bring their importation to the utmost limit of economic possibilities. There are in commerce such a quantity and variety of artificial and chemical manures, that there is some difficulty in choosing. They may be divided into—

Simple Manures and Compound Manures.

The simple manures contain only one fertilising element, the compound manures more than one. Among compound manures there are some which are naturally compound, that is which contain more than one fertilising element in the matter of which they are made; for example, guano, bones, etc., and others which are compounded mechanically, that is by mixing two or more manures, such as fish guano and leather waste; by mixing natural compound manures and simple manures (fish guano and sulphate of ammonia); by mixing simple manures, kainite, and basic slag, or by mixing simple or compound manures with neutral matter (sawdust or sand), for example.

Generally speaking, preference should be given to simple manures for the following reasons.

1st. The first and more important reason is that simple manures are generally, or one might say always, cheaper by the unit than compound manures. They can be obtained practically direct from their source, so that their purchase lies between the producer and the consumer only. There is no middle man, no handling and no useless transport.

2nd. They are easily used; only containing one fertilising element one can calculate exactly the quantity of each variety required. As much as is necessary of any determined element can be given independent of the quantities of other manures. With compound manures this is scarcely possible, because they will not contain the proportion of elements suitable to a given soil.

3rd. Different manures require to be used at different depths in the soil. For example, it is not good to plough or harrow in Chili nitrate, while slag or kainite generally require to be well incorporated with arable soil. Hence one can easily use simple manures at the depth which suits them best, whilst in using compound manures this is not possible. Being mixed, some will be too deep, and others not deep enough.

4th. Different manures need to be applied at different seasons. One would not use nitrate in November, because it would be irretrievably lost, though slag could very well be used on arable at this season without any such risk. Each manure has its corresponding time for application. With compound manures, in which of course all the elements are applied at once, sometimes one or more of them is not used at the time which suits it best.

5th. Simple manures used alone are not subject to the losses which arise as a result of certain mixtures in chemical manures, such as loss of ammonia [NH_3].

6th. Being simple and supplied straight from the source, they are less subject to adulteration.

Compound manures, again, are generally too dear. The reason why is not difficult to understand. Their price ordinarily includes—

1. The cost to the producer of each of the simple manures of which the mixture is compounded.

2. The cost of transport from the producer to the manufacturer of the mixture.

3. Handling and cost of storage here.

4. The cost of the making of the mixture.

5. Putting up into sacks and storing again.

6. Fresh cost of transport to the place where it is to be used.

7. General cost, trade charges, makers' profit ; and it is easy to understand that even with the most honest manufacturer, the price of the unit of fertilising matter will sensibly increase the cost and often not the value.

Besides, many compounds actually on the market enjoy an unmerited popularity, and fetch a price far beyond their real value simply as the effect of the law of supply and demand. Everybody knows them, everybody wants to have them. The output is limited, and the maker can easily demand a high price and still refuse orders. This shows that people buy by recommendation and habit, and not by knowledge of the subject. Manures ought always to be bought by the unit of fertilising material.

Many people still purchase by the ton, without even considering what that ton contains, or in any case without considering how much the units of fertilising material will come to. But it is not the ton of manure which is fertile, but the units of fertilising matter in it. When one pays good money one has a right to receive good manure ; and the purchaser should always compare the price of units of fertilising matter so as to buy that which under a similar form will cost the least.

The best way of ascertaining what one is buying is by analysing the manure, and to bring analysis into general use should be the work of an Agricultural Union. This society should occupy itself with buying various artificial manures for its members, itself controlling the value of the manures.

In the mean time each farmer could calculate for himself the price per unit that should be asked, and could have the analysis made for his guidance in a deal of any great importance.

Here is a means of calculating.

In the Guide to Experiments for 1915 for the County of Northumberland we find that the superphosphate employed contains soluble phosphoric acid equal to 26 per cent. phosphate of lime, and that it was worth £2 17*s*. per ton. Phosphoric acid, then, corresponds to 26 units of phosphate of lime. Therefore the unit per ton will come to £2 17*s*. ÷ 26 = 2*s*. 2*d*. approx.

Now, taking this price of 2*s*. 2*d*. per unit to the ton as a standard price, and supposing a super content of soluble phosphoric acid equal to 40 per cent. phosphate of lime, one would pay 40 units × 2*s*. 2*d*. = £4 6*s*. 8*d*. to the ton, and would gain an advantage in using this, as we shall see when we come to consider the cost of transport. Chloride of potash [KCl] costs £9 per ton, and contains about 50 per cent. potash (K_2O), so that the unit of potash costs here 3*s*. 7*d*. per ton. If we take kainite, supposing it contains, for example, 13 per cent. of K_2O to replace the KCl, we should pay 3*s*. 7*d*. × 13 = £2 7*s*. per ton, and we should pay even a little too much.

The same ought to be paid, for the unit of fertilising matter in compound manures as in simple. For each unit of fertilising matter, the standard price corresponding, should be calculated, and the buyer should determine for himself the value of the manure in comparison with the merchant's price. These are problems in the solving of which the farmer ought to be very skilled, and their understanding would in itself be of great service to him annually.

We have spoken of the very bad habit of using manure by the hundredweight or ton. For the most part such manuring indicates nothing. Here is an example. There are basic slags which contain 21 to 25 per cent. Ph. Ac.; there are others which contain 40 to 41 per cent. and even more. It is obviously impossible to make comparison between fields on which the first is employed and those where one has used the second. Supposing, for example, that we employ 18 to 28 ton units of Ph. Ac. per acre, or 4 ton units of Potash to the acre, etc. We have so many acres to manure, and we must look for a manure which will give us these quantities at the most advantageous price.

The Richest Manures.

On principle one would buy the richest manures—that is those containing the most units of fertilising matter to the same weight. When at the place of origin the price of the unit of the same manure is the same, the manure which costs most is the cheapest to buy. This is obvious, because a manure containing only 15 per cent. fertilising matter will cost in transport, sacks, time lost in spreading just as much as that which contains 30 per cent. fertilising matter, and in the end it is the units of fertilising matter which count.

These additional costs are spread in the first case over 15 units, and in the second, over 30. The difference is sometimes so great that it is often even better to take muriate of potash (KCl) in preference to kainite, though the unit of Potash costs decidedly more in the former than in the latter, because of the very important additional expenses ; but these in the kainite are based on 12 to 13 units, while in the KCl on 50 units of Potash [K_2O].

The comparative richness of the manure to be employed must therefore always be considered, and the price of the unit ought to be calculated when distributed on the fields. In this way all the costs are included.

Among manures some are of rapid action, others slow. Preference ought to be given, as a rule, to the rapid, because they will repay outlay more quickly. Very often manure merchants advance arguments in favour of those of their wares of which the action will still be felt in the following year, or even for many succeeding years. But supposing—which is not always the case—that all the fertilising elements will be assimilated after a greater or less number of years, the argument is not worth anything. Each particle of manure can only be absorbed once by the plants, and it can only pay when it is absorbed. Therefore the more quickly it is absorbed the more quickly will it pay. To equalise the price of the unit it is a mistake to buy now a manure which will not repay the outlay in three years or more. Generally it is preferable to use manures of such action that they will reimburse their cost the same year that they are applied, and to give each year the quantities of manure required.

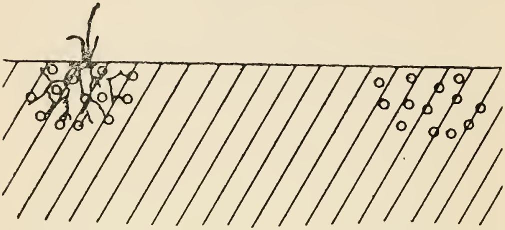
Besides, in using manure of slow action, how many units will the plants find at their disposal during the first year and during each of the succeeding years? There is no room in modern agriculture for all this waiting and all this uncertainty. Manures of very slow action ought rather to be regarded as *improvers* and not as manures, and then should be bought at a very low price.

Yet another manure is one having a more or less progressive action, finishing in a year or thereabouts. The action of these manures depends on their assimilability, which again depends on many factors. There are two especially, of very great importance, first their *solubility*, and second their *fineness*. The nature of the soil and the species of vegetation also play an influential part.

Assimilability.

The most important point about manures is their assimilability. A non-assimilable matter is not a manure, although it may contain nutritive elements. Certain mineral phosphates are only assimilable with difficulty, or not assimilable at all in ordinary soils, so that they often do not possess any fertilising value. This is why their introduction into more assimilable fertilising matter really constitutes an adulteration of the product. Other manures are more assimilable though not entirely so, and not immediately. These are the manures of more or less slow action. Others, again, are rapidly and immediately assimilable and these are the best manures. They are those which most rapidly repay outlay, and their employment is the most advisable.

1. Mineral Tricalcic Phosphates—Coarse and Inassimilable.



A. While the crop is growing. *A poor crop.*

B. After the crop. *It remains unchanged.*

Assimilability is generally in proportion to the solubility.

Solubility.

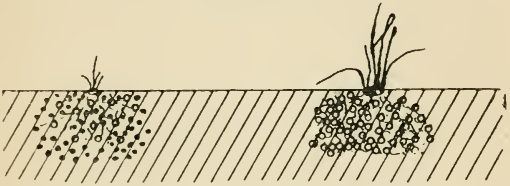
Manures which are soluble in water are, as a rule, regarded as very assimilable. A good example is the Ph. Ac. in superphosphates.

Then come the manures soluble in weak acids, the chief of which is basic slag, soluble in 2 per cent. of alkaline citrate. These are justly regarded as soluble manures, although less so than the superphosphates ; while the phosphates soluble in strong acids are justly considered as only slightly assimilable.

Those particularly which are only soluble in strong acids have, however, different degrees of assimilability for the same chemical form. This difference may arise from the more or less violent way in which they have been formed, from the very

2. Phosphoric Acid in Basic Slag. Different Solubility, same Fineness.

During the crop.

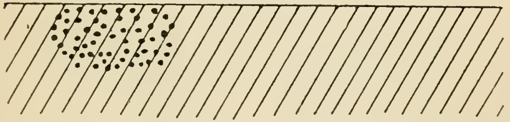


Total phosphoric acid.
Poor crop.

Phosphoric acid soluble in weak acids.
Good crop.

● = *Insoluble.* o = *Soluble. The general argument is that the total phosphoric acid will act next year—perhaps. The likelihood is that it will not—perhaps never.*

After the crop.



The insoluble phosphoric acid remains in the soil like this.

The soluble has been assimilated by the plants.

Since phosphoric acid is not bought to lie idle in the soil, it follows that total *phosphoric acid should never be bought.*

high temperature which accompanied their formation, from their more or less recent formation, or from the physical form in which they are presented, and from other causes. Thus tricalcic phosphate is usually slightly assimilable; it is very little so in the ordinary mineral phosphates, but more so in the Tunisian phosphates, and in steamed bone flour.

The most soluble being the most assimilable, they are generally taken as type manures and the value of units of other manures of the same nature established in comparison with them.

Fineness.

The fineness to which manures are reduced has a much greater importance than is generally attached to it. Some substances are not really manures only because they are presented in too large particles. A striking example is that supplied by Mr. Hendrick in morsels of bone coming from bone meal which, when dug up after lying in the earth for twenty years, were found to be still nearly as rich as the richest bone meals of commerce. Here is their analysis:

Humidity	4·75	per cent.
Organic matter [1]	26·75	,,
Tricalcic phosphate ...	52·10	,,
Carbonate of lime ...	14·40	,,
Silicaceous matter ...	1·60	,,
Indefinite	0·40	,,
	100·00	

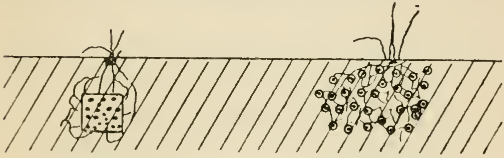
This shows that in twenty years these bones had given nothing to the plants.

[1] Containing N 3·53, equal to ammonia 4·29.

Some manures are of slow action because they are too coarsely ground. This is the case, among

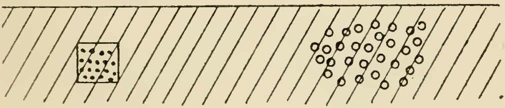
3. Different Fineness: same Solubility.

Same kind of manure and same quality under a different form. During crop.



Coarse manure. *Feeble growth.* Very fine manure. *Vigorous growth.*

The square and the small circles show the manure particles and the black points inside the circles and the square the fertilising matter contained in them.



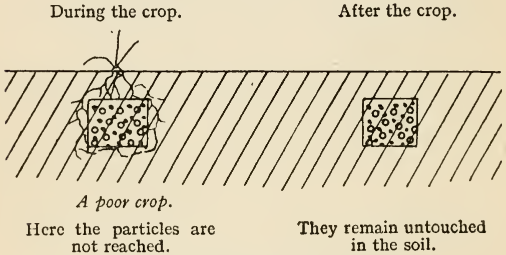
Only a few particles of the manure have been reached and absorbed by the roots. Here all the manurial constituents have been absorbed.

others, with certain slags, while the same slags finely ground are of comparatively rapid action.

That is why in sowing slag care must be taken to prevent its being blown away by the wind by mixing it with other manures to which it can adhere, or with some neutral matter (sand or sawdust), because the finest particles, that is those which would fly the furthest, are the best. Sometimes one hears it said, "It doesn't matter, they won't fly further than my land so they won't be lost." That may be, but it is a poor argument, for in any case they will fall where it was not intended to throw them, and will come to earth from 100 to 150 yards or even further from the place for which they were intended.

Fine manures, other things being equal, are always to be preferred to coarse manures. Indeed

4. Total Phosphoric Acid in Coarse Slags.



The two squares indicate large particles.
o = Soluble phosphoric acid. ● = Insoluble.

coarse manures should never be used, and if this rule were observed they would soon disappear from the market. It is only because of the ignorance of the public that badly ground manures find a market. If people really knew how slow they were they would scarcely employ them. In fact, if buyers were not so ingenuous as to cling to the richness of the units of these manures and persuade themselves that perhaps they may be more rapidly assimilable than they seem, they would not buy them. It would be more practical to convince ourselves that they are no more useful to us than to anybody else, and leave them alone. The worst of all is that things are often sold as manures which are obviously coarse, inassimilable, or nearly inassimilable products, and which are not worth much more as a matter of fact than the simply neutral materials which are sometimes sold as manure.

The nature of the soil influences the assimilability of certain manures. For example, acid soils will facilitate the assimilation of tricalcic phosphates, whereas in the same soils sulphate of ammonia will be less active.

Certain plants thrive best on certain manures, which are therefore of a greater assimilability for those plants. Oats, for example, utilise nitrates most easily and most rapidly. Some manures become more assimilable according to the treatment they receive. Thus bones are more assimilable after fermentation, and tricalcic phosphates after treatment with sulphuric acid ; but by these processes the manures suffer chemical changes and are no longer entirely the same.

Artificial chemical manures are generally concentrated. That is to say they contain in a little weight a great quantity of fertilising matter. Thus when one uses a hundredweight of superphosphate, one has given to the soil much more phosphoric acid than by using a cartload of farmyard manure. These manures are very easily handled, require little time for their distribution, are easily incorporated with the soil, and generally very little subject to loss. The units of fertilising matter as a rule come out at a reasonable price, and—since they cost, relatively speaking, very little for transport—can be employed everywhere. They are, besides, obtainable in very large quantities.

But great as has been the concentration of these manures, and great as is their value, greater still have been the incentives for their adulteration, by the introduction of neutral matter of no utility in agriculture in the place of fertilising matter. This substitution has been pushed to its furthest perhaps in slags, where sometimes it has been complete, simple products of colliery waste, finely pulverised, having been sold as slags when they did not contain a particle of genuine fertilising material. This is the

Adulteration of Manures.

Commercial manures, unfortunately, are often the object of adulteration. There may be a Fertilisers and Feeding Stuffs Act, but in the actual state of things it would be puerile to pretend that this is sufficient to protect the agriculturalist against the enterprises of unscrupulous manufacturers. Besides, the farmers themselves, by their neglect of making analyses, encourage, or at least do nothing to hinder, these dishonest practices. They themselves are, however, the only victims.

This state of things shows how great would be the utility of a Union of Agriculturists, one branch of whose activity would be the control of the quality of the manures bought by its members. Working in a co-operative manner there can be no doubt that the services such a union could render would be enormous, and they would also benefit the small holders who are naturally the least efficiently protected. In the meantime farmers would do well to club together and buy in common, each bearing a proportional part of the cost of analysis.

Generally speaking, manures in the form of salts are the least subject to adulteration, and for the others, buying first hand diminishes the risk of being deceived.

Compound and organic manures are much adulterated, although phosphates do not escape altogether. All sorts of things are used as adulterants, and nearly every manure has its own. The chief material of each is always of little value; it is often quite useless, and in some cases it is a substance known to be harmful to vegetation.

The most commonly employed is sand. It appears that there are actually firms selling sand in four grades of fineness intended for adulterating purposes. Then come ground glass, sawdust, peat, ordinary earth, very often cinders, waste from charcoal furnaces, charcoal dust, plaster, mineral phosphates, salts from skin preserving, common salt, the calcined residue of distilleries, sometimes kainite, etc.

The kainite employed in the adulteration of Chili nitrates sometimes has disastrous consequences because of its chloride of magnesia [$MgCl_2$]. The [$MgCl_2$] which the kainite contains eats the plants, and is even capable of killing those to which it is applied as a nitrate dressing in the month of May. It is an abominable fraud.

The adulteration of animal charcoal with the calcined residue from distilleries, containing cyanures, is also harmful to vegetation.

Some sulphates of ammonia and gas limes also contain cyanures without being adulterated.

As it is not advisable or reasonable for the farmer to experiment at his own risk, it is necessary to have recourse to analysis wherever possible.

The farmer should also be familiar with the way to set to work in taking a sample, etc., and ought, besides, to know the law which protects him against adulteration. That is why at the end of this brochure we have included a copy of the Law on Fertilisers and Feeding Stuffs.

The use of chemical manures enables us to obtain much better crops. Where formerly manures were altogether insufficient in comparison to the work of reclaiming the land, or where those obtained were incapable of supporting the farm stock, however reduced, now, thanks to artificials, we get magnificent results, and moreover these results are economically obtained. For very often because of the lack of a single fertilising element in the soil, formerly the whole crop would be reduced to a minimum, whereas in many cases it only required the addition of Ph. Ac., for example, to increase the capacity of the soil to an incredible extent. Not only have the crops been increased in quantity and that economically, but also the intrinsic quality of the results is much improved. This fact is not perhaps sufficiently grasped by agriculturists.

Remembering what they have accomplished in the matter of breeding, how greatly they have improved the breeds which they have raised, and calling to mind that a great part of this improvement has been obtained by good feeding, it is very obvious that they should persevere in the improvement of the quality of their crops. In improving the methods of cultivation and providing the soil with a concentrated manure just as they give cattle concentrated nutriment, they will increase to a great extent the quality of their products. These products in their turn will be more nutritious for the cattle, making each beast of better quality, and thus the improvement in cultivation will have a direct effect on the stock.

The use of artificial manure will promote the cultivation of enormous tracts of land till now unreclaimed. It will suffice merely to use the manures at our disposal, and, if they are used judiciously, the sterile land will disappear and give place to cultivation which will graze a much larger head of cattle. Sometimes it is said that certain chemical manures, nitrate for example, impoverish the soil. This is absolutely wrong. It is, on the contrary, the farmer who does so by not returning to the soil what his crops have taken out of it. This is the way nitrate works. The soil contained a reserve of Potash and Ph. Ac. or had received of these two manures in restitution more than the law of minimum had permitted the crops to take out, because of a lack of nitrogen. Apply nitrogen to this land and magnificent crops will result, but continue to apply nitrogen and they will get poorer and poorer if Potash and Ph. Ac. are not restored to the soil in sufficient quantities. Obviously the fault is that the farmer has not returned to the soil a sufficient proportion of the nutritive value which he has taken from it.

But if by means of manure he replaces the matter which the crops have taken out in excess will he still have a margin of profit? Yes. Because the reinforcements of manure represent a great increase of value in the crops, and the nitrogen, Potash and Ph. Ac. as aliments have a much greater value per unit than as manure. It is just as economical an operation as the transformation of foodstuffs into living stock, about which the farmer has no doubt whatever.

Acids.—Acids are chemical compounds, having the property when brought in contact with bases, and associating with them, of forming salts, at the same time losing their acidity. An acid soil, therefore, is one in which acid predominates. In other words it is a *sour* soil.

Base, or alkali.—Any substance which has the property of neutralising acids by forming a salt. By the addition of a base to an acid the quality of the acid is destroyed. A basic soil or alkaline is therefore a soil in which bases predominate.

Neutral.—This is the intermediate point between the acid and the basic states, when the action of the acids and the bases counterbalance each other.

The Functions of Manures.

In the distribution of *rôles* attributed to these manures, nitrogen forces and makes the grass grow, and also increases the volume of vegetable matter, and prolongs the period of vegetation. When assimilable nitrogen is applied in the springtime the plants immediately become green and begin to grow. But subsequent development is slow; the seed is formed later in the ear, and maturity retarded.

The luxuriant vegetation caused by the application of assimilable nitrogen weakens the stalks of the plants, renders them less resistant, and makes the corn more liable to "lay." That is why we have recourse to potash which will give solidity and body to the plants, and enable them better to resist the elements. Ph. Ac. also acts to the same purpose.

On the other hand, the addition of phosphoric acid hastens the formation of grain and ensures early maturity. The action of these three manures therefore counterbalance and complete each other so that there will be an abundant production of strong growth of good quality, ripening in good time. This last point ought to be taken into serious consideration in regions where summer is short and crops occasionally fail to ripen.

CHAPTER III

Nitrogenous Manures

Nitrogenous Manures in General.

The nitrogenous manures are the most important of all, and they are the dearest. They chiefly assist the formation of the albuminous matter in plants which constitutes the most valuable food. When the law of the minimum is satisfied they also assist very largely in increasing the bulk of the crops. Soils which are deficient in assimilable nitrogenous matters are incapable of producing sufficient crops. And where these latter are luxuriant the fact must be attributed to the abundance of nitrogenous manure, the presence of which is generally revealed by the dark or bluish-green tint of the leaves.

One important point to be considered, since the unit of nitrogen is so dear, ought to be only to choose manures in which the nitrogen is in easily assimilable form.

Fortunately for farmers there are on the market a large and ever growing number of nitrogenous products of a type suitable to supply the insufficiency in the soil.

But as the unit of nitrogen is so dear it will be necessary to buy it in a really assimilable form and to use it only in such a way that there will be no fear of loss in the drains.

All these products should be bought on analysis or origin. Often the nitrogen in organic compound manures will be questionable because it may be present in a form either slowly or partially assimilable or even almost entirely inassimilable.

Care should be taken, however, not to abuse the use of nitrogenous manures, specially on cereals, because in this case it will cause a tendency to lay the corn. It is also necessary to take care not to mix nitrogenous manures which are susceptible to loss, with others which will promote it, because such losses are at times very considerable.

Nitrate of Soda.

Nitrate of soda or Chili saltpetre comes from Chili, as its name indicates. It is still the most abundant source of nitrogen for agricultural purposes among the commercial manures. About 2,000,000 tons are exported per annum, but in spite of that there is still enough to last nearly another hundred years. It is extracted from beds of salts formed on a high plateau at an elevation of nearly 3300 feet, situated between the Andes and the coastal range on the Pacific border, in a hot climate, where it rains on an average only about once in six or seven years. Iquique and Antofagasta are the chief ports of exportation.

In this hot, rainless climate, the nitrate is formed by nitrification of the organic matter which is formed in the soil of the higher part of the plain. The rain water rushing down from the mountains has carried down the nitrate to the lowest level of the plain at the foot of the coast range. The water has evaporated and the beds of salts are left. In this way many superimposed beds of salt have been formed, covered by beds of sand brought down at the same time or deposited by the wind ; and so it is seen that sometimes the salt beds are separated by beds of sand. Generally the beds of salt are about a yard in thickness, but sometimes they are six or seven yards through and even more. To obtain the salt these deposits are blown up by mines. It is called *caliche*.

The deposits do not consist entirely of nitrate of soda. The best beds contain from 40 to 50 per cent. of nitrate, those of the third quality, which are the last to be worked, from 17 to 30 per cent. They always contain sea salt, often nitrate of potash, sometimes sulphate of soda, lime, and magnesia, and some impurities.

Profiting by the indications of differing solubility of the sea salt and the nitrate of soda the workers treat the *caliche* with boiling water, and the nitrate of soda crystallises in cooling, while the sea salt remains in solution. This water is again treated to extract the iodine, and the day that this was achieved the price of iodine went down by half.

The nitrate is dried in the sun and put into sacks. This nitrate is coarse and has a dirty appearance, containing a little sea salt, sulphate of soda or magnesia, water, and a few impurities, and about 95 per cent. nitrate of soda. It ought to contain about 15·5 of nitrogen, should not contain less than 15 per cent. and cannot contain more than 16 per cent.

It is very deliquescent, easily absorbing atmospheric moisture and very easily dissolving, so that in the vessels which carry it they have frequently to pump the nitrate water out of the holds. The sacks also absorb a considerable quantity of nitrate, often as much a kilogramme (2 lbs. 5 ozs.). These sacks should therefore always be washed and the water distributed on the land. It is imprudent to accumulate any number of empty, damp but unwashed nitrate sacks, because they may cause spontaneous combustion.

Nitrate should be kept in a dry place. If clods are formed in the mass they must be carefully broken, so that the manure may be spread very regularly. This is a point worthy of mention. All the care possible is not too much to take in the spreading of chemical manures, because, in spite of everything, the fertilising matters will never be so regularly distributed as in carelessly spread farmyard manure.

Nitrate is always given as a top dressing. The first light rain is enough to dissolve it and distribute it in the soil. In spring time the heavy rains may wash it away altogether. That is why it must not be given too early. In the summer, however, practically no loss need be feared. It should never be given in the winter, and when applied before winter it must be used in small quantities only, and early enough for the crops to use it up completely. Unless this rule is observed the unused residue will be entirely lost.

Do not mix it with superphosphates, because if the latter are very acid there will be a risk of creating nitrous vapours which cause a loss of nitrogen. Often farmers say that, after spreading nitrate in a dry season, the nitrate attracts to itself the moisture in the soil, forming round the grains of nitrate an aureole saturated with a solution of nitrate which destroys the plants with which it comes in contact, and, on the other hand, forms a zone of abnormally dry soil in which the plants suffer greatly from drought. Then do not spread nitrate when the soil is not sufficiently moist or when rain is not expected.

The soil has no power to retain the nitrates and the superfluous water drains them away. That is why it is always advisable not to give large doses and always to make two applications if possible. In summer time, however, the evaporation of the water of the soil will always be sufficient to prevent this wasting. A well-known action of nitrate is that it keeps a freshly turned soil damp, and makes a dry soil cool, to such an extent that in dry years the use of nitrate at the right season will have a very beneficial effect, the nitrate rendering the soil less permeable and to some extent preventing evaporation.

Nitrate of soda being the most active and rapid of all nitrogenous manures is quickly utilised by the plants, and in the spring on wheat crops discoloured by an excess of moisture during the winter the results become noticeable within two or three days in a fresh verdant colour. The addition of nitrate, which is often at a minimum in the soil, enables the farmer ordinarily to obtain a notable increase of crops; but the results fall off rapidly after a few years unless care is taken to use phosphates, and—nearly always—potash, in conjunction with the nitrate. Contrary to what one often hears, nitrate does not exhaust the soil, but in raising the dose of nitrate to the level demanded by the Law of the Minimum, the existing phosphoric acid and potash are enabled to augment the yield to an extent which they could not otherwise attain. Nitrate, then, does not exhaust the soil, but evidently requires to be used in conjunction with other fertilising elements which, thanks to the nitrate, the plants are able to absorb to the utmost, and so give a more abundant crop. The farmer should clearly understand the fact that manures never exhaust the soil, and as nitrate of soda is a manure therefore it is not exhaustive in its action. As we saw in the chapter on the necessity of manures, manure is all matter applied to the soil for the purpose of augmenting the quantity of plant food utilisable by the plants, and on the other hand we learned from the Law of the Minimum that the crops are proportionate—all conditions being equal—to the amount of manure that the soil contains in the least quantity; referring further on to exportation, restitution and importation. But in using nitrate of soda, which constitutes a single manure containing nitrogen only, it is necessary in order to obtain any result that phosphoric acid and potash should be present in the soil in proportion to the quantity of nitrogen. This proves that the former manuring was not right, that the soil was starved for want of nitrogen, that it was nitrogen hungry because the former manuring did not supply the necessary quantity which would have enabled the crops to take up the available phosphoric acid and potash.

The practice of giving nitrate of soda ($NaNO_3$) alone is, however, not to be recommended. The action of nitrate is generally very remarkable. It is an excellent manure of which the unit serves as a type for the price of the unit of nitrogen in all manures. Properly used, in soil which it suits, no other nitrogenous manure can equal it. It can be used in any soil, but it is particularly suitable to those only slightly lacking in lime, because the sulphate of ammonia will cause a further loss of lime. It is very good on strong soils; in light permeable soils it must be given in two applications so as to prevent waste.

It should not be employed on leguminous crops, but it suits everything else, especially wheat, grass, permanent pastures, mangolds, turnips, carrots and cabbages. On potatoes, however, sulphate of ammonia is to be preferred. On mangolds long practice has shown the advantage of giving the first half of the manure a little while after planting out and the second at the time of cleaning. In vegetable culture it is very valuable and is given at frequent intervals in strong applications.

Nitrate of soda is often adulterated with common salt, salts of potash and crystalline sand. That is why it must always be bought on the vendor's guarantee. To see if the sacks have been opened cut the string, which should be dirty on the outside and clean on the inside; moreover the mark of the cord should be clean on the sack. If it is not it has been opened. The sacks ought, also, to be thè original ones. Adulteration by means of kainitc, which, applied as a top dressing is corrosive, is abominable, since it may cause the loss of a crop, or at least seriously affect the results.

The action of nitrate of soda is only felt during one season, so that it must be renewed annually.

Sulphate of Ammonia.

Sulphate of ammonia, $(NH_3)_2H_2SO_4$, is a combination of ammonia (HN_3) and sulphuric acid (H_2SO_4). The sulphate of ammonia of commerce is never pure, but it ought not to contain more than 5 per cent. of impurities. It should then contain 20·2 per cent. nitrogen and 24·5 per cent. ammonia. The colour varies according to the impurities it contains, somé of which may constitute dangerous poisons to plant life. For example, very white sulphate of ammonia may contain free sulphuric acid. This sulphate will burn the hands and clothes of any one sowing it, rust the manure spreader, and corrode the plants it touches. Red or black sulphate often contains sulphocyanure of ammonia, of which Voelker has proved that less than 10 lbs. per acre is sufficient to destroy the entire crop, and there are sulphates which contain more than a cwt. Sulpho-cyanide of ammonia can easily be recognised, however, because in heating with lime it gives off a strong smell of ammonia.

Sulphate of ammonia is frequently adulterated with sand or common salt, and sometimes with sulphate of soda, but the fraud can be detected by throwing some of the sulphate on to a white hot shovel. If any residue is left the sulphate has been adulterated.

Sulphate of ammonia is principally obtained in the making of coal gas. By the distillation of coal, nitrogen is converted into ammonia, which is retained in the water used in the first purification of the gas. This water is mixed with sulphuric acid and sulphate is obtained. It is largely produced and used in England, Lawes and Gilbert being quoted amongst the best authorities on its use. For a long time it was believed that the ammonia ought to be nitrified to make it assimilable for plants, but it has been proved by Muntz and Bréal that cereals can assimilate it in a natural state. The process is generally as follows. When the conditions for nitrification are fulfilled the sulphate of ammonia reacts on the carbonate of lime and obtains from it carbonate of ammonia and sulphate of lime—which latter is lost in the drains. So that the prompt and constant use of lime after sulphate of ammonia is necessary. The carbonate of ammonia is then decomposed by the zoolites of the clay or the calcaire of the humates which fix the ammonia and free the sodium or calcium. Afterwards the microbe of nitrification turns the ammonia first into nitrite and then into nitrate of lime by oxidisation. For the oxidisation to act easily the soil must be well aerated, and also have some degree of warmth. It cannot take place in a cold soil. So that during the winter neither nitrification nor loss of nitrogen by means of sulphate of ammonia takes place.

Sulphate of ammonia must therefore be used on calcareous soils, or lime must be applied afterwards. It is not a manure of immediate action, like nitrate. It ought to undergo the process of transformation just described if used before the winter, but it has the great advantage of not wasting during the winter. It can therefore be applied to wheat before winter, when it will push it on. It will be better to give nitrate in the early spring to hasten the beginning of growth, but in the course of the summer sulphate is excellent by way of supplying the full complement of nitrate. Sulphate is preferable for malting barley and potatoes. Care must be taken not to mix it with basic slag and even more so with pure lime, because the loss of nitrogen caused by the action of the lime will be considerable. It can be used at the same time as slag or lime, but *separately*. Nitrogen corresponds to ammonia in the proportion of 1 to 1·215.

Cyanamide, Lime Nitrogen, Calcium Cyanamide, Nitrolim.

This is the name given to a valuable manure put on the market a few years ago. The nitrogen it contains is drawn from the air, and therefore constitutes an inexhaustible supply for agricultural purposes. It is a heavy, blackish substance, resembling granular gunpowder, but having a characteristic smell like acetylene. It is a nitrogenous product manufactured by the Frank and Caro process, by passing a current of air, deprived of its oxygen by red-hot copper filings, under pressure into a mixture of lime and coal brought to white heat in an electric oven. Carbure of calcium can also be used instead of coal and lime.

The cyanamide of calcium ($CaCN_2$) generally contains from 14 to 21 of nitrogen, so that it may be richer than nitrate of soda and almost as rich as sulphate of ammonia, but often it is equalised for market purposes with the contents of nitrate of soda, say 15·5 per cent.; moreover it contains 20 per cent. of combined and 40 per cent. of hydrated lime.

To protect it from the air it is supplied in sacks lined with paper, otherwise it would absorb the moisture and swell, increasing in weight and losing ammonia. Since it is in granular form it can be handled freely, and may be applied with the distributor. It must be harrowed in immediately to prevent any loss of nitrogen. For this reason it cannot be used as a top dressing. It must also be worked in some time before sowing because it might act unfavourably on the crop when, on account of the action of acids, it liberates its dicyanamide.

Its reaction is not rapid because the nitrogen has to pass through the ammoniacal state before it becomes transformed into nitrate, but it is a good manure, usually giving results comparable to those of sulphate of ammonia, sometimes better—thanks, no doubt, to the presence of lime. In peaty soils it has not given good results. Its value may be estimated as about that of sulphate of ammonia and its use is certainly to be recommended.

For the English market it is made in Sweden and Norway by an English company. It is produced also by a German company, and is used in the manufacture of gunpowder.

Nitrate of Lime.

Nitrate of lime, like lime nitrogen, is a valuable manufactured manure in which the nitrogen is also taken from the air. The manufacture of nitrate of lime is based on the principle that the oxygen and the nitrogen in the air combine under the influence of an electric flame. This fact explains why thundery years are generally fertile. The lightning, which is only an electric flame, produces in the air—which is charged with mists—nitrous and nitric acids which the rain washes down into the earth to form nitrates. Here is the process:— $N + O = NO$, oxide of nitrogen; $NO + O = NO_2$, bioxide of nitrogen; $2NO_2 + H_2O = HNO_3 + HNO_2$, nitric and nitreous acid. Birkeland and Eyde, two Norwegian savants, discovered these facts, and a factory at Nottoden in Norway produces considerable quantities. Nitric acid is produced by means of an electric spark from the air and dissolved in water, carbonate of lime being added to the solution. This is heated to saturation point and solidifies in cooling.

One essential condition of the manufacture is the command of a cheap electric current. The nitrate of lime thus obtained is in small, hard crystals, or reduced to powder containing about 13 per cent. of nitrogen which is soluble in water and very deliquescent. It must therefore be kept in a very dry place. It is packed in wooden casks lined with paper which serves to keep out atmospheric moisture.

It contains about 12 to 13 per cent. of nitrogen.

Nitrogenous Manures

It is an excellent manure, in which the nitrogen is directly assimilable and can be applied as a top dressing, like nitrate of soda, when it has a more rapid action than lime nitrogen. It has given satisfactory results in comparison with other nitrogenous manures (nitrate of soda and sulphate of ammonia). It is good for general use and better than nitrate on soils poor in lime; where, if applied at a favourable time, sufficiently rainy or damp, it improves the permeability. In a dry season nitrate of soda will have the advantage because it has just the opposite effect.

Nitrate of lime absorbs the moisture of the air. To avoid this it is put up in wooden barrels lined with paper, or water-tight drums. It melts if not properly stored, and so losses occur. Nitrate of lime generally contains a small quantity of nitride of lime, which, however, is readily transformed into nitrate.

When available, it might be recommended as manure.

CHAPTER IV

Phosphates in General

Of all the chemical manures to which we have recourse we find the greatest variety is derived from phosphates. There is a great diversity of matter, distributed practically all over the surface of the globe, which can furnish them. Mineral layers, more or less important and under different forms, are found in the greater part of Europe ; America possesses them in large quantities, and Africa supplies them also. After mineral products come phospho-guanos which exist in many foreign countries.

Then there are phosphates of bones of many kinds, guano of fish bones, and lastly slags.

The sources of phosphates therefore are obviously plentiful ; so much so, and in such diverse qualities, that it is not astonishing that sometimes one confuses them, and that it seems difficult to distinguish their value as fertilising materials in the great number of preparations that are recommended. Each producer preaches his own and finds it the best.

It should be said, however, that many of these phosphates cannot be regarded as manures in many soils, and it is absolutely necessary, therefore, that the farmer should be able to judge for himself the real value of the material that is offered for sale; and that, having made up his mind, he should compare the net cost of the unit of the various qualities of phosphates which he wishes to use.

It is as well that phosphates are plentiful, since they are in such great demand. Arable soil is the least rich in them generally, and the quantity is decreasing continually. The grain which is sold contains proportionately to the contents of the soil many more phosphates than any other agricultural produce, and the cattle, which end by being sold, also contain great quantities in their bones.

This explains the necessity for using large quantities of phosphate manures, and when applied in assimilable forms too large applications can rarely be given. For not only are phosphates like other manures, necessary to increase the produce, but also they improve its quality. And here is another very important advantage that we gain: by forcing fructification, they hasten maturity and so ensure earlier crops. Also in regions where summer is short and the ground very humiferous, where lime has to be used, phosphates are absolutely necessary to hasten maturity, which very often is late, and sometimes never comes at all.

In some very acid peaty soils the acidity should be utilised to solubilise tricalcic phosphates, either mineral or bone.

It is necessary therefore to consider separately all the substances which contain phosphates.

It is well to remember that phosphoric acid corresponds to 2·18 of tribasic phosphate.

Mineral Phosphates.

Mineral phosphates or phosphorites are found in many places all over the surface of the globe—in France, Belgium, Germany, Spain, Russia, England, America, and Africa. In England they are chiefly encountered in the form of phosphatic chalk at Taplow in Buckinghamshire, or in accumulations surrounding fossils in the Cambridge greensand, and in Bedfordshire in the same form. Deposits of coproliths, which we shall presently describe, are found in the lias, and also in the black phosphorites of North Wales.

The phosphoric acid is present in a form of insoluble tribasic phosphate of lime [$Ca_3(PO_4)_2$], associated with various impurities, such as carbonate of lime [$CaCO_3$], sulphate of lime [$CaSO_4$], magnesia [MgO], iron, aluminium, etc.

Mineral phosphates, especially the rich phosphates of Florida and of North Africa, are employed chiefly in the manufacture of superphosphates. Transformed into superphosphate they are extremely valuable and have been and continue to be of signal services to agriculture.

On account of the results of lucky trials, made under favourable circumstances, they have been used, ground more or less finely, without undergoing any process of transformation. Needless to say the results in general agriculture have often been contradictory and often negative, but in every case their value eventually has been in proportion to their fineness. Finely ground they may be used in very acid soil, but in neutral soil they will give no appreciable results—sometimes no results at all; so that some soils naturally rich in mineral phosphates will still respond to soluble phosphates. Simply ground they are still frequently used for the adulteration of other manures, principally compound manures, also guano, superphosphates, and basic slag, and in this way they have done bad service.

Good samples of mineral phosphates should contain from 50 to 75 per cent. tribasic phosphate, which corresponds to 23 to 34 per cent. phosphoric anhydride, P_2O_5 (anhydric phosphoric acid).

Assimilable Phosphates.

Phosphates to be assimilable, ought to be soluble in water, as is the case with superphosphates, or soluble in weak acids—as is the case with reverted superphosphate and basic slag, or capable of being rendered soluble in the soil, as may occur with tricalcic phosphates.

Trials which have given contradictory results have been made on the strength of comparative experiments, offering solutions of a problem which has not been discussed in the right light: for example, a trial in acid earth by means of superphosphate and tricalcic phosphate.

Generally speaking, by using superphosphate in neutral soil and in alkaline soil needing no lime, or even in a light acid soil, when we want to obtain a rapid action, good results will be obtained. Mineral phosphates should not be employed in such cases. As a rule basic slag should be used in soils requiring lime, in neutral or acid soils, and in soils that contain a great deal of humus. It may, however, be applied to soils which do contain lime.

Superphosphate and basic slag and the infrequent precipitate phosphates are the best forms of phosphate, and are nearly always preferable. In alkaline or neutral soils good results ought not to be expected from mineral phosphates. They are not suitable for soils rich in lime, but under certain conditions—for example in wet soils, decidedly acid and containing a great deal of organic matter, they give encouraging results usually, and sometimes very good ones. It is understood of course that when applying mineral phosphates lime is not also applied, because by neutralising the acids, and so arresting their action for the formation of assimilable phosphate from the tricalcic phosphate the benefit of the operation would be altogether lost. Large applications of mineral phosphates may be recommended on certain waste lands, before the first ploughing, seeing that the price is low; but even under the most favourable conditions, which do not occur frequently, they do not give such good results as slag.

Superphosphates.

The phosphates met with in nature, though sometimes very rich in phosphoric acid are not, however, very assimilable by plants, when regarded as manure, a fact which ought, without doubt, to be attributed to their chemical form, tricalcic phosphate $[(CaO)_3P_2O_5]$.

Liebig, in 1840, was the first to suggest treating them with sulphuric acid to make them more assimilable, measuring their assimilability by their solubility in water, and experimenting on bones; and two years later, after successful experiments on bones and mineral phosphates, Lawes established the first factory at Deptford.

Superphosphates, therefore, are the result of treating the substances contained in tricalcic phosphates [$Ca_3(PO_4)_2$], with sulphuric acid [H_2SO_4], and so rendering them super-assimilative by the following method. A suitable quantity of sulphuric acid is made to react on tricalcic phosphates, mineral phosphates for example. Theoretically one ought to get —$Ca_3(PO_4)_2 + 2H_2SO_4 = CaH_4(PO_4)_2 + 2CaSO_4 =$ plaster. But in practice one finds that a little free phosphoric acid has been formed and that a portion of tricalcic phosphate has not been touched, and the more foreign matter the mineral phosphate contains the more will this be the case.

This difficulty is partially met, however, by grinding the mineral phosphate very fine, and adding water to the sulphuric acid in such a manner as to make it thoroughly penetrate the mixture. In this way a good superphosphate ought not to contain more than 2 per cent. insoluble phosphate. In any case the insoluble phosphate is not counted in the super in fixing the price of the latter.

The mixture at this point is doughy, but the great quantity of plaster formed in the first reaction combines itself with the water and the whole becomes hard through the formation of gypsum. Before being applied to agricultural uses the superphosphate should first be ground.

Nearly 800,000 tons of superphosphate are made every year in England, the phosphates for which come from Florida, Algiers, and Tunis. There are many other sources of mineral phosphates as well, but these give the best results. The favourable action of superphosphates, especially on leguminous plants and on many root crops, is seconded by the presence of gypsum, of which we will describe the effect on page 141.

Thus nearly the whole of the phosphoric acids in superphosphates are soluble in water, but in some superphosphates, particularly when they contain compounds of iron and aluminium, the phosphate reverts when stored; that is to say, that though it was monocalcic and soluble in water [$CaH_4(PO_4)_2$] it returns almost to a bicalcic phosphate [$Ca_2H_2(PO_4)_2$], which is not soluble in water, but is so in weak acids.

Perhaps too much importance has been attached to this fact, because in reality this bicalcic phosphate can be regarded as workably assimilable; besides in the soil the monocalcic phosphate quickly returns to the bicalcic form, or something corresponding. The only advantage the monocalcic presents over the bicalcic is that the former being dissolved by the rain is more easily and completely distributed in the soil, up to the time that it is fixed by the carbonate of lime or the compounds of aluminium or iron in the soil. If rain is slow in coming, however, it will be already fixed and no longer soluble.

Superphosphate will be decidedly better if it contains much phosphoric acid [P_2O_5], and it is obviously wise to buy the richest, because, the price being gauged by the unit, transport will be cheaper when that unit is contained in the smallest bulk. The percentage of phosphoric acid [P_2O_5] is very variable, ranging from 25 to 40 per cent. or 50 to 80 per cent. as tribasic.

The difference between the value of monocalcic phosphate, superphosphate, and tricalcic phosphate of mineral phosphates, or of bones, is very great, being proportionate to their solubility and their assimilability.

In many soils, even when tricalcic phosphate is used in the form of a fine powder it is nearly inassimilable, and will be found of little value. This would be the case in soils poor in humus, also in calcareous soils, even although these contained only a small proportion of lime or magnesia.

It is not suitable for such soils, and should be used rather as an improvement than as a manure, at a proportionate price of a quarter, a fifth, or even less than that of super.

Superphosphate is a manure of immediate action and can be applied simultaneously with sowing. Sometimes it is used as a top dressing, although it is preferable to harrow it in. It will give good results with nearly all crops; but it is most effective on turnips, because they find it more difficult than any other plants to absorb the phosphoric acid of the soil, and so require a very assimilable form of it.

Since, however, super is somewhat acid itself, basic slag should be used in preference for pastures on very humiferous acid soil poor in lime. It should not be applied to very acid land, because, being soluble and finding no arresting base, it would simply be washed into the drainage and wasted.

Generally there is no need to fear this loss. Superphosphate is the phosphate manure for catch crops. The quantities manufactured annually show that it is in general use. It ought to be used more often than mineral phosphates and compound manures, which still occupy too important a place. For the value of phosphoric acid the unit type is that of superphosphates.

Bone Manures.

Bone manures are thought more of in England than in any other country. They have been in use a long time, and are sold in every conceivable form; merely more or less finely broken, fermented, steamed, distilled, incinerated, transformed into superphosphates, with their own phosphates precipitated, and so on. Because of the great demand for them their price is quite high enough, higher perhaps than is justified by the quantity and quality of their fertilising elements. In fact, seeing that products of higher value and cheaper price per unit are now on the market, they ought not to occupy the position they have held so long.

Providing they have not undergone any chemical transformation, bones form a slow manure, the effect of which is felt for many years, one, moreover, which is not subjected to any loss.

When they first came into use they were roughly ground, without any cleaning; later on they were ground more finely and eventually they were fermented by putting them into heaps and watering them with urine, in order that the nitrogenous organic matter they contained should be made assimilable. The output of this country, although great—60,000 tons—does not meet the demand, so they were imported from India and very largely from the Argentine, but also from Brazil, Morocco, Egypt, and the Continent, and within recent years the total importation had mounted up to about 50,000 tons per annum.

The Importance of Fineness.—This is a matter of the very first importance, far more so than is generally imagined ; and it is astounding that the demand for coarsely ground bones is still so great. A difference of 1 per cent. nitrogen and 5 per cent. phosphoric acid can easily be sacrificed to fineness of material, and in spite of this fineness bone will never be assimilated in a single year. It will generally take from two to three years. For this reason it is not a manure to be recommended.

There are cases where finely ground bones have given very good results—in acid soils for example; but these cases are the exception and cannot be in any way regarded as a general rule.

Green Bones.—It is not economical to use ground bones green. They contain too much fat and are not easily assimilable, either as regards phosphates or nitrogenous organic matter. The phosphate is in the tricalcic form, often called bone phosphate. They are more or less unevenly ground, but are always of slow and incomplete action, and consequently are poor value.

Green bones when dried and cleaned of their fat contain about 4 per cent. organic nitrogen and 50 per cent. tricalcic phosphate. They are converted into—

Bone Meals and *Bone Dust* without undergoing any further treatment. Their relative values depend upon the fineness with which they are ground. We have quoted elsewhere the analysis of badly ground bones given as manure and found twenty years afterwards without having suffered any change or yielded any of their fertilising matter. Honestly, they are of very little value as manure ; also they are much adulterated with neutral materials such as sand, bricks, cinders, etc.

The Bone Meals obtained from the East Indies and the River Plate are of about the same value as the home production.

Steamed Bone Flour.—In steamed bone flour the bones have been treated with steam, partially extracting the nitrogenous organic matter for the purpose of making glue. The bones, themselves very brittle, are reduced to an exceedingly fine powder. As a rule they contain more phosphates than green bones, sometimes from 60 per cent. to 70 per cent. and less nitrogenous organic matter, of which there is about 1 per cent. They are better worth buying by the unit than bone meal, because there is less demand for them ; nevertheless, they are a better manure.

Fermented Bones.—Sometimes pounded bones are fermented. For this purpose they are put into a heap where they heat, and from time to time horse urine is poured over them. After some weeks they become disintegrated. A good deal of nitrogen has been lost during the heating and fermenting processes, but the phosphates have become more assimilable.

Phosphates

Dissolved Bones.—It was Liebig who suggested treating bones with sulphuric acid, and Lawes who utilised the suggestion at Deptford in 1842–1845 in the manufacture of his superphosphate; but being too dear, those superphosphates were abandoned in favour of the cheaper mineral phosphates. They were called Bone Superphosphates, and contained about two-thirds phosphoric acid soluble in water, while the remaining third, being partly dicalcic phosphate, was also sufficiently assimilable. Bones, bone ash, and spoilt char were utilised in their manufacture, and being expensive, the manure was, in time, much adulterated. This bone super has been advantageously and economically replaced by ordinary super. A more or less diverse series of dissolved bone compounds was derived from it, but they are not interesting.

Bone Ash.—This is chiefly used to make Bone Superphosphate and comes from abroad. It is rich in phosphate, sometimes containing 80 per cent., and gives a good superphosphate, but is still too dear. The unit of phosphate in bone super ought not to cost more than in ordinary super, that of phosphate in ordinary bones more than finely ground mineral phosphates, or that of steamed bone flour more than reverted super. Generally speaking, bone super costs too much and therefore cannot be recommended.

Animal Charcoal.—For a long time animal charcoal has occupied an important position in the range of manures coming from bones. To make it, the bones are cleaned and then burnt in a closed receptacle. During the calcination part of the volatile products, including among others, ammonia is given off into condensers. What is left of the bones is converted into a black spongy charcoal, which makes an excellent decolorant for coloured organic matter. It was used before sulphuric anhydride [SO_2] was introduced in the decolouring of syrups, in the manufacture of sugar, etc. For this purpose it was finely ground. When the charcoal had absorbed all that it could retain of the coloured organic matter of the juice, it was calcined afresh, and was used again and again till it lost its sponginess, when it was called "spent charcoal" and was turned to agricultural purposes.

There are two kinds of charcoal.

1st. That of sugar manufacturers, which is the most plentiful. It makes a more or less coarse powder, containing about 70 per cent. tricalcic phosphate, 10 to 20 per cent. carbonate of lime, and practically no nitrogen. This is used to greatest advantage on acid lands, where it gives good results. It is often adulterated with earth, ashes, and sometimes even by the addition of the burnt residue of distillation, in which case it contains cyanures harmful to vegetation.

2nd. That of refineries, which, in a dry state, forms a fine powder. This charcoal holds a variable amount of tricalcic phosphate, generally between 50 and 70 per cent. It also contains 1 to 3 per cent. nitrogen. It is very easily adulterated, since its texture easily hides foreign matters, such as black peat, earth, wood-charcoal, charcoal dust, etc.

These two animal charcoals are often used directly in agriculture, because of their spongy texture which the rootlets can penetrate, and so give appreciable results. Their value is variable, according to the way in which they are used and their richness in fertilising elements. Their action is not so slow as that of many tricalcic phosphates, but generally they are turned into superphosphates, being monocalcic phosphates of high value and eminently assimilable.

They should never be bought except under analysis.

Deglutinised or Steamed Bones.—The name of this manure comes from the process of deglutinising bones by submitting them to the steam of super-heated water. In this process, as in the manufacture of animal charcoal, the bones have been previously degreased. The gelatine which is obtained from them constitutes nearly half of the nitrogenous organic matter, often even more; so that steamed bones are much poorer in nitrogen than green or fermented bones. On the other hand, they contain more phosphates, the proportions being about 0·9 to 1·5 nitrogen, and from 60 to 70 tricalcic phosphates.

Steamed bone is very easily and completely pulverised, the resulting powder being known as *Steamed Bone Flour,* which is the finest bone manure, although the phosphate is in a tricalcic form. On account of its fineness, however, this manure is generally comparatively assimilable, and although the value of the unit is sensibly less than in superphosphate, it may be used with advantage, especially in light acid soils.

It is sometimes mixed with superphosphate, but we do not recommend the mixture, because generally it only represents a very small proportion of superphosphate to the bone flour.

It is better to transform it into superphosphate of bone by means of sulphuric acid, when it constitutes a phosphatic manure of the finest quality. It is sometimes adulterated by the addition of gypsum, mineral phosphates, or marl.

Bone Ashes.

Bone ashes come from the Argentine, and are obtained by burning bones which are found there, sometimes in very large beds. They contain on an average 72 to 73 per cent. of tribasic phosphate. In this capacity they ought only to be employed on acid lands and should never be expensive. Transformed into superphosphates, they make a good manure, and should then be bought according to the unit of soluble phosphoric acid. They should always be bought on analysis, because they generally contain many impurities.

Precipitated Phosphate.

This is a product obtained by precipitating with milk of lime the phosphate produced by treating bones with hydrochloric acid. It is a fine white powder containing about 40 per cent. phosphoric acid. The process which is carried on in connection with the gelatine industry is as follows. The mineral matter of the bones is solubilised by means of a considerable excess of hydrochloric acid. Little by little milk of lime is added to this solution and stirred constantly, and the result is a precipitate of bi- and tricalcic phosphates and some foreign matter. The precipitate is then dried at a low temperature. When it has been properly made it ought to contain only a little tricalcic phosphate.

This chemical phosphate is of a fineness impossible to obtain by grinding. It is, owing to its bicalcic form (which is soluble in citrate of ammonia), and also to its extreme fineness that its action is so favourable. The tricalcic phosphate is not taken into account in fixing its price. It should only be bought on analysis, and when the price of the unit is not higher than that of slag.

Basic Slag,[1] Slag, Thomas's Slag.

This is a bye-product of manufactured steel from minerals which contain phosphoric acid. Iron containing phosphoric acid breaks easily under the hammer when cold. Therefore before minerals containing this acid can be utilised the acid must be eliminated. Thomas and Gilchrist discovered the way to extract phosphate from iron ore in 1878, and at first the residue or slag was simply thrown away. Small heaped-up mountains of it could be seen outside steel works. After conclusive trials, however, it was utilised as manure.

To extract the phosphate and obtain the slag the inside of a Bessemer converter is lined with limestone, and lime is also added to the molten contents. Then a very strong current of air forced into the mass oxidises the impurities and they are

[1] It is called "basic" because it contains 3 or more per cent. of free lime, of the total lime contents of 35–55:

taken up in the dross as silicates and other forms of phosphate. This floating dross is drawn off and the purified iron is left. The dross is black, very hard, and heavy. It is difficult to grind, but it has to be ground very finely, because its fineness is an important feature of the product. Two qualities of fineness are made—one of 50 per cent. and one of 80 per cent., that is to say, qualities of which respectively 50 per cent. and 80 per cent. will pass through a sieve having about 10,000 regular holes to the square inch. The phosphate, which forms in the slag at a temperature of from 1800° to 2000° Centigrade, is generally understood to be in the tetrabasic form [$CaO_4P_2O_5$], soluble in citric—which is a weak acid; whilst tribasic phosphates are only soluble in strong acids, which obviously makes a great difference. The tetrabasic form or any form other than tribasic in which phosphoric acid occurs is very useful, since it represents a reasonable degree of assimilability; but all the phosphate is not tetrabasic, and another portion is present in the tribasic form.

To determine the solubility of the phosphate the solubility in citric acid is fixed at 2 per cent., which corresponds approximately to the phosphoric acid absorbed by plants. With regard both to solubility and assimilability, tetracalcic phosphate is very similar to the bicalcic phosphate of precipitated phosphate, and to basic and reverted superphosphate. Even if it acts less rapidly than superphosphate it does nevertheless act in the same year. Turnips, which do not easily extract phosphoric acid from its combinations, but which at the same time requiring a large quantity of it, and should therefore receive it in a sufficiently assimilable form, generally give very good results with slag, especially in slightly acid ground.

Obviously all the assimilable phosphate is not in a tetracalcic form. It is probably present also in combination with silicate, in a form of double salt.

Another portion of the phosphoric acid is insoluble, that is, soluble only in strong acids—and sometimes very inassimilable.

The value of basic slag depends very largely, therefore, on the proportion of assimilable or inassimilable phosphates, and it should never be bought on the total content of phosphoric acid alone. When the phosphoric acid is only soluble in strong acids, it should be regarded as inassimilable, or so slowly assimilable that it ought not to be reckoned in the price of the manure. *Only solubility in citric acid should be accepted as a basis on which to determine the price.*

Again, the value of slag is in direct relation to its fineness. Phosphate, even though soluble in citric acid, is not easily assimilated in coarse slag, and may not be assimilable at all, seeing the extreme hardness of the particles. But we have explained the desirability of fineness in manures in a preceding chapter. Here it is sufficient to say that the degree of fineness will be another factor in deciding the purchasing value.

The lime present in slag also plays a very important part. In neutral soils or slightly acid soils which are deficient in lime, it supplies the foundation necessary for nitrification and for the fixation of ammonia and potash. Also it neutralises the acids in the soil. It is thanks to this quality that basic slag is so valuable in many soils, and that its use is so advisable and ought to be popularised. It is the phosphatic manure *par excellence* for acid land in general, but its action is appreciable everywhere.

For a long time it was recommended, without any particular reason, to apply slag in November, regardless of the fact that that month was either not soon enough, or too soon. Slag by itself cannot penetrate deeply into the soil. It is useless, therefore, to apply it with this object in November. In good slag the phosphoric acid is soluble in weak acids, but the chemical reactions of the soil are reduced to a minimum in the winter, and the physiological reactions are reduced to nothing at all, the plants not being in a state of vegetation. The assimilability of the phosphates of the slag are, above all things, dependent on the physiological action of the roots of plants; that is why their effect is progressive. When the phosphate of the slag is not assimilable it would become so better in summer than in winter.

On pastures it will give good results, even in peaty soils where the superphosphates may be lost in the drains. It is also the manure for sandy soils, and at the same time for those which lack phosphoric acid and limestone.

It is basic slag that has made it possible, or at any rate has greatly helped, to reclaim heather land, and it is to basic slag that Belgium, Holland, and Germany are indebted for their progress in this work. We do not consider that it is used sufficiently in England, although the economy of employing it has been shown by numerous demonstrations.

There is any amount of waste land only requiring to be slagged to be brought under cultivation. Its use is not justified simply because of its reputation, but because that reputation is genuine, and because, moreover, the price is reasonable, being generally a quarter less based on the unit than that of the unit in superphosphate, and not so dear as that of bone meals.

It usually contains from 9 to 18 per cent. phosphoric acid, corresponding to 20 to 40 per cent. tribasic phosphate. Sometimes, however, the content of phosphoric acid is as much as 22 per cent. or 48 per cent. tribasic and more, according to the kind of mineral from which the slag is derived.

Here is its average composition :—

Phosphoric acid	9–20	per cent.
Lime	35–55	,,
Iron compounds (oxides)	10–20	,,
Silica	5–15	,,
Magnesia	2– 5	,,
Aluminium	1–10	,,
Sulphuric acid	0·2– 1	,,

Basic slag must always be bought on analysis and with a guarantee of the quantity of P_2O_5 soluble in citric acid. The gross content of phosphoric acid can never be accepted as the price basis. If it were it would be an incentive to adulteration with insoluble phosphates. The purchaser should see, therefore, that the phosphates are all original, and, for the reasons stated above, always buy the richest possible.

On pasture slag should be applied in January or February. We must point out here that very fine basic slag of good quality ought not to be applied earlier. In doing so there is a risk of loss, since it is here used as a top-dressing. As a matter of fact, we have seen that these very fine particles are the best slag, also that they are most easily carried away by the wind, or washed away by heavy rains, so that the earlier they are applied the greater the risk of loss. Moreover, this is just the time of year when the grass is shortest, so that the manure will be most easily carried away by heavy rains.

For other crops the slag should be buried by a good harrowing, so as to mix it thoroughly with the soil, before sowing. In this case no loss need be feared. It should never be given to ordinary crops as a top dressing. On clovers it is better to give a double dose at the time of sowing the crop preceding the clover, so that it can be well distributed in the soil.

It should never be sown in windy weather, because the best and finest particles will fly furthest. They would often fall from 100 to 150 yards from the place for which they were intended, and be of no use to the plants that ought to receive them. To prevent slag from blowing away it can be mixed with kainite the day before it is used. This mixture, however, will become hard, and therefore ought to be used at once.

Slag should be spread by machine for preference. If sown broadcast the sower should take care not to work against the wind, because the lime in the slag may cause a serious irritation to the eyes. He should be provided with motor goggles, if necessary.

When the slag has caked in hard clods because of careless storage it must first be finely pounded with a heavy hammer. The lumps must not be thrown on the land as they are.

The sacks of slag should never be stood on the ground in the storing place, but placed on a plank platform.

Slag is adulterated with many things, of which some are inactive—such as ground cinders, or the waste from coal mines, and others having very little action—such as mineral phosphates.

The numerous trials which have been carried out in the countries where basic slag is largely used have demonstrated its excellence, and its great value as a manure.

Basic Superphosphate.

Basic superphosphate is simply superphosphate to which basic slag has been added. Since, however, we can obtain both constituents separately when it is desirable to use them, basic superphosphate has the usual drawback of compound manures—the unit is too dear.

It has been argued that monocalcic phosphate is transformed into bicalcic in this mixture. As we have already had occasion to say, *apropos* of reverted phosphates, this in our eyes is not a great inconvenience, as long as the manure is not given as a top dressing but is harrowed in. As a matter of fact, when the soluble phosphate of the superphosphate is put in the soil it will be lost by drainage if it cannot find a base for fixation, or becomes bicalcic and insoluble in the water, and the oft-quoted advantage or solubility of superphosphate is reduced to nearly nothing, since it must first have rain (which does not always arrive) to help its dissemination, the dispersal by reason of solubility, by the water in the soil, being reduced to a minimum, and practically limited to two or three inches of the top soil, because of its insolubilisation by the bases.

On the other hand, bicalcic phosphate is very assimilable by plants, so that reversion ought not to be regarded as an obstacle to its employment. If it were not too dear it could be applied to any acid land where superphosphate cannot be used advantageously, because of the lime in the basic slag. But it must be noted that the value of basic superphosphate does not lie in the total phosphoric acid, but depends very largely on the quality of basic slag employed.

If the farmer understands the use of basic slag and superphosphate he need not employ basic superphosphate.

Coproliths.

Coproliths are impure mineral phosphates, presented in the form of hard nodules, brown or reddish in colour, varying in size from a pigeon's egg to an ostrich's. The name is derived from the Greek, and means "stones of dung." They are fossil excrements attributed to fishes or to saurians that lived in prehistoric times, and are found in many places in England, notably Suffolk and

Cambridgeshire, also in Bucks, Beds., Dorset, the Isle of Wight, etc.

Lawes used them in 1845 in making superphosphates to replace bones which were too scarce and too dear. Phosphate is present in the tricalcic form [$Ca_3(PO_4)_2$]. Their least value of phosphoric acid [P_2O_5] is 20 to 23 per cent., with some considerable exceptions, however, as they sometimes contain from 40 to 47 per cent. tricalcic phosphate. But besides phosphate of lime and other phosphates they also contain sulphates, carbonates, fluoride, etc., which make the manufacture of superphosphate difficult. That is why they have been replaced by other phosphates without these inconveniences. The Coproliths are often ground very finely, and used as a tribasic phosphate manure. They are not always suitable for this purpose, since in alkaline or simply neutral soils, they will have very little effect. But in acid soils they will be one of the best insoluble phosphates to use, costing less than bones, and giving almost as good value.

CHAPTER V

Potassic Manures in General

The Occurrence and Functions of Potash in the Soil.

Setting aside farmyard manure, in which in any case there is a great loss of potash—often more than half—the restoration of potash taken from the soil or the supplying of natural deficiencies was only accomplished for a long time past by the application of wood ashes, seaweed ash, burnt weeds, and salts obtained from the French Midi and nitre beds. Peat ash contains practically no potash.

The sources were quite insufficient either to make good deficiencies caused by the crops sold, or the losses in the manure; also a part of the potash derived from them is still required in the manufacture of glass, soft soap, and gunpowder.

There is a lack of potash therefore in the majority of soils, and in some—those very acid and peaty for example—there may even be none at all. We shall see how these acid soils dissolve the potash: in the absence of lime the humus cannot retain it and it is carried off by the rain water. Such soils therefore require potash as well as lime, but the moment there is sufficient lime in the ground no further loss of potash will take place.

Sandy soils with little or no humus are equally unable to hold their potassic salts. But here it is not sufficient only to apply lime, because there is not enough humus to retain the potash, or to prevent loss. It will be wiser in this kind of land to use only a little potassic manure at a time—just what is necessary for the crop, and not to apply it a long time in advance. For if in the generality of cases there is little or no loss of potash, in the two cited the total loss will be very serious, that is if there is an insufficiency of humus and lime.

Forms in which Potash is found.

Potash is usually restored to the soil in one of the three following forms :

1st. In the form of farmyard manure or seaweed.

2nd. In the form of ash.

3rd. In the form of chemical manure.

Actually we have a great variety of potassic manures, the source of the majority, however, being the mines at Stassfurt in Germany ; and for many years past Leopold's Hall has been the station whence an enormous bulk of potassic products has streamed out in all directions all over the world. The exploitation of these potassic salts began in 1860 and developed to such an extent that in 1906 about 5,200,000 tons, or 1700 waggons of 10 tons, were exported every working day. In 1905 2,500,000 tons of kainite alone were sold, yet the Stassfurt mines still contain uncalculated reserves. They are derived from the evaporation of sea water in a deep rather narrow ravine, so that the mines contain a greater quantity of sea salt (NaCl) than of potash, and for a long time the potassic salts were regarded as the waste product of chlorure of sodium.

The potassic salts are generally mixed with magnesia. That is why in crude potassic—and even in prepared salts, common salt and magnesia are found as well as potash. The chief crude salts are kainite and carnalite. Kainite is still sold under the names of Hartsalz and Schoenite. Kainite is used either crude or burnt to red-heat point to drive out the chlorure of magnesia, and then is distributed in that form to the agriculturist.

Carnallite is chiefly converted by means of concentration and crystallisation, or by the reaction of sulphuric acid, into muriate and sulphate of potash, and these again are crude salts.

In Glasgow potash is obtained from seaweed. Beetroot salins (that is the residue of molasses after distillation—called *vinasses*, which is evaporated and calcinated and then is called salins) yield it, and also Yolk. Very often a product is sold under the name of sulphate of potash which is nothing more nor less than a mixture of all sorts, but chiefly containing different chlorures.

At the present time, when the need of potash is being more strongly felt than ever, because the chief source is temporarily barred, other existing sources which are too little known must be tapped instead. Seaweed burning, for instance, can be carried on all along the Atlantic coast (the weed must obviously be burnt because otherwise it would weigh too much), and on a sufficiently large scale. The salines of the

French Midi, whence it can be brought *viâ* Marseilles, the salins of beetroot, etc., can be exploited, and above all by constructing tanks for urine, covering our farmyard manure, and so checking loss, we can reduce the necessity of looking abroad for our potash to a minimum.

The necessity for supplying potash to the soil has been questioned, and occasionally even doubted. Such discussions serve no purpose. Many soils are in real need of it, and most are better for it, but in some cases the ground already contains sufficient.

Manurial Attributes of Potash.

Still, a distinction must be observed with regard to the nature of the crops on which it is tried, one kind being able to assimilate the potassic combinations in the soil more easily than another. Furthermore, in some cases the simultaneous use of other manures or substances acting as lime does has caused the immediate utilisation of the potash present.

Potash is one of the principle elements—sometimes nearly predominant—in the ash of plants, and it must be restored to maintain the fertility of the soil; only in its application certain points must be observed.

Commercial potassic manures are more or less corrosive in themselves. Moreover, they are frequently mixed with magnesium salts which are actively injurious to the roots of vegetating plants. That is why these compounds are generally applied before sowing, and sometimes a long while in advance and on fallow, so that the rains can wash away the chlorure of magnesia (which is very soluble by the way) before the seeds begin to germinate.

Kainite should never be given as a top dressing to a growing crop or it will kill a great part of it.

Potash can be used as a top dressing for pasture land and clover in February at the latest, and for preference in January ; and should never be applied after the first cutting of clover.

Properties of Potash.

Potash salts, especially the chlorure, are very soluble in water, but in spite of this no loss need be anticipated as long as there is limestone in the soil, because potash is very quickly rendered indissoluble and fixed on the humates. In fact, experiments made at Rothamstead show that they sink very little below the surface. In these trials nearly the whole quantity could be located within ten inches of the surface, despite the fact that the ploughings of many years had evidently mixed the soil very thoroughly. That is why it is advisible to harrow in potassic manures well, so as to ensure some part penetrating to a fair depth instead of letting it all remain near the surface.

If an application of kainite is followed by a sufficiently prolonged period of dry weather it may happen that the potash, and more particularly the chlorure of magnesia, absorbing all the moisture in the soil, will form concentrated solutions which are extremely corrosive and destructive to plants. This will affect pasture, wheat, etc., equally. When applying potash to soils that are poor in limestone it will be necessary to give a preliminary dressing of the latter to prevent the potash being lost. Moreover, it will be necessary to renew the application, because the fixation of the potash will cause a loss of lime in the drains. In practice this restitution of lime can often be effected by the employment of slag as a phosphatic manure.

Generally speaking, if the potassic salts are dry the colour will matter little, but the content of potash must be guaranteed, and the purchaser should also ask for the content of accessory salts, and demand the exact name of the manure he is buying. The believers in magnesia as a manure, for example, will be contented to use kainite, which will give them magnesia in very large quantities. Kainite itself is not much adulterated, but it is sometimes used to adulterate chlorure and sulphate of potash. It is also occasionally used to adulterate nitrate of soda, and this fact is the more serious, because, nitrate generally being given at the commencement of vegetation, the kainite may then injure or destroy the crop.

Kainite.

Kainite, the best known potassic manure, is a crude salt, mined from deep-seated beds at Stassfurt, in Germany. It is of a dirty colour generally, sometimes pinkish, but the colour does not matter; the kainite is equally good in either case.

Crude kainite consists of various more or less pure salts, mixed after coming from the mine to contain a proportion of from 12 to 13 per cent. potash. It must not contain less than 12 per cent., and is generally guaranteed at 12·4 per cent. Formerly it was considered that the potash it contained was present under the form of sulphate. This is not so. It is in the form of chlorure.

Kainite contains about 35 per cent. common salt (NaCl); about 30 per cent. salts of magnesia, especially sulphate, but often also chlorure; 12·5 per cent. water of crystallisation, and a small quantity of impurities.

Considerable quantities are sold annually under the names of Kainite, Hartsalz, and Schoenite. In 1905 there was an output of nearly 2,500,000 metric tons.

Care must always be taken that the kainite does not contain chlorure of magnesia, because that is not only harmful to vegetation, but, being deliquescent, impairs the keeping qualities of the manure. When the kainite has become hardened by storing, it is very difficult to apply, and the lumps must first be crushed by means of a mattock or spade, or, if large quantities are being employed, by a grinding machine.

Calcined kainite, from which the chlorure of magnesia has been expelled by heat, can be bought, and is to be preferred. Kainite is the potassic manure in which the potash is the cheapest per unit at the place of origin, but because of its evanescence preference should be given to concentrated chlorures of potash in places far from the source. In the former case the cost of transport has to be paid on substances which do not constitute manure.

Kainite is very suitable for pastures, clover, beetroot, corn, etc.

Carnallite.

This is a crude salt of potash extracted at Stassfurt. It is of variable colour, according to the impurities which it contains. It is red, yellow, grey, black, often pink, etc. It is deliquescent, therefore difficult to preserve. Crude carnallite gives bad results when applied to growing crops, being corrosive because of the chlorure of magnesia which it contains. Employed in this form it ought to be buried a long time in advance so as to destroy its harmful characteristics, which are thus eliminated before sowing or planting. If used fresh it is destructive to any crop. It is chiefly used in the manufacture of chlorine and sulphate and potash. It is a compound of chlorure of potash and of magnesia ($KClMgCl_2$ $6H_2O$) of water, chlorure of soda, and kieserite. Nearly 2,500,000 tons per annum are extracted and used, for the greater part in the manufacture of chlorure of potash. For this purpose a solution of chlorure of magnesia ($MgCl_2$) is saturated in heat, and the carnallite dissolved in it. The KCl crystallises in cooling.

Sylvinite.

This is a mixture of common salt and chlorure of potash, etc., extracted at Stassfurt. As it is not largely exported, it is of no particular interest.

Chlorure or Muriate of Potash.

When pure, this is a white salt, and takes the form of cubic crystals. It is very soluble in water, and has a salty taste. It is efflorescent, in distinction to the chlorures of sodium and magnesium, which are deliquescent, and is therefore easier to keep than kainite. It ordinarily comes from Stassfurt, where it is generally obtained by the treatment of carnallite. The manure of commerce is never pure, it always contains chlorure of sodium ($NaCl$), a little chlorure of magnesium ($MgCl_2$), a little sulphate of magnesia ($MgSO_4$) water, and some impurities. If it were pure it would contain 63·1 per cent. K_2O. Commercially it is known as chlorure of potash ; 1st, the three times concentrated, which contains nearly 30 per cent. K_2O, and, 2nd, the five times concentrated, which contains nearly 50 per cent. potash K_2O. This is the better form. Chlorure of potash constitutes the concentrated potassic manure most generally used, because its unit of K_2O is less dear than in the concentrated sulphate [K_2SO_4], moreover, the advantage of using it at a great distance from its place of origin is clear, because of the considerable cost of transport, which increases the price of the unit of K_2O in the poorer product. The five times concentrated contains three times as much potash as kainite ; so that though the K_2O costs less to the unit in the kainite at the place of origin, it will cost more at its destination, because it will take four tons of kainite to equal one of KCl. Thus the carriage of kainite costs more than the cost to buy.

Muriate of potash is also obtained from salins of beetroots and ashes of seaweed. It sometimes contains 55 per cent. K_2O ; very often, however, it does not contain more than 50 per cent. Seaweed ash ought to attract more attention just now because potash from other sources is, and will be, difficult to obtain.

Another source of supply is the salt marshes of the French Midi, which contain nearly 45 per cent. K_2O. These muriates can be distinguished because they contain sulphate of magnesia ($MgSO_4$).

When buying, a guarantee of the title of the manure is essential, and that with the highest title must be bought. It is a suitable potassic manure for almost every kind of crop, but should not be used on tobacco, because of its chlorures, while it gives a poor flavour to potatoes.

Sulphate of Potash or Potassium Sulphate (K_2SO_4).

This is in the form of a white salt crystallised in prisms, and thus is distinguished from KCl, which crystallises in cubes. The crystals resist the action of the air; they have a salt taste with a bitterness which also distinguishes them from KCl, and moreover they are relatively less soluble in water.

The manure is made by making sulphuric acid (H_2SO_4) react on chlorure of potash (KCl) or on carbonate of potash (K_2CO_3). The chief source of supply of sulphate of potash is still the beds of Stassfurt. It is obtained by the treatment of carnallite, and contains nearly 50 per cent. K_2O.

In France it is made from the salins of beet-root and then contains nearly 50 per cent. potash.

It has also been made in Scotland from seaweed ash.

This sulphate is the potassic manure for tobacco, because it contains no chlorure, which is injurious to the quality of that crop.

Also it does not give potatoes the bad taste which KCl gives. For these two crops one ought always to have a guarantee that there is no chlorure in the manure.

In K_2SO_4 the unit of potash costs even more than in KCl, because the latter is more easy to prepare, and the former is in greater industrial demand. It is the dearest of the potassic manures, nitrate of potash [KNO_3] being rarely employed.

Being so dear, it is sometimes adulterated with chlorure of sodium, sulphate of sodium, or crude Stassfurt salts just like KCl.

Its use is limited to tobacco and potatoes.

Nitrate of Potash (KNO_3).

This is still called Nitre or Saltpetre. It is in the form of white crystals and light prisms.

It is very soluble in water and has a piquant taste, and, if thrown on to a red-hot shovel, fuses without lighting.

It is found in certain parts of India, where it is formed from organic matters in a soil rich in potash. The product evidently is not pure. England has drawn on the Indian supplies for a long time, but now it is generally made by the reaction of chlorure of potash on nitrate of soda. The unit of nitrogen and of potash respectively will then be of superior value to that of nitrate of soda and chlorure of potash. Its general use is not justified on account of its price.

Formerly it was made in nitre beds. These were layers of horse manure well aerated, and watered with urine, in which wood ashes were mixed and the potash from the ashes absorbed the nitric acid which was formed.

In olden times nitrate of potash was chiefly employed in the manufacture of gunpowder, and is still used in some powders, and for fireworks, etc.

Because of its industrial usefulness the price has always been too high to permit of its being used in agriculture, unless in the form of crude saltpetre, containing from 5 to 20 per cent. impurities.

Only tobacco and certain vegetables would repay its application. Tobacco especially likes it because of the quantity of potash and the absence of chlorures. The relation between the potash and the nitrogen is not favourable. It generally contains 13 per cent. nitrogen and 44 per cent. potash.

On account of its high price nitrate of potash is subject to adulteration with many substances, such as chlorure of potash, sulphate of potash, nitrate of soda, and even chlorure of soda.

Carbonate of Potash [K_2CO_3].

This is a white salt crystallised and caustic. It is the *potash* of commerce and is used chiefly in the manufacture of glass and of soft soap. This makes its price generally too high for agricultural purposes.

It is obtained from various sources, such as from the decomposition of sulphates, when it contains nearly 85 per cent. carbonate of potash, besides 3 per cent. chlorure of potash and 2 per cent. sulphate; and from Yolk, when it contains 75 per cent. carbonate, 4 per cent. sulphate, and 7 per cent. chlorure of potash.

The salins of beetroot produce it, as we have seen, and the residue of distillery from molasses, which gives 35 per cent. carbonate, 17 per cent. chlorure, and 6 per cent. sulphate of potash. These generally contain a little cyanure and are therefore dangerous to use, cyanure being a violent poison both for plants and animals. Carbonate of potash is most frequently given to plants in the form of wood ashes. This contains from 10 to 30 per cent. potash, and along with the carbonate of potash a little sulphate is also found.

Potash Manure Salt.

Under this name are sold more or less impure chlorures of potash, to which are added crude Stassfurt salts.

The title only serves to hide the inferior product, in which the potash is generally fixed at too high a price, and which often contains a harmful chlorure of magnesia.

There are also double sulphates of potash, and of magnesia, which generally contain only about 27 per cent. potash. These are often adulterated too.

These preparations do not usually deserve the attention given to them.

Yolk.

This is the deposit caused by perspiration which is found on sheep's wool. It is soluble in water. The raw wool contains about 4 per cent. potash, so that the water in which sheep are washed before shearing, or that in which the wool is washed after shearing, ought to be put on the land.

CHAPTER VI

Ashes and Soot

Ashes.

These are the waste products left from combustion. They contain the mineral matters of the substances burnt and vary in richness, therefore, according to the material from which they are derived.

Wood Ashes.—Wood ashes are the mineral matter which is left when wood is burnt.

The quantity of ash varies considerably, according to the vegetable matter from which it is produced.

Thus, leaves in 100 parts of dry matter give 15 per cent. ash; sapwood in 100 parts of dry matter give 3 per cent. ash; bark in 100 parts of dry matter give 7 per cent. ash; heart in 100 parts of dry matter give 5 per cent. ash.

The more herbaceous the matter the higher the proportion of ash.

The composition of ash varies considerably according to the species of wood from which it is derived—oak, birch, fir, etc.; according to the part of the wood used—leaves, bark, etc.; and also according to the age of the material burnt.

The chlorures being eliminated together with a little phosphoric acid by incineration, wood ash can be used on tobacco. It is known that tobacco burns in direct proportion to the potash which it contains, and inversely in proportion to the chlorine.

Birch ash is poor and beech relatively poor in potash—10 per cent., and 6 per cent. phosphoric acid. Oak is a little richer ; but poplar is as rich in potash as kainite—12 to 13 per cent., and also contains 10 per cent. phosphoric acid, while elm is very rich, containing 20 per cent. or more of potash. Pine, which contains about 10 per cent. of potash, is poor in phosphoric acid, only containing 4 per cent.

As a whole wood ash contains from 5 per cent. to 25 per cent., with an average of 8 per cent. It forms an excellent potassic manure frequently employed as a top dressing after the first cutting of clover, also on grass land, where it tends to promote clovers. On beans it is also very useful.

Formerly, by washing and purifying the ash, pearl ash was produced, which was at that time the source of POTASH. Ash also furnished the base which fixed the nitric acid formed in the nitre beds, whence was obtained the nitrate of potash used in the manufacture of gunpowder.

Wood Ashes.

These are relatively abundant on farms where big hedges are used. The ashes should be sheltered from rain to preserve the potash. They are valuable chiefly for their potash, and less so for their phosphoric acid and carbonate of lime, of which there is only a small quantity. Potash is found in these ashes chiefly in the form of carbonate, also as sulphate and to a small extent as silicate.

Washed Cinders.

Washed cinders from bleaching houses or soap works can be employed as an improvement. They contain about 40 per cent. carbonate of lime, 3 to 5 per cent. phosphoric acid, and potash perhaps up to 1 per cent. They can be used where carbonate of lime might be applied, in strong and acid soils generally, or even as a top dressing to pastures. Their use is certainly advantageous, partly owing to the phosphoric acid and potash they contain. Their carbonate of lime is not so active as that of the slag of defecations from sugar refineries.

Bone Ash.

Bone ashes come from the Argentine, and are obtained by the incineration of fossil bones which are found there in extensive layers. They contain an average of from 72 to 73 per cent. tribasic phosphate. Therefore they should only be used on acid soils. Transformed into superphosphates they make an excellent manure. They should be bought by the unit of soluble phosphoric acid, but only on analysis, because they generally contain many impurities.

Ashes of Peat.

These must be regarded simply as improvements, since generally they contain only lime, first in the form of carbonate, and, secondly, in the form of sulphate. Very little potash or phosphoric acid is found in them, and such as existed in the plants from which the peat was formed have disappeared in the subsoil. These ashes are used on pastures, but chiefly on clover and lucerne. Their beneficial action can be attributed partly to the sulphate of lime. Their composition is variable; the content of sulphate ranging from 15 to 40 per cent., while they contain nearly 40 per cent. carbonate of lime. They can be used freely—from 20 to 100 cwt. per acre. To obtain the ash in large quantities, as soon as the peat is dry, it is put into stacks and burned very slowly, when about 1 ton of peat will produce 1 cwt. of ash. In Holland they are used in large quantities.

Coal Ashes.

These are chiefly used as an improving agent for heavy clayey ground, which they make more workable, and for low-lying grounds, which they make more permeable. They evidently only operate by the elements which they contain. Coal ashes are much poorer than anthracite ashes, and these only contain 16 per cent. of lime; but they also contain 10 per cent. sulphuric acid, and that is where their use comes in. They contain also 1·5 per cent. of magnesia, 0·5 per cent. phosphoric acid, and 0·6 per cent. potash. Sifted and mixed with garden soil they make it earlier because of their black colour.

Ashes of Heather, Furze, and Bracken.

Heather, furze, and bracken yield an ash fairly rich in potash, heather being the poorest with about

15 per cent., and furze the richest with about 30 per cent. Broom and furze contain as well a certain quantity of phosphoric acid. The presence of broom shows phosphoric acid in the soil. Bracken is relatively poor in phosphoric acid. When the plants are young and not too strong, instead of burning, it is better to bury them where they grow by ploughing in.

Soot.

Soot is the deposit on the sides of chimneys of unburnt particles, driven out by the smoke of our hearths. The more incomplete the combustion the more abundant is the formation of soot—as is easily proved by looking at a lamp. Soot contains potash, and phosphoric acid ; but above all ammonia and sulphuric acid (that is to say sulphate of ammonia) are formed. The composition of soot is very variable, depending upon its origin ; its action on vegetation is due in some cases to sulphate of ammonia, or equally in the case of leguminosæ to free sulphuric acid.

Some soot contains great quantities of potash, and then is suitable for clovers. It also contains from 1 to 3 per cent. of nitrogen. As the quality varies very much, however, it ought to be bought cheaply, or on analysis. It is used for various crops, wheat, and pasture, but above all it is recommended for vegetable culture. It can be used freely in the garden, where, as with coal ashes, its black colour tends to make the soil earlier.

CHAPTER VII

Magnesia and Silica

Magnesia [MgO].

The question of magnesia has been much discussed of late years in consequence of certain trials intended to demonstrate its efficacy as manure. We think that the result of the magnesia in these trials had not been satisfactorily isolated from that of complementary agencies, and magnesia cannot be brought into general use without danger, because we should then have to pay more for kainite, owing to the units of magnesia contained in it. In the trials made the introduction of magnesia produced a very notable increase of crops, including the potato crop, and it also seemed to act favourably on the size and quality of grain. Magnesia is chiefly found in the salts of Stassfurt mixed with potash. Raw kainite contains some chloride of magnesia ($MgCl_2$). Calcined kainite contains sulphate of magnesia in considerable quantities. Chloride of magnesia is caustic and, when spread on growing crops, burns them. Moreover, in sacks it is deliquescent—that is to say it absorbs the moisture from the air and makes kainite difficult to keep. In dolomite magnesia is found in the form of carbonate. It is not advisable to use lime which contains dolomite on growing crops because the lime carbonates more rapidly than the magnesia, which retains its caustic properties for a long time, and injures the vegetation.

Sufficient magnesia therefore can be given to the soil without having recourse to any special manure, which would only increase the price of the crops.

Silica (SiO_2).

Silica is found in many plants. Since, however, when consumed it remains entirely unchangeable in the droppings, it can afford no nourishment to plant life. It therefore is not a manure, and it is unnecessary to give it to plants. Its work consists chiefly in giving solidity and hardness, support and protection, to that part of the plants in which it is always found—near the periphery. It is notably present in grasses, and in cereals, where it is found in the stems, the leaves and the husk of the grain, but never in the region of growth or in that reserved for the embryo. It is silica that makes the hard core and hard underskin sometimes found in pears. It does not appear to be necessary for the growth of plants, and if present in any quantity in sugar beet hinders the extraction of the sugar.

CHAPTER VIII

Organic Manures

Need to ascertain their Relative Value.

Organic manures, including farmyard manure, are of great utility, because in addition to the fertilising substances they contain in a more or less assimilable form, they also give humus, which is indispensable to agriculture and the advantages of which will be shown later. They are therefore very valuable. It is essential, however, to ascertain their relative value before buying them, because some of them really contain very little fertilising matter, and for that reason are scarcely worth the cost of transport. In others the fertilising matter exists in a badly assimilable form. This again lessens their value. Others lose their fertilising matter in storage. There is also a need, perhaps, to take precautions against the possibility of adulteration especially in the *higher priced manures*, and to get a guarantee of origin or of the form in which the fertilising agent are present, if necessary.

They are chiefly used in the maufacture of compound manures.

Organic Manures

Green Manure.

Green manure can be divided into two categories, non-leguminous and leguminous. The non-leguminous are more often sown as catch-crops after wheat. They only collect the nitrates formed in the soil at the end of the season, which would otherwise be washed away. The other manures necessary to their development they evidently draw from the soil. Their utility, therefore, lies in conserving the nitrogen, but they also play an important part in adding humus to the soil and thereby making a good crop possible where the results otherwise would be mediocre.

As non-leguminous green manure turnips or mustard or rape are usually chosen, but spurry, rye, and buckwheat are also used. It is much better to have a non-leguminous green manure than none at all, but recourse to leguminosæ is infinitely to be preferred. While capturing the nitrate formed in the soil, they also take possession, by means of bacteria located in the nodules of their roots, of the free nitrogen of the air and assimilate it, thus accumulating in the stem and the roots of the plants a quantity of nitrogen which is the most valuable manure, and by far the most expensive in agricultural use.

Other deep-rooting green manures fetch up the phosphoric acid and potash from the subsoil. These accumulate in every part of the plant, and when ploughed in are at the disposal of the next crop and much nearer the surface, and so placed that the roots can draw on them abundantly.

Among the leguminous green manures are included red, white, and crimson clover, afalfa, sainfoin, vetches, serradella, and lupins. The exposed portion of clover, afalfa, and sainfoin is too valuable to be used for manure only, and is invariably given to stock. But the stubble and roots generally contain enough humus and nitrogen for a wheat crop without any addition of farmyard manure.

The nitrogen which is found in the roots and the nodules is transformed quickly enough under the action of ferments into nitrate.

The vetches are often used as grazing, but also are frequently ploughed in as green manure; serradella is treated in the same way. They are both sown in the wheat and are extremely useful on most soils.

On soils poor, but not calcareous, yellow lupins should be used in preference. Lupins are of no use as food, but as green manure they are extremely valuable and would enable the greater part of the waste land to be cultivated. They grow so freely that an ordinarily good crop gives to the soil twenty tons of manure. From this one can judge their usefulness in reclamation work where no farmyard manure is available. For this purpose they should be sown with slag and potash.

On light calcareous soil, however, one would use white or crimson clover for preference, buckwheat, rye, turnips, etc., whilst in strong soils vetches, horse beans, red clover, and rape.

This little table shows the percentages of fertilising matter contained in 100 parts in the following green manures :—

	Water.	Nitrogen.	Phos. Ac.	Potash.
Vetches	82	0·59	0·12	0·61
Lupins	80	0·50	0·11	0·15
Clover	79	0·58	0·12	0·43

It is advisable to use green manures on a large scale particularly where farmyard manure is scarce, and also where the regular cultivation of catch-crops is not possible. It should be sown along with the wheat.

If possible it should be ploughed in when the greater number of the plants are in flower, this being the time when they contain the maximum amount of fertilising matter and also the greatest bulk of humus, and when the latter is in the form most easily broken up and assimilated. The manures should be buried some time before the sowing season and should be in process of decomposition before the autumn wheats are sown, because these do not like a soil that is not well settled. Green manures are usually followed by a wheat crop. Pastures converted into arable furnish a cheap green manure and give good crops providing that they are given assimilable phosphates and a little potash.

Farmyard Manure.

For hundreds of years farmyard manure was the only fertiliser employed on the land. It was upon this manure that the restitution depended. We have seen what losses of fertilising matter it undergoes, but in spite of that it is still the manure chiefly used.

In principle it ought to be composed of animal droppings both solid and liquid as well as of litter. But, as we have seen, a great portion of the fertilising matter is only partly preserved or altogether lost. The solid droppings contain the portions of food not consumed and inassimilable, or unassimilated. These contain nearly the whole of the salts of lime and magnesia, the phosphates, and the nitrogenous organic matter which is difficult to digest.

The salts of lime and magnesia and the unassimilable phosphates are not subjected to any loss, but the nitrogenous organic matters under the action of moulds and ferments may lose their nitrogen to a greater or less extent; according to the conditions and to the organic combinations in which they exist, or the stage of decomposition which the manure reaches.

Liquid excrements, as we have also seen, usually contain very little lime or phosphoric acid ; but, on the other hand, present nearly the whole of the potash contained in the food and the greater portion of the nitrogenous matter. The potash being in a soluble form is subject to loss in the drains ; and the nitrogenous organic matter being present in the form of urea and hippuric acid is easily transformed into carbonate of ammonia, decomposing into ammonia and carbonic anhydride, which escape into the air and represent a total loss.

Litter.

Litter only gives to the manure the fertilising matters which it contains ; thus a poor litter such as pine needles, impoverishes the manure, whilst a rich litter, such as pea or bean straw, enriches it, but it also makes the value of the manure vary according to its absorbent properties. Thus peat-moss litter, not rich in itself, can absorb from five to seven cwt. of liquid to the cwt. (of moss), and so forms the best absorbent in use, whilst a cwt. of earth will only absorb half a cwt. of liquid. These two litters have, however, one great advantage over all others, that of retaining the ammonia ; only of course a great quantity of earth must be used in proportion to the peat-moss. Wheat, oat, and barley straw absorb nearly 2½ times their weight in liquid, but oat straw will be chiefly used for fodder, and barley straw has the reputation of being an irritant. On an average one would allow 9 lbs. of litter daily per head of large stock, that representing about 1½ tons per annum.

The straws of leguminosæ, although unfortunately not at all plentiful, make a litter rich in nitrogen, but as they are very rough and coarse they are mixed with other litters.

Variation in Value and its Causes.

Heather is a poor litter, but bracken is excellent.

It can be easily understood that the value of manure varies largely according to the feeding and treatment of the stock. Thus breeding stock appropriate a great part of the nitrogenous matter, which is essential for the formation of tissue, and the phosphoric acid and the lime for the building up of the frame, and give to the litter much less than the grazing stock, which, requiring hydrates of carbon more than anything else, and receiving substantial food, emit far richer excrements.

Dairy stock will not give such a rich manure, because their milk contains a great deal of phosphoric acid and lime, while draught horses and oxen, having no need of further development, but chiefly assimilating the carbonic hydrates and disassimilating the other substances, also give a rich manure.

Farmyard manure differs, further, in accordance with the kind of animal that produces it, and in this respect it is distinguished as "hot" and "cold" manure. That of sheep, for example, is very hot, that of the horse hot. These contain relatively little water and much nitrogenous matter. They are called "hot" manures because they ferment easily and emit much vapour, ripening very quickly, so that their nitrogen is soon in an assimilable form at the disposal of the plants. These manures act rapidly, but their action is not very prolonged. They are specially suitable for cold soils in which they hasten the commencement of vegetation. In the neighbourhood of towns they are chiefly used by market gardeners to make hotbeds in which the temperature has to rise very rapidly and very high, but in which the action cannot be very prolonged because after a short time the temperature falls.

Cattle manure is cold, that of pigs very cold, both containing a great deal of water. These manures ferment and also ripen very slowly. They are best for light lands and those lacking in humus, and if their action is very slow it is also very prolonged. They are of no use for hotbeds because they do not develop a high temperature, but, on the other hand, their temperature, such as it is, is maintained for a very long time. They can be used for warm beds, though not hot.

Keeping and Management of the Dung Heap.

Again, the value of manure depends very largely, one might almost say chiefly, on its conservation and maturing. On some farms, not to be imitated, the manure is carried into the yard, and left exposed to the wind, sun, and rain. The manure dries on the outside, overheats, and is soaked, and this happens over and over again according to the atmospheric variations. It matures irregularly. The rain draws up all the fertilising elements and carries them away. The outside, dry and wet alternately, but never in a condition favourable to ripening, does not undergo much alteration, but loses all the matter it has absorbed. Meantime the interior of the heap ferments, and overheats, white moulds develop and free the ammonia in great quantities, whilst the fermentation transforms the ureas into carbonate of ammonia, which decomposes rapidly, and by decomposition liberates the ammonia, till in the end there is nothing left but the insoluble matters. Futhermore, from the heap of manure a trench or gutter will draw off all the goodness it has contained into a ditch, and so it will be irretrievably lost to the farm.

This way of making manure, which, unfortunately, is not rare, constitutes an unpardonable waste and a grave mistake on the part of the farmer. It ought never to be allowed.

The first step towards improving this defective system lies in the formation of a regular heap well compressed. The second lies in covering the heap with earth, as it is formed. Then comes a platform for the manure with a pit for the liquid manure. Or the manure may be covered in. This is a notable improvement; but the best way of all of making and keeping is in a close-covered place close to the pit of liquid manure. Here no desiccation by the wind even laterally can take place; no violent continual evaporation caused by the displacement of the air, no loss of fertilising matter in the sewer. On the contrary, there will be a regular formation of manure well compressed throughout the mass, without white anaerobic moulds, but formed of brown humus in the presence of moisture and conserving the whole of the liquid manure. Such an arrangement ought to be found on every farm, and the first step every farmer ought to take is the construction of a water-tight manure pit, under a roof. This is the sort of thing that pays, paying immediately, and will have continuous beneficial effect on the farm.

On ordinary farms the general way is to mix the various manures to get an average dressing which can be used all round. No special manure is put aside except for some definite purpose.

The value of manure therefore will vary considerably according to the various factors which may influence it. The greatest difference in its value arises from the way in which it is prepared. Thus a manure carefully made in a shed, well compressed and watered regularly with liquid manure, will be worth say 10*s.* per ton. If so, the same manure made outside but roofed over will be worth from

7s. to 8s., while when it has been left in the open, exposed to air and rain, it will not be worth more than from 1s. to 4s. The difference is enormous and helps to account for many a shortage.

Carting, Spreading, and Top Dressing.

In any case the manure should stay in the shed or under cover as long as possible. Sometimes, however, on large farms it would be difficult to cart all the manure required just at sowing time. A good plan in this case is to cart the manure beforehand to a corner of the field and make a well-compressed heap about 4 to 5 feet high, covered with four inches of earth.

The spreading of manure as a top-dressing is sometimes recommended. That can be best done in winter. Still it is not so advisable as ploughing in because of the possible loss of soluble matter which can be carried off by rain, or drawn up by the sun. In any case this method is better than dividing the manure into little heaps which lie on the land till time of sowing. The fields in which this has been done are recognisable by patches of abnormal vegetation in the places where the earth has soaked up the fertilising matter. Ploughing in may be recommended.

Means of Preventing Loss.

In all manure, no matter how it is made, a certain part, large or small, of the nitrogen is lost between the moment of dropping and maturity. Sometimes this loss is enormous, including more than half, three-quarters even, of the total nitrogen in the manure.

This can largely be prevented. It indicates a waste of liquid manure, and a bad maturing process. But there are other losses of which the farmer does not suspect the existence, but which nevertheless are very important. These losses begin immediately after the emission of the droppings, and include in ordinary cases from 30 to 50 per cent. of the entire nitrogen. These figures represent in England the value of many million pounds annually. Ureas are transformed into carbonate of ammonia, which decomposes into ammonia and carbonic anhydrides. This ammonia—therefore the nitrogen—is lost in the air. To retard or prevent this loss, sulphate of iron has been tried, but it was not satisfactory; then gypsum was tried, but that was not economical; but research has shown that the sooner the droppings are absorbed the less waste is caused. Moss litter can retain much more ammonia than ordinary straw, and dry earth, though it absorbs much less liquid, has the power of retaining a great quantity of ammonia, thus reducing the loss by half.

It has been actually proved therefore, contrary to the theory which was held for a long time, that the custom practised in the north of Belgium of using earth as part litter is an excellent one, and that if it were followed in England it would represent a very considerable source of profit to agriculture. The losses in ammonia continue during the whole course of maturing under the defective conditions we have described, whilst they are reduced to a minimum under the good systems.

It is not necessary, to ensure its goodness, that the manure shall have turned black or that it should have been three months in the manure pit. It is sufficient and preferable that it should only have been macerated and have become dark, but not completely black, and that it has been from eight to ten weeks in the pit. In this way the greater part of the hydrocarbonated matter will be left in it, and the humus will not be destroyed by prolonged fermentation.

On a well-managed farm the loss of nitrogen will thus be reduced to a quarter, or less, while the lime, potash, and phosphate will be recovered whole. So obviously there is no excuse for any one who suffers a greater loss than this. Here is the content of fertilising matters in the chief types of farmyard manure :—

	Water.	Dry Matter.	Nitrogen.	Potash.	Phos. Acid.
Horse manure (Muntz & Girard)	64·9	35·1	0·48	0·84	0·32
Cattle ,, ,,	69·0	31·0	0·57	0·88	0·26
Sheep ,, ,,	66·8	33·2	0·64	1·50	0·40
Pig ,, (Wolf)	72·4	27·6	0·45	0·60	0·19
Rothamstead mixture (Voelcker)	76·0	24·0	0·64	0·32	0·23

Mixed Manures.

Mixed manure can be employed on any crops, and an application of 6 to 7 tons to the acre is recommended, or from 10 to 12 loads. Root crops require more. A very general practice, particularly on strong land, is to give large dressings at more or less regular intervals, especially on root crops, when they are needed. It would be more practical, however, to give the farmyard manure every year in smaller quantities in association with chemical manures. These heavy dressings are neither useful nor necessary except on land that has been exhausted by excessive cropping, or altogether neglected, when they will restore the fertility of the soil. In these particular cases an ordinary dose of manure will give practically no results, since the clay and the humus will absorb and keep for themselves all the fertilising matter contained in it, leaving nothing for the crops.

In light soils repeated applications are not only advisable but necessary. The least practical use to which farmyard manure can be put is to spread it on meadow land, though that is still a common practice. As a matter of fact, nearly the only good it does lies in the protection it gives to the soil. It should be given to pasture only when the soil is shallow or the manure superabundant. Manure as a top dressing is only advisable in gardening where it isolates the soil, thereby retarding evaporation and maintaining the friability of the top soil.

In many districts top dressings are happily disappearing, farmyard manure being advantageously superseded by chemicals. The former, well made, brings fertilising elements to the soil in what is considered assimilable form, but the whole of the nitrogen and the phosphoric acid are not absorbed even in the second year. The action of farmyard manure is not confined only to that of its fertilising elements, but the humus it contains increases the retentive power of the soil, as will be seen in the chapter on that subject, with regard to ammonia, potash, and phosphoric acid. It mellows the land, or renders it more compact, as the case may be, regulates the aeration, helps the permeability, and makes it more workable.

Organic Manures

For strong lands preference should be given to slightly matured manure, but for light lands it should be well ripened.

In fixing the price of manure and regarding its value as an improvement, the value of its fertilising matters is estimated as follows. The price of the nitrogen is rather less than that of the nitrogen in nitrate ; that of the potash is equal to the potash in chlorure of potash ; and that of the phosphoric acid is equal to that of slags.

The quantity of farmyard manure varies according to the feeding conditions, the kinds of animals, the litter, and the housing. In prolonged (permanent) housing, however, the production can be calculated as 9 cubic tons for a horse, 13½ for a cow, ½ for a sheep, and 1⅓ for a pig ; taking the average weight of a cubic ton as about 10 cwt. or a little more.

Urine.

Urine is liquid animal excrement, and is produced in great quantities on a farm. Both its quality and quantity vary according to a number of circumstances. It always contains in solution disassimilable nitrogenous products and soluble mineral salts derived from digested food and waste of tissue. In it is found the greater part of the potash and nitrogen contained in the food. In the case of herbivorous animals the urine is alkaline and does not therefore contain phosphates, whilst in that of swine they are found in a considerable quantity. The quality of urine differs strongly according to the breed of animal. Thus that of pigs, which contains nearly 97 per cent. of water, is scarcely worth the cost of transport, while that of horses, containing not more than 90 per cent. of water, is much richer. Here are some averages :—

Animal.	Water.	Nitrogen.	Phos. Acid.	Potash.
Sheep	88·5	1·30	0·01	1·80
Horses	90·0	1·50	a trace	1·00
Cattle	91·0	1·00	"	1·35
Pigs	97·0	0·50	0·15	0·70

The quantity is, of course, largely dependent on the nature of the food ; thus, cows fed on mangolds give twice as much as those fed on hay. Horses fed on young clover give much more than those kept on a dry régime. The urine of pigs and cattle is comparatively abundant, whilst that of horses is much less so, and that of sheep quite insignificant.

In young animals, also in milch cows which use a part of their food for the replacing of living tissue or for the production of milk, it is not rich, whilst that of grazing beasts, only making fat, which does not contain fertilising elements, is very rich.

Draught horses and oxen also produce a rich urine, because they do not transform anything into increase of organic matter, and their work only calls for hydrocarbons. A food that is richer in nitrogen and more digestible will give a better urine, because the albuminoids appear in it almost complete. To get a liquid manure that will be useful for every purpose it is necessary to blend the various urines.

Nitrogen is found in urine chiefly in the form of urea and hippuric acid. When applied to the soil these compound nitrogens are rapidly transformed into matter assimilable by the plants, so that the effect of an application of urine will only be felt during one season.

The best way of using it is to absorb it in farmyard manure, which will be considerably enriched thereby and form a complete manure. But the urine is often too abundant to be completely absorbed. It is therefore carefully collected in impermeable tanks, and watered on to the manure, which it helps to mature. Unfortunately, on many farms it is altogether neglected ; and allowed to flow away into the drains, causing serious loss which must be replaced by bought manures if the farm is not to become impoverished. This is an unpardonable waste.

The urine used in watering the manure heap is itself further enriched by the soluble potash of the manure, the few phosphates and the portion of nitrogen rendered soluble in the course of the transformations which the manure has undergone during the ripening process. Being alkaline, it (the urine) dissolves part of the humic matter which gives it its dark colour. In itself, solid farmyard manure is far from being complete, and it is necessary to use with it a corresponding proportion of urines, which are then called liquid manure.

On all good farms, that is to say practical farms, the liquid ought to be collected directly after emission or after it has passed through the manure. It ought to be stored close to the manure heap so as to be easily handled in watering in order to prevent white mould making its appearance. It thus will help in the formation of manure and will play an important part on the farm. Care must be taken that rainwater or the drainage from the soil in winter never get mixed with the urine, because if this happens very often it will not be worth the cost of transport. It is evident that farms where the waste of manure is accepted to the extent of not troubling about the liquid manure, cannot be called well-managed.

Liquid manure is often employed on pastures, or as a dressing for wheat in spring time. Used simultaneously with phosphates, it is good for turnips as catch-crops. As a dressing it should be applied in rainy weather, but never in dry sunny weather, because then it is caustic. It is much better to choose the right time for applying it than to dilute it with water, for this simply increases the cost of transport while adding nothing to its usefulness.

It should not be used just before or during the winter, because at this season a portion of its fertilising matter will inevitably be lost. It can be applied before sowing, with nearly all kinds of crops, and it is largely used in market-gardening. It is also applied to orchards in June. At this season it is particularly useful in assisting the formation of flower-buds which will appear soon after, and the practice will have an influence on the regular production of fruit.

Liquid manure is richer than urine because it also contains the soluble properties contained in the evacuations and in the litter.

It forms a valuable liquid manure which can be spread on practically any fields in the spring and on land intended for catch-crops.

Guano.

Formerly what was understood by Huano-dung in Spanish was the deposits of excrement of sea-birds which lived on fish, the refuse of their meals, and occasionally the bodies of their own species, accumulated for ages on the sea-coast or in the islands of Peru, in a hot climate and in rainless regions.

These deposits were found chiefly in the Chinchas, a group of uninhabited islands in the Pacific, not far from the west coast of South America. The Incas always employed guano in their agriculture. Van Humbolt was the first to bring it into Europe in 1804, but it was not till 1840 that the first cargo was unloaded in England. This was the first real commercial manure.

The results from this manure were so unexpected and so marvellous that five years later 300,000 tons were imported. The demand grew with its popularity, and so great were the exportations that at the beginning of the seventies the rich natural deposits which attained in places a height of from 20 to 25 yards, and were estimated at 10 million tons, were unhappily exhausted. It was an ideal manure of sustained and rapid action. It contained from 14 to 16 per cent. nitrogen, so that it was as rich in nitrogen as nitrate; from 12 to 14 per cent. Ph. Ac., equal to 27 to 30 per cent. tribasic phosphate, making it as rich as many superphosphates; and from 2 to 3 per cent. potash.

Part of the nitrogen was soluble in water and directly assimilable by plants, the rest was in a form easily converted into assimilable combinations. There was a little in the actual form of nitrate, and the rest was urate and phosphate of ammonia, etc.

A quarter of the phosphoric acid was soluble in water, the remaining three-quarters being in a tricalcic form, but certainly in a state of assimilability comparable to, if not better than, that of bones.

The guano of the Chincha Islands was exhausted, but the reputation of its value was firmly established. Hence guanos of poorer quality were imported, coming from many parts of Peru, Bolivia, Colombia, Patagonia, the coast of Australia, South-West Africa, and the Pacific Islands. These were not so old as the first, therefore not so concentrated, and under a less assimilable form, coming some from regions of little rain, others from more rainy regions; mixed with feathers, refuse of fish, and bones of birds—when they were called *feather guano*—but diminishing progressively, sometimes rapidly, in value. However, people still paid a high price for them, especially when one considers that in the meanwhile had appeared on the market (in small quantities, it is true) the Augamos guano which contained close on 19 per cent. nitrogen.

It is comprehensible that in hot regions with frequent rain nitrogenous organic matter tended to disappear, also the soluble phosphates and a good part of the potash, consequently concentrating the tricalcic phosphates. This was called then phospho-guano.

Sometimes these phospho-guanos, from which the organic matter had disappeared, became hard and formed a species of rock ; they were then called *crust-guanos* or *guanorites.*

There are actually on the market preparations called guanos which are made of blood, flesh, the bones of animals or of fishes, and fish refuse. Apart from this there are certain flesh guanos made from the refuse of extracts of meat works ; these are "made in England," and are called blood or fish guanos. Unfortunately, they are generally too dear.

Farmers appear to have the impression that the strong odour of ammonia given off by some guanos, the moist guanos from Bolivia for example, is a proof of their superior value. On the contrary, it is a sign that they are in the process of losing their ammoniacal riches. Good guano ought to have the brown colour of burnt chicory ; it ought to be easily pulverised and to contain no particles of sand or of gravel, but to be smooth to the touch and without a strong odour.

The composition and value of actual guanos vary considerably, and, owing to their well-established reputation, they are often sold at a price in excess of their value. In order to maintain this reputation, attempts have been made by means of these poor guanos to make a manure as concentrated as the Chincha guano, by mixing it with nitrate, sulphate of ammonia, organic nitrogen, phosphates under the form of superphosphates, also insoluble phosphates, etc., and of potash—these are called fortified guanos. Their value depends largely upon the form of manure to which they are added. They have in every case the fault of artificial manures, that they cost too much. Their use is not advised, because the farmer can always find the fertilising matters they contain at a more advantageous price.

But a real and notable improvement in this poorer guano was to treat it with sulphuric acid, [H_2SO_4], so as to fix the nitrogen, which is lost in the decomposition of the carbonate of ammonia in the form of sulphate of ammonia, and to transform the insoluble tribasic phosphates into soluble and directly assimilable superphosphate. This is done on a large scale, and the results are called dissolved guano.

Compared to the original guano, this guano is of equal content, but of much superior value. Its action is more rapid and more energetic, but it will not be felt for more than a year. The units of fertilising matter can be bought at the price of the type units, but should not be dearer.

Good modern nitrogenous guano is the fresh dung of birds. Its value varies considerably, according to its content of nitrogen and phosphoric acid. The proportion of potash does not change much. It contains from 2·5 to 11·5 per cent. nitrogen, with an average of more than 4 per cent., corresponding to 3 to 14 per cent. of ammonia, 15 to 40 per cent. phosphate, in the tricalcic form [$(CaO)_3P_2O_5$], 2 to 4 per cent. potash. It is nearly always bought too dearly, for its value is not equal to that of dissolved guano.

Phospho-guano only contains 1 to 3 per cent. nitrogen, but may occasionally contain 65–70 per cent. tribasic phosphate. Neither in nitrogen nor in phosphoric acid has it the value or the assimilability of good guanos. It is a slow and expensive manure.

Fish Guano.

The manufacture of fish guano is one of the best industries from the agricultural point of view, and as long as it can be carried on economically, it ought to be encouraged. It is, as a matter of fact, returning to the land that which the sea has taken from it. Every river, every stream, every rainstorm carries down to the sea soluble fertilising elements, washed out of the earth. It is at the expense of the fertilisers which are taken from the soil that the fish of the sea are multiplied, and the sea never returns what it has taken.

The question ought to be considered, therefore, of the formation of a fishing-fleet working for the guano manufacture, so that it should be no longer a minor industry. This would allow of much cheaper production. For the objection to fish manure is that the demand is much greater than the supply. Hence, in accordance with the natural law, prices are so high that it is not possible to recommend its purchase, since the manure would not repay the outlay.

There are other manures in which the fertilising units are equally good, and much cheaper. Before it can be a profitable investment for the farmer, the output must be increased or the price lowered.

The fish guano industry received a great impetus in 1870, when the rich beds of guano of Peru were exhausted.

It is found on the market under various names :—

1. Fish guano. 2. Fish manure. 3. Fish powder.

It constitutes what is known as a complete manure, containing nitrogen, phosphoric acid, and potash, though the latter is only in small quantities.

The guano is obtained by drying the fish and afterwards reducing it to powder.

Fish manure varies in quality and composition, according to the material from which it is obtained, the method of preparation, and the impurities found in it. If made from salt fish, it contains a great deal of salt, which, not being manure and taking the place of that which is, lessens its value. If the fish waste includes the livers, which are oily, the value of the manure is again diminished, because the conserving qualities of the oil hinder the decomposition of the organic matter and retards its assimilation.

Herring Guano, still called Guano Powder, is oily throughout, and of inferior quality to that obtained from non-oily fish, known as White Fish Guano. However, the oil, having no value from the agricultural point of view, makes the manure poorer than its drawbacks warrant, for it must be present in considerable quantities to retard the decomposition of organic matter for any appreciable time; 3 or 4 per cent. is not harmful from this point of view.

Guano made of waste, especially if it is made of bones, can contain great quantities of phosphates; sometimes, if it is made exclusively of bones, representing as much as 50 per cent. phosphate, and about 4 per cent. nitrogen.

When the waste consists more especially of the flesh of the fish the proportion of phosphates diminishes, and that of nitrogen increases. The flesh of fish, like that of other animals, contains about 15½ per cent. nitrogen, and only a little phosphoric acid, while the bones contain many phosphates and a good quantity of nitrogenous organic matter. Guano made by drying over an open fire loses a part of its nitrogen during the process.

Generally in well-managed works the preparation is made in closed pans, and there is no loss. In such places the oil is extracted more or less perfectly to be used in the manufacture of soap.

Some makers dry the fish insufficiently, and then the guano can contain as much as 35 per cent. water. This water not only uselessly takes the place of the manure, which is consequently impoverished, but when the guano is stored causes loss of nitrogen in ammoniacal form by fermentation and fungi.

Fish guano rarely contains any great quantity of silicate matter, when present in any quantity it denotes impurity.

It is obvious, then, that fish guano varies considerably in quality. Its purchase needs close attention, and it must never be bought without analysis, because its value can vary from single to double or even more, and will do so especially according to the proportion of nitrogen which is found in it. The price of the units must be compared with those of other commercial products, and purchase only be made when the prices are found to be favourable.

Here are the approximate contents of good average fish guano.

Average Fish Guano.

Moisture	17	per cent.
Organic matter	60	,,
Phosphoric acid	7	,,
Lime	7	,,
Magnesia	4	,,
Various	5	,,
Contains Nitrogen N	7	,,
Corresponding to Ammonia NH_3	8½	,,
Corresponding to tribasic phosphates of lime	15½	,,

The finer the guano, the more it will be worth, but in any case the value of the unit of nitrogen is notably less in this guano than in the nitrate of soda ($NaNO_3$), or in sulphate of ammonia [$NH_3(H_2SO_4)$]. The unit of phosphoric acid is of equal value to that of bone phosphate, but never has the value of the phosphoric acid in the superphosphates, which are monocalcic or dicalcic phosphoric acid. The potash is equal in value to commercial potash.

The guano of oily fish will be bought by the unit at a slightly lower rate than that without oil. If the prices are equal, preference should be given to the latter. Fish guano is never a manure of rapid action, because the nitrogen only exists in a form of organic combinations, which are slow to decompose and become assimilable. The same remark applies to its phosphates, which are in a tribasic form. On the other hand, it is not lost in the soil, and can be applied a long time in advance, when its action will be progressive and sustained. It is, therefore, a slow manure, which will make its action felt for many years, and from this it has partly got its reputation. It is precisely this feature, however, that should make it less valuable, because each unit of fertilising matter can only be absorbed once by the plants, and since all the units of the manure are paid for in advance, one has to invest one's money in the soil a long time before any returns are obtained in crops.

The proportions of the nitrogen and phosphoric acid are very variable and are rarely well balanced. Potash must always be added, and likewise nitrogen and phosphoric acid. The manure should be applied to root crops, preferably before winter. It should not be used for pastures, because the nitrogen would be wasted by the washing away of the organic matter.

The colour is blackish-brown, and its texture renders it eminently suitable for all mixtures. The makers of compound manures employ it on a large scale. The mixture is very easy to make, and would be a good one if it were not too dear.

The manure called Equalised Fish Guano has received an addition of potash and soluble phosphoric acid.

Bat Guano.

This guano, which forms another interesting source of manure, comes from the dung, refuse, and bodies of bats accumulated in caves since time immemorial. It is sometimes found in great quantities. Being formed under shelter, the fertilising materials have not been washed away by rain, but in some places infiltration has caused a partial loss, and then, the humidity favouring fermentation, part of the nitrogen has been given off in the form of ammonia. This explains the difference in their quality, and is a reason why they should only be bought on analysis. In any case, they are a very active manure, better generally than modern guanos. Here is their average composition: 5 per cent. nitrogen; 9 per cent. phosphoric acid.

They are found in many places—Cuba, Venezuela, Algeria, Spain, Sardinia, Madeira, and elsewhere.

Blood.

Animal blood, being the vehicle of all the materials assisting in the constitution of the body, contains all the elements of which the body is composed—that is 80 per cent. water, 2·5 to 3 per cent. organic nitrogen, 0·55 per cent. of phosphoric acid as tricalcic, and 0·5 per cent. potash [K_2O]. Consequently it is chiefly rich in nitrogenous matter. It can be employed in a fresh state as long as it is not spread in large quantities on growing plants, which it would burn.

As a matter of fact it is rarely employed in a liquid state, because it cannot always be used immediately, and if kept, the nitrogenous organic matter becomes tainted and emits a nauseating smell. When it is obtainable in small quantities it is better to absorb it in some kind of neutral material, or preferably to add it to leaf compost, when it will have a real value.

But when it is obtainable in large quantities it is preferable to convert it into

Dried Blood.

There are two methods of making dry blood, but the richness of the product obtained does not vary much. First the blood may be allowed to coagulate and the fibrine which can be put to another use is separated. Then the clotted blood is dried, when it contains about 10 per cent. nitrogen, a little phosphoric acid [P_2O_5], and a little potash [K_2O]. Afterwards it is pulverised and applied directly to the ground, or employed in the manufacture of composite manures.

By the second method the fibrine is removed before the formation of the blood clots and treated separately, but it is added later to the defibrinated blood before desiccation.

The dried blood is in the form of black or brownish grains of bright fracture. It can also be pulverised, in which state it is perhaps a little easier to spread; this form is, however, less advisable, because it easily absorbs the moisture of the atmosphere. This absorption increasing its weight, but diminishing the percentage of nitrogen, does not, however, represent a real loss, because being bought by the sack the extra weight is immaterial, while the produce is bagged sufficiently soon after the manufacture of the manure to avoid waste; but it has been observed that, after having absorbed moisture, the dried blood throws off its ammonia, and this means considerable loss. Also pulverised dried blood may be easily adulterated, nitrogenous organic matter, difficult to assimilate, sometimes being added. Its purity should be guaranteed.

Dried blood contains normally about 13½ per cent. water. It should never be bought except under guarantee of analysis, because the amount of nitrogen can alter so considerably between the moment of manufacture and that of delivery.

Dried blood contains from 10 to 13 per cent. nitrogen, sometimes 17 per cent.; phosphoric acid as tricalcic 1·10 to 3·25 per cent.; potash [K_2O] 0·6 to 0·7 per cent. It is an organic nitrogenous manure of rapid action, because under the influence of bacterial fermentations the organic nitrogen is converted first into ammonia and then into nitric acid—hence the usefulness, or even the necessity of lime in the soil. If lime is not present naturally it must be introduced, so that the operations of transformation can be facilitated and the nitric acid quickly converted into nitrate of lime.

Our opinion is that too high a price is often paid for dried blood, and that the different blood manures, though they may be good, are not always worth what is asked for them.

The value of the unit of nitrogen which the material contains in its pure state is a little inferior in value to that of nitrate of soda and sulphate of ammonia, but it is comparable to that of guano of Peru.

Dried blood is freely employed for such crops as corn, hops, turnips, mangolds, or even for pastures, and, in the colonies, for sugar cane and coffee.

Organic Manures

Pigeon and Poultry Dung.

This manure is not generally plentiful. There are only a few poultry keepers and pigeon fanciers who could supply it, and that produced on the farm is very often neglected. It is a strong manure, which ought to be collected carefully and can be applied with great advantage to the garden. Properly diluted it makes a liquid manure which gives excellent results both with vegetables and flowers.

Pigeon dung is richer in nitrogen than poultry (with which are naturally included turkeys, geese, etc.), and contains from 1 to 3 per cent. nitrogen and from 2 to 3·25 per cent. phosphoric acid as tricalcic. Where it can be obtained in any quantity, it should be given in preference to beetroot and drumhead cabbage, but not to leguminosæ.

Town Refuse.

This is collected by the scavengers, and comprises the sweepings of roads and market places, and the contents of dustbins.

In it are found the droppings of horses, straw, leavings from meals, vegetable refuse, fish unfit for food, cinders, house sweepings, paper, bricks, old mortar, broken glass, bottles, tins, sand, etc.

The value of town refuse varies considerably according to what it contains, according to the quarter from which it comes (the rich quarters giving the best results), and also according to the season, winter producing chiefly cinders, and summer vegetable waste. In a green state it constitutes a slow manure not to be greatly recommended, unless its price is low. But when it has been screened in a heap, so that it has begun to decompose, its value is considerably raised. It must be cleansed of objects likely to hurt or hinder the crops. That is why it is necessary to go over the fields where town refuse is spread with a basket and collect these foreign substances. As it very often contains various seeds, it should only be applied to cleaned crops ; also it could be used in market gardens on the outskirts of towns where the cost of transport is not high. On the spot where it is bought on waggon or boat, the price should not be more than one shilling per cubic ton. Very often it will not be worth even as much as this if it has to be carried any distance.

Sewage.

This is the matter passed off to the sewers of towns, collected in reservoirs and treated in a manner differing according to the system adopted.

It includes human excrements, domestic sink water containing animal and vegetable waste, slops, blood from slaughter houses, stable urine, street flushings which contain the droppings of animals, the rubbish of markets and workshops, and the dust formed by the wear of the materials of which the roads are made.

All this is turned into large cement tanks, and allowed to subside, and the liquid on rising is drawn off into another tank, and these decomtations are continued until the residue deposited has become quite insignificant. The deposits are treated in turn. They contain a great deal of water, but they are raised and allowed to dry and then converted into powder, or sometimes after the addition of lime they are passed on into filter presses in which the water is expressed and the solid matter compressed into cakes. This sewage from which the greater part of the soluble constituents has been taken still contains fertilising matter to be employed with success, in triennial applications, on sandy soils where farmyard manure would be needed. Under these conditions the fatty and soapy matters which if used regularly and abundantly would be an obstacle to the aëration and the permeability of the soil will, in the time, be destroyed. The price of one shilling a ton at which it is sold in some places makes its use worth while.

Seaweed.

The use of seaweed is confined to the sea coast, more especially the west, but as the English coast line is of great extent, it is nevertheless of some importance. It is derived from two classes of marine plants—the genus Fucus represented by the species which grow in the tract lying between high and low water, which are much the poorer as manure, and the genus Laminaria to which belong the submarine plants which are brought up by the tide and left exposed when it recedes.

Seaweed, although really a complete manure containing side by side with humus the different fertilising elements necessary for crops, does not, however, contain them in suitable proportions. It is poor in phosphoric acid, and not sufficiently rich in nitrogen, but it is rich in potash, and so rich in chloride of potash (KCl) and soda ($NaCl$, common salt) that these chlorides may be a positive hindrance to the crops.

Seaweed ought not to be used continually on the same ground, but alternately with farmyard manure, or better still in conjunction with equal quantities of farmyard manure. This would allow the rain water to carry away the excess of chlorides in question, without permitting them to do any harm.

Being too poor in phosphoric acid all seaweed manure ought to receive reinforcement of this manure. Then it could be used advantageously for clover and potato crops, but for the latter an addition of sulphate of ammonia and nitrate of soda ($NaNa_3$) will be required, while on mangolds an addition of nitrate of soda, given in preference in two lots, is necessary. The use of seaweed brings up the clovers on pastures as do all potassic manures.

It is not recommended for turnips because the phosphoric acid cannot be assimilated quickly enough, and also it contains too little of it for crops of this kind. It is less rich in nitrogen than farmyard manure, and what it possesses is not comparable to that of farmyard manure, because it is present in a form very difficult of assimilation. It is therefore a slow fertiliser. After a little time in the soil it loses a great part of its bulk. The large quantity of water it contains makes it unsuitable for transport to any distance.

Here are average contents of its principal constituents derived from about 10 analyses :

	Water	75 per cent.
(1)	Organic matter	20 ,,
	Phosphoric acid	0·25 ,,

Corresponding to tribasic phosphate of lime ..	..	0·50 per cent.
Potash	..	1·05 ,,
(1) Content of nitrogen ..	..	0·44 ,,
Corresponding to ammonia	..	0·53 ,,

Leather Waste.

This is made by reducing old skins and the waste made by saddlers, shoemakers, curriers, and bookbinders to a fine powder. The waste is treated with steam, or baked, and then ground. The value of this leather waste lies theoretically in its organic nitrogen, since phosphoric acid [P_2O_5] only exists in insignificant quantities. It contains about 5·5 per cent. of nitrogen, but even although reduced to a fine powder this nitrogen lies in the soil an indefinite time, and is practically unassimilable. It is an asset which cannot be utilised, so that its manurial value—as experience has shown—is insignificant.

Unscrupulous makers of chemical manures use it to adulterate their goods, but leather waste ought not to be employed as manure, and manure containing it ought not to be bought. Its presence in chemical manure may be detected by means of a microscope.

Refuse of Skins.

These waste products of the skinner's industry connected with hares, rabbits, etc., come from Germany, and contain many feet which, not having undergone any preparation, will make a manure of very slow action. Since they contain small bones the tricalcic phosphate, which is not very considerable, only becomes assimilable after some years. The uncleaned waste skin also takes a long time to decompose. This is why they are good for sandy soils intended for practically permanent crops, which exclude the possibility of administering fresh supplies of organic matter to retain the humus. They should be applied in the year the plantation is made, and previous to that in quantities of about 8 cwt. of skin waste to the acre in addition to farmyard manure.

In subsequent years liquid and chemical manures should be given. The skin waste will operate for three or four years in preventing the destruction of humus. Where it is available it may be used, as from practice we know that under certain conditions it is extremely useful, and with its help profitable nurseries may be established in sandy soil. This shows that under certain circumstances one is justified in employing manures of which the organic matter is of slow decomposition.

Wool waste could be employed in the same manner. Cotton waste does not contain any nitrogen.

Nitragin.

In the nodules of their roots the leguminosæ have colonies of nitrogenous bacteria. These bacteria, without differing essentially in themselves, are, however, so much more active according as they are adapted to such and such a variety of leguminosæ. That is why cuttings of nitrogenous bacteria were commercially prepared for each variety. It was sufficient to dilute the culture, and sprinkle the soil with the solution. This operation was called

" Inoculating the Soil." Sometimes also the seed was soaked in the solution, in which case the soil was not sprinkled with it.

Those who believed in inoculating, however, often contented themselves with taking one or two cartloads of earth from a field containing a certain crop—say clover—and spreading it on a field which they intended to crop in the same way, and good results were obtained.

CHAPTER IX

Improving the Condition of the Soil

After the manures come the improvements. Obviously here we shall not refer to such improvements as draining, etc., but only of those which represent direct *additions* to the soil. We will confine ourselves, therefore, to improvements, first calcareous, second humiferous.

A soil without humus is infertile ; with too much it is acid. A soil without lime in it cannot develop nitrification and its crops will be poor and lacking in quality. When there is an excess of lime it burns the humus, wastes the nitrogenous organic matter, and renders the soil sterile. It is in this that the danger of using too much lime lies. Humus and lime are two indispensable improvements which must be constantly renewed because they are constantly destroying each other in making themselves useful. They constitute the reactives of the soil which may be regarded as a great laboratory. But they must both be present in the right proportions. There must not be an excess of the one or the other, because then they would be injurious. There must be plenty of both, but in good proportions, and that is what we have to ensure. It is to these two improvements that we are indebted for the possibility of reclaiming much land that without their aid would be uncultivable.

The *rôles* played by the two improvements are very different in their effects, so that we shall have to discuss them separately. Let us first examine the calcareous improvements.

Calcareous Improvements.

There are many calcareous improvements. Their action varies, evidently, according to the chemical form of their constituents, the proportions in which these are encountered, and the soil on which they are employed.

Among them lime is the most important. After it comes limestone, chalk, gypsum, etc., coal ashes, turf ash, etc. We will treat each of these substances separately, establishing at the beginning, however, a well-defined distinction between lime and the carbonates of calcium or limestone, because these frequently give rise to confusion.

Although derived from carbonate of calcium ($CaCo_3$), caustic lime (CaO), whether quick or slaked, has very distinct and important properties which the carbonate does not possess, and which make its value, whilst the lime becoming recarbonated in the soil very rapidly acquires the properties of limestone. It is obvious that we should not pay the cost of burning lime where limestone will suffice, but, on the other hand, we should not apply limestone when lime is necessary.

Thus when wishing to destroy rushes one would use lime.

In soils where free acids are encountered in considerable quantity—such as peaty soils—lime would be used to absorb them. It acts very rapidly and thoroughly; for while limestone can neutralise acetic and humic acids, for example, only lime is able to neutralise carbonic and tannic acids. Lime alone is capable of transforming the organic matters of the vegetable mould and of producing ammonia (NH_3) from the nitrogenous organic matter. It is thanks to these two capacities that we are able to conquer waste places, acid soils that are too humiferous, and especially waste soils of granitic origin.

Its use generally produces unforeseen effects, because the lime hastens the disintegration of alkaline silicates, freeing the potash and placing it at the disposal of the plants. We have said that when lime has done its work it does not remain in the soil as quicklime (CaO), but is transformed in proportion to the extent of its action. A great part thus becomes carbonate of lime. This is very important, because quicklime, in spite of the services it renders, will become harmful and prevent the soil from enjoying the advantages which it had procured. Thus lime impedes nitrification, or stops that which is taking place, whilst limestone not only helps it but is indispensable. To these qualities are due some of the varying results obtained by their use. It is calcium carbonate which gives to the nitric ferment the CO_2 which it needs, and which moreover neutralises the nitric acid as it is formed. Hence without calcium nitrification ceases.

In the chapter on phosphates we see, *à propos* of the reversion of phosphates, that the soluble phosphates are rapidly indissolubilised in the soil by becoming insoluble phosphates of Ca, which practically prevents their loss by drainage. But on the other hand limestone promotes the solubilisation of phosphates of iron and aluminium already existing or formed at the same time as the insoluble phosphates of Ca. The water charged with CO_2 penetrates the soil attacking the insoluble limestone and rendering it soluble in the form of bi-carbonate of calcium. (This soluble calcium forms by evaporation the stalactites and stalagmites of caves.) But in solution it possesses one important property. It is capable of coagulating clay. Clay swells in water. The soluble carbonate coagulates it and these clayey calcareous coagulum facilitate the circulation of water in the soil. This enables the soil to dry more rapidly. Freed of its excess of water the earth is much easier to work and much earlier in season. This fact is greatly appreciated in stiff clayey country where the spring can be greatly retarded because the moisture makes the ground too sticky.

With regard to humus we also see that the limestone coagulates the humic acid and that with this the lime forms humates. We know too that limestone has the power to enable humus and clay by capillary action, to fix the manures and to transform them into carbonates, thus preventing the prevalence of ammonia, potash, and of phosphates. The lime, while waiting to be transformed into carbonate which encourages nitrification and consequently the production of nitrate, has the advantage of freeing the ammonia, which is immediately accessible for the plants.

In many places it is sufficient only to apply lime to the soil to get a crop of wheat where formerly such a thing was impossible.

Lime (CaO).

Lime comes from the calcination of limestone, which is more or less pure calcaire ($CaCo_3$). By calcination the carbonic anhydride [CO_2], commonly called carbonic acid, is expelled, and what remains (CaO) is quicklime. So many lime kilns are still used in England that it is unnecessary to describe their working. Limestone is found in many parts of England. It is easily recognised, because under an acid (vinegar) it effervesces. This test is particularly striking if chlorhydric acid is used. The purest limestone is obviously the best, because it will give the most lime. Lime is white when the limestone is pure. In this case it swells considerably with water, and the best lime gives 95·97 per cent. of lime. Less pure limestone, containing clay, is not good. The lime derived from it has the property of hardening under water, and gives hydraulic lime, which is not suitable for agricultural purposes. It contains 70 per cent. of lime. Siliceous lime is poor, only swelling slightly, and of a grey colour. It contains more than 70 per cent. of lime. Lime obtained from calcareous dolomites is brown or yellow. It is very efficacious, but perhaps more or less injurious according to the quantity of magnesia it contains. Lime having a greater affinity for the carbonic anhydride and other acids, the magnesia may retain its caustic properties for a long time, or else its caustic action on plant life is more harmful.

This lime contains from 55 per cent. to 65 per cent. of lime, and about 25 per cent. of magnesia. Lime can also be obtained by burning the shells of molluscs, etc., when they can be found in sufficient quantity.

Basic slag forms a good source of agricultural lime. It contains, as we have seen, besides phosphoric acid, about 50 per cent. of lime, of which 3 to 5 per cent. are free. In many soils this lime represents a part of the value of the slag. A dressing with slag will give the soil a small dose of lime, but very often quite sufficient.

Good quicklime should be in blocks as large as possible. It should be white, and ought to be entirely burnt, allowing very little waste when finished. It should be made from the purest limestone obtainable. When plunged in water for a couple of minutes and withdrawn it ought to disintegrate completely and rapidly, throwing off a great deal of vapour and swelling considerably. In large lumps it cannot be slaked during transport, and still less carbonated, in which case it would have lost a great part of its value.

Lime must therefore always be fresh. The waggons in which it is carted ought to be covered, so as to shelter it from CO_2, from rain and atmospheric moisture. Slaked lime is easily carbonated. Then it no longer has a caustic action on organic matter, and can no longer directly neutralise the acids in the soil. The two great qualities which make the value of the lime will then be lost. Moreover, the finer the lime the more will it be carbonated, since a greater surface will be exposed to the influence of the carbonic anhydride. In large blocks this surface obviously will be reduced, being practically nil in good lime. The finer the lime is pulverised the greater will it be, and in ground quicklime, which has been stored a long time, the carbonisation will be almost complete.

Lime must be slaked on the ground where it is to be used. To ensure this it should be put in small heaps on the field, about seven yards apart each way. They must be covered with earth to exclude the air. It is essential that this is done before the lime should be slaked, which will be accomplished in from two to seven days, sometimes more, by the water in the soil. The lime is then reduced to a fine powder and uniformly spread with shovels. After spreading it is ploughed in at once.

Lime is an essential plant food, and soils that are naturally poor or that have become impoverished, will never give good crops of clover, for example, which at harvest contain about 45 lbs. of lime to the ton. But most soils contain sufficient to satisfy the requirements of the plants. On the other hand, lime taken from the soil is practically returned in the manure, because the cattle do not retain the greater part of it, and no loss takes place in the manure. We can then very often dispense with lime dressing or, in any case, only apply it in small quantities. Thus slag manures will be more than sufficient to supply all that is required, and even more since 1 cwt. of slag often contains more than 50 lbs. of lime (50 per cent., or thereabouts).

But lime ought not to be regarded so much as a manure, but as an improvement, and it is in this capacity that it renders enormous services to agriculture, in which very often it plays a part as important as, even more important than, manure. There are soils, of course, to which it is not necessary to give lime; there are others in which its use would be dangerous; but not to employ it at all under any form, on the pretext that the soil generally contains sufficient, is a great mistake. On the other hand, we must guard against its abuse, for it has been abused terribly in times past, so much so as to give rise to two dictums—inexact it is true: "Lime enriches the father and impoverishes the son"; and again, "Lime once and make a fortune. Lime twice and lose it." Well! in either case the blame ought not to be put on the lime, but on the person who has abused it. It would be better to say, "When lime has impoverished the soil it is because the farmer does not know how to use it." And when one hears of applications of four and five tons to the acre, sometimes even of seven to ten, one is not astonished at the harmful results.

Heavy dressings on land under ordinary cultivation ought to be avoided. The very conspicuous and rapid action of lime has given it a vogue, and has led to the practice of giving it in large quantities. But in so doing the farmer is really killing the goose that lays the golden eggs—in other words, he is destroying the humus in the soil. Much, however, as we condemn this abuse of lime, we certainly recommend its reasonable use.

But to be able to apply lime with a knowledge of the subject one must understand the part it plays and the services which it renders, and on that knowledge one must base its use and avoid its abuse.

The use of lime must always be combined with that of potash and assimilable phosphates, because, a great quantity of nitrogen being liberated in the form of ammonia by this means, a tendency to vigorous vegetation will be promoted, and all the necessary elements being present in sufficient quantity there is no loss of nitrogen as long as the dressings of lime are not exaggerated.

On the other hand, tribasic phosphates, whether mineral or animal, must not be used at the same time as lime, because the lime, neutralising the acids in the soil, makes them powerless to act on the insoluble phosphates, since it is the acid which, by making a combination with one or two bases, renders the phosphates assimilable.

In acid soils nitrification is not produced, unless the acidity is first saturated with lime, whilst too much lime hinders the progress of nitrification. When the lime is in excess it burns the organic matters on which the ferments depend, which promote the microbes of nitrification, thus destroying the conditions which are necessary to their development. Therefore, in destroying the humus by an excess of lime one is destroying that which is essential to the fertility of the soil. It follows, of course, that the more humiferous the soil the more lime can be applied, and the more acid it is, the more one ought to apply it. Therefore the quantity of lime which may be too much in one soil may be only what is right in another, and may not be sufficient in a third.

The application of lime to very humiferous and very acid soils—peat, for example—is of paramount importance. On account of its great acidity this kind of soil solubilises all the salts of potash and phosphates, and in the absence of humates they pass into the subsoil and are washed away. This fact explains the poverty of peat in these elements.

Soils which are thus naturally impoverished can only be made fertile by the introduction of lime. Until lime is applied, even though larger quantities of manure are applied, the results will only be mediocre and the manures will be lost. It is only after applying lime that manures can be used without risk of waste. And limestone cannot take the place of lime completely.

In very strong clayey land lime tends to improve the texture of the soil. It makes it more friable, less compact, more permeable to water, and therefore earlier and more penetrable by air, and also renders it easier to work. On such soils one frequently finds from four to six tons of lime applied per acre, where $1\frac{1}{2}$ to 2 tons would really be better, because it must be remembered that the humus already in the soil renders just the same services.

Lime makes sandy soil more compact, and so hinders the harmful infiltration of air and helps retain the moisture. It must be used cautiously, however, because the introduction of humus to this kind of soil is often a long business. Half a ton of lime to the acre will be sufficient.

Too much lime destroys what is commonly known as "the old force" of the soil, and so it is a manure—

the only one—which can really impoverish the soil. For nitrate, as we saw, does not impoverish.

The most favourable time to apply lime is between the dressings of farmyard manure. By using the right quantity of lime the formation of ammonia will be promoted, and also that of nitrate from the inassimilable nitrogenous organic matters in the soil, and so economical crops can be obtained.

In order that carbonated lime or plain limestone can be effective in acid ground they must first be treated with the acids of the soil. The finer the limestone the more easily will it be affected, but the effect will also be in direct relation to the strength of the acids. In any case the action of limestone will be slow, less energetic, and less complete than that of quicklime, and some acids—such as carbonic acid and tannic acid—will have no action upon it whatever. Therefore, carbonate (of lime) is not sufficient to neutralise these acid soils, whereas quicklime acts rapidly and efficiently in the formation of the humates, which play such an important part in retaining the ammonia and other fertilising matters. Besides the carbonate formed from lime will be found in the soil in a much finer form than can be obtained by ground limestone, etc., and then will have more effect than ordinary limestone.

Large applications of lime are generally to be condemned. First on account of the outlay they represent. Afterwards, the lime, acting energetically on the organic matters and mineral constituents of the soil, makes them very assimilable to plants which at the outset will produce a luxuriant vegetation, the effect being still quite marked in the second and even the third year. During this period the soil is rendered permeable, very workable, liberally accessible to air and water, and consequently subjected to violent reactions. All the time too the organic matters of the soil have been yielding their ammonia and producing nitrate; the humus has been oxidized; the phosphates and the potassic salts have been freed by the humates which have been destroyed; and all this nutriment, which the plants were incapable of absorbing in the short time in which it was produced, has sunk into the soil and been carried off in the drains by the rain water. The fertility of the soil has been destroyed, the "old force" has disappeared, the ground has been ruined, and the productivity of subsequent years reduced to such a low ebb that it can only represent loss to the farmer.

It will take several years, and the application of considerable quantities of organic matter, mostly in the form of farmyard manure, to restore the soil to its former fertility.

In the case of soils ruined by liming, and converted a long time since into poor pasture, a reasonable dressing of lime will enable them to produce fresh crops.

Lime may be applied at intervals for years, until poppies are seen in the wheat and the cornflowers are disappearing. Then it must be only applied in reduced quantities.

Ground Lime or Agricultural Lime.—This product is frequently devoted to a purpose for which it is not suitable. Often it is nothing but waste from limekilns, either ground or not according to the name it bears. Very often it is slaked lime [$Ca(OH)_2$] carbonated by contact with the air, losing in consequence the greater part of its value. This being the case it is absurd that it should sometimes be sold at a higher price than lump lime, which is really valuable. Lime ought to be in as large lumps as possible, providing that it can be well burnt, because in this state it is less exposed to the air. Even if it is well applied, ground lime cannot saturate all the acids of the soil, burn organic matters, or in many cases promote nitrification. In fact, it might give rise to a new proverb, "Agricultural lime impoverishes those who employ it, and enriches those who produce it."

Agricultural lime sometimes contains large quantities of impurities derived from the limestone itself and from the coal used for burning. About 50 per cent. of these impurities have been found in some cases. If such a sample were slacked and afterwards carbonated its weight would be much increased by carbonization and absorption of water, and its value considerably diminished. Therefore the contents and form of lime should be guaranteed. This typical case might be illustrated by the following figures.

We will take a farmer, living a long way from the limekiln, and, say, five miles from the station :

Quicklime in lump costs 17*s.* a ton at the kiln.

Agricultural or ground lime costs 17*s.* 6*d.* a ton at the kiln.

To get equal value from each he must use two tons of agricultural lime per acre, or only about half a ton of quicklime per acre.

A. Agricultural Lime.			B. Quicklime.		
Per acre.	£	s.		s.	d.
2 tons at 17*s.* 6*d.* per ton at kiln	1	15	½ ton	8	6
Transport by rail at 3*s.* per ton		6	½ ton	1	6
Cartage at 1*s.* 6*d.* per ton ..		3	½ ton		9
Handling and distributing on the fields (it is unnecessary to cover with earth), 2 tons ..		1	Unloading, spreading and respreading lateral ..	1	0
Total	£2	5		11	9

1st Difference (certain), £2 5*s.* 0*d.*—12*s.* 6*d.*=£1 3*s.* 3*d.* per acre.

2nd Difference (probable), better effect by B than by A.

Agricultural lime will be found in the soil many years after it has been applied, often without any alteration. The name ground lime is generally applied to ground limestone. Pure limestone corresponds to about 56 per cent. of lime [CaO] and about 44 per cent. of carbon dioxide [CO_2]. Therefore the value of ground limestone is always less than that of its corresponding quantity of lime.

Gas Lime.—Gas lime is the waste from the second purification in the manufacture of lighting gas, which consists of passing it over sieves spread with wet lime, so as to take out the sulphurous compounds which would otherwise destroy the pipes. This lime contains a series of calcinous compounds, among which are sulphites and cyanides, which are poison both to plants and animals, along with a little ammoniacal nitrogen varying between 0·25 and 0·5 per cent. It is the presence of these poisons which causes gas lime to be sometimes used as a weed killer on garden paths, or to destroy slugs, therefore it should never be used fresh in agriculture. It should never be spread on fallows, because by the consequent exposure it will carbonate and lose part of its value, neither is it to be recommended for use on mossy pastures, unless the harmful products have been oxidized beforehand. It should be employed in preference in composts, or with the cleanings of ponds and ditches. It must at least lie three months so that its dangerous combinations can be destroyed by oxidization. Then it could be employed anywhere where one would use lime, but much larger quantities are required than of quicklime, and because of the extra work entailed, one should never pay more than a fifth as much for it, while generally speaking quicklime will be more economical.

Its composition varies according to the quality of the lime employed, the length of time allowed for its purification, and also the quality of the coal which furnished the gas. Its value varies according to the quantity of nitrogen, of carbonate and sulphate of calcium, and also according to the quantity of water which it contains.

This latter varies from 21·5 to 30 per cent.

Here is an example of its approximate composition :—

Water	27 per cent.
Caustic lime	17 ,,
Carbonate of calcium	25 ,,
Sulphites and sulphates	25 ,,
Sulphur	4 ,,
Various	2 ,,
	100

Its popularity has chiefly arisen from its smell, and this—which is only the results of sulphurous combinations—is much more prominent than its value, which is in reality nothing to boast about.

Slag from Sugar Manufacture.

This consists of the residue of the lime employed in sugar factories for precipitating the organic matters of the juice which impede the crystallisation of the sugar. After the precipitation of these organic matters the excess of lime is next precipitated by saturating the boiling juice with carbonic anhydride —the result being carbonic calcium. These slags, therefore, are composed of precipitates of organic matter and impalpable carbonate of lime [$CaCO_3$]. The value of slags is partly attributable to the fineness of the insoluble calcium present in an impalpable form, and partly to the nitrate and phosphoric acid it contains. Wolff gives the following analysis of its important constituents :—

Water	43·3	per cent.
Insoluble carbonate of lime	0·35	,,
Organic matters	17·2	,,
Phosphoric acid	0·1	,,
Nitrate	0·5	,,

The carbonate of calcium in the form of impalpable elements is the most active of all the carbonates of calcium. Its action will be rapid and not long-lasting. Its use is recommended in the neighbourhood of sugar works, but it does not justify the heavy cost of transport.

It would cost probably from 1*s.* 6*d.* to 2*s.* a ton.

Shells.

Shells of dead marine animals, brought up by the rising tide and left, can be usefully employed if they are crushed very finely. In some places there are depôts of shells which can be converted into lime. They contain 95 per cent. of carbonate of calcium.

Gypsum.

Sulphate of calcium is found in two different forms.

1st. White, crystallised, without water in crystallisation. This is "anhydrite" [$CaSO_4$].

2nd. White or colourless, crystallised with two molecules of water under crystallisation. This is gypsum, $CaSO_4+2H_2O$. In the mass it forms alabaster, which can easily be distinguished from calcide because it can be scratched with a nail. Gypsum is soluble in 450 times its volume of water. It is the presence of gypsum which makes the water of Paris cloudy, when it comes from the main, and makes it unsuitable for consumption.

Plaster of Paris is $CaSO_4$, obtained by burning gypsum, which, during the operation, loses its 2 molecules of water. When using equal quantities of sulphate of calcium either gypsum or plaster can be employed. Burned plaster when pure contains 90–92 per cent. $CaSO_4$ and 8–10 per cent. water; gypsum plaster when pure contains 79 per cent. sulphate of Ca and 21 per cent. water. Generally it contains some impurities, when of course these percentages will be reduced.

It is found in many places all over the world, especially in the United States, in France near Paris, and in England in Derbyshire, only containing calcium and sulphur, which are not necessary to the soil in the form of sulphate of calcium [$CaSO_4$], because they are given in sufficient quantities in lime or phosphates, and especially in the sulphates of the potash salts. Different explanations of its action on plant life have been given. The right one has not yet been found, though its discovery seems to be imminent. Formerly the results were attributed to the reactions of anhydrite on the salts of the soil; then to the promotion of nitrification after the double decomposition which created favourable conditions for this process. In some alkaline soils (Na_2CO_3) in America, where formerly young plants were completely destroyed, the neutralisation of the alkali by means of gypsum has rendered the land cultivatable, although only 2½ to 3 cwt. per acre were employed.

Recent experience tends to show that gypsum acts beneficially in driving the alkali from the soil into the subsoil, and these alkalis, combining with the humic acids of the subsoil, render the humates assimilable.

Deep-rooted plants profit best by gypsum. Its use is recommended for leguminosæ in general, and above all for clovers, lucerne, and sainfoin, on which in some cases it doubles the crops. The instance of Franklin, writing in big characters in a field of lucerne, "This has been gypsum," is now a classic. It is frequently used on carrots:

The increase of weight obtained by the use of gypsum is very noticeable, but it is partially due, probably, to the absorption of additional water caused by the gypsum. It is known that gypsum clover is difficult to dry. Until final experiments have decided the real value of gypsum in agriculture, it would be better not to popularise its use. Under no circumstances should it be used for cereals, or in ground that lacks humus. Gypsum can be economically supplied by means of superphosphates, in which about 50 per cent. is present. This explains the favourable action of superphosphates on some deep-rooted crops.

Chalk (Marne).

Chalk is really a mixture of clay and calcaire; dolomite or sand often being found in it.

Chalk swells and disintegrates under the action of air and moisture. It is easily recognisable because when worked upon by strong vinegar it becomes effervescent.

The composition of chalk is very variable. It contains more or less limestone, clay, sand or dolomite.

One meets at all depths. When near the surface its presence is revealed by characteristic vegetation, such as coltsfoot, thorns, thistles, plantains, etc.

It is divided into upper and lower chalk; these differ in nature and in quantity, and consequently the soils deriving from them differ also. It is chiefly in the upper chalk that one finds flint beds; this chalk is white although the surrounding soil is often black, by mixture with a part of the uppermost stratum laid bare by erosion, or because of the accumulation of organic matter. These soils are easily cultivated, being rather light; though poor, they are capable of producing good crops when well treated, and respond freely to the manures. Where chalk is clayey the quantity of clay is predominant, and the proportion of calcium is sometimes reduced to 10 per cent. In this case it ought not to be used ; but with nearly 35 per cent. of limestone it is excellent on sandy and dry lands. It decomposes less quickly and less completely and is darker in colour.

When chalk is sandy, the quantity of sand predominates. It would sometimes be 85 per cent. ; when there is about 40 per cent. limestone, it is very suitable for wet clayey land, because it makes it at the same time less tenacious and more friable. It does not form a sticky mud with water, and easily decomposes. When it is dolomitic it contains a considerable proportion of carbonate of magnesia, sometimes 30 per cent. or more, and 50 per cent. of carbonate of Ca. This form is very frequent in England ; it is suitable for clayey soils, for pastures in wet situations, and, generally speaking, for all soils requiring limestone.

One should avoid making lime of these magnesian chalks, because the magnesia which they contain by the transformation of carbonate of magnesia into oxide of magnesia ; this magnesia is caustic, as we have seen, to growing plants, and ought always to be applied a long time in advance to the fallow.

One should for choice employ each kind of chalk on the soil which it suits, it then has a double value ; that of the limestone carbonates is evidently the most important, but that of the second element, whichever it may be, is not negligible. The best chalk is that which disintegrates most thoroughly and is reduced to the finest particles.

To use it one lets the chalk disintegrate in the heap on the ground to be treated. When it is ready, it is distributed over the surface of the ground in little heaps about 8 yards apart, like lime. It should be spread for preference in autumn. When necessary, before ploughing in, it can be reduced by the harrow. One should sow in the following spring.

It is really a mixture of clay and of limestone, and it often contains dolomite or sand which is given them.

The lower chalk does not contain flint beds, and is less white; the soil derived from it is more tenacious, as though containing more clay. A dressing of sand is sometimes useful. It yields excellent crops when it receives manure at the same time as humus. The whitest chalk contains the most lime, it is then called calcareous. It disintegrates easily and is especially suitable for clayey and damp soils rich in humus. It contains more than 50 per cent. carbonate of lime and forms a paste with water.

One can apply this in alternate layers, like gas lime, with farm manure or vegetable debris, such as twitch, potato-tops, leaves and waste of crops generally. After some time the heap is turned and used when the chalk is completely disintegrated. The chalking ought to be renewed more or less frequently according to the quantity of chalk employed, and to the quantity of carbonate of calcium it contains. The average applications are 1 to 20 cubic yards to the acre, renewed every ten years.

Humus.

Humus is animal or vegetable residue which is found in the soil in various conditions, either not yet decomposed, in process of decomposition, or decomposed—soluble or insoluble.

Theoretically it ought to be considered only as humus. It ought not to include nitrogen, but as a matter of fact it does. It is this material which gives the soil its colour, and makes it earlier, because being black it easily absorbs the heat of the sun.

It has the property of retaining water in the soil; so that certain soils too rich in humus retain too much water; but, generally speaking, humus is valuable, largely because it helps to retain the fertilising matters, which otherwise would be too easily lost in the subsoil.

Humus possesses two opposite characteristics, according to the soil in which it is found. It gives more cohesion to sandy soils, rendering it more compact and less permeable, and makes clayey soil more friable, porous, and permeable. It promotes the development of the bacteria of nitrification and of favourable moulds. The bacteria of nitrification travel little through the soil, and in sour sandy soil they are very often non-existent, because of the absence of lime. That is why when attempts were formerly made to cultivate these soils, only very poor results were obtained from green manures in the first year. To introduce them, the agriculturist had to turn to humiferous soil close by, where he knew the bacteria were found, and spread one or two cartloads of this soil on the surface of the new plot.

Humus differs according to the manner in which it is produced.

1st. In arable soils, properly aerated and sufficiently moist, and containing carbonate of calcium. It is produced when the temperature is favourable by bacteria and moulds. This formation of humus is accompanied by a considerable reduction in volume of the matter from which it is formed. The losses are heaviest in oxygen, less in carbon, and lightest in nitrogen.

This is the finest humus.

2nd. Another variety of humus is formed when the surroundings are slightly acid and well-aerated, but the bacteria are not so active because of the absence of carbonate of calcium, and soon give place to moulds. This condition will be found in heather lands and some pastures.

3rd. A variety of humus is formed in marshes by anaerobic bacteria. This formation of humus under water is accompanied by the formation of marsh gas. During periods of atmospheric depression this gas escapes sometimes in large quantities, lights spontaneously and produces the will-o'-the-wisps (*ignis fatuus*). This formation of humus gives peat.

As humus possesses all the animal and vegetable matter of the soil, it gives off ammonia in decomposition, which later, under favourable conditions, is transformed into nitrate and other bodies.

This formation of ammonia will be the more rapid in action because it will have the influence of more carbonate of calcium and at a suitable temperature. It is an important point in agriculture, for upon it is based the use of lime as an improvement. One should not use too much of it, or the usefulness of the nitrogen will be lost.

Humus rapidly absorbs (and retains) the potash, lime and ammonia of manures; it forms also humates which are not soluble in water, and prevent them being carried away in the drains by the rain water. Therefore chemical manures should be employed carefully on land which is lacking in humus.

But when the manures contain muriate of potash and common salt, as is the case with seaweed and kainite, they present a loss in calcium and in magnesium.

The humus in decomposing produces carbon dioxide, CO_2, which helps the decomposition of mineral matters, such as the phosphates and potassic compounds, and makes them more assimilable to the plants. Humus disappears rapidly in arable soil in hot weather, and it is very necessary to import it to the places where it does not exist naturally in sufficient quantities.

Here is about the quantity of humus present in arable soils :—

1. Sandy soil, 2 per cent.
2. Loamy soil, 3 to 4 per. cent.
3. Clayey soil, 4 to 6 per cent.

With pasture, clover or seeds on the same soils there would be a higher proportion of humus.

CHAPTER X

Auximones

A NEW chapter, it appears, must be added to the book of manures. We have, perhaps, reached a turning-point in the history of agriculture. A revolution has been prepared in the secrecy of the laboratory, and the revolutionary is Prof. W. B. Bottomley, of King's College, London.

In the Canary Islands one sometimes sees the roofs of the houses converted into stables. In London one can see them devoted to the cultivation of vegetables and potatoes. In fact, in the course of experiments on the elements accessory to plant nutrition, Mr. Bottomley has, after long and patient research, managed to isolate a product possessing the most extraordinarily stimulating properties on vegetation. This product he has named Auximone, from the Greek word *αὐξίμος*, meaning "promoting growth." It is an accessory food for normal plant growth. The nature of auximones has not been exactly determined yet. They are not, however, either moulds, fungi, or bacteria. Neither are they living organisms, seeing that in a retort they can resist a temperature of 134° C. maintained for half an hour.

They are contained in the silver fraction of phosphotungstic acid precipatated from an aqueous extract of the evaporated residue of alcoholic solution of bacterized peat. They are probably isolated in the form of crystals or *batonnets*. Raw peat does not contain them. It must be inoculated, and it is during inoculation that they are produced from the humus. They are therefore the result of bacteriological action.

The effect of the auximones is absolutely astonishing. Even in an infinitesimal proportion they stimulate growth in an extraordinary manner, as was seen when we visited Prof. Bottomley's laboratory.

He had taken three or four potatoes and put them, without any earth, in an ordinary wooden box. In the bottom of the box was a layer of sphagnum and another layer was placed on the top to exclude the air. From these three or four tubers in a few weeks he had obtained a heavy crop of potatoes. Other experiments which are being carried on in the laboratory with wheat, maize, etc., are also very interesting. All that was necessary to get those results was to administer small quantities of liquid containing auximones.

Auximones act, that is evident. But how? The problem is in a fair way to be solved. Meanwhile, in the opinion of those who have seen the results, the laboratory trials ought to be exchanged for practical application, and if the results then confirm the hopes raised by those now known, the effect of the discovery will be incalculable, rendering inestimable benefits to agriculture and causing profound changes in its methods. It would at the same time give an impetus to the exploitation of bacterized peat, which could be sold at the price of nitrate, turning deposits of peat, now of little value, into veritable gold-mines.

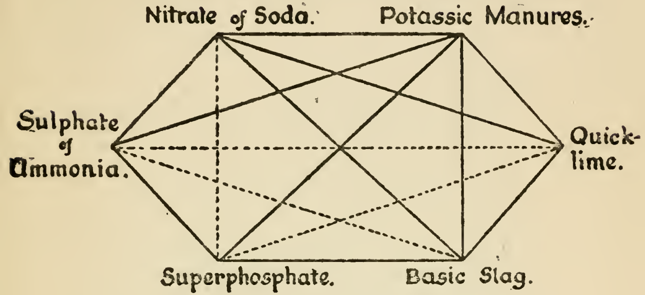
How do the auximones act? Is it in the manner of ferments and nitrifying bacteria such as those in the nodules of leguminous plants, enabling the nitrogen of the air to become fixed and utilised? Have they a favourable action on the production of hydrates of carbon? Have they any influence on the assimilability of the fertilising matters? Under what system of manuring are they most easily assimilated by the plants? All these questions must be answered before we can benefit by all the advantages owing to the discovery.

One fact has struck us—that auximones are not an aerial element, the stalks and leaves of the potatoes being relatively small in comparison to the crop. Since "nothing is created, and nothing is destroyed," one is tempted to ask whence comes this extraordinary growth. One thing certain is that the auximones only form an *accessory* element of alimentation for the plants; or only help the assimilation of other aliments, but in no wise supply these aliments themselves. These must come from the outside.

Is the assimilation of nutritive matter by this method of culture in the same proportion as in ordinary crops? And the crops themselves, are they as proportionately rich in nutritive matter as ordinary crops? If so, in what form will additional manure have to be provided? Is the increase of weight and size attributable to a single element? It is proved that this increase is not simply due to the quantity of water absorbed. But does it depend in any way on the carbonic hydrates, the nitrogen, or the ashes? Analysis of a portion of the crop would furnish most interesting evidence in this respect. If the increase is influenced by the carbonic hydrates it will be of value in the production of sugar, potato fecula, starch, etc.

If it concerns the nitrogen of the air the growth is equally important because it will save us entirely or partly from the need of buying this manure. If at the same time it concerns ash we shall have to look for the dominant element of the ash to be able to restore it to the soil, and eventually so that we can import it. The questions connected with the form in which manures ought to be administered to crops, so that their nutritive value can be augmented in the same or greater proportion, are equally important. A great part of the problem, therefore, still remains to be solved. No doubt a more complete knowledge of the auximone will enable us to reach the solution more quickly by indicating the lines on which research with regard to its method of action should be carried out. The question of auximones is perhaps the most important that has ever arisen.

QUANTITIES OF MANURES WHICH MAY BE USED TO THE ACRE.



THE BLACK LINES INDICATE MANURES THAT MAY BE MIXED.
THE DOTTED LINES INDICATE MANURES THAT MAY NOT BE MIXED.

NOTE.—Superphosphates containing an excessive quantity of carbonate of lime should not be mixed with sulphate of ammonia.

The calculations refer to typical manures. The corresponding quantities of other manures belonging to the same type can be determined by consulting the foregoing chapters. The figures must be varied according to the quality of the soil. For example, poorer soils will generally require 1 or 2 cwt. more of basic slag than good soil.

Winter Wheat.—In good soils—Farmyard manure 7 to 8 tons, with addition of 3 to 4 cwt. of basic slag at 30 per cent., and ½ cwt. of sulphate of ammonia at seed time and 1 cwt. of nitrate of soda in spring.

If coloured bluish-green after winter, none, or only half, of the nitrate needed.

In poorer soils—8 to 10 tons of farmyard manure with the addition of 5 to 6 cwt. of basic slag; ½ to ¾ cwt. of muriate of potash and ½ cwt. of sulphate of ammonia at seed time, and 1 cwt. of nitrate of soda in spring.

Spring Wheat.—One cwt. of sulphate of ammonia, and half of the quantity of phosphoric acid should be applied as superphosphate, at seed time; later 1 cwt. of nitrate of soda. In poorer soils 1 cwt. of muriate of potash. The farmyard manure should be applied as soon as possible and a long time before sowing.

Quantities

Oats.—In good soils—1 to 1¼ cwt. nitrate of soda—1 cwt. of superphosphate and 1½ to 3 cwt. of basic slag—1 cwt. of muriate of potash in poorer soils. Farmyard manure to be applied early.

Winter Barley.—In good soils—¾ cwt. of sulphate of ammonia and ¾ cwt. of nitrate of soda. 1 cwt. of superphosphate. 1 cwt. of basic slag. In calcareous soils ¾ cwt. of muriate of potash.

Spring Barley.—In good soils—¾ cwt. of sulphate of ammonia and ¾ to 1½ cwt. of nitrate of soda—1 to 2 cwt. of superphosphate and 1½ to 2 cwt. of basic slag. ¾ cwt. of muriate of potash in poorer soils.

Rye.—Generally grown in poorer soils—6 to 7 tons farmyard manure and 5 cwt. of basic slag; ¾ to 1 cwt. of muriate of potash and after winter 1¼ cwt. of nitrate of soda.

Buckwheat.—Farmyard manure early applied, with a supplement of 2½ cwt. of basic slag and ¼ of muriate of potash. Where no farmyard manure available, supply a surplus of 1 cwt. of basic slag, 1 cwt. of muriate of potash, and ¾ cwt. of nitrate of soda.

Potatoes.—8 to 10 tons of farmyard manure, 6 cwt. of superphosphate, 1½ cwt. of sulphate of potash, 1 cwt. of sulphate of ammonia, and ¾ cwt. of nitrate of soda.

Mangolds.—15 tons of farmyard manure, 2 to 3 cwt. of nitrate of soda, 2½ to 3 cwt. of basic slag, and 2½ to 3 cwt. of superphosphate, 1 to 1½ cwt. of muriate of potash.

Swedes.—8 tons of farmyard manure, 1 cwt. of sulphate of ammonia, 3 cwt. of superphosphate, 2 cwt. of basic slag, 1 cwt. of muriate of potash.

Turnips.—7 to 8 tons of farmyard manure, ½ of sulphate of ammonia, ½ of nitrate of soda, 4 to 5 cwt. of superphosphate, 1 cwt. of muriate of potash.

Carrots.—7 to 8 tons of farmyard manure, 3 to 4 cwt. of superphosphate, 1 cwt. of chlorure of potash, 1 cwt. of nitrate of soda, 1 cwt. of sulphate of ammonia.

Cabbages.—15 to 20 tons of farmyard manure, 4 cwt. superphosphate and 1½ cwt. of muriate of potash.

Hay.—1¼ to 1½, sometimes even 2 cwt., nitrate of soda with addition in exhausted fields of 5 to 7 cwt. of basic slag, or on dry soils 2½ cwt. superphosphate and 2½ cwt. or more basic slag, ¾ or 1 cwt. of muriate of potash.

Clover.—At the same time as protective crops—4 to 5 cwt. of basic slag, or as top dressing 2½ cwt. basic slag and 2 cwt. of superphosphate, and 1 cwt. of muriate of potash.

Fertilisers and Feeding Stuffs Act, 1906

6 Edw. 7, Ch. 27. A.D. 1906.

ARRANGEMENT OF SECTIONS.

CHAPTER 27.

An Act to amend the law with respect to the sale of Agricultural Fertilisers and Feeding Stuffs.

[4th August 1906.]

Be it enacted by the King's most Excellent Majesty, by and with the advice and consent of the Lords Spiritual and Temporal, and Commons, in this present Parliament assembled, and by the authority of the same, as follows :—

Warranties as to fertilisers and feeding stuffs.

1.—(1) Every person who sells for use as a fertiliser of the soil any article which has been subjected to any artificial process in the United Kingdom, or which has been imported from abroad, shall give to the purchaser an invoice stating the name of the article and what are the respective percentages (if any) of nitrogen, soluble phosphates, insoluble phosphates, and potash contained in the article, and the invoice shall have effect as a warranty by the seller that the actual percentages do not differ from those stated in the invoice beyond the prescribed limits of error.

(5) Any statement by the seller of the percentages of the chemical and other ingredients contained in any article sold for use as a fertiliser of the soil, or of the nutritive and other ingredients contained in any article sold for use as food for cattle or poultry, made after the commencement of this Act in an invoice of such article, or in any circular or advertisement descriptive of such article, shall have effect as a warranty by the seller.

(6) Where an article sold for use as a fertiliser of the soil or as food for cattle or poultry consists of two or more ingredients which have been mixed at the request of the purchaser, it shall be a sufficient compliance with the provisions of this section with respect to percentages if the invoice contains a statement of percentages with respect to the several ingredients before mixture, and a statement that they have been mixed at the request of the purchaser.

Power to appoint analyst and samplers.

2.—(1) The Board of Agriculture and Fisheries shall appoint a chief agricultural analyst (hereinafter referred to as the chief analyst), who shall have such remuneration out of moneys provided by Parliament as the Treasury may assign. The chief analyst shall not while holding his office engage in private practice.

(2) Every county council shall, and the council of any county borough may, appoint an official agricultural

analyst (hereinafter referred to as an agricultural analyst) and one or more official samplers for their county or borough.

(3) The council of any county or county borough may also appoint a deputy agricultural analyst, who shall, in case of illness, incapacity, or absence of the agricultural analyst, have all the powers and duties of the agricultural analyst, and where the deputy acts this Act shall apply as if he were the agricultural analyst.

(4) The appointment of an agricultural analyst, deputy agricultural analyst, or official sampler shall be subject to the approval of the Board of Agriculture and Fisheries.

(5) A person whilst holding the office of agricultural analyst shall not engage or be interested in any trade, manufacture, or business connected with the sale or importation of articles used for fertilising the soil or as food for cattle or poultry.

Power to have fertiliser or feeding stuff analysed.

3.—(1) Every purchaser of any article used for fertilising the soil or as food for cattle or poultry who has taken a sample thereof within ten days after delivery of the article to him or receipt of the invoice by him, whichever is later, shall, on payment of the required fee, be entitled to have the sample analysed by the agricultural analyst.

(2) An official sampler shall at the request of the purchaser and on payment by him of the required fee, and may without any such request, take a sample for analysis by the agricultural analyst of any such article as aforesaid which has been sold or is exposed or kept for sale, but, in the case of an article which has been sold, the sample shall be taken before the expiration of ten days after the delivery of the article to the purchaser, or the receipt of the invoice by the purchaser, whichever is later.

(3) Where a sample has been taken with a view to the institution of any civil or criminal preceeding, the person taking the sample shall divide the sample into three parts, and shall cause each part to be marked, sealed, and fastened up, and shall deliver or send by post

two parts to the agricultural analyst and one part to the seller.

(4) An agricultural analyst to whom a sample is submitted for analysis under this section—

(*a*) if the sample has not been divided into parts and the parts marked, sealed, and fastened up as herein-before mentioned, shall send a copy of the certificate of his analysis to the person who submitted the sample for analysis; and

(*b*) if the sample has been so divided into parts, shall analyse one of the parts of the sample delivered or sent to him and retain the other, and shall send a certificate of his analysis in the prescribed form and containing the prescribed particulars to the person who submitted the sample for analysis, and where that person is not the purchaser of the article also to the purchaser, and in every case to the seller and to such other persons (if any) as may be prescribed, and shall report to the Board of Agriculture and Fisheries in the prescribed manner the result of any such analysis: Provided that if the agricultural analyst does not know the name and address of the seller he shall send the certificate intended for the seller to the purchaser, to be by him forwarded to the seller.

(5) At the hearing of any civil or criminal proceeding with respect to any article a sample whereof has been analysed in pursuance of this section, the production of a certificate of the agricultural analyst, or, if a sample has been submitted to the chief analyst, then of the chief analyst, shall be sufficient evidence of the facts therein stated unless the defendant or person charged requires that the analyst or the person who made the analysis be called as a witness: Provided that this subsection shall not apply—

(*a*) where the sample has been taken otherwise than in the prescribed manner; or (*b*) where the sample has not been divided into parts and the parts marked, sealed, and fastened up as herein-before mentioned.

(6) If in any such legal proceeding (other than a proceeding which cannot be instituted until an analysis has been made and a certificate given by the chief analyst) either party to the proceeding objects to the certificate of the agricultural analyst, the party objecting shall, on payment of such fee as may be fixed by the Treasury, be entitled to have submitted to the chief analyst the part of the sample retained by the agricultural analyst, and to have that part analysed by the chief analyst and to receive from him a certificate of the result of his analysis.

(7) Where a sample is, under this section, sent for analysis to the chief analyst or to an agricultural analyst, there shall be sent with the sample the invoice (if any) relating to the article from which the sample was taken, or a copy of the invoice or of any prescribed part thereof.

Power of Board of Agriculture and Fisheries to make regulations.

4.—(1) The Board of Agriculture and Fisheries may make regulations—

(*a*) with respect to any matter which under this Act is to be prescribed;

(*b*) as to the qualifications to be possessed by agricultural analysts, deputy agricultural analysts, and official samplers;

(*c*) as to the manner in which analyses are to be made;

(*d*) as to the manner in which samples are to be taken and dealt with; and

(*e*) generally for the purpose of carrying this Act into execution:

Provided that nothing in this section or in any regulations made thereunder, shall affect the right of the purchaser of an article used for fertilising the soil, or as food for cattle or poultry, to have analysed by the agricultural analyst a sample of an article taken by him or at his request otherwise than in accordance with the regulations.

(2) All regulations made under this section shall be

laid before both Houses of Parliament as soon as may be after they are made.

Provisions as to county and county borough councils.

5.—(1) The council of a county or county borough may concur with one or more other such councils in making any appointment which they are authorised to make under this Act, and as to the apportionment in the case of such a joint appointment of the expenses amongst the several councils.

(2) The council of any county or county borough may contribute towards any expenses incurred by any agricultural body or association in causing samples to be taken for analysis by the agricultural analyst.

(3) The council of any county or county borough may fix the fees payable in respect of the making of an analysis and the taking of any sample at the request of a purchaser.

(4) The expenses of the council incurred in the execution of this Act shall be defrayed, in the case of a county council as part of their general expenses, and in the case of a county borough council out of the borough fund or borough rate.

Penalties for breach of duty by seller.

6.—(1) If any person who sells any article for use as a fertiliser of the soil or as food for cattle or poultry commits any of the following offences, namely :—

(*a*) Fails without reasonable excuse to give, on or before or as soon as possible after the delivery of the article, the invoice required by this Act ; or

(*b*) Causes or permits any invoice or description of the article sold by him to be false in any material particular to the prejudice of the purchaser ; or

(*c*) Sells for use as food for cattle or poultry any article which contains any ingredient deleterious to cattle or poultry, or to which has been added any ingredient worthless for feeding purposes and not disclosed at the time of the sale ;

he shall, without prejudice to any civil liability, be liable, on summary conviction, for a first offence to a fine not exceeding twenty pounds, and for any subsequent offence to a fine not exceeding fifty pounds:

Provided that a person shall not be convicted of an offence under paragraph (*b*) of this subsection if he proves either

(i) that he did not know, and could not with reasonable care have ascertained, that the invoice or description was false; or

(ii) that he purchased the article sold with a written warranty or invoice from a person in the United Kingdom, and that that warranty or invoice contained the false statement in question, and that he had no reason to believe at the time when he sold the article that the statement was false, and that he sold the article in the state in which it was when he purchased it.

(2) In any proceeding for an offence under this section it shall be no defence to allege that the purchaser, having bought only for analysis, was not prejudiced by the sale.

(3) A prosecution for an offence under this section shall not be instituted except with the consent of the Board of Agriculture and Fisheries, and the Board shall not give such consent until the part of the sample retained by the agricultural analyst has been analysed, and a certificate of analysis given, by the chief analyst.

(4) In any prosecution under this section the summons shall state particulars of the offences alleged, and also the name of the prosecutor, and shall not be made returnable in less time than fourteen days from the day on which it is served, and there must be served therewith a copy of any analyst's certificate obtained on behalf of the prosecutor.

Penalties for tampering.

7. If any person fraudulently—

(*a*) tampers with any article so as to procure that any sample of it taken under this Act does not correctly represent the article; or

(*b*) tampers with any sample taken under this Act;

he shall be liable on summary conviction to a fine not exceeding twenty pounds, or to imprisonment for a term not exceeding six months.

Penalty for obstructing official sampler.

8. If—

(*a*) the owner, or the person entrusted for the time being with the charge or custody of any article sold or intended to be sold for use as a fertiliser of the soil or as food for cattle or poultry refuses to allow an official sampler to take a sample of the article for the purpose of analysis ; or

(*b*) the purchaser of any such article refuses to give to an official sampler the invoice of the article or a copy thereof or of any prescribed part thereof ;

he shall be liable on summary conviction to a fine not exceeding ten pounds.

Institution of prosecutions and appeals.

9.—(1) Subject to the provisions of this Act as to the consent of the Board of Agriculture and Fisheries, a prosecution for an offence under this Act may be instituted either by the person aggrieved, or by the council of a county or borough, or by any body or association authorised in that behalf by the Board of Agriculture and Fisheries.

(2) A prosecution for an offence of causing or permitting an invoice or description to be false in any material particular shall not be instituted under this Act—

(*a*) after the expiration of three months from the date when the invoice was received by the purchaser ; nor

(*b*) unless a sample for analysis has been taken, and an analysis by the agricultural analyst has been made, and a certificate of analysis has been given, in accordance with regulations made under this Act :

But the proceedings may be taken as well before the court having jurisdiction in the place where the purchaser of the article to which the invoice or description relates resides or carries on business, as before the court having jurisdiction in the place where the invoice or description was given.

(3) Any person aggrieved by a summary conviction under this Act may appeal to a court of quarter sessions.

Construction and application.

10.—(1) For the purposes of this Act the expression "cattle" shall mean bulls, cows, oxen, heifers, calves, sheep, goats, swine, and horses; and the expressions "soluble" and "insoluble" shall respectively mean soluble and insoluble in water, or, if so specified in the invoice, in a solution of citric acid or other solvent of the prescribed strength, and the percentage of soluble phosphates and percentage of insoluble phosphates mean respectively the percentage of tribasic phosphate of lime which has been, and that which has not been, rendered soluble.

(2) This Act shall apply to wholesale as well as retail sales.

Application to Scotland.

11. In the application of this Act to Scotland—

(1) The expression "council of any county borough" shall mean the town council of a burgh, and the duties and powers of councils of counties and county boroughs shall be performed and be exerciseable in a county by the county council, and in a burgh by the town council, and the expenses incurred by a council in the execution of this Act shall be defrayed out of a rate to be levied, fixed, and paid in like manner as the local rate under the Diseases of Animals Act, 1894: 57 & 58 Vict. c. 57.

(2) The expression "burgh" means a burgh which returns or contributes to return a member to Parliament, not being a burgh to which section fourteen of the Local Government (Scotland) Act, 1889, applies: 52 & 53 Vict c. 50.

(3) Penalties for offences under this Act may be recovered summarily before the sheriff in manner provided by the Summary Jurisdiction Acts, and any person aggrieved by a summary conviction may appeal therefrom

MY GARDEN

By Eden Phillpotts. 207 pages. 60 full-page illustrations. Cheap Edition, 6*s*. net. By post, 6*s*. 5*d*.

"It is a thoroughly practical book, addressed especially to those who, like himself, have about an acre of flower garden, and are willing and competent to help a gardener to make it as rich, as harmonious, and as enduring as possible. His chapters on irises are particularly good."—*World*.

ROCK AND WATER GARDENS: Their Making and Planting

With Chapters on Wall and Heath Gardens. By F. H. Meyer. Edited by E. T. Cook. 6*s*. net. By post, 6*s*. 4*d*.

"In this book the author has studied every detail of Nature's ways in order to reproduce in the garden the charms of natural scenery."—*Standard*.

TREES AND SHRUBS FOR ENGLISH GARDENS

By E. T. Cook. 12*s*. 6*d*. net. By post, 12*s*. 11*d*.

"It contains a mass of instruction and illustration not always to be found altogether when required, and as such it will be very useful as a popular handbook for amateurs and others anxious to grow trees and shrubs."—*Field*.

GARDENS FOR SMALL COUNTRY HOUSES

By Gertrude Jekyll and Lawrence Weaver. Third Edition, revised and enlarged, large 4to, cloth gilt, 15*s*. net. By post (inland), 15*s*. 7*d*. 300 pages, and over 400 illustrations, with coloured frontispiece. No owner of a small country house who wishes to improve its garden can afford to be without this notable book.

The Spectator says: "There could be no more helpful book than this to consult."

THE CENTURY BOOK OF GARDENING

Edited by E. T. Cook. A Comprehensive Work for every Lover of the Garden. 624 pages, with about 600 illustrations, many of them full-page 4to (12 in. by 8½ in.). 21*s*. net. By post, 21*s*. 10*d*.

"No department of gardening is neglected, and the illustrations of famous and beautiful gardens and of the many winsome achievements of the gardener's art are so numerous and attractive as to make the veriest cockney yearn to turn gardener. If 'The Century Book of Gardening' does not make all who see it covet their neighbours' gardens through sheer despair of ever making for themselves such gardens as are there illustrated, it should, at any rate, inspire every one who desires to have a garden with an ambition to make it as beautiful as he can."—*Times*.

GARDENING FOR BEGINNERS

(A Handbook to the Garden). By E. T. Cook. Coloured plates and over 200 Illustrations, plans and diagrams from photographs of selected specimens of Plants, Flowers, Trees, Shrubs, Fruits, etc. Sixth Edition. 12*s.* 6*d.* net. By post, 13*s.*

"One cannot speak in too high praise of the idea that led Mr. E. T. Cook to compile this 'Gardening for Beginners,' and of the completeness and succinctness with which the idea has been carried out. Nothing is omitted. . . . It is a book that will be welcomed with enthusiasm in the world of gardeners."—*Morning Post.*

Natural History, etc.

THE PEREGRINE FALCON AT THE EYRIE

By Francis Heatherley, F.R.C.S. Illustrated with wonderful photographs by the Author and C. J. King. Demy quarto, cloth, gilt, 5*s.* net. By post, 5*s.* 5*d.*

ANIMAL LIFE BY THE SEASHORE

By G. A. Boulenger, LL.D., D.Sc., Ph.D., F.R.S., F.Z.S., and C. L. Boulenger, M.A., D.Sc., F.Z.S. A simple and concise manual for all who wish to increase their knowledge of the habits and life histories of the wonderful creatures which are to be found on the sea-shore. Nearly 100 Illustrations. 5s. net. By post, 5*s.* 4*d.*

PASTIME WITH GOOD COMPANY

Pictured by G. D. Armour, with an Introduction by Horace G. Hutchinson, containing over 50 artistically printed plates, each one worth framing. Quarto, 15*s.* net. By post, 15*s.* 6*d.*

OUR COMMON SEA-BIRDS

By Percy R. Lowe, B.A., M.B., B.C., with chapters by Bentley Beetham, Francis Heatherley, W. R. Ogilvie-Grant, Oliver G. Pike, W. P. Pycraft, A. J. Roberts, etc. Large quarto, gilt, with over 300 pages and nearly 250 Illustrations of extraordinary merit and beauty. 15*s.* net. By post, 15*s.* 7*d.*

Architecture, etc.

SMALL COUNTRY HOUSES OF TO-DAY

Edited by LAWRENCE WEAVER. Contains the picked work of more than forty of the best Architects of the day. Over 300 Illustrations. Second Edition. Large quarto, 15*s*. net. By post, 15*s*. 6*d*.

SMALL COUNTRY HOUSES:
Their Repair and Enlargement.

By LAWRENCE WEAVER. Forty Examples chosen from Five Centuries. 250 pages, 300 Illustrations. Large quarto, 15*s*. net. By post, 15*s*. 6*d*.

HOUSES AND GARDENS BY E. L. LUTYENS

Described and criticised by LAWRENCE WEAVER. 400 folio pages and 600 magnificent Illustrations. Second Edition. Quarter buckram, 25*s*. net; half morocco, 35*s*. net. Postage, 10*d*. extra.

GRINLING GIBBONS AND THE WOODWORK OF HIS AGE (1648-1720)

By H. AVRAY TIPPING, M.A., F.S.A. Large folio, quarter buckram, 25*s*. net; half morocco, 35*s*. net. Postage, 10*d*. extra. Nearly 250 Illustrations.

IN ENGLISH HOMES

The internal character, furniture, and decorations of some of the most notable Houses of England. Volumes I., II., and III., **and the recently issued fourth volume—**

ENGLISH HOMES OF THE EARLY RENAISSANCE
(Elizabethan and Jacobean Houses and Gardens)

Edited by H. AVRAY TIPPING, M.A., F.S.A. Each of these four magnificent volumes contains about 500 matchless Illustrations. Folio. £2 2*s*. net each. By post, £2 3*s*.

WINDSOR CASTLE

An Architectural History collected and written by Command of Their Majesties Queen Victoria, King Edward VII., and King George V., by Sir W. H. ST. JOHN HOPE, Litt.D., D.C.L. Limited to 1,050 copies, of which only a few remain. In two sumptuous imperial quarto volumes, and a portfolio, bound in half sheepskin. £6 6*s*. net.

Poems

A LITTLE BOOK OF QUIET

Poems by DOROTHY FRANCES GURNEY. 2*s*. 6*d*. net. By post, 2*s*. 10*d*.

POEMS

By DOROTHY FRANCES GURNEY. 5*s*. net. By post, 5*s*. 5*d*.

THE "COUNTRY LIFE" ANTHOLOGY OF VERSE

Edited by P. ANDERSON GRAHAM. Cloth, 5*s*. net. By post, 5*s*. 5*d*. In sheepskin, 8*s*. 6*d*. net. By post, 9*s*.

PHOTOGRAPHY FOR BEGINNERS

An instructive and practical book, worded clearly but non-scientifically, for the tyro camera user. 1*s*. net. Cloth, 1*s*. 6*d*. net. Postage, 3*d*. extra.

FRENCH HOUSEHOLD COOKING

By Mrs. FRANCES KEYZER. Shows how simple and inexpensive is the art of cooking as the French understand it. 1*s*. net. Cloth, 1*s*. 6*d*. Postage, 3*d*. extra.

THE FIGHTING TERRITORIALS

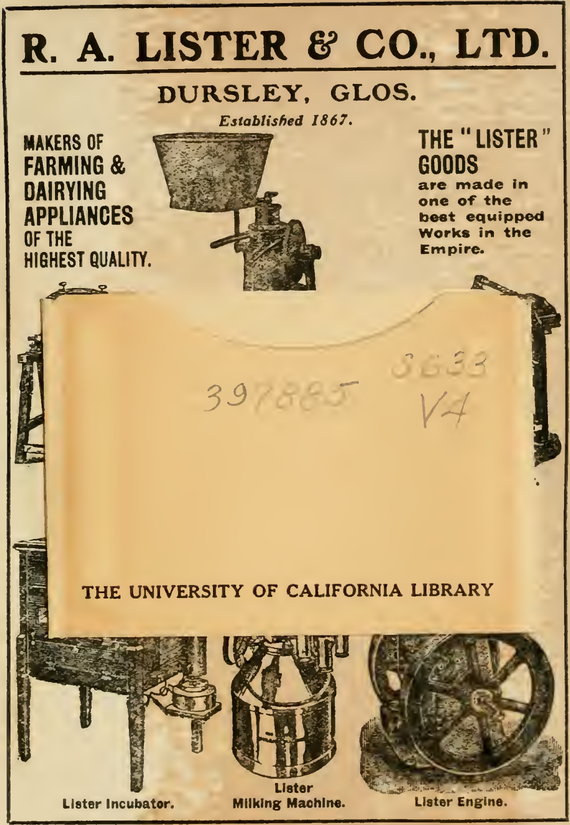
By PERCY HURD. Second impression. 1*s*. net. By post, 1*s*. 4*d*.

ECONOMIES IN DAIRY FARMING

An important Work on Dairying, by ERNEST MATHEWS (the well-known Judge and Expert). 7*s*. 6*d*. net. By post, 7*s*. 10*d*.

MEMORIALS AND MONUMENTS; OLD AND NEW.

Two hundred subjects chosen from seven centuries. By LAWRENCE WEAVER, F.S.A. With Collotype Reproductions of 180 Photographs and 80 other Illustrations. In this book the whole art of memorial design is now for the first time examined in all its aspects—historical, critical, and practical. To all who contemplate setting up a memorial this book offers essential guidance. 12*s*. 6*d*. By post, 13*s*.



A few of our Leading Lines are illustrated above. Write for catalogues.