[September, 1894.

Queensland.

DEPARTMENT OF AGRICULTURE, BRISBANE.

BULLETIN No. 3.

SECOND SERIES.

MANURES: their Management and Use,

WITH

SPECIAL REFERENCE TO QUEENSLAND CONDITIONS.

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The Bulletins of this Department will be sent free to such Individuals interested in Farming as may request them. Address all applications to "The Under Secretary for Agriculture, Brisbane."

BRISBANE

BY AUTHORITY: EDMUND GREGORY, GOVERNMENT PRINTER, WILLIAM STREET.

1894

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MANURES: THEIR MANAGEMENT AND USE.

Chapter I.

THE NEED OF MANURING SOILS.

The question of adding artificially to the supply of plant food in the soil, by any process of manuring, is, like all other agricultural operations, to be determined by its ultimate profitableness. There are few soils that are not benefited—*i.e.* made more productive—by the addition of some form or other of fertiliser. It by no means follows that the profits of the operation are alike universal. "Will it pay to manure?" is the question, but the answer is not likely to be reached from considerations purely theoretical. The expense of applying fertilisers upon a considerable scale, even when their first cost is not great, is certain to be a large item. This, to the farmer, is a present and entirely appreciable reality; the returns from the operation, on the other hand, are remote, and contingent upon events connected with the seasons, markets, &c. It is not surprising, therefore, that the use of manures, particularly by cultivators in new countries, is almost constantly deferred, until failing crops and profits enforce the need of making up to the soil the losses due to constant cropping. There are doubtless soils here and there that would be positively injured, in their crops, by manure, and there are others that would be improved by the application, without giving returns commensurate with the cost of applying the fertiliser; but unquestionably a very large proportion of Queensland soils demand fertilising in order that profitable returns may be realised from them. I feel perfectly safe in saying that not one-tenth of the crops grown annually in Queensland owe anything to the action of manures artificially applied. The true course for the farmer of new countries is to carefully conserve the natural riches of his soil. This he can do with least expense—(1) by a judicious alternation of crops; (2) by laying down his lands for a time as stock pastures; (3) by the use of green manures; and (4) by returning to the soil all wastes of the farm. The true test of the good farmer is the uniform maintenance of large and profitable yields. The inevitable signs that the farmer is losing his grip upon his acres are the gradual loss of cropping power in the land, or the growth of good crops only during favourable seasons, and the increase of weed growths with consequent increased cost in cultivation.

THE RESOURCES OF SOILS.—Sir John Bennet Lawes, in his celebrated experiments, has grown wheat continuously for forty-eight years upon the same land unmanured, getting an average yield of 13¾ bushels of grain per acre. In some parts of Europe crops of wheat, and in others of barley, are grown, one crop every two or three years, the land lying idle in the intervals of cropping; and this process has been going on for centuries with a steady average annual yield. In South Australia a similar practice in respect to wheat has been in vogue many years. Facts like these, which might be greatly multiplied, serve to show the vast resources of agricultural soils in plant food. In recent years, the word exhaustion, when used in connection with the soil, has taken an entirely different meaning to that originally given it. Now, exhausted soils are those which no longer produce crops to a profit. To recoup the soil for waste of all sorts, waste from excessive cropping, waste from the wash of soils and the incessant chemical and other changes going on in them, and to increase the store of plant food in naturally poor soils, at the same time compelling them to yield profitable crops, is the problem set before every cultivator. The soil is rich in the elements of plant food, and these are being crumbled down and shaped for the use of growing vegetation. Even the most enduring rocks are being constantly dissolved and changed into new forms or compounds by this process of weathering. There is no doubt that agricultural soils—that is, those which are productive when first broken up and subdued—can be made to produce crops, up to a certain standard, indefinitely, without the aid of manures. This standard, however, will only rarely meet the requirements of the modern farmer. He must, to meet taxes, pay labour, and support his family, compel the land to do more than it is *naturally* able to do. To accomplish this he must add to the resources of his soil by the use of manure in some form.

Wastes in the Soil.—One of the important objects sought in ploughing, harrowing, and tillage operations generally is to put the soil in such shape that weathering will go on most rapidly. The crop that follows this cultivation gets the benefit of the provision thus made for it in part only. Do what we will we shall not be able to gather all the plant food that has been broken down and prepared for plants, in the course of each season's cropping. Some of the nitrogen, in the form of ammonia, escapes from the soil as vapour; the nitrates, with lime and smaller amounts of potash and phosphoric acid, are carried into the soil beyond the reach of plant rootlets, or out of it, in drainage water. In a sense, then, cultivation may be said to be a source of waste. This fact doubtless explains the decadence of the practice of fallowing. Seventy years ago the summer fallow had a place in most systems of farm management. Now it is practised only rarely, usually for a special purpose, like the cleaning of very foul lands. In warm countries, where the rainfall is heavy, as in the coastal districts of Queensland, this natural waste must be enormous. Here well nigh every condition favours chemical and biological changes of the greatest intensity. The soil is nearly always warm and moist, and almost as constantly subject to the copious washings of tropical rains. As a result humus does not accumulate in the soil generally as it does in cooler regions. Instead, the elements of which humus is formed are dissipated as vapour, or carried through the soil and into drainage streams. The following description, by a traveller, of the soils along the Amazon, quoted by Storer, "Agriculture in its Relation to Chemistry," vol. 1, p. 454, explains the want of fertility on many Queensland scrubs and forest soils:—"The ground is sandy, as it is almost everywhere along the Amazons, and not very rich; it is nearly bare above, for mould does not form in the tropics, except about swampy places. At the north the leaves fall together and rot under the snow, but here they drop one by one all through the year; they dry up, are broken to dust, and so pass away in the air. Fallen logs and branches are eaten by insects.

There is nothing left to form a rich soil of. In fact it is a mistake to suppose that all this rampant tropical growth depends upon any inherent fertility of the ground. The sun and the moist air make up for barren soil. Besides the rains there are the heavy dews, and the winds are always soaked with moisture. The sand has no richness of its own, but it aids growth by carrying rain to thirsty roots." To this Storer adds: "So, too, when land in temperate climates, instead of being left to itself, comes to be cultivated, there will then be in many cases a constant drain upon the humus; and in order to keep up the fertility of the field there will be no need of applying to it new quantities of nitrogen, either in the form of farmyard manure or of peat taken from some place where humus has accumulated in excess."

The sources of waste in our soils are strikingly shown in the celebrated Rothampstead experiments of Sir John Bennet Lawes. It was there found that while thirty-seven days were required for nitrification—the process by which nitrogenous materials are changed into nitric acid by the action of an organic ferment or microbe—at a temperature of 52 degrees, the same process was completed in eight days at a temperature of 86 degrees. Investigators have shown that at 98·6 degrees nitrification is ten times more rapid than at 57 degrees. We thus see how rapidly the Queensland climate acts in changing crude nitrogenous materials into the easily soluble and easily lost form of nitric acid. How the elements of fertility thus changed are lost to the soil is shown in the following slightly abridged table, taken from reports of the Rothampstead experiments:—

NITROGEN supplied in MANURE, recovered in the CROP and in DRAINAGE, and unaccounted for in CROP or DRAINAGE, in the EXPERIMENTAL WHEAT FIELD—Two years.

—	In Pounds per Acre. Nitrogen per Acre per Annum.				
	In Manure.	In Crops.	In Drainage.	In Crop and Drainage.	Unaccounted for.
Unmanured continuously	0	12	15	27	+27
Mixed mineral manure ...	0	16	17	33	+33
Mixed mineral manure and 200 lb. ammonia salts	44	27	22	49	+ 5
Mixed mineral manure and 600 lb. ammonia salts	132	49	43	92	40
400 lb. ammonia salts alone	88	14	50	64	24
400 lb. ammonia salts and superphosphates	88	29	39	68	20
400 lb. ammonia salts and mixed mineral manure	88	32	74	106	+18
Unmanured 1865 and since	0	14	16	30	+30

This table well deserves the careful attention of Queensland cultivators. It must be borne in mind, however, that the conditions favouring nitrification and subsequent waste are vastly more active in Queensland than in the comparatively cold and slow climate of England. We here see that the crops recovered from the land are not the sole, or even the principal, sources of waste in cultivated lands. These facts explain why, in common with those of tropical and semi-tropical countries generally, Queensland soils are so constant in their demands for manure in some form.

Queensland Soils.—All Queensland farm lands are not situated within the tropical belt, although in all the country between the main range and the sea the climatic influences are essentially tropical. Moreover, enormously productive soils are found in large areas, the whole length of the coast. These rich lands may with sufficient accuracy be classed as volcanic, black, or chocolate soils, and alluvial lands. The volcanic soils owe their fertility to inherent qualities, great depth, fineness of particles, and often friability and natural drainage. The black soils are, as a rule, naturally very fertile and deep, but often lack drainage. They were rich to begin with, and part with their wealth slowly under cultivation. The chocolate soils, on the other hand, are generally very deep, as well as uniform above and below, well drained and exceedingly loose and permeable. To these qualities rather than to intrinsic fertility do most of the coastal chocolate soils owe their productiveness. Here the feeding ground of plants is enormous, and as air and rains penetrate the soil readily, the plant easily finds its compensation for more condensed fertility. For the fertility of alluvial lands Nature has made herself directly responsible by piling upon them, at irregular intervals, the wastes of other soils. The poor lands of Queensland owe their condition to their original lack, perhaps, of fertility but certainly of depth and fineness, and to those climatic influences which are constantly operating to prevent accumulations of plant food in them. The constant heat hastens decomposition* and thus produces waste, while the washings of heavy rains adds to the loss. If our poor forest soils were clothed with deciduous trees, with their autumnal profuse downcast of leaves and branches, held to the ground by snow and ice, and to slow decomposition by prolonged low temperature, these poor lands would be rich, as lands similarly situated are in "cold" countries. It is plain to me that the Queensland farmer of the future will be forced to manure his fields, or to practise those methods of conserving fertility which are understood by, and practised by, the skilful husbandman of other lands. At the present time our cultivators, as a rule, are, in common with the farmers of all new countries, taking the best from the best soils, and giving nothing in return. Washington, in the course of a letter to Arthur Young, stated the exact truth when he said, "In all countries where land is cheap and labour is dear, the people prefer cultivating much to cultivating well."

Checks upon Waste.—Despite the natural influences tending to waste the elements of fertility in soils, most of them in a state of nature lose nothing from year to year; many undoubtedly slowly increase in fertility. This is true of most scrub soils, and alluvial lands in general, and even forest soils, most likely, hold their own in the progress of time. The behaviour of soils in a state of nature ought to give the farmer a clue to the means of preventing loss of fertility in cultivated lands. Without stopping to point out reasons or analogies, we may say:—

1. The system of cropping which keeps the ground covered, as with a mulch, is advantageous in this respect: to leave soils bare during much of the season is always wasteful and exhausting.

* This word is used for convenience, and at the expense of accuracy. It really stands for all those complex chemical, biological, and physical changes which are known to be going on in the soil, and which really are a very different thing from decomposition.

2. During the growth of leguminous crops (clovers, vetches, peas, beans, &c.), and to a less extent where the land is laid to grass, the soil gains in fertility. In a general way, it may be said that lands which are not disturbed increase their stores of nitrogen—in other words, become more fertile. The loss sustained by soils is not, in large part even, due to the removal of crops from the soil, but from washing and other causes incident to cultivation.

3. Long periods of drought are undoubtedly favourable to the retention of nitrogen in the soil, as is also prolonged cold weather.

The practical man will not find it difficult to see which, if any, of these suggestions is applicable to his surroundings.

Chapter II.

GREEN MANURING.

By the phrase "green manuring" the practice of ploughing under some crop, in its green state, for the benefit of succeeding crops is meant. This is one of the cheapest and simplest methods of fertilising large areas of worn land. The practice is probably as old as agriculture, and its utility has rarely been questioned. Nevertheless, it has a recognised place in few systems of farming, except in connection with the growth of red clover. The labour of ploughing the land and seeding the same to some crop, is so light, as compared with the labour and expense of applying fertilisers, that the wonder is that the merits of green manuring have not received more general practical recognition. A long list of cultivated plants, nearly all quick growing bulky annuals, have been employed for this purpose. In different parts of England and the Continent, the vetch, rape, spurry, and lupines have been favourites for green manuring; while in America rye, oats, buckwheat, setaria, and in the Southern States the cow pea (*Dolichos sinensis*), have each been found useful as sources of soil fertility.

Leguminous Crops as Fertilisers.—The recent investigations of scientific men proving the ability of leguminous plants—peas, beans, clovers, vetches, and the like—to appropriate free nitrogen from the atmosphere has awakened fresh interest in the subject of green manuring. It has long been known that crops of clover and lucerne greatly improved soils, even where only the stubble of these crops was ploughed under. The reason for this is now apparent, and old practices, in this respect, admit of rational explanation. It is now clearly understood that the farmer has, in this great class of plants, an agent for the transformation of the nitrogen, existing in boundless quantities in the atmosphere, into the humus of soils. How this is done has not yet clearly been made out. The fact itself is, for all practical purposes, sufficient. We are not to understand that green crops other than the leguminous are worthless as a source of fertility, even though they derive their nitrogen almost entirely from the soil, and so make no real addition to it. Withal they have most useful features; equally with leguminous crops they cover the soil during the period of their growth, and so check natural wastes, and when ploughed under greatly improve the physical condition of heavy lands, making them more friable and so amenable to tillage operations. Moreover, the non-leguminous crop represents a season's accumulations in the soil, and this, in the most available form, is at the disposal of the succeeding crop. Without doubt, all the advantages derivable from the use of crops other than leguminous are to be obtained from the use of legumes, and besides the important one before alluded to, so that, when the latter are available, sound policy will dictate their use. The list of leguminous plants of proved suitableness for field cultivation in Queensland is far from complete. Nearly all the crops of this family, occupying a large place in agriculture, come to us with reputations established in cold countries. Most of the clovers fail in Queensland soil. It is true that lucerne thrives well in all parts of the colony, but its slow early growth and perennial habit unfit it for the short and quick work demanded of a manuring crop. Besides, lucerne can only be successfully grown on the richest of soils, those which, for the present, at least, need no additions to their fertility. Experience with the lupin is wanting in Queensland, but, from theoretical considerations, this crop is a promising one for use in fertilising our run-down soils. Vetches and field peas are too costly, in seed, and the crop is too precarious to warrant cultivation for fertilising purposes alone.

THE COW PEA.—From our present knowledge of this subject we are clearly warranted in placing the cow pea (*Dolichos sinensis*) at the head of the list of legumes suited to this purpose. This plant has been extensively grown in the Southern States of America, where its reputation as a green manuring crop, always good, is rapidly extending. It has there been shown that an annual crop of this plant has contained nitrogen worth £5, valuing nitrogen at its prevailing market price in other fertilisers. In Queensland, although of recent introduction, it has found universal favour with cultivators wherever it has been tried, either as a fodder plant, for which it is well suited, or as a fertilising crop. The cow pea has the great advantage over most other crops for this purpose, in that it makes a vigorous growth even upon very poor soils, where heat and moisture are not wanting. Other promising legumes for green manuring are a variety of Mauritius bean which has been tried on a limited scale in North Queensland, the crimson clover (*Trifolium incarnatum*), and white lupines. The cow pea is natural to hot moist climates, and while it endures periods of drouth well, it will not thrive in cold climates or during the cold season of warm countries. It also makes a very quick growth, three crops being harvested in a single season at the State Nursery at Kamerunga, near Cairns. Upon poor soils which it is desired to hurry into condition, a dressing of mixed superphosphate and potash would prove most useful. The dose would vary with the apparent needs of the soil, but not unlikely 250 lb. of bone meal and 300 lb. of kainit or 75 lb. of muriate of potash would be a fair average application. Such preliminary dressing, besides securing a vigorous growth of the green crop and ultimate large stores of nitrogen, would leave valuable residues for succeeding crops. There is a very long list of varieties of the cow pea, although only three—the Clay Coloured, Whip-poor-Will, and Black Eye—have, to my knowledge, found their way to Queensland. Of these the best, by far, for our purpose, is the Clay Coloured, distinguished by its yellowish clay coloured seed and rampant growth of vines. It should always be borne in mind by the cultivator that in preparing the soil for the green crop we are in reality working for the moneyed crop which is to follow. The better the tillage given the soil for the cow pea, the quicker and surer the ultimate success of the entire operation. After this thorough preparation of the soil, the cow pea may be broadcasted at the rate of one bushel to a bushel and a-half of seed per acre. As soon as the crop begins to show ripened pods about the field it is in condition to be turned under; and in case seed, for future sowings, is required, the crop may remain untouched until a sufficient supply of ripe seed pods has appeared. These may be hand-picked, and the crop of vines ploughed in immediately afterwards. It is better to plough the crop under in a somewhat over-ripe condition rather than in the opposite state of extreme greenness and succulency. It is commonly complained that a heavy crop of under-ripe pea vines "sours" the ground injuriously. The question when to plough under the green crop so that the most may be obtained from it is one that is best answered in the case of the particular crop that is to follow the green manuring. To plough the green crop under in the autumn, for a spring planted crop, is certainly, in the Queensland climate, and on light and well-drained soils, wasteful practice. The process of nitrification goes on, more or less, actively all the winter, and long before spring the bulk of the nitrogen of the green crop has got beyond the reach of the crop for which the green one was a preparation. In Louisiana the practice is to plough under pea vines early in September, the cane planting following about one month later. Upon very light soils, I should certainly leave the pea vines untouched until the near time of planting, even though much of a winter season intervene. Upon heavy lands, having a large admixture of clay, on the other hand, excellent results are obtained from turning under the green crop in the autumn. Such lands, besides being made more friable by this treatment, show their ability to retain the nitrogen of the green crop, in greatly increased cropping power. The operation of ploughing under pea vines and other green crops is best performed with a plough cutting a wide furrow and equipped with a keen rolling coulter and one of the devices, figured below, for dragging under the rampant surface growth.

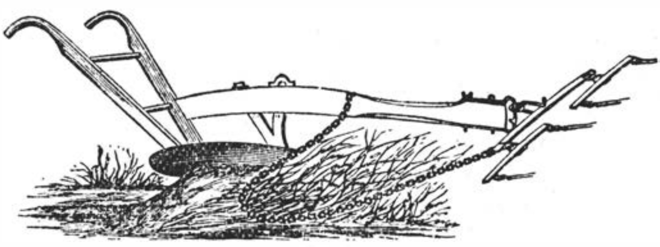

Fig. 1.

Fig. 2.

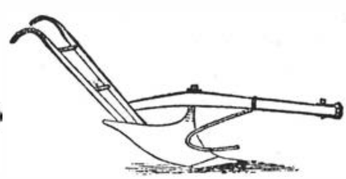

Fig. 3.

These figures call for no special explanation. The chain (Fig. 1) is available on every farm, but where much of this work is to be done it will be found worth while to provide the weed-burier (Fig. 2) or weed hook (Fig. 3). The straight rod has the advantage that it is not liable to be caught by obstructions, but it is really less efficient than either the chain or curved rod. In common practice the chain is attached at one end to the swingle bar and at the other to the beam of the plough, the chain forming a loop, the bight of which hangs over the revolving furrow. The chain should be so adjusted as to just drag the green stuff under without being caught by the furrow. I have found, in practice, that the best results are obtained by attaching the chain near the end or "bridle" of the beam rather than at its middle, as shown in the figure. A very little practice enables any ploughman to adjust either device, so that really excellent work will be accomplished. For the rods shown in the cuts, steel should be employed, as elasticity is desirable to enable them to pass safely over obstruction. The steel rods in use for making rake teeth are excellent for this purpose. Where the cow peas or other green crops are not thoroughly buried beneath the soil a rank growth, often very difficult to destroy, marks the lap of every furrow.

Circumstances will dictate the treatment of the field after it has received this green crop. Where the land is really poor, or where the time of planting the crop, for which the green manuring is a preparation, will admit, it may be advisable to treat the soil to one or even two more green crops before the final planting of the field. In any case the land must not be allowed to remain long unoccupied and uncovered. It is absolutely essential to the success of this operation that planting follows swiftly upon ploughing in of the final green crop. In a climate like that of Queensland, so energetic in its influences tending to waste fertility in soils, it is preferable to allow the green crop to become over-ripe and lie for a considerable time upon the surface before ploughing, provided it covers the ground completely. Here again we have a case in which judgment is demanded in a choice of evils. If the ground is allowed to remain fallow after receiving the green crop, there is an undoubted loss of nitrogen, and there is certainly a loss where the green crop becomes over-ripe before being incorporated with the soil. The extent of deterioration in pea vines after their maturity is shown by analyses of a crop, made at different dates during the autumn and winter of 1889-90 by the Alabama (U.S.) Experiment Station :—

Green vines collected in October contained 2·62 per cent. of nitrogen.

Dry vines collected in December contained 0·81 per cent. of nitrogen.

Dry vines collected in January contained 0·66 per cent. of nitrogen.

In the case where considerable time intervenes necessarily between the maturity of the cow-pea crop and the time of planting the crop that is to follow, the plan of ploughing under the crop of pea vines and promptly sowing the ground to some nitrogen fixing crop is to be commended. The nature of this catch crop will depend upon the locality and season, but setaria, rape, rye, oats, wheat, or buckwheat are each and all excellent for this purpose.

A Smothering Crop.—The influence of the green crop in smothering and holding in check nearly every form of weed growth is well understood by practical men. It may be said that this smothering function of the green crop is altogether peculiar to it. The application of direct fertilisers is often attended with great risk of introducing to the field some new form of weed growth, and all forms of manure stimulate and invigorate indifferently the crop and its rival growth of weeds. The farmer who has allowed his acres to become foul with weeds will find, in a succession of manuring crops, a cheap and easy means of cleansing and fertilising his lands at one operation. It has been brought to my attention that a strong growth of cow peas has proved efficacious in subduing a rank growth of that, in some respects, most pernicious of weeds, nut-grass. To get the full benefit of the manuring crop, in holding weeds in check, this green crop must be given a clear advantage over the weeds in the start, otherwise the operation will be reversed, the weeds smothering the green crop. The necessary precaution is that the ground shall be ploughed in such condition and season as will ensure the prompt and vigorous early growth of the smothering crop. To this end it is imperative that seeding follows ploughing with the least possible delay.

Green Manures in Different Soils.—One great and unquestioned advantage of the green crop used as a manure is the increased friability of soils due to its action. Farmers who have had experience with green manuring delight to tell how like an "ash heap" the most stubborn clays have become through the action of a crop ploughed under. This fact explains the preference so generally given heavy land for the application of green manures. It also, in a large degree, gives us the reason for the favour shown crops other than the legumes for this purpose. Heavy soils carrying abundant clay and rich in humus are, besides being improved physically—mellowed—much more largely benefited chemically, than sands. Chemical action goes on in them much less rapidly than in loose soils, and they grasp and retain the nitrogen of the green crop more completely. On the other hand, light lands may, for the time, receive positive damage from a green crop turned under. Loose sands, for instance, turned by the plough are quickly penetrated by the atmosphere, and thus part with their moisture rapidly. Seeds sown upon such land fail to find the condition for vigorous growth either in the soil above or the souring mass of vegetation beneath. These are the facts, briefly stated, which explain the common failure of green manuring upon loose soils. The familiar agricultural principle, that heavy lands need breaking up and disintegrating, and light lands consolidating, cannot be lost sight of in making plans for the application of crops as green manure.

From the foregoing the advantages and disadvantages of green manuring will be gathered directly or by inference. The practice is essentially a wasteful one, and so unscientific, and cannot be universally recommended. The cane crop, better than almost any other grown in Queensland, lends itself to the practice of green manuring. The sugar-cane by occupying the ground for a series of years creates a keen demand for nitrogen in it, as well as for the smothering action of the green crop upon weeds. Besides, cane-growing is never connected with stock-raising or other manure-making agency. The essential wastefulness of green manuring becomes apparent when we remember that a single acre of cow pea has a feeding value close to £5, while the manure made from this fodder would be worth something over £4. Green manuring may be unreservedly recommended for bringing large areas of run-down land into condition, such that green manures are no longer needed for their successful management; for occasional use as a smothering crop, and for a much more general use in connection with those crops or systems of farming which compel the farmer to constantly look outside of his own farm for the means of maintaining its fertility.

EXPERIENCES WITH GREEN MANURES.—This topic may be appropriately concluded by references to the experiences of a few large and successful Queensland cultivators with green manuring. The subjoined extracts are from letters recently received by the writer:—

Messrs. A. H. and E. Young, Fairymead Plantation, Bundaberg, write—"We are very much pleased with the cow pea as a green manure. Unfortunately we are unable to give actual results, owing to the floods of 1893 having destroyed over 200 acres of a magnificent crop of peas which we were on the point of ploughing in. The land on which this crop grew is now in cane and promises well, but as the whole of the crop of peas disappeared leaving only the roots, the experiment was spoiled. Last September, however, we again sowed about 200 acres with cow peas and again had a splendid crop, the ground being covered with a dense growth eighteen inches high, every inch of the ground being covered. This crop we ploughed in in the month of March, 1894, and after giving it three weeks to rot, we drilled the ground and planted it with cane (we found three weeks' time sufficient to rot the peas). This cane is still very young but is looking well, and promises a good yield.

"We have the highest opinion of the cow pea for green soiling; the land turns up in splendid condition after it; and such a mass of vegetable growth cannot fail to enrich the soil greatly. We have also found it a most valuable fodder, both horses and cows being very partial to it. Our horses thrive remarkably upon it, rapidly putting on flesh and showing a beautiful sleek skin. As far as our experience goes, the best time in this district to sow is in the month of September, after all fear of frosts is over, and it should be ploughed in when in blossom and the green peas are showing. We found half a bushel* of seed to the acre, sown broadcast, ample. It should be sown on the ploughed ground, and covered with the drag on disc-harrow. The land should be well drained and no surface water allowed to lodge on it, for the cow pea is very sensitive to excess of moisture. In our opinion this is one of the most valuable plants ever introduced into the colony. * * * * * * The practical difficulty of ploughing in and covering such a mass of material gave us great trouble, and we found it necessary to roll the peas down in front of the ploughs. The latter should be very high in the beam to give plenty of clearance, and the wheels should be as much forward as possible, so that the furrow being turned by the plough is not jammed between it and the furrow-wheel. We found sulkey ploughs the only ones that would cover this crop effectually."

* This amount of seed is certainly too small for light or inferior lands.—E. M. S.

Mr. Edward W. Knox, General Manager, Colonial Sugar Refining Company, Limited, Sydney:—"So far we consider the American cow peas excellent for green manuring for cane crops; but that, as you suggest, there may be found other beans equally good, or, in some respects, even better. To these apparently belong the black and the red Mauritius beans, and, although opinions differ as to their merits—perhaps because these beans were amongst the first green manures introduced by us, when green manuring was not understood—we have received some very encouraging reports on them from several of our cultivation officers. At Homebush, in the Mackay district, these beans have been found to even smother nut-grass, and as they are perennial, the killing of the nut-grass is probably only a question of time."

Mr. R. M. Boyd, Ripple Creek, Herbert River:—"I have pleasure in informing you that I find them (cow peas) of great benefit on sugar land: not only is their manurial effect most marked, but they appear to increase in beneficial effect on the soil, which ploughs up in looser and better order where these plants have been grown. The cow pea grows with us all the year round, and we plant it at any time we have a field to fallow. We endeavour to take a crop of seeds before ploughing in, but believe that when in blossom is the best time for turning it under. I find that this plant will stand excessive rain on well-drained land, but standing water quickly kills it. I plant broadcast if seed is plentiful, and drill in two-foot rows with a corn-planter if my stock is small."

Chapter III.

FARM-YARD MANURES AND THEIR APPLICATION.

By the phrase "farmyard manure" is here meant all the various liquid and solid accumulations of farm and garden, having value as fertilisers but worthless for most other uses. The term includes the excrements of animals, the litter used in connection with them, and the combinations of these substances, fermented and otherwise. The farm and farmyard is by far the most important source of farm fertility. The great body of cultivators employ no other manures than those produced in the course of their own operations. There are almost innumerable instances of farms maintained in a high state of productiveness through judicious cropping and the conservation and application of those residues of the farm which go under the general name of farmyard manures.

WHERE MORE MANURE IS CALLED FOR.—The farmer who finds that under his system of management this supply of home-made fertilisers is inadequate to the demands of the land may often, by a slight change of cropping or in the general plan of his operations, increase the available supply of manure without the necessity for outside purchasing. What these changes should be will depend upon local circumstances, but in a general way it may be said that—

1. Increased attention to live stock;
2. The growth of larger supplies of stock foods for home consumption;
3. Feeding purchased foods; and
4. Laying down the land to grasses or clovers—

are the lines along which the farmer must act to increase the home supply of fertilisers. The fruit-growers and market gardeners along the Queensland coast, who are now paying large prices, with miles of cartage added, for city refuse, would often find profit in one of the diversions from their ordinary practices indicated above. There is no necessary antagonism between market gardening and dairying, for instance, or between banana-growing and pig-feeding. As a rule, the cows or pigs might be relied upon to pay their way in the ordinary products of feeding; but if in the transaction no more than the manure could be put aside as clear gain the business will generally be accounted a profitable one. The farmer who undertakes to increase in this way the available manure supply will find profit in the study of the tables, further on, giving the manurial values of different stock foods. The philosophy of this suggested plan of feeding boughten foods upon the farm is, that such foods are sold presumably *for their feeding value alone*, thus giving the purchaser and feeder the manures resulting at a nominal cost. The following figures obtained from actual feeding experiments, made at one of the American experiment stations, is of interest in this connection as showing the value of manure produced by different animals under ordinary conditions of liberal feeding:—

Animals.	Food.	Food consumed per animal daily.	Manure excreted per animal daily.	Composition of Manure.			Value of Manure.	
				Nitrogen.	Potash.	Phosphoric Acid.	Per ton (2,240 lb.)	Per Animal daily.
		lb.	lb.	per cent	per cent	per cent	s. d.	d.
Cows ...	Hay, silage, beets, wheat, bran, corn meal, cotton seed meal, malt sprouts	75·5	81·5	0·50	0·29	0·45	11 1	4½
Horses (at work)	Hay and oats (estimated ⅗ manure collected)	...	52·5	0·47	0·94	0·39	12 9	3½
Sheep ...	Grain, beets, and hay	5·3	7·2	1·00	1·21	0·08	19 6	0¾
Swine ...	Corn meal, or corn meal and flesh meal	3·6	3·5	0·83	0·61	0·04	14 10	0¼

This table shows in a striking way the important relation which live stock sustain to farm fertility. The direct loss sustained by farms from which the substances here fed are marketed in the usual way may here be roughly computed. Different foods would undoubtedly have given different results; foods rich in nitrogen, potash, and phosphoric acid will invariably give manures correspondingly rich in these elements of fertility. Moreover, it is known that the bulk of the nitrogen, potash, and phosphoric acid are voided in the manure in nearly the same proportions as existing originally in the food. This has been clearly shown in the feeding trial made in another of the American stations (Maine). In this experiment two lots of sheep were fed, one with a ration rich in nitrogen, and the other upon foods deficient in this element. The results of five days' feeding of the two lots are given in the subjoined table:—

—	Hay and Cotton Seed Meal.		Hay and Corn Meal.	
	In Food.	In Manure.	In Food.	In Manure.
	Oz.	Oz.	Oz.	Oz.
Nitrogen	3·6	3·9	1·6	1·5
Potash	2·2	2·0	1·1	0·8
Phosphoric acid	1·4	1·3	0·5	0·4

In the report of this experiment the results are summarised as follows:—"The amounts of nitrogen, phosphoric acid, and potash in the manure residue stand in direct relation to the amounts of the same ingredients in the food, the loss in the present instance averaging only about 10 per cent.

"The urine contained nearly half the potash of the total excretion, and from half to three-fourths the nitrogen, but no phosphoric acid, the latter being wholly in the solid excrement."

These facts indicate authoritatively the means by which poor Queensland soils may be made better, and the rich soils kept up to a high average of cropping power. If it be said that much, particularly of the tropical farming of Queensland, cane-growing for example, does not admit of stock-keeping as an adjunct, there is still open to these cultivators green manuring in connection with the moderate use of purchased fertilisers, and upon every plantation there are vast possibilities of increasing the supply of manure, through careful husbanding of the various odds and ends of sugar-growing, begasse, trash, filter press cake, the manure of working animals, and the like, which alone will go far towards placing the plantation on an independent basis as to the manure supply. This, to my mind, is perfectly certain. Sugar-growing, no more than any other branch of farming, even where pursued only on the best scrub soils, as is now generally the case, can long stand the scourging system now in vogue, which, for the most part, takes everything from the soil and gives nothing in return. Every calculation of the profits of the business which does not take into account the inevitable outlay for manure supplies is a faulty one, and is sure, if acted upon, to bring disappointment in the end. The question set before intending cane-growers is not what are the profits of virgin soils from cultivation alone, but how to maintain the standard of profit and the fertility of the plantation at a common and high level.

The Value of Manures.—The quality of manure and its consequent value depend upon the food from which it is made, and the care taken in preserving it. The droppings of animals fed upon straw, grass, and herbage deficient in nutriment, are deficient in the elements of fertility. The passage of these substances through the digestive system of the animal adds nothing to their value. Indeed, as has already been shown, the animal retains a certain and appreciable amount of the nitrogen, potash, and phosphoric acid of its food, the manure showing a corresponding loss, even where the urine has been carefully saved. The amount of these substances retained will vary considerably with animals under different treatment. Young and growing animals, milch stock, and animals gaining in flesh rapidly will, other things being equal, retain the largest amounts of fertilising constituents contained in foods. The common mistake of farmers is their assumption, in practice, that all manures of a particular kind have equal value. Stable manure, for instance, is generally valued at so much the load, although it is possible for one load to be worth four or five times as much as another. This is shown in the following table of the manurial value of a few foods, in which allowance has been made for the amount of fertilising constituents retained by the animal. The current prices of commercial fertilisers is the basis of this calculation of values:—

VALUE OF MANURES FROM ONE TON OF FEED.

	£	s.	d.
Lucerne hay	2	3	9
Maize fodder	1	15	7
Oaten hay	1	13	10
Millet-setaria—green	0	13	0
Cow-pea vines—green	0	10	6
Cow-pea vines—hay	2	13	11
Sorghum—green	0	8	6
Barley straw	1	2	10
Oat straw	0	9	9
Wheat straw	0	15	1
Barley	2	1	10
Maize	1	15	0
Oats	1	13	3
Linseed	3	3	8
Wheat bran	3	10	9

Undoubtedly the quantity of food, the amount of daily ration, has much to do with the value of the manure obtained as a result of the feeding. An animal fed sparingly upon even the best of foods will give a manure much less valuable than that obtained from full feeding. This fact explains the preference shown by English farmers for manure from highly-fed work horses and fattening cattle.

WASTES IN MANURES.—One has but to consider the possibilities of loss in manures to see how small a portion of farm-made fertilisers is utilised by the farmer. In the first place, about one-half of what may be called the manurial contents of food is discharged in the liquid excrements. This is practically all lost in nearly every stable and stockyard in the colony. Then the loss from the fermentation and washing of manures piled in the open is undoubtedly very great. The writer, at the Kansas Experiment Station, made a series of careful experiments, which were carried on through two years, to test this point. It was here found that exposed piles of manure in the course of six months lost fully one-half in weight, and parted with about 40 per cent. of its nitrogen. Like results have been made from experiments made at other American stations. From these facts it would seem that the farmer who allows the urine of his animals to go to waste, and exposes the solid excrements to the weather in piles without protection for several months, has for his soil not much more than 25 per cent. of the fertiliser actually available to him.

THE PRESERVATION OF MANURES.—Considering the possibilities of loss in manures kept for a length of time, it may well be questioned whether under the ordinary conditions of the farm it is worth while to attempt its storage. My own practice has been, wherever circumstances allowed, to haul the manure afield as fast as it was made, spreading it evenly over the ground from the cart. Manure thus spread dries out at once in fine weather, and fermentation ceases, while the rains which leach through it carry with them into the soil the soluble constitutents of the manure. Even where the field is to remain unploughed for a considerable time it is more economical, where circumstances permit, to spread the manure upon it in this way than to leave it exposed to the risks which attend ordinary methods of storage. In many cases it will not be found practicable to follow the plan above outlined ; the land may not be ready to receive the manure, or conveniences for carting may be wanting. Besides, a fertiliser that acts quickly, as well fermented dung does, may be wanted for some special crop. These considerations raise the question how best to store manures so that they may be carried on for future use with the least waste ?

The two chief sources of waste in manures are due to fermentation and the escape of resultant gases, and the leaching action of water percolating through the manure mass. The waste through fermentation or decomposition is always slight—so slight, in fact, that its influence may generally in practice be disregarded. The elements of fertility exist in farmyard manures for the most part in an insoluble condition. Of nitrogen there is only a small amount in soluble form, while the contained phosphoric acid and potash are largely insoluble ; but in any case these valuable minerals can only be lost in appreciable quantity through the action of water. The result of fermentation, then, is to increase the solubility of a manure, and where this process is a slow one, as is the case in compact piles, the bulk of the ammonia is caught before it can reach the surface, and held in the form of soluble salts. How the putrefactive changes going on in the manure pile are brought about need not to be discussed here at length. Modern science has shown us that through the agency of various species of microbes the organic constituents of manures are speedily broken down or "decomposed," and their elements rearranged in new forms. As a result of the activity of these peculiar organisms, the insoluble mass of the manure pile is made soluble, and so available to plants. Nitrogen takes the form of ammonia or nitric acid, and mineral elements are released from combination with materials, all taking on the forms easiest available to plants and most easily lost to the farmer. To preserve manures with the least possible loss, while undergoing this fermenting process, a course is open to the farmer which is justified alike by science and sound practice—

1. The manure must be kept in solid masses. Such compact piles, under ordinary conditions, retain their moisture throughout; fermentation proceeds slowly in them, and the gaseous products of

fermentation are retained in the heap. The old-fashioned practice of frequently turning the manure heap, whatever its value in cool climates, ought to be abandoned in Queensland, because of the inevitable waste that attends it.

2. The manure pile must be so placed that water must not leach through it, either into the ground beneath or out upon the surface. Ordinarily the annual rainfall will do no more than to keep the manure suitably moist. The danger from leaching is to be expected rather from the water which flows upon the manure from a higher level. Necessary measures must be taken to prevent this, either by diverting the water from the manure by means of ditches, or by locating it so that precautions of this kind are unnecessary. The need of an abundant supply of litter to retain the urine and other liquids of the manure will be apparent from the above considerations. The escape of these liquids into the ground beneath will be prevented by making it impervious to water, by the addition of a layer of wet clay thoroughly worked (puddled) with the hoe, and if a concave form be given to the bottom of the yard, loss from leaching of water will be small indeed. The farmer who keeps his stable manure in masses made solid by the tread of animals or other means, meanwhile cutting it off from the inflow and outgo of water, will have small cause of complaint of loss in storing manures for limited periods of time, even in hot and warm seasons.

Application of Manures.—The constant tendency of manurial elements, particularly all forms of nitrogen, towards lower levels in the soil, through the action of water, until they pass beyond the reach of plant roots or escape from the soil completely in drainage waters has already been pointed out. This fact furnishes the reason for the modern methods of applying fertilisers. The old practice was to haul the manure afield, dumping it in heaps, afterwards spreading the heaps as suited the convenience of the farmer. These heaps became at once the seat of active fermentation, and the products of fermentation were rapidly carried into the ground directly beneath the heaps with each recurring rain; moreover, unless great care was practised the heaps were not likely to be equally distributed over the ground, the finer and best rotted portions remaining about the position of the heap, giving to the crop following a spotted appearance, caused by overgrowth at these points. It is best therefore, where circumstances permit, to spread the manure directly from the cart, a practice which has an additional advantage in being economical in labour.

The following rules for the application of manures serve to illustrate principles as well as the best practices of modern farmers in this regard :—

1. Heavy application of manure, at one time, is almost certainly wasteful. Small doses and often should be the rule with fertilisers, whatever their nature may be. Better far to give the land 10 tons of manure for three years in succession than 30 tons once in three years. The loss and dissipation of manurial elements in the soil go on constantly, while the crop feeds only at certain seasons of the year. Excessive manuring is wasteful, because it loads the soil with plant food beyond the present requirements of the growing crop, while the waste from large masses of manure in the field is large and constant. Modern

methods bring us constantly towards the Eastern method of manuring the plant rather than the soil. Certain crops, again, are notoriously gross feeders, making constant and large demands on the resources of the soil and showing, by rapidly diminishing yields, any failure on the part of the soil to meet their natural demands. These are, for the most part, coarse-growing broad-leaved plants, like the banana, sugar-cane, maize, and among vegetables the cabbage and the beet. With these crops it is difficult to overdo with manures, although the crop may be damaged in special products like the sugar of the cane and beet by a too generous application of nitrogenous manures.

2. Whenever practicable, haul the manure to the field as fast as made and spread directly from the dray. This is economical in practice and sound in principle. There is no danger of loss from the escape of the volatile matters of manure that is in direct contact with the soil.

3. The more nearly manure is kept to the surface of the soil, and the more thoroughly it is mixed with it in cultivation, the better. Probably the best treatment that can be given manure on the soil is to spread it on the surface of the ploughed ground, and afterwards work it into the soil with the harrow or cultivator. The subsequent tillage operations in connection with the growing crop generally forbid this course, and make the ploughing under of manure a necessity.

4. In respect to the time of applying manures (to the crop) hard and fast rules are difficult to make. In a general way, well-rotted manures and others, like horse or sheep manure, which are quick in action, had better be applied in the spring, or at such time as to meet the immediate requirements of the crop. Crops, however, vary enormously in respect to their manurial requirements. A grain crop manured in the spring is often stimulated to a late growth of rank feeble straw, which gives a diminished yield of grain. Other crops, fruit trees, pineapples, bananas, &c., often demand the forcing effects of manure late one season in order to make the crop of the next. In the climate of Queensland, manures, as a rule, may be applied with the expectation of receiving quick returns for the application.

Chapter IV.

THE ELEMENTS OF FERTILITY IN SOILS.

All of the various forms of material things are, so far as present knowledge goes, combinations of certain chemical elements about seventy in number. By chemical element is meant a substance that cannot by any means be separated into other substances. Thus iron and nitrogen and gold are called chemical elements, because whatever treatment they may be made to undergo they cannot be made to yield up aught but iron, nitrogen, or gold, as the case may be. These seventy elements, by combination in an infinite variety of ways, serve to make all the varied and wonderful objects of earth and air. The soil is but a combination of a few of these elements, and the plants growing from the soil represent another blending of certain of these same elements. The many ways in which these elements vary in form, chemical qualities, and methods of combination need not to be dwelt upon at length here. So far as agriculture is concerned, our interest in this subject is limited to the comparatively small number of elements that go to make up soils, fertilisers, and vegetable products.

Elements of Soils and Crops.—Soils vary greatly in composition as they do in fertility, but the best and most fertile rarely contain more than fourteen of these chemical elements. Soils primarily are the result of chemical action and the weathering process upon rocks. They come to us as a crude compound of coarse and fine materials, mixed with a greater or less amount of the remains of vegetation (organic matter) combined with more or less of moisture. The following table fairly shows the groupings of these elements in familiar substances as shown in the composition of fertile soils:—

4·0	per cent.	of	organic matter
0·1	„	„	nitrogen
20·0	„	„	water
75·9	„	„	mineral matter.

Of the seventy elements of our soils, it is known that only fourteen are absolutely essential to the production of the various forms of vegetable growth. These elementary substances are named as follows:—Carbon, hydrogen, nitrogen, oxygen, phosphorus, sulphur, chlorine, silicon, calcium, sodium, iron, magnesium, manganese, and potassium. If we subject vegetation to the action of fire, we find that a certain and small amount only remains with us in the shape of ash. This incombustible ash represents the mineral constituents of the plant derived from the soil. A large portion of the plant, however, has escaped during the process of combustion, in the form of gas. This destructible portion of plants is made up of the following elements:—Carbon, oxygen, hydrogen, and nitrogen, and in a less degree sulphur and phosphorus. These two classes of elements, the mineral and the gaseous constituents of plants, differ in several important respects. First, in their source; with the exception of sulphur and phosphorus, the combustible portions of plants are derived directly or indirectly exclusively from the air, while the mineral elements are received wholly from the soil. Again, the two classes exist in widely different proportions in vegetation. Thus, the gaseous or air-derived elements constitute nearly 95 per cent. of the vegetable kingdom, taken as a whole, while the mineral elements of plants vary greatly between a fraction of 1 per cent. and 10 per cent., or even more.

Importance of Chemical Analysis.—These facts and much besides, the whole forming the subject-matter of agricultural chemistry, have come to us through the industrious labours of modern chemists. They have shown us the reasons for many of the practices of the farmer, the causes of his success and failures, and have suggested many of the improvements which characterise modern agriculture. From the great benefits which chemistry had already conferred upon agriculture, it was expected that striking advantages would be derived from the analysis of soil and the plants growing from it. It was assumed that we had only to know the composition of the soil and the demand that crops made upon it, in growth, to be able to control all the conditions of successful cultivation. These expectations have never been realised. This failure is not due to the imperfection of chemical methods; it is owing rather to the fact that profitable production in farming is in a large degree contingent upon causes quite outside the domain of chemistry. A soil, for example, may be fertile, but for *physical* causes unproductive. Again, soils not abounding in the elements of fertility are productive because physically their condition is good. Some of the richest agricultural districts of Queensland owe their prosperity to a soil that is, from a chemical standpoint, far from rich; this soil is in the condition of an impalpable powder, so that every part is accessible to the rootlets of plants. It is also very deep and well drained, and to these facts its productiveness is due. Again, fertility in soils depends, not upon the gross amount of this or that element of value, but upon the comparatively small amount which is soluble and so available to plants. The *existence* of elements of agricultural value in the soil chemistry can determine, but their *condition* or suitableness to the wants of plant life is not brought out by chemical analysis.

After this statement of the inutility of chemical analysis, the question where and under what condition it may be usefully employed is sure to be raised. An eminent agricultural chemist (Dr. R. C. Kedzie, of Michigan, U.S.A.) says:—"Chemical analysis of the soil is of value in determining whether a soil is capable of fertility or the contrary, also in determining the measure of its possible fertility. There are certain ash constituents which are absolutely necessary for plant growth, in the absence of any one of which vegetable growth is impossible; if the supply is relatively limited, plant growth will be limited correspondingly. If all the ash elements are present in sufficient amount and in available form, such soil is capable of fertility. Hence, chemical analysis of a soil is of importance in determining possibility of fertility and of the relative fertility which may be secured under favourable circumstances."

THE ELEMENTS OF APPLIED FERTILITY.—Of the fourteen elements above referred to as necessary in the soil to the perfect development of plants, only three—nitrogen, phosphorus (in the form of phosphoric acid), and potash—come within the scope of the farmer's care and skill, and so need consideration here. The remaining eleven are always to be found in agricultural soils, and generally in quantity sufficient for the needs of growing crops. The loss or failure of any one of these three elements in the soil is attended with prompt failure of cropping power, while the return of one or more to poor or worn soils is always followed by increased productiveness. The important place held by these three substances in the economy of agriculture warrants a brief statement here of their qualities and relations as elements.

NITROGEN.—This is the element that is easiest lost to the soil, and that costs most to replace when once parted with. We have already drawn attention to the constant loss of nitrogenous compounds to the soil, through the leaching action of water. In like manner both phosphoric acid and potash are subject to waste, but in a much less degree. Nitrogen is a gas without colour, taste, or smell. It forms, without combination with other elements, about four-fifths of the air we breathe, and in combination with other substances occupies a large place in nature. Nitrogen combined with hydrogen forms ammonia, a gas that is formed in the decomposition of vegetable and animal substances containing nitrogen, and which is distinguished by its pungent odour. Combined with both hydrogen and oxygen again, nitrogen forms *nitric acid* or *aqua fortis*; and if in nitric acid some metal like sodium is substituted for the hydrogen of the acid we have formed a *nitrate*, in this case the nitrate of sodium. Under certain conditions of temperature and moisture, the nitrogen of vegetable and animal substances is rapidly changed, through the instrumentality of microbes, into nitric acid and the nitrates. This process is known as nitrification.

Nitrogen as it exists in the uncombined state in the atmosphere is available to plants only in a limited and obscure way. The great class of plants known as leguminous undoubtedly take uncombined nitrogen from the air. Nitrogen in the form of ammonia is taken by certain plants directly from the atmosphere, while others utilise the ammonium salts existent in the soil. But by far the largest part of nitrogen used by plants is taken through their roots in the form of nitrates. It is in this form that nitrogen is most available and most valuable to growing plants.

Phosphorus.—Next to nitrogen, phosphorus is the most costly ingredient of fertilisers, and that in greatest demand. Phosphorus, in the free or uncombined state, is nowhere found in nature. When isolated by the chemist it oxydises rapidly, taking fire at once if exposed to the atmosphere, the phosphorus uniting with the oxygen in the proportions of two atoms of the former to five of the latter. Most usually phosphorus is found united with oxygen and calcium (lime), the combination going under the name of phosphate of lime or calcium phosphate. It also combines variously with potash, soda, alumina, and other metals.

The chief sources of our supplies of phosphoric acid for use as fertilisers are: 1st. Bones, fresh or otherwise; 2nd. Deposits of animal remains found in caves along the Queensland coast and elsewhere in tropical countries; 3rd. Fossil remains of animals, chiefly excrementitious matters; 4th. A by-product of the process of smelting iron, known as Thomas Slag. Phosphoric acid in the form of phosphate is found in small amounts in all soils, but is rarely abundant. These soil phosphates being only sparingly soluble, yield a moderate but steady supply of plant food from year to year, and thus are placed beyond the power of the husbandman to waste them.

Phosphoric acid is found in three principal forms; *soluble phosphoric acid* implies phosphoric acid that is freely soluble in water. This form, whatever its origin, tends slowly towards the second form of *reverted phosphoric acid*, which is insoluble in water but soluble in ammonium citrate. Experiments show the soluble and reverted forms of phosphoric acid to be nearly equally valuable as plant food. *Insoluble phosphoric acid* is often unavailable to plants on account of its insolubility. Very fine grinding of the materials, treatment with sulphuric acid, or subjecting them to the influences of decay, are some of the means by which the insoluble phosphates are fitted for use in the field.

Potassium.—This element, like phosphorus, is never found in a free state in nature. It is a constituent of many minerals: united with oxygen, in the proportions of two atoms of potassium to one of oxygen, we have the potash of commerce. Potassium, as a constituent of fertilisers, ranks next to phosphorus in costliness. In plants, soils, and fertilisers it exists as chloride, sulphate, carbonate, &c. It is most costly in the form of sulphate and cheapest as chloride (muriate). The supply of potash, used as fertilisers in Queensland, comes chiefly from wood ashes, very variable in quality but everywhere abundant, and small quantities of Kainit recently imported from the celebrated Stassfurt mines of Germany. My own observations of Queensland soils lead me to believe that the forest lands, particularly those distributed along the coast, are often deficient in this element, and that in consequence fertilisers rich in potash might often be applied to great advantage.

Chapter V.

COMMERCIAL FERTILISERS.

By the term "commercial fertiliser" is meant any substance or artificial mixture put upon the market, under a peculiar name, for use as a fertiliser. The value of manures and the profitableness of manuring are rarely questioned by practical men, but the policy of using commercial fertilisers for soil amendment is a constant subject of debate. Abundant experience has shown us that great crops are possible from the use of artificial manures, but large crops are not necessarily profitable ones. It may often happen that to produce an extra ton of cane or bushel of maize per acre requires an outlay for manure that carries the cost of the entire crop beyond the line of profit. The view all along held by conservative farmers has been that commercial manures were profitable only when applied in special cases—to give particular crops an early start, to stimulate worn-out lands to the production of manure-making crops, and in particular to reinforce the supply of home-made dung. This view of the function of commercial fertilisers in the economy of the farm has undoubtedly been considerably modified in recent years. Commercial fertilisers now find a larger and more profitable general use than ever before: where a few used them occasionally, and for a special purpose, the many now give them a large place in every year's operations. The present cheapness of these fertilisers, their great variety and excellence, due largely to the utilisation of the wastes of manufacturing establishments, have contributed to the modern change of sentiment respecting their use.

Soil Residues.—The common charge made against commercial fertilisers is that they act, like alcohol in the animal body, as mere stimulants to growing crops, leaving the soil hungrier and more attenuated than before with each crop grown by them. Doubtless this idea owes its inception to the fact that a few hundredweight per acre, more or less, of a concentrated fertiliser is quickly parted with by the soil, leaving none of the residual humus, that more or less permanent form of fertility which remains after a dressing of farmyard dung. This fact is strikingly shown in the experiments of Messrs. Lawes and Gilbert. The manuring given certain plants, their average produce, with the alteration in the nitrogen content of the first nine inches of soil, during sixteen years, is shown in the table here reproduced:—

Plot.	Manures per acre annually supplied—1865-1881.	AVERAGE PRODUCE PER ACRE.		NITROGEN PER ACRE IN FIRST 9 INCHES OF SOIL.		
		Dressed Grain.	Total Produce.	1865.	1881.	Gain (plus) or loss (minus) in 16 years.
		bshls.	lb.	lb.	lb.	lb.
3	Unmanured	$11\frac{1}{8}$	1,715	2,507	2,404	-103
5A	Mixed mineral manure	$12\frac{3}{4}$	1,963	2,574	2,328	-246
10A	Ammonium salts, 400 lb.	$17\frac{7}{8}$	2,881	2,548	2,471	-77
11A	Ammonium salts with superphosphate	$23\frac{1}{4}$	3,856	2,693	2,676	-17
7A	Ammonium salts with mixed mineral manure	28	4,993	2,829	2,908	+79
9A	Nitrate of sodium, 550 lb., and mixed mineral manure	36	6,949	2,834	2,883	+49
16A	Unmanured	$13\frac{1}{2}$	2,194	2,907	2,557	-350
2	**Farmyard manure, 14 tons**	**$31\frac{1}{2}$**	**5,356**	**4,329**	**4,507**	**+173**

The great difference in the results obtained from the different applications is apparent in this table, but in nothing is this disparity seen as in the marked decline or small gains of soil-nitrogen shown in all except the plot receiving farmyard manure. Speaking to this point, Mr. Robert Warrington, an associate of Lawes in the work at Rothampstead, says:—"The plots which have received farmyard manure show, as in the wheat experiments, the largest amount of nitrification; in the barley experiments there is, however, a point of special interest. After twenty years' continuous application of farmyard manure, the plot was divided, and one-half has since received no manure. The sampling of the soil took place ten years after the application of farmyard manure had ceased. The effect of the residue of the previous manuring was, however, still very apparent. The soil contained both more nitrogen and more nitric acid than any other plot, save the one continuously treated with farmyard manure. We have here a striking example of the slowness with which residues of farmyard manure decompose in a clay soil. The effect of the old manuring is very distinctly seen in the crop."

This writer points out that the variation of the nitrogen residues of the soil shown in the table depends not so much upon the amount of nitrogen supplied in the manure, as upon the size of the crop obtained from the different applications. "The figures in the table show, however, that the nitrogen in the soil did stand in a plain relation to the amount of crop grown on the land. Where the ammonium salts were applied without ash constituents—Plot 10A—the produce was the smallest, and so is the nitrogen in the soil; and this nitrogen, like the crop, is a diminishing quantity. Where superphosphate was supplied with the ammonia, the crop is considerably increased, and so is the nitrogen of the soil, which has shown little change in sixteen years. Where the ammonia is used with a full supply of ash constituents the produce is the largest; the nitrogen, too, is largest, and shows a tendency to rise."

Without touching the question of profits—which is quite another matter—these experiments indicate very clearly that chemical fertilisers applied to suit the wants of soil and crop are not necessarily an injury to soil—may, indeed, be a lasting benefit to it.

Market Fertilisers used at a Profit.—The profits growing out of the use of commercial manures are chiefly dependent upon the cost of the fertiliser and the price of the resultant crop. Like ploughing, fallowing, or draining, therefore, the use of purchased fertilisers is to be determined by economical considerations, and not by chemical or other theories concerning them. The writer offers, without argument, a few of the practical considerations likely to be helpful to the farmer who contemplates using them.

1. It may be questioned whether commercial fertilisers can ever be profitably used with crops of low average value, the profits of which come through the cultivation of large areas of cheap land by the use of improved machinery. Wheat, at present prices, with other grain crops and the grasses, generally clearly come within this category. After five years of continuous experimental cultivation of wheats and oats, and six years with maize, using a great variety of fertilisers on a considerable scale, the Director of the Ohio (U.S.A.) Agricultural Experiment Station thus comments on the results of the work: "At present prices of cereal crops and of fertilising materials respectively, the profitable production of corn, wheat, and oats upon chemical or commercial fertilisers or upon barnyard manure, if its cost be proportionate to that of the chemical constituents of fertility found in commercial fertilisers, is a hopeless undertaking, unless these crops be grown in systematic rotation with clover or a similar nitrogen storing crop; and the poorer the soil in natural fertility the smaller the probability of profitable crop production by means of artificial fertilisers.

2. They have an undoubted position in practical farming in piecing out or reinforcing the natural supply of farm dung, and, even where the home supply is ample, an addition to it of some concentrated fertiliser may often be made to advantage Lawes and Gilbert have shown that mineral elements available to the wheat crop are greatly in excess of nitrogen supplied in farmyard manures. Hence nitrogenous manures, added to that obtained from the barnyard, gave a largely increased yield. This idea ought not to be lost to colonial sugar-growers. The great masses of fermenting megass so often seen about the plantations might easily be made the basis of a really valuable fertiliser by treatment something as follows:—Give to the megass a liberal dressing with lime to reduce acidity and promote nitrification; then, after applying the megass in quantity such that it may be readily turned under, give the land (subject to such modification as the condition of the soil suggests) 200 lb. sulphate of ammonia, with 250 lb. of bone meal and an equal quantity of kainit.

3. They may often be used to great advantage, in conjunction with some green crop like the cow pea, in lifting worn-out soils into profitable condition. A dressing of, say, 300 lb. of kainit or equivalent

potash fertiliser per acre, with 250 lb. of bonedust, if applied the preceding autumn, might be expected to give a green crop sufficient to furnish to the soil a large supply of needed nitrogen.

4. Special manures are frequently in demand by Queensland soils deficient in one or more of the elements of fertility. Along the coast and in "forest" soils the want often is potash, or it may be nitrogen, or the phosphates. To give such soils a complete manure (one containing nitrogen, phosphoric acid, and potash) like farmyard dung, would, aside from the waste of the operation, fail to meet the requirements of the soil.

5. What the soil requires and how much in the way of artificial fertilisers, cannot, as has been shown, be determined by a chemical analysis or from purely theoretical considerations. Our only recourse is actual trial of the different fertilisers representative of the three elements of value in manures. The differences of soils, in respect to fertility, and the variable demands of crops upon them, is the explanation of this fact. The farmer who would know what his soil needs must resort to the same means he is accustomed to employ in learning the capacity of his farm in other respects, for wheat, or maize, or sugar-cane, for example. This is best done by dressing small areas of land designed for planting, with ammonia sulphate, bonedust, kainit, or wood ashes, and mixtures of these in measured quantities, and carefully noting the results. The conclusions reached as a result of such experimental undertakings are not likely to be set aside by the results of subsequent field work.

Manures for Special Crops.—A long experience with artificia fertilisers has taught the English farmer that, under the conditions there prevailing, certain crops have a special affinity for particular manures. The grasses, generally, it has been found, give best returns for the use of the nitrates, while leguminous crops (lucerne, clovers, peas, beans, &c.) are most favourably influenced by mineral manures, and root crops, particularly turnips, by superphosphate. In a similar way it is shown that phosphates must, except with very run-down soils, be a prominent ingredient of all manures designed for the sugar-cane, too much of the nitrates tending to give excessive growth of stalk and blade, with low density of the juice and hard milling qualities. Tobacco and potato growers again are cautioned against the use of muriate of potash as an application to these crops, as tending to give a bad burning leaf in the one case, and sogginess and bad flavour in the other. These facts, to my mind, suggest caution in the use of artificial manures, and nothing more. They represent undoubted tendencies which generally may be heeded, in practice to advantage, but which upon particular soils may be ignored to equal advantage. For example, a heavy crop of cow peas, with its great burden of nitrogen turned into a soil of moderate fertility, may be expected to give a profitable crop of cane, while a dressing of well-rotted dung is often the one thing necessary to a successful crop of potatoes or tobacco. All this leads to the remark that the so-called special manures—"potato manure," "cane manure," and the rest—with which enterprising manufacturers have loaded the markets, are, taking all the circumstances of farming into account, even when honestly made, likely to prove a disappointment. Professor S. W.

Johnson, than whom there is no higher authority, says, concerning the analysis of certain special manures: "An examination of these analyses and those of special fertilisers made in past years abundantly justifies the conclusion that on the farms of this State it is quite as rational to use a 'corn manure' on potato land as a 'potato manure' for the tobacco crop, as any other way. To attempt to construct a fertiliser specially adapted to growing a particular crop on soils which differ so widely in composition, and have been so differently fertilised and tilled as those of Connecticut, is irrational and useless. Objection to these goods only applies to their names, and to the theory on which they are made and on which their special claim rests." This is in all respects as true of Queensland as it is of the American State.

The old idea of the commercial fertiliser was that it should be so compounded as to return to the soil as nearly as possible the exact amounts of those elements which were removed by the crop. Doubtless this is the theory underlying the compounding of many special manures now in the market. The familiar practice before referred to of applying mineral manures to leguminous crops rich in nitrogen, superphosphates to root crops deficient in phosphates, and nitrogenous manures to grass lands certainly not abounding in nitrogen, seems to show how often well-meant theories are set aside in practice. Speaking of their experiments, Lawes and Gilbert say: "There is no conceivable condition of chemical combination and of distribution within the soil in which the various constituents could be annually supplied so as to be all annually taken up by growing vegetation. . . . . Further experience teaches that, in the actual conditions of our soils and of agricultural practice, the exact composition of the crops we remove or wish to grow is no direct guide to the description and the amount of manurial constituents which will be most effective. It is, then, under the existing conditions of practical agriculture, certainly not necessary to supply to the land all the constituents that have been removed from it, or that would be contained in the crops it is wished to grow."

Nitrogenous Fertilisers.—The absence of a sufficient supply of nitrogen in the soil is speedily shown by a feeble, spindling growth of plants of a pale-green or yellow colour. The first effect of abundant nitrogen in the soil is to greatly promote the growth of branches and foliage at the expense of flowers and seed. The foliage assumes the deep-green colour which we are accustomed to associate with perfect plant healthfulness, and the growth of stems and leaves is likely to be continued past the time when, normally, the energies of the plant are directed towards seed production. Nitrogen alone tends to give a late crop, deficient in seed, but having abundant coarse, lush stalks and foliage.

In Queensland nitrogenous manures can scarcely be said to have a place in the market. Stable manure is generally used and appreciated probably at its full value; this, with smaller amounts of the refuse of meat works, breweries, and tanneries, and sulphate of ammonia, nearly completes the list of artificial supplies of nitrogen used by Queensland cultivators. Our feeble interest in this question is shown by the fact that not one of the gas companies of the colony utilises its liquors in the manufacture of the sulphate of ammonia;

while, except in the case of one establishment, all the blood and much of the tankage and other refuse of meat-works and slaughter-houses is carted away as waste, to be disposed of by the least laborious method available. The following are a few of the more common of the nitrogenous fertilisers in the market:—

Nitrate of Soda, sometimes called Chili saltpetre, is obtained from certain desert regions of South America, particularly Peru, where it forms in places a crust over the soil. With every 100 lb. of pure nitrate of soda there are 63 lb. of nitric acid, equivalent to nearly 16½ lb. of nitrogen and 37 lb. of soda. This nitrate is one of the quickest acting of the manures of commerce. On this account it is customary to apply it in the spring, or even upon the growing crop. It is very commonly used to reinforce other manures—stable dung, for example—deficient in nitrogen, although it is often used alone to stimulate the early growth of garden vegetables, and even flowers. In England 100 lb. to 150 lb. are often applied per acre, in connection with a dressing of stable manure.

Sulphate of Ammonia is produced in the treatment of the ammoniacal liquor of gasworks, with sulphuric acid. Generally speaking, ammonium compounds find less favour with the farmers than do the nitrates. Every 100 lb. of the sulphate contains about 25 lb. of ammonia, equivalent to about 20½ lb. of nitrogen. It is put to substantially the same uses for which the nitrates are employed, and, like them, should be applied to growing crops and in frequent small doses, otherwise the loss from leaching will be great.

Peruvian Guano is obtained from certain rainless islands on the coast of Peru; it collects as a result of the constant droppings of sea fowls. This is a very concentrated and active form of nitrogenous fertiliser. The purest quality contains 12 to 13 per cent. of nitrogen, and nearly an equal amount of phosphoric acid. Accumulations similar to those of the Peruvian coast occur at various points on the Queensland coast. These, however, are wanting in nitrogen, this element having been lost through the leaching action of the prevailing rains.

Other important sources of nitrogen mostly available to the Queensland farmer, with the percentage of contained nitrogen in parentheses after each, are:—Dried blood (10 per cent.), tankage (7 per cent.), cotton-seed meal (7 per cent.), horn and hoof waste (13 per cent.), meat scrap (10 per cent.), wool waste (6 per cent.).

It is possible for nearly all farmers to maintain this costly, easily lost, element nitrogen with only the occasional necessity for resorting to purchased supplies of nitrogen. The dung of grain-fed horses is a valuable, generally accessible manure rich in nitrogen; blood and the various other waste of meat works and slaughter-houses, often containing as high as 11 per cent. of nitrogen, are a few of the other nitrogenous fertilisers which come within the means and circumstances of many cultivators. Withal, it should never be forgotten that in the cow pea crop we have, as pointed out in a previous chapter, a means of restoring the fertility of lands, *at wholesale*, that is within the reach of every farmer owning a team and a plough.

Phosphoric Acid Manures.—Phosphatic manures in various forms are more generally and extensively used in Queensland than either nitrogenous or potash fertilisers or both combined. The great abundance and cheapness of fertiliser materials rich in the phosphates in part explains their popularity with colonial farmers.

Phosphoric acid plays an important part in the life of all plants, albeit its precise function in plant nutrition is not clearly made out. Undoubtedly it aids in the nutrition of plants, besides giving them the ability to assimilate other ingredients, particularly mineral elements. The phosphates induce an early development and maturity of the plant, especially in its seed, on which account it is valuable in balancing in the plant excessive growth of leaf and stalk induced by nitrogenous applications.

Bone is the principal source of the phosphatic manures in use in Queensland. As a rule, these manures are either ground bone or the residual products of the digestors of meat works (tankage), although phosphatic guanos, obtained at various points in the tropical section of the colony, are finding favour with the considerable number of farmers who have tried them. Ground bones, however, on account of their abundance and cheapness, are likely to hold their own in the market for phosphates for years to come. Bone phosphate, existing in the form of a tri-calcite (three-lime) phosphate makes up about 90 per cent. of the ash or earthy ingredients of bone. A good article of ground bone should contain about 23 per cent. of phosphoric acid and 4 to 6 per cent. of nitrogen. The value, however, of bone dust as a fertiliser is not contingent alone upon the amount of nitrogen and phosphoric acid which it contains, as will be inferred from the following statements of fact:—The three-lime phosphate is insoluble in water, but dissolves in acid and solutions of certain salts; it may by chemical treatment be converted into one-lime phosphate (*superphosphate*), in which condition it is readily soluble in water. Again, green bone contains much fat, which hinders decomposition, cutting off each particle of bone from the solvent action of plant roots and soil water.

Bone dust is, other things being equal, valuable in proportion to the fineness with which it is ground. This fine bone dust decomposes rapidly, liberating at once its contained nitrogen and phosphoric acid. The importance of fine grinding is shown by the relative values assigned by chemists to the nitrogen and phosphoric acid found in ground bones. Storer tells us that at the New Haven (Connecticut) laboratory the nitrogen and phosphoric acid of bone dust that passes through a sieve whose meshes measure $\frac{1}{50}$-inch is valued at 9d. and 3d. respectively. That from bone which escapes through meshes between $\frac{1}{25}$ and $\frac{1}{12}$-inch is rated at 7d. and $2\frac{1}{2}$d., while everything larger than $\frac{1}{6}$-inch has its nitrogen and phosphoric acid rated at 5d. and 2d. the pound. The old plan was, and is now, in Queensland, to some extent, to haul to the field roughly broken fragments and splinters of bones, at the rate of one to two tons per acre, which were ploughed under in the usual course of tillage operations. A more wasteful method of handling a valuable fertiliser can with difficulty be conceived. Such coarse fragments of bone are, undoubtedly, lasting in the soil, but their influence is always feeble. Two annual dressings of 400 lb. each of finely-ground bone dust would, under nearly all conditions of soil and climate, give greatly larger crop returns than this excessive application of coarse bones. *Finely*-broken bones worked into the ground, in liberal quantities about such permanent occupants of the soil as fruit trees, vines, &c., are often advantageous in assuring the plantation steady supplies of plant food. But even here the same amount applied in annual small doses of finely-ground dust would, besides acting more quickly, on the whole give greatly better results.

There are in vogue various methods of reducing bones other than that of grinding. A common and successful practice is to prepare a pit or other water-tight receptacle—even barrels or hogsheads are used for the purpose—and placing in this bones and wood ashes in alternate thin layers, keeping the mass constantly moist. At the expiration of a few months the bones are found so much disintegrated that they crumble to a powder under slight pressure. In like manner, bones kept in a damp manure pile become friable and soft, although the time required for such reduction is greater than in the treatment with ashes.

Superphosphate of Lime.—This highly valued phosphate has never received much attention from the cultivators of Queensland. Nor is it likely or particularly desirable that it should compete in a market that already is overstocked with the cheap products of the meat works and numerous boiling-down establishments of the colony. The reforms most needed in the preparation of fertilisers desired for colonial use are the most careful conservation of the wastes of slaughtering establishments, particularly blood, and greater attention to the reduction by grinding or otherwise of the abundant supplies of phosphatic materials. While superphosphate has little more than theoretical interest for Queensland farmers, it might without doubt often be hopefully used in the case of several crops; in giving an early growth to plant cane, and particularly with potatoes and in gardening operations generally.

The superphosphate of lime does not occur in nature. As before shown, the phosphate of lime exists in bones in the form of an insoluble tri-calcite, which when treated with sulphuric acid becomes the soluble mono-calcite (one-lime) superphosphate. By treatment with sulphuric acid a portion of calcium is taken from the phosphate and united with the sulphuric acid, forming the comparatively valueless sulphate of lime. This sulphate, with the soluble phosphate remaining, forms the superphosphate of commerce. Storer gives the following method of manufacturing "home-made" superphosphate, which serves, besides, to illustrate the principle of its manufacture:—"Pour 50 lb. of oil of vitriol (sulphuric acid) into a volume of water equal to that of the acid, stirring the water meanwhile with a stick. Pour this diluted acid upon 100 lb. of bone meal that is contained in a wooden trough, and stir the meal carefully with a hoe. The product admits of being dried, after a fashion, by stirring it up with earth or with gypsum." In the manufacture of lime superphosphate great care is required in apportioning the acid to the raw phosphate. Where an excess of acid is used, aside from the waste of acid, the product is a pasty mass that is handled with difficulty. Where, on the other hand, a too small quantity is employed, the dissolution of the raw phosphate is very imperfectly accomplished, and thus the solubility of the entire mixture is affected.

Other sources of phosphates available as manures are the spent bone black obtained from sugar refineries, containing 58 per cent. of the phosphate of lime; bat and other guanos, very variable in composition but often really excellent fertilisers; and the modern Thomas Slag, a by-product of the manufacture of iron and steel, containing from 19 to 30 per cent. of phosphoric acid in a form easily utilised by plants.

Potassium Compounds.—It is not easy to state precisely the rôle which potash plays in the nutrition of plants. Its deficiency in any soil is made speedily manifest by the enfeebled growth of the crop it bears; although the plants do not perish outright where potash is lacking in the soil. It contributes greatly to the growth of wood and the fleshy parts of fruits, and in a remarkable degree gives tone to growing plants. Trees, for example, which fail to set their fruit after flowering, or drop their fruit prematurely, may often be cured of these bad habits by a liberal use of some potash fertiliser. All soils contain potash in greater or less quantity, but the amount made annually available to plants is not large. The loss of potash through the action of drainage water is small. The tendency in most soils is to change soluble potash into a more insoluble form which is only slowly redissolved to meet the requirements of growing crops.

The following are the more familiar forms in which potassium compounds are used as fertilisers:—Kainit, wood ashes, muriate of potash, chloride of potash, nitrate of potash (saltpetre), cotton-seed hull ashes (24 per cent. potash), and tobacco stems (6 per cent. potash).

Kainit.—This form of potassic fertiliser has recently been introduced to Queensland cultivators with whom it has found favour. It comes to us from the celebrated mines located in and about Stassfurt, in North Germany. Kainit is a crude mixture of several compounds, chief of which are chloride of sodium (common salt) with the sulphates and chlorides of potassium (13 per cent.), sodium, and magnesium. In view of the fact that materials like common salt, of slight or doubtful value to the soil, make up nearly 80 per cent. of kainit, the question of refining away these crudities in the interest of cheapened transportation, if for no other reason, should receive the attention of manufacturers and vendors of this commodity. Kainit is recommended particularly for light soils, which, it is claimed, are rendered very compact and retentive of moisture by it. It may be applied for all the uses to which the muriate of potash is put. Experience shows that for tobacco, potatoes, and sugar beets kainit should not be used, as it injures the burning qualities of the tobacco, and is prejudicial in various ways to the other crops mentioned. As much as 700 lb. of kainit are used per acre, although the amount commonly used is much less than this. Its best effects are seen when used in connection with some nitrogenous or phosphatic fertiliser. Bone dust may be used to excellent advantage in this way, using equal weights of each.

From Europe and America come reports of the very effective use of kainit on soils infested with wire worms, cut worms, and the other forms of insect life hibernating or living in the soil. Experience had here and there seems to show that in Queensland it is equally useful in dealing with this numerous class of insects. Repeated trials, made by the writer, show that the destructive " grub " of Queensland cane-fields is apparently not in the least inconvenienced by the presence of kainit, in large quantities, in the soil infested by this pest.

Sulphate of Potash.—This is another product of the North German mines which is much in vogue as a fertiliser. It is the basis of nearly all of the potash fertilisers on the market; it is costlier but much more efficient, in general experience, than the muriate. This form of potash is obtained with difficulty in the pure state, it being very commonly mixed with the cheaper muriate. Pure potassium sulphate contains about 50 per cent. of potash, although the article usually found on the market will rarely give more than 35 per cent.

Nitrate of Potash or saltpetre is a valuable fertiliser on account of both the nitrogen and potash which it contains. The demand for this chemical in the manufacture of gunpowder has carried the price beyond the point at which it can be used as a fertiliser.

Cotton Seed Hull Ashes are in great demand in America as a fertiliser for the tobacco crop. They vary a good deal in composition, yielding from 15 to 30 per cent. of potash and 5 to 10 per cent. of phosphoric acid. Bright ashes—those white in colour—show a much larger proportion of contained potash than the dark coloured article.

Wood Ashes.—The amount of potash contained in wood ashes varies greatly in the different varieties of trees. Speaking from observation alone, my impression is that the ashes obtained from our forest trees are often deficient in potash, while those from the scrub timbers, including the mangrove, are often rich in this mineral. It exists in wood ashes, mainly in the form of a carbonate, the amount varying between 4 and 7 per cent. Wood ashes that have been exposed to the action of water (leached) are worthless as fertilisers. Coal ashes contain no element of value as a fertiliser, and, except as they are of occasional advantage in meliorating heavy soils, are worthless as a manure.

Lime or Carbonate of Calcium. — Lime is a necessary ingredient of every agricultural soil. Without it plants cannot grow. Further, there are few soils that do not contain it in quantity sufficient for the needs of every crop. On this account lime is rarely applied as a direct fertiliser; its value depends chiefly upon its marked ability to improve the texture of soils, particularly heavy clays, and to hasten the decomposition of mineral and organic matters of the soil. This latter effect, in the opinion of Storer, " is probably one of the most important produced by lime." (Agriculture, Storer, vol. 2, p. 146.) Besides, lime fixes in the soil valuable materials like ammonia and potash, which otherwise might be lost; it reduces acidity in soils, binds together the particles of loose sands, and often destroys insects, worms, and fungi infesting soils. Withal lime has small place in the agriculture of Queensland, I am persuaded. Its cost probably precludes its use in improving the texture of clay lands, and in this climate, its effect, whatever it might be in decomposing organic materials in the soil, would be a positive injury to the great majority of our soils, which already part too freely with their organic contents. Colonial farmers who may wish to put in practice, in Queensland, old country ideas in respect to liming land will do well to bear in mind the difference in the demands which climate, soil, and crop make upon the cultivator in Queensland and in Great Britain.

Considerations in Purchasing Fertilisers.—As a rule it will be found that the more concentrated fertilisers, while expensive in first cost, are cheapest in the end. In purchasing these concentrated forms of fertility, we save freight and storage charges, in the first instance, and much heavy work in subsequent handling. For example, a ton of sulphate of ammonia, costing £12, will contain something more than three times the nitrogen contained in a ton of tankage, costing £4 per ton. The gain to the farmer in this case in handling and applying the concentrated sulphate will appear to every practical man. Fertilisers cannot be too finely ground and screened. We have already shown that the value of bone dust is dependent directly upon the fineness with which it has been reduced, but, to a certain extent, this is true of all classes of fertilisers. Again, excessive moisture is undesirable in fertilisers. Besides adding to the weight and cost of the fertiliser containing it, moisture adds to the labour of handling, and induces a more or less rapid decomposition in fertilisers of organic origin.

Valuation of Fertilisers.—To most farmers who use purchased fertilisers, the chemical guarantee which accompanies the goods is of small significance. The purchaser knows, in a general way, that the manure is chiefly valuable for the nitrogen, phosphoric acid, and potash which it contains; but the varying shades of value in the different forms of nitrogen, and the relative value of the three ingredients themselves, he does not, as a rule, concern himself about. Where the fertiliser trade has assumed considerable proportions, manufacturers guarantee the particular article sold to contain such a per cent. of nitrogen, phosphoric acid, or potash, as the case may be. Generally this guarantee is subjected to constant test by analyses made by a competent government chemist, who certifies to the character of the goods examined by him. Where, as in Queensland, there is no Government oversight of the business in commercial fertilisers, we must rely wholly upon the honesty of the manufacturer, unless we care to go to the expense of securing a private analysis of each package of fertiliser bought, which, it is needless to say, few purchasers care to do.

The value of a fertiliser is its market price, and not its efficiency in the soil, as shown by the increased crop which it gives. This value, then, may be less or more than its real value, although for business reasons the two values are not likely to be kept widely separated for any considerable length of time. How this market value of a given fertiliser may be estimated is shown in what follows.

In the entire absence of Queensland data, I use here the trade values of fertilising ingredients adopted by the American experiment stations, although most likely they average too high, by nearly or quite one-fifth, to suit Queensland conditions.

	Price per lb. in pence.
*Nitrogen in ammonia salts	8½
Nitrogen in nitrates	7¾
Nitrogen in meat, blood, and mixed fertilisers ...	8¾
Nitrogen in fine-ground bone and tankage ...	7½
Nitrogen in coarse bone and tankage	3½
Phosphoric acid, soluble	3¼
Reverted phosphoric acid	3
Phosphoric acid in fine bone and tankage ...	3
Phosphoric acid in coarse bone and tankage ...	1½
Phosphoric acid in wood ashes	2½
Potash, high grade sulphate	2¾
Potash, kainit	2¼
Potash, muriate	2¼
Organic nitrogen in mixed fertilisers	8¾
Insoluble phosphoric acid in mixed fertilisers ...	1

Chemical analyses often show the three elements in combination not referred to in this tabulation. There the nitrogen may be given as ammonia or the potash may appear as the chloride or sulphate, in which case it will be necessary to reduce such compounds into their equivalents of the element or other compound required. These conversions may be made by the use of factors as shown below:—

1. To change ammonia into equivalent nitrogen, multiply ammonia by ·8235.
2. To change nitrogen into equivalent ammonia, multiply nitrogen by 1·214.
3. To change muriate (chloride) of potash into equivalent potash, multiply muriate by ·63.
4. To change potash into equivalent muriate of potash, multiply potash by 1·585.
5. To change sulphate of potash into equivalent potash, multiply sulphate by ·54.
6. To change potash into equivalent of sulphate of potash, multiply potash by 1·85.
7. To change phosphoric acid into equivalent phosphate of lime, multiply phosphoric acid by 2·183.
8. To change soluble phosphate into equivalent phosphate of lime, multiply soluble phosphate by 1·325.

How these tables are used will be best seen by means of an example. Suppose one of the mixed fertilisers common in the markets be purchased, which is guaranteed to contain—nitrogen 3 per cent., soluble phosphoric acid 6 per cent., reverted phosphoric acid 4 per

* These data, and much of the tables that follow, are taken from Bulletin 55 (new series) of the New York (U.S.A.) Agricultural Experiment Station, prepared under the direction of Dr. Peter Collier.

cent., potash 2 per cent. The commercial value, first of 100 lb. of this fertiliser and then of one ton (2,240 lb.) will be shown in the following calculation :—

	s.	d.
3 per cent. nitrogen—in 100 lb., 3 lb.—at 8¾d.	2	2¼
6 per cent. soluble phosphoric acid—in 100 lb., 6 lb.—at 3¼d.	1	7½
4 per cent. reverted phosphoric acid—in 100 lb., 4 lb.—at 3d.	1	0
2 per cent. potash—in 100 lb., 2 lb.—at 2¼d. ...	0	4½
Value of 100 lb.	5	2¼

Multiplying this value of 100 lb. (62¼d.) by 22·4 gives us as the value of one ton (2,240 lb.) of this fertiliser, £5 16s. 6d.

To take another example, in this case a Queensland manufactured bone-dust. The analysis shows for this article the following composition :—

	Per cent.
Moisture	5·38
Organic substances (containing 3·78 per cent. nitrogen, equal to 4·59 per cent. ammonia)	40·10
Lime	29·15
Phosphoric acid (equal to 48·78 per cent. phosphate of lime)	21·42
Carbonic acid	1·06
Insoluble (sand, &c.)	0·72

The only ingredients of this fertiliser that have a money value are the nitrogen and phosphoric acid. Arranging these as before, and we have in tabular form the value of 100 lb. of this fertiliser with the calculations for one ton.

	£	s.	d.
3·78 per cent. nitrogen—in 100 lb., 3·78 lb.—at 7½d.	0	2	4¼
21·42 per cent. phosphoric acid—in 100 lb., 21·42 lb.—at 3d....	0	5	4¼
Value of 100 lb.	0	7	8½
Value per ton of 2,240 lb. ...	8	12	8

It is possible for every user of commercial fertilisers in this way to estimate the value of any of the various goods that are offered in the market. The price here named is much too high for the Queensland markets. To get the actual selling price of this class of goods, delivered in Brisbane, without railway charges or the profits of middlemen, it will be necessary to reduce the price given by nearly 50 per cent. As before stated, the great bulk of slaughter-house refuse and the by-products of meat works and boiling-down establishments are utterly lost to agriculture. Of that which is manufactured and put in condition for use, by far the larger part goes out of the colony, largely to New Zealand. So long as this condition of things continues in the colony, the values of fertilisers will remain low, and for the most part no more than nominal.

Below are given analyses of a considerable number of fertilisers and fertilising materials—mostly from American sources—with estimated values. We wish to say again that these values are mostly too high for Queensland conditions. However, these prices given will be found useful in showing the *relative* values of different substances bought for fertilising uses, if for no other reason :—

COMPOSITION OF FERTILISERS AND FERTILISING MATERIALS.

—	Moisture.	Nitrogen.	Potash.	Phosphoric Acid.			Value per ton of 2,240 lb.
				Available.	Insoluble.	Total.	
Materials containing phosphates.							£ s. d.
Bone dust (Runcorn, Queensland)	8·68	3·64	...	...	...	23·29	
Bone dust (Lake's Creek, Queensland)	5·38	3·78	...	...	...	21·42	
Bone ash...	7·00	...	...	...	...	35·89	3 6 1
Bone black	4·60	...	...	..	...	28·28	2 12 8
Bone meal	7·47	4·12	...	8·28	15·22	23·50	9 8 4
Bone meal (free from fat) ...	...	6·20	...	...	...	20·10	9 19 4
Bone meal (dissolved)	..	2·60	...	13·53	4·07	17·60	4 15 5
Thomas Slag (English) ...	...	...	...	6·09	13·31	19·40	3 5 9
Guano (Rock Islet, Gulf of Carpentaria)	8·26	...	...	...	...	28·51	
Materials containing potassium.							
Cotton-seed hull ashes ...	7·33	...	23·80	...	...	8·50	6 19 7
Kainit	3·20	...	13·54	...	...	...	2 16 10
Muriate of potash	2·00	...	52·46	...	...	...	11 0 3
Nitrate of potash	1·93	13·09	45·19	...	...	...	18 19 1
Spent tan-bark ashes	6·31	2·04	...	...	...	1·61	0 17 11
Sulph. potash	1·25	...	38·60	...	...	...	9 18 1
Sulph. potash and magnesia...	4·75	...	23·50	...	...	...	6 0 7
Wood ashes (American) ..	12·00	...	5·50	...	...	1·85	1 16 10
By-products and refuse.							
Cotton hulls	10·63	0·75	1·08	...	..	0·18	4 17 10
Cotton-seed meal	...	6·52	1·89	...	...	2·78	6 9 2
Hop refuse	8·98	0·98	0·11	...	...	0·20	0 17 5
Linseed cake (new process) ...	6·12	5·40	1·16	...	...	1·42	5 0 9
Linseed cake (old process) ...	7·79	6·02	1·16	...	...	1·65	5 12 0
Malt sprouts	10·28	3·67	1·60	...	...	1·40	3 14 8
Oat bran...	8·19	2·25	0·66	...	...	1·11	2 3 4
Spent brewers' grains (dry) ...	6·98	3·05	1·55	...	...	1·26	3 3 7
Spent brewers' grains (wet) ...	75·01	0·89	0·05	...	...	0·31	0 16 7
Wheat bran	11·01	8·88	1·62	...	...	2·87	3 8 8
Materials containing nitrogen.							
Cotton-seed meal	6·80	6·66	1·62	...	...	1·45	5 17 7
Dried blood	12·50	10·52	...	...	...	1·91	9 0 8
Horn and hoof waste	10·17	13·25	...	...	...	1·83	4 15 1
Meat scrap	12·09	10·44	...	...	...	2·07	9 0 1
Nitrate of soda (pure)... ...	...	16·47	...	...	...	...	11 18 0
Sulphate of ammonia	1·00	20·50	...	...	...	...	9 16 1
Tankage	13·20	6·82	...	5·02	6·23	11·25	7 7 11
Tobacco stems	10·61	2·29	6·44	...	...	0·60	3 11 1
Wool waste	9·27	5·64	1.30	...	...	0·29	2 4 0
Castor pomace	9·98	5·56	1·12	...	...	2·16	4 15 8

By Authority: EDMUND GREGORY, Government Printer, William street, Brisbane.