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MISSISSIPPI

AGRICULTURAL EXPERIMENT STATION.

BULLETIN, NO. 5.

Fertilizers.

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THE USE OF FERTILIZERS.

Bulletin No. 3 of this Station gave the Fertilizer Law of the State and analyses of such feltilizers as are sold in the State. The aim of the present bulletin is to give some facts in regard to the most economical use of fertilizers, both natural and artificial. Some of the facts given are the results of work done at this Station, while others have been collected from various sources which are inaccessible to the majority of farmers. While the bulletin contains little which is new, we believe the facts and principles given to be of sufficient importance and general interest to warrant the Station in publishing them in the present form.

A fertilizer is a substance, which, when applied to a soil, will enable the soil to produce an increased crop.

If it were necessary for a fertilizer to contain all the food needed for plant growth, fourteen elements would be necessary to make it complete, but as most soils contain an abundance of eleven elements, a fertilizer needs to contain only the three which are usually deficient, viz: Nitrogen, potash, and phosphoric acid.

It is true that a chemical analysis of almost any soil will reveal the presence of a sufficient amount of these three to produce a large number of heavy crops, but unfortunately, such an analysis will show nothing of their condition or availability, and hence is of very little value in determining the kinds and amounts of fertilizers needed for a given field. This is especially true of the phosphoric acid, which combines very readily with the iron in the soil, and so becomes insoluble and unavailable for plant food. All the food of plants is absorbed in either a liquid or gaseous form, so that, even if the plant food be present in abundance, it cannot be used by the plant unless it is in a form in which it can be dissolved in water, or in some of the very weak acids found in the soil. Insoluble food is of no more value to a plant than is raw iron ore to a manufacturer of watch springs. The plant must not only have an abundant supply of food, but this food must be in such a mechanical and chemical condition as to be available to the plant during the few weeks in which it is making its growth. However rich a soil may be in available plant food, we need not look for a good crop if the ground is so hard and lumpy that it cannot be penetrated by the roots, and it is useless to apply any fertilizer which contains plant food locked up in an insoluble form; so that, whatever crop we may attempt to grow, or whatever fertilizer we may apply, a thorough pulverization of the soil is essential to success.

We have on record 110 analyses of soils from various portions of the State. Estimating that six inches in depth of soil from an acre weighs 2,000,000 pounds, we find that an average of these soils contains per acre:

Potash	6,060 pounds.
Phosphoric Acid	2,190 pounds.
Nitrogen	3,680 pounds.

A crop of 750 pounds per acre of seed cotton removes from the soil:

Potash	8.50 pounds.
Phosphoric Acid	7.20 pounds.
Nitrogen	25.25 pounds.

At this rate, the average Mississippi soils contain a sufficient amount of these ingredients to last:

Potash	750 years.
Phosphoric Acid	304 years.
Nitrogen	158 years.

From this it is at once seen that absolute soil exhaustion, so as to make our soils truly barren, is practically impossible, especially if the cotton seed be restored to the soil, but as the amount of these ingredients which is in a condition to be available to the plant is usually less than one per cent. of the amount present, it can be readily seen that for continued cropping, it is necessary either to add to the amounts already in the soil, or to so change that which is present as to prepare it for use. The whole question of fertilizing thus resolves itself into a consideration of which of the two methods we can pursue at the lesser cost.

Lime is the only substance known which can be applied cheaply, and which will render the insoluble plant food available, and even this is quite limited in its effects. Upon most soils it acts favorably for a time, but soon loses its power, and if applied too frequently, renders the soil less productive than before. On nearly all soils, therefore, it will be found most economical to add the necessary elements directly, rather than to depend entirely upon an unreliable disorganizer.

Fertilizers may be classed as (1) Natural, and (2) Chemical. Natural fertilizers include stable manure, cotton seed in its various forms, green crops, and marls. Of these, stable manure is by far the most valuble for general use, as it contains all the elements needed for plant growth in a condition in which they are soon available; and in addition, its principal bulk is composed of humus-making material which is needed for all excepting very fresh or alluvial soils.

Although stable manure is always regarded as a "complete" fertilizer, and is a standard with which others are compared, it is of very variable composition and value, its composition being determined by the animals from which it comes, their food, age and condition, the amount of straw and bedding which has been mixed with their droppings, whether it has been sheltered or exposed to leaching rains, the length of time since it was made, and by many other causes. A ton of ordinary stable manure with the usual proportions of droppings and litter contains about eleven pounds of potash, five of phosphoric acid, and twelve of nitrogen, available for plant food, but we find many samples varying widely from these amounts though the proportions remain about the same.

In estimating the value of such manure it should be borne in mind that in no case does the manure contain more plant food than did the food fed to the cattle which produced it. A ton of wet and dirty straw is worth no more as a fertilizer than is the same amount of dry straw, and if a milk cow is fed with straw alone her manure will be worth less than the straw by just the amount of potash, phosphoric acid and nitrogen which has been taken out of it for the production of milk. By passing food through an animal we add nothing to its manurial value excepting as it is ground up and softened by digestion so that it will decay more rapidly when spread in the field. When food is eaten by an animal very little of its manurial is lost, the ingredients assimilated in digestion being principally the carbonaceous and fatty portions which are of little or no value as fertilizers. Reckoning potash to be worth five cents a pound, phosphoric acid seven cents, and nitrogen seventeen cents, if a steer is fed on straw alone and neither gains nor losses flesh during the time of feeding, the manure will contain, according to Wolff:

Potash	.575 per cent.	worth per ton	$ .565
Phosphoric Acid	.270 "	"	.378
Nitrogen	.320 "	"	1.088
Total value			$ 2.031

If clover hay be used in the place of straw, the value will be as follows:

Potash	2.311 per cent.	worth per ton	$ 2.311
Phosphoric Acid	6.63 "	"	.928
Nitrogen	5.92 "	"	2.013
Total value			$ 5.252

According to the same authority the value of the manure from a ton of a ration mixed in the proportion of twenty pounds of ordinary hay and eight of cotton seed meal will be $12.54; if in the proportion of twenty pounds of hay and eight of corn it will be $6.49; if in the proportion of twenty pounds of clover and six of corn it will be $8.95; if in the proportion of twenty pounds of clover hay and five pounds of cotton seed meal it will be $13.29.

The values given above are for the excrement only and when mixed with litter, cornstalks and weeds, or if the urine is permitted to be lost, the value per ton of what is hauled to the field will be correspondingly less.

From these statements it is seen that the value of a ton of barnyard manure may vary greatly even if we consider only that part of it which is composed of animal excrement. As a matter of fact such manure is always mixed with a greater or less amount of straw, cornstalks and other litter which add bulk and weight, but very little to its fertilizing value. The differences in value are really greater than indicated above, as the figures given are for the values in the barn-yard, and in estimating its value in the field the cost of hauling must be deducted from the value in the yard. The cost of hauling and spreading a ton of poor manure is the same as that for the same amount of good manure, and if we estimate this cost at twenty-five cents per ton it will make the field value of manure from straw alone only $2.08, while that from a better ration, say twenty pounds of clover to five pounds of cotton seed meal, will be $13.04. Good feed for stock pays, not only in the better growth of the animals, but also in the greatly increased value of the manure; and it will usually be found that a ration which will produce the cheapest beef will also give the best manure.

When stock is fed so as to secure the most rapid growth from a given expense for feed, and so as to make the best manure, it is still an important matter to know how to care for and to handle the manure to the best advantage.

As the most valuable parts of the manure are the urine and the soluble portions it is evident that it is very poor economy to take it out of the stable and expose it to the weather in heaps about the yard. With continued rains the fertilizing elements will be largely washed away, while, if the weather is dry, the heaps will soon heat and drive off a large portion of the nitrogen in the form of ammonia. In order to retain its original value the manure must be preserved both from leaching and from heating. This may be accomplished in several ways. Where neat cattle alone are fed it is a very common practice to allow the manure to accumulate in the stalls during the whole feeding season, or until it becomes so deep as not to leave room for the stock. This is an excellent plan provided sufficient bedding is given to absorb the urine and keep the stalls dry. All the excrement is saved, and when kept trodden down in such a compact mass there will be no heating. Horse manure cannot be kept long in this way, as it heats more readily and if left undisturbed will very soon begin to give off the characteristic pungent odor which indicates the escape of ammonia. If but few horses or mules and a larger number of neat cattle are kept, the horse manure can usually be kept unchanged by mixing it with that in the cattle

stalls and allowing the cattle to tramp it all together. Where the stables have wooden floors, or for any other reason it is not desirable to let the manure accummulate in the stalls, a shelter should be provided so that it need not be exposed to the rain. A cheap and convenient shelter may be made by digging a pit three or four feet deep, throwing the dirt to the sides so as to make them about two feet higher than the level of the yard. Make the pit twenty-five by forty feet, and slope the ends so that a wagon can be driven through it. Cover the pit with a roof of rough plank extending two feet beyond the sides, and high enough not to interfere with driving through. Run a single line of plank from the stable door to this pit, and the manure can be wheeled out daily and thrown in with very little trouble. In this way, the urine can all be saved with the other manure, and the heap will be kept so moist that there will be little danger from heating. If the bottom of the pit is of well tramped clay, there will be almost no loss from leakage, and should the heap have a large proportion of horse manure, heating may be prevented by occasionally pumping the urine over the heap, but this will seldom be necessary. A pit similar to the one described is in use at the Station barns, and holds all the accumulations from about eighty cattle and fourteen mules during four months. So far, we have had no trouble from heating. There will always be more or less manure scattered about in the yard, and this, together with the refuse feed, mouldy hay or grain, blood, hair, and entrails from butchering, and other waste material should be thrown into the pit with the manure. If hogs are kept where they can have access to the pit, they will secure a considerable amount of food from it, especially if the cattle are fed with whole corn, and will add largely to its value by their own droppings, and by keeping it so thoroughly stirred as to prevent heating.

When in such a pit, the manure undergoes a slow process of decay in which there is but little loss. There is also a considerable evaporation of water, which makes the manure lighter and less bulky for hauling, and more available for the immediate use of the crops to which it is applied. While the two methods of keeping manure which have been described are the best economy, there are many farms on which it is not convenient to practice either, and the manure must be left exposed to the weather from the time it is taken out of the stable. In such cases it is usually best to haul and spread it on the field at once, and then plow it under as soon as the condition of the ground will permit. When spread on the field, there will be no loss from heating, and nearly all of the soluble matter which is washed out by the rains will find its way into the soil, and be retained near the surface. Clay absorbs impurities from water much more readily than sand, so that if the manure is to be left exposed for a considerable time, it should be put on those fields having a clayey rather than a sandy soil. Heavy clay soils are improved mechanically by the use of coarse and fresh manures, while for sandy soils which are already too light, it is better to use the older and finer manures. The custom of hauling manure to the field and leaving it in heaps is seldom good economy, as, if the heaps are large they are almost sure to lose by heating, and in any case, the manure has to be handled a second time. The manure can be spread in but little more time than is needed for dumping it in piles, and the work can be much more easily done from the wagon than from the pile. It is important that the manure be as evenly spread, and as thoroughly mixed with the soil as is possible, and when spread on the ground for some time before plowing, the rains wash out and carry into the soil such a large proportion of the soluble matter, that many recommend this method rather than the immediate plowing under. In most cases, this must be decided by the condition of the soil and the season. If plowed under in the fall, it will become very thoroughly decayed before needed for plant food in the spring, and if it is not hauled out until spring, it must be plowed under at once in order to prepare the land for planting.

In the northern states, where the seasons are short and the period of active plant growth extends over but a few weeks, great stress is laid on the importance of composting manures, and having them thoroughly rotted before using. Here, where the growing season is longer, the rainfall greater, and decay more rapid, composting is of much less advantage, and for ordinary farm crops for which stable manure alone is used, it will seldom pay for the necessary labor. It is true that perfectly fresh stable manure contains a very large percentage of water and a small percentage of soluble plant food; but in composting nothing is added to the value of the manure. It becomes more thoroughly mixed and decay is hastened, so that a larger percentage can be used at once by the plant, its bulk is materially decreased, and it loses a large percentage of water.

Dr. Voelcker, of the Royal Agricultural College, in England, made exhaustive examinations of stable manure of different ages, and different manures, from which he obtained some very interesting figures which are of value in this connection. He found that a ton of fresh stable manure composed of cow, horse, and pig dung, mixed with the straw and litter used for bedding contained:

Water	1,323.4 pounds.
Organic matter	564.8 pounds.
Ash	111.8 pounds.
	2,000.0 pounds.

The organic matter and the ash contained:

Nitrogen	12.75 pounds.
Phosphoric Acid	6.50 pounds.
Potash	13.50 pounds.
	32.75 pounds.

The value of these ingredients, as valued here, would be:

Nitrogen	$2.30
Phosphoric Acid	.52
Potash	.81
	$3.63

This does not represent the full actual value of the manure, however, as no account is made of the humus-making material, or of the mechanical effect in loosening the soil.

When the manure was in a heap and exposed to the weather, it changed as follows:

	November 3d.	*April 30th.*	*August 23d.*
Fresh	2,000 lbs.	1,428 lbs.	1,405 lbs.
Water	1,323 lbs.	941 lbs.	1,061 lbs.
Dry matter	677 lbs.	487 lbs.	344 lbs.
Loss		572 lbs.	595 lbs.

The loss occurring between November and April was in water 382 pounds, and dry matter 190 pounds, the loss in water being a gain in value by the decrease in weight, and the loss in dry matter being principally of organic matter, the manure was worth fully as much in April as in November. It must be borne in mind, however, that while this manure was exposed to the weather, it was so placed that there was no waste from leaching. From April to August there was a loss of 143 pounds of dry matter, of which 3.5 pounds was nitrogen, and an increase of 119 pounds of water, thus making the manure less valuable and more expensive to haul.

When kept under shelter the same length of time, the changes were quite different, as follows:

	November 3.	*April 30th.*	*August 23d.*
Fresh	2,000 lbs.	992 lbs.	800 lbs.
Water	1,323 lbs.	566 lbs.	347 lbs.
Solids	677 lbs.	426 lbs.	433 lbs.
Loss		1,008 lbs.	1,200 lbs.

In this experiment the loss of the water in the first period amounted to more than 37 per cent. of the entire weight, while the loss of dry matter was 251 pounds, or about 12 per cent. This might have been expected, as the heating would drive off a large portion of the moisture, besides causing a more rapid decay of the vegetable matter. When kept until August 23d, there was a still further loss of 213 pounds of water, and of 8.2 lbs. of nitrogen.

The greatest loss occurred when the manure was spread over the surface of the yard, as follows:

	November 3d.	*April 30th.*	*August 23d.*
Fresh	2,000 lbs.	1,730 lbs.	1,226 lbs.
Water	1,323 lbs.	1,385 lbs.	859 lbs.
Solids	677 lbs.	345 lbs.	367 lbs.
Loss		270 lbs.	774 lbs.

In this experiment, the loss in nitrogen, the most valuable element in the manure, was very marked, the amount present being

November 3d	12.9 pounds.
April 30th	9.2 pounds.
August 23	5.0 pounds.

From these and other experiments, Dr. Voelcker makes the following conclusions:

"The soluble organic and mineral constituents of dung are much more valuable fertilizers than the insoluble. Particular care, therefore, should be bestowed upon the preservation of the liquid excrements of animals, and for the same reason the manure should be kept in perfectly water-proof pits of sufficient capacity to render the setting up of dung-heaps in the corner of fields, as much as it is possible, unnecessary.

"The urine of the horse, cow, and pig, does not contain any appreciable quantity of phosphate of lime, whilst the drainings of dung-heaps contain considerable quantities of this valuable fertilizer. The drainings of dung-heaps, partly for this reason, are more valuable than the urine of our domestic animals, and, therefore, ought to be prevented by all available means from running to waste.

"The most effectual means of preventing loss in fertilizing matters is to cart the manure directly on the field whenever circumstances allow this to be done.

"On all soils with a moderate proportion of clay, no fear need be entertained of valuable fertilizing materials becoming wasted if the manure cannot be plowed at once. Fresh, and even well rotted manure contains very little free ammonia; and since active fermentation, and with it the further evolution of free ammonia, is stopped by spreading out the manure on the field, valuable volatile manuring matters cannot escape into the air by adopting this plan.

"As all soils with a moderate proportion of clay possess in a remarkable degree the power of absorbing and retaining manuring matters, none of the saline and soluble organic constituents are wasted even by a very heavy fall of rain. It may, indeed, be questioned whether it is more advisable to plow in a manure at once, or to let it lie for some time on the surface, and to give the rain full opportunity to wash it into the soil.

"Cart the manure on the field, spread it at once, and wait for a favorable opportunity to plow it in. In the case of clay soils, I have no hesitation to say the manure may be spread even six months before it is plowed in, without losing any appreciable quantity in manuring matter.

"I am perfectly aware, that on stiff clay land, farm-yard manure, more especially long dung, when plowed in before the frost sets in, exercises a most beneficial action by keeping the soil loose, and admitting the free access of frost, which pulverizes the land, and would, therefore, by no means recommend to leave the manure spread on the surface without plowing it in. All I wish to enforce is, that when no other choice is left but either to set up the manure in a heap in a corner of the field, or to spread it on the field, without plowing it in directly, to adopt the latter plan. In the case of very light sandy soils, it may perhaps not be advisable to spread out the manure a long time before it is plowed in, since such soils do not possess the power of retaining manuring matter in a marked degree. On light sandy soils, I would suggest to manure with well-fermented dung, shortly before the crop intended to be grown is sown.

"Weight for weight, rotted dung is more valuable than fresh.

"In the fermentation of dung, a very considerable proportion of the organic matters in fresh manure is dissipated into the air in the form of carbonic acid and other gases.

"Properly regulated, however, the fermentation of dung is not attended with any great loss of nitrogen, nor of saline mineral matters.

"Ammonia is not given off from the surface of well compressed dung-heaps, but on turning manure-heaps, it is wasted in appreciable quantities. Dung-heaps, for this reason, should not be turned more frequently than absolutely necessary.

"No advantage appears to result from carrying on the fermentation of dung too far, but every disadvantage.

"Farm-yard manure becomes deteriorated in value, when kept in heaps exposed to the weather, the more the longer it is kept.

"If the rain is excluded from dung-heaps, or little rain falls at a time, the loss in ammonia is trifling, and no saline matters, of course, are removed; but, if much rain falls, especially if it descends in heavy showers upon the dung heap, a serious loss in ammonia, soluble organic matter, phosphate of lime, and salts of potash is incurred, and the manure becomes rapidly deteriorated in value, whilst at the same time it is diminished in weight.

"Well-rotted dung is more readily affected by the deteriorating influence of rain than fresh manure.

"Practically speaking, all the essentially valuable manuring constituents are preserved by keeping farm yard manure under cover.

"The worst method of making manure is to produce it by animals kept in open yards, since a large proportion of valuable fertilizing matters is wasted in a short time; and after a lapse of twelve months, at least two-thirds of the substance of the manure is wasted, and only one-third, inferior in quality to an equal weight of fresh dung, is left behind."

COTTON SEED.

When stable manure is not available, cotton seed in some form is an excellent substitute. Its composition varies somewhat with the season and soil where grown, but for all practical purposes may be regarded as containing per ton, one thousand pounds of hulls and one thousand pounds of kernels. From the kernels about three hundred pounds of oil may be obtained, leaving seven hundred pounds of meal. The whole seed, hulls, and meal contain about

	Nitrogen.	*Phosphoric Acid.*	*Potash.*
Whole Seed	2.8 per cent.	1.4 per cent.	1.14 per ct.
Hulls	.7	.7	.88
Meal	7.	3.	2.

With that composition the pounds per ton of each element will be

	Nitrogen.	*Phosphoric Acid.*	*Potash.*
Whole Seed	56.	28.	22.8
Hulls	14.	14.	17.6
Meal	140.	60.	40.

The values of these elements at present prices are

	Nitrogen.	*Phosphoric Acid.*	*Potash.*	*Total.*
Whole seed	$10.08	$1.96	$1.14	$13.18
Hulls	2.52	.98	.88	3.38
Meal	25.20	4.20	2.00	31.40

The Station purchased this season at the following prices, viz:

Cotton seed	$ 7.20 per ton.
Hulls	4.00 per ton.
Meal	19.00 per ton.

At these rates nineteen dollars will purchase

2.6 tons of seed, worth	$33.27
1 ton of meal, worth	31.40
4.75 tons of hulls, worth	16.06

Such purchases will give

Profit on purchase of seed	$14.27
Profit on purchase of meal	12.40
Loss on purchase of hulls	2.94

These figures, however, must not be taken as meaning that it is better in all cases to buy cotton seed instead of meal, but rather, the comparative benefits to be expected from each *when used under the most favorable circumstances.* For some crops, and on some soils, the meal will be much the cheaper fertilizer. All animal and vegetable fertilizers contain a greater or less amount of organic matter, or humus-making material, which is of great value to barren or exhausted soils, but which will be of no benefit, and may sometimes be actually a detriment to creek bottom lands, newly cleared timber land or to other soils, which are already supplied with black humus. Heavy clay soils ordinarily contain a fair amount of plant food, but are usually deficient in humus, and are so compact and solid that they cannot be easily penetrated by roots, nor will they admit of the rapid percolation of water, which is essential to a productive soil. On such soils, seed will be much more valuable than meal, both on account of its greater fertilizing

and humus-producing properties, and also on account of its mechanical effect in making the soil lighter, more porous and friable, more easily worked, and less liable to bake after heavy rains. The seed will not act as quickly as the meal, neither will it be exhausted so soon; a large proportion of it, especially of the hulls, remaining in the ground until the second year. On land which is to be permanently cropped, there will be no loss, its mechanical effect in loosening the soil more than making up for the small amount which may be lost by leaching.

The form in which the seed is used will influence the rapidity of its action. It must decay and become soluble before it can be used as plant food. If fresh seed is used, this will require some weeks; if the seed is killed by wetting and heating, the process is hastened; but if the seed is crushed, it will be ready to act still more quickly.

When a stimulating fertilizer is wanted to push a crop forward rapidly for a short time only, the meal is better than even crushed seed, as it decomposes so rapidly as to become almost immediately available, and will produce its entire effect within a very few weeks. On very light and sandy soils which are already sufficiently loose and friable, or when the soil is underlaid with gravel so as to leach badly, meal is more economical than seed.

As will be seen from the analysis on a preceding page, cotton seed hulls have but little fertilizing value, and as a fertilizer alone they do not pay at the prices quoted. Where the main object of an application is to loosen a too heavy soil, or a mulch is wanted to protect tender plants, strawberries, etc., the hulls are useful, but are worth more to use as stock food than to use on ordinary crops. Hull ashes, as usually found in the markets, contain about nine per cent. of phosphoric acid and twenty pounds of potash, making their value $32.60 per ton. As usually found in the market, they are more or less mixed with coal ashes, but we have never examined a sample which was not well worth the price asked—usually about $20.00 per ton. In the immediate vicinity of oil mills, seed is often worth more, and hulls less than the prices given above, so that often the use of hulls will be found more economical than the seed.

GREEN MANURING.

Green manuring, or the plowing under of green crops, is beneficial in two ways: First, by practically giving the soil a rest for a year; and second, by increasing the amount of available plant food. As stated on a preceding page, nearly all soils contain an abundance of plant food to produce a full yield of almost any crop, but most of this food is in an unavailable condition. This insoluble matter is acted upon differently by different plants, each kind of plant taking certain elements and leaving others in a condition in which they are ready to be absorbed by some other kinds of plants. The beneficial effects of crop rotations depend on this principle, and the crops commonly used for green manuring are not those cultivated for other purposes. By using special crops for green manures, the plants find an abundant supply of food which has been rejected by the farm crops, and so can make a vigorous growth where regular crops would fail. The materials which they take up from the soil and from the air, they do not remove from the field, but by their decay in the soil they leave available for future crops not only the elements of which they themselves are composed, but also those which have been rendered available by the root action of the manurial crop. In addition to this, they leave in the soil nearly their whole weight in humus-making material.

The most valuable crops for green manuring are those which have the deepest roots, as such will draw up from the subsoil a large proportion of their mineral food, which, when the crop is plowed under, is left near the surface, where it is available for such shallow-rooted plants as oats, corn, and grasses. In decaying, the deep plant roots leave minute openings in the subsoil, which are valuable aids in making the subsoil porous and permeable to water.

The plants commonly used for green manuring in this State are pea vines and red clover. In 1887 Prof. Myers, the former Chemist of the Station, made complete analyses of these plants, together with an analysis of Japan clover (*Lespedeza striata*), with the following results, viz:

PLANT.	Pounds.	Phosphoric Acid, lbs.	Potash, lbs.	Nitrogen, lbs.	Value.	Total value.
Pea vines—tops	2,000	10.959	15.01	46.36	$ 9.40	
Pea vines—roots	522.1	2.285	5.29	8.28	1.83	$11.23
Lespedeza—tops	3,523	14.16	18.92	72.93	14.34	
Lespedeza—roots	1,442	30.43	15.27	16.78	5.75	20.09
Clover—tops	1,202	82.21	8.72	36.99	12.48	
Clover—roots	642	5.02	2.38	13.96	2.84	15.32

In the figures given above, those for lespedeza roots are the average of two analyses, and those for clover are from plants taken in October, which were only eight months from seed. Prof. Myers says: "The peculiarity of the growth of the cow pea precludes the possibility of arriving at much idea of the actual rate of production by washing out a few square feet. In this case I have, therefore, found the ratio of root to top, which in the samples examined was 1 to 3.83. I then calculated the composition upon the yield of 2,000 pounds of tops to the acre."

The table is somewhat misleading, as the pounds per acre for each plant do not fairly represent the average yield of the respective crops. The pea vines and clover are too small, and the lespedeza too high. If we make an estimate on a crop of two tons per acre for pea vines and clover, and one ton for lespedeza, we shall be nearer the ordinary values. The table will then read as follows:

PLANT.	Pounds.	Phosphoric Acid, lbs.	Potash, lbs.	Nitrogen, lbs.
Pea vines—tops	4000	21.918	30.04	92.72
Pea vines—roots	1044	25.70	10.58	16.56
Lespedeza—tops	2000	8.04	10.74	41.40
Lespedeza—roots	819	17.28	8.67	9.53
Clover—tops	4000	273.58	29.01	123.10
Clover—roots	2136	16.70	7.91	46.45

By this showing, clover becomes the most valuable crop of the three, which accords with the general experience. There are two reasons for this: First, because the clover contains the largest percentage of nitrogen, which is the most expensive element in plant food; and second, because it is deeper rooted, and so brings a larger proportion of its food from the subsoil, where it is inaccessible in other plants. The common saying, that "clover seed is the cheapest fertilizer," has a solid foundation.

The value given above must not be taken as actual, but as being comparative only. That is, if it would cost $11.23 to purchase the fertilizing elements in the tops and roots of the acre of pea vines, then it would cost $20.09 to buy the amount of these same elements found in the acre of lespedeza, and $15.23 for those in the acre of clover. The nominal value of these green manures is far above their actual value, from the fact that all the fertilizing elements are valued as being immediately available for the succeeding crops, while as a matter of fact, an indefinite proportion may not be available for a long time, and some of the plant food is in such excess that it cannot be consumed.

The Experiment Station of the Storrs School, in Connecticut, as given in bulletin No. 3 of that Station, has made some interesting and very useful examinations of the amount of roots of plants found at different depths in the soil. From the report, it would appear that the amount has an important bearing on the value of different crops for enriching the land on which they grow. Clover appears to stand far above all others, for in addition to the mechanical benefit of its roots, it was found that the roots and stubble—that is, what is left after the mowing—contain large percentages of the three most valuable ingredients of plant food, and at the same time a large amount in quantity is left in the soil. In one instance, a heavy crop left a little over three tons of dry stubble and roots, containing 180 pounds of nitrogen, 71 of phosphoric acid, and 77 pounds potash. The report of the Station states that it would require 1,100 pounds of nitrate of soda, 400 pounds of dissolved bone-black, and 150 pounds of muriate of potash, to furnish the same amount of fertilizing materials; but these materials would, however, have the advantage of being used at once by the growing plants, and before the decaying roots and stubble could supply them. Wheat and other grain crops, as a class, were found of little value for enriching the land by their roots. Timothy—stubble and roots together, with the young after-growth—was found to possess much enriching value, which was mostly confined quite near the surface. In the cow pea, three-fourths of the roots were within six inches of the surface, although a portion went down more than three feet. In timothy, the difference in favor of six inches of the surface was still greater, and greater still with buckwheat, where the upper six inches of the soil held 25 times as much of the roots as the next six inches.

The objection sometimes urged against green manuring is that if the crop is plowed under in the fall, it leaves the ground bare and subject to washing and leaching during the winter. This objection has force on broken and hilly lands only, and even there may be avoided by plowing so early that a crop of weeds will have time to cover the ground before cold weather.

Stable manure, which has been produced on the farm, is the cheapest and best fertilizer for all ordinary crops, because it is a waste product, but when the supply of this is insufficient, resting the land and plowing under some deep-rooted crop will, in many cases, be the cheapest method for keeping up the fertility of the soil.

MARLS.

Bulletin No. 4, of this Station, gives analyses of marls found in Mississippi. It will be seen, that while of general occurence throughout the State, very few of the marls are rich enough in phosphoric acid and nitrogen to make them sufficiently valuable to pay the cost of long hauling. The best specimen we have received is from Wayne county, Section 3, Township 8, Range 7 west., which is valued at $2.34 per ton, and the next best is from Chunky Station, Newton county, valued at $2.24 per ton. None of the Mississippi marls, so far as known, contain over 2.06 per cent. of phosphoric acid, which is found in a sample from Columbus, in Lowndes county. In some of the soils in this State, phosphoric acid and nitrogen are needed more than potash, so that in such cases it will often be found that a marl rich in

phosphoric acid and poor in potash may be more beneficial than one of which the total value is made up largely from its potash.

If the beds are near at hand, it will be profitable to haul marl for use on creek bottoms and "sour" soils, when the teams are not otherwise employed, but there are few cases in which it will pay for hauling more than two or three miles. From ten to twenty wagon loads should be used per acre, and its effect will be increased if applied to the land just before plowing under some green crop. If this is impracticable, it will be improved by adding half a ton of ashes per acre. In estimating the values of marls, no account has been made of the large percentage (usually 40 to 60 per cent.) of lime which they contain, because that element is usually abundant in most of our soils; but whenever lime is wanted it can be well replaced with marl.

COMMERCIAL FERTILIZERS.

The economical use of commercial fertilizers is one of the most difficult problems with which we have to deal, as in many cases they are the cheapest fertilizer which can be obtained, while in other cases, the money paid for them might as well be thrown away. They may contain the three necessary elements of plant food in some definite proportions, but it is so seldom that a particular crop and field require these elements in exactly the proportions in which they are found in any one of the staple brands, that it is difficult to decide which it is best to purchase. While it is a simple matter to make an analysis of a soil, and of the crop which we may wish to grow upon it, these analyses tell us little as to what may be the best fertilizer for us to use. The analysis of the soil does not tell us its condition, whether the plant food it contains is in an available form, or anything of the mechanical condition of the soil. Plant food in the soil may be available for one plant while it is not so for another, and, for some reason which we are unable to explain, most plants grow best in a soil containing certain available elements far in excess of the amounts consumed in growth. It is known that an abundance of nitrogen is necessary to produce a vigorous growth, that potash is necessary for the production of the woody parts of the plant, and that phosphoric acid is largely consumed in the production of the seeds; but in order to produce the best results, these elements should be furnished to the soil in different proportions for different plants, and these proportions are by no means those which are found in the plants themselves. What these proportions are, the chemist cannot tell us, and we can learn them only by experiment.

As has been shown on a preceding page, most of the soils in this State are already fairly well supplied with potash, so that, as a rule, it is less needed than are nitrogen and phosphoric acid, and in purchasing fertilizers, some mixture of nitrogenous and phosphoric acid compounds will be found more economical than the complete fertilizers which contain the three elements. Grain and grass crops are most largely benefited by nitro enous fertilizers, while peas and similar crops respond more readily to an application of potash. For cotton and corn, a mixture of nitrogen and phosphoric acid will commonly give the best results, but the form in which these can best be applied will vary with the soil, expense, and crop. As a rule, they can be used more economically if mixed with barnyard manure, cotton seed, or meal, than if used alone. Very few of the commercial fertilizers contain any appreciable amount of humus making material, which is so essential to a vigorous plant growth, and so are, to that exent, deficient as a complete fertilizer.

Most commercial fertilizers have phosphoric acid in the form of acid phosphate as a basis. To this is usually added potash in the form of kainit and a small amount of nitrogen in the form of dried blood, fish scraps, leather refuse, or sometimes nitrate of soda, or some other cheap nitrate salt. These are mixed in various proportions according to the "brand" which it is desired to manufacture, and then placed on the market at a price decidedly in advance of the cost of the raw materials, as it should be; the usual estimate of the actual cost of mixing and sacking ordinary brands in New Jersey is $2.85 per ton. In addition to this cost, the manufacturer is entitled to a fair profit for handling the goods, so that by the time the fertilizer reaches the consumer, the price becomes so high that many planters are unable to purchase as liberally as true economy would indicate.

We fully believe that, in all ordinary circumstances where commercial fertilizers are needed, the farmer will find it cheaper to purchase the raw materials and mix them for himself in the proportions best adapted to his particular soil and crop.

Nitrogen can be obtained in the form of nitrates at a cost of about seventeen cents per pound, but if it be obtained from the use of cotton seed, it will cost only 13.6 cents, and from cotton seed meal 14.3 cents; and at these figures no account is made of the value of the potash, phosphoric acid, and humus-making material contained in the seed; which if reckoned in the cost at the usual prices it will bring, would reduce the cost of nitrogen less than ten cents.

Neither the cotton seed nor the meal contains as much phosphoric acid as is needed to make a complete fertilizer, therefore that element must be obtained from other sources. Acid phosphate furnishes it in the cheapest and most available form known, and is the fertilizer which should be purchased more largely than all others. On some soils, an application of this alone will give a profitable increase of crop, but it is more economical to use it as one of the ingredients of a compost, mixing it thoroughly with other fertilizers which contain an excess of nitrogen or nitrogen and potash.

For composts, stable manure is the best possible foundation. If this is stored in a pit, as described on a preceding page, an excellent mixture for cotton lands can be made by throwing cotton seed and acid phosphate over the pile once a week, or still better every day, in the proportions of one ton of seed and one of phosphate to every four tons of manure. If the heap does not contain too large a proportion of horse manure, it will not heat sufficiently to injure it, and by the time it is to be hauled to the field, the seed will be killed, and in an excellent condition for immediate use by the plant. A ton of such manure will contain 17.67 pounds of nitrogen, 12.80 pounds of potash, and 52.67 pounds of phosphoric acid, and will cost, besides the manure, about $5.43. For soils deficient in potash, the mixture may be improved by the addition of a ton of kainit, which will make the composition of a ton of the mixture contain 15.15 pounds of nitrogen, 45.26 pounds of potash, and 45.15 pounds of phosphoric acid. It is only on a farm where a large amount of stock is kept, that this practice can be followed; where the stable manure cannot be had in sufficient quantities for such a compost, an excellent mixture can be made by using 700 pounds of stable manure, 700 pounds of cotton seed, and 600 pounds of superphosphate. Such a mixture will contain 40 26 pounds of nitrogen, 26.99 pounds of potash, and 61.27 pounds of phosphoric acid. This mixture contains a larger proportion of nitrogen, which is rendered necessary by the absence of the humus-making material contained in the former mixture. With an abundance of decaying organic matter in the soil, nitrification goes on rapidly, and a large amount of nitrogen is absorbed from the air. In the absence of this organic matter or humus, nitrification proceeds very slowly, and more nitrogen must be applied in the fertilizer.

If stable manure is wholly unavailable, and the planter is obliged to purchase all his fertilizers, cotton seed and acid phosphate will produce better results on clay lands than will any form of chemical fertilizer alone, as such soils are always improved mechanically by the use of the seed, and the seed is also the cheapest source of nitrogen. For such a mixture equal weights of seed and acid phosphate may be used, a ton of which will contain 53.2 pounds of nitrogen, 36.4 pounds of potash, and 113 pounds of phoshoric acid and will cost about $16.30. For alluvial soils, less nitrogen will be needed, and the acid phosphate alone or phosphate and kainit may be used with good results.

Chemical fertilizers are valuable only for the nitrogen, potash, and phoshoric acid which they contain. In he purchase of a fertilizer, attention should be given to these only. Acid phosphate is undoubtedly the cheapest form in which we can procure phosphoric acid, and where an abundance of stable manure is not to be had, it will pay to use it freely. Potash can be had most cheaply in the form of kainit. The ammonia in crushed seed or in meal is as readily available as that in most chemical fertilizers, and as the seed is the cheapest source from which it can be obtained, seed or meal should always form a large part of any fertilizer which may be used. We do not mean to say that acid phosphate and kainit are the only chemicals which should be used, or that it will never pay to buy any of the "complete" fertilizers found in the market, for under some circumstances, and on some soils, their use will be very profitable, but we do not recommend their indiscriminate use whenever it is thought desirable to manure a field. Such an unthinking purchase of a commercial fertilizer is as wasteful use of money as would be the purchase of "seeds" without knowing what crop we desired to grow. If the dealer kept, and we used but three kinds of seeds, we might, perhaps, receive a kind which would be of value to us, but when one wishes to grow corn, it is wise to buy corn seed for planting. So, too, in buying fertilizers, it is the best economy to buy just what is needed for the particular soil and crop for which it is to be used, and it is a needless waste to purchase plant food which cannot be consumed. It should be borne in mind that for all crops, and for all excepting rich alluvial soils, humus-making material is as necessary as any other ingredient of plant food, and that the use of chemical fertilizers alone without green manuring or resting the land occasionally, will sooner or later reduce the farm to a condition where the return for the crop will not equal the outlay for fertilizers. Where mixed farming is pursued and the manure and cotton seed are all taken back to the fields, and a proper crop rotation is followed, the farmer will have no occasion for the purchase of fertilizers of any kind. Where the farm is managed exclusively for the production of any single crop, except grass, a portion of the fertilizers needed must be purchased. On our large cotton plantations, ammoniated super-phosphate will usually be found the most economical, acid phosphates standing next in value. On such plantations, when the seed is all returned to the field there is but little loss in fertility, but the phosphoric acid will finally become exhausted, and must be replaced in some form. The rich lands in the Delta region of the State have a supply of potash, nitrogen, and humus sufficient for many years to come, and for such lands the phosphates are the only fertilizers needed at present. On the higher lands there is a deficiency of phosphoric acid, nitrogen, and humus, all of which must be frequently renewed.

Whether it is best to use commercial fertilizers broadcast or directly on or under the plants must be decided by the special soil and crop where used, but as a rule, it is more economical to apply them broadcast rather than in the drill. Any one who has seen even half-grown corn or cotton plants from which the soil had been washed, has noticed that the roots had spread entirely across the spaces between the rows, and that near the plants the roots had but few feeding rootlets, while near their extremities, the feeding rootlets were far more numerous; showing that the plants were drawing most of their nourishment from a considerable distance.

When fertilizers are placed under the seed they are often so concentrated that they actually kill the tender rootlets which come in contact with them. All ordinary seeds contain a sufficient amount of nourishment to sustain the young plants until the roots are several inches in length, as may be seen by planting corn or similar seeds in a box filled with pure sand. The seeds will germinate and the roots will grow to be a foot or more in length as freely as when planted in rich soil.

As has been stated before, roots cannot absorb food in masses, but in solution only, and for this reason it is important to apply a fertilizer in such a manner that it may become thoroughly mixed and incorporated with the soil in which the roots are to feed. Roots possess an almost intelligent power in their absorption of food, and will be developed most abundantly in those parts of the surrounding soil where available food is most abundant. When too concentrated, or in excess, a fertilizer is positively injurious rather than beneficial, while if mixed with the entire mass of the soil within reach of the roots it will induce the increased growth which is desired.

For these reasons it is usually better to apply fertilizers broadcast when but one application is to be made. On sandy soils, or soils which leach badly, it is better to make at least two applications, the first of which may be made in the drill; and it makes but little difference whether it be placed under or over the seed, provided it does not come in contact with it.

For putting commercial fertilizers in the drill we have found nothing better than a corn or cotton planter which can be gauged to distribute any required amount. If applied by hand it will be less evenly distributed, and will often be left in lumps which will be worthless, if not injurious. The second application may be made by hand, or by running a planter in the middle of the space between the rows, and should be followed at once by a cultivator to mix the fertilizer with the soil and preserve it from loss by the action of the air or heavy rains. The fertilizer applied first may be of a less soluble kind than the second application, as the crop has a much longer time for its assimilation. The first application should include the acid phosphates, ground bone, plaster, etc., while the second should be of super-phosphates, kainit, cottonseed meal and other quick acting kinds.

If the fertilizer is applied broadcast it can be distributed more evenly if mixed with a considerable bulk of stable manure or cotton seed to increase its bulk when it can be distributed from a wagon. If that cannot be done, a little practice will enable one to scatter the right amount. A small plot, say a quarter of an acre running the length of the field, should be measured off, and the desired amount of the fertilizer weighed and scattered. Only one or two such trial plots will be necessary to learn just how much should be used in going across the field each time.

There are several machines in the market for the distribution of fertilizers, but we have found none that are better than a corn or cotton planter for sowing in the drill, and a common grain drill for sowing broadcast.

In Great Britain, where nearly all the land is farmed on the tenant system, and where the original fertility of the soil has been long since exhausted by continued cropping, great attention has been paid to the length of time required for the complete exhaustion of different fertilizers, and the amount of each remaining in the soil at the end of each year. According to Scotch estimates, these are as follows:

Kind of Fertilizer.	*Exhausted (in years.)*	*Per cent. remaining in the soil unexhausted at end of each year.* 1	2	3	4	5	6	7
ON UNCULTIVATED CLAY LOAM.								
Lime	12	80	65	55	45	35	25	20
Bone meal	5	60	30	20	10	00	00	00
Phosphatic guanos	5	50	30	20	10	00	00	00
Dissolved bones and plain superphosphates	4	20	10	5	00	00	00	00
High grade ammoniated fertilizers, guano, etc	3	30	20	00	00	00	00	00
Cotton seed meal	5	40	30	20	10	00	00	00
Barnyard manure	5	60	30	20	10	00	00	00
ON CULTIVATED LIGHT OR MEDIUM SOILS.								
Lime	10	75	60	40	30	20	15	
Bone Meal	4	60	30	10	00	00	00	
Phosphate guanos	4	50	20	10	00	00	00	
Dissolved bones and plain superphosphate	3	20	10	5	00	00	00	00
High grade ammoniates, guanos	3	30	20	00	00	00	00	00
Cotton seed meal	4	40	30	20	10	00	00	00
Barnyard manure	4	60	30	10	00	00	00	00
ON UNCULTIVATED PASTURE LAND.								
Lime	15	80	70	60	50	45	40	35
Bone meal	7	60	50	40	30	20	10	00
Phos. guanos	6	50	40	30	20	10	00	00
Dis. Bone, etc	4	30	20	10	00	00	00	00
High grade ammoniated guanos	4	30	20	10	00	00	00	00
Cotton seed meal	5	40	30	20	10	00	00	00
Barnyard manure	7	60	50	40	30	20	10	00

Sulphate of ammonia, nitrate of soda, sulphate, nitrate and muriate of potash are generally held to be entirely exhausted by the crops grown the season of their application.

The figures given above are always used in fixing the price for new tenants. In this country, no such careful estimates have been made, but the proportions probably vary but little from those in other countries.

Many complaints are made of the exhorbitantly high prices at which chemical fertilizers are sold. Taking into account the expenses for freights, and sacking, loss on bad debts and interest on

the money invested, there are but few fertilizers which can be sold for less than the prices asked by reputable dealers. During the present season, we have made analyses of forty-three brands. Of these, nine were found to be below the minimum guaranteed value, and only six were up to the highest standard of the limit claimed by the manufacturer, showing very clearly the need of constant and careful supervision by the State for the protection of purchasers, who are obliged to depend almost wholly upon the statements of the dealers. The honest dealer, like any other honest man, intends to give a full equivalent for money received, but unfortunately, there are dishonest dealers as well as ignorant purchasers, so, for the protection of the honest dealer and the ignorant purchaser, the State inspection laws should be sufficiently comprehensive to include both. As the law now stands, purchasers are fairly well protected against fraud on the part of dealers or manufacturers residing in this State, but are afforded no protection whatever against dealers in other States. New Orleans, Memphis, Nashville, and Charleston, probably furnish three-fourths of the fertilizers purchased in this State, and the law should furnish the same protection against fraud in shipments into the State that is afforded against dealers here. Commercial fertilizers are used more largely in Georgia than in any other State, and the laws of that State governing the fertilizer trade are generally regarded as being the best in the United States. Alabama and Louisiana have adopted very nearly the same law on the subject. It has been suggested that all of the Gulf States, together with Tennessee and Kentucky, might agree on some uniform mode of fertilizer inspection which would be a mutual advantage and equal protection to all. It is hoped that our next State Legislature will give the subject the careful consideration which it deserves.