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Exhaustion and Restoration of Soil Fertility; Fertilizers and their Use

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Exhaustion and Restoration of Soil Fertility.

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AGRICULTURAL COLLEGE, MISS.

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The bulletins of the Station are sent free of charge to all farmers in Mississippi who apply for them.

SUMMARY.

Nearly every foot of soil in Mississippi was once fertile and productive, and what we have to do to make them all so again is to bring them back as nearly as possible to their original condition. Exhausted soils cannot be made fertile at once by the use of any amount of fertilizer, any more than a poor steer can be made fat immediately by giving him a crib full of corn. It takes time to exhaust a soil, and it also takes time and persistent effort to restore its fertility. Green crops must be the foundation of all restorative work, and then a comparatively small amount of commercial fertilizers will complete the task.

On clay soils which are too poor to produce other crops, sow lespedeza, give a top dressing of meal, and plow the ground at the end of the second season.

When the soil is sufficiently fertile to produce a fair crop, sow cow peas, and fertilize with meal, acid phosphate, or land plaster. Sow the peas early, plow them under early, and sow rye.

On lands underlaid with lime, and in the black prairie region, sow melilotus and plow under at the end of the second season.

For the sandy lands of the pine woods region, cow peas are the best restorative crop which can be grown.

On lands which are already in good condition, and which need only to have their fertility maintained, sow red clover or alfalfa.

The poorer and more exhausted the soil, the greater the need for liberal supplies of humus.

Use chemicals to supply known deficiencies in the soil, rather than as the principal fertilizer.

Save, protect, and use all the stable manure.

Good soils are easily kept in good condition, and should improve with every year of cultivation.

EXHAUSTION AND RESTORATION OF SOIL FERTILITY.

W. L. HUTCHINSON.

EXHAUSTION.

When the producing power of a soil is reduced below a certain point of supposed profitable culture, which may be different for different cases or different crops, it is said to be exhausted, though no one supposes that in any given case the soil is entirely deprived of producing power. The fertility of a soil is dependent upon two things, viz: its natural strength, and its condition. The readiness with which the insoluble plant food in a soil becomes available by natural agencies, and the length of time that this will continue, determine the natural strength, while such physical properties as favor the growth and development of plant roots and the acquisition by these of the available plant food in the soil, determine its condition. The natural strength of a soil may be practically inexhaustible, while a soil in good condition may be easily reduced to one of poor condition. There are few cultivated soils in this state that have not suffered a material loss of plant food, while their once favorable condition is changed to such an extent as to reduce the productiveness of the soil below the point of profitable cultivation. It remains for succeeding farmers to restore the once favorable condition of our soils and, at the same time, obtain from them at least a living.

Exhaustion may be better prevented when the processes by which it is brought about are better understood. A knowledge of the composition of soils and the kind and character of substances which they furnish plants is necessary in our study of the processes of exhaustion. The great bulk of all soils consists of ordinary sand and clay; and the proportion in which these ingredients occur gives rise to the terms sandy, sandy loam, and clayey soils. Besides these, soils contain lime, potash, magnesia, soda, iron, maganese, phosphoric acid, sulphuric acid, chlorine, organic matter containing nitrogen, and water. The sand and the clay are of no importance as plant food; but they have a very great influence on the productiveness of a soil, as in most cases the mechanical condition, and to some extent the temperature, is determined by the proportion of these substances present. The clay also exercises a wide influence by its properties, which enable it to hold moisture and to fix or preserve other substances which are to act as plant food, and thus prevent their leaching from the soil. Plants obtain all of their water, nitrogen, lime,

magnesia, potash, phosphoric acid, and all other mineral food through their roots; and it is all furnished by the soil except in certain cases in which a part of the nitrogen is obtained from the air. Plants cannot take anything from the soil until it is dissolved, or brought in solution. The soil water is the principal dissolving agent, though the plant roots themselves exercise quite an important solvent action. It is thus seen that whenever plants or crops are removed from soils more or less of the plant-food ingredients in the soil have been taken from it, depending on the nature and amount of the crop so removed. This, however, is only one of the ways by which a soil is exhausted. Large amounts of some of the plant-food ingredients of soils are leached out by the underground water and are carried off by the streams. Nitrogen and potash are especially liable to be lost in this way. This source of loss is greatest in the fall and winter months, and is also very much greater from bare lands than from those covered with growing crops. Boussingault, a French experimenter, made some investigations on a soil containing, to the acre, as much as 900 pounds of nitrate of potash to the depth of a foot. After three weeks of rainy weather, during which two inches of rain fell, there was left only forty pounds of the nitrate. It is estimated that the Rhine daily carries into the sea 220 tons of the nitrate; the Seine, 270; and the Nile 1100 tons. All streams and drainage waters contain more or less of these compounds; but in the South both of these sources of loss have been trifling as compared to the loss from surface washing. The greater portion of our surface soil has been allowed to be washed into the valleys or carried by the streams into the seas. In addition to this, some of the organic matter, including the valuable nitrogen, has been converted into gas and escaped into the air. The removal of crops from the soils of the South has been a rather small factor in their exhaustion and in many cases we can hardly regard the soils as having been exhausted at all. They have been washed away. As all loss of plant-food ingredients from the soil by surface washing can be prevented, and should be reduced to a minimum. Without this, any effort to restore fertility to the soil will meet with poor success. The losses which are sustained through the leaching of underground water may be largely prevented, though not entirely. This loss is best prevented by keeping the ground always covered by a growing crop, especially during the fall and winter, when this loss is likely to be the greatest. Organic matter and clay have a tendency to fix the plant-food ingredients and prevent their being carried out by the water and this is the reason that land with a clay subsoil is so well adapted to improvement. It is also true that by incorporating organic matter into it, a

sand bed may be made to retain plant food quite satisfactorily. The character and amounts of plant-food ingredients contained in different crops is shown in the following table compiled by Mr. Patterson, of the Station staff:

AMOUNT AND VALUATION OF FERTILIZING INGREDIENTS CONTAINED IN COMMON SOUTHERN AGRICULTURAL PRODUCTS.

PLANTS.	Bushels per acre	Pounds per acre	Pounds Nitrogen per acre	Pounds Potash per acre	Lbs. Phos. Acid per acre.	Value
						$
WHEAT—grain	25	1500	30.75	8.40	13.50	5.71
straw		3500	19.00	38.50	7.00	5.12
chaff		250	1.80	2.10	1.00	.42
whole plant		5250	51.55	49.00	21 50	11.25
OATS—grain	35	1225	21.56	5 88	2.45	3.65
straw		3000	16.80	48.90	8.40	5.39
chaff		250	1.60	1.12	.32	.31
whole plant		4475	39.96	55.90	11.17	9.35
CORN—grain	50	2800	46 80	10 36	15.96	8.34
fodder		1200	20.28	46.80	5.88	5.69
cobs		470	1 08	1.08	.09	.22
husk		420	2 89	6.51	.34	.77
whole plant removed		4890	71.05	64.75	22.27	15.01
RYE—grain	25	1400	24 64	8.12	11.90	4 69
straw		3500	14.00	30.10	8.75	4.04
chaff		310	1.79	1.61	1.73	.44
whole plant		5210	40.43	39.83	22.38	9.17
BARLEY—grain	25	1200	19.20	5 64	9.36	3.63
straw		2500	10.00	21.50	6.25	2 89
chaff		180	.90	2 07	.52	.26
whole plant		3880	30.10	29 21	16.13	6 78
COTTON—seed cotton		1000	27.77	10.96	9.50	5.19
lint cotton		333	.83	2 63	.20	.27
*COW PEAS—vines (hay)		6000	97 80	54.78	31.62	18.99
peas	25	1500	53 30	21.60	13.35	9.75
hulls		500	5 00	2.30	80	.91
SWEET POTATOES	200	12000	27.60	56.40	19 20	7.92
IRISH POTATOES	100	6000	12.00	17.40	4 20	2.89
TOBACCO		500	17.50	53.48	7.00	5.64
BERMUDA HAY		4000	37.20	76.40	15 26	10.16
*LESPEDEZA HAY		4000	82.80	21 60	17.60	14 38
*MELILOTUS HAY		6000	118.00	109.80	33.48	24.87
*RED CLOVER HAY		4000	87.20	91.20	17.88	18.49

*Restorative crops.

In explanation of the table it should be stated that crops which derive all their nitrogen from the soil are known as "exhaustive crops," while those which have the power to assimilate their nitrogen from the air are commonly known as "restorative crops." To the latter class belong cow peas, lespedeza, melilotus, red clover, and other leguminous plants, which are among the most valuable restorative crops known, even though they may be cut for hay, and the bulk of the crop removed from the land.

RESTORATION.

The first effort that should be made in an attempt to restore fertility to a soil is to stop, as far as possible, any further loss of plant food ingredients except such as are removed in crops. Some of the ways of doing this have been alluded to under the previous heading. There are various ways known to every farmer for preventing surface washing, any or all of which may be resorted to as circumstances may demand. Levying, tile drainage, deep culture, subsoiling, and sodding are among the most important means to be used for this purpose. Loss from leaching is most satisfactorily prevented by keeping the land always covered with growing crops to take up the plant food as rapidly as it becomes soluble, while a clay sub-soil and a liberal amount of organic matter have a tendency to prevent losses by leaching. Deep culture and all other operations that give land a large absorbing power for water are beneficial. Having adopted such precautions as will prevent surface washing and loss from leaching, or at least reduce them to a minimum, it becomes a comparatively easy matter to repay the losses sustained by the removal of crops, and to increase the amount of available plant-food ingredients in the soil.

Two means may be resorted to for this purpose, viz: the application of manures and fertilizers, and the aiding of the processes of Nature in bringing into a soluble condition some of the insoluble ingredients of the soil. Gypsum, or landplaster, and lime are the two substances which are almost exclusively used for the latter purpose, and they are sometimes called stimulant fertilizers. Gypsum releases potash, and the functions of lime are thus given by Dr. Hilgard:

"a. It improves the mechanical condition of the soil.

b. It renders the phosphoric acid and the potash in the soil more readily available.

c. It favors nitrification.

d. It preserves the humus."

It is often found advantageous to still further aid the accu-

mulation of available food by turning green crops into the soil. In returning to the soil, by the use of chemical fertilizers, such ingredients as are removed by crops it has not been found profitable to return any except nitrogen, phosphoric acid, and potash. In many instances it is only necessary to return one; and in others, two of these three substances. In practice, it has been found best to apply phosphoric acid in the form that is soluble in water. Complete commercial fertilizers aim to supply these three substances; and generally contain, to the ton, from 150 to 200 pounds of phosphoric acid and from 25 to 40 pounds each of nitrogen and potash. Where 500 pounds of such a fertilizer is put on an acre there is returned to the soil from 35 to 50 pounds of phosphoric acid and from 6 to 10 pounds each of nitrogen and potash. On the lime soils of this state, such as are found in the north-east and central prairie regions, the application of fertilizers has failed to produce an increase of crop. The failure of these soils to produce large crops seems to be due entirely to their unfavorable mechanical condition, which may be readily corrected by growing on them such tap-rooted plants as red clover, cow peas, and melilotus. On the yellow loam lands of the state, a return of phosphoric acid seems to do but little good; while an application of potash and nitrogen gives good results. On the sandy and sandy-loam lands, a complete fertilizer should be used in such quantity as to return to each acre at least 40 pounds of water-soluble phosphoric acid, and 10 pounds each of nitrogen and potash. Larger applications will be found to give good returns.

NITRIFICATION AND ROTATION OF CROPS.

It is by nitrification that the nitrogen in the soil is converted into nitrates and ammonia salts, the principal forms in which nitrogen is available for plant food. The conditions favorable for the nitrification of the organic matter in the soil are as follows:

1. Porosity, which allows a free circulation of air through the soil, and thus oxygen, one of the necessary agents, is furnished.

2. A moderate amount of moisture. Excess of water or absolute dryness stops the action.

3. Proper temperature, the most desirable being 98 deg. F., the extremes being 40 and 130 degs. F.

A rich sandy-loam soil usually furnishes these conditions in summer in a very satisfactory manner, and by proper tillage and management all soils may be brought to a condition favorable to nitrification, and to do this should largely be the object of all field operations.

Rotation of crops may often be used to advantage in maintaining the fertility of a soil or in restoring fertility to it. Crops appear to feed almost as differently as animals do, though this difference must be understood to mean the portions of the soil from which crops obtain their food, the proportion of the ingredients taken up, and the relative ease with which they obtain food from the soil. Some crops appear to be coarse feeders, and obtain bountiful supplies of food where others can get but little; and again, some get their food from deep in the soil, while others feed near the surface; some take up larger proportions of potash, while others give preference to nitrogen or phosphoric acid. Again, some plants leave large quantities of organic matter, containing nitrogen and mineral ingredients in the stubble and roots which are left in the soil; while others leave very little. Some are allowed to produce seed; others are not. Some make their principal growth in winter; others, in summer. All these facts influence the effects of different crops on soil. Red clover leaves in the soil three to four times as much vegetable matter, in the stubble and roots, as do rye, barley, oats, or wheat; and in the clover plant there is half as much root as top, while in the cereals there is only about one-fourteenth as much. Cow peas and melilotus belong to the same family as red clover; and, like it, obtain a large amount of their food from the lower layers of the soil. All of these plants have the power of collecting, through their roots, atmospheric nitrogen, and this adds to their fitness to act as restorative crops. They collect and concentrate in the upper layers of the soil large quantities of available plant food; and by means of their long tap roots, render the sub-soil open and porous, facilitating drainage during excessive rain, and aiding in the elevation of water from the lower to the upper layers of the soil during excessively dry weather.

FERTILIZERS AND THEIR USE.

S. M. TRACY.

During the six years since this station was organized it has given more attention to the use of fertilizers, the kinds best for use on different soils, and the best methods for using them, than to any other subject. In this work the station has used fields representing the four soils most common in the state; the sandy clay region of the north-west, the black prairie of the north-east, the yellow clay loam of the central region, and the sandy pine woods soil of the southern part of the state. Hundreds of plots have been used, some of them continuously with various forms of commercial fertilizers, others have been fertilized only by the turning under of green crops, while on still others the two methods have been combined. Partial reports of the results of this work have been published in the Annual Reports of the station and in Bulletins 5 and 24, while the present bulletin gives the results secured up to the close of 1893.

The use of fertilizers is one of the most complex questions with which the farmer has to deal, as their effects are always greatly modified by the condition of the soil to which they are applied, the previous cropping of the land, and the character of the season during which they are used. Cotton seeds are always beneficial to heavy clay soils, while they are almost worthless for very light and sandy soils; kainit is of no benefit on newly cleared hardwood timber lands, while it is of the highest value on those same lands after they have been in cultivation so long that the supply of available potash is exhausted.

Fertilizers act both chemically and mechanically, the latter action being, in many cases, of even greater importance than the former. A very stiff clay soil may contain an abundance of plant food for a heavy crop, and at the same time be so hard and compact as to be almost sterile. If such a soil be made light and porous by any means, even by mixing with it sand, gravel, broken brick or any other similar material, its producing power will be greatly increased; while if it be made loose by an application of cotton seed, coarse stable manure, or even straw, it will be still more improved. On very light and sandy soils however, the seed and coarse manure might be positively injurious by making a too light soil still lighter; and for such lands meal, well rotted manure, or commercial fertilizers will be much more beneficial. The mechanical condition of a soil has fully as much to do with its productiveness as has its chemical qualities, and in fertilizing any land the most important thing to be done is to

first bring it into a good mechanical condition, after which its natural fertility will go far toward supplying the needs of the growing crop.

To be in good mechanical condition the land must be well drained, either naturally or artificially, it must have a subsoil which is sufficiently porous to allow the roots to penetrate deep, and it must be free from hard lumps and clods. Good drainage is, perhaps, the most important, as when that is secured, the other conditions are easily obtained. Land which is rolling, or that which has a moderately sandy subsoil, seldom needs artificial drainage, but on almost every farm there are wet and seepy hillsides or low and wet places along creek bottoms which can be greatly improved by a few open ditches to cut off seepage from above, or can be brought into a still better condition by laying a few lines of tile. Tile is now manufactured at West Point, in this state, and though it is more expensive at first, it gives the best results and leaves the fields free from the open ditches which make cultivation inconvenient and which require constant care.

If the subsoil is too compact, as in a great part of the black prairie region, it can be loosened most easily by the growing of plants having strong tap roots, like those of melilotus, red clover and cow peas.

It is commonly said that a "complete" fertilizer need contain only the three mineral elements which are usually deficient in the soil, viz: potash, phosphoric acid, and nitrogen. Practically however, we find that though a soil may be rich in each of the elements which go to make up the plant, it is impossible to secure good, or even fair crops, unless it contains, in addition to these, a liberal supply of humus, which is formed whenever vegetable matter decays in the soil, and it is in the formation of this material that the practice of plowing under green crops has its greatest value. It is plentiful in all fresh soils, but becomes exhausted by continued cultivation in hoed crops, especially in the hill lands, and the supply must be renewed before chemical fertilizers can be used to advantage. It is the necessary foundation of all fertility, and without it the use of any commercial fertilizer is sure to be disappointing. If the fertilizers used do not contain humus-making material it must, sooner or later, be supplied by the plowing under of green crops, or by turning the land out to rest.

A chemical analysis of almost any soil will reveal the presence of a sufficient amount of potash, nitrogen, and phosphoric acid to produce good crops for many years to come, but unfortunately, such analyses show nothing of their condition or availability for immediate use, and so are of but little value in deter-

mining the amounts or kinds of fertilizers needed for different fields. The ordinary soils of Mississippi contain over 2,000 pounds of phosphoric acid (equal to about 10,000 pounds of acid phosphate) per acre, and if this were all available it would be largely in excess of the needs of any crops. As a matter of practice we find that, on many soils, when we add 250 pounds of acid phosphate, or two and one half per cent of the amount already in the soil, the yield will be nearly or quite doubled.

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 chemical analysis of a soil does not tell us its condition, whether the plant food it contains is in an available form, or anything of its mechanical condition. Plant food in the soil may be available for one kind of plant while it is not so for another, and, for some reason which we are unable to explain, all 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 consumed largely 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 found in the plants themselves.

The whole question of fertilizing thus resolves itself into a consideration of whether we can best modify the soil so as to make the food which is already present available, or whether it will be cheaper to add fresh supplies. In nearly all cases we find a combination of the two methods more economical than is the close following of either. Much of the unavailable food in the soil can be made available by draining and thorough cultivation and pulverization of the soil, the plowing under of an occasional green crop will maintain the supply of humus, and with such treatment the addition of comparatively small amounts of commercial or other fertilizers will be all that is needed. Whether it will be most economical to produce all the fertilizers needed on the farm, or to purchase the more concentrated commercial forms, must depend largely on the circumstances of the farm where they are to be used, and is a matter which will be considered in later pages of this bulletin.

A fertilizer is any substance used for increasing the available plant food in the soil.

Fertilizers may be classed as (1) Natural, and (2) Chemical. Natural fertilizers include stable manure, composts, cotton seed in its various forms, green crops, and marls.

STABLE MANURE.

Stable manure is undoubtedly the best fertilizer we have for general use, as it contains all the elements needed for plant growth in a condition in which they soon become 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 regarded as a "complete" fertilizer, and is a standard with which others are compared, it is of very variable composition, its value 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 the droppings, whether it has been sheltered or exposed to leaching rains, the length of time since it was made, and by many other causes. An increase in the amount of cotton seed meal fed to the animals is very quickly followed by a corresponding increase in the amount of nitrogen in the manure, wheat bran gives a marked increase in the phosphoric acid, while there are few feeds which give a manure richer in potash than does clover hay. In some recent experiments made at the New York (Cornell) Station the value of the manure from cows fed on different rations varied from $1.76 to $2.47 per ton, and from $1.69 with calves to $4.17 with sheep These figures give the results of work done where the ration was rich in grain, and where nearly all the urine was saved by using water-tight floors or a sufficient amount of bedding. Had the urine been allowed to waste the value of the manure would have been much less, as large proportions of both potash and nitrogen are excreted in the urine.

The fertilizing values of some of the more common feeding stuffs, as given in the "Experiment Station Hand-book" per ton are as follows:

	Potash.	Phosphoric Acid.	Nitrogen.	Total.
Mixed Hay,	$1.05	$ .27	$4.23	$5.55
Red Clover,	2.20	.38	6.21	8 79
Alfalfa,	1.68	.51	6.57	8.76
Melilotus,	1.83	.56	5.94	8.33
Cow Pea,	1.47	.52	5.70	7.69
Corn Silage,	.37	.11	.84	1.32
Oat Straw,	1.24	.20	1.86	3.30
Oats,	.62	.82	6.18	7.62
Corn Meal,	.80	.63	4.74	6.17
Corn and Cob Meal,	.47	.57	4.23	5.27
Wheat Bran,	1.61	2 39	8.01	12.01
Rice Bran,	.24	.29	2.13	2.66
Cotton Seed Meal,	1.79	2.68	19.92	24.39

It should be borne in mind that the figures given above represent the nominal fertilizing values of the different feeds, and are far from showing their actual values when used in the field. Under good barn management not more than eighty per cent of the fertilizing value of food given to stock is recovered in the manure, and when the urine is allowed to waste not more than fifty or sixty per cent is recovered. There is a still further loss from the fact that fields seldom need the different fertilizing elements in the exact proportions in which they are found in the manure, and so a portion of such as are in excess of the amounts needed will not be consumed. To balance this loss however, there is a positive gain in the humus-making material which has not been counted in the estimated value, and for clay soils which have been in cultivation for a long time the humus is often of greater value than the combined potash, phosphoric acid, and nitrogen. The actual value of stable manure will vary with every variation of the field to which it is applied.

As the most valuable parts of the manure are the urine and the soluble portions, it is very poor economy to take it out of the stable and expose it to the weather in the yard. In order to retain its original value it must be preserved from both leaching and heating, and 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. This is an excellent plan when sufficient bedding is given to absorb the urine and keep the stalls dry. All the excrement is saved, and when kept tramped 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. A cheap and convenient shelter for manure may be made by digging a pit two feet deep, throwing the dirt to the sides so as to make them higher than the level of the yard, and sloping the ends so that a wagon can be driven through. Make the pit twenty-five feet wide, and long enough to hold the accumulations of six months, covering it with a roof extending two feet beyond the sides, and high enough so that a wagon can be driven 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 most of the urine can be saved, and if the bottom of the pit is of well tramped clay there will be almost no loss from leakage. Should the pit contain a large proportion of horse manure, heating may be prevented by arranging a gutter to carry water from the roof, and give the pile an occasional wetting down. A pit similar to the one described, and twenty five by forty feet, has been in use here for several years, and holds all the accumulations from about eighty cattle and fourteen mules

during four months, and has never given trouble by heating. There will always be more or less manure scattered about the yard and this, together with the refuse feed, mouldy hay or grain, blood and entrails from butchering, and other waste material should always 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 when 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.

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 when 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 when convenient. 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 thoroughly than does sand, so that if the manure is to lie in the field for some time before plowing under, it should be put on those fields having a clayey rather than a sandy soil. Heavy clay soils are greatly improved in their mechanical condition 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 more decayed manures. The custom of hauling manure to the field and piling 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 the second time. The principal cause of loss, both in value and amount, are from the washing and leaching to which manure is exposed in an open yard, and any plan which will prevent these, or which will transfer the leaching process from the stable lot to the field, will save fully one-half the value of the manure from an open lot which is cleaned up but once a year.

COMPOSTS.

In the northern states, where the seasons are short and the period of active plant growth extends over only a few weeks, great stress is laid on the importance of composting manures and having them thoroughly rotted before using. Fresh stable manure contains a very large percentage of water, and a smaller percentage of soluble plant food than it does when composted and thoroughly rotted, but in composting nothing is added to the material already in the manure. By composting, it becomes

more thoroughly mixed, and decay is hastened so that a larger proportion of it can be used at once by the plant, but it is also rendered less lasting in its effects. Here, where the growing season is longer than at the north, 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. When the manure is wanted as a top-dressing and for immediate effect, or where the supply is limited and is to be increased by the use of commercial fertilizers, it will often pay well to compost in order to secure a thorough mixing and more even distribution in the field.

COTTON SEED.

When a sufficient supply of stable manure is not available, cotton seed, in some form, is an excellent substitute, and is probably the best material which can be used on soils which need either nitrogen or vegetable matter. Five years ago, when the seed could be purchased for six dollars per ton they were, in nearly all cases, the most effective fertilizer which could be bought for the money, but with the increased demand for them, and the higher price for which they are now sold, it will often be found cheaper to supply the needed vegetable matter by the plowing under of green crops, and to supplement that by the use of commercial fertilizers. Whether whole seed, meal, or hulls, can be used to best advantage depends on the condition of the soil and crop to which they are applied. On heavy clay soils seed will be much more beneficial than meal, both on account of its greater bulk of humus-making material, and also its greater mechanical effect in making the soil lighter.

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 by the growing crop. If fresh seed is used, this will require some weeks; if the seed is killed by wetting and heating, or by steaming, the processs of decay is hastened; and 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 available in a few days, and will produce its whole effect within a few weeks. On very light and sandy soils which are already loose and friable, and where the soil is underlaid with gravel so as to leach badly, meal is more economical than seed, and when the fertilizer is to be applied to growing crops, meal is always to be preferred. Cotton seed hulls have but little fertilizing value. Where the main object is to loosen a too heavy soil, or a mulch

is wanted to protect tender plants, strawberries, etc., they are useful, but under ordinary circumstances are worth more to use as food for stock than as a fertilizer for field crops.

GREEN MANURING.

Green manuring, or the plowing under of green crops, is the cheapest and most effective method for building up poor soils, and for maintaining the fertility of those already in good condition. It furnishes the necessary humus. it leaves supplies of potash and phosphoric acid in the surface soil where they are immediately available for future crops, and when leguminous crops are used, large amounts of nitrogen are assimilated from the air and made ready for other crops to use. On heavy soils its mechanical effects are very marked, not only in loosening the surface soil which is turned by the plow, but also by loosening the subsoil deeply and so making it permeable to the roots of other crops. Green manuring is to fertilizing what grazing is to raising cattle. Crops can be grown by the use of stable manure, cotton seed, and chemicals, and cattle can be grown on a diet of dry hay and grain, but neither is the most economical plan to be pursued permanently. In Mississippi we are fortunate in having a large number of plants which can be used for this purpose, some of which are perennials like alfalfa and red clover, others like melilotus are biennials and do their work in two seasons, while still others, like lespedeza and cow peas, are annuals. Vetches and rye can be grown during the winter months, and a crop of pea vines can be grown in two months of summer weather. There is no time in the year when it is not possible to have restorative crops growing which will go far toward preparing the ground for succeeding crops. The plants most commonly used for green manuring are the legumes, the best of which are cow peas, melilotus, alfalfa, red clover, and lespedeza; and also the grasses. Of these, the leguminous plants are far more valuable than are grains and grasses, from the fact that they have much larger and stronger root systems, and so are able to gather food which is beyond the reach of the more shallow rooting grasses. They are all plants having strong tap roots which will force their way through the subsoil and so make it loose and porous; they bring up from the subsoil a large amount of potash and phosphoric acid which is left in the surface soil, and as nearly all legumes are rank growers they furnish more humus-making material than do the grasses. The most important reason, however, for using the legumes is the fact that they are able to assimilate nearly or quite all their nitrogen from the atmosphere, while most other plants consume only that which is already in the soil. Ni-

trogen is the most expensive element of plant food, and the one which it is the most difficult to secure. The roots and stems of of grasses contain only about one and one-half per cent of nitrogen, while the amount found in legumes is about two and a half per cent. While the grasses take one and a half pounds of nitrogen from the soil, elaborate it into plant food, and then leave it in an available condition for future crops, the legumes take nearly double the amount from the air where it is unavailable for other plants, and add it to the amount already in the soil. The roots and stems of legumes are also richer in both potash and phosphoric acid than are the grasses, and so, both chemically and mechanically, they are the more valuable plants for use as green manures.

Cow peas are very commonly used for green manures from the fact that they will grow on almost any soil, will make a large bulk of stems and roots, and can be grown in one season. When a restorative crop is wanted to occupy the ground for one summer only this is the best which can be grown, and if planted early, the crop will mature in time for a second crop to be grown on the same land if desired. Whether the vines should be cut for hay and only the roots and stubble used for manure, and whether the vines should be plowed under in the fall or left to protect the surface from washing during the winter, are the questions which bring out long discussions at almost every farmer's institute, and which no single statement will answer. Various plans have been followed at the Station, and we find that in this, as in all other work with fertilizers, we must be governed by the condition of the field in which the crop is grown. On heavy soils we have found it much better to plow under the whole crop, while on lighter and more sandy soils we have found it better economy to graze the crop, as such soil needs compacting rather than loosening, and the droppings from the cattle compensate for a large part of the fertilizing material carried off. If soils are liable to wash, it is desirable to have them covered during the winter, and in such fields it is better to defer plowing until spring than to leave the ground bare three or four months. If the peas are planted so as to mature in August and are then plowed under, the ground will soon be covered with a second growth of vines, wild grasses and weeds, which will give fair winter protection. When pea vines are allowed to remain on the surface of the ground during the winter they lose very largely, both in humus-making matter and in nitrogen, and so are far more effective as a fertilizer when plowed under in the fall. Cow peas respond very quickly to an application of fertilizer, meal, acid phosphate, and land plaster being the best for such use, and in many cases we have found that it paid better to secure a rank growth by using fertilizers on the peas than to have

the smaller crop of vines and to use the fertilizer on the succeeding crop. When grown on very stiff soil where all the vines were to be plowed under for their loosening effect on the land, we have found it an economical plan to plow as soon as the vines were mature, and then to sow rye, oats, or barley for a winter growth. In this way the full effects of the vines are secured to the soil, while the grain crop covers and protects the soil from washing during the winter. Of the three crops named, rye is the most hardy and the one to be preferred. It is only when such a crop is wanted for winter growth that any of the grains or grasses can be recommended for green manuring, as they are all shallow rooting plants which add nothing to the soil except humus-making matter, and their principal value is in their power to grow during the winter, and so hold in the soil the fertility which has been accumulated and made available by the leguminous crops.

For lime soils in which the supply of humus has been exhausted by long cultivation, and which are too poor and hard to produce a good growth of peas, lespedeza is the best crop which can be grown, as it will make a fair growth on the hardest and thinnest of soils, and even there it will send its tap roots a foot or more into the ground and do good work in preparing the land for peas or other more rank growing plants. A top dressing of meal applied in June is a wonderful stimulant to lespedeza, and where the field is to be cultivated the next season, will make a good profit on its use. Lespedeza will make a moderate growth on the poorest clay hills, and will improve with each succeeding crop so that, in time, the most exhausted fields may be made productive by its use, though the work may be greatly hastened by plowing the land after one or two years. As it does not mature until late in the fall it is better not to plow the land until spring, when if plowed early, the lespedeza will again cover it without reseeding, and will make a much better growth than on land which has not been plowed.

Red clover is undoubtedly the best plant which can be grown for green manuring on soils where it will succeed, and when a crop is wanted to occupy the ground for two years or more. It requires a fairly good soil for its growth, and its bulk of root is not equal to that of melilotus, but its hay is of such superior quality that, on the whole, it is the best plant to use for maintaining fertility on soils which are already good. As a green crop to be grown as a part of a rotation it has no equal, but it is not advisable to plant it on very thin soils, or on soils which are poorly drained or very sandy. It is a plant for maintaining fertility rather than for the building up of exhausted soils. It succeeds admirably on the black prairie soils, and its culture can be made very profitable in all that section of the state.

For strong lime lands, even those which have become greatly exhausted and are in bad mechanical condition, melilotus is the best restorative crop which can be grown. It will grow on the white limestone points which will support no other plants, and will make heavy crops on the black prairie lands where the subsoil has become so compact that it cannot be penetrated by the roots of cotton and other plants. Its large roots give it a remarkable power in rendering this subsoil porous, and by their decay at the end of the second season they leave the ground full of small openings which assist greatly in draining and aerating the soil. It requires much less care in planting than does red clover, will grow on a poorer soil, will make a larger bulk of both stems and roots, and if cut when not more than two feet high, will make excellent hay.

Although alfalfa grows well in many parts of the state, and is one of the best hay plants on loose and well drained soil, it is not often grown where green manuring is the main object of the crop. Pound for pound, its roots and stems are worth about the same as those of red clover, but it is more difficult to secure a good stand of the plants, and as when the stand is once secured it will remain good for many years, it is more valuable as a hay-producing plant than as a fertilizer.

To sum up the whole matter: we find lespedeza the best restorative crop for very thin and barren soils. When the soil has been partially restored by the use of lespedeza, improvement can be hastened by using cow peas; and on land which is to be used for a green crop during one season only, peas are best. On all lime soils which are in poor condition, melilotus gives the best results; and for soils which are already fertile and in good condition, needing only to be kept up and gradually improved, red clover is the best green manuring plant we have.

MARLS.

Marls are found quite commonly in the northern part of the state, and occasionally in the central and southwestern sections, but are seldom rich enough to make them of sufficient value to pay for hauling long distances The best specimens we have received have been from Wayne and Newton counties, and which had a nominal value of about two dollars per ton. None of the Mississippi marls, so far as known, contain over 2.06 per cent of phosphoric acid, which was found in a sample from Lowndes county; and a sample from Wayne county contained 2.27 per cent of potash. If the beds are near at hand, it will be profitable to haul such marls for use on creek bottoms and "sour" soils, but there are few cases in which it will pay for hauling more than

two or three miles. From ten to twenty loads per acre should be used, and it will be more effective if applied to the land just before plowing under some green crop. In estimating the values of our marls, no account has been taken of the lime which they contain, as nearly all lands in the immediate vicinity of marl deposits are already well supplied with that material.

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 and best fertilizer which can be obtained, while in other cases the money paid for them might as well be thrown away. The so-called "complete" fertilizers, which are so commonly used, are composed largely of acid phosphate, which supplies the necessary phosphoric acid. The potash is supplied in the form of kainit, muriate of potash, or sometimes hull ashes; and the nitrogen is added in nitrate of soda, sulphate of ammonia, cotton seed meal, castor pomace, dried blood, and other similar materials. The composition and values of the different brands sold in this state are so fully treated in Bulletin No. 2, published by the State Chemist, that the matter need not be repeated here. Copies of this Bulletin may be had by addressing Prof. W. L. Hutchinson, State Chemist, Agricultural College, Miss.

In many cases these "complete" fertilizers are the best and most economical which can be used, but as most soils already contain a sufficient supply of one or two of the fertilizing elements, it is usually better to purchase the raw materials, and mix them in the proportions in which they may be needed. It is needless to apply nitrogen to fields in which pea vines or clover have recently been plowed under, or potash to recently cleared timber lands. Whether it will be best to purchase potash, phosphoric acid, or nitrogen, will depend on the natural character and present condition of the field where it is to be used.

On soils which have been in cultivation some time, potash has always given good results, and the best forms in which it can now be purchased are as kainit, muriate of potash, and hull ashes. The Station has used each of these continuously, and for all ordinary crops there seems to be but little difference in the value of the same amount of potash from either. Kainit usually contains about twelve per cent of potash, muriate about fifty, and hull ashes about twenty With these proportions, four hundred pounds of kainit contains the same amount of potash as is found in ninety-six pounds of muriate, or in two hundred and forty pounds of hull ashes. In other words, if the kainit is worth

fifteen dollars per ton, then the muriate will be worth sixty-two and one-half dollars, and the hull ashes twenty-five dollars. Which should be purchased will depend on the local selling price of each. It should be noted, however, that hull ashes, in addition to the twenty per cent of potash, contain about nine per cent of phosphoric acid, which gives them an additional value of about five dollars per ton for use where phosphoric acid is needed. At the prices for which these materials have been sold for the last three years, hull ashes has been the cheapest form in which potash could be purchased, but at present the prices of both hull ashes and kainit are increasing, while muriate of potash is sold for much less than was its price a few years ago.

Where phosphoric acid is needed, as it is in considerable quantities on all soils not rich in lime, and to a less degree on lime soils, acid phosphate is undoubtedly the cheapest and best form in which it can be obtained. The fertilizer values of the different brands of acid phosphate vary with the amount of water and citrate soluble phosphoric acid which they contain, those having the larger proportions of these being the more prompt in their action, and more expensive to purchase. We have found it more profitable to use the more soluble forms on early maturing crops like grain and corn, while for cotton, which continues to grow until killed by frost, the less soluble and less expensive grades have given good results.

When both hull ashes and phosphoric acid are to be used on the same field, they should never be applied at the same time as, if mixed while fresh, the ashes render the phosphoric acid insoluble and unavailable for immediate use by the plant, though kainit and acid phosphate may be mixed without injury to the latter. Potash fertilizers being more easily soluble than the phosphates, we have found it better to apply the phosphates from one to two weeks before using the potash. When large amounts of fertilizers have been used we have found it more profitable to apply them broadcast before planting, but where the application is small, three hundred pounds or less per acre, we have found it better to put it in the drill and mix thoroughly with the soil by running a "bull tongue" plow along the rows before planting. When using both phosphate and potash fertilizers we have found it better to apply the phosphate before planting and the potash at the first cultivation.

When a soil is rich in humus it is seldom necessary to make any further application of nitrogenous fertilizers, and as they are very quickly soluble, and are soon lost to the soil by both leaching and volatilizing, they should never be used until the crop has made a considerable growth. Cotton seed

meal and nitrate of soda are the best forms in which nitrogen can be purchased, and for general use the meal is preferable. As nitrogenous fertilizers have a much greater effect upon the growth of the plant than upon the production of fruit, they are not needed on soils which will produce a satisfactory growth of stalk, but may be used to great advantage where the plant growth is weak and small.

Very few commercial fertilizers contain any appreciable amount of humus-making material which is so essential to a vigorous plant growth, and so are, to that extent, deficient as a perfect fertilizer, and will usually be more effective when composted with stable manure, cotton seed, or some other vegetable matter. The well known "Furman's Formula" is one of the best forms of compost, and is made by using 750 pounds each of stable manure and cotton seed with 367 pounds of acid phosphate and 133 of kainit. For use on soils which are deficient in lime, as in the extreme northeastern corner of the state, and in nearly all of the state lying south of the Vicksburg and Meridian Rail Road, these seem to be the best proportions which can be used. In the region where the soil is already rich in lime, as in nearly all of the northern part of the state, we have found it better to reverse the proportions of acid phosphate and kainit, or even to omit the phosphate altogether and replace it with an equal weight of kainit, or half the amount of hull ashes. The cost of either of these composts will be about five dollars per ton, and for the first year not more than five hundred pounds per acre need be used. As the land improves in condition larger amounts can be assimilated, and the application should be increased five hundred pounds yearly so long as it produces a corresponding increase in the crop. Furman claimed to have found it profitable to use at least four tons per acre, and that by its use he increased the yield of cotton from less than one-fourth of a bale to more than three bales.

Both the regular Furman mixture, and the mixture in which the acid phosphate was replaced with kainit, have been used on the yellow clay loam of the Station farm, for four years, and in every case the results have been in favor of the mixture containtaining the larger amount of kainit. The soil here is rich in lime, and the average yields during the four seasons have been:

Unfertilized Plots	435	lbs. per	Acre.
250 pounds Acid Phosphate	423	" "	"
250 " " Kainit	721	" "	"
Furman's Formula, Regular	810	" "	"
" " Acid Phosphate replaced by Kainit	1174	" "	"

Results almost the reverse of these have been secured during the three years of work at the branch station at Lake, which is in

the pine woods region on a soil poor in lime. There the fertilizers used and yields secured have been:

Unfertilized Check Plots	Yield 614 lbs.
35 bushels Cotton Seed, or 200 pounds Meal 200 pounds Kainit	" 846 "
35 bushels Cotton Seed, or 200 pounds Meal 200 pounds Acid Phosphate	" 1253 "
35 bushels Cotton Seed, or 200 pounds Meal 200 pounds Acid Phosphate 200 " Kainit	" 1105 "
50 bushels Cotton Seed 400 pounds Acid Phosphate 200 " Hull Ashes	" 1169 "
100 bushels Cotton Seed 200 pounds Acid Phosphate (Two years) 200 " Hull Ashes	" 1249 "

The results of the work at Lake have been more uniform and constant than at either of the other stations where similar work has been done, and indicate very plainly that, for such soil, no potash is needed in addition to that supplied in the cotton seed; that 200 pounds of acid phosphate will produce a large increase in the yield, and apparently as great an increase as will be secured by double the amount. The plots receiving potash and cotton seed showed an increase of 232 pounds over the yields of the unfertilized check plots, but this increase may reasonabiy be credited to the application of the 35 bushels of cotton seed, while the average yield of all the plots which received acid phosphate was 1194 pounds.

At the Holly Springs branch station, though similar work has been continued through four seasons, the results are far from being decisive, and show very plainly the necessity for continued repetitions and duplication before any final conclusions can be drawn. In some of the series acid phosphate has appeared decidedly superior to kainit, while in other series, on what appeared to be similar soils, kainit has given much the better results. In nearly every case, however, a mixture of cotton seed meal with the chemical fertilizer used has been highly advantageous, while meal alone has seldom been as profitable as have been some of the mixtures and composts.

So far as can be seen from the work done, the upland clay soils of that region will be fertilized most economically by the use of either meal or compost to furnish vegetable matter and nitrogen, and to these should be added both phosphoric acid and potash, more of the latter than the former being needed. For the sandy valley lands cotton seed meal seems the best foundation for the fertilizer, and to that should be added more phosphoric acid than potash, though both are needed.

Whether commercial fertilizers and composts should be applied broadcast or in drill depends principally on the amounts

used. When the amount is small, we have secured the best results by placing it in the drill; and when a second application is to be made during the growing season the first should always be in the drill. When the application is large, and is of such materials as acid phosphate, ground bone, or hull ashes, all of which act more slowly than do meal and the ordinary commercial brands, we have found it to be fully as well to make the application broadcast. When fertilizers are put in the drill before planting, care must be taken to have them thoroughly mixed with the soil as, if left in bulk, the young roots are sure to be burned and withered as soon as they reach it. Any ordinary amount can be mixed with the soil by running a bull-tongue along the rows after the fertilizer is applied. When a second application is made it should be followed at once by a cultivator to mix it with the soil.

At neither the home station, nor at either of the branch stations have as good results been secured by the use of commercial fertilizers alone, as when they have been used in connection with a liberal amount of vegetable matter. Humus is just as necessary to a fertile field as is potash or phosphoric acid, but a soil which is rich in humus will often give a much larger yield if stimulated and assisted by the addition of other materials. Lands may be built up and kept in good condition by the use of stable manure, cotton seed, and green manuring, but the same results may be secured at less expense if these are supplemented by a judicious use of chemicals.