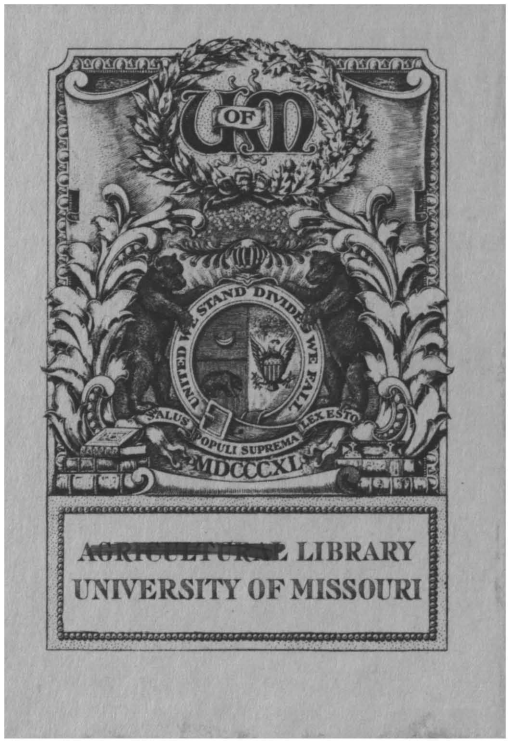

THE USE OF GREEN MANURES AND COVER CROPS FOR THE SOUTH.

By

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A THESIS PRESENTED FOR THE DEGREE OF MASTER OF SCIENCE IN AGRICULTURE.

UNIVERSITY OF MISSOURI

1907.

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THE USE OF GREEN MANURES AND COVER CROPS FOR THE SOUTH.

CHAPTER 1

HISTORICAL

INTRODUCTION

The problem of restoring the fertility to the worn soils and of maintaining that of the new or fresh soils is perhaps the most serious one with which the farmers of the cotton states are confronted. It is indeed unfortunate that the usual methods and practices of cotton farming tend to rapidly wear out and destroy the fertility of the soil, and before we can be safe and permanently prosperous in farming, our methods and practices must be such as to result in increasing the productiveness of our soils. The original fertility of a soil is dependent upon two things, viz: its natural strength and its physical condition. The first of these - the natural strength, is determined by the readiness with which the insoluable plant food in a soil becomes available by natural agencies, and the length of time this availability will continue. While the physical condition is dependent upon such properties as favor the growth and development of plant roots and the acquisition by these of the available plant food in the soil. The natural strength of a soil may be practically exhaustible and at the same time the fertility of the soil very low, on account of its poor physical condition. And a good soil in a good physical condition easily reduced to one of poor condition by improper handling. This last is true of almost all of the soils of the South. There are few cultivated soils of this section that have not suffered a material loss of plant food, while their once

favorable physical condition is changed to such an extent as to reduce their productiveness. It remains for succeeding farmers to restore the once favorable conditions of our soils, and gain for the South its deserved recognition as a fertile and productive region, or to continue the wasteful and exhaustive methods of the past and produce a section whose chief glory will rest in the legends of a once fertile soil. Nature, it would seem on the one hand with its warm climate, its abundant rainfall, its loose and broken soils, and its seemingly careless farmers, caters to the exhaustive processes. But, if we pause to consider on the other hand the almost numberless varieties of soil restoring plants, the mild climate that makes it possible for some of these plants to be grown on the soil throughout the entire year, and the rapidity with which a part of the farmers are grasping the advanced methods of farming, we see how just is nature, and how diligently she strives to balance her forces.

The Experiment Stations and most successful farmers have put forward a number of methods by which the fertility of the worn soils may be restored, and that of the fresh soils maintained, or even increased. Some advocate deep plowing, and terracing or hillside ditching to prevent washing and the use of commercial fertilizers to make up for any deficiency of plant food that may exist. Or, in other words, they advocate the spending of a portion of one year's proceeds to maintain the yield for the succeeding year. Others advocate a method which combines stock raising with cotton and corn farming. This method has many advantages, and its only serious drawback is the tick fever quarantine, which prevents the animals from going on the

northern markets, except for immediate slaughter. Others advocate crop rotations. A method that has many advantages, the main object of which is to maintain the fertility with the continued production of crops and the increase in productiveness of naturally poor or worn out soils. Still others advocate the turning under of green crops for manure, and the growing of cover crops to catch what plant food becomes available and thus to prevent washing and leaching of the soils.

It is the aim of this paper to support the latter method and put forward the points in favor that have been discovered by the Station workers and practical farmers. To do this I shall be compelled to draw heavily from the Department and Station publications, and will include the results obtained by a number of prominent farmers of Mississippi to whom I have applied for information. A discussion will also be given of results determined from experiments conducted by the writer on the soils of the Missouri State Farm. These experiments will show the effect of a number of crops - wheat, oats, alfalfa and sod as compared with bare or fallow soil through the fall and winter months. Only the nitrates are determined in the analysis. The determinations are madd monthly.

LOSS OF NITRATES.

The leaching out and washing away of the nitrates as they are formed in the soil unless there is a crop growing on the land to take them up, is perhaps the most destructive agent of soil fertility. It has been determined that nitrification goes on very rapidly at 54 F. reaching its maximum at 99 F. We see then that our soils in the South are almost continuously in a state in which nitrification can take place,

and therefore that the loss from leaching must be very great.

The most extensive work on the loss of nitrates has been conducted by Lawes and Gilbert at the Rothamstead Experiment Station, in England.

Lawes found by placing three gauges covering $\frac{1}{1000}$ acre each at depths of 20, 40, and 60 inches respectively, and allowing no vegitation to grow thereon, and by making analyses from time to time that the loss of nitrogen through the drainage gauges exceeded 40 pounds per year. In addition to this he brings out three other points, viz: (1) That water passing these gauges is much richer in nitrogen than the rain which falls upon them. (2) That it is richer in nitrogen during the autumn than at any other season of the year. (3) That the drainage in another field where a crop of wheat was in luxuriant growth contained no nitrogen at all.(1)

Deherian(2) compares the results of 1893, which was a poor crop year, with those of 1894, a good crop year, as follows:

During the year of poor crops the percent of nitrogen was much higher than during the year of good crops. The poverty of the water of '94 is attributed to the vigor of the plants grown, which by means of their numerous roots completely assimilated the nitrates. The diminished amount of drainage water was attributed to the vigorous leaf growth, which returned to the atmosphere all of the water supplied by precipitation, except during wet seasons. Abundant drainage was secured only during the winter, while during the summer no water passed off in the drains.

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(1) J. B. Lawe's Essay on Loss of Nitrates.

(2) Exp. Sta. R., Vol.6 (Deherian Compt. Rend. 120. (1895) No. 10)

He calculated that the wheat crop of '94 per hectare (2.471 acres) contained 91 kilograms (200.2 pounds) of nitrogen, and in '93 only 44.2 kilograms (97.24 pounds), but in '93 the soil lost 49.7 kilograms (190.14 pounds) of nitric nitrogen in the drainage water, while in '94 the loss from this source was insignificant. The total amount of nitrogen removed from the soil in the good season of '94 was therefore 91 kilograms (200.2 pounds), as against 93.9 kilograms (206.5pounds) in the poor season of '93.

Further experiments by Deherian confirm previous conclusions that fallow soils loose much more nitrogen in drainage than those covered with crops, and emphasize the importance of fall catch crops.

The following table gives the more important results obtained by him with 20 vegetation boxes bearing various crops. (grapes, sugar beets, wheat and oats)

Bare soil	Loss per hectare	Ratio of drainage to rainfall.
'93 - '94	101.60 Kg.	4.5
'94 - '95	79.80 Kg.	5.5
Soil bearing crops		
'93	33.25	7.6
'94	.20	135.0

Schlösong maintained that the results secured in these experiments were for the most part, for obvious reasons, much in excess of the truth and that examinations of water from streams draining a given area would furnish a much more accurate measure of the loss of nitrogen by drainage. He gives determinations of nitrogen in water from Siene, Morne, Yonne and Oise, and estimates based on the results are given which indicate that each hectare (2.4 acres) of soil in the Seine basin

loses 4.2 Kilograms (9.24 pounds) of nitric nitrogen if 1/6 of the rainfall escapes in the drainage, 6.44 Kilograms (14.16 pounds) if 1/4 escapes, and 8.48 Kilograms (18.65 pounds) if 1/3 escapes. He concludes that these results do not warrant definite cunclusions, but they nevertheless indicate that the loss from drainage water is not so important as has been supposed.

Deherian's[1] work for five years with vegitation boxes at Grignon demonstrates that the loss of nitrates from a bare soil is much greater than from one covered with a crop, and that this discrepancy in not in every case accounted for by the amounts of nitrogen used by the plants. From data obtained by experiments with wheat, it is estimated that the amount of nitric nitrogen utilized by the crop and removed in the drainage water was only 94 Kilograms (206.8 pounds), while the amount of nitric nitrogen removed by the drainage water from a check plot of bare soil was 200 Kilograms (440 pounds). This wide discrepacy is partially explained by the fact that during a portion of the growing season the moisture was insufficient for the needs of the growing crop and active nitrification in the soil. In experiments with corn during the growing season, in which the rainfall was abundant, the amount of nitric nitrogen utilized by the crop and found in the drainage water was 197 Kilograms (431.4 pounds), as compared with 200 Kilograms (440 pounds), found in the drainage water of bare soil. With vetch as the cover crop the loss was 7 Kilograms (15.4 pounds) on covered soil against 28 Kilograms (61.6) on bare soil. The difference (21 Kilograms) added to the amount of nitrogen added to the

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(1) Exp. Sta. Rec. Vol. 9. (Deherian, Ann. of Agronomy (1877) No.6)

soil by the vetches (82 Kilograms) supplied the covered soil with an excess of nitrogen over the bare soil of 103 Kilograms, or an amount equal to that furnished by 40 tons of barnyard manure or 730 Kilograms of nitrate of soda.

DEPTHS AT WHICH NITRIFICATION TAKES PLACE.

Hall[1] of the Rothamstead Station reports that practically all of the nitrification going on in a comparatively close soil takes place in the first nine inches, which gets stirred and aerated by the action of the plow. In the Rothamstead soils all samples to a depth of 3 feet contained the nitrifying bacteria, however. It will therefore be realized that the most favorable conditions for nitrification are when the soil is subjected to a bare summer fallow and is thoroughly worked.

But if a wet autumn and an early winter succeeds, the nitrates are washed down into the subsoil out of reach of the crop, which then shows a very low return for the previous summer fallow.

A table shows the rapidity with which nitrification may take place after harvest. The evidence goes to show that for three months before the harvest of the wheat crop the soil in which it is growing is practically free from nitrates; but if heavy rains occur after the ground has been plowed up after harvest, the condition becomes very favorable to nitrification, because the soil is warm, well aerated, etc. Therefore heavy autumn rains before the land is again occupied by a crop to take up the available nitrates, may easily cause serious loss to the land, and some quick growing cover crop to take up the nitrates as they become available should be grown. These crops may be plowed under and the loss that would have occurred avoided.

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(1) Hall on the Rothamstead work.

There was little difference in the percolation and quantity of nitrogen removed in the 40 and 60 inch gauges. The drainage from the 60 inch gauge was more uniform in concentration throughout the year owing to the amount of water retained by the deeper soil. The main discharge also came a little later in the year in the 60 inch gauge. The concentration varied greatly for different months, however, being lowest in February when the temperature was still very low and the soil had been thoroughly leached by the winter rains. The concentration and loss of nitrates remained low until July when the temperature was higher and the rainfall had been sufficient to wash through the soil. The concentration then made a considerable jump and continued to rise until in September when it reached its maximum. The maximum loss of nitrates occurred as soon after this as the rainfall had become sufficient to wash through the soils, which was in November. After this the concentration and loss of nitrogen gradually diminished. These results were secured on a soil that had been kept fallow and bare where the maximum loss occurs. In experiments on plots growing wheat, the drainage through the summer was very light owing to large quantities of water being taken up by the growing plants. The loss of nitrates was correspondingly lower for the reson that they were consumed by the plants. But as soon as the wheat crop was removed and the rainfall became heavier, the analyses showed a much higher percent of loss on these plots.

EFFECT OF MANURES ON THE LOSS OF NITRATES.

Hall found that the nitrification took place much sooner after an application of manure especially those containing ammonium salts. When there was percolation the increase in nitrates began to show immediately after the application of manure. Even in the autumn ammonium

salts were converted into nitrates in a very short time. He gives an example and a table which shows that nitrification increased rapidly for three weeks when the maximum was reached showing that most of the nitrifying process was finished in that time after the manure had been applied. Another table is given showing the results for barren land and for cropped land, and also of different systems of manuring demonstrating that the loss in drainage was greater during the periods after harvest than during the period of crop growth, and on the barren soil the loss was greatest when the temperature was highest and the rainfall heaviest.

EFFECT OF THE SEASON OF THE YEAR ON NITRATE CONTENT.

Professor King, of the Wisconsin (1) Station reports the results of experiments to determine the amount of nitrates in the soil at the beginning of and the end of winter. Samples of soil taken April 9th just when the frost had thawed out of the soil were compared with those taken November 29th of the previous fall when frosting began. There were only four cases out of 36 determinations where there was a loss of nitrates during the winter months when the soil was frozen leaving 32 in which there was an actual gain. There was a notable gain of nitrates, even in the fourth foot of soil. The mean value is shown in the following table:

Mean gain of nitrates in parts per million	1st foot	2nd foot	3rd ft	4th ft
	8.724	7.028	5.13	.7885
" " " " " pounds " acre	23.9	38.35	23.28	3.64

The observations thus indicate a total in the surface four feet of 79.27 pounds. It is the opinion of Professor King "that there are but two sources of nitrates which can have contributed to this

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(1) Annual Report Wisconsin Station 1901.

observed increase in the soil. These are: 1st, nitrification in the soil, and 2nd, capillary movement of water upward sweeping forward and bringing nitrates from below the the four feet with it".

It was shown that nitrification takes place at a few degrees above freezing, which proves that it was possible for the gain to have been caused by the nitrification. The author states, however, that the probability is that the major part of the gain is due to the capillary movement of the water. During the winter months when the ground is grozen there is considerable enternal evaporation of soil moisture just below the frost zone, the water condensing and freezing in the soil above or escaping into the atmosphere. This loss of moisture by internal evaporation would tend to maintain a capillary movement upward to make good this loss, and with it would come whatever salts the water might carry in solution. It appears that both sources of nitrate referred to above were responsible for the gain.

The same author reports his experience with variations in the nitrification in soils, and (1) their subsoils. A number of cylinders were filled with soil from the surface six inches, from 6 - 12 inches, and from 12 - 18 inches deep. The soil was cultivated to certain depths, in some and mulched, in some left firm in some of the cylinders. The cylinders were placed in ventilated cases where the air current was kept constant. The avaporation was maintained by the additions of water at the bottom of the cylinders. The author gives this summary of the results:

"1st, The largest development of nitrates occurred in the surface 6 inches, and the least in the soil of the 3rd 6 inches.

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(1) Wisconsin Bulletin No. 92.

This was to be expected because of the larger amount of total nitrogen present but the amounts of are not proportional to the total amount of nitrogen in the three soils.

"2nd, there was less nitrates in the lowest zone of 16 to 20 inches of soil at the close of the experiment than at the start. This may be due to the denitrification in very wet soil or to the salts having been swept upward by the capillary movement of water.

"3rd, The larger amount of nitrate in the zone of soil 16 to 20 inches below the surface than was present at the beginning of the experiment may be regarded as establishing the fact that the process of nitrification can go on at this depth, and as the nitrates formed were swept upwards by capilarity thus continually tending to reduce the amount present, it appears that the process must have been vigorous at this level.

"4th, The increasing amounts of nitrates shown in the soil as the surface is approached must be due in part at least to capillary concentration but also quite likely to more rapid nitrification."

INFLUDENCE OF DIFFERENT CROPS ON THE NITROGEN CONTENT.

King found that the nitrates start in the spring and increase rapidly until June 1st on clover and oat ground, and until July 1st on corn and potato ground; from these dates they fall more or less rapidly until August 1st, when crops are growing most vigorously. After this date they remain nearly constant with a tendency to rise slightly until September. The amount of nitrates in the soil under the clover and oat crop was much smaller than in the soil under corn and potato crops. But there was 22 percent more nitric nitrogen developed in the soil upon which clover had grown than corn, and 13 percent more than after

oats during the same time but under like conditions. The virgin soils which had grown corn continuously the same number of years that a similar soil had grown clover contained at the beginning of the experiment nearly three times as much nitrogen and ended with 17 percent more. Soil growing oats begun the experiment with 2.6 times as much nitrogen and closed it with 13.8 percent more. Clover and alfalfa seem to hold the nitric nitrogen in the soil down to a lower limit than corn, oats and potatoes did, but when the crop was removed from the ground nitrification went on faster in the clover and alfalfa soil.

It would seem from Professor King's results that a little fertility is lost from the soil by leaching during the months of an ordinary Wisconsin winter. The conditions with which he was dealing, however, are quite different from those of the workers mentioned above, and also from those with which we are forced to contend in the South, where the soil seldom remains frozen more than a week at a time, and where the rainfall is very abundant.

GREEN MANURING.

Green manuring dates back more than 2000 years. It was practiced by the Romans and from that time until now has formed an important resource of the farmer. If we consult nature, we find that the practice dates back even to the time when vegetation first began to grow. The plants are soil builders. They are the agents employed by nature to cover bare spots, to protect lands from the washing of torrential rains, from the burning, baking, and sterilizing action of the sun, and finally, to make the soil fertile. When the natiral conditons become sufficiently favorable to admit of the growth of any green vegetation, the surface soil is first covered and protected by grasses.

They are the agents that serve to build up fertile beds of soil. They gradually form turf and the rotting turf makes humus, which is, from an agricultural standpoint, the most valuable constituent of the soil. The soil that can stand continued cropping longest are those richest in humus. Green manuring then, as is practiced by the farmer is a well founded practice. It has many advantages.

Humus, or organic matter, is undoubtedly the most important factor in the fertility of the soil. It acts as an absorbant of moisture. Soils rich in humus soak up more water and hold it longer than those poor in organic matter. It changes the physical condition and gives that firmness and tilth so characteristic of a rich soil. It makes the soil less susceptible to abrupt changes of temperature by absorbing and slowly radiating heat. It takes up nitrogen, phosphoric acid, potash, lime, magnesia, sulphur, and other inorganic plant foods, and thus retards the loss by leaching. Through the action of minute forms of plant life which live in the soil the humus is finally attacked and broken down, and the plant foods are gradually released in a form in which they can be utilized by the growing plants. The maintenance of the humus supply is therefore the most important factor in the restoration of worn out soils.

SOME CROPS FOR GREEN MANURING.

Among the crops most extensively used for green manuring in the Cotton States are cowpeas, clovers, melilotus, vetch, velvet beans, beggar weeds, alfalfa, and rye. A discussion of these is given below.

In the south where they grow in such profusion the leguminous plants take first rank as soil restorers. In selecting a crop for turning under, however, attention must be given as to its suitability to the soil, climate, and any peculiar local condition that may exist.

for instance, we would not sow the warmth and light loving cowpea in a thickly shaded orchard, but would use for this purpose the velvet bean or some one of the clovers. On soil containing excessive amount of lime we would use the mellilotus, while on one wanting in lime we would use the cowpea rather than alfalfa or clover. I n heavy clay soils holding large quantities of water we would plant alsike clover, and the vetches would do well for the sandy soil.

COWPEA (Vigna Senesis)

Origin.

Owing to its ability to adapt itself to all kinds of soils, and being an annual the cowpea takes by far the most important place as a green manuring plant in the South. Its exact origin is unknown, but is supposed to have come from India or China where it is said to be indigenous. It has been grown in the southern States for at least one hundred and fity years. It was probably first introduced on plantations in South Carolina. From this original introduction and from subsequent importations its cultivation has spread to almost every farm and plantation in the southern states.(1)

VARIETIES.

The socalled varieties of cowpeas are very numerous. Nearly every community has a pea with special characterics, bearing the name of its originator. The varieties are originated by selection and propagation from sports. The soil, climate, time of planting, and method of cultivation are also factors that work in the change of form and

(1) Farmers Bulletin 102, U. S. Department of Agriculture.

modification of the plant. Experiments have shown that the clay pea, usually a heavy runner, may by continued cultivation on sandy soils in the more northern latitude, become a bunch pea.

Dr. Stubbs (1) reports his experience with two varieties of Clay peas whose seed were in every respect identiaal in appearance, side by side on the same ground and under the same mode of treatment, and yet one would prove to be a prolific bunch and the other an immense runner. One would early ripen its fruit, while the other hardly produced late in the season enough seed to replace those sown. Seed grown continuously in the warm moist climate of the South tend to produce large quantities of vine. While if the same seed are cultivated continuously in the more northern latitude they tend to produce a heavy fruiting variety. So, for our purpose in this work, we may confine ourselves to the heavy vining varieties of the South which are the Clay, Unknown, Black, Red, Red Ripper, and so on.

ADVANTAGES.

The chief factor that gives the cowpea its superior value as a green manure is, of course, its power to assimilate large quantities of nitrogen from the air and convert it into a form in which it can be used by the succeeding crops. But there are other factors of almost equal importance. We may summarize them as follows:

The cowpea shades the soil in summer and keeps it in a condition most favorable for nitrification and leaves it in a loose condition of good tilth for the following season; It has a heavy root development and therefore pumps up large quantities of water from large areas and great depths and with this water the mineral constituents that are dissolved in it, storing them in the surface soil where the succeeding crops can use them; it has the peculiar ability of being

(1) La. Bull. No. 40.

ble to adapt itself to all kinds of soils and to a large extent to the different climates. The hot southern sun seems to agree with it while the other crops fail; its rapid growth enables the farmer to produce two crops in a single season; it serves as a cleaning crop by shading out the noxius weeds and grasses; every crop grows well after it; proving its value as a preparatory crop; it pumps off the excess of water during the wet season of the year.

With all of these advantages, it is no wonder that the cowpea has earned for itself the title "the poor man's bank".

An idea of its real vale as a green manure and soil restorative crop can perhaps be best shown by the results obtained from actual field experiments as conducted by the various experiments stations of the Cotton States. These experiments show its adaptability to the various soils, as well as the gain in crops due to its use.

The Arkansas Station (1) found in a three years rotation with Pea vines, cotton being the staple crop, the following results:

The plot which was planted in cotton each year decreased in yield during the three years from 830 pounds of seed cotton the first year to 431 pounds the third year. While the plot that had the Pea vines increased in yield to 1557 pounds the third year, showing a difference of 1126 pounds of seed cotton in favor of the pea vines at the end of the trial. In a one year's trial at the Newport Sub-Station the yield from the plot upon which the vines where turned under after the Peas were picked off was 1409 pounds; that from ~~which~~ the plot upon which the pea stubbles only were turned under was 1291 pounds; and that from the Plot which received no treatment was 1008 pounds. This experiment shows a gain of 401 pounds in favor of the vines and 283 pounds in favor

(1) Arkansas Bulletin No. 23. Experiment Station.

of the stubbles alone. With wheat as the staple crop they secured the following results from the cowpea as compared with various kinds of mineral manure.(1)

Plot No.	Fertilizer used	Yield of wheat
1	No fertilizer	5 bu. 46 lbs.
2	No Fertilizer	5 bu.
3	10 loads horse manure	15 bu. 16 lbs.
4	150 pounds acid phosphate	6 bu. 28 lbs.
5	150 pounds Kanit	6 bu. 91 lbs.
6	200 pounds Gypsum	7 bu. 53 lbs.
7	Peas turned under green October 10th	16 bu. 53 lbs.
8	Pea stubbles	10 bu.
9	Mature vines with pods on	18 bu.
10	Mature vines without pods	15 bu.
11	Green vines with pods on turned under July 31st	14 bu.

(1) Arkansas Experiment Station Bulletin 29.

This experiment teaches us that the plots treated with mineral fertilizer yields much less than those treated with cowpeas. Stable manure and cowpea vines are about equal in value. The best results are obtained from cowpeas when the vines are allowed to mature and turned under with the pods on.

The North Carolina Station (1) found that cowpea vines increased the yield of wheat on an average of 13.78 bushels per acre in 1891 and 15.6 per acre in 1892. The use of the cowpea also nearly doubled the number of stalks per stool, increased the height of the plants nearly nine inches and the length of the heads five-eights inches.

The Georgia Station (2) secured a yield of 1893 pounds of seed cotton when the peas were picked and the vines turned under; a yield 1849 pounds when the vines were mowed, left on the ground to dry and turned under later; and a yield of 1700 pounds when the vines were turned under green. These results are further substantiated by later experiments which are reported in Bulletin No. 23.

The following table shows the gain due to the use of cowpea vines and cowpea stubbles on cotton, corn, oats, wheat and sorghum as determined by the Alabama Experiment Station. (3)

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(1) North Carolina Station Bulletin No. 91.
(2) Georgia Station Bulletin No. 24.
(3) Alabama Station Bulletin 120.

Test crop	Amt. per acre	increase	Percent per acre	increase
	vines	stubbles	vines	stubble
Cotton	696 lbs.		83%	
Corn	3.6 bu.	1.6bu.	15	6
Oats	10.4 bu.	2.6 bu.	84	309
Wheat	5.9 bu.	8.7 bu.	190	280
Sorghum	2.1 tons	2. tons	57	55

This bulletin reports very interesting results. We see from the table that the stubbles alone seem to furnish sufficient humus and plant food for the needs of most crops. The use of vines failed in most cases to increase the yield to any appreciable extent over that of the stubbles alone. The same bulletin further gives results of experiments to show what crops are most favorably affected by the vines or stubbles of cowpeas and velvet beans. The data in the following table will answer this question.

Test crop	After legume vines			After legume stubbles.		
	No. of test	% increase	value of increase	No. of test	% increase	value of increase.
Cotton	4	63	$14.17	1	49	$11.30
Corn	1	81	6.15	1	32	2.14
Oats	3	189	6.80	2	334	11.24
Wheat	2	182	4.53	2	215	5.36
Sorghum	4	78	14.02	2	57	13.87

The percent in increase atrributable to either the stubbles or vines was greater with fall oats and wheat than with the cotton, corn, or sorghum, showing that the crop planted soonest after the legumes had matured, that is, the crops that can be planted soonest after the legume is turned under or is ready to be turned under is able to use more of the nitrogen made available by the plantsthan are those planted the following spring. This is what we would expect, however, as the stubbles or vines that have to remain in the ground over winter and be subjected to the leaching and washing process would be compelled to loose at least a part of their nitrogen, whereas those immediately follwed by a crop of growing plants would yield up their nitrogen and other valuable elements to the plants as fast as they become available. It would not be understood from the above statement, however, as advocating planting a crop on the land as soon as the vines were turned under. Experiments at a number of the stations have proven that it is best to let the vines decay to some extent before planting the succeeding crop. The gases and acids generated by the fermenting green vegetable matter is injurous to the seeds and young plants, and the loose condition of the soil may effect the yield While the increase in growth was markedly greater with the oats and wheat planted in the fall, the increse in money value was very much higher in favor of cotton and sorghum. The money value is determined by the supply and demand, however, and does not enter into the discussion of fertility. The results obtained at the other station where the cowpea has been tried agree with the above and it is needless to go into further detail concerning their effect on the yield of crops. We may now consier the question of how or why it produces these results. The answer may be looked for in a consideration of its chemical

composition and in its physical effect on the soil.

The following comparison will give the composition of the cowpea in the various states. The table is given for average yield of peas per acre.

State	Vines			Roots		
	Pounds of nitrogen	Pounds of phos acid	Pounds of potash	Pounds of nitrogen	Pounds phos acid	Pounds of potash
Alabama	115.5#	39#	89#	7.75#	7#	39#
Arkansas	68	14	50			
Connecticut roots and vines	98	23	75			
Rhode Island	157	23	75			
South Carolina	205	33	155			
Mississippi (a)	76.8	18.1	24.7	15.9	4.4	10.1
Louisana	56	16.	92	8.5	4.5	110.0

(a) Note: The amount reported for the Mississippi stations are calculated on the basis of 3000 pounds of vines per acre from the percentages given in bulletin No. 40.

We see from the table that the cowpea analyses a very high percent of nitrogen and potash, and also a large amount of phosphoric acid. The greater part of this nitrogen is assimilated from the air by means of the tubercle bacteria found in the nodules on the roots on soillow in nitrogen or humus. The average amount of nitrogen for the above semen states is about 110 pounds per acre. This at 15 cents per pound, which is the market value of nitrogen, would amount to $20.50 per acre for the nitrogen alone, the potash and phosphoric acid cannot be figured in this way as they are constituents of the soiland were accumulated directly therefrom. The only credit that we can assign the peas in regard to potash and phosphoric acid is that they are brought to the surface and converted into a soluble form, and can therefore be appropriated by the succeeding crop; whereas they would otherwise have remained deep in the subsoil out of reach of the ordinary farm crops. We must not overlook the very great influence that the cowpea exerts upon the soil in a physical way, The large roots go deep down into the subsoil and thus open up passages through which the water and air can pass giving better drainage. The humus that is incorporated in the surface soil serves the same purpose in addition to furnishing the humic forms of plant food. It also loosens the soil and makes it fine and friable; thus improving the tilth.

INJURIOUS EFFECTS OF TURNING UNDER GREEN COWPEAS. (1)

Some of the Stations, notable the Arkansas Station, have found that when large quantities of green vines are turned under and, the crop planted thereon before the vines have time to decay, injury to the plants are liable to occur. Seeds and young and newly

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(1) 14th Annual Report Arkansas Experiment Station.

germinated plants are the ones injured most in this way. The injury is evidently due to the early products of fermentation, such as the acids and gases eliminated by the green vegetable matter in close proximity to the seed and young plantlets. These injuries may be easily eliminated by allowing the plowed under green material to reach an advanced stage of decomposition before planting the succeeding crops.

TIME OF PLANTING AND TURNING UNDER COWPEAS FOR GREEN MANURE.

The time and manner of sowing cowpeas for green manure is largely determined by the exegencies of the farmer and the price of seed. As a general rule, however, the longer the growing season the larger is the yield of vines. This fact would suggest planting the seed as soon as possible after the danger of cold has passed. The general practice is to put the seed in during the latter part of May and the first of June after the early maturing crops such as wheat, oats, and early truck crops have been removed. Peas planted at this season produce the heaviest yield of vines, but planting may be done as late as August and good results secured.

The method of planting is usually governed by the price of seed and by the nature of the land. On the higher soils broadcasting is generally to be preferred. When planting is to be done in the growing corn the seed are usually sown between the rows of corn at the time of the last cultivation.

The time of plowing under the vines is best determined by the character of the soil upon which they are growing. If the soil is a heavy stiff clay that needs to be loosened and made lighter, it is best to plow them under while they are yet green, as they are more

effective in their aerating and mellowing action. If the soil is sandy and already too light, green vines should never be truned under, but should be left on the surface until.decayed. The mellowing action is thus reduced to a certain extent. In a case of this kind, it has been found a very good practice to graze the vines. Most of the fertilizing material removed is returned in the droppings from the animals, and the soil is made firmer and more compact by the tramping of the animals. The truly scientific disposition of them would be to turn under when about mature, and follow with some small grain crop such as oats, vetch, wheat, or rye; these to be turned under before planting the next season's crop.

(CLOVERS.)

All of the true clovers belong to the genus trifolium, referring to the leaf with three leaflets. The varieties discussed here are all annuals except red clover, which is a perennial.

CRIMSON CLOVER (1) (Trifolium In Carnatum)

This plant is variously called crimson clover, scarlet clover, German clover, Italian clover, and sometimes long headed clover. It is closely related to the Red clover, and resembles the plant very much, except that it is an annual. It has a very strong root system that deeply penetrates the soil, and therefore, like the cowpea, brings up large quantities of water and mineral plant food to be deposited in the surface soil. It, as are all the true clovers,is a legume and assimilates the greater portion of its nitrogen from the air, by means of the nitrogen assimulating bacteria found in the root nodules.

1) Farmers' Bull. 147. U. S. Dept. Agr., 1902.

It thrives best on warm, loose, sandy soils, and does not do well on the heavy class of soils.

In Delaware it has been used quite extensively as manure, and seem to be superior to the red clover. In fact where it succeeds well, the Stations have generally recommended it ahead of red clover. This plant has been grown successfully and on rather an extensive scale in Delaware, Virginia, the Carolinas, Tennessee, Georgia and Alabama. Its advantages are chiefly four.(1)

(1) "It is a good"catch" crop and when a failure of red cloveroccurs it may be sown upon the same land and so preserve the regular rotation."

(2) "After the clover has been cut in early May, the same land may be plowed under and planted in corn."

(3) "It makes an excellent past ure during the fall months after the other green crops have dried up".

(4) "As a crop for green manuring it ranks high. It is turned under in the spring as it makes its growth during the fall and winter months. In this it differs from all other crops for green manuring". The above statements were made by Dr. Killebrew, grass expert of the Tennessee Station, and of course he was speaking only for Tennessee conditions. The plant is not so highly recommended further south where the other clovers, cowpeas and vetches do so well. Professor Dodson(2) of the Louisana Station, states that it is to be preferred to red clover where it can be successfully grown.

The time ofplanting is in August and September, and it is ready to be turned under in the early spring.

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(1) Killebrew on Grasses and Forage Plants, Tenn. Bul. 2, 3 & 4.
(2) La. Bul. 2nd Series, No. 72.

Red Clover (Trifolium Pratense)

This plant has been in cultivation perhaps longer than any of our leguminuos plants, having been grown for centuries. It succeeds best in the temperate climates being a very important crop in the central and eastern part of the United States. In the Gulf States it has not been so extensively grown, but succeeds well on the strong clay and black prairie soils of these States. It may be grown as far north as Minnesota[1] and succeeds well throughout Nebraska and has proven valuable in the Dakotas.

Throughout the United States as a whole red clover is perhaps used more extensively for green manuring than any other plant. Where it can be grown successfully this plant is undoubtedly the best for maintaining the fertility of the soil that is already comparatively rich,[2] but requires rich, well drained, deep soil that is not too sandy. It succeeds admirably on the rich black prairie soils of Mississippi and Alabama; and its main use is in maintaining the fertility of soils rather than the building up of the worn out soils.

In the souththe success with this crop has been quite variable. It succeeds well in some sections while in others it is a complete failure. With the cowpeas, velvet beans and vetches as rivals its future, save in limited areas, is rather doubtful. The following data concerning its root system collected by the Minnesota Station[3] will serve to give a good idea of its value as a soil renovater. They found that the amount of roots and the depths to which they penetrate varied greatly, depending upon the character of the land. In a

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(1) Farmers Bul. No. 16, U. S. Dept. Agr., 1894.
(2) Miss.Station Bul. No. 20.
(3) Farmers Bu. No. 16, U. S. Dept. Agr.

favorable soil a plant one month old had a root extending seven inches into the ground; at two months old it had reached a depth of two feet, at five months old its length was five feet eight inches. From this we can imagine the amount of mineral plant food that is brought to the surface, and the beneficial effect that is produced upon the physical condition of the soil upon which red clover is grown. In the south the best time for planting is in the fall as soon as possible after the first of September. When sown at that time on thoroughly plowed and finely pulverized soil that has been well compacted by a thorough rolling to prevent drying out, the seed seldom fails to germinate, and to make sufficient growth to become well established before cold weather. On good soil the clover should be ready to turn under by the latter part of April. However, the usual practice is to cut it for hay about the middle of May when it shouldyield about 2 or 2 1/2 tons of hay, then cut again for hay in July when the yield is much lighter. After this it begins to fail and is generally plowed under in the fall.

We see from the above that to secure the maximum results from red clover, we must give up the land to it for at least one year. Whereas with the other crops mentioned above as its rivals we need not miss growing the regular staple crop for a single season.

Japan Clover (Lespideza striata)

This plant should be accorded a very important place in the ranks of leguminous soil restorative crops of the Gulf States.(1) It was introduced into this country from Japan about 1830 and is now thoroughly naturalized over the whole country south of the Ohio River. It grows on all soils but reaches its maximum growth on the good loams containing

(1) Farmers Bul. No. 102 U. S. Dept. Agr.

a fair amount of lime. I have seen it thriving abundantly on the "old fields" in Mississippi that had been turned over to the mercies of the "old field" pines. (Pinus Taeda) And again I have seen it thriving equally or more abundantly on the rich black prairie and stiff and loose clay loams of the same State. On the worn out and abandoned cotton farms it vies with the "old field" pine as to which shall be the first to render them aid. It generally wins the contest at first but is eventually forced to yield possession to the vigorous and shading pines.

The plants are small, having, when crowded long slender stems with small leaves. On good soil they grow to be two feet high. If the plants are thinly set on the soil they take on more of a bushy shape and produce a good crop of seed. On real poor soil they sometimes spread out and remain near the ground. The seeds are not often planted. They seem to be well distributed everywhere. This is one of its most important values. When the land is left idle it takes posession of its own accord, and saves the expense of buying seed. It catches well though when planted. The land needs only to be scorified with a cut-a-way to insure a stand. Lespedeza makes its growth during the summer months. It comes out rather late in the spring, dies down in the fall. It endures heat and drouth without injury.

The seed should be planted in early spring and when used for green manuring the plant could then be turned under early enough in the fall to be followed by oats and vetch or other winter crops. We could in this manner grow two crops for turning under in one year. As indicated above, however, the plant is used mostly for bringing up the "old field" lands that have been turned out. In this way it generally

has to serve the double purpose of pasturing and renovating. For land that is to lay idle, we, perhaps, have no plant equal to it, but where the land is needed for cultivation the heavier growing clovers, cowpeas, and velvet beans should be used.

Sweet Clover. (Mellilotus Alba)

Mellilotus bears a close resemblance to alfalfa, but is larger and coarser and is especially adapted to soilscontaining very large quantities of lime. It is therefore most valuable on the yellow loan ans white lime soils. Profeser Tracy (1) formerly of the Mississippi Station,said; "As a restorative crop for yellow loam and white lime soils this pplant has no superior, and for the black prairie soils it has no equal. Most of the black prarie soils are still very rich in plant food and during the early part of the season cotton makes a rank growth on them and promises a heavy crop; but with the August and September drouths the bolls drop from the stalks and the crop is far less than expected from the rank growth of the stalk. The use of the ordinary commercial fertilizer seems to have very little effect on such soils, and the trouble with them appears to be in their mechanical condition, rather than in want of plant food. Draining with tile has worked well where we have tried it, but this is too expensive to be generally adapted and we have found the growig of an accasional crop of mellilotus to accomplish fully as good results". Professor Tracy might well have added that it will thrive on and produce a soil on the bare rotten limestone outcrpps. The writer observed it growing luxuriantly on the lime rock exposed in railroad cuts and on the sides of hills from which all of the soil had been washed away. When once started on a soil it will maintain itself indefinitely if left alone.

(1) Miss. Bull. No. 20.

Good results can be secured to the soil and at the same time large crops of hay harvested. When sown in the spring on fairly good soil a crop of hay can be saved in the fall, and two or three cuttings saved the next year. The plants should then be allowed to mature seed, to re-seed themselves as the roots die out in the third year. If the hay is not desired, it may be pastured through the winter and spring months to good advantage, but of course the land is restored faster by allowing the stalks to mature each year. Cultivation is not practiced after the plants have once started. The writer is of the opinion that its work is most effectually accomplished when the stalks are allowed ot mature and rot on the sufface. It would be a rather difficult task to plow under the plants effectually after they had reached a height of 4 or 5 feet, which is not an unusual height for them to attain. The roots are also very large and extend deep inot the subsoil. It is the decay of these roots and the forming of drainage pores that constitutes one of the most important sources of value of the mellilotus plant.

Truly speaking then, we can hardly consider mellilotus as a green manuring crop, but it is a very important soil renovating and building plant, and therefore as such deserves a place in this paper. It deserves unrestricted recommendation for all of the calcareaus soils of the South where renovation or organic matter is needed to improve the physical conditions. The best time for planting is in the spring, and for plowing under in the fall.

Miscellaneous clovers.

In addition to the crimson, red, and Japan clovers we have a number of other varieties that may be classed under the head of miscellaneous clovers. They are short lived and generally unreliable. The writer has observed the Burr clover making a vigorous growth on the campus of the Mississippi Agricultural and Mechanical College where the soil is a rich black prairie. It comes out in January or February and dies down in early spring. Alsike clover does not do well in the South, though it is highly recommended in some sections of the United States as a crop for wet soils, on which it is said to grow well. Neither burr, alsike, nor white clover, which is perhaps next to burr clover in importance in this class, are able to compete with the other and more vigorous plants that can be made to occupy the land at the same season of the year that these would, and therefore cannot be recommended. However, they all belong the the Leguminous family and share in common with the other clovers the ability to send their root deep into the soil and to assimilate the free nitrogen of the air, and where they grow the soil is improved to some extent. It would be a poor practice to use them in the place of red clover, vetch, etc.

Is this Sour Vetch this variety?

Vetch (Vicia Villosa)

Hairy vetch is an annual legume, and therefore requires re-seeding each year unless allowed to reseed itself. This, it will readily do if not grazed or cut too close in the spring. The pods when mature, open with some force and throw the seeds to some distance. By this means the plants are well and evenly distributed. Vetch stems or vines grow very long and slender and are unable to support themselves. It is therefore generally planted with oats or rye to support it in order that the mower can do its work. This practice is to be recommended when the vines are to be used for hay It is not necessary when grown for manure. The vines when grown alone form a dense mat several inches deep over the surface. This serves to choak out any weeds that may appear, and at the same time forms a deep mulch thereby producing a mellowing effect upon the sod. Vetch is of European origin, and was introduced into the country by the Department of Agriculture. It did not assume any very great importance as a field crop until about 1890. Since that time it has been the subject of experiments in most of the States of the Union, as well as in Canada. It is now successfully cultivated over a very large area of country. In the north vetch is grown as a summer crop. In the south, however, its greatest value is as a winter crop. Vetch is probably the most valuable plant for that season grown. The vetch has a quadruple value serveing equally well for hay, winter cover crop, pasture, or renovation.

Like almost all other plants, vetch makes its best growth on a rich and somewhat moist soil. It will, however, make an excellent growth on soils that are dry and sandy in character, but will not, of course

make an abundant growth on poor clay soil or those composed largely of sand out of which the humus and other plant food elements have been exhausted. When it is desired to establish the vetch on soils of that character, it is best to apply a liberal application of fertilizer. When once started the vetch will take care of itself, if the vines are allowed to decay on the surface or are plowed under. On many of the soils in the cotton states artificial inoculation is necessary to obtain the maximum results in the shortest time.(1) Experiments have shown that the vetch will inoculate itself the second year, when grown on the same land, provided a liberal dressing of nitrate of soda or stable manure is applied to insure a vigorous growth the first year.

HAIRY VETCH FOR GREEN MANURING OR SOIL IMPROVING.

Director J. F. Duggar of the Alabama Experiment Station has conducted the most elaborate experiment(2) with the vetch that have come under my observation. I will quote his report of these experiments He says: "The superiority of legumes over other plants for green manuring has already been referred to." In the south the cowpea is the standard for green manure, or soil improvement. Hairy vetch seems the equal of the cowpea and has the advantage of growing in the winter thus preventing leaching of fertilizing material, and displacing no summer crop.".

" In an experiment which will be detailed in another bulletin corn was planted in May and in June, 1898, and on adjacent plots where a few days before had been plowed in, on different plots, either the stubbles of hairy vetch, the entire growth of vetch, stubbles of rye, or the entire growth of nearly mature rye plants. The yield of corn in 1898 was at least 50 percent and in some instances 100 percent

(1) Ala. Sta. Bul. No. 105
(2) " " " " "

greater on the plots where vetch or vetch stubbles had been plowed in than on plots where rye had been sown.

"The same plots, uniformally fertilized were again planted in corn in the spring of 1899. The present appearance of the crop (August 1899) indicates the superiority as fertilizers of vetch stubbles or vines is still maintained."

"Still more strikingly has a crop of silage corn planted a few days after plowing in vetch or vetch stubble, shown the great value of hairy vetch as a fertilizer or green manure, these causing nearly the quadrupling or the trebling of the yield on an adjoining plot."

" In both of these experiments here onlu briefly alluded to the entire vetch plant was compared with the roots and stubbles as a fertilizer with corn, the yield of grain was scarcely different, whether the entire vetch plant or only the stubble has been plowed in. With the silage corn, the yield was 2 3/4 tons less than on the plot where the vetch, vines,stubbles and roots had been plowed in. This superior yield of silage corn resulting from the plowing in of the entire growth of vetch was more than the offset by 3600 pounds of hay per acre obtained from the vetch-stubble plot".

"The data given in the following table was collected to determine the stage of growth where hairy vetch is most valuable as green manure.

Analyses of vines and roots and stubbles of hairy vetch harvested on different dates.

Material analyzed	Date and stage when cut	Fertilizing material		
		Percent nitrogen	Percent phos. acid P205	Percent potash K2 O
Tops; hairyvetch	April 19, just before bloom	3.75	.81	2.18
Tops " "	April 26, 5% bloom showing	3.03	.78	2.14
Tops, " "	May 2, full bloom	2.75	.79	2.21
Tops, " "	May 9, seed pods formed; not filled	2.99	.74	2.68
Roots & stubbles h. v.	April 19, just before bloom	2. 36	.49	1.23
Roots & stubbles h. v.	April 26, 5% of bloom showig	2.03	.48	.88
Roots & stubbles h. v.	May 2, full bloom	1.97	.48	.88
Roots alone	May 9, seed pods formed	2.19	.43	.96
Stubbles, leaves, blooms	May 9, seed pods formed	2.07	.42	1.14
Rye tops	Dough stage, May 7, 1898	.52		
Rye, roots and stubbles	May 7, 1898, dough stage.	.35		

It should be noted that the tops of hairy vetch plants are about six times as rich in nitrogen as the corresponding portion of nearly mature rye plant, and that the roots and stubbles are also about six times as rich in nitrogen as those of rye.

The practical points are more clearly brought out in the following table which shows the number of pounds of nitrogen, phosphoric acid, and potash contained in the vetch crop on one acre.

Date when cut	Air dry material	Pounds of nitrogen	Pounds of phos. acid.	Pounds of potash
April 19, vines	3117	117.0	25.2	70.0
April 19, roots & stubbles	850	20.0	4.2	10.5
April 19, Total	3967	137.0	29.4	80.5
April 26, vines	3705	112.3	28.9	79.3
April 26, roots and stubbles	870	17.7	4.2	7.7
April 27, Total	4575	130.0	33.1	87.0
May 2, vines	5789	159.2	45.6	127.9
May 2, roots and stubbles	1054	20.8	5.1	9.2
May 2, Total	6843	180.0	50.7	137.1
May 9, vines	5463	173.3	40.4	156.4
May 9, roots alone	346	7.0	1.5	3.4
May 9, stubbles and fallen material	1061	22.0	4.5	12.1
May 9, Total	6870	202.8	46.4	171.9

The total amount of air dry vines, roots and stubbles increased at first slowly, and later rapidly up to the time of full bloom, after which there was no increase. The maximum amount of air dry material was nearly 3 1/2 tons. This was on stiff, reddish upland loam thoroughly supplied with root nodule bacteria through the artificial inoculation of the preceeding crop of hairy vetch".

"The amount of phosphoric acid obtained its maximum at the time of full bloom, while the quantity of potash appropriated increased rapidly as the plant grew older." The same is true of the nitrogen.

There is then, as much nitrogen, when at its maximum in a crop of vetch as there is in 1 1/2 tons of cottonseed meal, which is worth at the time of this writing about $22.00 per ton. Calculating on the 1 1/2 ton basis we find that a crop of vetch contains $32.00 worth of nitrogen. Not all of this however, can be credited to the vetch as a part - an indeterminate part of the nitrogen came from the soil. It is believed by the writer that at least 3/4 of it comes from the air. The amount taken from the air depends upon the richness of the soil, but for comparison let us assume that only one-half came from the air. We still have a value of $16.00 due directly to the vetches ability to assimilate nitorgen from the air. The value to the physical condition of the soil and of the phosphoric acid and potash made available by its use further greatly enriches the value of the vetch as a green manuring plant.

The analyses show that 1/5 of the nitrogen is in the roots, stubbles, fallen leaves, etc., and that 4/5 is in the vines. The table shows about the same proportion for the phosphoic acid and potash. These figures makes the necessity of plowing under the whole crop apparent when the question of fertility alone is being considered.

Director Duggar summarizes the teaching of his experiment thusly: (1)"That hairy vetch when stocked with an abundance of root nodules, is able to accumulate exceedinly large quantities of nitrogen from the air; (2) That when the entire growth is to be turned in as a green manure, the plowing should be postponed as late in the life of the plant as practicable. (3) That the greater portion of the fertilizing material is in the vines or tops, although the roots and stubbles often contains sufficient nitrogen for the succeeding crop."

A number of the other experiment stations are equally as strong in their recommendations of vetch as green manure as is the Alabama Station.

TIME OF SOWING VETCH SEED.

September is the best month for sowing vetch seed in the Cotton States. In the southern portion of these states and along the Gulf Coast the seed may be sown as late as October 15th. The writer had some sown on the first day of January 1905 in east central Mississippi. The seed germinated immediately and made an excellent crop. The vetch of this planting was in full bloom abd ready for cutting for hay about the first of June. Sowing may be done in August, if the land is in some other crop that requires cultivation this late in the year. If the seed are sown when this plowing is done the extra labor of re-plowing the land is saved. There is considerable risk of drought though in planting in August. Broadly speaking, planting may be recommended from the middle of August until Christmas, from September 1st to October 15th of this period being preferable. Planting may be done also in the latter part of January, and the first of February with spring oats. Fall planting, however, is to be recommended in all cases where it is possible. The vetch than serves the double purpose of a winter cover crop and a spring green manuring crop.

The seed should always be sown broadcast. The preparation of the land should be about the same as that required for oats. The seed

broadcasted at the rate of about 30 quarts per acre, and harrowed in with any ordinary tooth or disc harrow. If the land is very light, sandy and poor it is a good practice to apply a liberal dressing of mineral fertilizers, and be sure that the soil contains the vetch nodule forming bacteria in sufficient numbers to insure enough bacteria to assimulate a sufficient quantity of nitrogen from the atmosphere. This ability to assimilate the free nitrogen of the air and convert it into a form in which the plants can make use of it, constitutes one of the most important sources of value of the vetch plant.

TIME OF TURNING UNDER.

Vetch should not be turned under before it reaches the stage of full bloom. We have seen from the tables given above that it contains its maximum amount of fertilizing constituents at this stage. In addition to this enough seed have matured by this time to re-seed the land for the next winter. Plowing in at this time will give plenty of time to grow a good crop of late cotton, corn, or silage, or better still a crop of cowpeas for turning under or pasturing in the fall. By following vetch with cowpeas we are enabled to grow two cover and three green manuring crops with the loss of the use of the land for the regular staple crop for only one year. The above may appear to be a broad statement, but it is true. The vetch the first season furnishes winter cover and green manure for the first season, the cowpeas for the summer and fall. The vetch re-seeds itself and occupies the land through the second winter and furnishes a crop of green manure to be turned under in time to be followed by any of the staple crops.

It would seem to appear that all of theevidence go to support and substantiate Professor Duggar's conclusion "that hairy vetch seems to be the equal of the cowpea.

THE VELVET BEAN. (Mucuna Utilis)

The velvet bean seems to have been grown in Florida as a trellis plant to shade the porches from the hot sun for a number of years- perhaps twenty-five. A farmer was the first to realize its value as a general crop plant and accordingly called attention of the Florida Experiment Station to it. This was in 1895. The Florida Station began experimenting with it in 1896. Since that time the velvet bean has been tried at most of the Gulf State Experiment Stations. The experiments have proven it to be fully equal, if not the superior, of the cowpea. As yet there has not been produced a variety that will mature seed further north than the latitude passing through about the central portion of the Gulf States, Mississippi, Alabama, Louisana, etc. From the writer's experience with the plant at the Florida Station he is thoroughly of the opinion that by careful selection of seed it will be an easy matter to produce a strain that will mature seed as far north as Tennessee, etc. In fact, he secured seed there from a first year's selection that the plants from which blossomed in the latter part of July or the first of August, whereas the plants from the ordinary seed did not bloom until nearly a month later. The plant thrives well as far north as Alabama and Mississippi but does not produce seed.

The great merit of the velvet bean, the one in which it outdistances all competition, is the enormous amount of vine that it is able to produce. This, coupled with its ability to assimilate large quantities of nitrogen from the air makes the bean in every respect the equal or superior of the south's standard legume- the cowpea- Its chief disadvantage in comparison with the other legumes is, as referred

to above, its inability to produce seed in the short seasons. For this purpose at least eight months is required.

Some very interesting experiments have been conducted at the Florida,(1) Alabama,(2) and Louisana(3) Stations to ascertain the amount of nitrogen and humus produced by the velvet bean. In these investigations the vines and roots were collected and weighed and analyzed separately. The weights and analyses vary greatly for the three States. It is not surprising, however, as the condition of temperature, rainfall, and soil must have varied equally as much as do the products of the plants. These results are tabulated below.

Amount of humus afforded by the velvet bean in Florida, Ala, and La.

	Fla.	Ala.	La.
Weight of green material from an acre	Lbs. 21132	Lbs. 14040	Lbs. 22919
Weight of dried material from an acre	5953	8240	7495
Weight of dried roots from an acre	690	1258	.191
Weight of nitrogen in dry vines from an acre	13156	18870	17013
Weight of nitrogen in dried roots	9.7	12.18	2.9
Weight of nitrogen in entire plant	141.26	201.28	173.0

(1) Fla. Bul. No. 60.

(2) Ala. Bul. No. 104.

(3) La. Bul. No. 55.

Director Duggar of the Alabama Station reports some striking examples of the fertilizing effects of velvet beans on sorghum, cotton, corn and oats.(1) With sorghum after sorghum the yield of clover hay was 3.65 tons; sorghum after velvet bean stubbles 5.80; sorghum after velvet bean vines 6.76 tons. The increase due to use of the entire plant was 3.11 tons, or nearly double that of sorghum following sorghum. The increase due to the use of cowpea stubbles and cowpea vines in the same experiment was 2.01 and 2.09 tons respectively for stubbles and vines. With cotton after cotton the yield was 837 pounds; with cotton after cowpeas 1533 pounds of and with cotton after velvet beans 1373 pounds of seed cotton per acre. This shows a gain of 696 pounds of seed cotton per acre after cowpeas, and 546 pounds after velvet beans. Reducing these to percentage cowpeas make a gain of 83 percent and velvet beans a gain of 64 percent. This indicates that it is surely more valuable to the farmer to grow a bale of cotton per acre on his land every second year than it is to produce about half a bale per acre yearly, If the above results would hold good for every year, considering the increase in yield of cotton, the improved fertility and physical conditions of the soil, and the reduction of cost of labor, the farmers of Alabama could well afford to change their method of farming to a rotation of cotton and cowpeas or velvet beans. A crop of vetch and oats could be grown during the winter season of each year which would still further enhance the value of the land and the proceeds of the farmer. The gain in yield of corn where phosphate was used in connection with the velvet beans as fertilizer, was corn after phosphate alone 13.58 bushels, velvet bean stubble and phosphate 17.93 bushels, velvet bean vines and phosphate 25.90 bushels, and velvet bean

(1) Ala. Sta. No. 120 - 1902.

vines alone 21.48 bushels of corn per acre. The percentage increase due to the bean stubbles was 32 percent (4.35 bushels) that due to the vines was 81 percent. (12.32 bushels) The increase attributable to 100 pounds of acid phosphate was 4.42 bushels per acre. The yield of oats was 8.4 bushels per acre after non-leguminous plants, 28.6 bushels per acre after velvet bean vines, 38.7 bushels per acre after velvet bean stubbles, 28.8 bushels per acre after cowpea vines, and 34.4 bushels per acre after cowpea stubbles.

Professor Duggar thinks that this is an extreme and not an average case. Again of from 10 to 15 bushels of oats per acre due to the use of the peas and beans would perhaps be more nearly an average increase. However, these results prove conclusively that the value of beans as a fertilizer is very great.

TIME OF PLANTING.

The beans should be planted just as soon as danger from frost is past. The long growing season required to mature the seed make this early planting absolutely necessary, unless it be for the extreme southern portion of Florida where the temperature is such that growth will continue well into the winter.

The best method of planting is in rows about 5 or 6 feet apart on good soil. On the poorer soils 3 to 5 feet apart. The seed should be dropped 12 - 18 inches apart 1 - 2 in a place. Some prefer to sow them broadcast, but in rows is generally conceded to be the better method, as the plants may then be cultivated while young to keep down the grass and weeds. The plants also thrive better when given plenty of space. The time for plowing under is about the same as for the cowpea.

BEGGAR WEEDS(Desmodium tartuosun)

In some sections of the South, - Florida particularly, the beggar weed has become very popular in recent years. It is a legume andmakes a vigorous growth on sandy soils. On sandy soil the plants grow to a height of 5 or 6 feet. If allowed to mature they become hard and woody. So much so that their value as manure or hay is decreased. However, if it is ploed under at the proper stage of its growth there is no apparent reason why it should not prove a very important green manuring plant.

It has received more attention from the farmers of Florida than those of any other State. They use it quite extensively for cover crops in the orange groves as well as for hay and green manure on the truck farms. The seed should be planted broadcast on well prepared soil in May or June. Some sow in the corn at the time of the last cultivation. The crop is then ready for hay or turning under by the middle of september.

RYE.

Of the non-leguminous green manuring plants rye stands first. It is a sure and excellent manurial crop for sandy soils, and is preferable to clover as it will grow on soils too poor for clover. It is too shallow rooted and otherwise defective to bear a comparison with clover, cowpeas, velvet beans, vetch, etc., however, where these plants will grow, and some one of them may be grown on any soil that will produce a good crop of rye. Clover is about the only one of the above named plants that can not compete with the rye on poor soil.

Rye intended for manure should be sown broadcast from the middle of September to the middle of October. It is then ready for turning under early enough for any of the staple crops the next spring.

MISCELLANEOUS NON-LEGUMINOUS CROPS.

There are a number of the grasses that thrive luxuriantly during the summer months in the South that might be profitably used as green manures. Among these may be mentioned Bermuda grass, Carpet grass, Crab grass, St Augustine grass, etc., etc. But as none of these are able to utilize the atmospheric nitrogen and all of them make their growth during the summer months, and where they will grow well there is a legume that will also grow well, it would seem best to consider them under the discussion of summer cover crops. It is not the best practice to use grass for green manure when it is possible to grow a legume for the same purpose.

COVER - CROPS.

By the term "cover crops" is commonly understood a crop used to fill a gap, whether caused by the failure of one of the regular crops of the farm or one coming between the main crops. It is a crop which occupies a field which, in the more common farm practice would remain bare or uhproductive. It is often an emergency crop, that is, a crop not planned for, but introduced to supply a want which is a consequence of accident or unforseen conditions. A rigid regard for the teachings of farm economy would make a cover-crop, save those sometimes introduced under the spur of unforseen contingincies, as regular members of our rotations as any of the crops of the farm. A proper regard for the value of catch crops is a positive necessity in the farm climate of the south,

especially on the cotton farms that have been subjected to the clean culture demanded by that plant.

BENEFITS TO BE DERIVED FROM COVER CROPS.

Cover crops prevent the particles of soil from being blown from place to place by the wind. They prevents washing; they add large quantities of humus; they mulch the soil and protect it from the burning and sterilizing rays of the sun; they send their deep roots into the soil, thus improving its physical condition; and finally they take up the plant food element as they become available and prevents them from being leached and washed away. The loss from leaching is perhaps the most damaging to the soil of any of the above named actions which catch-crops tend to counteract. Boussingsalt found that in a soil containing 900 pounds of nitrogen in a depth of one foot only 40 pounds was left after three wekks of continuous rainy weather. Lawes found by placing three gauges covering $\frac{1}{1000}$ acre each, at depths of 20, 40, and 60 inches, and allowing no vegetation to grow thereon, that a loss of nitrogen exceeding 40 pounds passed through the drains yearly. He also found (1) that the water passing through these gauges was much richer in nitrogen than the rain which fell upon them, (2)that the drainage is richer in nitrogen in the autumn than at any other season of the year, and (3) that the drainage in another field where a crop of wheat was in luxurious growth, contained no nitrogen at all. The facts brought out in these statements should prove to us conclusively the necessity of growing cover-crops, and particularly those that are able to grow through the fall and winter months.

SELECTION OF COVER-CROPS.

A cover-crop, in so far as may be possible, should combine the following characteristics; cheap seed, ability to thrive when sown broadcast, rapid growth, freedom from qualities either in root or seed, which will cause it to become a troublesome weed, a deep vigorous system, the ability to take a part of its nitrogen from the air, hardiness in winter, ability to stand frost and grow at a low temperature, and value as a green manure.

The importance of these characteristics are in most cases perhaps evident; but concerning some of them a word in explanation may be desirable.

The ability to thrive when sown broadcast is very important, as this is the quickest method of planting, and in most cases the farmer has little time to devote to the production of cover-crops at the season of planting. By this system further, the land is more completedly covered, and the roots more evenly disseminated through the soil to take up the valuable plant food, Cover-crops are not generally cultivated,and thick sowing tends to keep down the weeds, etc.

The time coming between or after the main crops is usually short. Therefore, the cover-crop should be able to make a rapid growth in order to do its work more thoroughly. The rapid growth keeps down weeds.

A deep and vigorous root system enables the crop to gather an abundance of food, the deep roots open up pores through the subsoil and improves the physical condition.

An important object of the cover-crop should he to improve the soil. Those crops which can assimilate atmospheric nitrogen serve this purpose most efectually. Other crops return to the soil

only what nitrogen they gather from it; and the soil cannot be enriched in this element by their growth. That the culture of almost any crop may be made to some extent a soil improver is quite true; but only by the culture of leguminous plants can the store of nitrogen in the soil be increased.

Cotton and corn as grown in the South occupy the land from March to Novermber. Therefore the season for a cover-crop is short. Hence the necessity of a rapid grower.

The ability to stand frost is in a great many cases a highly important characteristic of the cover-crop. The scarcity of labor often renders it impossible to get the cotton crop harvested until late autumn. The time before the probable frost is shortened. In a case of this kind only such crops as will continue to grow in spite of the frost will prove of much value. Further, it is in late fall when the soluable nitrogen compounds are most susceptible to being washed out of the soil by heavy rains unless the soil is filled with feeding rootlets of growing plants. Only crops which resist frost can prevent loss.

Clean culture demanded by the cotton plant tends to rapidly reduce the humus content of the soil. It is a good practice, therefore, to turn the cover-crops under in spring before planting the regular crop.

The crops that came nearest fulfilling the above mentioned characteristics are: vetch, the clovers, oats, rye and rape. Of these vetch and oats sown together take by far the leading rank. This is shown by reports from the farmers. Out of thirty-two reports from prominent farmers of Mississippi in answer to a question addressed them, nine recommend the use of oats and vetch sown together, seven

recommended oats alone. The experiment stations are unanimous in their recommendation of oats and vetch. The clovers are also of much value as a cover-crops. Rye is perhaps the most vigorous of any of the crops named above unless it be rape. It is the writer's opinion that rye would prove superior to oats for sowing with vetch. Professor Bennett, of the Arkansas Stations states that rye ripens about two weeks ahead of vetch and is therefore not well fitted for combining with it. He found wheat to be superior to either rye or oats for sowing with vetch. Oats are used more extensively on account of their value as food for animals. In this respect they are superior to rye. Rape makes a luxuriant growth through the winter months and is a splendid pasture plant for sheep and swine. It merits a more extended recognition.

The above crops are used almost exclusively for winter months. For the summer months the cowpea is preeminently the leader and is used more than all other crops combined. The long growing season required by the velvet bean renders it worthless as a catch-crop, except for orchards and orange groves. Beggar weeds are very valuable for covering the sandy soils of Florida after the truck crops are taken off in the spring.

Of the grasses used for this purpose Bermuda grass is perhaps the most effective. It forms a dense sod and a thick cover. The difficulty of ridding the land of it when once well sodded is the greatest drawback to Bermuda grass. The dense sod is very effective as a soil binder and prevents washing. Bermuda is used quite extensively on the terraces, levees, etc., for this purpose. Crab grass, carpet grass and St. Augustine grass are also very effective cover grasses. They all possess the ability to form heavy root systems and thereby prevent washing.

DISPOSITION OF COVER-CROPS.

Where the land is in need of humus the best possible disposition of the cover-crop is to convert it into manure by plowing under when mature. Cover-crops, however, are quite often used for hay or for green feed or pasture. If the excrement of the animals is saved and returned to the soil as manure very little of the plant food elements is lost, and where the soil is well supplied with humus and feed is scarce, the cover-crop may be very profitably used as feed for animals. But when the enrichment of the soil is the point to be attanied, it is perhaps always best to turn under the plants for green manure.

CHAPTER 11.

EXPERIMENTAL INVESTIGATIONS.

In the preparation of this thesis it was deemed advisable tosuplement the historical data with that obtainied by experimental research. Consequently it was decided to make monthly determinations of the nitrogen in the soils of the experimental plots of the Station farm. Eight of these plots were selected. The samples were taken on the fifth of each month beginning with November 1906 and ending May 5t, 1907. The samples were taken from a composite of three borings forty inches deep; the first eight inches of surface soil constituting the first, the next sixteen inches of subsoil the second, and the next sixteen inches of subsoil the third sample. Plot No. 1 has been in asture for a number of years and has a very good sod of bluegrass and timothy on it. The place of sampling was in a valley a few feet from a ditch through which the water has been running most of the season. The soil is of alluvial origin, but of fine material, not typical of allubium deposits, and is rather low in the plant food elements.

Plot No. 2 is on a level portion of the field. Cowpeas were the crops grown on it in 1904 and 1905, and corn in 1906. The soil was bare during the experiment, but was plowed a few days before the April samples were taken. There was a considerable increase in the nitrate content for April and May due, possibly in part, to the plowing.

Plot No. 3 is located on the south slope of the field and has been in alfalfa for the last three years. The alfalfa made only a medium growth up to March, after which except for a part of April it was very vigorous. The nitric content is much lower after March. This is quite possibly due to the increase d demand of the plants for food

to support of the rapid growth.

Plot No. 4 is also on the south slope of the field and has grown wheat and cowpeas for the last six years. There was a good crop of wheat in the soil during the experiment.

Plot No. 5 is onthe northeat slope of the field. It grew corn for three years previous to 1906, when it grew cowpeas. The soil was bare during the experiment, but was plowed a few days previous to the April sampling, and here again we have a relatively high gain in the nitrates for April and May, apparently due in part to the plowing.

Plot No. 6 is in the edge of a driveway through the field. It bears a heavy sod of bluegrass and timothy.

Plot No. 7 is on the level near 6. It grew wheat for a number of years previous to the experiment, but was sown to oats in the fall of 1906. The oats made a very good start during the fall, but were killed by the cold in winter and the plot may be considered as bare during the test.

Plot No. 8 is near 6 and 7. It has been in wheat for the past three seasons. A heavy dressing of manure was applied in the fall of 1906 just before the wheat was planted. The wheat made a very vigorous growth. The soil in the experimental field is a fairly good quality of silt loam, rolling sufficiently to give good drainage, but no washing takes place. The surface soil averages eight or ten inches in depth. Below this is a clay silt subsoil, very waxy and quite impervious to moisture which would indicate that it is resistant to the leaching process.

METHOD OF MAKING THE DETERMINATIONS.

The samples were taken with an auger. Dried in an oven as quickly as possible and then ground in a mortar and thoroughly mixed. The sample for the determination was then taken from the composite. The chemo-Colorimetric method used in the examination of water for sanitary and technical purposes was followed. Prepare the soil solution by taking 50 grams of the composite, placing it in a clean linen bag and pour over it in a mortar 200 cc of a one percent solution of formaldehyde made up of 244 cc. of distilled water 5.36 cc of a saturated solution of potassium alum crystals and 0.64 cc of commercial formalin, knead the soil for two and one-half minutes, at the same time constantly turning the bag in the mortar. Ring the bag out as dry as possible, pour the solution into a glass jar and set away to clear, which requires about twelve hours. When clear draw the solution off into another glass jar. Treat this clear solution with about two grams of G. Elf carbon black and let stand from twenty to thirty minutes. Then filter. This gives a perfectly clear solution. Measure 25 cc of this clear solution into a clean porcelain evaporating dish by means of a pipette and evaportate to dryness over a steam bath. When dry add one cc of phenol-disulphonic acid prepared after the method in use by the Bureau of Soils (take three grams of pure crystalized phenol, and 37 grams (20.1 cc) of pure concentrated sulphuric acid, mixed together and heat for six hours at 100 degrees C. by setting the loosely corked bottle in boiling water) and work thoroughly over the surface with a stirring rod until the residue has dissolved. After ten minutes, including the time of working, add about 20 cc of distilled water and neutralize with ammonium hydroxide, using litmus paper as an indicator. This produces a yellowish tint, the intensity of

which depends upon the amount of nitrates present, from which the colorimetric reading is made. Rinse the colored solution into the colorimetric test tube and make upto some convenient amount, say 50 cc. Compare this with a standard Kno3 solution made by dissolving 0.1631 grams of pure, dry potassium nitrate, that has been heated just about to the fusing point, in distilled water and making up to one liter. Of this stronger solution take 100 cc and make it up to one liter. This constitutes the standard nitrate solution and contains 0.01 millograms of NO3 in each cc. Ten cc of this is evaporated and treated the same as in the method described above for the soil solution, and is made up to 100 cc, having a strngth of one part of nitrates per million. The amount of nitrates in the soil solution can easily be calulated from the readings of the colorimeter.

Should the color produced by the soil solution prove too intense to match with the standard, an aliquot may be taken and made up to some convenient amount and the readings be made from this.

CHANGES IN THE NITRATE CONTENT OF THE VARIOUS PLOTS DURING THE EXPERIMENT.

A reference to the table and charts shows that there was a very marked falling off in the nitrate present in all plots December 5th as compared with November 5th. This loss is due to one or more of three causes. The soil had been well cultivated during the cropping season and large quantities of nitrates were formed during the warm period after the cultivation had ceased. When the November rains came these nitrates were either washed deeper into the soil, changed into insoluble forms by the process of denitrification or taken up by the growing plants. It is possible that denitrification was the

Table showing the number of parts of nitrates per million parts of soil during the months of the experiment for the various plots.

No.	Crop	Pts. NO_3 per million	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Average
			Month							
1a	Sod	" " "	0.84	0.70	0.40	0.30	0.80	0.68	1.00	0.645
1b	"	" " "	0.80	0.90	0.28	0.50	0.80	0.60	1.60	0.782
1c	"	" " "	0.40	0.40	0.28	0.50	0.80	0.88	1.20	0.637
2a	Bare, after corn	" " "	1.82	0.46	0.88	0.70	1.80	2.80	3.80	1.751
2b	" " "	" " "	0.40	0.70	0.80	0.90	1.20	1.00	2.20	1.028
2c	" " "	" " "	0.50	0.40	0.40	0.50	1.20	1.00	1.80	0.828
3a	Alfalfa	" " "	1.40	0.60	1.20	0.50	2.20	1.40	1.00	1.185
3b	"	" " "	1.50	0.50	0.60	0.90	1.20	1.00	1.40	1.014
3c	"	" " "	1.10	0.40	0.52	0.60	1.00	1.00	0.80	0.775
4a	Wheat	" " "	1.50	0.50	0.60	0.40	1.00	1.40	0.80	0.842
4b	"	" " "	0.70	0.60	0.72	0.80	1.00	1.20	1.00	0.860
4c	"	" " "	0.60	0.80	0.32	0.50	0.80	1.00	1.60	0.802
5a	Bare after cowpeas	" " "	3.20	0.70	0.80	0.90	3.00	3.60	3.80	2.157
5b	" " "	" " "	1.00	0.80	1.12	0.80	2.80	1.80	2.20	1.502
5c	" " "	" " "	1.40	0.54	0.48	0.80	0.80	1.20	2.00	1.031
6a	Sod	" " "	2.20	0.78	0.72	0.90	3.00	1.40	1.00	1.428
6b	"	" " "	1.50	1.00	0.80	1.50	1.60	1.80	1.40	1.557
6c	"	" " "	1.40	0.48	0.40	0.80	1.20	1.00	1.60	1.125
7a	Oats	" " "	1.82	1.00	1.00	1.20	2.00	3.28	3.80	2.014
7b	"	" " "	1.10	0.50	0.80	1.00	1.80	1.00	2.40	1.228
7c	"	" " "	0.90	0.50	0.40	0.10	1.00	1.00	1.80	0.957
8a	Wheat	" " "	1.90	0.60	1.52	1.00	1.20	0.68	1.80	0.957
8b	"	" " "	2.00	0.50	0.60	1.20	1.00	0.60	2.20	1.157
8c	"	" " "	1.00	0.60	0.28	0.70	0.72	0.60	1.00	0.700

Note the numbers followed by (a) represent the first 8 inches of, surface

soil, those by (b) the first 16 inches of subsoil, and ~~by~~ those (c) the second 16 inches of subsoil.

dominating factor in the loss, as the crops were not far enough advanced to consume the large quantities lost, and the rainfall (2.93 inches) was insufficientto wash through the soil after the long drouth that had preceeded these rains. However, that the tendency of the nitrates was to wash downward is shown by the increase in almost every plot, in the first sixteen inches of subsoil. The loss was smaller and more uniform during December and January on account of the low temperature and heavy rainfall. The table below shows that the temperature was low enough during these months to stop the formation of nitrates almost entirely, while the rainfall was sufficient to wash through the soil the greater portion of what was formed.

TABLE SHOWING MAXIMUM, MINIMUM AND MEAN TEMPERATURE AND PRECIPITATION FROM OCTOBER 1906 TO MAY 1907.

Month	Maximum	Minimum	Mean	Total precipitation
October	66.50	44.2	54.4	0.40
November	48.6	31.9	40.2	2.93
December	42.5	27.8	35.2	1.60
January	42.	25.3	33.6	5.65
February	42.1	22.9	32.5	.57
March	61.8	41.9	51.6	2.99
April	57.6	37.1	47.4	3.85

That the formation of the nitrates was retarded and that they were leached out of the soil is further shown by the large increase in the March determinations. The latter part of February and the first days of March were very warm and nitrates were rapidly formed. The .57 inch of rainfall for the period was not sufficient to leach them out and, hence the high content for this determination. The same is still further brought out by the results of the April 5th determination. The 2.99 inches of rain that fell, coming after the low precipitation of the previous month, did not leach through the soil in sufficient quantity to counteract the effect of the high mean termperature of 51.60 on the formation of the nitrates, and hence again we have an even more marked increase, except in those plots where the growing plants utilized them as they were formed.

INFLUENCE OF DEPTH ON THE NITRATE CONTENT OF THE SOIL.

Considering an average for all of the plots, we find, as was brought out in the historical discussion of this subject, that the greatest amount of nitrates is formed in the surface soil and that it decreases as the depth increases. The average for the surface 8 inches for all of the plots is 1.372 parts per million; for the first 16 inches of subsoil it is 1.153 parts per million; and for the second 16 inches of subsoil it is 0.857 parts per million. This shows that nitrates are formed to a depth of 40 inches. But a glance at the table or charts will show that the variation is much greater in the surface soil than in the subsoil. It seems then to be an established law that the nitrate content of a soil decreases as the depth increases, and that the variability of the content in any stratum of soil increases as the surface is approached. This, however, is what we would naturally expect. The surface soil is warmer, better aerated, and the con-

conditions for nitrification are more favorable, whereas the reverse is true as we go deeper into the soil.

THE EFFECT OF GROWING CROPS ON THE NITRATE CONTENT.

It is unfortunate that there were not a larger number of varieties of plants growing from which to study this phase of the subject. However, as will be seen from the tables the plots with crops growing upon them retained their nitrogen much better than did those that were bare. This is shown by a comparison of the total amount of nitrates found in plot No.5, which had previously grown cowpeas and left bare afterwards, with that found in plot 8 which received a heavy application of stable manure and was sown to wheat. The total for plot 5 in November was 5.60 parts, and for December 2.04 parts - a loss of 3.56 parts. While for plot 8 growing wheat the total for November was 2.90 parts and for December 1.60 parts or a loss of 1.30 parts. Thus we have a loss from the bare plot of 3.56 parts against that of 1.30 parts from the plot growing wheat. A comparisn of the same plots for the last three months of the experiment brings out even more strongly the value of a cover-crop. The total nitrates for plot 5 on March 5th was 6.60 parts per million, while for No. 8 there was only 2.92, a difference of 3.68 parts more in No. 5 than in No. 8 that is capable of being washed out should sufficient rain fall. The large difference in the amount of nitrates in the plots at this time may be partially due to the decaying pea roots in No. 5.

In April when the wheat had grown larger and and required more nitrogen, the difference increased to 4.28 parts. During April, which was a very cold month, and when practically no growth was made by the wheat, the difference was reduced to 3 parts, but the total nitrate content of both plots was increased being 8 parts in No. 5 and 5 parts in No.

chart 1.

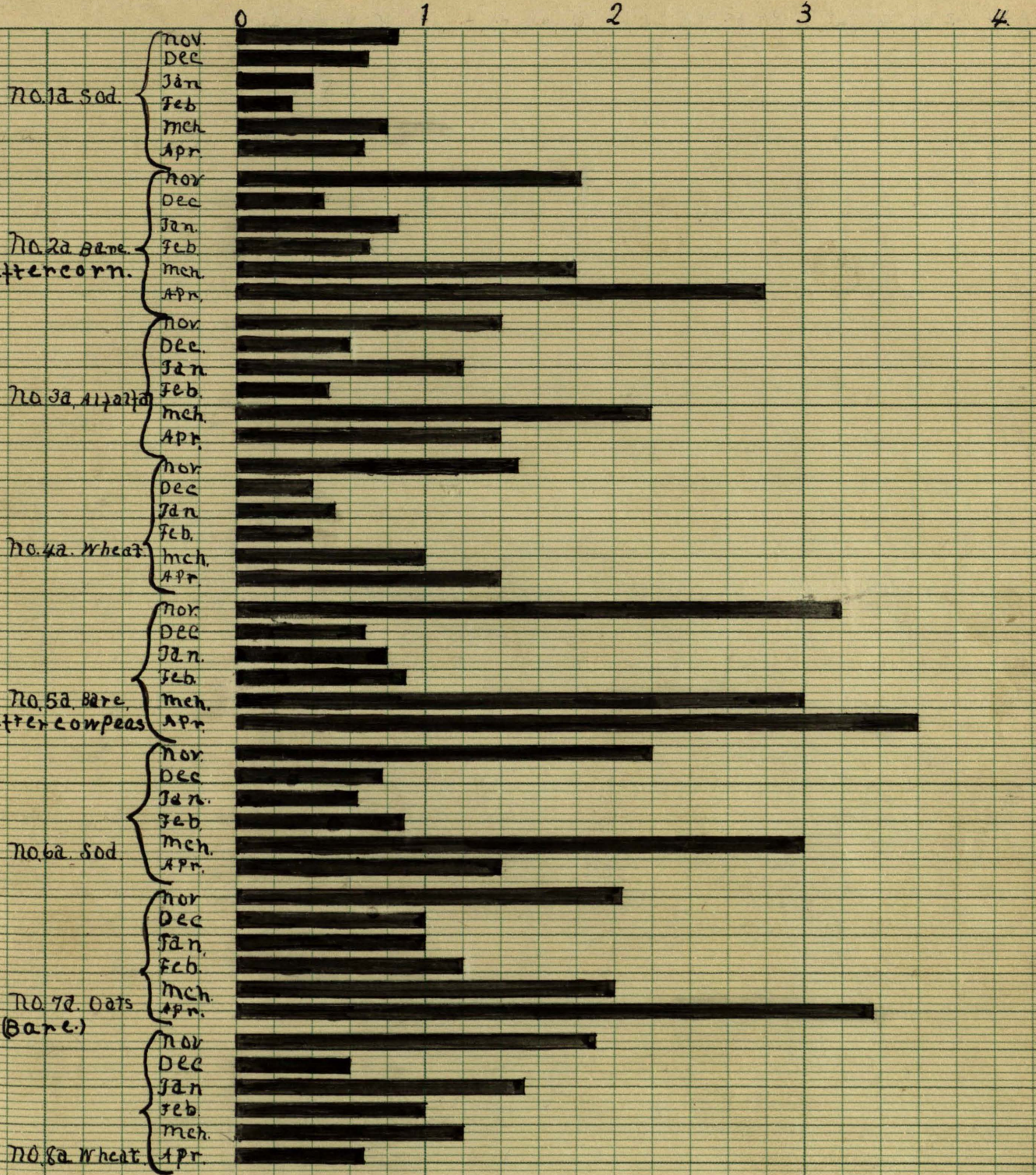


Chart showing the amount of nitrates in the 1st 8 inches of surface soil. for each plat.

Chart II.

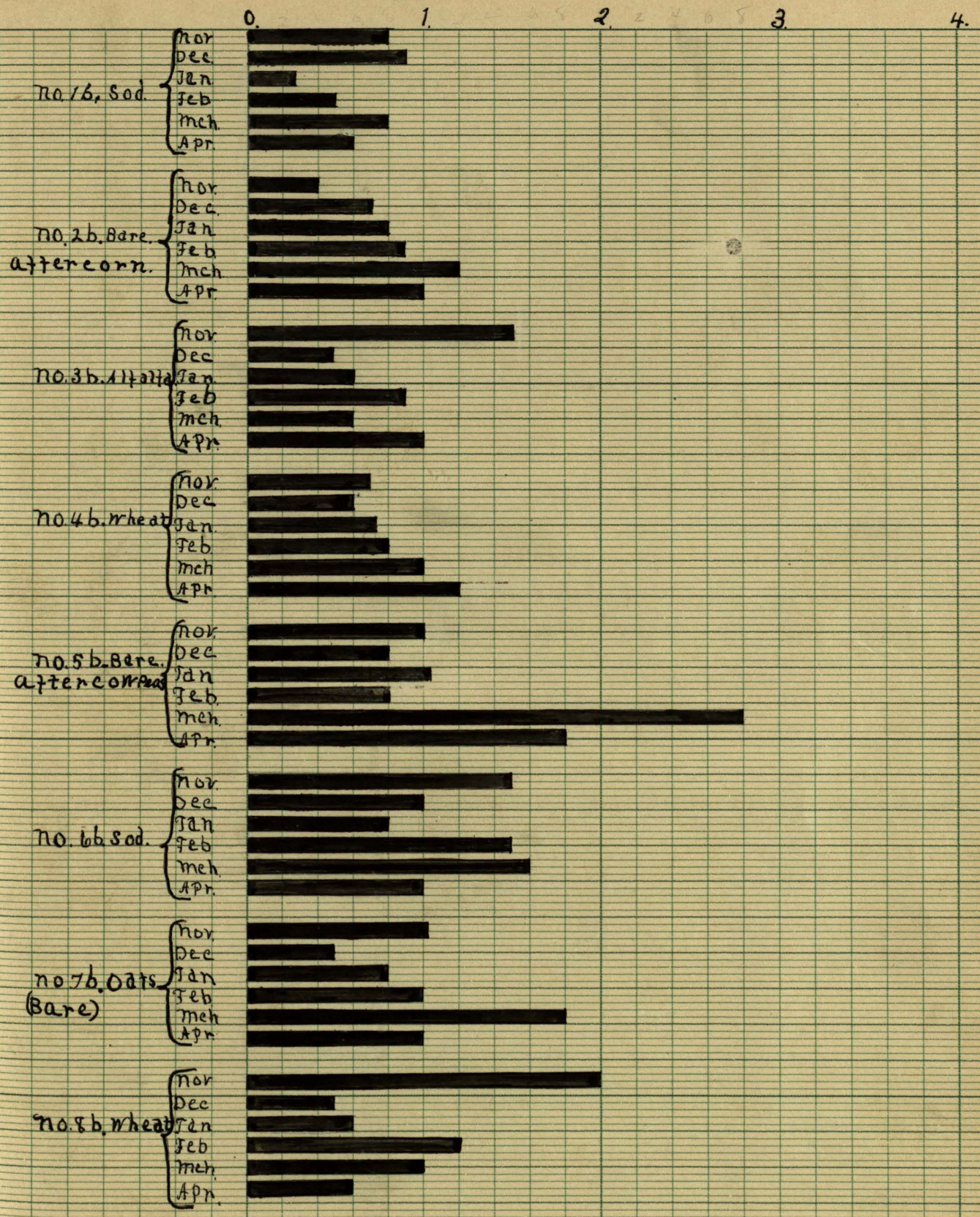


Chart showing the amount of nitrates in the 1st 16 inches of sub-soil for each plat

Chart III.

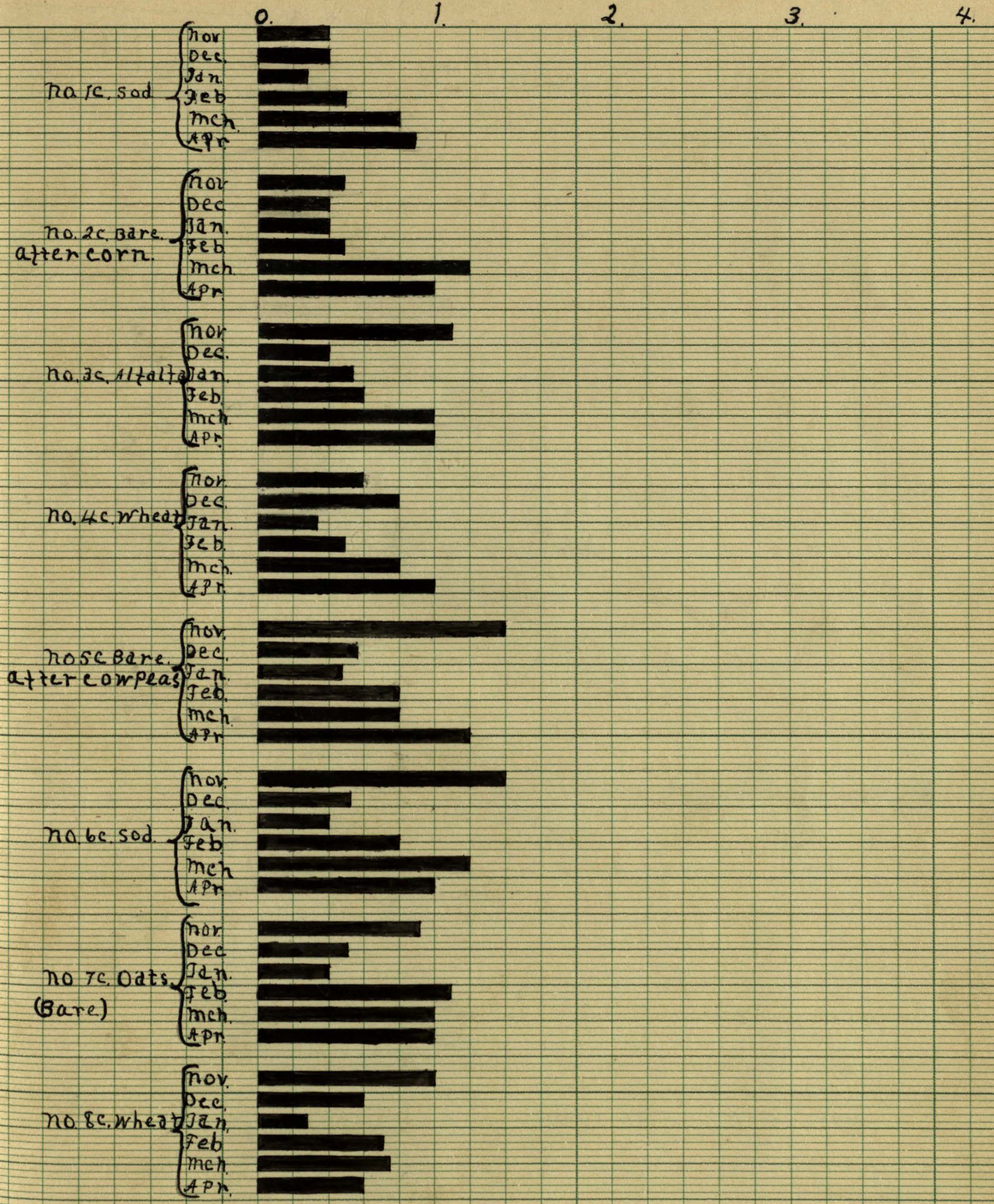
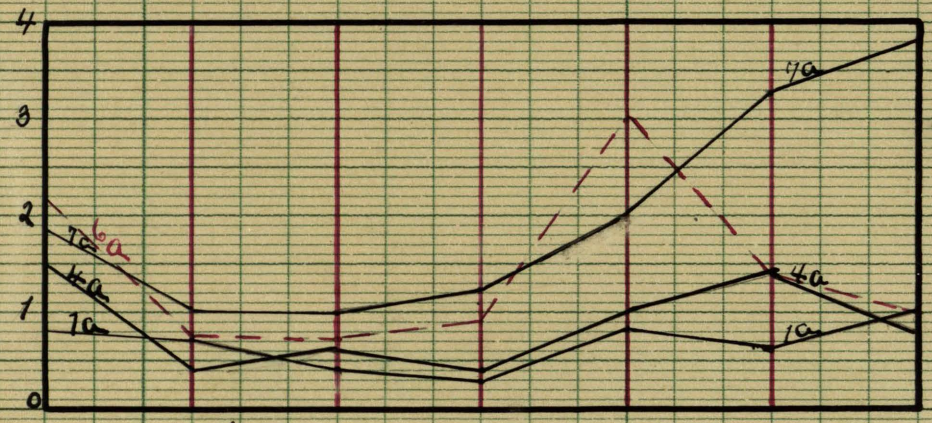
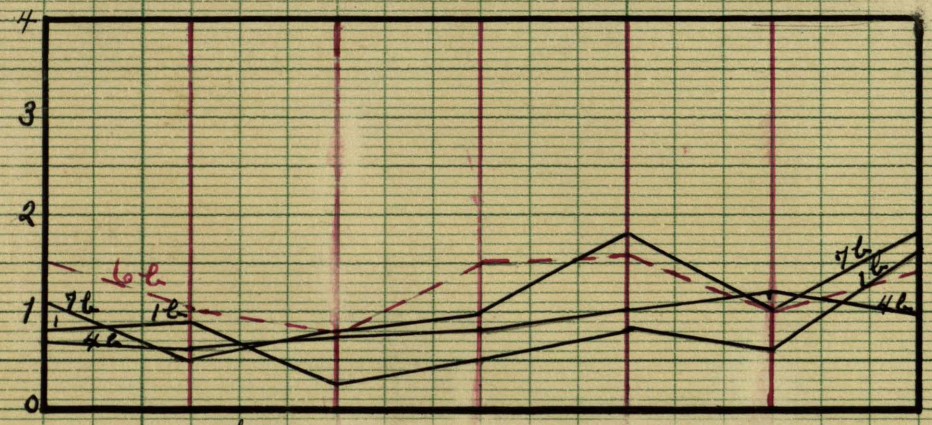


Chart showing the amount of nitrates in the ~~2nd~~ 16 inches of subsoil for each plat.

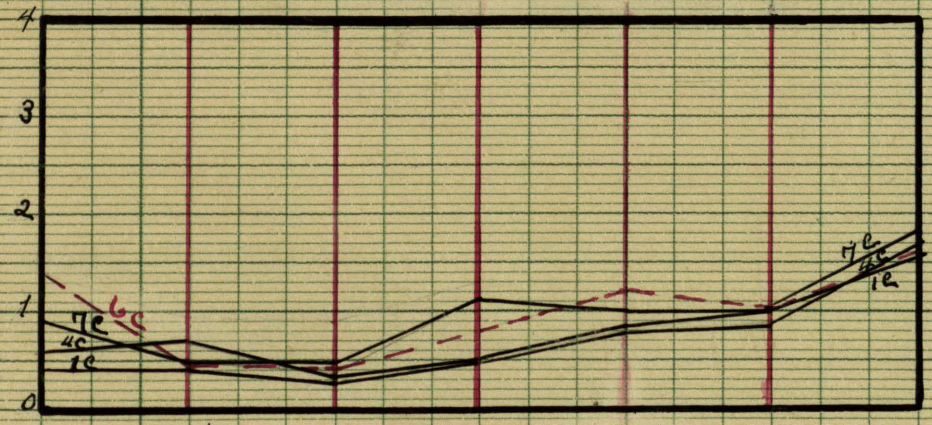
Nov. Dec. Jan. Feby. Mar. Apr. Plate I



1st 8 inches of surface soil



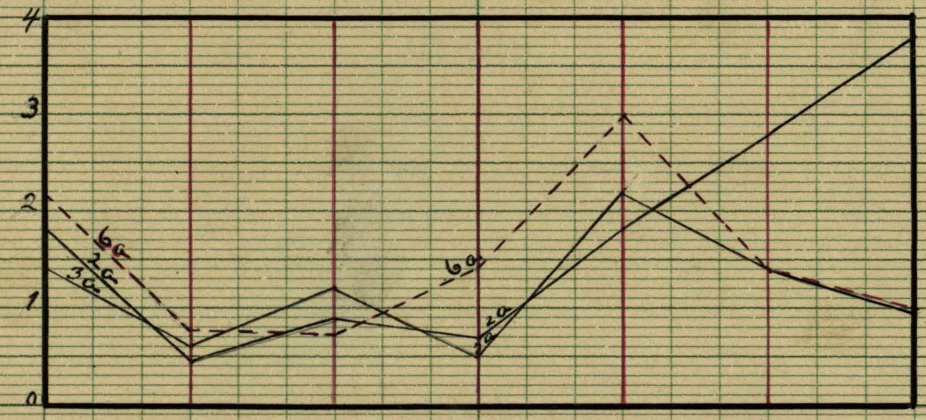
1st 16 inches of subsoil



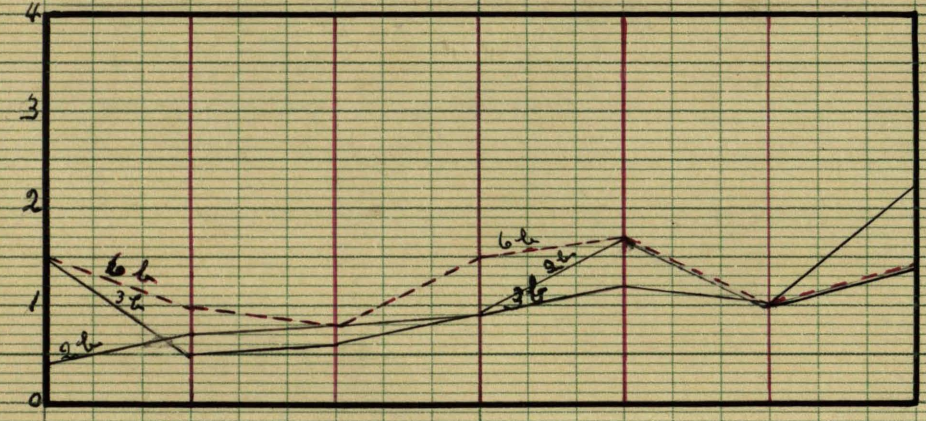
2nd. 16 inches of subsoil

Plate showing the curve of nitrates in the 1st 8 inches of surface soil, the 1st 16 inches of sub soil, and the 2nd. 16 inches of sub soil of Plats 1, 4, 6, and 7 during the experiment.

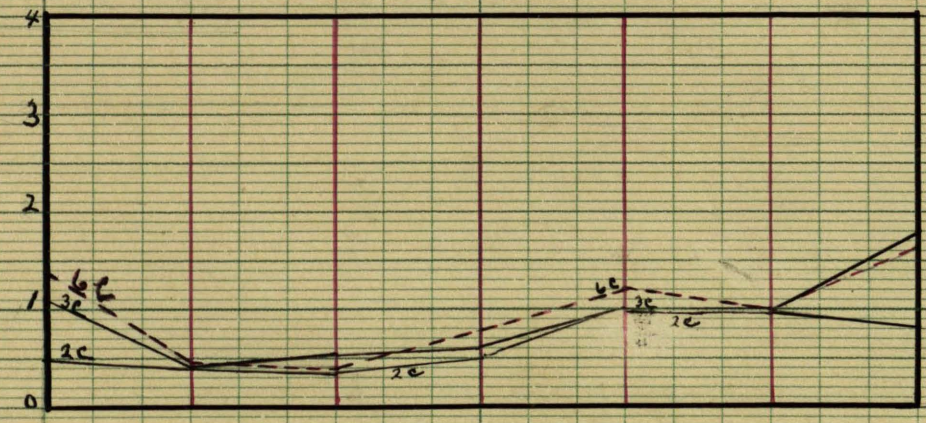
Nov. Dec. Jan Feby. March Apr. Plate II.



1st 8 inches of surface soil.



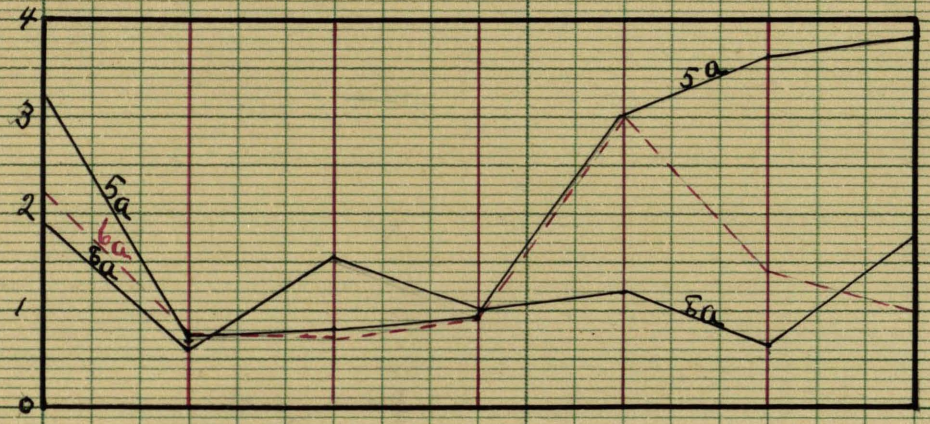
1st 16 inches of subsoil.



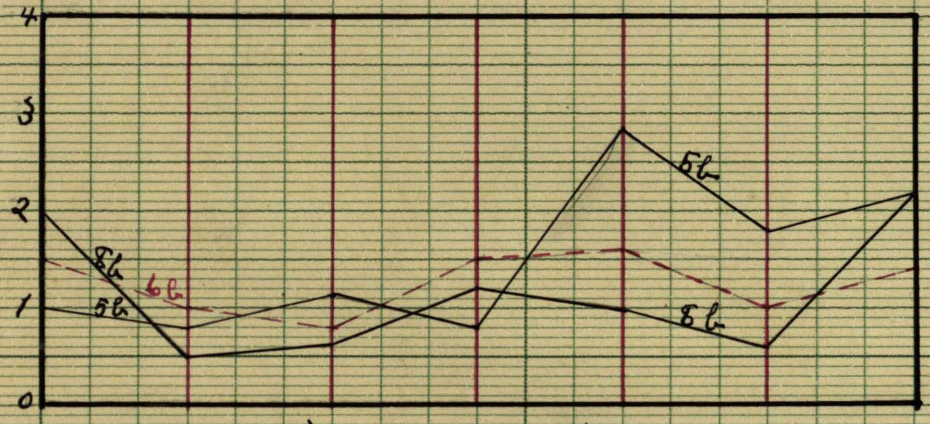
2nd 16 inches of subsoil.

Plate showing the curve of nitrates in the stratas of soil 0-8, 8-24, 24-40 inches for plats no 2, 3 and 6.

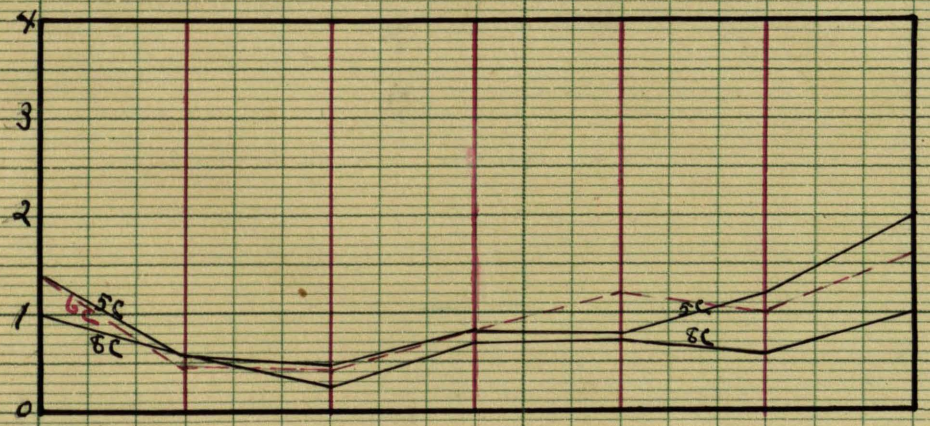
Nov. Dec. Jan. Fuby. March April Plate III.



1st 8 inche of surface soil



1st 16 inches of subsoil



2nd. 16 inches of subsoil

Plate showing the Curve of nitrates in the stratas of soil 0-8, 8-24, 24-40 inches for plats no 5, 6 and 8.

When it comes to the relative value of the different crops for holding or utilizing the nitrates, our results would seem to indicate that wheat hardly measures up in value to that of a heavy sod of timothy and bluegrass, or to alfalfa, Comparing plot No. 4 which is bearing an average crop of wheat with plot No. 6 bearing a heavy sod, we find that for November plot No. 4 has a total 2.80 parts, and for December 1.80 parts, or a difference of one part, while plots 6 in November had 5 parts and in December 2.26 parts, or a difference of 2.74 parts. We have then the sod using 2.74, while the wheat uses 1.00 part. The alfalfa shows a like difference between November and December of 2.50 parts, indicating that, it used 2.50 while the wheat used only one part. The differences in favor of the sod and alfalfa may be due, however, to the difference in age. We must remember that the wheat at this time was very young, while the sod had been set for a number of years and the alfalfa had grown for three seasons. It seems quite possible that these older plants would use more nitrogen than the young wheat, just beginning its growth. But a comparison of the same plots for March and April when all of the plants were making a very vigorous growth, shows .80 parts more nitrates in the wheat plot in April than in March, while in the sod there were 2.40 parts, and in the alfalfa 1.00 part less in April than in March. This again indicates that the sod and alfalfa uses more nitrogen than the wheat. It may be argued that these differences are due to leaching, but a reference to the table given above shows that the precipitation for the months from which the comparison are drawn was insufficient to leach the soil. Notwithstanding this difference in favor of the other plants so far as these investigations go, wheat will remain the most important winter cover-crop for this section, due to its being a regular farm crop.

SUMMARY OF EXPERIMENTAL INVESTIGATIONS.

The points brought out in this investigation may be summarized as follows:

1. There was a marked change or loss of nitrates from the time of the first determination, November 5th to that of March 5th.

2. The most marked change during this period occurred between November 5th and December 5th.

3. There was a very marked increase during February shown by the determinationsmade March 5th.

4. The bare plots show a relatively higher nitrate content on March 5th than did those bearing crops.

The determinations for April 5th shows an actual decrease from those of March 5th for the plots bearing crops while those that were bare shows a considerable increase, proving that the growing plants utilized a large portion of nitrates that were formed.

The plots bearing crops, especially plot No.8 in wheat, showed a somewhat higher nitrate content May 5th than on April 5th, due to the retarded growth of the plants in April, which was a very cold month.

The changes were greater in the first 8 inches of surface soil, second greatest in the first 16 inches of subsoil, and least in the second 16 inches of subsoil.

The determinations tend to indicate that sod and alfalfa utilizedmore nitrogen than did the wheat.

Wheat, however, will always remain a very important winter cover-crop owing to its ability to take up large quantities of nitrates, and being a regular winter farm crop.

SUMMARY OF REPORTS FROM FARMERS OF MISSISSIPPI.

Further south the conditions, as indicated by the data obtained from practical farmers of Mississippi, are somewhat different from those of Missouri. There, from a practical standpoint, oats sown alone or combined with vetch stand first for winter crops. Fifty-nine letters were addressed to practical farmers of Mississippi with questions concerning their experience with various crops,- cowpeas, vetch, velvet beans, clovers, alfalfa, oats and rye, - for green manure and cover-crops. Thirty-three sent returns with the following results:

Eighteen recommended cowpeas for green manure; two clover; six vetch; one rye; five velvet beans, and eight no experience. Thirteen recommended oats for cover or pasture during the winter and to be cut for hay in the spring; eight vetch and oats sown together for winter cover and hay in the spring; five rye for cover, to be plowed under in the spring; and one recommended mellilotus for cover during the winter. Although oats are used more extensively for winter cover, there is no doubt in the mind of the writer but that a combination of oats and vetch is the best cover crop possible for the south. By using the winter turf oats they ripen at the same time as the vetch and can therefore be used for hay or for manure, preferably hay. With those having had experience, it was the unamimous opinionthat the cowpea is the best crop for restoring the fertility of worn soils, and also for hay. Velvet beans have not been extensively tried, but are highly prized by those who have used them. One farmer thought they were worth at least 25 percent more than the cowpea as a soil builder. They will very probably closely rival the cowpea when a quicker maturing variety is produced.

CHAPTER 111

GENERAL CONCLUSIONS.

The facts brought out in the discussion may be summarized as follows:

(1) That nitrates are capable of being washed out of the soil by heavy rains.

(2) That they are washed out of soils not frozen unless there is growing on the soil a crop to take them up as they are formed.

(3) That the loss from leaching is greatest in a warm climate, and least in a cold climate.

(4) That the soils in the cotton states have suffered seriously from washing and leaching.

(5) That this loss to the southern soils may be stopped and the farms restored to their former degree of fertility by the judicious use of green manures and cover crops.

(6) That the best crops for this purpose are those able to assimilate nitrogen from the air.

(7) That of this class of plants the cowpea is the standard in the South, and is closely followed by vetch, velvet beans, the clovers, etc.

(8) That of the nonleguminous plants best adapted for this purpose oats and rye stand first.

(9) That cowpeas, velvet beans, vetch, clovers, etc., should not be turned under before they are mature except in special cases.

(10) That these special cases are those in which the soil has a tendency to pack or run together.

(11) That on soils of this nature the green vines have a tendency to loosen them up and improve the physical condition.

(12) That green vines should never be plowed under on loose sandy soils, and that sometimes on soils of this nature it is best not to plow under the vines until spring.

(13) That the land should always bear a winter crop during the winter months.

(14) That the best time for planting these crops is in September or October but they may be planted earlier or later than this time.

(15) That for Missouri conditions bluegrass and timothy sod and alfalfa are good retainers of nitrates, so far as these investigations show, but from an economic standpoint wheat is the most valuable crop for this purpose.

(16) That the farmers of Mississippi have found either vetch and oats sown alone or combined to be the best cover crop to come between the regular staple crops.

(17) That the majority of the Mississippi farmers recommend the cowpeas as the best green manuring crop for summer use.