U. S. DEPARTMENT OF AGRICULTURE.

FARMERS' BULLETIN No. 16.

LEGUMINOUS PLANTS

FOR

GREEN MANURING AND FOR FEEDING.

BY

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WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1894.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., March 30, 1894.

SIR: I have the honor to transmit herewith for publication as a Farmers' Bulletin an article on the value and use of leguminous plants for green manuring and for feeding, prepared under my direction by E. W. Allen, PH. D., assistant director of this Office. The scientific investigations in this country and abroad on the assimilation of nitrogen of the air by leguminous plants and the practical experiments with numerous varieties of these plants in the fields and in the stables of experiment stations, as well as by progressive farmers, have more definitely established the importance of these crops in maintaining or increasing the fertility of our agricultural lands and in providing our live stock with well-balanced rations. The résumé of this subject from the standpoint of advanced theory and practice, which this article contains, can in my judgment be usefully distributed in all sections of our country.

Respectfully,

A. C. TRUE,
Director.

Hon. J. STERLING MORTON,
Secretary of Agriculture.

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LEGUMINOUS PLANTS FOR GREEN MANURING AND FOR FEEDING.

GREEN MANURING.

Green manuring, or plowing under green crops raised for that purpose, is one of the oldest means of improving the fertility of the soil. It was advocated by Roman writers more than two thousand years ago, and from that time until now it has formed a most important resource of the farmer, especially where the supply of barnyard manure is insufficient. Its advantages are many. The more striking are that it furnishes the surface soil with a supply of the fertilizing materials needed by crops, increases the humus, and improves the physical qualities and the tilth of the soil. As a humus-former green manuring stands next to barnyard manure.

By means of green manuring, land which is practically barren may be brought up to a state of fertility where it will produce profitable crops. As a single instance of this may be mentioned the experiments carried on by the Michigan Experiment Station on the "Jack-pine plains" of that State. In 1888 experiments were undertaken on the light sandy, almost barren, soils of these plains. Green manures were used mainly, supplemented by cheap fertilizers. In three years marked improvement was evident, not only in the physical character of the soil, but also in the increased yields of various crops.

Again, green manuring may be used to take the place of more expensive fertilizers and manures on soils already under cultivation. It is in this latter use that it finds its widest application.

There has been much speculation as to the manner in which the crops commonly used for green manuring could gather such large quantities of fertilizing materials. It will be remembered that the principal fertilizing ingredients required by plants are nitrogen, phosphoric acid, and potash. These are each and all more or less essential to the healthy growth of crops. Consequently they are applied to the soil in the form of commercial fertilizers and other manures. In attempting to explain how the fertility of the soil is maintained by green manuring it has been said that plants with long roots, like clovers, feed deep down in the soil or subsoil on materials beyond the reach of surface-feeding plants; and that when the tops of these plants die down and are mixed with the surface soil they enrich it much the same as an application of barnyard manure. This is undoubtedly true, but it fails to explain how such large quantities of materials can be obtained, especially when clover is grown continuously for a number of years. The question has finally been solved by one of the most interesting and important discoveries yet made in agricultural science. It has been found that certain plants can feed upon the nitrogen in the atmosphere and store it up in their tissues as they grow. They take their phosphoric acid and potash from the soil, but they obtain their nitrogen very largely from the air. Hence they draw from the air a material necessary to the growth of crops, which in the form of commercial fertilizers, as nitrate of soda, ammonium sulphate, dried blood, etc., is paid for at the rate of from 15 to 20 cents a pound.

HOW PLANTS GET NITROGEN FROM THE AIR.

The air we breathe is about four fifths nitrogen and one fifth oxygen. We use the oxygen in breathing but discard the nitrogen. It has been regarded merely as a material for diluting the oxygen, which would otherwise be too strong for our use. All attempts to economically render this nitrogen of the air available for plant food, by chemical means, have been unsuccessful. Recently it has been discovered that the so-called leguminous plants—clovers, peas, beans, lupines, vetches, etc.—can take up this nitrogen of the air, and can grow without being manured with nitrogen if manured with phosphoric acid and potash.

The manner in which this nitrogen assimilation takes place has been carefully and patiently studied by scientists, and although the details are not fully understood the primary cause has been found. It is believed that plants are enabled to get this nitrogen through the activity of the lower forms of life, bacteria or microbes, which can only be seen with the aid of a powerful microscope. These organisms live in the soil and are to be found where leguminous plants have been grown. They produce or cause the plant to produce little nodules, or tubercles, on the roots. It is through these tubercles that the plant gets its atmospheric nitrogen. The air enters the soil by the numerous pores or openings in it, which are produced by plowing, cultivating, and working the soil, by the decay of rootlets, by earthworms, etc. By just what physiological processes the nitrogen assimilation takes place is a question still in dispute among scientists. It is sufficient for practical purposes to know that nitrogen is taken up from the air by the growing plant, directly or indirectly; and that this nitrogen assimilation takes place as a result of the life of bacteria. It is a peculiar fact that few, if any, root tubercles are formed when leguminous plants are manured with nitrogen; the plants must first hunger for nitrogen before the tubercles are formed, and the presence of tubercles indicates that the plant is taking nitrogen from the air.

Now, curious as it may seem, there appear to be different forms of bacteria for different kinds of plants. Hence it sometimes becomes necessary to provide crops with the necessary bacteria before they can use the nitrogen of the air. This is done by applying a light dressing of soil in which the kind of plants it is wished to grow have been previously grown. This is called soil inoculation. It is sometimes necessary in growing a crop on a piece of land for the first time in several years. Suppose, for instance, that peas which had been sown on land manured with phosphates and potash but without nitrogen failed to grow luxuriantly. If the other conditions were favorable, the inference would be that bacteria of the right kind were lacking in the soil, and a light dressing of soil in which peas had previously been successfully grown might be applied. Such treatment as this has been repeatedly tried with success on a large scale.

These discoveries throw a new light on green manuring and on the plants best adapted for green manuring. They recommend it more highly than ever before as a soil renovator and a cheap means of maintaining the fertility of a soil. They show that while both leguminous and non-leguminous plants enrich the soil alike in humus-forming materials, in proportion to the size of the crop, they differ in respect to the source of their nitrogenous materials. While non-leguminous plants derive their nitrogen supply almost exclusively from the soil, leguminous plants may take theirs largely from the air. Consequently, if spurry, buckwheat, mustard, etc. (non-leguminous plants), are grown on the soil and the crop plowed in, the soil is not materially enriched in nitrogen; the process is simply returning to the soil all the nitrogen which the crop took from it. But since leguminous plants may derive the larger proportion of their nitrogen from without the soil—that is, from the air—their use for green manuring actually enriches the soil in nitrogenous matter.

It will thus be seen that by green manuring with leguminous crops it is possible to manure the soil with nitrogen from the air, a free and inexhaustible source, and thus avoid buying fertilizers containing much nitrogen. This greatly lessens the expense for commercial fertilizers, for nitrogen is the most expensive element the farmer has to buy. As stated above, it costs from 15 to 20 cents a pound, while potash and phosphoric acid cost only 5 to 7 cents, or even less. Although grains, grasses, corn, cotton, root crops, tobacco, etc., can not use the nitrogen of the air, green manuring enables them to benefit by it indirectly.

SOME CROPS FOR GREEN MANURING.

Among the leguminous plants more commonly used for green manuring in this country and in Europe are cowpea, alfalfa, clovers, melilotus, serradella, lupines, vetch, and horse bean. Some of these are described below.

COWPEA.

The cowpea is widely used as a green manure in the Southern States. According to the North Carolina Experiment Station, "the cowpea, being a tender annual, should always be sown in the spring. It will give a good yield sown as late as July 1, but the earlier it is sown after danger of frost is passed the heavier the yield. The pea is usually sown broadcast at the rate of 2 bushels per acre and plowed or harrowed in. The cowpea is not affected by heat, and is less sensitive to drought than any of the clovers."

Experiments have shown that cowpeas respond readily to applications of potash and phosphates, and are able to derive their nitrogen very largely from the air. Inasmuch as cowpeas are large gatherers of nitrogen, and also secure considerable amounts of potash and phosphoric acid through their extensive root system, which reaches down to the subsoil, they have a high fertilizing value. How to get the greatest benefit from the fertilizing constituents of cowpeas is one of the problems on which the experiment stations are working. If the cowpeas are plowed under in the fall and the ground left bare until spring a large share of the nitrogen will be leached away. By sowing wheat or rye after the cowpeas are plowed under part of this loss may be avoided. If the vines are cut and allowed to lie on the ground during the winter the nitrogen is rapidly lost. In an experiment at the station in Alabama it was found that vines gathered in October had from 1.45 to 2.62 per cent of nitrogen, while if left on the ground until January they had only about 0.70 per cent, *i. e.*, they lost two thirds of their most valuable fertilizing ingredient.

Experiments at the Louisiana station show that 1 acre of cowpeas, yielding 3,970.38 pounds of organic matter, turned under, gave to the soil 64.95 pounds of nitrogen, 20.39 pounds of phosphoric acid, and 110.56 pounds of potash, of which at least 8.34 pounds of nitrogen, 4.43 pounds of phosphoric acid, and 18.1 pounds of potash were furnished by the roots. Analyses made at the South Carolina Station show that cowpea hay contains 1.42 per cent of potash, 0.39 per cent of phosphoric acid, and 2.71 per cent of nitrogen. Cowpea roots contained 1.19 per cent of potash, 0.28 per cent of phosphoric acid, and 0.94 per cent of nitrogen; the roots and stubble, two months after the crop was harvested, contained 0.83 per cent of potash, 0.26 per cent of phosphoric acid, and 1.35 per cent of nitrogen. Experiments elsewhere showed that the vines from a given area weighed six times as much as the roots, and were 8½ times as valuable for manure.

Cowpeas and melilotus have given good results as green manure on the canebrake lands of Alabama. "Before the land was sowed in melilotus and cowpeas it was not considered worth cultivating. This season (1890) it produced as fine a crop as the best lands of the station highly fertilized."

ALFALFA.

Alfalfa or lucern has long been cultivated in Europe, and is grown quite extensively in some of the Western and Southern States. It seems probable that it may be introduced with advantage into many parts of the Southern States east of the Mississippi, and over a wide tract of the more arid regions of the Southwest. Under favorable conditions it will live from eight to fifteen years, and does not run out as clover does. It has been grown successfully for seven years at the experiment station at Geneva, N. Y., but in recent experiments on 30 farms in different parts of Vermont it was very largely winterkilled. While a Southern climate is more favorable to alfalfa, numerous experiments have shown that it will do well in many localities in the Northern States, and when established will produce from three to five crops each season for a number of successive years. Alfalfa is said to be especially adapted to dry climates, and withstands drought much better than ordinary clovers. For this reason it is largely relied on in Colorado and California, especially where irrigation is used.

The value of alfalfa for green manuring has been quite thoroughly studied by the New Jersey Experiment Station. Seed was sown broadcast at the rate of 15 pounds per acre. A fertilizer containing phosphoric acid and potash with a little nitrogen was applied. It appears from these studies that alfalfa derives nitrogen from some other source than the soil, and draws potash through its long roots from the deeper layers of the subsoil. In three years 90 pounds of nitrogen per acre was applied in the fertilizer, and the crops harvested in that time contained 912.8 pounds of nitrogen per acre. The fertilizing materials contained in the crops harvested in four years are shown in the following table:

Fertilizing ingredients in alfalfa during different seasons.

Year.	Pounds per acre.		
	Nitrogen.	Phosphoric acid.	Potash.
1886	261.6	39.6	203.5
1887	253.6	45.7	286.9
1888	290.2	52.4	292.2
1889	360.0	63.6	255.5

The average of the above table is 304 pounds of nitrogen, 50 pounds of phosphoric acid, and 260 pounds of potash a year. These amounts would be furnished by a dressing of 1,900 pounds of nitrate of soda, 500 pounds of muriate of potash, and 300 pounds of South Carolina superphosphate. The phosphoric acid and potash were naturally derived from the soil. The 300 pounds of nitrogen would cost in the form of nitrate of soda, at the present low price of 15½ cents a pound, $46.50.

RED CLOVER.

Red clover has been cultivated for centuries. It succeeds best in a temperate climate not deficient in moisture. In the central and eastern part of the United States it constitutes one of the most important hay crops. Though not generally grown in the Gulf States it succeeds on the strong clay lands and black prairie soil of the South. It may be grown as far north as Minnesota, but frequently does not thrive in newly settled sections. It has been successfully grown all over Nebraska, where it is recommended for early pasture as well as for hay, and where it withstands drought. It has proved valuable in South Dakota. Most of the experiment stations give favorable reports of this plant. In Nevada, however, without water the growth is light.

As a green manure it is perhaps more extensively used in the United States than any other plant. Twenty pounds of seed per acre is the quantity usually recommended. The seed is frequently adulterated with weed seed. At the Mississippi Station light-colored and dark seed germinated alike in the ground. Clover is sown broadcast. In cold climates spring sowing is customary. The Connecticut Storrs Station recommends sowing after grain in the latter part of July, in order to secure an early crop the next season. In the South seeding in September or October and in February is successful. In Kentucky seed sown between February 2 and March 1 nearly all germinated.

Studies of the root system of red clover grown at the Minnesota Station showed that the amount of roots and the depth to which they penetrate vary greatly, depending on the character of the land. In a favorable soil a plant one month old had a root extending 7 inches into the ground; at two months old it had reached a depth of 2 feet; at five months its length was 5 feet 8 inches. The root development is most extensive on drained land. The stand is also better on drained than on undrained soils.

CRIMSON CLOVER.

Crimson clover, also called scarlet clover and Italian or German clover, grows from 1 to 2 feet high, with flower heads from 1½ to 2 inches long and of a bright crimson color. Though not generally grown in the North it made a growth of 26 inches at the Maine Station. It thrives on soil too light for other clovers. In the South it is valuable on non-calcareous, sandy, or light clay soils. It has been highly recommended for green manuring and its value for that purpose has been studied especially by the Delaware Experiment Station. That station reported that in 1891 2,340 acres of crimson clover were grown in Delaware, 1,277 acres being used for green manuring. It is sown both in the open field and in orchards. The quantity of seed used depends upon the aims of the sower, varying between 5 and 15 pounds per acre. It is also sown among corn, and with a broadcasting machine 4 acres per hour can be seeded. It may be grown either as a winter crop, covering the soil during September, October, and November, or as a summer crop. As a winter crop it may either precede or follow the Southern cowpea vine. In Delaware a very large acreage of field corn is sown to crimson clover immediately after the cultivation of the corn is finished for the season.

Crimson clover is sown in Delaware the latter part of July or during August. In the South the seed may be sown from August till the middle of September or even later in extreme southern latitudes. It is important that considerable growth should be made before winter. On the other hand, to obtain a good stand, one must wait for a suitable season. It is not necessary to prepare the land especially for the clover crop, but the seed may be sown in fields of cotton, corn, or vegetables immediately after the cultivation and without covering. If clover is the only crop a light brushing or rolling is in order. The seed may also be sown among the vines of a pea crop. Crimson clover begins its growth as the peas die, and these two renovating crops supply a very large amount of organic matter to the soil.

Failure to secure a stand of crimson clover is frequent, due sometimes to the seed and sometimes to the season. The newly germinated plants are easily killed by a scorching sun. On stubble land a catch may be secured by harrowing deeply and then sowing the seed and rolling or harrowing lightly.

In Delaware crimson clover can be cut for hay or for silage early in May. In the South it blooms in April. A yield of from 1 to 2 tons of excellent hay may be secured from very thin land. The hay is taken off in time to allow the use of the field for other summer crops. In Delaware some farmers, while plowing under the green crop in orchards, turn the furrows so as to leave the heads of clover above ground. These heads bear seed and thus afford a stand the next year. In cutting for hay in orchards other farmers leave strips of uncut clover along the rows of trees. From these strips the seed is scattered for the next year's crop.

Crimson clover may follow grain or grass as well as cultivated crops. After cultivated crops it usually makes a good catch with slight expense. Orchards on thin soils may be benefited by plowing in crimson clover for several years in succession. On rich soil and for some crops it is possible to incorporate too much organic matter with the soil. Crimson clover leaves the land in good condition for a crop of cotton, corn, or vegetables. It has been found an excellent substitute for nitrate of soda in growing sweet potatoes in Delaware.

At the Delaware Experiment Station crimson clover yielded at the rate of 13 tons 566 pounds of green material per acre (exclusive of roots and stubble), containing 131 pounds of potash, 35 pounds of phosphoric acid, and 115 pounds of nitrogen. As a source of nitrogen for fruits, field crops, and vegetables it has given highly satisfactory results, in some cases surpassing nitrate of soda.

The following illustration of the result of using crimson clover for green manuring is from a recent report of the Delaware Experiment Station:

Seed of crimson clover costing $1 per acre was sown in a corn field near Newark, in 1891, immediately after the last cultivation of the crop. The clover passed out of blossom during the first week of June, 1892. A test made at that time indicated that the green crop then standing weighed 8 tons 600 pounds per acre. It was plowed under on the 5th instant; Mastodon seed corn was planted on the 7th. An adjoining plat upon which tomatoes had been grown in 1891, and upon which no clover had been seeded for many years, was also planted with the same variety of corn on the 7th instant. A portion of this corn on the tomato plat was top-dressed with nitrate of soda, 100 pounds per acre, costing $1. The tomato plat yielded 24 bushels of shelled corn per acre, the tomato plat with nitrate of soda yielded 30 bushels, and the plat manured with crimson clover yielded 48 bushels.

Eight tons 600 pounds of crimson clover from seed which cost $1 per acre added 24 bushels to the corn crop. One dollar invested in nitrate of soda and used as a top-dressing added 6 bushels to the corn crop. Hence in this case $1 invested in clover seed returned four times as much as $1 invested in nitrate of soda. As to the relative amount of labor involved the sowing of the seed and the broadcasting of the nitrate possibly balance each other. Plowing down a green crop is doubtless far more costly than plowing bare ground. This drawback may reduce the above-named apparent gain by approximately 25 per cent.

JAPAN CLOVER.

Japan clover (*Lespedeza striata*) has been very successfully grown at the North Carolina Experiment Station and is strongly recommended as a renovator of worn soils. At the station it was grown on a very poor stiff clay soil with a light dressing of phosphate. Other clovers, lucern, and serradella, did very poorly on this soil, but the Japan clover presented a most luxuriant appearance throughout the season. The seed is broadcasted at the rate of about 12 pounds per acre and covered with a smoothing harrow or roller. The seed costs from 12 to 20 cents a pound, and can be bought of most of the larger seed firms. The seed should be sown in the spring after danger of frost is over, as the plant is very tender. Japan clover seems to prefer a moist clay soil, but does well on almost any soil except pure sand, and thrives without fertilizer on exhausted soils. Drought checks its growth for a time, but not seriously.

The North Carolina Station says:

> The ability to grow on land too poor to produce even broom sedge, and to crowd out all other plants; its dying each winter and leaving its roots to fertilize the soil; and its possessing the nitrogen-fixing power peculiar to the pulse family of plants, place Japan clover at the head of renovating plants adapted to the climate of Southern States. It is unequaled as a restorer of worn fields, such as are generally turned out to grow up in pines.

LUPINES.

The three species of lupines more commonly grown are the white, the yellow, and the blue lupine. The plants are bushy, somewhat woody, and generally too coarse for good fodder, though they are used in some countries for sheep. The seed is exceedingly nitrogenous and in Europe is used for cattle food. As it contains a bitter alkaloid injurious to animals it must be disembittered before feeding. Kellner's process of disembittering lupine seed consists in soaking the seed in water for twenty-four hours, with frequent changes of water, steaming for one hour, and then extracting for two days, with frequent stirring. In the latter operation the discolored water is drawn off frequently and fresh water added. Five pounds daily of this disembittered lupine seed may be fed to cows per 1,000 pounds live weight.

Lupines are much used in Europe for green manuring. They thrive on a light sandy soil, make a rapid growth, and produce large amounts of organic materials, which when plowed into the soil improve it in humus and enrich it in nitrogen. A practice recommended for bringing up very poor soils is to grow a crop of lupine manured with kainit, turn the crop under, and follow it with winter rye manured with Thomas slag phosphate.

In order to derive the greatest possible advantage from the green manuring, the lupines should be sown early in May. By the first half of August, which is believed to be the best time of the year for plowing under, the seed of the lupine will be nearly or quite formed, and the crop will contain the maximum quantity of nitrogenous matter. Four, or better six, weeks should intervene between the plowing under of the lupine and the sowing of the rye.

Under such a rotation a poor sandy soil will gradually improve in humus until the change is perceptible to the eye in the darker color of the soil, and there will likewise be an increase in fertility.

In Europe large tracts of barren waste have been brought into condition for profitable cultivation by green manuring with lupines treated with phosphates and potash salts.

COMPOSITION OF GREEN LEGUMINOUS CROPS.

The following table gives the average amounts of water and fertilizing materials in 100 pounds in a number of green leguminous crops:

Fertilizing ingredients in 100 pounds of green leguminous crops.

	Moisture.	Nitrogen.	Phosphoric acid.	Potassium oxide.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
Red clover	80.00	0.53	0.13	0.46
White clover	81.00	0.56	0.20	0.24
Alsike clover	81.80	0.44	0.11	0.20
Crimson clover	82.50	0.43	0.13	0.49
Alfalfa	75.30	0.72	0.13	0.56
Cowpea	78.81	0.27	0.10	0.31
Serradella	82.59	0.41	0.14	0.42
Soja bean	73.20	0.29	0.15	0.53
Horse bean	74.71	0.68	0.33	1.37
White lupine	85.35	0.44	0.35	1.73
Yellow lupine	83.15	0.51	0.11	0.15
Flat pea (*Lathyrus sylvestris*)	71.60	1.13	0.18	0.58
Common vetch	84.50	0.59	1.19	0.70

GREEN MANURING COMPARED WITH FEEDING THE CROP.

In spite of the many advantages of green manuring, there are conditions under which it can not be regarded as a rational and profitable practice. It involves the absolute waste of large quantities of the very best kind of fodder. For this reason green manuring on good soils can only be recommended when the conditions of farming do not admit of the careful preservation of manure. The crops should be fed to animals and the manure carefully saved and returned to the soil. It is in this manner only that the full value of the crop can be secured. By feeding the crop this animal food is saved, and at the same time from three quarters to nine tenths of the fertilizing materials (nitrogen, phosphoric acid, and potash) in the crop may be returned to the soil in the manure, if this is properly cared for. Animals need for their nutrition nitrogen, fat, and carbohydrates (starch, sugar, etc.). The nitrogen in foods is in the form of protein (albuminoid materials). It is the same nitrogen which in green manuring enriches the soil. These leguminous crops are unusually rich in protein—far richer than most other coarse fodders. For instance, while hay from grasses contains from 6 to 8 per cent of protein, red clover hay contains 12.5 per cent, alfalfa hay 14.3 per cent, and cowpea hay 16.6 per cent of protein. If grass hay and corn are fed, such concentrated feeding stuffs as cotton-seed meal, gluten meal, linseed meal, etc., must be fed to make up the supply of protein needed. If leguminous crops are fed, much less grain will be required.

As nitrogen is the most expensive fertilizing element, so protein (nitrogen) is also by far the most expensive food element. By feeding the leguminous crops instead of plowing them under a twofold result is secured—animals are nourished without buying expensive grain feeds, and the soil is enriched to very nearly the same extent as in green manuring.

Beyond question the nitrogen of the air, which is obtained without cost through the agency of leguminous plants, is best utilized in improving the productiveness of the land and increasing the profits of the farm when it is used in the production of milk and meat and thereby in the production of cheap barnyard manure. What has been said of the nitrogen applies also to the carbohydrates and fats which the plant derives from the carbonic acid of the air. If the crop is fed, the carbohydrates and fat serve to nourish the animal and a portion in turn passes into the barnyard manure, and when applied to the soil has a favorable effect on the humus formation. This is the true economy of material. It is following out the law of nature. Its profitableness will depend upon the price of feeding stuffs in general. The higher the prevailing price of hay and other feeding stuffs the larger will be the profit from feeding the crop rather than using it for green manuring. Let us consider a few examples of the value of a crop for green manuring and for feeding on different kinds of soils.

SERRADELLA ON MEDIUM SANDY SOILS.

Take, for instance, the case of serradella on the better class of sandy soils. This plant does well on medium light sandy soils. It may be sown among winter rye in spring. Under these conditions it produces an unusually luxuriant vegetation which may either be plowed under with good effect on the crop following, or it may be pastured. Serradella is an excellent fodder plant and may be fed with none of the danger attending the feeding of lupines. It may be fed either green or as hay or silage. It is eagerly eaten by all kinds of farm animals, retains its palatability and food value up to the end of blooming, and has a very favorable effect on the secretion of milk.

The claim is frequently made, in advocating growing serradella for green manuring, that it is an exceedingly cheap means of securing nitrogen; that with a small expenditure for seed, and no extra labor except that of sowing the seed, a large amount of nitrogen is secured from the air. Admitting this, has not this nitrogen, in the form in which it exists, namely, as protein, a much higher value when used for feeding animals than when plowed under? If it is a cheap source of nitrogen for manuring, is it not also a cheap source of protein for feeding, especially when three quarters of the nitrogen in the crop is recovered in the manure?

A German authority on feeding and farm management has calculated the matter on a financial basis. Assuming an average crop of 17,600 pounds of green serradella, which is a moderate crop, he finds the nitrogen in the crop from an acre to be worth $11.06. This is taken as the value of the crop for green manuring, as the nitrogen is the only fertilizing element not derived from the soil, and the barnyard manure furnishes nearly as much humus as green manuring.

The estimated profit from feeding the crop of 17,600 pounds of green serradella to milch cows, when the barnyard manure is returned to the soil, is $23.12. In this calculation every possible expense attending the feeding is taken into account, including care of animals, interest on money, cost of carting the barnyard manure to the land, etc., and allowance is made for the phosphoric acid and potash sold in the milk. The comparison stands then as follows:

Profit from feeding crop of serradella from 1 acre	$23.12
Value of crop of serradolla from 1 acre for groen manuring	11.06
Difference	$12.06

This calculation shows the crop of serradella to be more than twice as valuable for feeding as for green manuring.

The above calculation assumed a daily milk yield of 7½ quarts, sold at 2¼ cents per quart. On the basis of only 1½ cents per quart of milk, the feeding value would be $13.52, or still $2.46 higher than the value for green manuring.

GREEN MANURING ON MEDIUM RICH SOILS.

Green manuring on medium rich soils has much less to recommend it than on sandy soils. Although the green manuring of light sandy soils with lupines is often of very great advantage in enriching the soil in humus, this advantage does not hold good in the case of better soils.

There are other plants better adapted than lupines to serve as fallow crops on these better soils. Serradella does well, but as a rule is not to be recommended for a principal crop, and when sown with rye, giving a good yield, it is often so choked out as to amount to very little. But where it can be grown with advantage as a first crop on better soils it must be fed to be utilized to the fullest extent, as pointed out above.

Peas and vetch are especially adapted for fallow crops, and can be recommended for green manuring. But as they are also good fodder plants, all that has been said above regarding this subject applies to them with equal force.

An experiment of interest in this connection was made at the Agricultural Institute at Halle, Germany, in 1891. About 3 acres of land was used which had been in winter wheat in 1890 and in winter rye in 1891. A mixture of 194 pounds of white field peas, 44 pounds of common sand vetch, and 35 pounds of yellow lupine seed per acre was sown August 11. The crop was plowed under October 28. A good growth had been made and the crop was fitted either for green manuring or for feeding. The yield was at the rate of 8,650 pounds of green material per acre. This contained by analysis 0.575 per cent of nitrogen, or 49.74 pounds of nitrogen per acre, which at 15 cents per pound gave a value for the crop for green manuring of $7.46 an acre.

In the spring of 1892 white pearl barley was sown on the whole area and also on an adjoining piece not green manured. The crops were harvested August 18, with the following results per acre:

Yield of barley per acre with and without green manuring.

	Grain.	Chaff.	Straw.
	Bushels.	*Pounds.*	*Pounds.*
Plat green manured with peas, vetch, and lupine	61.38	366	3,260
Plat not green manured	61.48	385	2,908

An effect of the green manuring is only noticeable in the amount of straw, which is larger by about 350 pounds per acre where the mixture of peas, vetch, and lupine had been plowed in.

The barley crop from the green-manured plat contained 68.56 pounds of nitrogen per acre, and that from the plat not green manured 56.6 pounds of nitrogen. This difference of 11.96 pounds of nitrogen is nearly all accounted for by the nitrogen contained in the seed sown on the green-manured plat, so that it may be that on this medium rich soil green manuring was without any effect whatever on the crop immediately following it. The pea and vetch plants produced root tubercles, and it is probable that had the plants been allowed to fully develop and ripen the effect of the tubercles would have been much more apparent in the amount of nitrogen in the crop plowed under. But the richer the soil is the larger the proportion of nitrogen which will be taken from the soil and the less from the air. This nitrogen-gathering appears to go on best in a soil deficient in available nitrogen, as already mentioned.

The author estimates the green forage as worth $3 per ton for feeding, which would make the crop worth $13 per acre, or $5.54 more per acre than the estimated value for green manuring.

GREEN MANURING ON SANDY LOAM SOILS.

Compared with the above green-manuring trial on medium rich soil, the result was quite different in a similar trial in 1891 on a sandy loam soil poor in humus. A piece of land which for many years had received uniform cropping and manuring was divided into two plats of about one fourth acre each. Rye had been grown on both plats that season. On one plat white field peas were sown in the rye stubble August 15. The other plat was given the same preparatory treatment, but remained bare. Both plats were plowed November 2. The pea vines had grown to a height of 15 to 18 inches, and a large weighed sample showed that the green crop was at the rate of 3½ tons per acre, containing 37⅓ pounds of nitrogen.

March 23, 1892, barley was sown on both plats. The green-manured plat received no other manuring, but the other plat received an amount of nitrate of soda furnishing 28 pounds of nitrogen per acre. The barley was harvested August 9. The yield on the two plats was practically the same. The agreement in percentage of nitrogen is equally striking. The total nitrogen per acre in the crop from the green-manured plat was 60.34 pounds, and from the nitrate of soda plat 60.12 pounds. The green manuring, with 37.33 pounds of nitrogen per acre, had given a result equally as good in every way as an application of 28 pounds of nitrogen per acre in the form of nitrate of soda. But even with this favorable result there was no financial advantage from the green manuring as shown by this single crop. It furnished 37.33 pounds of nitrogen per acre, which at 15 cents per pound would be worth only $5.60, which would no more than pay for the pea seed used.

ALFALFA AND CRIMSON CLOVER FOR FEEDING.

Suppose that, instead of being plowed under, the alfalfa grown at the New Jersey Experiment Station, as referred to (p. 9), had been fed to animals and the manure carefully saved and returned to the soil. The total yield of four cuttings during the season of 1889 was about 23 tons of green alfalfa per acre. The value of this crop for fodder at $3 per ton would be $69 as compared with its value of $46.50 for green manuring, and it is fair to assume that some $35 worth of nitrogen would be returned to the soil in the manure. The crop of 13¼ tons of crimson clover reported elsewhere (p. 11) would be worth about $40 for feeding as compared with $17.25 for green manuring. When made into hay crimson clover is an excellent feeding stuff and rivals bran in composition. Instead of cutting the crop it may be pastured to advantage.

COWPEA FOR FEEDING.

A prominent agriculturist in the South says of the cowpea:

> For the production of a nitrogenous food in the shape of a forage crop the cowpea vines are almost without a rival. * * * On an acre of ordinary land this crop will probably produce more digestible food than either oats or corn. The manure resulting from feeding this crop is of the highest value and should be carefully preserved and returned to the land.

At the Rhode Island Experiment Station a crop of 17½ tons of green cowpea forage was harvested. This contained 157½ pounds of nitrogen, which at 15 cents per pound would make the crop worth $23.63 per acre for green manuring. At $3 per ton the 17½ tons would be worth $52.50 for feeding and there would be less than one third of the fertilizing ingredients lost in feeding the crop.

What has been said of the above crops applies with equal force to other crops commonly used for green manuring. The matter resolves itself into this, that on medium and better classes of soils green manuring is not as profitable as feeding the crop. When the crop is fed the stubble and roots are left to the soil, and they together with the manure enrich the soil in fertilizing materials and in humus to very nearly the same extent as plowing the whole crop under. With the exception of perhaps one fourth of the fertilizing materials, the soil shares all the advantages to be obtained from green manuring when the crop is fed and the manure preserved. More labor is involved in feeding but in return more milk and more beef are made, or the purchase of expensive grain is largely avoided.

In a rational system of farming not a single pound of protein which can be used as food for stock should be plowed into the soil. Of course there are conditions under which green manuring is to be recommended in preference to feeding the crop, and unfortunately such conditions prevail at present over a considerable part of this country. Unless the manure is carefully collected and preserved the advantages from feeding disppear to a large extent. In some sections of the country, even where manures are at present necessary, little or no care is taken of the barnyard manure. A large proportion of the fertilizing and humus-forming ingredients is lost, either through leaching, surface-washing, or fermentation and decay. The farmer who permits this waste, whether through ignorance or carelessness, is sure to feel the loss either in diminished crops or in increased bills for fertilizers. The barnyard manure should be as scrupulously cared for as any other farm product. It has been repeatedly shown in experiments in the East in growing stock for beef, mutton, and pork that a very large proportion of the profit was in the manure. If the value of the manure was left out of the account there was little or no profit from the operation. If the manure was valued at current rates for fertilizing materials a fair profit was apparent.

ADVANTAGES OF SOILING.

The advantages of soiling, or feeding animals largely or wholly on green forage crops in the barn instead of pasturing them, are that less land is required to maintain a given number of animals, the food supply can be better regulated, the animals do not waste their energy in searching for food, and the manure can all be saved and applied to the soil. The arguments for partial soiling are that the amount of feed furnished by pastures is very irregular, being usually abundant and of good quality early in the season, but falling off later from droughts or early frosts. In the case of milch cows unless some supplementary food is given at such times the milk flow diminishes and the cows fall off in flesh.

Concerning the relative amounts of food furnished by pasturing and by soiling, the Pennsylvania Experiment Station found in experiments in two years that "in round numbers we can produce from three to five times as much digestible food per acre by means of the soiling crops (rye and corn or clover and corn) as is produced by pasturage such as is represented by our small plat." The plat in question was believed to fairly represent the average pasture. From feeding trials with the above soiling crops and pasture grass the average yield of milk per acre was calculated as follows:

Yield of milk per acre of land.

	1888.	1889.
	Pounds.	*Pounds.*
Soiling	3,416	5,671
Pasturage	928	1,504
Difference	2,488	4,167

It will be understood that the above is partly an estimate, but it points very strongly in favor of soiling.

Trials at the station in Wisconsin showed that "by soiling in summer a certain area of land will yield double the amount of milk and butter that it will when pastured."

The Connecticut Storrs Experiment Station maintained 4 cows from June 1 to November 1 on a little less than 2½ acres of soiling crops with the addition of a very light grain and straw feed.

At the Ontario Agricultural College and Experimental Farm about three fourths of an acre of soiling crops (green clover, green peas, tares, oats, and corn fodder) was sufficient, with the addition of 252 pounds of wheat bran, for 2 cows for sixty three days. "We might expect, therefore, to grow on about 1 acre sufficient green food to feed a cow for two hundred days under ordinary conditions."

If soiling is to be practiced it is important to have a succession of green fodders throughout the growing season, with each in its best stage of growth for feeding. There should be no breaks in the succession and each crop should be used as nearly as possible at the time when it contains the largest amount of valuable food constituents.

From three years of experience and observation in the practice of soiling, the Connecticut Storrs Station suggests the following series of crops for soiling in central Connecticut:

Crops for soiling in central Connecticut.

Kind of fodder.		Amount of seed per acre.	Approximate time of seeding.	Approximate time of feeding.
1. Rye fodder	bushels	2½ to 3	Sept. 1	May 10-20.
2. Wheat fodder	do	2½ to 3	Sept. 5-10	May 20-June 5.
3. Clover	pounds	20	July 20-30	June 5-15.
4. Grass (from grass lands)				June 15-25.
5. Oats and peas (each)	bushels	2	Apr. 10	June 25-July 10.
6. Oats and peas (each)	do	2	Apr. 20	July 10-20.
7. Oats and peas (each)	do	2	Apr. 30	July 20-Aug. 1.
8. Hungarian grass	do	1½	June 1	Aug. 1-10.
9. Clover rowen (from 3)				Aug. 10-20.
10. Soja beans	bushels	1	May 25	Aug. 29-Sept 5.
11. Cowpeas	do	1	June 5-10	Sept. 5-20.
12. Rowen grass (from grass lands)				Sept. 20-30.
13. Barley and peas (each)	bushels	2	Aug. 5-10	Oct. 1-30.

The growing of a leguminous plant and a cereal together, as oats and peas, to be fed as green forage, has proved quite popular where it has been tried. The experiment stations in nearly every State have tested the adaptability of various fodder plants, leguminous and non-leguminous, and can furnish information as to selection, where seed can be obtained, etc.

By a judicious selection of soiling crops not only can a much larger number of cows be kept on a given area of land, but the land may be brought into a higher state of cultivation and fertility, and much grain may be spared.

Soiling is a feature of a more intensive system of farming, and finds more extensive application as the value of the land increases.

VALUE OF LEGUMINOUS CROPS FOR FEEDING.

Why should the farmer go on raising meadow hay as his main supply of coarse fodder and buying grain to supplement it, when by growing leguminous crops the nitrogen required by animals can be produced at the lowest cost? The crops of red clover, crimson clover, Japan clover (*Lespedeza*), cowpea, alfalfa, soja bean, horse bean, serradella, and many others of this class far surpass common hay in the food materials they contain, both pound for pound and in yield per acre. They may be grown as catch crops and used for soiling or pasturage, or they may be grown for making hay or silage. By mixing the green crops with corn and ensiling the two together a palatable and nutritious food is produced which is much richer in protein (nitrogen) than silage made from corn alone.

The cultivation of these leguminous plants involves somewhat more labor, as a rule, than raising grass hay, but it is believed that it will prove profitable for it enables the farmer to raise his own concentrated feed at the same time that he raises his coarse fodder. For instance, a recent experiment has indicated that soja-bean meal is fully equal to cotton-seed meal for milk and butter production. This meal is one of the richest feeding stuffs we have. It exceeds linseed meal and gluten meal in protein (nitrogen) and far exceeds these and cotton-seed meal in fat. It is only surpassed in protein by cotton-seed meal and some of the oil cakes little used in this country. The beans can be thrashed out and ground and the straw fed as coarse fodder. This straw is richer in food materials than a good meadow hay. It contains 9½ per cent of protein while meadow hay averages about 7½ per cent. The cowpea may be treated in similar manner. The ground cowpeas are a richly nitrogenous feed, although not as rich as soja-bean meal; and the vines are nearly or quite equal to clover hay and far surpass grass hay in richness.

The following table shows the average composition of hay from leguminous crops as compared with hay from grasses:

Average composition of hay from grasses and leguminous crops.

Hay from—	Water.	Protein.	Carbohydrates.	Fat.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Red top	8.9	7.9	76.0	1.9
Orchard grass	9.9	8.1	73.4	2.6
Timothy	13.2	5.9	74.0	2.5
Hungarian grass	7.7	7.5	76.7	2.1
Kentucky blue grass	15.0	8.2	78.1	4.4
Red clover	15.3	12.3	62.9	3.3
Crimson clover	13.4	14.0	55.6	4.1
Japan clover	10.9	13.8	63.1	3.7
Alsike clover	9.7	12.8	66.3	2.9
White clover	9.7	15.7	63.4	2.0
Alfalfa	8.4	14.3	67.7	2.2
Cowpea	10.7	16.6	62.3	2.9
Serradella	9.2	15.2	65.7	2.6
Vetch	8.4	14.5	67.8	2.1
Soja bean	6.3	14.5	66.6	5.6
Average for grasses	10.94	7.52	75.64	2.70
Average for leguminous plants	10.20	14.37	64.14	3.23

It may be said in general that 100 pounds of hay from leguminous crops contains about twice as much protein as 100 pounds of hay from grasses. The leguminous hay may be safely estimated as worth from one fourth to one third more for feeding than common hay. This is true in spite of the fact that it does not usually command a higher price in the markets, owing to certain prejudices against its use.

Assuming that the common grasses yield 2 tons of hay to the acre, and clovers, etc., 3 tons of hay, the amounts of food materials and fertilizing materials in the crops are approximately as follows:

Relative yield of food and fertilizing materials in crops of hay from grasses and from leguminous crops.

Hay from—	Assumed yield per acre.	Food materials in crop per acre.			Fertilizing materials in crop per acre.		
		Protein.	Carbohydrates.	Fat.	Nitrogen.	Phosphoric acid.	Potash.
	Tons.	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*	*Pounds.*
Red top	2	158	1,520	38	23.0	7.2	20.4
Timothy	2	118	1,480	50	25.2	10.6	18.0
Red clover	3	369	1,887	99	62.1	11.4	66.0
Alfalfa	3	429	2,081	66	65.7	15.3	50.4
Cowpea	3	408	1,809	87	58.5	15.6	44.1
Soja bean	3	435	1,998	168	69.6	20.1	32.4

The amount of hay produced on different farms varies so widely that it is difficult to strike an average, especially for the leguminous crops. It will be seen that on the above basis, which is believed to be a fair one, the leguminous crops furnish from two to four times as much protein per acre as common grasses, together with much more fat and rather more carbohydrates. They also contain nearly three times as much nitrogen and about twice as much potash. It should be remembered that under favorable conditions they may draw a large proportion of this nitrogen from the air, instead of depleting the soil, and that their long roots enable them to feed upon the potash deep down in the soil beyond the reach of surface-feeding plants.

SUMMARY.

(1) Green manuring improves the physical properties of the soil by making the soil more porous and adding to its supply of humus. It brings up the dormant plant food from deep down in the soil and deposits it near the surface, where it can be used by plants feeding near the surface.

(2) Green manuring with buckwheat, Hungarian grass, and other non-leguminous plants adds practically nothing to the soil which was not there before, except a mass of vegetable matter which decays and goes to form humus.

(3) Green manuring with clovers, peas, beans, lupines, etc. (leguminous crops), actually enriches the soil in nitrogen drawn from the air. These plants can grow with very little soil nitrogen. They store up the nitrogen of the air as they grow, and when plowed under give it up to the soil and to future crops. It is the cheapest means of manuring the soil with nitrogen.

(4) But animals, as well as plants, require nitrogen for food. By feeding the crops of clover, cowpea, etc., only about one fourth of the fertilizing materials of the crop is lost if the manure is properly cared for. As the nitrogen of the air is the cheapest source of nitrogen for

plants, so it is the cheapest source of protein (nitrogen) for animals. The leguminous crop is best utilized when it is fed out on the farm and the manure saved and applied to the soil. The greatest profit is thus secured and nearly the same fertility is maintained as in green manuring.

(5) For renovating worn or barren soils, and for maintaining the fertility where the barnyard manure is not properly cared for, green manuring with such leguminous crops as cowpea, clovers, and lupines is recommended. A dressing of potash and phosphates will usually be sufficient for the green manuring crop.

(6) The practice of green manuring on medium and better classes of soils is irrational and wasteful. The farmer should mend his system so that the barnyard manure will be as well cared for as any other farm product. Loss from surface washing, leaching, fermentation, and decay should be guarded against. Then the feeding of richer food will mean richer manure and better and cheaper crops.

(7) The system of soiling, or feeding green crops in the barn in place of pasturage, enables a larger number of animals to be kept on a given area of land, and the manure to be more completely saved. For this purpose leguminous crops are extremely valuable.

(8) Hay from leguminous crops is about twice as rich in protein as hay from grasses. In the one case this protein (nitrogen) is obtained very largely from the atmosphere; in the other it is all drawn from the fertility of the soil. Leguminous crops yield larger crops of hay to the acre than grasses. Hence the production of food materials on an acre, especially protein, is several times larger with leguminous crops.

(9) If allowed to ripen, the seed of the cowpea and soja bean furnishes an extremely rich concentrated feed which can be ground and fed in place of expensive commercial feeds. The straw remaining may be fed as coarse fodder, for it is richer than ordinary hay.

(10) Grow more leguminous crops. They furnish the cheapest food for stock and the cheapest manure for the soil. They do this because they obtain from the air a substance necessary for plants and animals alike, which costs in the form of fertilizers and feeding stuffs from 15 to 25 cents a pound.

FARMERS' BULLETINS.

These bulletins are sent free of charge to any address upon application to the Secretary of Agriculture, Washington, D. C. Only the following are available for distribution:

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No. 16. Leguminous Plants for Green Manuring and for Feeding. Pp. 24.
No. 18. Forage Plants for the South. Pp. 30.
No. 19. Important Insecticides: Directions for Their Preparation and Use. Pp. 20.
No. 21. Barnyard Manure. Pp. 32.
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