DEPARTMENT OF AGRICULTURE

CENTRAL EXPERIMENTAL FARM
OTTAWA, CANADA

CLOVER AS A FERTILIZER

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To the Honourable

The Minister of Agriculture.

SIR,—I have the honour to submit for your approval Bulletin No. 40 of the Experimental Farm series on 'Clover as a Fertilizer.' This has been prepared jointly by Mr. Frank T. Shutt, Chemist of the Dominion Experimental Farms, and myself.

The question of the maintenance of the fertility of soils is one of the utmost importance to farmers. The soils of a country are a natural resource of immense and permanent value, which should be so treated as to increase rather than lessen in value as time goes on. Where soils have had their productiveness impaired by careless farming, they may be rapidly improved or gradually restored to fertility by occasional dressings of barn-yard manure and the ploughing under of crops of green clover Such treatment will also be found of inestimable value in maintaining the fertility of farm lands generally. In Bulletin No. 40 evidence is submitted gathered chiefly from the experimental work conducted for some years past at the Central Experimental Farm, as to the usefulness of clover for this purpose. It is believed that this information will be of much value to farmers in all those parts of the Dominion where clover can be successfully grown.

I have the honour to be, sir,

Your obedient servant,

WM. SAUNDERS,

Director Experimental Farms.

OTTAWA, July 7, 1902.

Clover: 2nd Year's Growth. Illustrating extensive root system.

	Tons.	Lbs.
Foliage	13	1,640
Roots (to a depth of 2½ ft.).....	6	1,112

June 24, 1902.

CLOVER AS A FERTILIZER

BY

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All practical and observant farmers know that the producing power of soils is steadily reduced when successive crops are grown and no adequate return of manure or other fertilizer made. It is also generally known that this exhaustion of fertility is more rapid when no regular system of rotation is followed. Why is this? The reasons are these: First, there is the withdrawal of plant food by the growing crops; and second, the gradual loss of humus or organic matter, which brings about an unfavourable condition of the soil. We hope to show in this bulletin that the growing and ploughing under of clover may be employed to lessen or prevent these effects of wasteful farming.

Loss of Plant Food.

Plants take the food necessary for their maintenance and growth from two sources—the air and the soil. Hence, every crop harvested must lessen the store of plant food in the soil and leave it more or less impoverished. The elements thus withdrawn are chiefly nitrogen, phosphoric acid, potash and lime. These are found in large proportions in most soils, where they exist in two conditions—soluble or readily available, and insoluble and hence unavailable. Only a small percentage of the total amount of plant food in a soil exists in the more soluble and valuable form; much the larger part is locked up, and hence is of no immediate value to growing crops. By the practice of good methods of cultivation, such as are usually followed by the industrious farmer, portions of the insoluble plant food are gradually changed into soluble and available material. Where no systematic efforts are made to maintain the fertility of the land, and where there is also a neglect of cultivation, the small proportion of plant food existing in soluble forms in the soil is soon so far exhausted that satisfactory crops cannot be grown, and such land is often regarded as worn out and useless. The fact is that usually it is only the soluble plant food which is exhausted; the larger portion, in insoluble form, is still ready to respond to good farming, by which it may be gradually brought to such condition as will result in profitable returns.

Large Stores of Fertility in the Soil.

It has been estimated from the results of many analyses that good average agricultural lands in Europe contain of these important elements of fertility, in each acre of soil a foot deep, about the following proportions:—Nitrogen, 3,500 lbs. or more; phosphoric acid, from 3,000 to 6,000 lbs.; and potash, 5,000 to 8,000 lbs. Analyses made at the Experimental

Farm Laboratories during the past twelve years clearly show that the soils of Canada compare most favourably with those of Europe as regards the quantities of these essential constituents. Lime is also present in widely varying proportions. Where a soil has been partly or largely formed from the disintegration of lime-stone rocks, this element is usually present in sufficient quantity for all the requirements of plant growth for many years; but where the rocks from which the soil has been mainly derived contain little or no lime, this ingredient is sometimes deficient. Where lime forms less than one per cent it is deemed wise to give an occasional dressing of this substance, especially to such soils as are of a clayey nature.

Soil Exhaustion by Growing Crops.

The extent or rate of soil exhaustion from cropping is indicated by the particulars in the following table, which gives the approximate amounts of the essential elements of fertility removed in ten years from an acre of land by ordinary farms crops, where the yields mentioned are obtained.

PLANT FOOD REMOVED BY CROPS IN TEN YEARS.

Yearly yield per acre.	Nitrogen.	Phosphoric Acid.	Potash.
	Lbs.	Lbs.	Lbs.
Timothy hay, two tons per acre.	600	400	900
Oats, 50 bushels per acre of grain with 2,200 lbs. of straw.	460	164	356
Spring wheat, 25 bushels of grain per acre with 2,200 lbs. of straw.	422	233	395
Barley, 35 bushels per acre of grain with 2,000 lbs. of straw.	325	164	270
Indian corn grown for fodder to the late milk or glazing stage, 15 tons per acre.	660	330	1,170
Turnips, roots only (the tops being left on the land to plough under), 15 tons per acre.	540	300	1,140
Mangels, roots only, 15 tons per acre.	570	270	1,149
Carrots, roots only, 15 tons per acre.	600	270	780
Sugar beets, roots only, 15 tons per acre.	630	240	1,110
Potatoes, tubers only, 200 bushels per acre.	408	192	684
Apples (trees in full bearing), fruit, leaves and wood.	650	150	900

We thus see that reduced yields must inevitably follow successive cropping (unless plant food is from time to time returned); for the amounts given in the above table represent for the most part withdrawals from that limited store of immediately available plant food to which we have already drawn attention. If, during the ten years referred to, the land has had regular dressings of barn-yard manure, say, once in five years, of about 20 tons to the acre, there would by this means be restored to the soil about 400 lbs. of nitrogen, 200 lbs. of phosphoric acid, and 360 lbs. of potash, with the further advantage of a large addition of humus. With a suitable rotation of crops this return would do much towards making up the losses mentioned.

The crop producing power of soils is also lessened under such circumstances as we have referred to, by the wasting of their organic matter. Humus,

which is the term applied to this semi-decomposed vegetable matter, results from the partial decay in the soil of roots and other parts of plants. Though not in itself a direct form of plant nourishment, it is nevertheless one of the most important constituents of all fertile soils.

Since the value of green manuring, that is the turning under of a growing crop, such, for instance, as clover, is partly due to the humus that it eventually furnishes, we may consider briefly the chief functions of this constituent.

Functions of Humus.

It is the natural storehouse and conservator of nitrogen, which element is the most expensive of all plant foods when it becomes necessary to purchase it in commercial fertilizers. Where humus is abundant in the soil, it is associated with a liberal supply of nitrogen, and it has been noticed that the amount of humus present gives an excellent indication of the quantity of organic nitrogen the soil contains. It has also been observed that as the humus disappears the nitrogen goes with it.

Humus furnishes the food upon which the micro-organisms in the soil live. These convert its organic nitrogen into nitrates, the compounds which alone can supply crops with their nitrogen.

It contains also considerable quantities of mineral food constituents. These, in the further decomposition of the humus,—a process continually going on in the summer when the soil is moist—are liberated in forms available to growing crops. In this way humus furnishes a large proportion of the potash, lime, &c., used by crops.

Humus increases the power of soils to absorb and hold moisture. This is a very important function. Since all the plant food furnished by the soil must be taken up in solution, the amount of water required by crops in their feeding is enormous. For every ton of dry matter produced in plants, it is estimated that about 325 tons of water are required. Hence, several hundred tons per acre are needed for the growing of a single crop.

It also regulates and protects against extremes of soil temperatures; opens up and mellows heavy soils, and serves materially to diminish the loss of fertilizing elements by drainage, and thus affects further improvement.

Waste of Humus.

Cultivation by ordinary farm methods, with plough, harrow, cultivator, &c., while most important and essential, exposes the soil to the action of the air and dissipates, to some extent, its humus. Further the bacteria which are constantly at work in soils have their power as regards the oxidation of organic matter increased by the operations necessary to produce a good mechanical condition of the soil. This means not only a loss of organic matter, but also of nitrogen. Soils in which grain is grown year after year lose, it is stated, much nitrogen by this oxidation of humus, and this loss is greatest in those soils which are richest in nitrogen.

The Mechanical Condition of the Soil.

Though it may be stated that the chief function of a soil is to furnish certain elements for the nourishment of crops, it is equally true that in order to give the best returns, a soil must be fairly retentive of moisture, must contain air, and must form a firm and suitable support for the growth of plants and allow an easy foraging ground for their roots. Such a soil is said to be in a good state of culture or tilth.

Soils differ greatly in their character, not only chemically, but mechanically. The three chief types are light porous sands, heavy clays, and peaty soils. The most fertile loams are those in which these three are blended, that is a proper admixture of sand, clay and humus. When sand

predominates, the soil is not so retentive of moisture, furnishes but a scant supply of plant food, and easily loses by oxidation and leaching a proportion of its most valuable constituents. Stiff plastic clays, which puddle in wet weather, and subsequently dry into hard lumps or masses, do not allow the air to permeate them or the growing roots to easily penetrate in search of the food they require. They may contain large quantities of plant food, but with such unfavourable mechanical conditions this food is of little value. Peaty soils are often sour (a property detrimental to farm crops), are not sufficiently heavy and compact, dry out readily, and lack mineral constituents. It is for these first two classes of soils that clover may be used with the greatest benefit, for it is evident, whether sand or clay predominates, a certain proportion of vegetable matter is necessary to make the soil suitable for seed germination and to furnish that warm, moist aerated medium that is essential to luxuriant growth. A poor physical condition of the soil and a lack of sufficient moisture are qualities which follow the loss or absence of humus and they are factors which prevent the crops from utilizing, to the extent they otherwise would, such plant food as a soil may possess.

The Value of Clover as a Fertilizer.

The main object in view in the preparation of this bulletin is to call the attention of Canadian farmers to the very practical and convincing results which have been obtained at the Central Experimental Farm, in increased crops, by the ploughing under of green clover. This practice has been found to increase the crops for several successive seasons. Similar experiments have been tried on the branch experimental farms, with good results, and reports have reached us from many farmers, who have followed with much profit the teaching of the experimental farms in this respect. There seems no reason to doubt that if this method of fertilizing the land were more generally adopted, a considerable increase might be had in the average production of the more important farm crops at very little cost. The experiments conducted at Ottawa have been so planned as to realize the greatest advantages from the clover without interfering with the regularity of the farmers' crops.

These experiments were begun on the Central farm in the spring of 1894, when a field was sown with a variety of two-rowed barley (Canadian Thorpe) and, at the same time, seeded with Mammoth Red clover at the rate of 12 pounds per acre. After the barley was harvested the clover grew rapidly and made a good stand before winter. It was allowed to grow until the following season. By the third week in May, about the time when such a crop should be ploughed under for the planting of Indian corn or potatoes, the clover was quite heavy. On May 25, a box one foot square inside and four feet deep was sunk to its full depth in this crop and by lifting it carefully a fair section of the plants and roots was obtained. On washing away the earth, some of the roots were found to extend down fully four feet, and had thus been able to feed on the stores of fertility existing in the lower depths of the subsoil, beyond the reach of most other crops, and to transfer and utilize these in building up the stalks and leaves. The extensive root system of clover is clearly illustrated on Plate 1. The green leaves and stems in the sample taken were separated from the partly decayed leaves about the base and also from the roots and each weighed and analysed separately. The proportion of nitrogen in pounds per acre found in the different parts of the crop was as follows:—

Green leaves and stems	101·3	lbs. per acre.
Semi-decayed material on surface	22·5	"
Roots to a depth of four feet	48·5	"
Total nitrogen	172·3	"

While the ploughing under of a growing crop of clover furnishes the soil, as already stated, with a large amount of organic matter, much of which is subsequently converted into humus, it is evident from the above figures that there is another and still more important part which clover plays in enriching the land, that is, by adding nitrogen. Clover is a plant which belongs to the class of legumes and these have that remarkable property of being able to take a large proportion of the nitrogen they need for their growth from the air. The careful researches of many eminent scientific investigators have shown that the legumes obtain nitrogen from the air found in the interstices between the particles of soil, through the agency of certain micro-organisms present in the soil. These bacteria, whose special function is the assimilation of free nitrogen, attach themselves to the roots of growing clover or other legumes, forming thereon small nodules or tubercles. These nodules, swarming with their countless inhabitants, are to be found in sizes varying from a pin's head to a pea and frequently scattered in large numbers over the roots of the plant. An illustration of clover roots bearing nodules is given in Plate 2. The nitrogen taken in by these microbes and converted into soluble compounds is used by the clover and stored in the tissues of the roots, stems and leaves. The legumes to which clover belongs are especially rich in nitrogen, and though we are unable to say exactly what proportion of this element is taken by them from the air, we may be sure that under favourable conditions the greater part is from that source. These facts, thus briefly put, represent probably the most important discovery in agricultural science of the nineteenth century.

The chief value of ploughing under a crop of clover lies, then, in the addition of humus and its associated mineral plant food and in the addition of nitrogen. By the subsequent decay in the soil of the turned under clover, these constituents are converted into available food for future use for farm crops and fruits. While the growth and harvesting of other crops leaves the soil poorer in nitrogen, the growth of clover, even when the crop has been harvested and the roots only left, leaves the soil invariably richer in this constituent.

INFLUENCE OF CLOVER ON FARM CROPS.

Since 1894, systematic experimental work has been carried on at the Central Experimental Farm with clover to ascertain the practical fertilizing value of this crop. The clover has been sown in the spring with wheat, barley or oats in the proportion of ten pounds of the clover seed to the acre. This has always resulted in a good stand of clover before the close of the season, as it grows rapidly after the grain is harvested. If it is intended to use the land for growing spring grain the following season, the clover is ploughed under about the middle of October; but if the land is to be used for potatoes or Indian corn, the clover is left until the following spring, when, by the second or third week in May, it will have made a heavy growth and will furnish a large amount of material for turning under.

Increase of Crops in 1898 from the Ploughing under of Clover.

In the spring of 1897, eight plots of one-twentieth of an acre each were sown with grain—two of them with spring wheat, four with barley and two with oats. The soil was a sandy loam of fair quality, which had received a dressing of about 15 tons of fresh barn yard manure in the spring of 1896, which was followed by a crop of roots. These plots were all sown on May 5, two with each sort of grain, one of them in each case with Mammoth Red clover in the proportion of 10 pounds per acre, the other without clover. The wheat was sown at the rate of $1\frac{1}{2}$ bushels; barley (six-rowed) $1\frac{3}{4}$

bushels; barley (two-rowed) 2 bushels; and oats 2 bushels per acre. The wheat ripened August 9; six-rowed barley, July 26; two-rowed barley, August 2; and the oats, August 9.

The following gives particulars of the crop:—

	Bush.	Lbs.
No. 1—Preston wheat with 10 pounds clover per acre..	16	30
2— " " without clover.....	19	..
3—Odessa barley (six-rowed) with clover.....	42	24
4— " " " without clover.....	37	34
5—Bolton barley, (two-rowed) with clover.....	37	4
6— " " " without clover.....	35	..
7—Banner oats with clover.....	57	32
8— " " without clover.....	61	6

After harvest the plots which had been sown with clover produced a rapid growth of this plant and by October had formed a heavy mat of foliage; the alternate plots on which no clover had been sown were, of course, bare. All these plots were ploughed early in October, about eight inches deep. In the spring of 1898 the land was disc-harrowed and twice harrowed with the smoothing harrow, after which all the plots were sown with one variety of oats, namely, the Banner. The oats were sown on April 27. The difference in the growth of the grain on these plots was soon very noticeable, and, as the season advanced, especially just before the heads appeared, the difference in height and vigour of growth in favour of the plots where the clover had been grown was very remarkable. So clearly was this manifest that it could be distinctly seen at a considerable distance, and the outline of those plots on which clover had not been grown could be readily traced by the decidedly shorter and less vigorous growth. After the grain was fully headed, the difference in appearance was not so clearly noticeable at a distance, but by a careful examination it could be easily traced. When ready to harvest, these plots were cut and threshed separately, and the following results obtained:—

CROP OF BANNER OATS IN 1898.

—	Straw, yield per acre.	Oats, yield per acre.	
	Lbs.	Bush.	Lbs.
Plot 1—On which Preston wheat was sown in 1897 with clover.....	3,770	56	6
Plot 2—After Preston wheat without clover.....	2,160	37	2
An increase in yield after wheat on the plot with clover of.....	1,610	19	4
Plot 3—On which Odessa barley was sown in 1897 with clover	2,180	37	12
Plot 4—After Odessa barley without clover	1,450	30	10
An increase in yield after barley on the plot with clover of	730	7	2
Plot 5—On which Bolton barley was sown in 1897 with clover.....	3,180	51	26
Plot 6—After Bolton barley without clover	2,090	44	24
An increase in yield after barley on the plot with clover of.....	1,090	7	2
Plot 7—On which Banner oats was sown in 1897 with clover.....	5,110	55	
Plot 8—After Banner oats without clover	2,260	44	4
An increase of yield after oats on the plot with clover of.....	2,850	10	30

The lower yields reported on plots 3 and 4 were due to the poorer quality of the soil, which was a light sandy loam. The other plots had a heavier sandy loam of much better quality.

The results of these tests show that the average yield of grain on the four plots with clover exceeded by 11 bushels and 1 pound per acre the yield on those where no clover was used.

Increase of Crops in 1899, the Second Year from the Ploughing under of Clover.

In 1899, the same plots were all sown with one variety of barley, the Mensury, and again we found marked differences in favour of the land sown with clover in 1897. No other fertilizer had been used.

CROP OF MENSURY BARLEY IN 1899—SOWN AFTER BANNER OATS IN 1898

—	Straw, yield per acre.	Barley, yield per acre.
	Lbs.	Bush. Lbs.
Plot 1—On which Preston wheat was sown in 1897 with clover	3,120	40 20
Plot 2—After Preston wheat in 1897 without clover	1,740	25 20
An increase in yield after oats on the plot with clover of	1,380	15
Plot 3—On which Odessa barley (six-rowed) was sown in 1897 with clover	2,620	32 24
Plot 4—After Odessa barley (six-rowed) in 1897 without clover	2,440	27 44
An increase in yield after oats on the plot with clover of	180	4 28
Plot 5—On which Bolton barley (two-rowed) was sown in 1897 with clover	2,470	33 26
Plot 6—After Bolton barley (two-rowed) in 1897 without clover	2,000	29 28
An increase in yield after oats on the plot with clover of	470	3 46
Plot 7—On which Banner oats was sown in 1897 with clover	3,270	44 38
Plot 8—After Banner oats in 1897 without clover	2,320	33 36
An increase in yield after oats on the plot with clover of	950	11 2

Increase in the Yield of Grain and Straw for the First and Second Years.

The average increase in grain after the ploughing under of green clover was: for the first year, when oats were used, 11 bushels 1 pound per acre; and in 1899, when these same plots were sown with barley, the average increase was 8 bushels 31 pounds per acre.

The figures given show that the average yield of straw from the four plots treated with clover was: for the first year, 3,560 pounds per acre, and for the second year, 2,870 pounds; whereas, the weight of straw obtained from the adjoining plots, where clover was not used, was 1,990 pounds per acre in 1898, and 2,125 pounds per acre in 1899. This shows a larger yield of straw where clover was used, of 1,570 pounds per acre the first year, and 745 pounds the second year.

These results are indeed remarkable. They show in the case of the plots under consideration that the ploughing-under of a single crop of clover,

sown with the grain in 1897, produced a wonderful increase both in straw and grain. From the added fertility and humus thus supplied, the crop of straw, when compared with the adjoining plots on which clover had not been sown, was increased 78 per cent in 1898 and 35 per cent in 1899. The increase in the crop of grain was still more remarkable, since it shows a slightly higher percentage for the second year than it did for the first. The increase in the weight of grain on the plots treated with clover, was: in 1898 over 28 per cent; whereas, in 1899 it was over 29 per cent.

Increase in Field Crop of Oats in 1899 from the Ploughing under of Clover.

Early in the spring of 1899 a field of four acres of land was ploughed about 4 inches deep. The soil was a sandy loam of medium quality. On two acres of this land barley had been grown in the spring of 1898, and with it 10 pounds of red clover seed had been sown. After the grain was harvested, the clover made rapid growth, and before winter set in, it had formed a good mat of foliage about a foot high. One acre had been in Brome grass *(Bromus inermis)* in 1898; half an acre had been sown with a mixture of pasture grasses without clover, and another half acre with a mixture of pasture grasses associated with a good proportion of clover.

After ploughing and harrowing, the whole area of four acres was sown with one variety of oats—the Bavarian. Where clover had been ploughed under, its effect was very clearly shown in the growth of the oats, the crop grown after clover being much greener in colour and more vigorous in growth of both leaf and stalk, and when measured about the time the heads of grain were shooting out, the plants on an average were about a foot taller than the oats on the adjoining land, where no clover had been used.

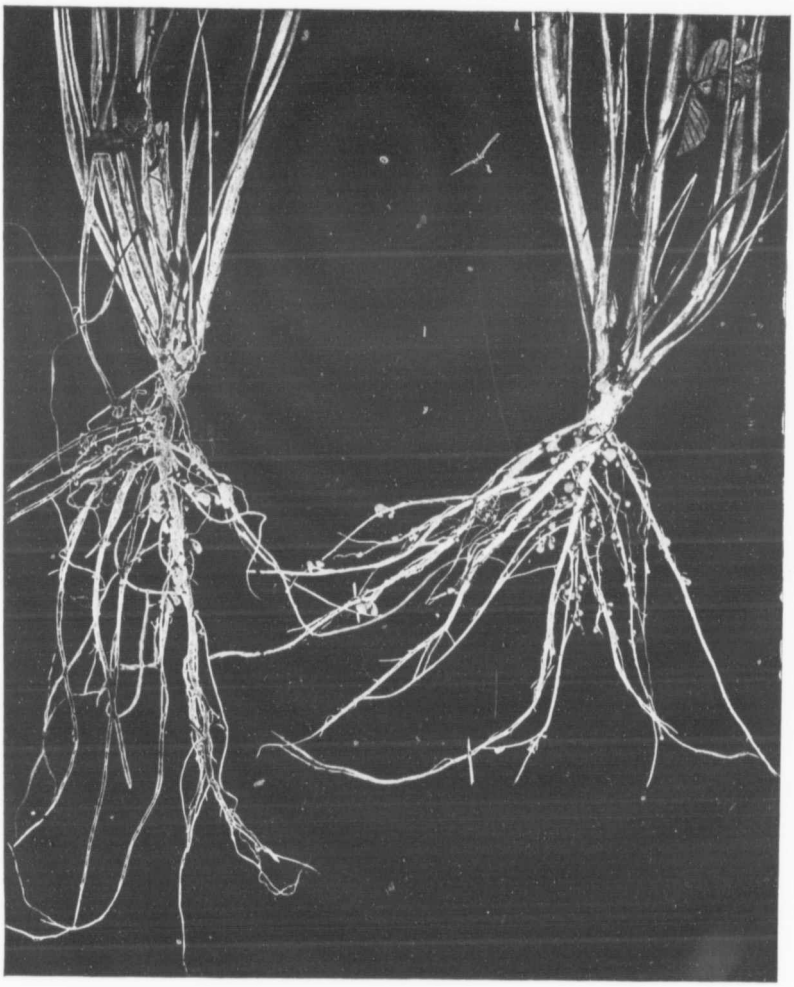
When harvested the results were as follows:—

	Per acre.	
	Bush.	Lbs.
1 acre of oats sown after Brome grass	33	8
½ " " mixture of pasture grasses without clover	36	16
½ acre of oats sown after mixture of pasture grasses with clover	46	4
2 acres of oats sown after barley with clover	43	28

The average of the crop sown where no clover had been used was 34 bushels 29 pounds per acre, while the average of that sown after clover was 44 bushels 33 pounds—a difference of 10 bushels 4 pounds per acre in favour of the crops grown after the ploughing under of clover.

Increase in Yield of Oats in 1900 from Plots after Clover.

In the spring of 1899, six plots of one-fortieth acre each were sown with grain. Two of these plots were sown with Preston wheat; two with Mensury barley; and two with Banner oats. One of these plots in each case had clover sown with the grain at the rate of 12 pounds per acre; the other had no clover. The soil was a sandy loam of fairly good quality, and up to this time the land had been used as a nursery. After the grain crop had been taken off, the clover was allowed to grow until late in the autumn, when it was ploughed under to the depth of 6 or 7 inches. In the spring of 1900, the land was harrowed twice with a disc-harrow and twice with a smoothing harrow, and sown with one kind of oats, viz., New Zealand, at the rate of two bushels of seed per acre. The oats were sown on May 4, 1900, and the crops harvested are shown in the following table:—



ROOTS OF YOUNG CLOVER PLANTS, SHOWING NODULES.

July 2, 1902.

CROP OF NEW ZEALAND OATS IN 1900.

—	Yield of oats per acre in 1900.	
	Bush.	Lbs.
Plot 1—On which Preston wheat was sown in 1899 with clover.....	53	18
Plot 2- After Preston wheat was sown in 1899 without clover.....	51	26
An increase in yield after wheat on the plot with clover of.....	1	52
Plot 3—On which Mensury barley was sown in 1899 with clover.....	58	28
Plot 4—After Mensury barley was sown in 1899 without clover.....	56	16
An increase in yield after barley on the plot with clover of	2	12
Plot 5—On which Banner oats was sown in 1899 with clover.....	58	28
Plot 6—After Banner oats was sown in 1899 without clover..	56	16
An increase in yield after oats on the plot with clover of	2	12

In this instance the plots sown with clover averaged 57 bushels 2 pounds per acre, while those on which no clover had been sown averaged 54 bushels 31 pounds—a difference in favour of the plots treated with clover of 2 bushels 5 pounds per acre. This increase was the smallest at any time obtained where clover had been ploughed under, and was probably due in part to the fact that the grain with the clover was sown a week later than usual and the subsequent growth of the clover was light and unsatisfactory.

Increase in Yield of Oats in 1901 from Plots after Clover.

In the spring of 1900, another set of six plots was sown with grain—two with Preston wheat, two with Mensury barley and two with Banner oats. One of these plots in each case had common red clover sown with the grain at the rate of 12 pounds per acre; the other had no clover. The soil was a sandy loam of fairly good quality, which had received no manure since 1897, when it had a coating of about 12 tons per acre.

After the grain crop was taken off the clover was allowed to grow until about the middle of October, when it was ploughed under to a depth of 6 or 7 inches. In the spring of 1901, the land was harrowed twice with a disc-harrow and twice with the smoothing harrow, and all the plots were sown on May 4th with Banner oats at the rate of 2 bushels of seed per acre, and harvested August 5th.

CROP OF BANNER OATS IN 1901.

—	Straw, yield per acre.	Yield of oats per acre in 1901.	
	Lbs.	Bush.	Lbs.
Plot 1—On which Preston wheat was sown in 1900 with clover.....	3,440	49	14
Plot 2—After Preston wheat was sown in 1900 without clover.....	2,480	47	2
An increase in yield after wheat on the plot with clover of.	960	2	12
Plot 3—On which Mensury barley was sown in 1900 with clover	2,640	42	12
Plot 4—After Mensury barley was sown in 1900 without clover.....	1,920	37	22
An increase in yield after barley on the plot with clover of.	720	4	24
Plot 5—On which Banner oats was sown in 1900 with clover.... ..	3,040	40	
Plot 6—After Banner oats was sown in 1900 without clover.....	2,240	35	10
An increase in yield after oats on the plot with clover of...	800	4	24

In this instance the plots sown with clover gave an average return of 43 bushels 31 pounds per acre, while those on which clover had not been sown gave 40 bushels—a difference of 3 bushels 31 pounds in favour of the plots with clover. There was also an average increase in the weight of the straw of 827 pounds per acre, being somewhat over 35 per cent.

Taking these twelve trials made with plots of oats during the past four years, the average gain in yield of grain from the use of clover has been about 7 bushels per acre; and in the case of the barley, in which only three trials were made, the average gain was 8 bushels 31 pounds per acre. In the field crop of four acres of oats grown in 1899, the average increase in yield was 10 bushels per acre.

Increase in Crop of Indian Corn in 1898 after Clover.

Favourable results have also been obtained from a series of plots on which Indian corn was planted after clover had been ploughed under. These tests were conducted on plots of one-twentieth of an acre each, which were sown with a crop of two-rowed barley in 1897, when different sorts and quantities of clover were sown with the grain, except plots 7, 10 and 12, which were left as check plots on which barley was sown without clover. The soil was a sandy loam of fair quality, which received a dressing of about 12 tons of barnyard manure per acre in the fall of 1896. In this case the clover was allowed to remain during the winter and to grow until the 23rd of May, 1898, by which time most of the plots had made a heavy growth. The land was then ploughed about 6 or 7 inches deep and harrowed twice with the smoothing harrow before planting.

The variety of corn chosen for this test was Longfellow, which was planted on the 25th of May with the seed drill, in rows 3 feet apart, and was cut on the 15th of September. This corn made a medium and even growth of from 7 to 8 feet, was leafy from top to bottom, and the stalks were well eared, many of the ears then beginning to ripen. The following results were obtained:—

CROPS OF INDIAN CORN (LONGFELLOW) IN 1898.

—	Quantity and Kind of Clover Sown in 1897 with Two-Rowed Barley.	Yield of Fodder Corn per acre in 1898.	
		Tons.	Lbs.
Plot 1..	Mammoth Red clover, 4 lbs. per acre	15	560
" 2..	" 6 "	15	1,720
" 3..	" 8 "	15	1,440
" 4..	" 10 "	15	1,360
" 5..	" 12 "	16	1,920
" 6..	" 14 "	17	1,860
" 7..	Check plot, no clover sown	13	160
" 8..	Common Red, 10 lbs. per acre	22	200
" 9..	Alsike clover, 6 "	15	640
" 10..	Check plot, no clover sown	14	960
" 11..	Alfalfa, 14 lbs. per acre	14	1,320
" 12..	Check plot, no clover sown	13	280
" 13..	Crimson clover, 24 lbs per acre	14	20
" 14..	Alsike, 6 lbs.; orchard grass, 14 lbs. per acre	19	200
" 15..	Alfalfa, 6 lbs.; " " "	14	1,280

These results clearly show the influence of green clover as a fertilizer for Indian corn. The three check plots on which clover had not been sown

gave an average crop of 13 tons 1,133 lbs.; whereas, the other twelve plots, on which different kinds and quantities of clover had been sown, averaged 16 tons 877 lbs.—a difference of 2 tons 1,744 lbs. per acre. It is worthy of note that the plot on which 10 lbs. of common red clover seed had been sown gave 22 tons 200 lbs., while the check plot alongside of it, which had no clover, gave only 13 tons 160 lbs. per acre.

Increase in Crop of Indian Corn in 1900 after Clover.

In the spring of 1899, six plots of one-fortieth of an acre each were sown with grain—two with Preston wheat, two with Mensury barley, and two with Banner oats. One plot in each case had clover sown with the grain at the rate of 12 lbs. per acre; the other had no clover. The soil was a sandy loam of fairly good quality, and up to this time the land had been used as a nursery. After the grain was cut, the land was left untouched until May 24, following, by which time the clover had made a good growth, when it was ploughed under to a depth of 6 or 7 inches. The land was then harrowed twice with a disc-harrow, and twice with a smoothing harrow. The corn was sown with the seed drill on May 25, in rows 3 feet apart, and cut for ensilage on September 13. The variety used for this test was Longfellow.

CROPS OF FODDER CORN (LONGFELLOW) IN 1900.

	Yield of Fodder Corn per acre in 1900.	
	Tons.	Lbs.
Plot 1—On which Preston wheat was sown in 1899 with clover	19	1,560
" 2—After Preston wheat without clover	16	1,160
An increase in yield after wheat on the plot with clover of.	3	400
" 3—On which Mensury barley was sown in 1899 with clover	17	1,120
" 4—After Mensury barley without clover	16	1,440
An increase in yield after barley on the plot with clover of.		1,680
" 5—On which banner oats was sown in 1899 with clover	18	1,720
" 6—After banner oats without clover	14	1,800
An increase in yield after oats on the plot with clover of.	3	1,920

Here we see that the three plots on which the clover had been sown in the proportion of 12 lbs. per acre gave an average weight of 18 tons 1,466 lbs. of fodder corn per acre; while the three on which clover had not been sown averaged 16 tons 133 lbs.—a difference in favour of the plots sown with clover of 2 tons 1,333 lbs. per acre.

Increase in Crop of Indian Corn in 1901 after Clover.

In the spring of 1900, six plots of one-fortieth of an acre each were prepared for this experiment, as described in the test for 1900. The kinds of grain used and the treatment of the land were the same. The alternate plots were sown with 12 lbs. of Common Red clover per acre, which was

ploughed under the following May. The variety of corn used for this test was Selected Leaming, which was sown with the seed drill May 23 and cut for ensilage September 18.

CROPS OF FODDER CORN (SELECTED LEAMING) IN 1901.

—	Yield of Fodder Corn per acre in 1901.	
	Tons.	Lbs.
Plot 1—On which Preston wheat was sown in 1900 with clover.....	27	1,760
Plot 2—After Preston wheat was sown without clover.....	19	1,280
An increase in yield after wheat on the plot with clover, of..	8	480
Plot 3—On which Mensury barley was sown in 1900 with clover.....	27	880
Plot 4—After Mensury barley was sown without clover.....	15	1,600
An increase in yield after barley on the plot with clover, of..	11	1,280
Plot 5—On which Banner oats were sown in 1900 with clover.....	25	1,600
Plot 6—After Banner oats were sown without clover.....	20	160
An increase in yield after oats on the plot with clover, of....	5	1,440

In this series of experiments the three plots on which the clover had been sown gave an average weight of 27 tons 80 pounds of fodder corn per acre; while those on which clover had not been sown averaged 18 tons 1,013 pounds—a difference in favour of the plots sown with clover of 8 tons 1,067 pounds per acre, an increase of over 40 per cent. A marked difference could be seen in these plots from an early period in their growth, and, as the crop approached maturity, the increase in height, vigour and leafiness in the corn grown on the plots sown with clover was so striking that it could be clearly seen at a considerable distance.

Taking the results of these 18 experiments made with Indian corn during three years, the average gain in weight of green crop from the use of clover has been 3 tons 1,694 pounds per acre.

Increase in Crop of Potatoes in 1899 after Clover.

In the spring of 1899, a piece of rather light sandy loam of fair quality was planted with potatoes of the variety known as Daisy. Nine rows of these were planted, each 560 feet long, 2½ feet apart, on land on which barley had been grown the previous year. Common Red clover had been sown with the barley in the proportion of 10 pounds of seed per acre. After the grain was cut, the clover made a rapid growth, and had formed a good mat of foliage about 12 inches high by the middle of October, when it was ploughed under about 7 or 8 inches deep. On land adjoining, of the same quality, which had received similar cultivation, 9 rows of the same variety of potatoes were planted on the same day. The previous crop on three-fourths of this latter piece of land had been pease and on the other one-fourth, carrots.

The potatoes were planted on May 25 and were dug October 3.

	Lbs.
Plot 1—On which barley was sown with clover, turned under in October, 1898, the potatoes gave a total yield of	4,208
Plot 2—After pease and carrots, where no clover had been sown, the total yield was	3,025

These results show a difference in favour of the crop where clover was used of about 28 per cent. The foliage of the potatoes grown after clover was much more vigorous and even, and was of a deeper green colour.

Increase in Crop of Potatoes in 1900 After Clover.

In the spring of 1899, six plots of one-fortieth of an acre each were sown with grain—two with Preston wheat, two with Mensury barley, and two Banner oats. One plot in each case had clover sown with the grain, at the rate of 12 lbs. per acre; the other had no clover. The soil was a sandy loam. In the spring of 1900, the clover was ploughed under and the plots were all planted with one variety of potatoes, namely, Rochester Rose. These were planted on May 28, and were dug October 5, with the following results:—

CROPS OF POTATOES (ROCHESTER ROSE) IN 1900.

—	Yield of potatoes per acre.	
	Bush.	Lbs.
Plot 1—On which Preston wheat was sown in 1899 with clover	320	—
Plot 2—After Preston wheat without clover	280	40
An increase in yield after wheat on the plot with clover of	39	20
Plot 3—On which Banner oats was sown in 1899 with clover	301	20
Plot 4—After Banner oats without clover	290	40
An increase in yield after oats on the plot with clover of	10	40
Plot 5—On which Mensury barley was sown in 1899 with clover	330	—
Plot 6—After Mensury barley without clover	280	—
An increase in yield after barley on the plot with clover of	50	—

In these experiments the three plots on which the clover had been sown gave an average of 317 bushels 7 lbs. per acre; while those on which clover had not been sown averaged 283 bushels 47 lbs. per acre—a difference in favour of the plots sown with clover of 33 bushels 20 lbs. per acre.

Increase in Crop of Potatoes in 1901 After Clover.

In the spring of 1900, six plots of one-fortieth of an acre each were prepared for this experiment as described in the test for 1900. The kinds of grain used and the treatment of the land were the same. The alternate plots were sown with 12 lbs. of common red clover per acre, which was ploughed under May 22, 1901. The variety used for this test was the Everett. The potatoes were planted May 23, in rows 2½ feet apart and about one foot apart in the rows, and were dug October 4.

CROPS OF POTATOES (EVERETT) IN 1901.

—	Yield of potatoes per acre.	
	Bush.	Lbs.
Plot No. 1—On which Preston wheat was sown in 1900 with clover. ..	440	—
Plot No. 2—After Preston wheat without clover.....	396	40
An increase in yield after wheat on the plot with clover of..	43	20
Plot No. 3—On which Banner oats was sown in 1900 with clover.....	420	—
Plot No. 4—After Banner oats without clover.....	396	—
An increase in yield after oats on the plot with clover of....	24	—
Plot No. 5—On which Mensury barley was sown in 1900 with clover....	411	—
Plot No. 6—After Mensury barley without clover.	381	20
An increase in yield after barley on the plot with clover of..	29	40

In these experiments the three plots on which clover had been sown gave an average of 423 bushels 40 lbs. per acre ; while those on which clover had not been sown averaged 391 bushels 20 lbs. per acre—a difference in favour of the plots sown with clover of 33 bushels 20 lbs. per acre.

Does Clover Sown with Grain Lessen the Yield of Grain?

To gain information on this point, experiments were carried on in 1895 with 18 plots of one-tenth of an acre each, all of which were sown with Canadian Thorpe barley at the rate of two bushels per acre. On 14 of these plots clover was sown in different proportions, using from 2 lbs. to 16 lbs. per acre. On the other four plots clover was not sown ; they were left as check plots for comparison. These plots were all harvested separately ; but the yield did not show any material difference between the check plots and those on which the clover had been sown with the grain.

In 1896, a more extended series of experiments of the same character was conducted. One group of 13 plots of one-tenth of an acre each, was sown with Odessa barley with different quantities of clover per acre. The second group had 16 plots, 8 of which were sown with grain, using 10 lbs. of Mammoth Red clover seed per acre, two of them with wheat, two with oats, and four with barley—the remaining eight (alternate plots) being sown with the same varieties of grain without clover. These were all harvested and threshed separately and the results showed that the sowing of clover with grain has no material influence on the yield of grain.

In 1897, a similar trial was made with 8 plots of one-twentieth of an acre each, four being sown with grain—one each of Preston wheat, Odessa and Bolton barleys, and Banner oats, associated in each case with 10 lbs. of Red clover seed per acre. The alternate plots were sown with the same varieties of grain without clover. The results of the harvest in 1897 confirmed the conclusions which had been reached in 1895 and 1896, that the growing of clover with the grain has no perceptible influence on the resulting crop.

Quantity of Seed and Variety of Clover for Best Results.

The value of green clover ploughed under as a fertilizer depends much on the weight of the leaves, stems and roots which the crop contains. The quantity of clover seed sown per acre and the length of time the clover

is allowed to grow are the two factors which chiefly influence this result. It is generally conceded that each ton of the mixed leaves, stems and roots, when ploughed under, will add to the soil as much nitrogen as two tons of average barn-yard manure, while other essential fertilizing constituents are gathered to some extent from depths to which the roots of many other plants do not reach, and thus the clover plant is practically an enricher of the soil in these ingredients also.

Many experiments have been conducted to gain information regarding the weight of clover (roots and foliage) produced per acre under different conditions.

The plan adopted in making the estimation in the case of each of the plots reported on below, was to cut out a small block 4 feet by 4 feet (16 sq. feet) to the depth of 9 inches and carefully gather and weigh all the stems, leaves and roots found within this area.

CLOVER SOWN WITH ODESSA BARLEY IN 1897.

Nine Plots of Clover with Odessa Barley were Sown May 6, 1897, and dug October 20, 1897.	Weight of Clover (roots and foliage) per acre.	
	Tons.	Lbs.
Plot 1—Mammoth Red clover, 4 lbs. per acre produced	5	550
2— " " " 6 " " "	5	1,996
3— " " " 8 " " "	6	974
4— " " " 10 " " "	7	293
5— " " " 12 " " "	6	1,612
6— " " " 14 " " "	6	506
7—Common Red " 10 " " "	8	595
8—Alsike " 6 " " "	5	207
9—Alfalfa " 14 " " "	3	1,307

After the sample blocks had been taken, these plots were not ploughed under that autumn, but were left undisturbed until May 21, 1898, by which time the clover had made a very strong growth and produced a heavy mat of foliage, nearly two feet high. Similar blocks to those already referred to, 9 inches deep and covering 16 square feet, were cut out of these plots May 21, 1898, when the following weights of leaves, stems and roots of clover were obtained :—

CLOVER SOWN WITH ODESSA BARLEY, 1897.

Samples Dug May 21, 1898.	Weight of clover (roots and foliage) per acre.	
	Tons.	Lbs.
Plot 1—Mammoth Red Clover, 4 lbs. per acre, produced	13	1,225
2 " 6 "	13	1,225
3 " 8 "	15	1,139
4 " 10 "	16	1,520
5 " 12 "	15	628
6 " 14 "	13	203
7—Common Red Clover, 10 "	15	1,138
8—Alsike 6 "	15	1,649
9—Alfalfa 14 "	5	1,070

Clover Sown with Ligowo Oats in 1897.

A sample dug October 20 from a field crop of $4\frac{1}{2}$ acres sown on April 30, 1897, with Ligowo oats and 10 lbs. Mammoth Red Clover per acre, produced 8 tons 505 lbs.

Clover Sown with Mensury Barley in 1898.

A similar course of experiments was tried in 1898, when ten plots were sown with Mensury barley on April 27 with clover seeds of different quantities and sorts. They were dug November 5, 1898, and gave the following quantities of clover residues:—

CLOVER SOWN WITH MENSURY BARLEY, 1898.

			Weight of clover (roots and foliage) per acre.	
			Tons.	Lbs.
Plot 1—Mammoth Red clover,	4 lbs.	per acre, produced	5	123
2 "	6	"	5	634
3 "	8	"	5	1,655
4 "	10	"	6	1,262
5 "	12	"	6	761
6 "	14	"	6	1,866
7—Common Red clover,	10	"	5	1,570
8—Alsike clover,	8	"	4	167
9 "	6	"	5	124
10—Alfalfa,	14	"	2	933

These results seem to indicate that 10 or 12 lbs. of clover seed to an acre gives the best results, and that Common Red clover serves the purpose well. The very large increase in the weight of leaves stems and roots when the clover is left over to grow until about May 21 the following year, points to the importance of giving the clover the opportunity of making this extra growth whenever it is intended to plant the land with Indian corn, potatoes or any other crop which can be advantageously sown as late as May 21 to 25.

Value of Winter-Killed Clover.

To obtain information which would be useful to those living in localities where winter killing of clover is common, samples were collected in the spring of 1897 (the winter of 1896–7 having killed practically all the clover on the plots examined), and determinations made as to their manurial value. These clover residues consisted of the shrivelled and browned foliage and stems carefully taken from the surface of a block of soil 4 feet by 4 feet, and the dead roots in the first 9 inches of its depth.

All the clovers were sown at the respective rates mentioned below, on May 5, 1896, with Odessa barley at the rate of $1\frac{3}{4}$ bushels per acre. The barley on all the plots was cut July 27, 1896. The clover residues were collected May 1, 1897.

CLOVER RESIDUES WITH PROPORTION OF NITROGEN (1897).

—	Weight of clover residues per acre.		Nitrogen per acre.
	Tons.	Lbs.	Lbs.
Plot 1—Mammoth Red clover, 14 lbs. per acre	3	636	59
Plot 2— " " 12 "	3	976	77
Plot 3— " " 10 "	2	1,955	81
Plot 4— " " 8 "	3	976	76
Plot 5— " " 6 "	3	806	70
Plot 6— " " 4 "	2	594	58
Plot 7—Common Red clover, 10 "	3	125	62
Plot 8—Alsike clover, 6 "	1	1,233	33
Plot 9—Alfalfa, 14 "	1	212	26

It is evident from these particulars that notable amounts of nitrogen are present in these residues, and that winter killing of the clover does not form a sufficient excuse for neglecting this economical mode of enriching the soil.

Is the Ploughing under of Clover an Economical Practice?

It is urged by some that the burying of such a large amount of rich food as is contained in a crop of clover is wasteful. This would undoubtedly be true if the farmer had the stock to consume it, for by feeding the clover a part of it would be converted into high-priced animal products, and the manure produced and returned to the soil would give back about 75 per cent of the fertilizing elements contained in the crop. On most farms, however, there is not sufficient stock for such purpose, and in such cases we would strongly advise the growing and ploughing under of clover for recovering, maintaining and increasing the fertility of soils, as we know of no other material of equal fertilizing value that can be so cheaply obtained. We have shown that by sowing 10 or 12 lbs. of Common Red clover seed per acre, costing about $1 to $1.25, there would be a gain of at least 100 lbs. of nitrogen, the lowest price for which in artificial fertilizers is 10 cents per lb. Further, the added store of humus with its associated mineral elements is also of much value. Even when it is found desirable to harvest the crop and sell it off, the land will be considerably enriched, since nearly one-half of the fertilizing constituents of the clover is to be found in the roots.

Clover Compared with Barn-Yard Manure as a Fertilizer.

At the outset it should be understood that in advocating green manuring with clover, this crop is not brought forward as a material to replace barn-yard manure, but rather to supplement it and to make its application more effective. Barn-yard manure of good average quality contains about the following proportions of the chief fertilizing constituents:—

Nitrogen	10	lbs. per ton.
Phosphoric acid	5	"
Potash	9	"

An application of ten tons per acre will, therefore, enrich the soil, approximately by the following amounts :—

Nitrogen	100	lbs. per acre.
Phosphoric acid	50	"
Potash	90	"

The chemical investigations made in connection with these experiments have shown that a vigorous crop of clover will contain, at a moderate estimate, in its foliage and roots—

Nitrogen	from 100	to	150	lbs. per acre.
Phosphoric acid	" 30	"	45	"
Potash	" 85	"	115	"

Respecting nitrogen, it is evident that by the use of clover we can with a single crop furnish the soil with as large a quantity as would be supplied by a dressing of 10 tons of manure per acre. The greater part of the nitrogen is gathered by the clover from the air, a source not otherwise available, and is therefore a distinct addition to the soil. The amounts of phosphoric acid, potash and lime in the clover have, it is true, been obtained from the soil, but have been largely drawn from depths beyond the reach of the roots of ordinary crops. The decay of the clover, moreover, liberates these important fertilizing elements in soluble and available forms, so that they can be readily utilized by the crops which follow.

Fertilizers for Clover.

Clover requires, for strong and healthy growth, considerable quantities of phosphoric acid, potash and lime. If the soil is well supplied with these, the clover plant, once established, can obtain with the aid of the germs in the nodules on its roots all the nitrogen needed for strong growth. Where the soil is poor in these mineral constituents, they may be supplied by using a dressing of wood ashes and superphosphate of lime. The unleached ashes of hard woods are a most valuable fertilizer. They contain on an average 5 to 6 per cent of potash, 2 to 3 per cent of phosphoric acid, and about 30 per cent of lime. A dressing of 50 to 100 bushels per acre would be sufficient. Where wood ashes cannot be had, one of the German potash salts now found in the fertilizer market may be used in its place. One of these, muriate of potash, contains about 50 per cent of actual potash and may be used in the proportion of 100 pounds per acre. Kainite, which is one of the lower grades of these salts and contains about 12 per cent of potash, should be applied to the extent of about 400 pounds per acre.

Superphosphate of lime will be found a convenient form in which to apply phosphoric acid and lime. Good brands will usually contain about 15 per cent of phosphoric acid in an immediately available form. From 250 to 300 pounds per acre would be a suitable dressing. Thomas' phosphate is also a useful source of phosphoric acid, especially for sour soils and such as are deficient in lime. It contains from 12½ to 17 per cent of phosphoric acid present in a form which, though not immediately soluble, gradually becomes available for plant use.

On peaty or mucky soils, lime is often the only addition needed to secure good crops of clover. From 20 to 40 bushels per acre will usually be sufficient. Marl may be used as a source for lime where it is cheaply obtainable, but should be applied in somewhat larger quantities.

Where a soil is particularly poor in quality, a dressing of barn-yard manure will be found of great advantage in starting the clover. This will not

only furnish a supply of food immediately available for the crop, but will aid in keeping the soil in a moist condition, which is important in clover growing. Heavy clay soils require underdraining before they will give their best returns with clover. A moist, mellow, well aerated soil, which is most suitable for successful clover growing, cannot often be had on stiff clay land which has not been drained.

Summary.

The advantages connected with the ploughing under of clover may be summed up as follows:—

1. There is an enrichment of the soil by the addition of nitrogen obtained from the atmosphere.

2. There is an increase to the store of available mineral plant food (phosphoric acid, potash and lime) in the surface soil taken by the clover in part from depths not reached by the shallower root systems of other farm crops.

3. There is a large addition of humus, whereby the soil is made more retentive of moisture, warmer and better aerated, conditions favourable to vigorous crop growth. Humus also furnishes the material best adapted for the development of those forms of germ life that act so beneficially in the soil.

4. As an agent for deepening and mellowing soils, no crop gives such satisfactory results as clover.

5. Clover also serves a useful purpose as a catch crop during the autumn months, when the ground would be otherwise bare, retaining fertilizing material brought down by the rain, and also that formed in the soil during the summer months, much of which would otherwise be lost through the leaching action of rains.

6. As shown conclusively by the particulars we have submitted, obtained by careful experiment over a number of years with the more important farm crops, the ploughing under of green clover has a most marked effect in increasing the soil's productiveness.