T H E S I S

on

SOIL NITROGEN AND ORGANIC MATTER AS AFFECTED BY AUSTRIAN WINTER PEAS.

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INTRODUCTION

The maintenance of organic matter and of the nitrogen supply of our soils is essential in every system of permanent soil fertility.

Field peas have been the most promising legume for maintaining nitrogen and organic matter in the soil at the Branch Experiment stations at Moro and Burns, Oregon. On the dry farming experiments at Moro it has been found practical to grow peas annually. At Idaho (23) and at Utah (13) they have found the growing of peas beneficial on their dry farm soils. Peas have a short season of growth, their residues decay quickly, and they do not so thoroughly exhaust the soil moisture, so that succeeding crops are "burned out" as occurs after the deeper rooted legumes.

The investigations herein reported were started in the fall of 1927 to secure exact information as to the gain or loss in soil nitrogen and organic carbon from growing Austrian Winter Peas as a green manure crop under controlled conditions with different treatments.

HISTORICAL

The literature and work on the subject of Symbiotic Nitrogen fixation by plants is very extensive. Only the

literature bearing more directly upon the problem of nitrogen fixation with peas and the value of legumes as green manure crops will be cited.

The value of legumes as a means of maintaining the producing power of soils was recognized by the early Romans (9). Later, researchers noted that legumes acted abnormally in response to nitrogenous fertilizers and tended to benefit succeeding cereal crops. These abnormalities were the basis of much early research. Priestley concluded that plants obtained their nitrogen as well as their carbon dioxide from the air. Liebig also was of this opinion, but he further stated that legumes were especially fitted for this task. It was about 1834 that Boussingault (13) began a series of field experiments, in which he studied different rotations. He analyzed the soil both before and after the experiments, thus keeping a record of the loss or gain of the various elements. He found that when the rotation contained a legume there was a gain in soil nitrogen. More careful work in closed vessels on heated soil revealed that the higher plants were not capable of utilizing the free nitrogen from the air. From these experiments it was generally concluded that plants obtained their nitrogen from the soil. Atwater (5) later found evidence that legumes, quite contrary to this belief, utilized the

nitrogen of the air indirectly.

It was in 1886 that Hellriegel and Wilfarth (26) brought to light the important information that a symbiotic relationship existed between such plants as legumes and nitrogen fixing bacteria of the soil, in which nitrogen from the air is made available for the plant utilization. They worked with peas in nitrogen-free sterilized and unsterilized soil. In this experiment they found that good growth and nodule development took place in the unsterile soil, while in the sterile soil growth was retarded. However, when the sterile soil was inoculated with unsterilized soil, a crop of normal growth and nitrogen content resulted. Sir Henry Gilbert (26) of the Rothamsted station confirmed the results of Hellriegel and Wilfarth with different legumes. Atwater and Wood (6) also confirmed their results, and demonstrated that there is a connection between the root tubercles and the acquisition of nitrogen. Cereals, they found, failed to manifest the power of acquiring nitrogen. It was also noted that tubercles, such as are formed on the roots of legumes, failed to develop on the roots of the cereals. In their experiments under controlled conditions, peas were found to increase the nitrogen content of the soil. Wood (51) carrying the work further, found as a result of fifty experiments with plants grown in sea sand, that

all plants grown without the addition of nitrates gained in nitrogen. Some of the plants supplied with nitrates indicated a loss, while others gained nitrogen in varying amounts. Peas, cowpeas, beans, vetch, alfalfa, and scarlet clover were the plants found having the ability to gain nitrogen in excess of that supplied.

Aoby (1) grew peas in two soils, one a clay soil with 0.0783 per cent nitrogen and the other a "humus rich" soil with 0.4050 per cent nitrogen. In both soils the peas were grown without nitrogen treatment, and with nitrogen added at four intervals making a total of 2 gms. per pot of 4 kgm. of soil. Analyses were made for total nitrogen at the beginning and at the conclusion of the experiment and any increase in total nitrogen was credited as nitrogen fixed. The experiment showed a loss of nitrogen in his fallow pots, but a decided increase for those in which peas were grown. "Peas growing in a rich soil fixed 1.976 grams nitrogen per pot, while in the same soil treated with nitrogen, the fixation was but 1.621 grams. In the clay soil the corresponding figures are 2.759 grams and 1.987 grams, respectively; a decrease of 0.355 and 1.772 grams due to the nitrogen added. This indicates that in the soil rich, as well as one poor in nitrogen the addition of nitrogen depressed the fixation of atmospheric nitrogen.

Furthermore, in the soil which was low in nitrogen the amount taken from the air by the peas was greater than in the rich soil, both when untreated and treated with nitrogen." Lupton of Alabama showed that pea vines are very valuable as a fertilizer especially in nitrogen content. (20).

Hulbert (17) of Idaho, recommends the growing of field peas in the rotation with grain in substitution for the usual summer fallow. He says, "The effect of nitrogen added to the soil by a well inoculated crop of field peas is shown by the vigor in the growth of the following grain crop." Stephens (29) at Moro, Oregon has grown field peas in the crop rotation experiments for a number of years. Winter wheat and spring wheat averaged about two bushels per acre more after field peas than after corn, but slightly less than after fallow. Jones and Yates (18) on analyzing these same plots for nitrogen and organic matter found that where the rotation contained peas turned under (the pea fallow) the soil was enriched in nitrogen. Under similar dry farm conditions in Utah, Greaves (13) reports that where peas were grown as a substitute for fallow and turned under, the soil was enriched 240 pounds in total nitrogen in four years. In addition to furnishing the nitrogen for the wheat crop, the peas added

to the soil an average of 60 pounds of nitrogen per year.

Lohnis (19), in a carefully planned experiment, showed that peas have a beneficial effect upon succeeding crops. Garcia (12) ran a series of experiments in New Mexico, in which peas were used as the principal orchard green manure. Although no chemical analysis was made of either soil or plants, it is the opinion of the author that considerable nitrogen was added to the soil by plowing under peas. He says, "Trees and vegetables grown on plots where peas were plowed under have had a darker and richer foliage." Harlan (14) refers to an experiment where pigeon-peas were used as a cover crop to restore a depleted farm. The first year six hogsheads of sugar were raised, the fourth year twenty-four hogsheads were raised. This was an increase in crop yield of 400 per cent in four years from peas as a cover crop, without any other treatment.

More recent work, at the Mississippi Agricultural Experiment Station by Briscoe and Harned (7) brings further proof of the value of peas as nitrogen builders. In an extensive rotation experiment carried on by these men, peas were present in their two best rotations. They found a close

relation between the weight of the crops produced and the bacterial counts and the total nitrogen determined. They increased the nitrogen content of the soil 52 per cent by the growing of legumes in the rotation. Instead of growing their crops on plats, large cans were buried in the ground even with the surface, and the soil carefully mixed before being placed in the cans. This made it possible to sample more accurately for the bacteria counts, and prevented any loss of nitrogen through leaching.

The results of Lyon and Wilson (20) showed a loss of soil nitrogen from the growing of legumes and non-legumes continuously on plats for ten years. The crops were plowed under in the late fall or early spring, and the soil kept cultivated until the middle of July, when the crops were replanted. At the end of ten years, every plat excepting the one in grass sod which was never molested, was lower in total nitrogen than at the beginning. Peas in this case gave a loss of 380 pounds per acre. This was a greater loss than from rye and slightly lower than on the oats plat. At the Tennessee station, Moore (22) working with cowpeas as a green manure, found a steady decrease in the soil nitrogen for the first ten years, both where the cowpeas were removed

and where they were turned under. The second ten years still showed a loss where the crop was removed, but a slight gain where the crop was turned under. In a five year crop rotation of corn, soybeans, wheat, and clover and grass, the nitrogen content of the soil was steadily built up. The humus of the soil showed a slight decrease over the twenty year period.

Hartwell and Pember (15) grew legumes in pots for five years. Cowpeas and soybeans were grown during the summer. Vetch was seeded each fall and mixed with the soil in the spring. The gain in soil nitrogen from growing these legumes was found to be one ton per acre. Seven-tenths of this was in the tops and three-tenths in the roots.

Piper and Pieters (25) in classifying the legumes which are most widely used in the United States as green manures, place peas in the first ten. The value of such crops according to these authors is determined by; (1) its value as forage, both in quantity and quality, either as hay or pasture, and (2) its ability to supply additional nitrogen.

At the present time Austrian winter peas are being used very extensively in parts of the south, where they are fast becoming one of the most highly valued green manures.

Alexander (3), field crop specialist of Georgia, reports that the Austrian pea is becoming very popular in that state, especially in the pecan groves. Ruie (8) of South Carolina has found the Austrian winter peas well adapted to upper Piedmont conditions. At the Clemson station Austrian peas turned under supplied almost as much nitrogen as a crop of corn would utilize. The yield was increased by two bushels when ammonium sulphate was added as a top dressing at the rate of 100 pounds per acre. Austrian winter field peas made a greater yield of dry matter than any of the species of vetch. The per cent nitrogen was lower than that of the vetches, but the greater yield resulted in more nitrogen per acre added to the soil.

The organic matter supply of the soil largely determines the producing power of that soil. It is not only closely associated with the biological activity and the fertility, but plays an important role in the water holding capacity and in the tilth of the soil. Thatcher (30) says, "Recent researchers however have shown that the humus of the soil is so influential a factor in its water holding capcity and successful tillage that it is now known that the humus content of the soil is fully as important in dry farming regions and practices as in the older types." That the nitrogen content of a soil and the organic carbon are very closely

associated is shown by Sievers and Holtz. (27). These workers analyzed a large number of soils from different localities and found that for every pound of nitrogen present there were from ten to twelve pounds of organic carbon. They point out that a fundamental important characteristic of all soils is that both nitrogen and organic carbon content furnish a basis for the determination of soil organic matter. The N:C ratio of 1:11.4 as determined theoretically was very close to all the determinations made by them, regardless of the location or climatic conditions under which the soils were developed. Sievers (28), later working at Massachusetts, confirmed his earlier work with Holtz. In analyzing the plats of the Massachusetts station, which had been under various fertilizer treatments since 1890, he found these soils to contain an average N:C ratio of 1: 12.34, with a range between 10.19 and 13.94. This was but slightly higher than that found in the arid western part of the country. He says, "That the former conclusion, that there can be no apparent increase in soil organic matter without a proportionate increase in nitrogen, is apparently well founded."

It has been definitely demonstrated from the literature reviewed that when peas are grown as a green manure crop the nitrogen of the soil is increased. The organic matter would

also be increased proportionally. In this way the soil is benefited not only from an increase in fertility but also in the many other factors which go to make up a desirable soil. The importance of green manure cover crops, as an economical means of maintaining permanent soil fertility, is being emphasized more today than perhaps at any other time in the history of agriculture. Pieters and McKee (24) in a paper presented at the meeting of the American Society of Agronomy held in Washington, D. C., November 22, 1928, showed the important role legumes are taking in maintaining and improving the agriculture of today.

EXPERIMENTAL

Plan of the Experiment

There are several methods by which the fixation of atmospheric nitrogen by legumes can be determined. Of these, the one in which the soil is carefully analyzed, for total nitrogen, at the beginning and close of the experiment, is no doubt the most accurate. In this method all nitrogen can be accounted for, and any gain can be attributed to the nitrogen fixed by the symbiotic nitrogen fixing organisms. This method was used by the author in making the following research. The soils were carefully analyzed for total nitrogen at the beginning and at the close of this experiment. Any nitrogen-carrying materials which were added during the progress of the experiment were carefully analyzed and the nitrogen content noted. Nitrogen fixed by non-symbiotic microorganisms was accounted for.

Two soil series were used for the pot culture work in this experiment. Soil No. I consisted of Chehalis medium sandy loam, which is a rich, brown, recent soil, of the Willamette valley stream bottom. This soil had a nitrogen content of 1996 pounds in 2,000,000 pounds of surface soil, and had a pH of 7.15. Soil No. II consisted of a light very fine sandy loam, from the Sherman County Branch Experiment Station in the dry farm section of Eastern Oregon. It is a loessial soil formed from basalt, brown in color and fairly fertile. This soil contained 1752 pounds of nitrogen in two million pounds,

and had a pH value of 7.5. The soil was screened through a quarter inch screen and thoroughly mixed before being placed in the jars. A representative sample was taken out to be analyzed. Jars numbered 1 to 18 contained 6450 grams. Jars 19 to 24 contained 7450 grams and jars 25 to 48 contained 5730 grams of water free soil. All pots were run in triplicates with treatments on the basis of 2,000,000 pounds of dry soil. The treatments were the same for each soil type and are shown in table I and II.

A saturated copper sulphate solution was added to the first of three pots series of each soil as a sterilizer. The pots were then covered with earthen lids and kept covered throughout the experiment. No water was added to these pots except water containing $CuSO_4$. This was done as a precaution to check the activity of the non-symbiotic nitrogen fixing microorganisms that might be present. Pot series No. 2 were fallowed. Any differences in nitrogen content that might occur between the sterilized and fallow pots could be attributed to the non-symbiotic organisms. Pot series No. 3 and No. 4 received no additional treatment. The peas were harvested in series No. 3, while in No. 4 they were harvested, weighed, and then mixed with the soil. This gave a

Table I

Treatment Soil No. I.

Pot No.	Treatment
	Pot series 1.
1,2 & 3	Saturated solution of copper sulfate.
	Pot series 2.
4,5 & 6	Fallow
	Pot series 3.
7,8 & 9	No treatment, crop harvested.
	Pot series 4.
10,11 & 12	No treatment, crop weighed and returned to the soil
	Pot series 5.
13	200 pounds ammonium phosphate and 100 pounds potassium sulfate, crop harvested.
14 & 15	200 pounds ammonium phosphate and 100 pounds potassium sulfate, crop weighed and returned to the soil.
	Pot series 6.
16	200 pounds potassium phosphate and 100 pounds potassium sulfate, crop harvested.
17 & 18	200 pounds potassium phosphate and 100 pounds potassium sulfate, crop weighed and returned to the soil.
	Pot series 7.
19	Organic fertilizer (3 tons alfalfa tops), crop harvested
2 0 & 21	Organic fertilizer (3 tons alfalfa tops), crop weighed and returned to the soil.
	Pot series 8.
22	Organic fertilizer (3 tons alfalfa tops) and 100 pounds sulfur, crop harvested.
23 & 24	Organic fertilizer (3 tons alfalfa tops) and 100 pounds sulfur, crop weighed and returned to the soil.

Table II

Treatment Soil No. II

Pot No.	Treatment
	Pot series 1.
25,26 & 27	Saturated solution of copper sulfate.
	Pot series 2.
28,29 & 30	Fallow
	Pot series 3.
31,32 & 33	No treatment, crop harvested.
	Pot series 4.
34,35 & 36	No treatment, crop weighed and returned to the soil.
	Pot series 5.
37	2 00 pounds ammonium phosphate and 100 pounds potassium sulfate, crop harvested.
38 & 39	200 pounds ammonium phosphate and 100 pounds potassium sulfate, crop weighed and returned to the soil.
	Pot series 6.
40	200 pounds potassium phosphate and 100 pounds potassium sulfate, crop harvested.
41 & 42	200 pounds potassium phosphate and 100 pounds potassium sulfate, crop weighed and returned to the soil.
	Pot series 7.
43	Organic fertilizer (3 tons alfalfa tops), crop harvested
44 & 45	Organic fertilizer (3 tons alfalfa tops), crop weighed and returned to the soil.
	Pot series 8.
46	Organic fertilizer (3 tons alfalfa tops), and 100 pounds sulfur, crop harvested.
47 & 48	Organic fertilizer (3 tons alfalfa tops), and 100 pounds sulfur, crop weighed and returned to the soil.

Treatments given in pounds per acre.

comparison between the effect on soil nitrogen that peas may have when grown as a crop to be harvested, and when grown as a green manure crop. Pot series No. 5 received a complete fertilizer which contained 42 pounds of nitrogen per 2,000,000 pounds of soil, while Pot series No. 6 received mineral fertilizer, lacking in nitrogen. Pot series No. 7 and No. 8 received organic fertilizer of finely ground alfalfa tops containing 2.58 per cent nitrogen, which is equivalent to 154 pounds of nitrogen in 2,000,000 pounds of soil. Series No. 8 in addition, received 100 pounds of sulfur.

Austrian winter peas were grown in all pots which were cropped; these being watered with nitrogen free distilled water. Working under controlled conditions in the green house made it possible to grow two crops each year. Insects were troublesome and set the crop back some in each case. Nitrogen free sprays were used to control these insects so that none of the crops were failures.

Five crops were grown in Soil No. I, and in Soil No. II four crops were grown. The peas were harvested at blooming time, weighed, and the crops to be returned were cut up and thoroughly mixed with the soil.

All the pots in both soil series were inoculated with the

pea species Rhizobium leguminosarum. When the first crop was harvested, the roots of all the plants were carefully examined and found to contain an abundance of nodules, which showed the inoculation was effective. The crop from one pot in each pot series 5, 6, 7, and 8 was harvested. All crops harvested were dried and analyzed, and the nitrogen found was credited to the pot from which it had been taken.

Analytical Methods

The modified Kjeldahl-Gunning Method, was used for making all total nitrogen determinations.

The organic substances, such as pea seed and alfalfa tops were weighed out in two gram samples. Pea tops were air dried at 30° C. before analyzing. Two gram samples were used and a duplicate was weighed at the same time and dried at 101° C. The samples to be analyzed were finely ground and digested with 25 cc. concentrated sulfuric acid and 12 grams Hibbard's Mixture composed of 100 grams potassium sulfate, 5 grams copper sulfate, and 2 grams ferrous sulfate. When digested to clearness they were made alkaline with saturated sodium hydroxide and distilled. The ammonia was trapped in standardized N/10 hydrochloric acid.

The excess acid was back titrated with standardized N/10 sodium hydroxide. For determining the total nitrogen in the soil, 10 gram samples were used. Duplicate samples were weighed out and dried at 110° C. All nitrogen determinations, except pea seed and alfalfa fertilizer were calculated on oven dry basis. The analyses on the soil samples were made so as to include nitrate nitrogen. Sulfuric acid containing salicylic acid, 1 gram in 35cc of acid, was first added to the soil and allowed to stand at least two hours; then five grams of sodium thiosulfate was added and heat applied slowly for a few minutes. When frothing ceased, 12 grams of Hibbard's Mixture was added and the digestion carried on to clearness. The usual procedure was then carried out in neutralizing with alkali and distilling into standard acid. All soil samples were ground in an iron mortar until they passed through a 100 mesh sieve. Moisture in air dry soil varied from .2 to .3 of a gram in a 10 gram sample. Hydrochloric acid N/10 and sodium hydroxid N/10 were used in all nitrogen determinations with sodium alizarin sulfonate as an indicator. Titrations were made to check with in .2 of a cc which is equivalent to 0.0028 per cent or 56 pounds of nitrogen in 2,000,000 pounds of soil.

The organic material (pea tops) analyzed was made to check within 0.05 of one per cent. This was never equivalent to more than .002 per cent nitrogen difference in the soil. Blanks were run at intervals to check on nitrogen that might be present in chemicals. Nitrogen free distilled water and acid were used in all analytical work.

The Wet Combustion Method, as simplified by Hock (26) and Friedemann and Kendall (27), was used for determining the total carbon content of the soil. Two grams of soil were used for the determination. This was digested with a solution of chromic, phospheric and sulfuric acids. The carbon was liberated as CO_2 and trapped in N/2 sodium hydroxide. Enough molar barium chloride was then added to precipitate the carbonate present, the excess sodium hydroxide being titrated with standard N/2 hydrochloric acid, phenolphthalein used as an indicator. Blanks were run at intervals to determine the CO_2 present in apparatus and chemicals. The difference in cubic centimeters of acid used in titrating the blanks run and the unknown soil is due to the carbon content of the soil. This method includes organic and other forms of carbon. Soil samples were then checked for non-organic carbon content, according to Emerson (10). This was done by treating 50 grams of soil

with 30 cc of 2N Hydrochloric acid for thirty minutes. CO_2 liberated was trapped in N/2 sodium hydroxide and determined as above. The difference between the first and last determinations is due to the organic carbon in the soil.

In making all determinations the greatest precautions were taken. All standard solutions used in the determinations were made up in large enough volume so that any error which may have entered in from change of standard solution was avoided.

SOIL MICROBIOLOGY INVESTIGATIONS

The purpose of this investigation was to check on the effect of copper sulfate as a soil sterilizing agent. Special attention was given to its effect on the *Azotobacter* of the soil. The presence of fungi, algae, and bacteria were also checked. Composite soil samples were taken under sterile conditions from the copper sulfate treated, fallowed, and cropped pots of each soil.

Azotobacter were not present in the copper sulfate treated soil but were present in all other soil samples examined. The same results were obtained for the algae and bacteria. One species of fungus was found to persist on the copper sulfate treated soil. Numerous individuals of this fungus were present on the acid-peptone-glucose agar plates as well as on the plates containing soil-starch paste used in testing for the presence of *Azotobacter*. Aside from this one copper tolerating fungus the pots treated with copper sulfate were found free from other microorganisms.

RESULTS

Crop Grown on Soil No.I

Seeds to be planted were selected and carefully weighed for each crop. The first seeds sown were inoculated with Rhizobium leguminosarum organism, after which the soil was well inoculated; artificial inoculations were then no longer necessary. The soil was brought up to the optimum moisture content and kept at this point as nearly as possible with nitrogen free distilled water. Water applications were made according to personal judgment, from the apparent need of the crop.

Five crops were grown on this soil commencing in October 1927. All crops except the second crop were harvested when first beginning to bloom. The second crop was grown in the spring and placed outside the greenhouse. The plants under these conditions were infected less by insects and grew more vigorously. Table III gives the weight of each crop and an average of the five crops for each treatment. On the six untreated pots, it will be noticed that the first crop was practically the same on all pots. On these same six pots, the first three were harvested and the second three returned to the soil. In every case, the pots having the peas returned produced the greatest crop average. On the pots receiving a complete

Table III

Green Weight of Each Pea Crop
Grown on Soil No. I

Pot No.	1st Crop grams	2nd Crop grams	3rd Crop grams	4th Crop grams	5th Crop grams	Total	Average
7	20.12	91.17	37.76	54.5	67.49	271.04	54.21
8	21.70	95.54	32.91	58.0	66.39	274.54	54.91
9	14.33	93.75	26.58	50.7	62.23	247.59	49.52
10	19.26	99.48	48.28	81.0	61.04	309.06	61.81
11	19.77	107.05	49.86	76.5	50.97	304.15	60.83
12	21.42	118.06	40.86	87.0	59.89	327.23	65.45
13	22.00	124.17	46.70	59.0	66.73	298.60	59.72
14	28.32	124.45	45.06	81.0	72.59	351.42	70.28
15	23.15	112.48	49.57	97.5	79.87	362.67	72.51
16	20.31	93.11	46.77	77.0	51.74	288.93	57.99
17	19.09	116.90	57.57	102.0	38.11	333.67	66.73
18	17.61	100.96	46.01	89.0	59.71	313.29	62.66
19	25.91	97.10	41.28	43.5	54.07	261.86	52.37
20	27.37	105.01	49.88	70.5	62.49	315.25	63.05
21	18.86	79.72	40.76	55.0	62.39	256.73	51.35
22	21.86	100.56	44.83	59.0	72.77	299.02	59.80
23	26.58	87.83	47.81	74.0	76.14	312.36	62.47
24	23.75	86.27	40.44	52.5	74.67	277.63	55.53

fertilizer and those receiving fertilizer lacking in nitrogen, similar results were obtained. Pots in which the peas were returned, produced the largest crop in every case. Those pots to which organic fertilizer was added showed no increase in yields, over those receiving no treatment and slightly less than those receiving no treatment in which the crop was returned.

Crops Grown On Soil No.II

In the spring of 1928 after one crop of peas had been produced on soil No. I, it was decided to use in the experiment another soil type which differed in origin and nitrogen content. For this purpose a very fine sandy loam soil from the Sherman County Branch Experiment Station at Moro, Oregon was obtained. This soil received exactly the same treatment as the Chehalis soil. The seed was selected and weighed, and the soil kept at optimum moisture with nitrogen free distilled water, as nearly as possible.

Four crops were grown on this soil, all of which were average or better. The first crop, which was grown outside the greenhouse, along with the second crop on Soil No. I was by far the best crop produced. Table IV gives in detail the weight of each crop produced on each pot and the average weight in grams for the four crops grown.

Table IV

Green Weight of Each Pea Crop
Grown on Soil No. II

Pot No.	1st Crop grams	2nd Crop grams	3rd Crop grams	4th Crop grams	Total	Average
31	106.94	36.68	34.0	55.46	233.08	58.27
32	86.83	31.88	52.0	55.42	221.13	66.03
33	88.08	35.48	61.5	55.80	240.86	60.22
34	117.39	46.26	73.5	79.76	316.91	79.23
35	78.67	43.68	70.5	54.24	245.09	61.27
36	86.42	40.46	70.0	68.40	265.23	66.32
37	74.18	37.55	41.0	47.42	200.15	50.04
38	153.79	49.73	84.5	65.90	353.92	88.48
39	178.61	47.58	88.5	54.20	368.79	92.20
40	91.20	46.18	57.0	52.00	246.38	61.60
41	115.35	48.73	91.5	59.62	315.20	78.80
42	79.87	44.18	36.0	35.10	245.15	61.29
43	147.13	46.28	56.0	46.20	295.61	73.90
44	130.99	46.28	89.0	60.10	326.37	81.59
45	127.80	43.62	65.0	55.10	291.52	72.88
46	112.07	39.18	56.5	55.44	263.19	65.80
47	146.31	48.00	63.5	59.96	322.77	80.69
48	102.97	39.38	50.0	27.30	219.65	54.91

The average for all crops produced on Soil No. II was more uniform throughout, regardless of treatment given. The six receiving no treatment, show a slight better average yield on the three pots in which peas were returned to the soil than on those pots in which the peas were harvested. Pots 38 and 39 receiving a complete fertilizer and the peas returned to the soil show a much higher yield than pot 37 receiving the same treatment but having the crop harvested. Other treatments showed up better than the non-treated pots in which the crop was harvested, but no better than the non-treated pots in which the crop was returned.

Nitrogen In the Crops Harvested

The crops were harvested from the first pot in each pot series; then dried, weighed, and the total nitrogen content determined. Table V gives the total green weight, oven dry weight, grams and per cent of nitrogen for the five crops grown on Soil No. I.

Table VI gives the data for the crops grown on soil No. II.

There is very little difference in the per cent of nitrogen found in tops of peas where they were grown on the same soil, with different treatment. Treatments apparently had no effect on the amount of nitrogen taken up by the crop. When the per cent of nitrogen in crops grown on two different soils is

Table V

Nitrogen Content of Peas Grown
On Soil No. I

Oven Dry Basis

Pot	Treatment	Total Weight Green	Total Weight Oven Dry	Nitrogen Content	
		Grams	Grams	Grams	Per cent
7	None	271.04	45.52	1.6060	3.53
8	"	274.54	45.66	1.6045	3.52
9	"	247.59	43.55	1.5464	3.55
13	200 Lbs. $(NH_4)_2HPO_4$ 100 Lbs. K_2SO_4	298.60	51.94	1.8946	3.65
16	200 Lbs. K_2HPO_4 100 Lbs. K_2SO_4	288.93	45.93	1.5782	3.44
19	3T. Alfalfa Tops	261.86	47.18	1.6822	3.57
22	3T. Alfalfa Tops + 100Lbs. Sulfur	299.02	47.00	1.7263	3.67
	Average				3.56

Table VI

Nitrogen Content of Peas Grown
On Soil No. II

Oven Dry Basis

Pot	Treatment	Total Weight Green	Total Weight Oven Dry	Nitrogen Content	Nitrogen Content
		Grams	Grams	Grams	Per cent
31	None	233.08	46.02	1.3796	3.00
32	"	224.13	39.66	1.1179	2.82
33	"	240.86	45.20	1.2220	2.71
37	200 Lbs. $(NH_4)_2HPO_4$ + 100 Lbs. K_2SO_4	200.15	39.77	1.1017	2.77
40	200 Lbs. K_2HPO_4 + 100 Lbs. K_2SO_4	246.38	48.20	1.3768	2.86
43	3T. Alfalfa Tops	295.61	56.03	1.6931	3.02
46	3T. Alfalfa tops + 100 Lbs. Sulfur	263.19	49.78	1.3422	2.70
	Average				2.55

Treatments given in quantities per acre.

compared, there is a difference. For the average of five and four crops respectively, this difference is a full per cent more in the soil of a higher nitrogen content. The analysis for each crop is given in I to II of the appendix.

Nitrogen Balance of Soil No. I

The last crop grown on the pots was turned under and ample time allowed for it to completely decompose. Representative soil samples were then taken from each pot, air dried and total nitrogen determinations were made.

Table VII gives the results in per cent and pounds per acre of nitrogen found in the soil after growing five crops of Austrian Winter peas on soil No. I.

The results show conclusively a gain in soil nitrogen in all cropped pots. The sterilized and fallow pots show a decrease over the original soil. One pot in each of these series gives a gain of a few pounds, the other four showing a loss. The pots on which the crops were harvested, when the nitrogen removed by the crop was accounted for, showed by a wide margin the greatest amount of nitrogen fixed. These increases range from 200 to 250 pounds of nitrogen per acre. These same pots, when the crop is not taken into account, have shown but a very little gain in the soil nitrogen, and the pots

TABLE VII

NITROGEN BALANCE OF SOIL NO. I.

Pot	Treatment	Nitrogen Content after cropping. In Soil.	Removed from Soil in crop.	Soil + Crop	Total Nitrogen of pots at beginning of experiment	Nitrogen gained or lost.		Average gain or loss
		Per cent	Per cent	Per cent	Per cent	Per cent	Lbs/Acre	Lbs/Acre
1.	Copper sulfate saturated	.0962		.0962	.0998	-.0036	- 72	-86
1a	" " "	.0948		.0948	.0998	-.0050	-100	
2	" " "	.0950		.0950	.0998	-.0048	- 96	-82
2a	" " "	.0964		.0964	.0998	-.0034	- 68	
3	" " "	.1006		.1006	.0998	+.0008	+ 16	+2 0
3a	" " "	.1010		.1010	.0998	+.0012	+ 24	
4	Fallow	.1017		.1017	.0998	+.0019	+ 38	+29
4a	"	.0988		.0988	.0998	-.0010	-20	
5	"	.1013		.1013	.0998	+.0015	+ 30	- 6
5a	"	.0977		.0977	.0998	-.0021	- 42	
6	"	.0985		.0985	.0998	-.0013	- 26	-48
6a	"	.0964		.0964	.0998	-.0035	- 70	
7	No treatment	.1076	.0250	.1326	.1039	+.0287	+574	+580
7a	Crop Harvested	.1085	.0249	.1332	.1039	+.0293	+586	
8	" "	.1056	.0250	.1306	.1038	+.0268	+536	+536
8a	" "	.1058	.0249	.1308	.1038	+.0268	+536	
9	" "	.1067	.0240	.1307	.1037	+.0270	+540	+564
9a	" "	.1093	.0240	.1331	.1037	+.0294	+588	
10	No treatment	.1198		.1198	.1038	+.0160	+320	+346
10a	Crop returned to soil	.1224		.1224	.1038	+.0186	+372	
11	" " " "	.1215		.1215	.1037	+.0178	+356	+337
11a	" " " "	.1196		.1196	.1037	+.0159	+318	:
12	" " " "	.1271		.1271	.1038	+.0233	+466	+488
12a	" " " "	.1293		.1296	.1038	+.0255	+510	

TABLE VII CONCLUDED

Pot	Treatment	Nitrogen Content after cropping: In Soil.	Removed from Soil in crop.	Soil + Crop	Total Nitrogen of pots at beginning of experiment	Nitrogen gained or lost.		Average gain or loss
		Per cent	Per cent	Per cent	Per cent	Per cent	Lbs/Acre	Lbs/Acre
13	200 lbs. $(NH_4)_2HPO_4$ +	.1087	.0291	.1378	.1058	+.0320	+ 640	+643
13a	100 lbs K_2SO_4 Crop Harvested.	.1088	.0293	.1381	.1058	+.0323	+ 646	
14	200 Lbs. $(NH_4)_2HPO_4$ +	.1221		.1221	.1060	+.0161	+ 322	+328
14a	100 Lbs. K_2SO_4	.1227		.1227	.1060	+.0167	+ 334	
15	Crop returned to soil	.1268		.1268	.1060	+.0208	+ 416	+402
15a		.1254		.1254	.1060	+.0194	+ 388	
16	200 Lbs. K_2HPO_4+100Lbs.	.1087	.0243	.1330	.1039	+.0291	+ 582	+570
16a	K_2SO_4 Crop Harvested	.1072	.0246	.1318	.1039	+.0279	+558	
17	200 lbs. K_2HPO_4+100lbs.	.1229		.1229	.1036	+.0193	+ 386	+372
17a	K_2SO_4	.1215		.1215	.1036	+.0179	+ 358	
18	Crop returned to soil.	.1256		.1256	.1040	+.0216	+ 432	+408
18a		.1232		.1232	.1040	+.0192	+ 384	
19	3 T. Alfalfa Tops	.1096	.0226	.1322	.1111	+.0211	+ 422	+415
19a	Crop Harvested	.1090	.0225	.1315	.1111	+.0204	+ 408	
20	3 T. Alfalfa tops	.1225		.1225	.1110	+.0115	+ 230	+209
20a	Crop returned to soil	.1201		.1201	.1110	+.0091	+ 182	
21		.1231		.1231	.1111	+.0120	+ 240	+236
21a		.1227		.1227	.1111	+.0116	+ 232	
22	3 T. Alfalfa Tops + 100	.1087	.0232	.1319	.1109	+.0210	+ 420	+399
22a	Lbs. sulfur Crop Harvested.	.1067	.0231	.1298	.1109	+.0189	+ 378	
23	3 T. alfalfa tops +100Lbs	.1235		.1235	.1109	+.0126	+ 252	+238
23a	Sulfur	.1221		.1221	.1109	+.0112	+ 224	
24		.1234		.1234	.1110	+.0124	+ 248	+262
24a	Crop returned to soil.	.1248		.1248	.1110	+.0138	+ 276	

Table VIII

Nitrogen Balance of Soil No. I
Crops Harvested

Pot	Treatment	Nitrogen Content of soil after cropping	Nitrogen Content of soil at beginning	Nitrogen gained or lost	Nitrogen gained or lost	Average gain or loss
		per cent	per cent	per cent	lbs.Acre	
7	None	.1076	.1039	+.0037	+ 74	+83
7	"	.1085	.1039	+.0046	+ 92	
8	None	.1056	.1038	+.0018	+ 36	+38
8	"	.1058	.1038	+.0020	+40	
9	None	.1067	.1037	+.0030	+ 60	+86
9	"	.1093	.1037	+.0056	+112	
13	200 Lbs.$(NH_4)_2.HPO_4$	.1087	.1058	+.0029	+ 58	+59
13	+ 100 Lbs.K_2SO_4	.1088	.1058	+.0030	+ 60	
16	200 Lbs. K_2HPO_4 +	.1087	.1039	+.0048	+ 96	+81
16	100 Lbs. K_2SO_4	.1072	.1039	+.0033	+ 66	
19	3 T. Alfalfa Tops	.1096	.1111	-.0015	- 30	-36
19		.1090	.1111	-.002 1	-42	
22	3 T. Alfalfa Tops	.1087	.1109	-.0022	- 4 4	-54
22	+ 100 Lbs. Sulfur	.1067	.1109	-.0042	-84	

Treatments given in quantities per acre.

fertilized with 3 tons of alfalfa tops all show a loss.

Table VIII gives the nitrogen balance of the soil at the conclusion of the experiment on pots which were cropped and the crops all removed.

Nitrogen Balance of Soil No. II

Crop and soil samples were handled the same as in Soil No.I. The data obtained from cropping this soil to Austrian Winter peas is given in Table IX.

On this soil with four crops of peas, the results again show a positive gain in the total nitrogen of the soil on all cropped pots. All sterilized and fallow pots show a loss in nitrogen, while pots in which crops were grown and harvested did not in every case show greater gains in nitrogen fixed than the pots in which the crops were returned, as was the case in Soil No. I. Pot 37 which was treated with ammonium phosphate, and the crop harvested, gave a decrease of 200 pounds per acre over pots 38 and 39 receiving similar treatment, with crops turned under. The gain in nitrogen in pot 48 was very small. This pot while showing a gain of over 100 pounds of nitrogen per acre was far below any other pot which was cropped.

Table X gives the nitrogen balance of Soil No. II, which was cropped to peas and the crops harvested.

TABLE IX
NITROGEN BALANCE SOIL NO.II

Pot	Treatment	Nitrogen Content after cropping. In Soil.	Removed from soil in crop.	Soil + Crop	Total Nitrogen of pots at beginning of experiment	Nitrogen gained or lost.		Average gain or loss
		Per cent	Per cent	Per cent	Per cent	per Cent	Lbs/Acre	Lbs/Acre
25.	Copper sulfate saturated	.0861		.0861	.0876	-.0015	- 30	-54
25a	" " "	.0837		.0837	.0876	-.0039	- 78	
26	" " "	.0854		.0854	.0876	-.0022	-44	-57
26a	" " "	.0841		.0841	.0876	-.0035	- 70	
27	" " "	.0852		.0852	.0876	-.0024	- 48	-57
27a	" " "	.0843		.0843	.0876	-.0033	- 66	
28	Fallow	.0861		.0861	.0876	-.0015	- 30	-54
28a	"	.0837		.0837	.0876	-.0039	-78	
29	"	.0857		.0857	.0876	-.0019	- 38	-54
29a	"	.0841		.0841	.0876	-.0035	- 70	
30	"	.0826		.0826	.0876	-.0050	-100	-96
30a	"	.0830		.0830	.0876	-.0046	- 92	
31	No treatment	.0918	.0239	.1155	.0915	+.0240	+480	+476
31a	crop harvested	.0909	.0242	.1151	.0915	+.0236	+472	
32		.0918	.0194	.1112	.0915	+.0197	+394	+396
32a	" "	.0919	.0195	.1114	.0915	+.0199	+398	
33	" "	.0940	.0213	.1153	.0915	+.0238	+476	+445
33a	" "	.0909	.0213	.1122	.0915	+.0207	+414	
34	No treatment	.1125		.1125	.0915	+.0210	+420	+411
34a	Crop returned to soil	.1116		.1116	.0915	+.0201	+402	
35	" "	.1122		.1122	.0915	+.0207	+414	+391
35a	" " "	.1099		.1099	.0915	+.0184	+368	
36	" " "	.1105		.1105	.0915	+.0190	+380	+383
36a	" " "	.1108		.1108	.0915	+.0193	+386	

TABLE VXI CONCLUDED

Pot	Treatment	Nitrogen Content after cropping. In Soil.	Removed from soil in crop.	Soil + Crop	Total Nitrogen of pots at beginning of experiment	Nitrogen gained or lost.		Average gain or loss
		Per cent	Per cent	Per cent	Per cent	Per cent	Lbs/Acre	Lbs/Acre
37	200 Lbs. $(NH_4)_2HPO_4$ + 100	.0889	.0194	.1083	.0936	+.0147	+ 294	+268
37a	lbs. K_2SO_4 Crop Harvested	.0866	.0191	.1057	.0936	+.0121	+ 242	
38	200 Lbs. $(NH_4)_2HPO_4$ + 100	.1162		.1162	.0936	+.0226	+ 452	+448
38a	lbs. K_2SO_4	.1158		.1158	.0936	+.0222	+ 444	
39	Crop returned to soil.	.1166		.1166	.0936	+.0230	+ 460	+485
39a		.1191		.1191	.0936	+.0255	+ 510	
40	200 Lbs. K_2HPO_4+ 100 lbs.	.0906	.0241	.1147	.0915	+.0232	+ 464	+445
40a	K_2SO_4 Crop Harvested	.0889	.0239	.1128	.0915	+.0213	+ 426	
41	200 Lbs. K_2HPO_4+ 100 lbs.	.1129		.1129	.0915	+.0214	+ 428	+423
41a	K_2SO_4 Crop returned to soil	.1124		.1124	.0915	+.0209	+ 418	
42		.1062		.1062	.0915	+.0147	+ 294	+296
42a		.1064		.1064	.0915	+.0149	+ 298	
43	3 T. Alfalfa Tops	.0943	.0293	.1236	.0992	+.0244	+ 488	+489
43a	Crop harvested	.0940	.0297	.1237	.0992	+.0245	+ 490	
44	3 T. Alfalfa Tops	.1194		.1194	.0922	+.0202	+ 404	+378
44a	Crop returned to soil	.1168		.1168	.0992	+.0176	+ 352	
45		.1116		.1116	.0992	+.0124	+ 248	+276
45a		.1144		.1144	.0992	+.0152	+ 304	
46	3 T. Alfalfa Tops + 100 Lbs.S.	.0940	.0234	.1174	.0992	+.0182	+ 364	+356
46a	Crop Harvested	.0930	.0235	.1166	.0992	+.0174	+ 348	
47	3 T. Alfalfa Tops + 100 Lbs.S.	.1190		.1190	.0992	+.0198	+ 396	+ 416
47a	Crop returned to soil.	.1210		.1210	.0992	+.0218	+ 436	
48		.1053		.1053	.0992	+.0061	+ 122	+ 129
48a		.1060		.1060	.0992	+.0068	+ 136	

Table X

Nitrogen Balance of Soil No. II
Crops Harvested

Pot	Treatment	Nitrogen Content of soil after cropping	Nitrogen Content of soil at beginning	Nitrogen Gained or Lost	Nitrogen Gained or Lost	Average Gain or Loss
		Per cent	Per cent	Per cent	Lbs/acre	Lbs/Acre
31	None	.0916	.0915	+.0001	+ 2	- 5
31	"	.0909	.0915	-.0006	- 12	
32	None	.0918	.0915	+.0003	+ 6	+ 7
32	"	.0919	.0915	+.0004	+ 8	
33	None	.0940	.0915	+.0025	+ 50	+19
33	"	.0909	.0915	-.0006	- 12	
37	200 Lbs $(NH_4)_2HPO_4$	.0889	.0936	-.0047	- 94	-117
37	+100Lbs.K_2SO_4	.0866	.0936	-.0070	-140	
40	200 Lbs.K_2HPO_4 +	.0906	.0915	-.0006	- 12	-32
40	100 Lbs.K_2SO_4	.0889	.0915	-.0026	-52	
43	3 T. Alfalfa Tops	.0943	.0992	-.0046	- 92	-98
43		.0940	.0992	-.0052	-104	
46	3 T. Alfalfa Tops	.0940	.0992	-.0052	-104	-114
46	+ 100 Lbs. Sulfur	.0930	.0992	-.0062	-124	

Treatments given in quantities per acre.

In this soil, all the pots on which the crops were harvested except two, show a decrease in the nitrogen balance; neither of the two showing an increase, received nitrogen in the form of fertilizer. The other two pots, not receiving nitrogen in addition to that already supplied in the soil, showed but a small decrease, while all pots receiving nitrogen in the form of fertilizer gave a decrease, but not in proportion to the nitrogen added.

Organic Matter Content of Soil.

A number of investigators have shown that there is a very close correlation between the nitrogen and organic matter content of the soil. In order to determine the changes in organic matter content brought about by the growing of Austrian Winter peas, total organic carbon analyses were made. The organic matter content was obtained by multiplying organic carbon by the factor 1.724. This factor is the one most commonly used and although declared low by some authors was found satisfactory by Sievers and Holtz (24). Their work further demonstrates that the relationship between nitrogen, organic carbon and organic matter is fairly closely fixed. A rough approximation is frequently obtained by using the following factors.

Per cent total N. x 11.6 = Organic Carbon

Per cent Organic C. x 1.724 = Organic matter

Per cent total N. x 20 = Organic matter

Soil No. I

Table XI gives the organic carbon found for each soil treatment and the organic matter, which was calculated by using the factor 1.724. The per cent nitrogen and the nitrogen carbon ratio is also given.

The initial N:C ratio of 1:11.14 found in the soil agrees very closely with that (1:11.4) of Sievers and Holtz (24). The ratio for each of the sterilized and fallow pots has remained practically the same as the initial soil. All other soil treatments tended toward a narrowing of the ratio. The ratio becoming even more narrow in the soil which had pea tops returned as a green manure. Heavy applications of organic matter, in the form of alfalfa tops, tended to maintain the N:C ratio more nearly like that of the original soil.

Soil No. II

The initial N:C ratio of Soil No. II was 1:11.30, which is practically the same as was found in Soil No. I and also compares more closely with the ratio 1:11.4 found by Sievers

Table XI

The Effect of Austrian Winter Peas
On Organic Matter Content
and
Nitrogen Carbon Ratio of Soil No.1

Pot	Treatment	Organic Matter	Organic Carbon	Average Organic Carbon	Nitrogen	N : C Ratio
		Per Cent	Per Cent	Per Cent	Per Cent	
	Initial Soil	1.917	1.112	1.112	.0998	1:11.14
1	Saturated Solution	1.873	1.086			
1	of copper sulfate	1.765	1.024	1.055	.0955	1:11.04
2	"	1.864	1.081			
2	"	1.836	1.065	1.073	.0957	1:11.21
3	"	1.846	1.071			
3	"	1.886	1.095	1.083	.1008	1:10.74
4	Fallow	1.708	.991			
4	"	1.828	1.060	1.026	.1003	1:10.24
5	"	1.859	1.078			
5	"	1.940	1.125	1.102	.0995	1:11.08
6	"	1.890	1.096			
6	"	1.834	1.064	1.080	.0975	1:11.08
7	None	1.850	1.073			
7	Crop Harvested	1.855	1.076	1.075	.1081	1: 9.95
8	" "	2.063	1.196			
8	" "	1.954	1.133	1.165	.1057	1:11.02
9	" "	1.866	1.083			
9	" "	1.956	1.135	1.109	.1080	1:10.26
10	None Crop	2.089	1.211			
10	Returned to Soil.	2.216	1.285	1.248	.1211	1:10.30
11	" " "	2.135	1.238			
11	" " "	2.183	1.266	1.252	.1206	1:10.38
12	" " "	2.111	1.225			
12	" " "	2.187	1.268	1.247	.1282	1: 9.73
13	200 Lbs. Crop	1.868	1.084			
13	$(NH_4)_2HPO_4$ Harvested	1.920	1.114	1.099	.1088	1:10.10
14	and Crop	2.071	1.201			
14	100 Lbs. Returned	1.985	1.151	1.176	.1224	1: 9.63
15	K_2SO_4 to soil	2.010	1.165			
15		2.038	1.182	1.174	.1261	1: 9.31

Table XI Concluded

Pot	Treatment	Organic Matter	Organic Carbon	Average Organic Carbon	Nitrogen	N : C Ratio
16	200 lbs. Crop	1.894	1.098			
16	(NH_4) K_2HPO_4 Harvested	1.841	1.063	1.083	.1080	1:10.02
17	and Crop	2.072	1.202			
17	100 lbs. Returned	2.047	1.186	1.194	.1222	1: 9.77
18	K_2SO_4 to soil	2.155	1.250	1.232	.1244	1: 9.91
18		2.092	1.214			
19	3T. Alfalfa Tops	2.009	1.165	1.154	.1093	1:10.55
19	Crop Harvested	1.969	1.142			
20	3T. Alfalfa Tops	2.014	1.168	1.171	.1215	1: 9.65
20	and	2.023	1.174			
21	Crop returned	2.207	1.280	1.261	.1229	1:10.26
21	To soil	2.141	1.242			
22	3T. Alfalfa Tops	2.054	1.191	1.171	.1077	1 :10.87
22	Crop Harvested	1.984	1.150			
23	3T. Alfalfa Tops +	2.200	1.276	1.281	.1228	1:10.43
23	100 lbs. Sulfur	2.216	1.285			
24	Crop returned	2.205	1.279	1.268	.1241	1:10.21
24	to Soil.	2.167	1.256			

and Holts. The organic carbon content for each soil treatment and the organic matter, as well as the nitrogen and N:C ratio for this soil is found in Table No. XII.

The data in this table shows a very close likeness to that obtained on Soil No. I. The sterilized and fallow pots, as well as the pots on which the crops were harvested, all maintained a N:C ratio very close to that of the initial soil, while pots in which the crops were returned, all showed a narrowing of the ratio.

Table XII

The Effect of Austrian Winter Peas
On Organic Matter Content
and
Nitrogen Carbon Ratio of Soil No.II

Pot	Treatment	Organic Matter	Organic Carbon	Average Organic Carbon	Nitrogen	N : C Ratio
	Initial Soil	Per cent	Per cent	Per cent	Per cent	
		1.707	.990	.990	.0876	1:11.30
25	Saturated solution	1.645	.954	.943	.0849	1:11.10
25	of Copper sulfate	1.605	.931			
26	" " "	1.645	.966	.956	.0848	1:11.29
26	" " "	1.637	.950			
27	" " "	1.607	.933	.945	.0848	1:11.14
27	" " "	1.648	.956			
28	Fallow	1.596	.934	.913	.0849	1:10.75
28	"	1.553	.901			
29	"	1.643	.953	.945	.0849	1:11.13
29	"	1.614	.936			
30	"	1.558	.904	.900	.0828	1:10.88
30	"	1.542	.895			
31	None Crop	1.696	.984	.980	.0913	1:10.73
31	Harvested	1.682	.976			
32	"	1.786	1.036	1.042	.0919	1:11.34
32	"	1.808	1.048			
33	"	1.724	1.000	1.013	.0925	1:10.95
33	"	1.739	1.026			
34	None Crop	1.907	1.106			
34	Returned to Soil	1.916	1.111	1.109	.1121	1: 9.89
35	" " "	1.954	1.134			
35	" " "	1.942	1.126	1.130	.1111	1:10.16
36	" " "	1.922	1.115			
36	" " "	1.907	1.106	1.111	.1107	1:10.04
37	200 lbs. Crop	1.714	.994	1.025	.0876	1:11.67
37	$(NH_4)_2HPO_4$ Harvested	1.920	1.055			
38	and Crop	1.983	1.150	1.143	.1160	1: 9.85
38	100 lbs. Returned	1.957	1.135			
39	K_2SO_4 To soil	2.014	1.168	1.172	.1179	1: 9.95
39		2.027	1.175			

Table XII Concluded

Pot	Treatment	Organic Matter	Organic Carbon	Average Organic Carbon	Nitrogen	N : C Ratio
40	200 Lbs. Crop	1.672	.974	.986	.0898	1:10.98
40	K_2HPO_4 Harvested	1.720	.998			
41	and Crop	1.937	1.134	1.088	.1127	1: 9.65
41	100 Lbs. Returned	1.812	1.051			
42	K_2SO_4 to soil.	1.970	1.143	1.135	.1063	1:10.68
42		1.944	1.127			
43	3T. Alfalfa Tops	1.807	1.048	1.076	.0942	1:11.43
43	Crop Harvested	1.902	1.103			
44	3T. Alfalfa Tops	2.098	1.216	1.195	.1181	1 :10.11
44	and crop	2.027	1.175			
45	Returned to soil	1.957	1.135	1.100	.1130	1: 9.73
45		1.836	1.065			
46	3T Alfalfa Tops	1.850	1.073	1.071	.0935	1:11.46
46	Crop Harvested	1.843	1.069			
47	3T Alfalfa Tops +	2.204	1.278	1.241	.1200	1:10.34
47	100 Lbs. Sulfur	2.076	1.204			
48	Crop Returned	1.979	1.146	1.129	.1057	1:10.68
48	to soil.	1.915	1.110			

DISCUSSION

The data obtained in this experiment show substantial increases in the nitrogen content of the soil when Austrian Winter peas were grown as a green manure crop. Where the peas are harvested the nitrogen fixed or the nitrogen accounted for in the soil plus that removed in the crop was even greater than when used as a cover crop. The nitrogen content of the soil was changed but little when the crop was removed; Soil No. I showed an increase in all treatments except the two pots, which were treated with alfalfa tops, while Soil No. II showed a decrease in all pots except two receiving no treatment. The gain in nitrogen fixed varied from 300 to 500 pounds per acre. The lower gains were obtained on the soils receiving alfalfa tops, while the greater gain in nitrogen accounted for was in non-treated pots which had their crops removed. Where the pea crop was returned to the soil the activity of the organisms was lessened, if the nitrogen gained is taken as a measure of their activity. These results are contrary to those of Albrecht (30), who in a carefully planned experiment showed that large applications of organic fertilizers did not retard the nitrogen fixing organisms. In his experiment soil of very low nitrogen content was used.

Applications of Ammonium phosphate at the rate of 200 pounds per acre did not show a stimulating or retarding effect. Pot 37 of this treatment was low in crop yield in every crop grown and was likewise low in nitrogen fixed. Reasons for this cannot be accounted for.

The average gain of nitrogen in all harvested, and in all crop returned pots, gives a difference of from 44 pounds in Soil No. II to 200 pounds in Soil No. I, in favor of the pots in which the crops were harvested. The turning under of a green manure crops, and the addition of organic fertilizers, had less effect on the amount of nitrogen fixed, in Soil No. II which was low in nitrogen at the beginning of the experiment. Although the initial difference in nitrogen content of these two soils was very small, they behaved differently. Soil No.II with the lower nitrogen content, was cropped four times, with an average gain in nitrogen of 96 pounds per acre for each crop produced. Soil No. I which was cropped five times and showed 82 pounds of nitrogen fixed per acre for each crop. On the other hand where the crops were harvested the peas more than kept up the nitrogen level in Soil No. I while in Soil No. II there was a slight depression. The nitrogen found in the harvested crops will not explain the above results, for

the higher per cent of nitrogen was found in the crop produced on Soil No. I in every case. Soil No. II produced larger crop averages, which drew upon the soil nitrogen nearly as extensive for the four crops as soil No. I did in the five crops. In Table XIII is given summarized data of the nitrogen fixed in each pot series and the average for the two soils used.

No treatment used in this experiment was out-standing either in crops produced, or in stimulating or retarding the activity of the nitrogen fixing organisms. The efficiency of the non-symbiotic nitrogen fixing organisms in the fallow pots was not sufficient to accumulate enough nitrogen to measure. On the other hand these pots show a slight decrease in nitrogen content. The copper sulfate treated pots show a decrease which is greater than the fallow of Soil No. I and very nearly the same as the fallow of Soil No. II. The results found in these checks show, that all nitrogen fixed in the cropped pots, can be credited to the symbiotic fixation. Abey (1) found similar results in fallow soils.

The effect on the organic matter of the soil was very similar to that of the nitrogen. The ratio of nitrogen to carbon remained reasonably constant in all treatments, thus showing a similar increase in organic matter and nitrogen content.

Table XIII

Summary--Showing Gain or Loss in Nitrogen

Treatment	Soil No.1	Soil No.II	Average Soil No.I & II
	Lbs.Acre	Lbs.Acre	Lbs/Acre
Sterilized with $CuSO_4$	-49	-56	-53
Fallow	- 8	-68	-38
No treatment Crop Harvested	+560	+439	+500
No treatment Crop Returned to Soil	+390	+394	+392
200 Lbs.$(NH_4)_2HPO_4$+100 Lbs.K_2SO_4	+458	+400	+429
200 Lbs. K_2HPO_4 + 100 Lbs. K_2SO_4	+450	+388	+419
3 Tons Alfalfa Tops	+297	+381	+334
3 Tons Alfalfa tops +100 Lbs.Sulfur	+300	+300	+300
Average of six treatments	+408	+384	+396
Average of six treatments per crop	+ 82	+ 96	+ 89
Average all pots with crop harvested	+530	+411	+471
Average all pots with crops returned to the soil.	+330	+367	+349

The turning under of peas, narrowed the ratio some in every case. Table XIV gives the summarized data of the organic matter and nitrogen content, and their relationship to each other as expressed by the N:C ratio.

Table XIV

Summary--Organic Matter, Organic Carbon, Nitrogen,

And the Nitrogen Carbon Ratio

Treatment	Organic Matter	Organic Carbon	Nitrogen	N : C Ratio
Initial Soil	1.917	1.112	.0998	1:11.14
$CuSO_4$ saturated solution	1.845	1.070	.0973	1:11.00
Fallow	1.843	1.069	.0991	1:10.78
No treatment crop harvested	1.926	1.116	.1073	1:10.41
No treatment crop returned	2.154	1.249	.1233	1:10.12
200 Lbs.$(NH_4)_2HPO_4$ + 100Lbs.K_2SO_4	1.982	1.150	.1191	1: 9.66
200 Lbs.K_2HPO_4 + 100 Lbs. K_2SO_4	2.017	1.170	.1182	1: 9.90
3 Tons Alfalfa Tops	2.059	1.195	.1179	1:10.14
3 Tons Alfalfa Tops+100 Lbs.Sulfur	2.138	1.240	.1182	1:10.49
Average all crops harvested	1.934	1.122	.1079	1:10.40
Average all crops returned to soil	2.117	1.228	.1233	1: 9.96
Soil No. II				
Initial Soil	1.707	.990	.0876	1:11.30
$CuSO_4$ saturated solution	1.635	.949	.0848	1:11.18
Fallow	1.584	.919	.0842	1:10.91
No treatment Crop Harvested	1.744	1.012	.0919	1:11.01
No treatment Crop Returned	1.925	1.117	.1113	1:10.04
200 Lbs.$(NH_4)_2HPO_4$+100Lbs.K_2SO_4	1.948	1.113	.1072	1:10.38
200 Lbs.K_2HPO_4+ 100 Lbs. K_2SO_4	1.845	1.070	.1029	1:10.40
3 Tons Alfalfa Tops	1.936	1.124	.1084	1:10.36
3 Tons Alfalfa tops+100Lbs.Sulfur	1.977	1.147	.1064	1:10.78
Average All crops harvested	1.772	1.028	.0916	1:11.22
Average all crops returned to soil	1.966	1.141	.1131	1:10.08

SUMMARY

1. The growing of Austrian winter peas as a green manure crop, increased the nitrogen and the organic matter content of the soil.

2. The total nitrogen of the soil remained unchanged when the crop was harvested and removed in all cases except where alfalfa tops were used as a fertilizer material. In this case there was a slight decrease in the nitrogen balance of the soil.

3. The total nitrogen balance where peas are grown and harvested is higher than where peas are grown and turned under.

4. The nitrogen content in the tops was highest in peas grown on the soil containing the higher nitrogen content.

5. The crop when nearly mature contained the highest amount of nitrogen, although in the earlier periods of growth the per cent of nitrogen was greater.

6. Changes in the organic matter content of the soil correlates with those of the nitrogen content where the peas were either harvested or used as a green manure crop.

7. The turning under of the pea crop tends to narrow the Nitrogen Carbon ratio of the soil.

8. The addition of alfalfa tops to the soils decreased the amount of nitrogen fixed by the pea crop but helped to maintain the Nitrogen Carbon ratio more nearly like that of the initial soil.

9. A saturated solution of copper sulfate added to the soil proved toxic to all soil organisms except one type of fungus. This one persisted when in direct contact with crystals of copper sulfate.

10. The fallow soils showed no increase in Nitrogen content, although *Azotobacter* were present.

11. The change in nitrogen content from that of the initial soil was practically the same in fallow and in copper sulfate treated soils.

APPENDIX

Table I.

Nitrogen Content of Peas Grown
On Soil No. I.

Oven Dry Basis

Pot	Treatment	Total Weight Green	Total Weight Oven Dry	Nitrogen Content	
		grams	grams	grams	per cent
First Crop.					
7	None	20.12	3.19	.1415	4.44
8	"	21.70	3.63	.1562	4.30
9	"	14.33	2.77	.1187	4.29
13	200 lbs. $(NH_4)_2HPO_4$ + 100 lbs. K_2SO_4	22.00	3.92	.1910	4.87
16	200 lbs. K_2HPO_4 + 100 lbs. K_2SO_4	20.31	3.28	.1479	4.51
19	3% alfalfa tops.	25.91	4.34	.1827	4.21
22	3% alfalfa tops + 100 lbs. sulfur	21.86	4.11	.1661	4.04
Second Crop.					
7	Treatment same as above	91.17	17.80	.5235	3.03
8		95.64	19.27	.5418	2.81
9		93.75	17.89	.5237	3.01
13		124.17	22.81	.6730	2.95
16		93.11	18.75	.4811	2.57
19		97.10	19.70	.5369	2.73
22		100.56	18.92	.5329	2.83
Third Crop.					
7	Treatment same as above	37.67	5.72	.2635	4.61
8		52.91	5.01	.2352	4.66
9		26.58	4.35	.1923	4.42
13		46.70	7.14	.3474	4.87
16		46.77	6.94	.3298	4.75
19		41.28	6.48	.3231	4.99
22		44.83	7.04	.3482	4.95

Table I. Concluded.

Nitrogen content of Peas
Grown on Soil No. I.

Oven Dry Basis

Pot	Treatment	Total Weight Green	Total Weight Oven Dry	Nitrogen Content	
		grams	grams	grams	per cent
Fourth Crop.					
7	None	54.50	8.31	.2198	2.65
8	"	58.00	6.57	.1708	2.60
9	"	60.70	7.73	.2276	2.95
13	200 lbs. $(NH_4)_2HPO_4$ + 100 lbs. K_2SO_4	69.00	7.60	.2056	2.71
16	200 lbs. K_2HPO_4 + 100 lbs. K_2SO_4	77.00	7.55	.2110	2.80
19	3 T. Alfalfa tops.	43.50	6.06	.1740	2.87
22	3 T. " " 100 lbs. sulfur	59.00	5.54	.1514	2.84
Fifth Crop.					
7	Treatment same as above.	67.49	11.00	.4785	4.16
8		66.39	11.18	.5028	4.52
9		63.23	11.31	.4841	4.28
13		66.73	10.47	.4676	4.47
16		51.74	9.41	.4085	4.34
19		54.07	10.60	.4655	4.39
22		72.77	11.69	.5277	4.52

Table II.

Nitrogen Content of Peas Grown
On Soil No. II

Oven Dry Basis.

Pot	Treatment	Total Weight Green	Total Weight Oven Dry	Nitrogen Content	
		grams	grams	grams	per cent
First Crop.					
32	None	106.94	23.31	.6390	2.74
32	"	86.83	18.56	.4280	2.31
33	"	88.08	20.27	.4318	2.13
37	200 lbs $(NH_4)_2HPO_4$ + 100 lbs K_2SO_4	74.18	16.76	.3018	1.80
40	200 lbs K_2HPO_4 + 100 lbs K_2SO_4	91.20	21.02	.4750	2.17
43	3 T. Alfalfa tops.	147.13	31.16	.7979	2.56
46	3 T. Alfalfa tops. + 100 lbs. Sulfur.	112.07	24.73	.5100	2.07
Second Crop					
31		36.68	6.24	.2379	3.83
32		31.88	6117	.2207	3.58
33	Treatment	35.48	6.18	.2268	3.68
37	same	37.55	7.24	.2766	3.82
40	as above	46.18	7.29	.2989	4.10
43		46.28	7.56	.3052	4.04
46		39.18	6.78	.2645	3.90
31		34.00	6.62	.1565	2.36
32	Treatment	52.00	5.09	.1267	2.49
33	same	61.50	8.32	.2019	2.43
37	as above	41.00	7.53	.2275	3.02
40		57.00	9.39	.2610	2.78
43		56.00	9.38	.2749	2.93
46		56.50	8.35	.2112	2.53
Fourth Crop.					
31		56.46	9.85	.3464	3.52
32	Treatment	53.42	9.84	.3425	3.48
33	same	55.80	10.43	.3620	3.47
37	as above	47.42	8.24	.2958	3.59
40		52.00	9.60	.3419	3.56
43		46.20	7.93	.3151	3.97
46		55.44	9.90	.3565	3.60

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PLATE I

Figure 1. Austrian winter pea plants on Chehalis Soil.

Figure 2. Austrian winter pea plants on soil from the Sherman County Branch Experiment Station, Moro, Oregon.

Figure 1

Figure 2

PLATE II

Figure 3. Austrian winter peas grown on Chehalis soil receiving no treatment.

Plants 7 and 8 were harvested.

Plants 10 and 12 were returned to the soil.

Figure 4. Austrian winter peas grown on soil from the Sherman county Branch Experiment Station.

Plant 33 was untreated

Plant 38 received ammonium phosphate and potassium sulfate.

Plant 40 received potassium phosphate and potassium sulfate.

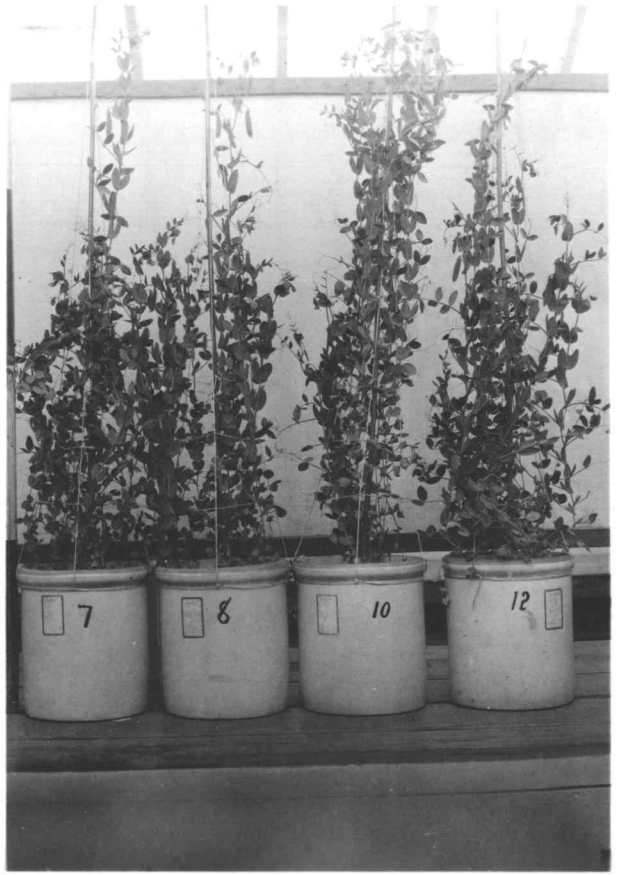

Figure 3

Figure 4