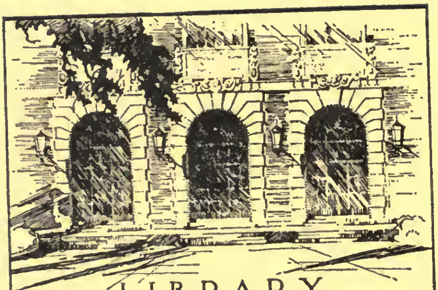

UNIVERSITY OF ILLINOIS
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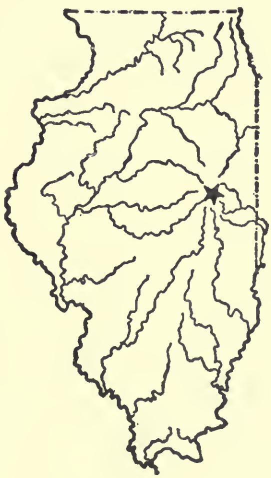
EXPERIMENTS IN HANDLING SWEET CLOVER

With Reference to the Accumulation and Conservation of Nitrates in the Soil

By Albert L. Whiting and Thomas E. Richmond



URBANA, ILLINOIS, JANUARY, 1927

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EXPERIMENTS IN HANDLING SWEET CLOVER

With Reference to the Accumulation and Conservation of Nitrates in the Soil

By Albert L. Whiting and Thomas E. Richmond[1]

The rapidly increasing use of sweet clover as a green manure testifies to its high value for this purpose. Whereas only a few years ago sweet clover was despised as a useless weed, so rapidly has it risen in the farmer's estimation that in the year 1926 it is reported that 744,000 acres in Illinois alone were given over to the cultivation of this crop.

Some of the reasons for the extraordinary manurial value of sweet clover are discussed in Bulletin No. 233 of this Station ("Sweet Clover for Nitrate Production," 1921). A principal reason is to be attributed to the fact that sweet clover produces such a large amount of very readily decomposable organic matter which upon plowing under decays promptly and makes available in the soil unusually large quantities of nitrogen for the nourishment of the corn or other crop that follows. The above mentioned bulletin presents experimental data substantiating this fact, and showing the actual amounts of nitrate present in the soil at different periods thruout the season. The relative amounts of nitrate produced under different systems of soil treatment are compared, thus furnishing information on the economic possibilities of sweet clover.

There are various questions connected with the culture of sweet clover, however, that have remained unanswered—questions pertaining to the proper manner of handling the crop in order to realize its maximum fertilizing value. Among such questions is that of the proper time of plowing down sweet clover for the most advantageous production of nitrate in relation to the nourishment of the succeeding crop. For instance, would fall plowing be better than spring plowing from the standpoint of nitrogen supply and conservation? Or, if plowed in the spring is earlier plowing better than later plowing in this regard?

The present bulletin reports the results of a study designed to throw some light on these questions. The relative merits of fall and spring plowing are considered, as are also spring plowing at different dates, and summer plowing of the second year's crop. Consideration is also given to the losses of nitrate from the soil and to means of preventing these losses thru proper farm practices, special attention being directed to the role that sweet clover plays in conserving soil nitrates during the fall, winter, and spring.

[1]Albert L. Whiting, formerly Chief in Soil Biology; Thomas E. Richmond, formerly Associate in Soil Biology.

In carrying out these studies, observations were made on a number of outlying soil experiment fields located in different sections of Illinois. These observations involved the taking of soil samples at various intervals of time, as indicated in the respective tables of results which follow, and the determination of the nitrate content.[1]

COMPARISON OF FALL-PLOWED AND SPRING-PLOWED SWEET CLOVER FOR NITRATE PRODUCTION

In order to compare the effect of fall plowing with spring plowing of sweet clover with respect to its value for nitrate production for corn, certain plots of Series 300 of the Joliet field were selected.

These plots had produced under their respective full soil treatments the following succession of crops: corn, oats, soybeans, wheat. In the spring of 1921 sweet clover was seeded in the wheat as a catch crop to be plowed under for the benefit of the corn to follow. The plots selected for the study were the following:

Plot 305—No treatment
Plot 307—Limestone and sweet clover
Plot 308—Limestone, phosphorus, residues, and sweet clover
Plot 309—Limestone, phosphorus, potassium, residues, and sweet clover

For making the desired comparisons these plots were divided into east and west halves. The east halves were all fall-plowed in November and the west halves were spring-plowed in the following May.

The condition of the sweet clover was excellent on Plot 309, good on Plot 308, and fair on Plot 307. An excellent job of fall plowing was done, the sweet-clover roots being cut off completely at a depth of about 7 inches and the tops turned under properly. Samples of soil were taken November 25 on both halves of the plots.

In the early spring the fall-plowed sweet clover began to grow, sending out many shoots from the crowns of the old roots and developing new feeding roots from the old root stocks. A severe winter had not killed it, and it grew so rapidly that it made a fair stand. The ground was double-disked, but still the sweet clover continued to grow until finally in order to subdue it the land was replowed. This was done about May 7, at the same time that the west half-plots were plowed. This experience in the fall plowing of sweet clover was certainly not encouraging as a practice to be adopted.

On May 5 soil samples were taken before the spring plowing. The unplowed clover was 14 inches high on Plot 309 West, 12 inches on Plot 308 West, and only about 8 inches in height and irregular in stand

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[1]For a description of the technic employed, including the methods of collecting soil samples and making analysis for nitrate nitrogen, the reader is referred to an article entitled "The Determination of Nitrates in Soil," Jour. Indus. and Engin. Chem. 12, 982.

on Plot 307 West. Spring rains kept the nitrates low up to May 5 and after.

On July 6 the following measurements of the height of the corn were taken which bring out well the comparative differences in growth:

Plot 305 East	17 inches
Plot 305 West	20 inches
Plot 307 East	18 inches
Plot 307 West	32 inches
Plot 308 East	24 inches
Plot 308 West	36 inches
Plot 309 East	30 inches
Plot 309 West	40 inches

The differences in vegetative growth between the east and west halves were evident a considerable distance from the field until the corn became mature. Corn on the adjacent Series 200 was much slower in its growth than the corn on the west side of Series 300.

The results of the nitrate determinations on the east and west halves of the respective plots are given in Table 1 in terms of pounds per acre of nitrate nitrogen in the surface soil.

The nitrate content in the fall (on November 25) was low in the surface soil and only slight differences were found between the east and west halves. These results would indicate that the nitrate content of the surface soil had been reduced to a nearly uniform amount as an effect of the 11 inches of rain from September to December. While the check plots showed 16.2 and 15.2 pounds of nitrate nitrogen per acre in the surface soil, it is to be noted that the treated plots contained about the same amount. But in addition there probably was present on the treated plots at least 100 pounds of nitrogen per acre in the sweet-clover crop, whether plowed or unplowed. This is a most significant fact that should not be overlooked in considering the sweet-clover plots, for the nitrogen contained in the sweet-clover plants is largely saved for another year.

In the spring, after 12.6 inches of rain, and with the growth of the crop on the treated plots, the nitrate was reduced on the west halves of Plots 308 and 309 to very low figures, apparently due largely to the clover growth. On Plot 307, where the poorest sweet clover was growing, the figures indicate a small increase in nitrate. The check plots show very little increase. With the advance of the season, attended by rising temperatures, the usual increase in nitrate content of the soil was manifested. The treated plots show a decidedly higher nitrate content than the untreated thruout the season. The phosphorus and potassium plots (Plots 308 and 309), in spite of the fact that they were supporting the heaviest growth of corn, show the highest nitrate content of all plots during the important feeding period of the corn crop.

Unfortunately there is some variation in soil type on the Joliet field which has been revealed thru a careful resurvey made subsequent

TABLE 1.—COMPARISON OF EFFECT OF FALL AND SPRING PLOWING ON NITRATE NITROGEN IN SOIL GROWING CORN; SWEET CLOVER PLOWED UNDER IN NOVEMBER AND MAY: JOLIET FIELD, FALL OF 1921 AND SEASON OF 1922

(Pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches) water-free basis)

Plot	Soil treatment	Plowed	Nitrate nitrogen on date of sampling				
			1921	1922			
			Nov. 25	May 5	June 7	July 6	Aug. 18
305-E	Check	Fall	16.21	19.41	29.13	32.82	56.18
305-W	Check	Spring	15.22	15.50	24.91	23.11	29.74
307-E	Lime, sweet clover	Fall	14.04	17.62	51.23	58.31	187.90
307-W	Lime, sweet clover	Spring	12.80	19.78	59.06	61.21	113.00
308-E	Lime, phosphorus, sweet clover	Fall	13.76	15.48	91.47	70.76	83.32
308-W	Lime, phosphorus, sweet clover	Spring	15.82	5.91	97.24	63.76	67.36
309-E	Lime, phosphorus, potassium, sweet clover	Fall	17.67	20.42	65.95	60.94	83.51
309-W	Lime, phosphorus, potassium, sweet clover	Spring	17.04	7.48	89.85	74.10	158.38
309-E	Lime, phosphorus, potassium, sweet clover	Fall	......	29.52[1]	50.98[1]	37.97[1]	......
309-W	Lime, phosphorus, potassium, sweet clover	Spring	......	11.00[1]	51.90[1]	64.32[1]	......

[1]These figures are for the subsoil stratum (20 to 40 inches) of Plot 309, which has a weight of 6 million pounds.

to these experiments. Probably the most serious disturbance from this cause would be found on Plot 309, where the east half is almost entirely occupied by the soil type now mapped as Black Clay Loam, poorly drained phase, while the west half is Brown Silt Loam On Plastic Calcareous Drift. It is not known to what extent the effect of these natural soil variations may obscure these experimental results; therefore, a very critical comparison of the data for Plot 309 is precluded. It is possible that the extreme variation exhibited in the August 18 samples for Plot 309 may be due to this difference in soil. For the same reason it seems futile to compare the subsoil data for the east and west halves. The figures, however, are not devoid of interest, for both half-plots show a liberal excess of available nitrogen present in the subsoil as well as in the surface soil in the period of greatest demand by the growing corn crop.

The physical condition of the soil on the east side of the plots was very bad, while it was ideal on the west side. The spring disking and replowing of the east side resulted in a cloddy condition that lasted all thru the season, and the large differences in the condition of the corn in its early growth on the two halves may have been largely due to the poor physical condition of the east half. It is evident that the fall growth of sweet clover, combined with its spring growth, in spite of two double-diskings on the east halves, furnished nitrates enough for about twice the crop grown. The corn yields did not vary on the east and west halves by significant differences, the yield being only 1.8 bushels greater on the east side of Plot 308, and 1.4 bushels greater on the west side of Plot 309.

The suggestion arises that perhaps lack of sufficient phosphorus, potassium, or other mineral elements of plant food may be limiting crop growth on this field. Such results as these nitrate data show are encouraging from the standpoint of the nitrogen problem, indicating, as do also the results reported in Bulletins 225 and 233, that with sweet clover used as a green manure, nitrification runs well ahead of crop requirements where proper soil treatment is applied.

The nitrate results for August 18 are very high for this time of the season. The possibility is suggested that this large amount of nitrate in the surface soil may be due to a rise of nitrate from the subsoil. The surface soil contained only 8.5 to 11.9 percent of moisture on August 18. Such a low moisture content will not support nitrification in this soil. Other cases of nitrate concentration in the surface soil will be presented in the data from other fields. Such an upward movement of nitrates is an important consideration, especially if it occurs at this time of year. The possibility of conserving the excess nitrogen for another year by planting a fall cover crop might well be considered in this connection.

With fall plowing on this field there was furnished more nitrate than was needed for one large corn crop. In view of this fact it would be desirable to find a satisfactory method of fall plowing, by which the sweet clover roots would be thoroly killed, since in some rotations the amount of nitrates developed under this practice would be ample to meet all crop requirements. *The present study indicates, however, that spring plowing of green sweet clover is better than fall plowing, considered from all standpoints, including nitrate production, physical condition of soil, and amount of mechanical labor involved.*

NITRIFICATION OF SWEET CLOVER SPRING-PLOWED AT DIFFERENT DATES

The effect of varying the date of plowing in the spring, on the value of green sweet clover as a nitrate producer, was studied in 1921 on certain plots of the Hartsburg experiment field, in Logan county, and of the Toledo field, in Cumberland county.

OBSERVATIONS ON THE HARTSBURG FIELD

The soil of the Hartsburg field is of a heavy type, being classified as Black Clay Loam. Sweet clover usually grows fairly well on the unlimed plot on this field.

The east side of Series 300 was plowed on May 4 and the west side May 13. Samples of the sweet clover were taken for analysis to determine the rate of nitrogen gain per acre. Unfortunately for this study some of the sweet clover was frozen three, and some four, times. The green weights and water-free weights of the crop at time of plowing were determined by cutting areas one yard square, obtaining the green weight in the field and the water-free weight after oven-drying. These results, together with the nitrate determinations in the surface soil, are arranged in Table 2.

The first soil samples were taken on May 3. The differences between the east and west sides were not very pronounced at this sampling. The sweet clover stand was irregular, and this may have contributed to some of the apparent variations. The treated plots on which sweet clover had grown very well in the previous fall, and fairly well in the spring, contained more nitrates than the checks, where a poor growth of sweet clover was present.

On the treated plots the nitrates increased, as anticipated—more rapidly on the east halves after plowing than on the unplowed west halves, up to May 17. Both east and west halves, however, increased in nitrates from the previous date of sampling; even the west sides about doubled in nitrate content. The cold weather seems to have had more effect in checking the growth of the sweet clover, than it had in reducing the activity of the nitrifying bacteria. Following the May 17

TABLE 2.—COMPARISON OF EFFECT OF EARLY AND LATE SPRING PLOWING ON NITRATE NITROGEN IN SOIL GROWING CORN; SWEET CLOVER PLOWED UNDER MAY 4 AND MAY 13: HARTSBURG FIELD, 1921

(Pounds per acre in 2 million pounds of surface soil (about 0 to $6\frac{2}{3}$ inches) water-free basis)

Plot	Soil treatment[1]	Clover plowed under	Weight per acre of sweet clover[2] (top growth only)		Nitrate nitrogen in soil on date of sampling								
			Green	Water-free	May 3	May 17	June 8	June 22	July 1	July 15	July 29	Aug. 24	Sept. 30
			tons	*tons*									
305-E	Check........................	May 4......	....	....	15.7	61.9	30.7	29.0	35.9	78.0	52.7	28.5	26.1
305-W	Check........................	May 13....	....	....	17.6	56.9	26.6	66.3	34.8	71.9	57.0	28.5	20.0
306-E	R, sweet clover................	May 4.....	4.69	.84	21.5	84.9	38.6	34.7	61.5	101.5	81.0	49.7	42.8
306-W	R, sweet clover................	May 13....	....	....	27.7	57.0	28.7	69.0	55.0	81.4	72.8	52.4	41.6
307-E	RL, sweet clover..............	May 4.....	4.30	.73	25.2	88.7	34.4	53.0	90.6	78.7	75.0	46.1	28.9
307-W	RL, sweet clover..............	May 13....	....	....	31.3	67.5	33.4	65.3	81.4	73.8	65.5	45.4	22.0
308-E	RLP, sweet clover.............	May 4.....	3.77	.67	37.3	80.5	45.4	99.4	102.0	108.5	104.5	44.9	29.4
308-W	RLP, sweet clover.............	May 13....	....	....	33.1	60.2	39.4	81.4	84.1	103.4	97.2	41.7	30.2
309-E	RLPK, sweet clover...........	May 4.....	5.73	1.01	33.2	73.2	62.6	83.1	81.5	92.0	75.1	36.1	30.5
309-W	RLPK, sweet clover...........	May 13....	6.36	1.28	37.7	69.6	63.9	112.5	75.8	95.7	72.7	32.4	26.6
310-E	Check........................	May 4.....	....	....	17.6	58.4	26.0	34.6	47.3	56.1	52.1	20.0	28.2
310-W	Check........................	May 13....	....	....	19.7	57.1	22.1	24.1	48.5	47.8	35.5	18.1	26.1

[1]R = Crop residues, L = Limestone, P = Rock phosphate, K = potassium fertilizer.

[2]The top growth on Plots 306-W, 307-W, and 308-W was killed by frost; no samples taken.

sampling, heavy rains reduced the nitrate materially on all plots except Plot 309, where the best growth of sweet clover had been produced. The large amount of green organic matter may have served to reduce the apparent loss of nitrate. On June 22 the west side, representing the later plowing, contained much the larger amounts of nitrate, except on Plot 308, where both sides were very high, and on Plot 310, where both sides were low. On the treated plots nitrates continued to accumulate on the east sides altho to a smaller extent than on the west sides. From July 1 to July 15 conditions were highly favorable for the rise of nitrate from the substrata thru evaporation, altho some nitrate was probably produced, inasmuch as the moisture did not fall to a prohibitive point on this field as it did on the Joliet field.

TABLE 3.—NITRATE NITROGEN IN TREATED AND UNTREATED PLOTS ON HARTSBURG FIELD, 1921
(Pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches) water-free basis.)

Average of—	May 3	May 17	June 8	June 22	July 1	July 15	July 29	Aug. 24	Sept. 30
Treated plots	30.90	72.70	43.30	74.80	78.99	91.88	80.45	43.57	31.50
Untreated plots	17.65	58.58	26.35	38.65	41.60	63.45	49.40	23.78	25.08
Increase for treatment	13.25	14.12	16.95	36.15	37.39	28.43	31.05	19.79	6.42

The large quantities of nitrate present are indicative of the success attained in its production by proper soil treatment, including the use of green sweet clover. In view of the fact that a corn crop of 50 to 63 bushels per acre was being produced on this land, it is evident that lack of nitrate was not a limiting factor in production. The presence of such large amounts of nitrate nitrogen during the critical feeding period of the growing crop demonstrates that on this kind of soil the nitrogen problem in production is largely solved thru the use of sweet clover, at least until the day when, thru further soil and crop improvement, much larger crops than are now grown shall be possible.

During August and September heavy rainfall markedly reduced the nitrate content of the surface soil, falling from as high as 108 pounds to as low as 29 pounds per acre (Plot 308 East). If the nitrate represented in this difference of 79 pounds was permanently lost, it means that a serious depletion of the most expensive plant-food element takes place, and the conservation of this fugitive element, nitrogen, by crop growth, or by bacterial action, or by both, is of deep concern as the next important step for consideration in the solution of the nitrogen problem.

The average nitrate content of the treated compared with untreated plots is given in Table 3. *The results show that thruout the season the nitrate in the soil of the treated plots exceeded that of the untreated plots.* The comparisons are especially interesting because the soil here is not acid, which means that the increases are largely due directly to the sweet clover. It is to be noted that these results are obtained on a type of soil regarded as naturally highly productive.

From the nitrogen standpoint there was no important advantage in either the May 4 or the May 13 plowing date, since nitrates were produced in excess for the critical feeding period whether the crop was plowed under at the earlier or the later date. There may be other considerations, however, in allowing the crop to remain as long as possible before plowing. The organic matter, nitrogen, phosphorus, and other elements contained in the sweet clover would increase in amount. The gain, of course, would be largest in the organic matter, the amount of air-dry material often increasing from 1½ to 2 tons an acre in early spring to as much as 5 tons an acre in late summer.

Observations on the Toledo Field

The Toledo Experiment Field, in Cumberland county, in southeastern Illinois, is located on the soil type designated as Gray Silt Loam On Tight Clay. This type of soil, without treatment, produces poor yields in general, and without lime sweet clover will not grow at all.

The south half of Series 300 was plowed on May 1, and the north half on May 16. Sweet-clover samples were taken, the data concerning which are given in Table 4. The dry weight of the sweet clover tops doubled in the 15-day interval.

On May 14, thirteen days after plowing, the nitrate content of the south sides, where sweet clover had been plowed under, was greater than that of the corresponding north sides, where it was allowed to stand. This ascendency, however, disappeared by the next date of sampling. Ample nitrate was produced on both sides of the plots. A very poor crop of corn was present on the check plots, which accounts in part for their high nitrate content, but some of the nitrate accumulation on the checks is to be ascribed perhaps to the rest period which this series had enjoyed thru previous partial crop failures. *On this field, the different dates of plowing did not show sufficient difference in the nitrate content to affect the crop. A liberal surplus was present at all times during the critical feeding period of the corn crop.*

The excessive amount of nitrate in the surface soil appears to have been due to a rise from the lower layers rather than to a direct production of nitrate in the surface, because the soil moisture was very low during July, ranging from 6.4 percent on Plot 309 to 11.6 percent on the check Plot 310. The rainfall for July was 1.92 inches, while it was 5.94 inches for August and 8.57 inches for September. Here again, as suggested above, the accumulation under excessively dry soil conditions may be explained by a rise of nitrates from lower levels. The great losses of nitrate from the surface soil due to rain are again ap-

TABLE 4.—COMPARISON OF EFFECT OF EARLY AND LATE SPRING PLOWING ON NITRATE NITROGEN IN SOIL GROWING CORN; SWEET CLOVER PLOWED UNDER MAY 1 AND MAY 16: TOLEDO FIELD, 1921

(Pounds per acre in 2 million pounds of surface soil (about 0 to $6\frac{2}{3}$ inches) water-free basis)

Plot	Soil treatment[1]	Clover plowed under	Weight per acre of sweet clover (top growth only)		Nitrate nitrogen in soil on date of sampling									
			Green	Water-free	April 22	May 4	May 14	June 7	June 23	June 30	July 14	July 27	Aug. 25	Sept. 29
			tons	*tons*										
305-S	Check	May 1	....	....	15.4	20.2	35.9	16.4	17.1	31.9	65.1	40.4	31.9	24.0
305-N	Check	May 16	....	....	7.6	11.6	34.5	15.8	20.5	34.9	63.8	39.4	22.0	26.6
306-S	Residues	May 1	....	....	23.4	23.2	34.3	19.3	19.6	30.7	64.9	43.2	21.5	23.5
306-N	Residues	May 16	....	....	7.7	20.9	36.5	21.9	19.5	28.2	69.6	39.9	18.6	23.2
307-S	RL, sweet clover	May 1	2.83	.56	23.5	22.5	68.9	43.4	26.2	63.3	103.0	82.3	43.2	44.8
307-N	RL, sweet clover	May 16	5.80	1.05	22.9	25.2	55.4	44.5	25.4	53.7	114.2	77.8	34.5	35.8
308-S	RLP, sweet clover	May 1	2.10	.42	23.1	19.3	66.7	46.6	57.7	57.2	100.4	74.9	38.1	40.1
308-N	RLP, sweet clover	May 16	5.27	.92	15.4	20.7	49.3	43.1	50.7	53.8	90.9	84.5	33.0	33.5
309-S	RLPK, sweet clover	May 1	4.23	.79	23.0	19.6	56.9	58.0	65.0	76.6	107.5	105.0	46.9	35.6
309-N	RLPK, sweet clover	May 16	11.78	1.84	30.6	22.8	40.0	60.4	24.5	100.6	113.2	89.4	36.6	34.5
310-S	Check	May 1	....	....	23.1	9.7	30.3	23.8	17.7	30.9	64.7	53.5	32.0	23.2
310-N	Check	May 16	....	....	7.7	11.7	35.0	20.5	19.7	29.4	67.3	50.0	17.8	24.8

[1]R = Crop residues, L = limestone, P = rock phosphate, K = potassium fertilizer.

parent. Plots 307, 308, and 309, averaged 104.8 pounds of nitrate nitrogen on July 14, but only 38.7 pounds on August 25, and 37.7 pounds on September 29. Thus an apparent loss of about 67 pounds occurred during this period. On this type of soil, with its impervious subsoil, the nitrate may not leach away altogether, but it may be lost thru denitrification when conditions of moisture and temperature are favorable for this process. On properly drained land a material loss from leaching would be expected.

In considering the results on the Toledo field, as well as those of the Hartsburg field, it might be well to point out that since sweet clover had been grown several times as a green manure, a generally higher level of nitrate accumulation existed on both of these fields than is usually found in soils not so treated, and this condition probably reduced the possibility of larger differences in nitrate content resulting from the effect of prolonging the spring growth period.

TABLE 5.—NITRATE NITROGEN IN TREATED AND UNTREATED PLOTS ON TOLEDO FIELD, 1921
(Pounds per acre in 2 million pounds of surface soil (about 0 to 6⅔ inches) water-free basis)

Average of—	April 22	May 4	May 14	June 7	June 23	June 30	July 14	July 27	Aug. 25	Sept. 29
Treated plots..	23.10	21.70	56.20	51.00	41.60	67.50	104.90	85.65	38.71	37.38
Untreated plots	14.15	16.20	34.40	19.60	19.00	31.00	65.90	44.40	23.95	24.21
Increase for treatment...	8.95	5.50	21.80	31.40	22.60	36.50	39.00	41.25	14.76	13.17

In Table 5 the average nitrate nitrogen contents of the treated and the untreated plots on the Toledo field are reported. *The treated plots growing sweet clover show much the larger amounts of nitrate present, in spite of the fact that these plots were supplying nitrate for the production of much larger crops than were the check plots.*

It is evident that on this field, as on the others studied, the nitrogen requirement has been much more successfully met than have those of other factors concerned in production. Lack of sufficient moisture, deficiency of available phosphorus or other elements of plant food, injury due to hot winds, or any one of the innumerable factors of production, working singly or in combination, must be regarded as the cause of limited crop growth on this field, rather than a shortage of the essential nitrogen.

GROWTH MEASUREMENTS AND NITROGEN CONTENT OF SWEET-CLOVER TOPS

Certain observations with respect to the spring growth of the sweet clover on the Hartsburg and Toledo fields were made, including the height, green weight, dry weight, and nitrogen content of the sweet-

TABLE 6.—COMPARISON OF HEIGHT, WEIGHT, AND NITROGEN CONTENT OF SWEET-CLOVER TOPS AT DIFFERENT STAGES OF SPRING GROWTH: TOLEDO AND HARTSBURG FIELDS, 1921

Field	Plot	Date of sample	Height	Green weight per acre	Percentage of water	Weight per acre of water	Water-free material		Weight per acre of nitrogen in tops
							Weight per acre	Percent nitrogen	
			inches	*tons*		*tons*	*tons*		*lbs.*
Toledo	307-S	April 22	6	2.420	85.68	2.073	.347	4.26	29.5
	308-S	April 22	5	1.960	85.20	1.670	.290	4.44	25.7
	309-S	April 22	8	4.840	87.33	4.227	.613	4.34	53.2
	307-S	May 4	8	2.831	80.21	2.271	.560	4.44	49.7
	308-S	May 4	7	2.105	80.00	1.684	.421	4.30	35.4
	309-S	May 4	13	4.235	81.23	3.440	.794	4.22	67.0
	307-N	May 14	18	5.808	81.87	4.755	1.052	3.74	78.6
	308-N	May 14	17	5.275	82.19	4.352	.923	3.60	67.4
	309-N	May 14	24	11.785	84.33	9.939	1.845	3.74	138.0
Hartsburg	306-E	May 3	6	4.694	82.17	3.857	.837	4.42	73.9
	307-E	May 3	6	4.307	83.02	3.576	.731	4.44	64.9
	308-E	May 3	6	3.777	82.14	3.103	.674	4.50	60.7
	309-E	May 3	8	5.735	82.32	4.721	1.013	4.22	85.5
	309-W	May 17	20	6.364	79.76	5.076	1.288	3.88	100.0

clover tops. The data for these measurements, together with the calculated nitrogen per acre for the respective plots, are recorded in Table 6. In looking over these results, the progressive increase, with advancing season, in the weight of nitrogen per acre in the tops is apparent. On the Toledo field, at the middle of May, there was contained in the tops, from 67 to 138 pounds of nitrogen per acre. On the Hartsburg field, 60 to 85 pounds of nitrogen per acre had accumulated in the tops by May 3.

On depleted soils, where the active organic-matter content is low, it would seem especially important that the crop be plowed under late the first time it is used, since on such soils one of the principal objects is to build up the supply of active organic matter as rapidly as possible.

NITRIFICATION OF SUMMER-PLOWED SWEET CLOVER

Thru the cooperation of the Bloomington Canning Company and the McLean County Farm Bureau, an opportunity was given to study nitrate accumulation and losses where second-year sweet clover, at a rather advanced stage, was plowed under. The sweet clover was about six feet high when plowing began, about July 22. The tops were still green and seed had not yet formed. The soil of this field is Brown Silt Loam, and it had been limed. There were 100 acres of the section in second-year sweet clover.

The question arose as to the loss of nitrates that might result from plowing while the crop was still green, and with about ten months intervening before sweet corn would be planted. It was suggested that oats and rye be seeded on adjacent plots, these, together with a fallow check plot, to be sampled for nitrate in order to determine the comparative value of these two crops for conserving the nitrates that would be produced from the green sweet clover. Plots of about one-fourth acre in area were arranged at the northeast corner of the field. Samples were taken soon after plowing, and again on August 25 (about one month later) before the oats and rye were seeded. The surface soil contained 77.8 pounds of nitrate nitrogen per acre on July 29, and 49.1 pounds on August 25. There were 10.44 inches of rain in August, which accounts for the pronounced reduction noted. Beginning October 1, a series of samples was taken in three strata to a depth of 40 inches on all plots, and as deep as 80 inches on the rye plot. The data are presented in Table 7.

It would appear that sweet clover increased the nitrate content of the fallow soil, since on November 3, 103.3 pounds per acre were found in the surface stratum, 107.2 in the middle stratum, and 92 in the lower stratum, or a total of 302.5 pounds in the 40 inches. This was two to three times as much as was found on the highest producing experiment fields sampled at the same time in the same manner. The much lower nitrate content of the oat and rye plots at this sampling is made evident by the figures for the upper and middle strata. The amount of nitrate in the lower strata (20 to 40 inches) is about the same as that of the fallow, which fact may be accounted for by the heavy rains having washed the soil equally on all plots before the oats and rye had grown sufficiently to use nitrate, and to offer protection against its descent. The oats in their fall growth attained a height of 14 inches and covered the ground. The rye made a thin stand at first, but stooled out to make a fair stand about 4 inches high by November 3. At this date there was a difference in nitrate present to a depth of 40 inches of 88.8 pounds between the fallow and the rye plot, and 119.2 pounds between the fallow and the oats plot..

In the spring the oat plot, as expected, contained the highest nitrate content in the surface soil. The rye grew until disked in, and the nitrate content on the rye plot was only 9.7 pounds. The fallow plot suffered heavily from leaching and contained only 7.8 pounds in the surface stratum. In July, with the sweet corn growing rapidly, there was a liberal excess of soil nitrate on all plots.

The oat plot was the most efficient in the utilization of the nitrate. This plot on May 4 contained about 50 pounds per acre more nitrate than the fallow plot. On July 5 it was the lowest of the three plots, which again, as in the previous year, would mean smaller losses because of the greater conversion of nitrate nitrogen into organic nitrogen.

The thing to be desired with respect to soil nitrogen is that it shall be held in the fall largely in an insoluble form, and that it shall gradually become available the following season in amounts just sufficient to keep pace with the demands of the growing crop. When an oats cover crop was included in the management of the soil of this Bloomington field, there was exhibited in a high degree this potential capacity to produce ample nitrate as needed.

For easier comparison of the data showing the distribution of nitrates in the soil at the time of the November 3 sampling, the figures given in Table 7 are computed in pounds of nitrate per acre, as shown in Table 8.

The distribution of the nitrate nitrogen in the different soil layers as represented in Table 8 shows the efficiency of these cover crops in checking the downward movement of the nitrates. The principle of the conservation of nitrates thru the presence of a cover crop is brought out by these figures. With a growing crop on the surface soil, a conversion of nitrate nitrogen to organic nitrogen is taking place at the same time that a reduced nitrification occurs, thus building up the supply of organic nitrogen for nitrification at a later period to meet future needs. Volunteer oats and other grains function in a limited degree in this manner. In cases where land is not to be used for growing other crops, sweet clover allowed to reach maturity will greatly increase the organic-matter content of the soil, and provide sufficient nitrogen for

TABLE 7.—COMPARISON OF EFFECT OF FALLOW AND COVER-CROP TREATMENTS ON NITRATE NITROGEN IN SOIL; SWEET CLOVER PLOWED UNDER DURING LATTER PART OF JULY, 1921: BLOOMINGTON,[1] 1921-22

(Pounds per acre, water-free basis)

Treatment	Oct. 1 1921	Nov. 3 1921	May 4 1922	July 5 1922
Fallow				
Upper sampling stratum, 0 to 7 inches	78.5	103.3	7.8	40.9
Middle sampling stratum, 7 to 20 inches	83.7	107.2	29.2	60.5
Lower sampling stratum, 20 to 40 inches	60.2	92.5	56.3	77.9
Total for 3 strata, 0 to 40 inches	222.4	303.0	93.3	179.3
Rye Cover Crop				
Upper sampling stratum, 0 to 7 inches	64.6	34.5	9.7	51.5
Middle sampling stratum, 7 to 20 inches	107.2	94.0	34.7	61.3
Lower sampling stratum, 20 to 40 inches	99.0	85.7	62.4	82.2
Total for 3 strata, 0 to 40 inches	270.8	214.2	106.8	196.0
Substratum, 40-80 inches	182.4	182.2	127.8	160.3
Oats Cover Crop				
Upper sampling stratum, 0 to 7 inches	56.2	29.5	27.9	50.3
Middle sampling stratum, 7 to 20 inches	84.6	63.1	48.9	46.6
Lower sampling stratum, 20 to 40 inches	85.2	91.2	69.9	50.4
Total for 3 strata	226.0	183.8	146.7	147.3

[1]Field of Bloomington Canning Company.

TABLE 8.—DISTRIBUTION OF NITRATE NITROGEN IN THE SOIL: SWEET CLOVER FIELD AT BLOOMINGTON,[1] 1921

(Pounds of nitrate nitrogen per acre-inch of soil)

Layers	Fallow	Rye	Oats
Upper sampling stratum, 0 to 7 inches	14.7	4.9	4.2
Middle sampling stratum, 7 to 20 inches	8.2	7.2	4.8
Lower sampling stratum, 20 to 40 inches	4 6	4.3	4.6
Substratum, 40 to 80 inches	....	4.6	....

[1]Field of Bloomington Canning Company.

two corn crops. When the sweet-clover crop is left for seed production nitrification is advantageously delayed, with the result that fall and spring losses are reduced. The volume of organic matter is not so great when the crop is left for seed as when plowed under green at a somewhat earlier stage of maturity. Under many circumstances, however, the method of growing the sweet clover to maturity is less advantageous than plowing it under green in the spring because by the latter method a year is not lost for growing a money crop.

The magnitude of the nitrogen losses that may occur is evident from this study of the Bloomington data. They are perhaps as large here as any that would be met with under almost any other condition because of the long interval occurring between plowing the green, rapidly decomposing clover crop and the planting of the succeeding grain crop, which gives time for the drenching rains of fall and spring to be effective in leaching away the nitrates formed.

Thus these experiments with sweet clover at Bloomington add a further demonstration of the efficiency of this remarkable plant as a producer of readily available nitrogen for soil improvement.

WINTER LOSS OF NITRATE

A study was made to determine the amount of nitrate lost from the 40-inch layer of the soil during the winter and early spring and the effect of the fertilizer treatments on reducing such losses. To this end, observations were made on certain plots of a number of the soil experiment fields located in different sections of Illinois.

Plot 404, which receives manure, limestone, and phosphate, the adjacent check (Plot 405), and the nearest sweet clover plot (usually 408) receiving crop residues, limestone, and phosphate, were selected on eight fields in northern and central Illinois, and on five fields in southern Illinois.

Fall soil samples were collected in November and December. The Dixon, Mount Morris, LaMoille, and Spring Valley samples were taken under two to four inches of snow. The remainder of the samples from the northern and central fields were taken after continuous rains, when the soil was very wet. The samples from the southern fields were taken after heavy rains.

Table 9 records the pounds of nitrate per acre in the fall and spring in three separate sampling strata, namely, the upper sampling stratum (0 to 6⅔ inches), the middle sampling stratum (6⅔ to 20 inches), and the lower sampling stratum (20 to 40 inches). The corresponding totals are found in the last three columns at the right. The differences between fall and spring results represent the amounts lost. Where the difference resulted in a gain instead of a loss a plus sign appears before the figures. Manure had been spread on Plot 404 on all the northern fields, which presumably would increase the losses for those plots.

It should be understood that wide variations in the soil types occur among these fields, and in some cases they occur within a given field. The types range in character from shifting sand to heavy clay. Since this work was carried out, a detailed soil map has been prepared for each of the Illinois soil experiment fields (see Bulletin No. 273). From these maps is derived the information regarding the soil types on the plots concerned in the present study, as given in Tables 9 and 10.

According to the figures of the last three columns of Table 9, which represent the total nitrates to a depth of 40 inches, the sweet-

TABLE 9.—LOSS OF NITRATE NITROGEN ON NORTHERN AND CENTRAL ILLINOIS EXPERIMENT FIELDS DURING WINTER AND SPRING OF 1921-22

(Pounds per acre)

Field and soil type	Sampling date	Upper stratum (0 to 6⅔ inches)			Middle stratum (6⅔ to 20 inches)			Lower stratum (20 to 40 inches)			Total for 3 strata (0 to 40 inches)		
		Plot 404	Plot 405	Plot 408	Plot 404	Plot 405	Plot 408	Plot 404	Plot 405	Plot 408	Plot 404	Plot 405	Plot 408
Dixon: Brown Silt Loam, with some Light Brown Silt Loam on each plot	Fall.....	18.36	21.24	18.07	34.29	34.22	30.00	43.21	56.09	37.41	95.86	111.55	85.48
	Spring...	17.17	4.62	16.23	24.28	20.68	29.62	33.90	25.53	39.40	75.35	50.83	85.25
	Loss.....	1.19	16.62	1.84	10.01	13.54	.38	9.31	30.56	(+1.99)	20.51	60.72	.23
Mt. Morris: Light Brown Silt Loam, shallow phase on most of north half of Plot 408	Fall.....	22.05	23.24	19 27	34.34	52.60	28.42	46.05	53.27	42.41	102.44	129.11	90.10
	Spring...	10.56	15.84	12.75	29.32	23.58	29.79	29.64	65.63	53.38	69.52	106.05	95.92
	Loss.....	11.49	7.40	6.52	5.02	29.02	(+1.37)	16.41	(+12.36)	(+10.97)	32.92	24.06	(+5.82)
LaMoille: Brown Silt Loam, Plot 408 and part of Plot 404; Black Clay Loam, poorly drained phase, Plot 405 and part of Plot 404[1]	Fall.....	44.39	40.28	38.51	52.19	48.73	59.48	39.27	42.24	83.12	135.85	131.25	181.11
	Spring...	11.98	8.01	20.84	19.06	19.22	19.04	22.54	22.68	28.18	53.58	49.91	68.06
	Loss.....	32.41	32.37	17.67	33.13	29.51	40.44	16.73	19.56	54.94	82.27	81.34	113.05
Spring Valley: Brown Silt Loam	Fall.....	14.58	15.41	18.38	35.58	26.39	30.07	39.39	37.20	46.73	89.55	79.00	95.18
	Spring...	12.92	12.55	16.36	18.10	18.41	29.16	21.92	16.65	50.12	52.94	47.61	95.64
	Loss.....	1.66	2.86	2.02	17.48	7.98	.91	17.47	20.55	(+3.39)	36.61	31.39	(+.46)
Kewanee: Brown Silt Loam	Fall.....	24.24	28.13	29.49	46.73	56.60	46.51	51.28	68.31	53.99	122.25	153.04	129.99
	Spring...	12.48	14.20	16.16	56.16	24.21	27.77	41.95	53.61	24.10	110.59	92.02	68.03
	Loss.....	11.76	13.93	13.33	(+9.43)	32.39	18.74	9.33	14.70	29.89	11.66	61.02	61.96
Aledo: Brown Silt Loam On Clay	Fall.....	22.45	19.34	18.70	37.37	29.64	30.51	34.04	31.55[2]	31.20	93.86	80.53	80.41
	Spring...	13.60	9.76	16.05	34.02	34.52	39.43	33.47	34.32	45.95	81.09	78.60	101.43
	Loss.....	8.85	9.58	2.65	3.35	(+4.88)	(+8.92)	.57	(+2.77)	(+14.75)	12.77	1.93	(+21.02)
Oquawka: Dune Sand..............	Fall.....	11.45	9.68	15.57	24.55	19.64	26.21	37.29	43.97	34.34	73.23	73.29	76.12
	Spring...	8.45	3.12	6.70	16.19	9.80	15.25	44.05	20.70	9.57	68.69	33.62	31.52
	Loss.....	3.00	6.56	8.87	8.36	9.84	10.96	(+6.76)	23.27	24.77	4.54	39.67	44.60
Carthage: Grayish Brown Silt Loam On Tight Clay, Plots 404 and 405; Black Silty Clay Loam On Clay, Plot 408	Fall.....	12.07	10.97	18.29	29.33	25.26	25.15	31.83	28.94	28.80	73.23	65.17	72.24
	Spring...	9.53	5.77	17.04	18.90	11.42	24.63	28.90	23.10	17.02	57.33	40.29	58.69
	Loss.....	2.54	5.20	1.25	10.43	13.84	.52	2.93	5.84	11.78	15.90	24.88	13.55

[1]A small area of Black Silty Clay Loam On Clay also occurs on Plot 404. [2]One determination only.

TABLE 10.—LOSS OF NITRATE NITROGEN ON SOUTHERN ILLINOIS EXPERIMENT FIELDS DURING WINTER AND SPRING OF 1921-22
(Pounds per acre)

Field and soil type	Sampling date	Upper stratum (0 to 6⅔ inches)			Middle stratum (6⅔ to 20 inches)			Lower stratum (20 to 40 inches)			Total for 3 strata (0 to 40 inches)		
		Plot 404	Plot 405	Plot 408	Plot 404	Plot 405	Plot 408	Plot 404	Plot 405	Plot 408	Plot 404	Plot 405	Plot 408
Toledo: Gray Silt Loam On Tight Clay	Fall......	11.64	11.71	11.30	17.13	18.92	19.43	25.44	22.57	22.50	54.21	53.20	52.33
	Spring...	5.81	5.77	11.63	22.39	11.34	19.13	28.71	23.19	11 19	56.91	40.30	41.95
	Loss.....	5.83	5.94	(+.33)	(+5.26)	7.58	.30	(+3.27)	(+.62)	11.31	(+2.70)	12.90	10.38
Newton: Gray Silt Loam On Tight Clay	Fall......	9.60	10.52	13.30	32.66	23.37	20.57	27.08	30.93	23.84	69.34	64.82	57.71
	Spring...	9.05	5.65	5.57	41.33	18.90	7.36	26.35	26.97	20.89	76.73	51.52	33.82
	Loss.....	.55	4.87	7.73	(+8.67)	4.47	13.21	.73	3.96	2.95	(+7.39)	13.30	23.89
Oblong: Gray Silt Loam On Tight Clay	Fall......	12.80	11.74	12.57	23.22	19.04	18.00	31.32	19.85	37.89	67.34	50.63	68.64
	Spring...	6.06	9.21	17.10	18.64	18.59	15.07	38.54	16.85	28.58	63.24	44.65	60.75
	Loss.....	6.74	2.53	(+4.53)	4.58	.45	2.93	(+7.22)	3.00	9.31	4.10	5.98	7.89
Palestine: Brown Sandy Loam, Terrace	Fall......	8.22	7.44	9.14	8.28	13.23	23.12	18.00	22.41	19.86	34.50	43.08	59.12
	Spring...	2.56	9.09	14.59	18.26	29.45	18.28	13.08	15.75	21.95	33.90	54.29	54.82
	Loss.....	5.66	(+1.65)	(+5.45)	(+9.98)	(+16.22)	4.84	4.92	6.66	+2.09	.60	(+11.21)	4.30
West Salem: Yellow-Gray Silt Loam On Tight Clay, Yellow-Gray Silt Loam On Compact Medium-Plastic Clay[1]	Fall......	10.04	11.80	16.52	18.61	29.54	20.57	22.05	21.53	27.50	20.70	62.87	64.59
	Spring...	7.83	3.62	8.82	30.05	7.52	25.65	34.78	10.84	11.19	72.66	21.98	45.66
	Loss.....	2.21	8.18	7.70	(+11.44)	22.02	(+5.08)	(+12.73)	10.69	16.31	(+21.96)	40.89	18.93

[1]Both types occur on each plot.

clover plots (No. 408) lost the smallest amount of nitrate (or else actually gained) on the Dixon, Mount Morris, Spring Valley, Aledo, and Carthage fields. The manure plots (No. 404) lost the smallest amount on two fields of this group, Oquawka and Kewanee. The check plots lost the largest amounts on the Dixon, Kewanee, and Carthage fields. On the LaMoille field the check plots and the manure plots lost about the same amount.

Pooling together all the fields of the northern and central group, the total loss of nitrate nitrogen (disregarding that absorbed by the growing crop) was 206 pounds per acre on the sweet-clover plots, 227 pounds on the manure plots, and 325 pounds on the check plots.

In connection with reduction of losses, the fact should be considered that the sweet clover itself contained at least 100 pounds and probably 150 pounds of nitrogen, some of which had been transformed from nitrate that otherwise would have been lost. In some cases where large amounts of nitrate were present, the loss is to be attributed to some extent to the contour of the field, as on the LaMoille field. On the Kewanee field, a growth of foxtail was probably a factor in preventing much greater losses than actually occurred. These studies were made during a season of excessive rainfall. In September and March there was about four times the normal rainfall and on most of the fields only a little less occurred in April than in March.

On the southern fields which, under most conditions, contain much less nitrate than the central and northern fields, the losses were small both as to absolute quantity and on a percentage basis. There is a possibility that early spring nitrification reduced some of the apparent losses. The manure plots gained nitrate on three fields, which suggests that early spring nitrification occurred, and where no crop was present to absorb the nitrate, it accumulated. On the sweet-clover plots the decrease in nitrate might be misconstrued as representing an utter loss, while as a matter of fact much of the nitrate was immediately absorbed by the growing plants. As observed in the other studies, when the large sweet-clover crops on these fields are taken into consideration, the apparent nitrogen losses become actual gains of about 100 pounds per acre.

Totaling the results for the six fields of the southern group, the manure plots gained collectively 27.5 pounds per acre instead of losing 61.9 pounds, as the checks did. It must be recognized that nitrate production may have taken place thru nitrification of the manure, which of course would partially, or perhaps wholly, offset the nitrate loss.

SUMMARY AND CONCLUSIONS

In order to obtain the maximum fertilizing value of sweet clover, the proper handling of the crop, particularly with reference to the time of plowing it under, must be given consideration. Observations were made on a number of soil experiment fields in Illinois of the development of nitrate in the soil thru the decomposition of sweet clover plowed under at different times of year.

It was found that nitrification of both fall- and spring-plowed sweet clover proceeded rapidly and to such an extent on one field (Joliet) as to furnish nitrate in excess of the requirements of a large corn crop. The spring plowing resulted in a better physical condition of the soil than fall plowing, and less labor was required in preparing the land for the crop. More active organic matter was plowed under on the spring-plowed land, and this is one of the most important considerations, especially in the initial use of sweet clover. Fall plowing of sweet clover is frequently desirable, but until more information is available as to methods for thoroly killing the crop, spring plowing should be the general practice.

Comparing early and late dates for spring plowing in preparation for corn, it was found that early plowing gave high nitrate at an earlier date than later plowing. At both the Hartsburg and the Toledo fields all dates of plowing permitted a rapid nitrification and an accumulation of nitrate sufficient to meet the needs of much larger crops than were produced.

The date of plowing sweet clover in the spring should be decided according to the urgency of the need of the soil for active organic matter, since the rapidity with which sweet clover decomposes after spring plowing insures prompt nitrification. Light, sandy, and open-textured soils, and those deficient in organic matter should have the sweet clover plowed as late as consistent with good soil preparation for the corn crop. Heavy soils, such as clays, loams, and in general those soils that have grown one or more crops of sweet clover, are not likely to be materially affected for corn production by the date of plowing the sweet clover.

Summer-plowed green sweet clover nitrifies rapidly and large amounts of nitrate accumulate, as indicated by the results reported from the study at Bloomington. Large losses of nitrogen result if no protective crop is seeded. Oats and rye proved efficient in converting much nitrate into organic nitrogen. The oats were more valuable in reducing losses than the rye, owing to their greater fall growth, and to the fact that they were incorporated into the soil in a dry condition rather than green.

From the standpoint of nitrate production, this manner of handling sweet clover, whereby it is allowed to grow thru the second season, is of no particular advantage except in special cases, because when plowed down in the spring as a green manure, it furnishes sufficient soil enrichment without sacrificing a year to the growing of this crop.

Under certain conditions nitrates appear to concentrate in the surface soil by rising from lower layers. That such a rise occurs is indicated by the observation that, with the moisture content of the surface soil remaining below the point for permitting nitrification, the nitrate content actually increased.

In not a few cases over 100 pounds of nitrate nitrogen was found in the surface soil, even in the presence of a 50- to 65-bushel corn crop at its period of heavy nitrate absorption. Such amounts of nitrate nitrogen should be converted by crops, or by bacteria, to some fixed form, in order that they may be conserved for use by succeeding crops. Under farm conditions, weeds in the corn, volunteer grains, and any crop growth on the land in late summer and fall, serve to convert much nitrate. If a legume is used for this purpose rather than a non-legume, the nitrogen so saved is more rapidly and completely nitrified the following year.

Studies made on thirteen Illinois experiment fields during a season of unusually heavy rainfall demonstrated the effectiveness of sweet clover in conserving soil nitrogen. Less nitrate was lost on sweet-clover plots than on corresponding manure plots or on check plots. These results were obtained where sweet clover is grown as a green manure in a four-year rotation.

Thus these investigations show that the method of handling sweet clover plays an important role in the realization of the full fertility value of the crop.