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Soil Fertility and Sweet Clover Production in Oklahoma

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The importance of sweet clover for pasture and for soil improvement has been recognized for a long period of time, but a lack of information concerning the effect of soil and climatic conditions on the growth of this crop has resulted in many failures. Sweet clover failure commonly occurs on poor soils; whereas, if the crop were planted on fertile land where the problem of soil improvement does not appear to be so important, a good growth would be secured.

One of the major soil fertility problems in Oklahoma is the maintenance of the nitrogen and the organic matter content of the soil. Many farmers are particularly interested in increasing the productive capacity of eroded fields and other land where the average yield of crops is low, and it is on such areas where sweet clover is usually planted, since it has been recommended as a good crop to grow for soil improvement.

When soils contain a good supply of mineral plant food, sweet clover is one of the best legume crops which can be grown to increase the nitrogen and organic matter content of the soil (except in areas of insufficient rainfall), therefore it has been the purpose of this investigation to study soil conditions which have been responsible for sweet clover failures and determine if possible what can be done to eliminate them.

The most important factors which have been responsible for sweet clover failures in Oklahoma are as follows:

1. Soil acidity or a lack of lime in the soil.
2. Lack of available phosphorus.
3. Soil moisture conditions as affected by rainfall or a nurse crop.
4. Poor seed bed preparation, which is chiefly a problem of soil moisture.
5. Inoculation and nodule production.
6. Time and method of seeding.
7. Variety of seed and whether scarified, hulled, or unhullled seed is used.

With the exception of the last two factors, the problems suggested are soil problems, and a lack of information concerning soil conditions and their effect on sweet clover production has been an important factor in delaying the progress of this investigation.

Experimental Results

A study of the effect of limestone of different degrees of fineness on the growth and yield of sweet clover was started on the farm of H. B. Brashear, Watova, Oklahoma, in the spring of 1926, and the first crop of sweet clover was harvested in the spring of 1927. The results of this experiment are given in Table I and a comparison of the sweet clover produced from an application of coarse, medium, and fine limestone is shown in Fig. 1. An adjacent plot receiving similar treatment was planted to alfalfa, but that crop failed since this soil was poorly drained and was not adapted to alfalfa production. Sweet clover was planted on this area in the spring of 1928 and an excellent growth of sweet clover was secured on the treated plots. A large amount of rain occurred in the spring of 1929 and the soil was very wet most of the time. Consequently the growth of sweet clover which occurred the second year was less than that which was produced the first season even on those plots which received three tons of finely ground limestone per acre. This experiment demonstrated the importance of good surface and subsurface drainage in order to secure a maximum growth of sweet clover during seasons in which an excessive amount of rainfall occurs.

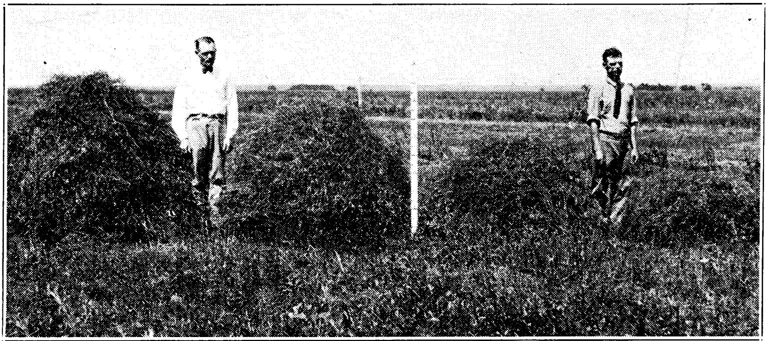

Fig. 1—Nowata County, Oklahoma. Yields of sweet clover on soil treated with different grades of ground limestone. At right, none; at left 6000 pounds of fine dust. See Table I.

Table I—Effect of Rate of Application and Fineness of Limestone on the Yield of Sweet Clover, H. B. Brashear Farm, Watova, Oklahoma

Plot No.	Treatment	Rate of Application in Pounds Per Acre	Yield of Sweet Clover in 1927. Pounds Per Acre
1	None	----	479
2	Coarse limestone	6000	916
3	Medium limestone	6000	1480
4	Fine limestone	6000	2279
5	Fine limestone	3000	3384
6	Fine limestone	1500	2867
7	Fine limestone	750	1645

The degree of fineness and the purity of the limestone samples used in the above experiment are given in Table II.

Table II—Degree of Fineness and Purity of Limestone Samples Used in the Experiment Reported in Table I

Sample No.	Description	Maximum Size of Particles	Above 1/20″	1/20″-1/60″	1/60″ and less	Per cent Purity
1	Coarse limestone	1/4″	68.0	18.9	12.9	68.1
2	Medium limestone	1/10″	18.8	40.0	41.2	95.4
3	Fine limestone	1/60″	.0	.2	99.8	92.2

The large amounts of limestone which were applied in this experiment did not completely neutralize the acidity in the soil, yet the application of a small amount of fine limestone produced a marked effect on the growth of the sweet clover. The subsoil was not acid; consequently the small amount of finely ground limestone which was added to this soil supplied the calcium needed by the sweet clover plants until the roots penetrated into the subsurface soil where an adequate supply of available calcium was present. Since as much fine material was added in 6000 pounds of the coarse limestone as occurred in the 750-pound application of fine limestone, theoretically as large a yield of sweet clover should have been produced on the plot treated with the coarse material. Since the experiment was not repeated except on adjacent plots, soil conditions may have been partly responsible for the difference in yield in this particular experiment. A larger yield of sweet clover also was produced from an application of 3000 pounds of fine limestone per acre than was produced from a 6000-pound treatment. This soil was low in easily soluble phosphorus, and the heavier application of limestone evidently reduced the availability of the phosphorus to the sweet clover plants.

A similar experiment, conducted in Haskell county on the farm of William Blankenship, at Stigler, Oklahoma, during the season of 1927 and 1928, gave very different results. Finely ground limestone, all of which passed through a 60-mesh sieve, was applied at the same rates as given in Table I; yet a complete failure of sweet clover occurred on all plots. On an adjacent area in which the soil was fertilized at the rate of 1000 pounds of finely ground limestone and 150 pounds of 16% superphosphate per acre, some sweet clover was produced. This experiment indicated that the supply of easily soluble phosphorus in the soil might be a very important factor in the successful growth of sweet clover. The yields of sweet clover secured from this experiment are given in Table III. The results are the average yield of duplicate plots.

Table III—Yields of Sweet Clover Produced From Various Lime and Fertilizer Treatments on the William Blankenship Farm, Stigler, Oklahoma

Plot No.	Treatment	Rate of Application in Pounds Per Acre	Yield of Sweet Clover in Pounds Per Acre
1	None	—	0
2	Fine limestone	750	0
3	Coarse limestone	1500	0
4	Fine limestone	1500	0
5	Coarse limestone	3000	0
6	Fine limestone	3000	0
7	Coarse limestone	6000	0
8	Fine limestone	6000	0
9	None	...	0
10	Fine limestone	1000	0
11	16% superphosphate	150	0
12	2-12-6	200	0
13	Farm manure	6000	334
14	Fine limestone 16% superphosphate	1000 150	1157
15	Fine limestone 2-12-6	1000 200	832
16	Fine limestone Farm manure	1000 6000	395

Even when farm manure and limestone were applied to this soil a very small growth of sweet clover was produced. Later investigations demonstrated very definitely that farm manure was not an economical source of phosphorus for sweet clover when planted on phosphorus deficient soils. The coarse limestone and the fine limestone used in this experiment came from the same quarry and analyzed 92% in terms of pure calcium carbonate. The mechanical analyses of the samples are given in Table IV.

Table IV—Mechanical Analysis of Limestone Used in the Sweet Clover Experiment Conducted on the William Blankenship Farm, Stigler, Oklahoma

Sample No.	Degree of Fineness (in inches) Above 1/10	1/10-1/20	1/20-1/40	1/40-1/60	1/60-1/100	1/100-1/200	Over 1/200
1 Coarse	40.5	15.4	12.3	6.5	4.7	7.6	12.0
2 Fine	----	----	----	----	3.4	25.2	71.4

Another experiment similar to this study was started on the farm of W. O. Rittenhouse, near Wagoner, Oklahoma; but due to variations in soil fertility, which were not evident at the time the different treatments were applied, only the effect of fine limestone on the growth of sweet clover was secured. The results of this experiment are given in Table V.

Table V—Effect of Finely Ground Limestone on the Growth of Sweet Clover, W. O. Rittenhouse Farm, Wagoner, Oklahoma

Plot No.	Treatment	Rate of Application in Pounds Per Acre	Yield of Sweet Clover in Pounds Per Acre
1	None	----	1090
4	Fine limestone	1500	3868
10	None		2049
13	Fine limestone	1500	4177

The soil on which this experiment was located was medium acid; yet the application of a small amount of limestone produced a marked increase in the yield of sweet clover. The acidity and easily soluble phosphorus content of this soil are given in Table VIII.

Table VI—Preliminary Studies on the Effect of Fertilization on the Growth and Yield of Sweet Clover at Stillwater and Glencoe, Oklahoma

No.	Treatment	Rate of Applcation in Pounds Per Acre	Yield of Sweet Clover in Pounds Per Acre: John Waltermire Farm, Glencoe	Exp. Sta. Farm, Stillwater (Range 6200)	Exp. Sta. Farm, Stillwater (Range 1100)
1	None		135	2600	0
2	Limestone	6000	285*	2900	0
3	Superphosphate	500	1214**		0
4	Limestone	6000	----	3840	2044
	Superphosphate	500			
5	Limestone	6000			
	Superphosphate	500	2150*	3600	2040
	Potash	150			

*Limestone applied at the rate of 2000 pounds per acre.
**Received 200 pounds of muriate of potash with the superphosphate.

In 1926 three other experiments were started, in addition to the limestone investigations which have already been discussed, in order to determine the effect of limestone alone and in combination with other plant foods on the growth of sweet clover. Two of these experiments were located on the Experiment Station Farm at Stillwater, Oklahoma. The other experiment was located on the farm of John Waltermire, near Glencoe, Oklahoma.

The results of these experiments are given in Table VI.

Table VII—Studies on the Effect of Applications of Superphosphate and Limestone on the Growth and Yield of Sweet Clover, and the Residual Effect of Sweet Clover on the Growth of Tame Pasture Grasses in 1929 and 1930. Norman Mounce Farm, Lenapah, Oklahoma

Plot No.	Treatment	Rate in Pounds Per Acre	Yield of Crop in Pounds Per Acre	
			Sweet Clover in 1928	Tame Pasture Grass in 1929-30*
1	None		314	2686
2	Limestone	8000	780	3154
3	16% superphosphate	500	920	3170
4	Limestone 16% superphosphate	8000 500	1598	4082

*Average for two crops.

The soil on Range 6200 at Stillwater, Oklahoma, is a Kirkland loam. It is a dark brown soil and has a very compact clay subsoil at a depth of 12 to 14 inches. The other two soils were Vernon sandy loams and the subsoils were very favorable for root development. All of the soils were medium to strongly acid and according to general recommendations for sweet clover production should respond to an application of ground limestone. In all of these tests the addition of limestone did not produce any appreciable increase in crop yield. The addition of superphosphate and potash to the soil at Glencoe, Oklahoma, produced a marked increase in the growth of the sweet clover, but the addition of limestone in addition to superphosphate produced the largest yields in all of these experiments. There was a big difference in the growth of the sweet clover on the unfertilized plots in these experiments. Several different factors were probably responsible for the differences in yield which were secured. On Range 1200, Stillwater, Oklahoma, and at Glencoe, Oklahoma, the subsoil is deficient in both limestone and easily soluble phosphorus. On Range 6200, Stillwater, the Kirkland subsoil contains some limestone and enough easily soluble phosphorus to produce a fair yield of sweet clover, and the surface soil contains more organic matter than the Vernon soils. Nevertheless it was necessary to add a phosphate fertilizer and limestone to this soil in order to secure a maximum growth of sweet clover. Although the Kirkland has a very compact soil, Fig. 2 illustrates how sweet clover roots will penetrate it to a depth of four or five feet. A pit was excavated and the soil was washed away from the roots in order to secure this photograph.

In the spring of 1927 another study to determine the effect of phosphate fertilization and the addition of limestone on the growth of sweet clover was started on the farm of Norman Mounce, near Lenapah, Oklahoma. This experiment was harvested in the summer of 1928 and the results are given in Table VII. The residual effect of the sweet clover on the production of pasture grass in 1929 and 1930 is also included. Although the total yield of sweet clover was not large, the combined effect of the growth of the legume and the fertilizer applied produced a marked increase in the yield of grass which would make it possible to graze a larger number of livestock on the fertilized area as compared with a similar plot which received no fertilizer treatment. A picture of the difference in the sweet clover produced on a fertilized and unfertilized plot is shown in Fig. 3. The plot on the right received no treatment. The plot on the left was fertilized with limestone and superphosphate.

Fig. 2—Experiment Station Farm, Stillwater, Oklahoma. Sweet clover roots penetrate compact clay subsoils.

A careful study of a considerable number of soils secured from experimental plots and other areas where sweet clover had been grown, and a correlation of the soil analyses with the response in plant growth produced by different fertilizer treatments, indicated that several different soil conditions might occur which would require different recommendations for the successful production of sweet clover.

The most important factors to consider are the relations which occur between the degree of acidity and the amount of easily soluble phosphorus in the surface and subsurface soil. Sweet clover production was very poor on soils which were not acid but were low in easily soluble phosphorus. Soils which contain no easily soluble phosphorus in the subsurface layers will not produce a good growth of sweet clover unless the surface soil contains an abundant supply of this important plant food. A poor soil will frequently produce a scattered growth of sweet clover plants which may appear to cover the ground when mature; however the total yield secured under such conditions is low. When soils are acid in the subsurface layers conditions are also unfavorable for sweet clover production unless the surface soil is neutral in reaction or has been neutralized by the addition of some form of lime. Sweet clover will frequently make a much better growth on a strongly acid soil which has a good supply of lime in the subsurface layers at a depth of 18 to 24 inches than on soils which are only slightly acid throughout the entire profile.

A comparison of the easily phosphorus content and the acidity of samples of soil taken from fields where sweet clover experiments have been conducted is given in Table VIII. Composite samples of soil were taken from three different places in each field at the different depths indicated in the table. The results of the analyses indicated that the easily soluble phosphorus content of all the soils was low in both the surface and subsur-

Fig. 3—Nowata County, Oklahoma. Yields of sweet clover. Soil treated with limestone and superphosphate (left) and untreated (right).

face layers. In all cases except one the largest amount of easily soluble phosphorus occurred in the surface six inches of soil, the exception being in the deepest sample taken from the H. B. Brashear Farm, Watova, Oklahoma. None of the surface soils was extremely acid. In two instances the subsurface was more acid than the surface soil. This condition is very unfavorable for the growth of sweet clover, particularly during periods of drouth when the surface soil is acid and does not contain a sufficient amount of calcium to meet the needs of the plant under normal conditions. Also when the surface soil is dry, very small amounts of available calcium can be secured by plant roots growing in the acid subsoil. Under such conditions sweet clover failure is very common.

One of the soils represented in Table VIII, from Chandler, Oklahoma, was not acid at the surface, but the acidity increased rapidly with depth. This soil presents a condition which is similar to the effect produced by the addition of lime to an acid soil which has an acid subsoil. Such a treatment would neutralize the acidity in the surface layers but would have very little immediate effect on the acidity of the deeper horizons. This soil, when sweet clover was grown on it, did not respond to an application of limestone but did respond to an application of superphosphate. In a later experiment the importance of mixing the limestone thoroughly into the surface soil was demonstrated, especially when both the subsurface and subsoils are acid. Acid subsoils are frequently found in Oklahoma and usually occur in soils derived from an acid sandstone, or in mature soils from which the limestone has been removed by the rain water which passes through them.

Further studies on the easily soluble phosphorus content of Oklahoma soils indicated that a very large percentage of the soils in Central and Eastern Oklahoma would respond to phosphorus fertilization. Information concerning the easily soluble phosphorus content of Oklahoma soils will be found in Bulletin No. 205 of the Oklahoma Agricultural Experiment Station.

Table VIII—Acidity and Easily Soluble Phosphorus Content of Soils Taken From Unfertilized Plots Where Sweet Clover Experiments Have Been Conducted, Data From Which Has Been Presented in Tables I, III, V, VI and VII

AREA FROM WHICH SAMPLE WAS SECURED

Depth of Sample in Inches	John Waltermire Glencoe, Okla.		Range 1200 Exp. Sta. Farm, Stillwater, Okla.		Range 6200 Exp. Sta. Farm, Stillwater, Okla.		Norman Mounce Lenapah, Okla.	
	pH	Easily Soluble Phosphorus in p. p. m.	pH	Easily Soluble Phosphorus in p. p. m.	pH	Easily Soluble Phosphorus in p. p. m.	pH	Easily Soluble Phosphorus in p. p. m.
0- 6	6.35	7	6.14	6	5.54	14	6.25	14
7-12	6.62	4	6.03	2	5.90	10	6.14	4
13-18	6.85	2	6.51	1	6.04	4	6.54	2
19-24	7.02	2	6.59	1	6.20	4	7.01	2
25-30	7.02	2	6.50	1	6.48	3	7.49	2
31-36	----*	----*	6.40	1.5	6.77	3	7.65	2
37-42	----*	----*	6.40	1	6.99	2	----	-

Depth of Sample in Inches	H. B. Brashear Watova, Okla.		Wm. Blankenship Stigler, Okla.		W. O. Rittenhouse Wagoner, Okla.		Frank Carpenter Chandler, Okla.	
	pH	Easily Soluble Phosphorus in p. p. m.	pH	Easily Soluble Phosphorus in p. p. m.	pH	Easily Soluble Phosphorus in p. p. m.	pH	Easily Soluble Phosphorus in p. p. m.
0- 6	5.93	8	6.31	10	6.27	8	7.30	9
7-12	6.02	3	5.80	7	6.25	3	6.84	4
13-18	6.58	1.5	5.54	2	6.80	2.5	6.46	3.5
19-24	7.20	1	5.57	2	7.65	2.5	5.97	3
25-30	7.56	3	5.38	2	7.77	3	5.40	3
31-36	7.46	6	5.24	4	7.94	4	5.11	3
37-42	7.44	14	5.42	2	8.41	5	----	_*

*Sandstone encountered at less than 36 inches deep.

In order to secure additional information in regard to the effect on the growth of sweet clover of the addition of different fertilizers, 23 experiments located in different parts of the State were started in the spring of 1930. Limestone, superphosphate, rock phosphate, potash, and farm manure were applied alone and in different combinations. The fertilizer treatments were harrowed or disked into the soil at the same time the seed was planted. Fifteen of these experiments were harvested in June, 1931, and the results which were secured are given in Tables X to XIII inclusive. In most cases the soils on which these experiments were located were low in easily soluble phosphorus; consequently a very good comparison can be made concerning the utilization of rock phosphate and superphosphate by sweet clover plants. A marked difference which occurred in the reaction of the different soils was also favorable for studying the growth of sweet clover as affected by different amounts of limestone applied to soils varying in degree of acidity. The analyses of the surface and subsurface soils secured from these experiments are given in Table IX. The surface soils were taken from unfertilized plots and were secured at a depth of 0 to 6 inches. The subsurface samples were taken at a depth of 12 to 18 inches.

Table IX—The Easily Soluble Phosphorus and Soil Reaction of Surface and Subsurface Soils Secured From Sweet Clover Experiments Which Are Included in Tables X, XI, XII and XIII

No.	Cooperator	Location	Soil Reaction		Easily Soluble Phosphorus	
			Surface	Subsurface	Surface	Subsurface
1	W. Blankenship	Stigler	Slight	Strong	Low	Very low
2	F. J. Blecha	Perry	Medium	Basic	Low	Low
3	L. F. Crocker	Pawnee	Medium	Slight	Very Low	Very low
4	Emil Dester	Deer Cr.	Medium	Slight	Low	Very low
5	Stanley Dugan	Pawnee	Medium	Medium	Low	Very low
6	George Kirk	Perkins	Medium	Medium	Low	Very low
7	Lincoln Co. Farm	Chandler	Neutral	Slight	Low	Very low
8	Cleve Martin	Mulhall	Neutral	Slight	Low	Very low
9	V. W. Miracle	Okemah	Medium	Neutral	Low	Very low
10	L. A. Morton	Duncan	Neutral	Slight	Very Low	Very low
11	H. L. Morrissett	Guthrie	Slight	Slight	Low	Very low
12	Roy Nichols	Checotah	Medium	Medium	Low	Very low
13	W. O. Rittenhouse	Wagoner	Medium	Medium	Low	Very low
14	Mrs. Mae Sumner	Vinita	Medium	Medium	Low	Very low
15	C. J. Wallerstedt	Perry	Slight	Neutral	Low	Low

In Table X the results of seven different experiments which received the same fertilizer treatments are compared. In most cases the yields represent the averages secured from triplicate or quadruplicate plots. Farm manure produced only a slight increase in the yield of sweet clover except on the soil at Duncan, Oklahoma, which is not acid and is very low in organic matter. Limestone applications were beneficial on soils which were medium acid and well supplied with organic matter. In most cases plots which were treated with manure and limestone, or with manure, limestone, and potash, did not produce any appreciable increase in the yield of sweet clover over that secured from either of these plant foods applied alone.

Table X—A Study of the Effect of Soil Treatment on the Growth and Yield of Sweet Clover

Plot No.	Treatment	Rate Per Acre	LOCATION OF EXPERIMENT AND YIELD OF SWEET CLOVER IN POUNDS PER ACRE						
			Cleve Martin Mulhall, Oklahoma	F. J. Blecha Perry Oklahoma*	L. A. Morton Duncan, Oklahoma	Stanley Dugan Pawnee, Oklahoma	V. W. Miracle Okemah, Oklahoma	W. O. Rittenhouse Wagoner, Oklahoma	Mrs. Mae Sumner Vinita, Oklahoma
1	None		1549	1435	700	647	1218	40	106
2	Manure	12000	1939	2088	2100	910	1231	271	732
3	Limestone	2000	1218	1532	940	1330	1977	510	1612
4	Limestone	6000	1631	1685	900	1330	2090	877	2058
5	Manure Limestone	12000 2000	1528	2816	2080	1680	1715	598	2424
6	Manure Limestone	12000 6000	1983	2946	2120	2170	2165	1277	3248
7	Manure Limestone Potash	12000 6000 100	1878	2892	1760	3290	2043	1250	3660
8	Limestone Muriate of potash	6000 100	2002	1674	570	2590	2043	703	2653
9	Superphosphate	200	2723	1681	1900	455	2031	563	380
10	Rock phosphate	400	3010	2001	3420	630	2974	1291	464
11	Rock phosphate	1000	3486	2689	3960	577	3006	1346	670
12	Superphosphate Limestone	200 2000	2216	2620	3840	4270	2362	1713	2938
13	Superphosphate Limestone	200 6000	2835	2533	3280	3535	2691	1930	4094
14	Superphosphate Limestone Muriate of potash	200 6000 100	2846	3120	1280	5110	2568	2624	4941
15	Rock phosphate Limestone	400 2000	3138	2141	4320	3745	3375	2611	3316
16	Rock phosphate Limestone	400 6000	3360	2228	3640	4410	3206	2230	4254
17	Rock phosphate Limestone Muriate of potash	400 6000 100	3325	2598	2240	4970	3281	2733	5901
18	Rock phosphate Limestone	1000 2000	3395	3272	4880	3990	3600	3195	4620
19	Rock Phosphate Limestone	1000 6000	3441	3055	3840	5180	3665	2093	4414
20	Rock phosphate Limestone Muriate of potash	1000 6000 100	3640	3480	3280	4690	3768	3508	6061

*Oats grown as a nurse crop.

Table XI—A Study of the Effect of Soil Treatment on the Growth and Yield of Sweet Clover

Plot No.	Treatment	Rate Per Acre	LOCATION OF EXPERIMENT AND YIELD OF SWEET CLOVER IN POUNDS PER ACRE				
			George Kirk* Perkins, Oklahoma	H. L. Morrissett Guthrie, Oklahoma	C. J. Wallerstedt Perry, Oklahoma	L. F. Crocker Pawnee, Oklahoma	County Farm Chandler, Oklahoma
1	None	----	147	0	1230	405	1868
2	Manure	12000	1078	1470	2280	1536	----
3	Limestone	6000	539**	315	2940	2232	1722
4	Superphosphate	200	980	560	3690	369	3705
5	Superphosphate	400	1372	1295	3330		3250
6	Rock phosphate	200	1078	700	3900	739	3120
7	Rock phosphate	1000	1568	1015	3000	1261***	3445
8	Manure Limestone	12000 6000	735**	2047	4520	----	2746
9	Manure Superphosphate	12000 200	1176	1190	----	2218	----
10	Manure Superphosphate	12000 400	1372	2975	----	----	----
11	Manure Rock phosphate	12000 200	1470	2205	----	2436	----
12	Manure Rock phosphate	12000 1000	1862	3010	----	2523***	----
13	Superphosphate Limestone	200 6000	882**	2695	3920	2784	4355
14	Superphosphate Limestone	400 6000	2156**	3500	4710	----	3250
15	Rock phosphate Limestone	200 6000	1176**	2065	4050	2479	3835
16	Rock phosphate Limestone	1000 6000	1764**	3360	3840	3219***	3250
17	Manure Superphosphate Limestone	12000 200 6000	1078**	4130	----	----	4680
18	Manure Superphosphate Limestone	12000 400 6000	1862**	4620	----	----	4550
19	Manure Rock Phosphate Limestone	12000 200 6000	1470**	2835	----	----	3705
20	Manure Rock phosphate Limestone	12000 1000 6000	1962**	4900	----	----	3445

*Plot pastured in spring and dry weather reduced growth materially.
**Only 2 tons of limestone applied in this experiment.
***612 pounds per acre.

Superphosphate containing 20 per cent of phosphoric acid did not increase the yield of sweet clover on soils which were medium or strongly acid. Finely ground rock phosphate, although applied at heavier rates per acre than superphosphate, produced only slightly larger yields of sweet clover under similar conditions. Three tons of limestone applied with either rock phosphatae or superphosphate produced slightly larger yields than one ton of limestone, although the returns secured from the application of one ton of limestone were much larger than the yields secured from the untreated plots or those which only received an application of a phosphate fertilizer. Since the limestone was not thoroughly worked into the plowed layer of soil, conditions were not as favorable for its maximum utilization as they would have been if the limestone could have been applied to some previous crop and the land plowed once or twice before the sweet clover was planted. Apparently the presence of available calcium is more important than the acidity of the soil in the production of this crop, since a satisfactory growth of sweet clover was secured from the lighter application of limestone when some form of phosphorus was also supplied.

Slightly larger yields of sweet clover were secured from 1000 pounds of rock phosphate than were produced from an application of 400 pounds of rock phosphate. From the standpoint of the economical production of one crop of sweet clover, the lighter rate of application would be recommended. The effect of the potash which was applied to these plots with limestone, and with limestone and the different phosphate fertilizers, was frequently noticed due to an increase in the growth of the stems of the plants which made those treatments conspicuous because of their height. A marked increase in yield due to the potash fertilization was secured in only two of the experiments. These experiments were located on the farms of Stanley Dugan at Pawnee, Oklahoma, and of Mrs. Mae Sumner at Vinita, Oklahoma. Both of these soils were medium to strongly acid in the surface and subsurface horizons.

The data reported in Table XI include a larger number of comparisons in which farm manure is used in combination with limestone, rock phosphate, and superphosphate than those reported in Table X. The results secured in these experiments indicate rather definitely that farm manure cannot take the place of limestone on acid soils and cannot take the place of phosphate fertilizers on phosphorus deficient soils. Superphosphate applied at the rate of 200 pounds per acre produced slightly larger yields of sweet clover than did the same amount of rock phosphate when broadcasted alone or in combination with farm manure or with farm manure and limestone. The early growth of the sweet clover was more rapid on the plots treated with superphosphate, which may be of some advantage in developing plants which can compete with weeds and grass for soil moisture. Although in more recent experiments where the superphosphate and rock phosphate were drilled with the sweet clover seed at time of planting the rate of growth was very similar. If rock phosphate is applied broadcast it should be thoroughly mixed with the soil because the plant roots must come in contact with the phosphate particles before they can secure phosphorus from them. In case of superphosphate, which is soluble in water, there is in most soils a considerable movement of the phosphorus before it is removed from the soil solution; consequently a thorough incorporation of superphosphate is not so important in order to secure good results from an application of this kind of a fertilizer. The data secured on the County Farm at Chandler should not be used to compare the utilization of the phosphorus in rock phosphate and superphosphate by sweet clover, since the subsoil on this particular experiment was not uniform and most of the treatments were not duplicated.

Although the largest yields of sweet clover were secured from the combined application of farm manure, limestone, and a phosphate fertilizer, farm manure is too valuable a fertilizer to use in the production of sweet clover under average conditions when similar results can be secured by applying either rock phosphate or superphosphate to soils which are deficient in phosphorus. If the soils are acid an application of both limestone and a phosphate fertilizer should be made.

Table XII—A Study of the Effect of Soil Treatment on the Growth and Yield of Sweet Clover

Plot No.	Treatment	Rate Per Acre	Experiment Location and Yield of Sweet Clover in Pounds Per Acre: Roy Nichols Checotah, Oklahoma	Emil Dester Deer Creek, Oklahoma	Wm. Blankenship Stigler, Oklahoma
1	None		192	1767	0
2	Manure	12000	2199		---
3	Limestone	6000	695	2265	0
4	Rock phosphate	400	849		----
5	Superphosphate	200	1367	2415	----
6	Superphosphate	500	2590*	----	----
7	Limestone	6000	1124	----	----
	Muriate of potash	100			
8	Manure	12000	3078	----	----
	Superphosphate	200			
9	Limestone	6000	3626	3120	4884**
	Superphosphate	200			
10	Manure	12000			
	Limestone	6000	4235	----	----
	Muriate of potash	100			
	Manure	12000	3051	----	----
11	Limestone	6000			
	Superphosphate	200			
12	Limestone	6000	4093	----	----
	Muriate of potash	100			
	Superphosphate	500			
13	Limestone	6000	3700*	----	----
	Muriate of potash	100			
	Manure	12000			
14	Superphosphate	200	5437	----	----
	Limestone	6000			
15	Rock phosphate	400	3643	----	7992
	Limestone	6000			
16	Rock phosphate	400			
	Limestone	6000	3996	----	----
	Potash	100			
17	Limestone	6000	5032*	----	----
	Superphosphate	500			
	Manure	12000			
18	Limestone	6000	5363	----	----
	Muriate of potash	100			
	Superphosphate	200			

*At east end of experiment and only one plot for each treatment.
**400 pounds of superphosphate per acre.

Table XII contains additional data on the effect of fertilization on sweet clover production. The combinations of fertilizers and rates of application of fertilizers which occur in this table are slightly different than those which have been presented in the previous tables. The soils on which these experiments were located were acid soils, and at Checotah and Stigler the subsurface soils were more acid than the surface. The soil at Deer Creek had a good supply of lime in the subsoil, although it was low in easily soluble phosphorus. These differences produced a marked effect on the growth of the sweet clover on the unfertilized plots, although in all cases an increase in the growth of sweet clover was secured from an application of limestone and a phosphate fertilizer. The texture of the soil at Checotah was a sandy loam and the stimulating effect of farm manure added to this soil was very pronounced since the soil was very low in organic matter. When farm manure is applied as a top dressing to a soil, a better stand of sweet clover is frequently secured than that which is obtained on adjacent plots to which manure is not added. This is due to the favorable effect of the organic mulch in holding the moisture in the surface soil during the early growth of the sweet clover. The manure also contains some plant food which aids in the growth of the young plants. The chief objection to farm manure is that it stimulates the growth of weeds and grass which may frequently be quite objectionable, since the weeds and grass compete with the young sweet clover plants for moisture and plant food.

The most pronounced effect of phosphorus on the growth of sweet clover was secured at Stigler, Oklahoma. This experiment was started in 1928 to study the effect of different rates of application of limestone of different degrees of fineness on the growth of sweet clover. A complete failure of the sweet clover which was planted in the spring of 1928 occurred where limestone was applied at different rates per acre and no phosphorus was added. In 1929 a fair crop was secured from adjacent plots which received a light application of fine limestone and a phosphate fertilizer, which indicated that both limestone and phosphorus were needed on this soil in order to produce a good crop of sweet clover. In the spring of 1930 the area was divided into three strips which crossed the limestone treatment made in the spring of 1928. One strip was treated with superphosphate, one strip was treated with rock phosphate, and one strip was left untreated except for the different amounts of limestone which had been applied at the beginning of the experiment. The yields of sweet clover secured from this plot in 1931 are given in Table XIII. The mechanical analyses of the different limestones used in this experiment are given in Table IV. All treatments occurred in duplicate and the results are the averages of yields which were secured from the different plots. Slightly larger yields were secured from the rock phosphate application than from the plots fertilized with superphosphate. The rate of phosphate fertilization in both cases was 400 pounds per acre and the cost of the two treatments was approximately the same. Phosphorus fertilization produced some growth of sweet clover on this soil but a combination of limestone and phosphorus is necessary for maximum growth. Larger yields also were secured from limestone applied at the rate of 3000 pounds per acre than when the rate of application was 6000 pounds per acre. Fifteen hundred pounds of either coarse or fine limestone applied with 400 pounds of phosphate fertilizer produced a very good yield of sweet clover on this soil. The limestone was applied two years before this experiment was started. After the limestone was added and before the sweet clover was seeded, the land was plowed and disked twice and a crop of mung beans was grown. Consequently it is quite possible that the high yields secured from this experiment may be due to the more thorough incorporation of the limestone with the soil. In all of the other experiments which are reported in this bulletin the limestone was applied to the surface of the soil and disked or harrowed into it to a depth of not more than 2 or 3 inches at the time the sweet clover was planted.

Photographs showing the effect of fertilization on the growth of sweet clover are shown in Figs. 4, 5, and 6.

Table XIII—A Study of the Effect of Soil Treatment on the Growth and Yield of Sweet Clover. Wm. Blankenship Farm, Stigler, Oklahoma

Plot No.	Treatment	Rate Per Acre in Pounds	Yield of Sweet Clover in Pounds Per Acre
1	None		0
2	100-mesh limestone	750	0
3	100-mesh limestone	1500	0
4	Coarse limestone	1500	0
5	100-mesh limestone	3000	0
6	Coarse limestone	3000	148
7	100-mesh limestone	6000	1665
8	Coarse limestone	6000	2146
9	Superphosphate	400	1961
10	Superphosphate	400	4810
	100-mesh limestone	750	
11	Superphosphate	400	4514
	100-mesh limestone	1500	
12	Superphosphate	400	5180
	Coarse limestone	1500	
13	Superphosphate	400	6068
	100-mesh limestone	3000	
14	Superphosphate	400	4144
	Coarse limestone	3000	
15	Superphosphate	400	4884
	100-mesh limestone	6000	
16	Superphosphate	400	3552
	Coarse limestone	6000	
17	Rock phosphate	400	1739
18	Rock phosphate	400	2701
	100-mesh limestone	750	
19	Rock phosphate	400	5254
	100-mesh limestone	1500	
20	Rock phosphate	400	7104
	Coarse limestone	1500	
21	Rock phosphate	400	8732
	100-mesh limestone	3000	
22	Rock phosphate	400	8140
	Coarse limestone	3000	
23	Rock phosphate	400	7992
	100-mesh limestone	6000	
24	Rock phosphate	400	8436
	Coarse limestone	6000	

Sweet Clover Production as Affected by Soil Moisture and a Nurse Crop

Very frequently sweet clover fails when planted with a nurse crop of small grain, especially when a poor distribution of rainfall occurs during the summer months. Sometimes the failure may be due to a lack of moisture, and in other instances it may be due to a lack of plant food in the soil. On the Experiment Station Farm, at Stillwater, Oklahoma, only one sweet clover failure has occurred during an eight-year period when the sweet clover was planted in the spring with winter wheat grown on an upland soil which had been fertilized with limestone and superphosphate. On an unfertilized plot the growth of sweet clover following a nurse crop of winter wheat has been very poor except when moisture conditions were favorable during the entire growing season.

Fig. 4—(Top)—Haskell County, Oklahoma. At right, limestone and rock phosphate applied to the soil produced good sweet clover. At left, complete failure occurred on soil treated with finely ground limestone.

Fig. 5—(Center)—Craig County, Oklahoma. At left, limestone and superphosphorus produced good sweet clover. At right, superphosphate applied alone produced no crop.

Fig. 6—(Lower)—Pawnee County, Oklahoma. At left, sweet clover produced from rock phosphate applied alone. At right, sweet clover on soil treated with rock phosphate, limestone, and potash.

Table XIV—A Study of the Effect of Oats Used as a Nurse Crop and Soil Treatment on the Growth and Yield of Sweet Clover. Geo. Kirk Farm, Perkins, Oklahoma

Plot No.	Treatment	Rate Per Acre	Yield of Sweet Clover in Pounds Per Acre	
			With Nurse Crop	Without Nurse Crop
1	None		147	147
2	Manure	12000	588	1078
3	Limestone	4000	343	559
4	Manure Limestone	12000 4000	588	735
5	Manure Superphosphate	12000 200	1274	1176
6	Manure Superphosphate	12000 400	2548	1372
7	Superphosphate	200	784	980
8	Superphosphate	400	1862	1372
9	Superphosphate Limestone	200 4000	1076	882
10	Superphosphate Limestone	400 4000	1764	2156
11	Rock phosphate	200	1076	1078
12	Rock phosphate	1000	2156	1566
13	Rock phosphate Limestone	200 4000	980	1176
14	Rock phosphate Limestone	1000 4000	1862	1764
15	Manure Rock phosphate	12000 200	1960	1568
16	Manure Rock phosphate	12000 1000	1862	1882
17	Manure Limestone Rock phosphate	12000 4000 200	1076	1470
18	Manure Limestone Rock phosphate	12000 4000 1000	1862	1960
19	Manure Limestone Superphosphate	12000 4000 200	1470	1078
20	Manure Limestone Superphosphate	12000 4000 400	1960	1862

Some information in regard to the effect of plant food and a nurse crop on the growth and yield of sweet clover was secured in connection with this investigation and the results are given in Tables XIV and XV. The data which are presented in Table XIV were secured on the farm of George Kirk, Perkins, Oklahoma. The fertilizers were applied and disked into the soil and oats were drilled on a portion of the area at the rate of 1¼ bushels per acre. Sweet clover seed which had been inoculated was broadcasted and harrowed into the soil before the oats were planted. The straw was short due to a lack of rain during the growing season, and the yield of oats was about 25 bushels per acre. The sweet clover was pastured until May 1, 1931, and because of the drouth which occurred that season the growth produced during May and the first part of June was small. In this particular experiment the nurse crop did not have any appreciable influence on the yield of sweet clover where fertilizers were applied to the soil when the sweet clover was planted. In some instances the sweet clover produced a larger yield where a nurse crop was grown. This difference may have been due to the protection which the young sweet clover received due to the presence of the oats, which did not grow large enough to shade the sweet clover.

Table XV—A Study of the Effect of Oats Used as a Nurse Crop and Soil Treatment on the Growth and Yield of Sweet Clover.
C. J. Wallerstedt Farm, Perry, Oklahoma

Plot No.	Treatment	Rate Per Acre	Yield of Sweet Clover in Pounds Per Acre: With Nurse Crop	Yield of Sweet Clover in Pounds Per Acre: Without Nurse Crop
1	None	----	640	1230
2	Manure	12000	1650	2280
3	Manure	12000	3120	4530
	Limestone	4700		
4	Superphosphate	200	1230	3690
5	Superphosphate	200	2610	3910
	Limestone	4700		
6	Superphosphate	400	1560	3330
7	Superphosphate	400	3330	4710
	Limestone	4700		
8	Rock phosphate	200	2040	3900
9	Rock phosphate	200	2820	4050
	Limestone	4700		
10	Rock phosphate	1000	1740	3000
11	Rock phosphate	1000	3540	3840
	Limestone	4100		
12	Limestone	4700	1770	2940

In Table XV data are presented which are similar to those presented in Table XIV except that the oats were planted at the rate of ⅔, 1⅜, 2 and 2⅔ bushels per acre. The spring was dry and the oats did not stool appreciably or grow very tall; consequently the sweet clover plants were not seriously shaded and a good stand of sweet clover was secured on all of the plots. In this experiment low yields of sweet clover were obtained from the unfertilized plots, both where a nurse crop was grown and where the sweet clover was seeded without a nurse crop. High yields were secured where limestone and phosphate fertilizers were applied regardless of whether the sweet clover was planted alone or with a nurse crop. When either manure, superphosphate, rock phosphate, or limestone was applied alone and a nurse crop was grown the yields were less than on those plots which received a similar fertilizer treatment but did not produce a crop of oats.

Similar results were secured on the farm of Emil Dester, at Deer Creek, Oklahoma, where oats were seeded as a nurse crop for sweet clover at the rate of ¾, 1¼, 1¾, 2¼ and 2¾ bushels per acre on soil which was deficient in phosphorus and calcium. On all plots where the nurse crop was used the yield was considerably reduced except on the fertilized plots, which produced a good yield of oats and also produced a good crop of sweet clover even when oats were seeded at a normal rate. The average yields secured from five replications in this experiment are given in Table XVI.

One of the reasons why sweet clover is not grown more extensively in many areas in Oklahoma is the very poor growth which is secured after the nurse crop is harvested. Very frequently when the sweet clover is allowed to grow the second season a very good crop is secured from plants which come up during the latter part of the summer and early fall. Where soils are supplied with enough limestone and phosphorus to produce a good growth of sweet clover without treatment, sweet clover can be planted alone and nearly as much nitrogen can be added to the soil in one year as can be secured when the crop is allowed to grow two years. The main difference is that a seed crop cannot be secured when the sweet clover is plowed under at the end of the first season. In order to kill the sweet clover so that it will not interfere with the following crop it should be plowed under after it starts to grow the following spring. Under certain conditions spring plowing may be objectionable, especially when too much rain occurs and also when an early crop is to be planted on the soil. Since many winters occur which are mild enough so that the sweet clover plants will remain alive and grow even after the land is plowed, spring plowing followed immediately by other tillage operations will be most satisfactory under average conditions.

Table XVI—A Study of the Effect of Oats Used as a Nurse Crop and Soil Treatment on the Growth and Yield of Sweet Clover, Emil Dester Farm, Deer Creek, Oklahoma

Plot No.	Treatment	Rate Per Acre	Yield of Sweet Clover in Pounds Per Acre	
			With Nurse Crop	Without Nurse Crop
1	None		616	1767
2	Limestone*	8000	1311	2265
3	Superphosphate	140	676	2415
4	Limestone	8000	2379	3120
	Superphosphate	140		

*Very coarse limestone was used; consequently a heavier rate of application was made.

In Eastern Oklahoma where soil moisture conditions are more favorable for crop production, sweet clover can be seeded with a nurse crop on good soils; and on poor soils a good growth of sweet clover will be secured provided those plant foods which are needed for the production of this important soil building crop are supplied before the sweet clover is planted.

In Western Oklahoma, although the soils are usually well supplied with enough limestone and phosphorus to produce a good growth of sweet clover, the problem of soil moisture is very important. Since planting sweet clover with a nurse crop delays its growth during the earlier part of the season, the plants under average conditions do not have a root system deep enough to secure the moisture needed to keep them alive during the long periods of drouth which frequently occur in midsummer. The small grain crop also removes a large amount of water which would be available for the sweet clover if planted on land which is not badly infested with weeds and grass. Since sweet clover is usually grown for the purpose of increasing the nitrogen and organic matter content of the soil, maximum yields should be secured if possible. If moisture is the chief limiting factor in crop production, the sweet clover should be planted alone in order that the young plants can make a good growth the first season. Better results frequently are secured when the sweet clover is planted in rows two or three feet apart and cultivated rather than planted with a grain drill and the plants are only a few inches apart.

Where sweet clover can be grown with a nurse crop it is quite important to recognize that the return secured from a nurse crop will help to pay the cost of applying the fertilizer and limestone; consequently in Central and Eastern Oklahoma where soil moisture conditions are more favorable for sweet clover production this crop can be seeded with small grain provided the rate of seeding of small grain is reduced so that the young plants will not be shaded and will have less difficulty in securing an adequate supply of moisture and plant food from the soil. Mature sweet clover will remove the soil moisture to a depth of five or six feet during periods of drouth and frequently the crops which are planted following the growth of the sweet clover may not produce a normal yield unless favorable rains occur during the growing season.

Inoculation and Sweet Clover Production

When soils are medium to strongly acid, conditions are very unfavorable for the growth of the bacteria which occur on the roots of sweet clover plants. When sweet clover is planted on soils which have been treated with limestone, the sweet clover seed or the soil should be inoculated in order that an abundance of nodules will develop during the portion of the season in which the soil moisture and soil temperature are favorable for the growth of these micro-organisms. The continual reseeding of sweet clover on an area of land will slowly increase the number of bacteria in the soil, but this is an expensive process since there is no income from the land while the crop is being grown; the cost of taxes, seed, and labor must be considered and the total cost charged to the nitrogen fixed in the soil by the growth of the sweet clover plants. Results secured from the natural inoculation of sweet clover grown on different soils in the same community or on different fields on the same farm may be very erratic.

When the leaves of young sweet clover plants are light yellowish green in color it is a good indication that the plants are not well inoculated or the bacteria if present are not furnishing the sweet clover with an abundance of nitrogen. A good example of the effect of inoculation on the growth and composition of sweet clover was secured during the seasons of 1930 and 1931 on the farm of Cleve Martin, Mulhall, Oklahoma. On one area the sweet clover was inoculated with a good commercial culture at time of seeding. On an adjacent area the sweet clover was seeded without any inoculation.

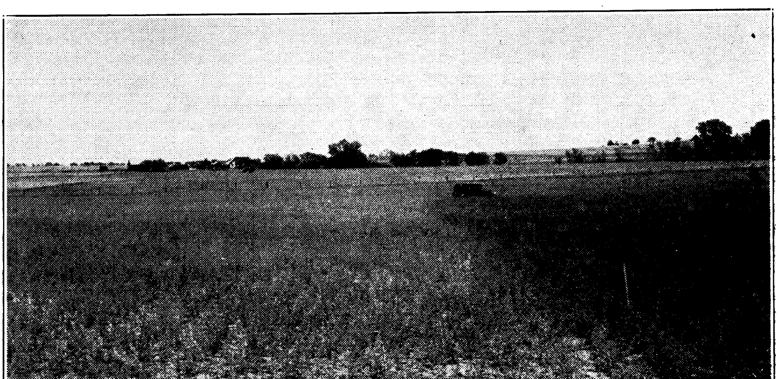

Fig. 7—Logan County, Oklahoma. At right inoculated sweet clover seed was planted; at left no inoculaton (See Table XVII).

The land had never grown sweet clover or any other crop which would cross-inoculate with it. An abundance of nodules occurred on the roots of inoculated plants, while only a very few plants produced from uninoculated seed contained nodules on their roots. The inoculated and uninoculated samples of sweet clover were harvested on May 31, 1931. The uninoculated samples of sweet clover were greenish yellow in color while the inoculated plants were medium green. This difference in color is shown in Fig. 7. The foliage on the inoculated plants also was more abundant than on the uninoculated plants.

The percentages of leaves and stems in the sweet clover hay produced on the different areas are given in Table XVII.

The inoculated sweet clover plants contained 6 per cent more leaves than the uninoculated sweet clover, and the nitrogen content of the inoculated plants was over .6% greater than the nitrogen content of plants which had very few nodules on their roots. A sweet clover plant which does not have nodules on its roots cannot increase the nitrogen content of the soil; consequently the inoculation of the seed or the soil with the sweet clover bacteria should not be neglected when there is any possibility that the soil does not contain an abundant supply of these important organisms.

Table XVII—Effect of Inoculation on the Percentage of Leaves and Stems of Sweet Clover Plants, Cleve Martin Farm, Mulhall, Oklahoma

Treatment	Per cent of Total Weight	
	Stems	Leaves
Inoculated	53.84	46.16
Uninoculated	60.00	40.00

The nigrogen content of the stems, the leaves, and the average for the whole plant are given in Table XVIII.

Table XVIII—Analyses of Inoculated and Uninoculated Sweet Clover Plants for Total Nitrogen, Cleve Martin Farm, Mulhall, Oklahoma

Treatment	Per cent of Total Nitrogen		
	Stems	Leaves	Whole Plant
Inoculated	1.055	3.946	2.379
Uninoculated	.814	3.125	1.738

Residual Effect of Sweet Clover on Crop Yield

No extensive information has been secured in Oklahoma concerning the residual effect of sweet clover on the yield of the crops which follow. Experiments which have been conducted in other states, where research work has been in progress for a longer period of time, indicate that sweet clover has the ability to fix large amounts of nitrogen when soil and climatic conditions are favorable. After the organic matter produced by the growth of the sweet clover decays, a marked increase in the yield of subsequent crops will be secured. Some information in regard to the effect of sweet clover on crop production and soil moisture conditions has been obtained in Oklahoma, and the results of these experiments are given in the following paragraphs.

The yield of sweet clover grown on the farm of Frank Carpenter, Chandler, Oklahoma, and the yield of corn which was grown after the sweet clover residues were plowed into the soil are given in Table XIX. A comparison of the corn produced on land which had produced no sweet clover and plots which had grown sweet clover is shown in Fig. 8. The season was very unfavorable for corn production due to the severe drouth which occurred in the summer of 1930, but an early variety of corn (Funk's 90-day) was planted which matured before the crop was seriously injured by the dry weather.

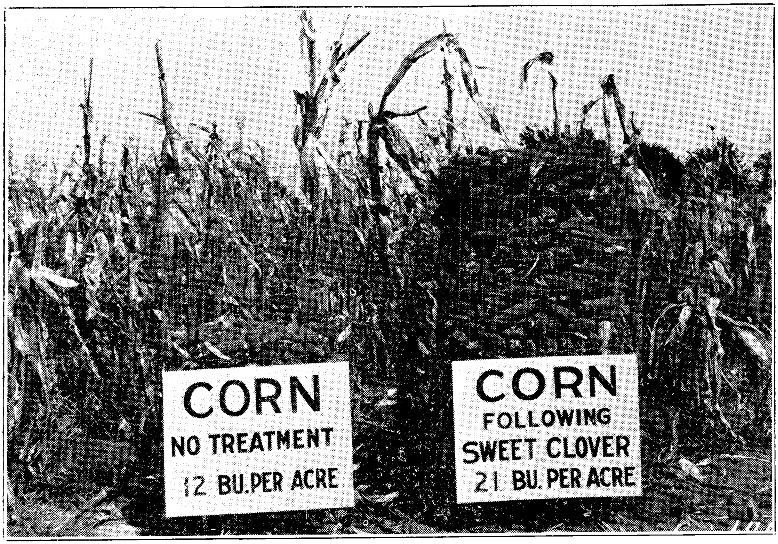

Fig. 8—Corn following sweet clover. Frank Carpenter Farm, Chandler, Oklahoma.

Table XIX—Yield of Sweet Clover and the Residual Effect on Corn. Frank Carpenter Farm, Chandler, Oklahoma

Plot No.	Treatment	Fertilizer Applied Per Acre for Sweet Clover	Sweet Clover Yield in Pounds Per Acre, 1929	Corn Yield in Bushels Per Acre 1930
1	None*	None	None	12.4
2	Limestone	2000 lbs	1210	21.0
3	Limestone	2000 lbs	1280	30.7
	16% superphosphate	500 lbs		
4	Limestone	2000 lbs		
	16% superphosphate	500 lbs	2500	28.6
	Muriate of potash	100 lbs		

*No sweet clover was planted on this plot.

The residual effect of the sweet clover indicates that nitrogen is an important factor in crop production on this soil which is quite typical of the average upland soil in the Central Cross Timber Area of Oklahoma. A marked response from the residual effect of phosphorus fertilization was also secured. This was probably due to the larger amount of nitrogen fixed by the sweet clover which grew on the plots that were fertilized with superphosphate at the time the sweet clover was planted.

In another experiment, data were secured on the yield of oats which was produced the second year following the growth of sweet clover on the farm of H. B. Brashear, Watova, Oklahoma. Sixty-one and three-tenths bushels of oats per acre were harvested from an area where sweet clover had been grown, while the production on adjacent land which had not been planted to sweet clover was only 32.1 bushels per acre. A comparison of the bundles secured from five equal areas of land is shown in Fig. 9.

The effect of soil treatment on the growth and yield of tame pasture grasses in which sweet clover produced the major portion of the forage during the first two seasons is given in Table XX. This experiment was conducted on the farm of Norman Mounce, Lenapah, Oklahoma. No yields were secured in 1927 and the forage produced in 1929 and 1930 was composed chiefly of Orchard grass and Redtop. Redtop predominated on the untreated soil, whereas the Orchard grass made a more luxuriant growth on the fertilized plots. This difference appears in Fig. 10 which shows bundles of hay harvested from equal areas on the different plots. In this experiment the sweet clover was seeded at the rate of 3 pounds per acre, and the Redtop and Orchard grass were seeded at the rate of 5 and 10 pounds per acre.

Table XX—Residual Effect of Sweet Clover on the Growth and Yield of Tame Pasture Grasses, Norman Mounce Farm, Lenapah, Oklahoma

Treatment	Yield of Crop in Pounds Per Acre		
	1928 Sweet Clover	1929 Grass	1930 Grass
None	314	2328	1968
Limestone	780	3279	2765
16% superphosphate	920	3170	2086
Limestone and superphosphate	1598	3876	3054

Fig. 9—Oats produced the second year following sweet clover; at left, average yield 61.3 bushels per acre; at right, no sweet clover, average yield 32.0 bushels per acre. H. B. Brashear Farm, Watova, Oklahoma.

Where the sweet clover was seeded at the rate of 15 pounds per acre a larger yield was secured, but the plants were so thick that no other vegetation was produced on these plots. The sweet clover was allowed to mature seed and an excellent stand of young sweet clover appeared the following season.

The chief advantage of a pasture mixture is that it furnishes grazing for a longer period as compared with a pasture which is planted to one kind of grass or legume. Where sweet clover is planted alone it may have a greater carrying capacity for a part of the season, but a grass mixture seeded with the sweet clover will produce a considerable amount of forage at times when the sweet clover crop is mature or when the young plants are too small to afford much grazing. If soil conditions are favorable for the growth of sweet clover, and if the pasture is not grazed too heavily so that some of the plants will mature seed, this crop will continue to reseed the land for a long period of time.

The use of sweet clover as a source of nitrogen for wheat has not been as promising as on some other crops. Data on an experiment conducted at Stillwater, Oklahoma, are presented in Table XXI. In this particular study the sweet clover residues have produced only a slight increase in the yield of wheat as compared with plots which received no treatment. The sweet clover was harvested for seed in order to secure some income from the land each year. As a result the soil was usually very difficult to plow since it was usually very dry after the sweet clover was harvested and the subsoil moisture was exhausted to a depth of four or five feet. In some instances, during seasons of favorable rainfall, a large amount of straw would be produced following the growth of the sweet clover; but the yield of grain would actually be less than that secured from plots which had not grown any sweet clover. The decrease in yield was produced by a lack of rain at the end of the growing season. Sweet clover was planted on the land every three years in this experiment. From the data secured it is quite evident that it will be necessary to use a four- or a five-year rotation and plow under the sweet clover earlier in the season in order to use this crop effectively in the production of wheat. This conclusion is especially true when strictly grain farming is being considered. If some income can be

Table XXI—Effect of Sweet Clover Residues on Wheat Production, Range 6200, Experiment Station Farm, Stillwater, Oklahoma

Plot No.	Treatment	Average Yield in Bus. Per Acre for All Plots for 1927-1931, inclusive
1	None	12.8
2	Superphosphate	16.3
3	Superphosphate Muriate of potash	17.4
4	P**, K*** and limestone	20.9
5	Sweet clover residues	13.2
6	Sweet clover and limestone	17.7
7	Sweet clover, L*, P**	19.8
8	Sweet clover, L, P, and K***	19.3

*L=Limestone; **P=Superphosphate; ***K=Muriate of potash.

derived from the sweet clover by pasturing with livestock, then the increase in the yield of the wheat following sweet clover would not need to be as great in order to be profitable as in case of a rotation where the loss of a crop on a portion of the land as a result of growing a soil-building crop must all be charged against the increases in yield of following crops produced as a result of plowing the legume crop into the soil.

Summary

This investigation was planned to study certain soil factors which are responsible for sweet clover failure in Oklahoma. The first problem which was studied was the effect of the addition of limestone of different degrees of fineness and at different rates per acre to soils which were acid and needed an application of limestone in order to produce a satisfactory growth of sweet clover. In the first series of experiments it was found that fine limestone was more effective in increasing the yield of sweet clover than was limestone which contained a large percentage of coarse material. It was also discovered that the acidity of the subsoil was quite an important factor in effecting the results which were secured.

The effect on the growth of sweet clover of the addition of limestone was far more pronounced when both the surface soil and the subsoil were acid than when the surface soil was acid and the subsoil was neutral or basic in reaction. When the soils which were studied in these experiments were only slightly acid in the surface and were not acid in the subsurface layers, very little response was secured from an application of ground limestone. When the surface of the soil was slightly acid and the subsurface was medium to strongly acid, sweet clover failed if limestone was not added along with other plant foods which were necessary for successful crop production. Soils which had a slight to slight plus acidity throughout the entire profile did not produce a satisfactory growth of sweet clover without an application of limestone. Consequently it is important to determine the acidity of both surface and subsurface soils before recommendations are made in regard to the use of agricultural limestone for sweet clover production.

In several of the experiments sweet clover failed on acid soils, in spite of application of limestone which should make conditions more favorable for the growth of the sweet clover. When some form of phosphate fertilizer was added to the soil with the limestone, a good growth of sweet clover was always secured.

Fig. 10—Residual effect of sweet clover on the growth of tame pasture grasses. Norman Mounce Farm, Lenapah, Oklahoma.

A second problem which was studied in this investigation was the relation between the available phosphorus content of the soil and the growth of sweet clover as affected by phosphorus fertilization. Most of the experiments were conducted on soils which were low in easily soluble phosphorus; although some of the soils, which contained a good supply of organic matter, were still producing good crops of corn and small grain. Soils which were only slightly acid at the surface and were not acid in the subsurface and the subsoil responded to phosphorus fertilization without an application of ground limestone. Where acid subsoils occurred or where the surface soil was slight plus to medium acid a combination of limestone and a phosphate fertilizer was necessary in order to produce a satisfactory yield.

The effect of rock phosphate and superphosphate as a source of phosphorus for sweet clover was also studied. It was found that both of these phosphates were readily utilized by sweet clover and that the rock phosphate produced larger yields of sweet clover on slightly acid soils than did superphosphate when limestone was not applied to the soil in addition to phosphate fertilization. Where limestone and the different phosphates were applied to medium and strongly acid soils, large yields of sweet clover were secured from all of the different treatments. To secure a maximum utilization of the phosphorus by sweet clover, a more thorough incorporation of rock phosphate with the soil is required than in case of superphosphate, especially when these fertilizers are applied broadcast at the rate of 200 pounds per acre. The lighter applications of rock phosphate did not yield quite as much sweet clover as similar amounts of superphosphate broadcasted on adjacent plots. However, recent data which have been secured on the application of fertilizers in the drill row with the sweet clover seed indicate that the rock phosphate is more effective in increasing the yield of sweet clover than equal amounts of superphosphate applied under similar conditions. Although the rock phosphate contains more total phosphoric acid than the superphosphate, which may be responsible for the increase in the yield of sweet clover, the cost of these two fertilizers is approximately the same. Since sweet clover can utilize the phosphorus in finely ground rock phosphate it may be the most economical source of phosphorus for soil improvement when sweet clover is used in a rotation system.

Potash fertilization did not produce any appreciable increase in the yield of sweet clover in most of the experiments. A response from potash fertilization was secured in two experiments conducted on sandy soils where both the surface and the subsurface soil were medium to strongly acid.

Farm manure did not produce any appreciable increase in the yield of sweet clover on the phosphorus deficient soils which were studied in this particular investigation, although a combination of farm manure, limestone, and a phosphate fertilizer produced the largest yields of sweet clover which were obtained. In most cases the amount of sweet clover secured from an application of limestone and a phosphate fertilizer was nearly as great as that secured from farm manure, limestone, and phosphorus; consequently under average conditions farm manure should not be utilized for the production of sweet clover since it can be used to much better advantage in increasing the growth of some other crop.

Another factor which may prevent a satisfactory growth of sweet clover, particularly in areas of high rainfall, is poor drainage. The addition of limestone and phosphorus cannot produce a maximum growth of sweet clover, if a water-logged condition of the soil restricts root development.

Although sweet clover frequently fails when planted with a nurse crop, it was found in this investigation that sweet clover can be grown with a nurse crop in Central and Eastern Oklahoma if a good supply of plant food is present in the soil and the rate of seeding of the nurse crop is reduced to one-half the ordinary rate of seeding for that crop. The small grain which is produced when a nurse crop is grown will also help to pay the cost of fertilization if limestone or phosphorus is needed for successful sweet clover production. Consequently the use of a nurse crop in sweet clover production is of economic importance. A nurse crop cannot be recommended for Western Oklahoma conditions since soil moisture is usually the chief limiting factor in sweet clover production in that part of the State. In order to secure a better utilization of the moisture available for crop production, it is quite possible that in Western Oklahoma sweet clover planted in rows 2 or 3 feet apart and cultivated may be the most successful way to secure a satisfactory growth of sweet clover, particularly on soils which contain a high percentage of clay.

The inoculation of sweet clover seed should not be neglected, especially when the crop is planted on acid soil or on areas where crops which cross-inoculate with sweet clover have not been grown. In this investigation it was found that inoculated sweet clover plants contained much larger amounts of total nitrogen and a higher percentage of leaves than uninoculated plants which did not have nodules on their roots.

Data were also secured on the residual effect of sweet clover on crops which were planted after sweet clover had been grown on the soil. A marked increase in the growth of corn, oats, and pasture grasses was secured. Where sweet clover is allowed to grow only one year it is best to plow the land in the spring after the sweet clover has started to grow because the plants are easier to kill at that time of the year than when plowed in late fall or during the winter.

The use of sweet clover as a source of nitrogen in the production of winter wheat has not been very effective in increasing crop yields on the Experiment Station Farm, at Stillwater, Oklahoma. The problem of soil moisture is a very important factor in connection with the effect secured from growing sweet clover in a rotation with winter wheat, since the sweet clover will remove the major portion of the available water to a depth of four or five feet and unless favorable rains occur during the summer and fall the subsoil will remain in a dry condition. The combination of a dry subsoil and a large amount of available nitrogen in the surface soil, which will stimulate vegetative growth, is very unfavorable for the maximum production of wheat.

An appendix has been prepared which gives the names of companies which produce agricultural limestone and also methods for the distribution of this material. The appendix also includes information concerning sources of inoculation for legume seed, sources of commercial fertilizer, and a discussion concerning the method of preparing a seed bed for sweet clover and the time of seeding sweet clover.

APPENDIX

The following information has been prepared for those who are interested in the production of sweet clover and where successful production may depend upon the proper treatment of the soil.

Sources of Agricultural Limestone for Oklahoma

Company	Office Address	Location of Quarry
Arkansas Lime Products Co.*	Texarkana, Ark.	White Cliffs, Ark.
Dolese Bros.	Oklahoma City	Bromide
Dolese Bros.	Oklahoma City	Crusher
Dolese Bros.	Oklahoma City	Richards Spur
Hughes Stone Company	Tulsa	Garnett
Independent Gravel Co.*	Joplin, Mo.	Carthage, Mo.
Monarch Cement Co.	Oklahoma City	Lost City (near Sand Springs)
Solvay Company*	Moline, Kans.	Moline, Kans.
Southern White Lime Co.	Pierce City, Mo.	Watts
Standard Paving Co.**	Tulsa	Gray
Zenith Limestone Co.	Tulsa	Price

*Produce a 10-mesh product, about half of which is dust.
**Produce a 100-mesh product which is all very fine flour.

There is a big difference in the quality of the agricultural limestone produced by different quarries, and screenings which contain a high percentage of dust are preferable since the coarse particles of limestone dissolve very slowly and are relatively unimportant in neutralizing the acidity in the soil as compared with the fine material. The cost of limestone screenings will vary from 50 to 75 cents per ton in carload lots f. o. b. quarry. Limestone which is ground to pass through a 10-mesh screen will vary in price from $1.00 to $1.50 per ton f. o. b. quarry. This type of material is called "Agstone" and is usually higher in percentage of fine material than ordinary screenings which contain a considerable amount of very coarse particles. Samples and prices of agricultural limestone can be secured from the different companies on request.

Method of Spreading Limestone

Limestone can be spread by hand from piles placed at regular intervals in the field or it may be applied directly from a wagon if only a small area of land is being treated. Where a large quantity of limestone is used a limestone spreader is more convenient and will save a large amount of labor. There are two kinds of limestone spreaders which are commonly used. One is the end-gate type which can be attached to the rear end of a wagon box and the other is the box-seeder type which is mounted on wheels like a grain drill. The capacity of the box-seeder type of lime spreader is low, and it must be filled several times in covering an acre of land if a heavy rate of application is applied; consequently the end-gate type of lime spreader is more desirable under average conditions.

Limestone spreaders can usually be secured from any company which makes farm machinery, and information concerning the different types of distributors can be secured from local implement dealers. The cost of an end-gate lime spreader will vary from $35 to $55.

Source of Inoculation for Legumes

The inoculation of legume seed is quite important on many soils where that legume or a legume with which it cross-inoculates has not been grown on the soil. The legume seed can be inoculated with commercial cultures or soil can be secured from a field where an abundance of nodules were produced on the roots of the legume crop, and a suspension of this soil and water can be made using one part of soil and two parts of water. After the suspension has been stirred thoroughly, allow it to settle one or two minutes, pour off the water containing some of the silt and clay, and mix it with the legume seed. Allow the seed to dry so that they will pour readily and then plant the seed immediately.

Although the use of commercial cultures is more expensive than the soil method of inoculation, the danger of securing plant diseases when soil is obtained from another farm is eliminated when commercial cultures are used. Also an effort is being made by many companies which prepare commercial inoculation to secure more vigorous strains of nitrogen-fixing organisms than those which may be present in the average soil. The cost of inoculating legume seed with a commercial culture will vary from 5 to 20 cents per acre, depending upon the size of the seed and the rate of seeding.

If commercial cultures of legume bacteria cannot be secured locally, they can be obtained directly from companies who manufacture them or from commercial seed houses.

Sources of Legume Inoculation in Oklahoma

Binding Stevens Seed Company	Tulsa
Clark and Keller	Shawnee
Hardeman-King Seed Company	Oklahoma City
Oklahoma Improved Seed Co.	Chickasha
Oklahoma Seed House	Muskogee
Treeman and Munger	Perry

Companies Manufacturing Legume Inoculation

A. Dickinson Co.	Chicago, Ill.
Edwards Laboratory	Lansing, Mich.
Hansen Inoculator Co.	Urbana, Ill.
The Kalo Company	Quincy, Ill.
The Nitragin Company	Milwaukee, Wis.
Urbana Laboratories	Urbana, Ill.

Legume cultures deteriorate with age unless they are stored in a cool place; consequently only fresh cultures or cultures which are less than a year old and have been stored under favorable conditions should be used.

Some difficulty occurs in securing a good production of nodules on summer legumes, particularly when the season is dry. This condition is not due to poor cultures of bacteria but is due to the lack of a sufficient amount of soil moisture, which is important for the development of large numbers of nodules on the roots of legume plants.

Alfalfa, bur clover, and black medic will cross-inoculate with sweet clover, and when these crops have been grown successfully on a soil and an abundance of nodules was produced on the roots of these crops, conditions will be favorable for the natural inoculation of sweet clover without applying a soil suspension or a commercial culture to the seed. Sweet clover will not cross-inoculate with cowpeas, soybeans, red clover, or lespedeza.

Seed Bed Preparation

Sweet clover failure frequently occurs due to a poor seed bed. This crop should be planted on soil which is loose at the surface but is firm in the lower half of the plowed layer. Disking cornstalk land or stubble land has given just as good results as early plowing when soil conditions are favorable for sweet clover production. Where moisture is a limiting factor in the growth of this crop a summer fallow following small grain will insure favorable moisture conditions for the growth of the sweet clover, which should be planted the following spring. Many farmers prefer to seed sweet clover on a soil which has a considerable amount of straw or stalks left on the surface to protect the young sweet clover plants from unfavorable wind and dashing rains. This protection is quite important in Central and Western Oklahoma, particularly on sandy soil where the young plants are easily destroyed or seriously injured by sand grains carried by the wind. If sweet clover is drilled in Sudan grass or cane stubble, a very good stand will be secured if the rainfall is favorable during the growing season.

Time of Seeding

Sweet clover may be seeded at different seasons of the year and a good stand will be secured when soil conditions are favorable, although the sweet clover which comes up soon after the seed is placed in the soil may not be the source of the plants which eventually survive and produce the crop.

Research under the direction of the Forage Crops Division of the Agronomy Department, at the Oklahoma A. and M. College, indicates that sweet clover should be seeded so that the plants will not be injured by frost. The use of unhulled seed provides good insurance against unfavorable weather such as frost or drouth since the seeds do not all germinate at the same time. The seedlings which first appear may be killed by frost; another group of plants may be destroyed by drouth or a beating rain; and it may be that the seeds which germinate and grow following the loss of the first two stands of sweet clover are responsible for producing the plants which finally remain and grow to maturity.

Method of Application of Fertilizers

Superphosphate, rock phosphate, or mixed fertilizers can be applied with a fertilizer drill or with special fertilizer spreaders similar to the box-seeder type of lime spreader. An end-gate lime spreader can be used to spread superphosphate or mixed fertilizers when the wind is not blowing, although it is difficult to secure a uniform distribution of the fertilizer over the surface of the soil.

A special box type of spreader which fastens to the rear end of a wagon box can be secured for spreading rock phosphate. Information concerning this spreader can be secured by writing to companies who sell this fertilizer or by consulting the county agricultural agent.

FERTILIZER MANUFACTURERS OPERATING IN OKLAHOMA

Sources of Superphosphate and Mixed Fertilizers

American Agricultural Chemical Co.	St. Louis, Mo.
American Cyanamid Co.	New York, N. Y.
Armour's Fertilizer Works	New Orleans, La.
	Nashville, Tenn.
	Houston, Texas
Arkansas Fertilizer Com.	Little Rock, Ark.
Ft. Smith Cotton Oil Co.	Ft. Smith, Ark.
Gate City Fertilizer Co.	Little Rock, Ark.
Hope Fertilizer Co.	Hope, Ark.
International Agricultural Corp.	Texarkana, Ark.
Keefe-LeStourgeon Co.	Arkansas City, Kan.
Meridian Fertilizer Factory	Shreveport, La.
Newhouse Chemical & Supply Co.	Little Rock, Ark.
N. V. Potash Export My., Inc.,*	New York, N. Y.
Pate Bros. Fertilizer Works	Sulphur Springs, Texas
Smith Agricultural Chemical Co.	Columbus, Ohio
Swift & Company Fertilizer Works	St. Louis, Mo.
	Shreveport, La.
	Chicago, Ill.
Synthetic Nitrogen Products Corp.	New York, N. Y.
Stumpp & Walter Co.	New York, N. Y.
Temple Cotton Oil Co.	N. Little Rock, Ark.
Tennessee Corp.	Lockland, Ohio
Virginia-Carolina Chemical Corp.	Shreveport, La.
	Memphis, Tenn.
Wilson & Co.	Oklahoma City, Okla.

*Distribute potash fertilizers.

Sources of Finely Ground Rock Phosphate

Ruhm Phosphate & Chemical Co.	Mt. Pleasant, Tenn.
Thomson Phosphate Co.	Chicago, Ill.