Green Manure and Cotton in a Double-cropping System on a Fine-textured Soil

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Briefly

Rainfall and soil characteristics have a major bearing on the results that can be achieved under the double cropping system reported in this bulletin. Results of this study show a reduction in cotton yields when green manure was grown during the winter preceding the planting of cotton. In most cases, the green manure crop depleted the soil moisture and resulted in an inadequate moisture for establishing a desirable seedbed and for starting the cotton crop.

Despite the disadvantages of this double cropping system, the green manure provided some protection from wind and water erosion during winter months.

No research data is available on the use of this management practice on sandy soils or under more favorable rainfall conditions. However, it is believed that higher rainfall or sandier soils or a combination of these conditions would result in more favorable crop yields.

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This bulletin reports the results of a study designed to determine the value of a double cropping system where green manure and a cash crop were grown on a fine-textured soil each year for several successive years. The double cropping system was tested under two management systems. In one system (Experiment I), cotton was planted each spring and followed each fall by a green manure crop. The second system (Experiment II) was a three-year rotation of cotton, an annual legume, and wheat, with vetch as winter green manure immediately preceding cotton and in no case was the cropping year devoted only to the growth of the green manure crop.

Each of the experiments was conducted during a 21-year period (1934-54). Experiments were located on the College Agronomy Farm at Stillwater. The average annual rainfall during the period was 29.79 inches, with a yearly range of 16.91 to 38.68 inches.

The soil used for these experiments was a Kirkland silt loam (0 to 1 percent slope).* This soil has a grayish-brown silt loam surface, 6 to 10 inches thick, over a darker grayish-brown, blocky, quite compact clay-pan which becomes browner below about 24 inches and contains some calcium carbonate concretions. Water moves very slowly through this soil. Table I shows total phosphorus and available phosphorus data for 1955. Tables III and V give nitrogen data.

Procedure

Two areas adjacent to each other were selected for the study in 1934. Each of these areas had been under experimentation since 1916. The area selected for Experiment I had been planted to cotton each year for the 18-year period, 1916-1934. The area selected for Experiment II had been in a three-crop rotation for the same period. Five general

* See Appendix I for a description of a typical soil profile.

fertility treatments had been applied to each of the areas from 1916 to 1934. The five treatments were as follows:

Treatment 1	Manure (Applied every third year)
Treatment 2	Manure and Rock Phosphate (Applied every third year)
Treatment 3	Residues (Crop residues plowed under each year)
Treatment 4	Residues and Rock Phosphate (Cotton stalks turned under each year; phosphate applied every third year)
Treatment 5	Untreated

After 1934, these same treatments were continued for each experiment except for a slight change in Treatment 3 of Experiment I. Beginning in 1934 this area received superphosphate each year when cotton was planted.

In order to determine the effectiveness of the green manure, each of the five treated areas was divided into two equal parts, one-half being used with green manure and the other half without green manure.

Experiment I

Experiment I involved the growing of cotton each year with and without vetch. The vetch was usually drilled between September 15 and October 15, although often the soil was very dry at that time of the year. The time of emergence of the vetch seedlings was dependent on soil moisture, which was quite variable. In practically all cases there was very limited winter cover, and the major growth occurred in late March and April. In seasons in which the green manure crops made considerable growth it was disked down before plowing under. The green manure crop was usually plowed under between April 7 and April 25. The cotton was normally planted between May 7 and May 20. That portion of the area not used for green manure purposes was plowed during December or January.

At least a fair stand of the green manure crop was obtained each year except for the cropping season of 1951, when very unfavorable fall moisture conditions caused a complete failure. The weights of green manure were recorded only 16 years out of the 21-year period. However, for every year except 1951, there was some growth to turn under.

Table I.—The Phosphorus Content of the Surface 2,000,000 Pounds of Soil as of September, 1955.

Treatment	Without Green Manure		With Green Manure	
	Total P (lbs.)	Available P	Total P (lbs.)	Available P
Continuous Cotton Area: Experiment I.				
No treatment	408	Low	396	Low
Manure	396	Medium +	380	Low
Manure + Rock Phosphate	600	Very High	552	Very High
Residues + Superphosphate	472	High	472	Medium +
Residues + Rock Phosphate	520	High	520	Very High
Rotation Area: Experiment II.				
No treatment	398	Medium	380	Low
Manure	436	Medium +	436	Medium +
Manure + Rock Phosphate	652	Very High	628	Very High
Residues	398	Medium	380	Low
Residues + Rock Phosphate	564	Very High	600	Very High

Results

Yield results are summarized in Table II. The general effect was a reduction in yield of seed cotton where green manuring was used in this double cropping system. The average decrease for all treatments amounted to 38 pounds per acre. Manure alone increased the average yield 42 pounds per acre with green manure and 49 pounds per acre where no green manure was used. Rock phosphate had little effect on the yield of cotton when used with manure. Rock phosphate used with residues (cotton stalks) gave 46 and 39 pounds per acre increases respectively with and without green manure. Superphosphate applied in the row at cotton planting time on plots receiving residues also had a greater effect on the yield of seed cotton than rock phosphate broadcast. The respective increases in this case were 61 and 74 pounds per acre with and without green manure. In this connection it is interesting to note that yields of the green manure itself were higher on plots receiving broadcast applications of rock phosphate than on areas receiving superphosphate in the row. Green manure yields were about the same for plots receiving residues and superphosphate in the row and plots receiving barnyard manure.

Data on the total nitrogen in the surface 2,000,000 pounds of soil as of September, 1955, are shown in Table III. An analysis of this soil before experimental work was started in 1916 showed that 2,000,000 pounds of surface soil contained 2,120 pounds of nitrogen.

Table II.—Effect of Green Manuring on Yield of Seed Cotton under Continuous Cotton for 21 Years (1934-54).

Treatment[1]	Av. annual green manure turned under[2] Lbs./Acre[3]	Av. annual yield of seed cotton: No green manure Lbs./Acre	Av. annual yield of seed cotton: With green manure Lbs./Acre	Av. annual decrease in yield Lbs./Acre	No. years green manuring increased yield	Years when increases occurred	Range of increases of seed cotton Lbs./Acre	Year of widest increase	Range of decreases of seed cotton Lbs./Acre	Year of widest decrease
Untreated	533	628	586	42	8	1934, 1935, 1936, 1940, 1944, 1946, 1951, 1954	3 to 94	1944	6 to 360[4]	1942
Manure	927	677	628	49	5	1938, 1940, 1944, 1946, 1951	9 to 105	1944	6 to 256	1939
Manure + Rock Phosphate	1320	653	642	11	6	1940, 1941, 1944, 1946, 1949, 1951	23 to 298	1940	5 to 153	1942
Residues + Superphosphate	911	702	647	55	6	1936, 1937, 1940, 1944, 1945, 1951	0 to 132	1940	0 to 498[5]	1942
Residues + Rock Phosphate	1125	667	632	35	8	1936, 1938, 1940, 1944, 1946, 1949, 1951, 1953	0 to 168	1938	0 to 332	1939

[1] Some of the manured plots received 5 tons and others 7.5 tons of barnyard manure every 3 years. The rock phosphate was applied broadcast at the time of applying the manure usually at the rate of 450 pounds per acre. The residues consisted of the cotton stalks and were left on all plots including the untreated plots. Rock phosphate was applied broadcast on the respective residue plots at the same rate and time it was applied on the respective manure plots. Superphosphate (0-20-0) was applied annually beginning in 1934 at the rate of 150 pounds per acre in the row on the respective residue plots at the time of planting the cotton. No superphosphate was used prior to the 1934 season.

[2] These data are averages for 16 years. Weight records were not recorded for the other years.

[3] Oven dry weight.

[4] This large decrease was realized in 1942 when the total yield of seed cotton was 1298 pounds on the "no green manure" plots. The same year it was 938 pounds on the green manure plots.

[5] The large decrease occurred in 1942 when the "no green manure" plots yielded 1510 pounds of seed cotton, while the yield on the green manure plot was 1012 pounds.

Table III.—The Total Nitrogen Content of the Soil Used for Continuous Cotton as of September, 1955.*

Treatment	Nitrogen in Pounds/Acre	
	Without green Manure	With green Manure
Untreated, Cotton stalks returned	1270	1325
Manure, Cotton Stalks returned	1280	1320
Manure, Rock Phosphate, Cotton stalks returned	1390	1535
Cotton Stalks, Superphosphate	1320	1365
Cotton Stalks, Rock Phosphate	1220	1420

* This soil contained 2,120 pounds of nitrogen for each 2,000,000 pounds of soil in 1916.

These nitrogen data indicate that during the last 40 years approximately 40 percent of the total nitrogen in the original surface soil was removed where no soil treatment other than the return of the cotton stalks was made. Considering an average of all of the treatments on the non-green-manure area the reduction in nitrogen has been about 39 percent, while the green manured area has had a reduction of about 34 percent. As an average of all green manure plots where phosphate fertilizer was applied, the nitrogen decrease has been approximately 32 percent rather than about 40 percent where no green manure or fertilizers of any kind were used. Hence green manure has helped somewhat in keeping up the nitrogen content, but the effect has not been great.

Experiment II

This experiment was conducted on the same soil type on an area adjoining Experiment I. In this case the cotton was grown in a 3-year rotation consisting of cotton, an annual legume (cowpeas, vetch, or Austrian winter peas), and wheat. In the earlier part of the rotation cowpeas was the annual legume crop used. During the last 7 years, vetch or Austrian winter peas was planted. The winter green manure crop, which was generally vetch, was planted in September after wheat. It was plowed under preceding the planting of the cotton, as indicated in Experiment I.

The amount of green manure produced in this experiment was somewhat greater than in Experiment I since immediately after wheat harvest the land was either double disked or one-wayed and allowed to rest until vetch seeding time. In Experiment I the cotton was still growing at the time of planting the green manure crop. The planting of the green manure crop, the incorporation of it into the soil, and the planting of the cotton were done on the same respective dates for the

two experiments. The untreated soil in Experiment II had only cotton stalks returned, the wheat straw and legume forage being removed. The manure and rock phosphate treatments have been similar to the same treatments of Experiment I, except during the last 6 years the rate of farm manure has been 5 tons per acre once every 3 years on all plots receiving this fertilizer, with one-half of them also receiving the wheat straw. In the earlier years, the wheat straw was removed from these plots. The residues were returned soon after harvest to the respective plots and the plots were disked or plowed to prevent the residues from blowing off the respective plots.

The manure and rock phosphate were applied broadcast in the late fall or winter preceding the cotton crop. The plots which were not devoted to the green manure crop were plowed within a short time after the harvest of the respective current crop of wheat or legume. Since the next year following cotton was devoted to vetch in the rotation, the vetch was drilled into the cotton stalks with no further seedbed preparation. During the time cowpeas were the annual legume used, a crop of vetch or Austrian winter peas was also grown in the cotton stalks and plowed under before planting the cowpeas on the area devoted to the green manure comparison. The change from a summer annual legume to a winter annual in the rotation was made because under summer temperatures and soil moisture conditions, inoculation of the cowpeas was erratic. Vetch was always well inoculated. The change also reduced summer tillage and allowed earlier seedbed preparation for the following wheat crop.

Results

The effect of the green manure crop on the yield of cotton is shown in Table IV.

The use of green manure caused the same general reduction in yield of seed cotton in this rotation experiment as with continuous cotton. In the rotation the reduction averaged approximately 44 pounds of seed cotton per acre per year.

Data on the total nitrogen content as of September, 1955, in the surface 2,000,000 pounds of soil are shown in Table V. The nitrogen content of this soil in 1916 was the same as that of the soil used in the continuous cotton study; namely, 2,120 pounds per acre in the surface 2,000,000 pounds.

Green manuring in this rotation has had very little value in keeping up the nitrogen content of the soil.

Table IV.—Effect of Green Manuring on Yield of Seed Cotton in a Rotation — 20 Year Average 1934-1954[1]

Treatment[2]	Av. annual green manure turned under[3]	Av. annual yield of seed cotton		Av. annual decrease in yield	No. years green manuring increased yield	Years when increases occurred	Range of increases of seed cotton	Year of widest increase	Range of decreases of seed cotton	Year of widest decrease
		No green manure	With green manure							
	Lbs./Acre[4]	Lbs./Acre	Lbs./Acre	Lbs./Acre			Lbs./Acre		Lbs./Acre	
Untreated	1045	743	704	39	5	1940, 1941, 1942, 1948, 1951	0 to 115	1941	0 to 219	1938
Manure	1455	857	816	41	11	1940, 1941, 1942, 1943, 1948, 1949, 1950, 1951, 1952, 1953, 1954	2 to 238	1952	4 to 389[5]	1938
Manure + Rock Phosphate	1683	849	801	48	8	1939, 1940, 1941, 1949, 1950, 1951, 1952, 1953	13 to 160	1952	7 to 508[6]	1938
Residues	977	788	775	13	10	1939, 1940, 1941, 1942, 1943, 1948, 1949, 1951, 1952, 1953	2 to 228	1941	7 to 230	1938
Residues + Rock Phosphate	1527	861	783	78	3	1948, 1949, 1953	10 to 171	1948	12 to 296	1952

[1] The year 1947 was omitted because of difference in time of planting the cotton on the plots.
[2] See footnote 1 under table 2 for rates and time of applying manure and rock phosphate. The residues consisted of cotton stalks, wheat straw, and legume straw, wheat straw, and legume straw.
[3] Oven dry weight.
[4] These data are averages for 14 years. Weight records were not recorded for the other years.
[5] Occurred during 1938 when yield of no green manure plot was 1250 pounds and that of green manure was 861 pounds.
[6] The no green manure plot had a yield of 1352 pounds of seed cotton compared with 844 pounds on the green manure plot.

Table V.—The Nitrogen Content of the Soil Used for the Cotton Rotation as of September, 1955.*

Treatment	Nitrogen in Pounds/Acre	
	Without Green Manure	With Green Manure
No treatment	1385	1410
Manure	1650	1693
Manure + Phosphate	1713	1713
Residues	1513	1573
Residues + Rock Phosphate	1593	1620

* This soil contained 2,120 pounds of nitrogen for each 2,000,000 pounds of soil in 1916.

Since the nitrogen content of the surface soil of these two experiments was the same at the start, it is possible to compare the rotational effects with continuous cotton on the nitrogen balance. This is brought out by comparing the nitrogen data presented in Tables III and V. It can be readily observed that the rotation has been somewhat more favorable to the nitrogen. The difference is about 5 percent in favor of the rotation comparing the untreated non-green manured plots in the two experiments. A similar comparison under green manure shows a difference of 4 percent in favor of the untreated rotation plot over the untreated continuous cotton plot. However, there was an average reduction of 39 percent in soil nitrogen in plots grown in continuous cotton without green manure. This compares with a 34 percent reduction in nitrogen where green manure and cotton were grown each year in a double cropping system. The average reduction was 25 percent for plots grown in rotation without green manure. There was a 24 percent reduction in nitrogen in plots grown in rotation with green manure. The present higher nitrogen content in the soil used for the rotation which includes wheat and an annual legume is probably due to at least two factors; namely, the nitrogen fixed by the legume in the rotation and the reduction of soil tillage incident to the growing of wheat compared with a row crop.

Discussion

The reduction in yield of seed cotton due to the double cropping was due to a number of factors, varying somewhat from season to season. Practically no growth of vetch occurred during November, December, January, and February, due to fluctuating temperatures and the low rainfall during these months. Vetch cannot be expected to make more than a start during October, therefore the crop is practically at a standstill until spring. Windy and dry weather often prevents early March

growth, hence it is normally sometime in April before there is sufficient growth to turn under for green manure purposes.

As a rule vetch makes good growth the last of March and during April when spring rains occur and temperatures are favorable. There is usually not enough moisture in the soil, however, to turn under the vetch without leaving these finer textured soils in a cloddy condition. Some years the growing vetch dried out the soil, causing plowing to be delayed until rains were received. Hence even with considerable further seedbed tillage, the seedbed lacks firmness. This lack of a firm seedbed may operate unfavorably by drying out the soil if the weather remains relatively dry. On the other hand, it may be too wet if excessive rains occur during the planting and early growth of the cotton. With the earlier prepared seedbed the moisture conditions are much more favorable under either of these two weather extremes.

It is a rare case when the seedbed following the green manure crop is as good as it is where earlier plowing is done. In some instances there is a delay in emergence of the cotton on the green manure plots due to dry soil. The poorer seedbed of the green manure plots is generally quite evident in the planting operations even when planting is delayed a month after plowing under the green manure crop.

No similar experiments are available on sandy soils in Oklahoma However, some farm observations indicate much more favorable results with the use of a green manure crop. Sandy soils allow for deeper moisture penetration. Also, the need for organic matter is usually greater in sandy soils. After plowing under a green manure crop, a better seedbed can usually be had on sandy soils since they have less tendency to clod. Also the clods which may be present are much easier to breakdown during seedbed preparation than is the case with the finer textured soils.

These experiments were conducted on a silt loam soil with a claypan subsoil. The green manure crop was part of a double cropping plan since all regular crops were grown annually. Winter cover crops used for green manure purposes may perform certain desirable functions such as protection from water or wind erosion even on some silt loam soils. However, in areas of Oklahoma receiving less than about 32 inches of rainfall, the use of these crops on finer textured soils in a double cropping system will likely result in lower average annual yields of cotton when the green manure crop is grown during the winter and up into April preceding the planting of cotton. *Because a practice may be helpful in controlling erosion, it does not necessarily follow that it will also always increase crop yields.*

Some of the fine-textured soils in the low rainfall belt of Oklahoma which are likely to produce lower yields when subjected to the cropping system reported here are designated as belonging to the following series: Abilene, Bethany, Calumet, Comanche, Foard, Harrold, Hollister, Kirkland, Prague, Renfrow, Stamford, Tabler, Tillman, and Windthorst.

Summary

The two experiments reported in this bulletin were designed to determine the value of growing a green manure crop in a double cropping system on a fine-textured soil under limited rainfall conditions. The experiments were conducted during a 21-year period (1934-54). Rainfall during that period averaged 29.79 inches with a range from 16.91 to 38.68 inches. The general effect of double cropping with green manure and cotton each year (Experiment I) was a reduction in yield of seed cotton. Also, nitrogen content of the soil decreased during the 21-year period.

Cotton yields also decreased when a winter green manure crop was grown in a rotation system of cotton, an annual legume, and wheat (Experiment II). Nitrogen content of the soil decreased in the rotation system, but the loss was less than in the continuous cotton sysem. Nitrogen loss was less where the green manure was used in the rotation than where no green manure was used.

Appendix I

Description of Typical Kirkland Silt Loam Profile

A_1	0-8 inches	Grayish-brown heavy silt loam; weak medium granular; friable; permeable; pH 5.8; a few fine pores; rests abruptly on the layer below.
B_{2-1}	8-22 inches	Dark grayish-brown clay; moderately fine blocky; very firm; sticky and plastic when wet; very slowly permeable; pH 7.0 at about 18 inches; sides of blocks are varnished and have strong clay films; occasional fine black concretions; grades through a 4-inch transition to the layer below.
B_{2-2}	22-32 inches	Grayish-brown clay; weak medium blocky; very firm and compact; very slowly permeable; pH 7.5; occasional fine black pellets; a few strong brown specks about the tiny root holes; many fine $CaCO_3$ concretions below 26 inches; blocks have a weak shine when moist; grades through a 3-inch transition to the layer below.
B_3	32-42 inches	Brown light clay; weak medium blocky; very firm; less compact than layer above; occasional black pellets and $CaCO_3$ concretions; pH 7.5; sides of blocks have weak dark-brown coatings when moist; grades to the layer below.
C_1	42-52 inches	Reddish-brown silty clay loam much like layer above; occasional large $CaCO_3$ concretions with black ferruginous films; pH 7.5; grades to the layer below.
C_2	52-64 inches	Reddish-brown silty clay loam splotched with 10 percent of red and occasional streaks of light gray; weak blocky; firm; slowly permeable; pH 7.5; occasional fine black pellets and fine $CaCO_3$ concretions grades to the layer below.
C_3	64-84+ inches	Red silty clay with occasional light-gray streaks and splotches; weak medium blocky; firm but not compact; pH 7.5+; many fines pores; material changes little to the greatest depth sampled. Definite evidence is lacking but it is likely that the substratum is Pleistocene alluvium. Definite banding has been observed in deep cuts in this general vicinity.