Experiments on Fertilization of Cotton, Alone and in Rotations and With Green Manure Crops, On Three Central Oklahoma Soils, 1927-1958.

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Experiments on Fertilization of Cotton, Alone and in Rotations and With Green Manure Crops, On Three Central Oklahoma Soils, 1927-1958.

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The question of how to fertilize summer-growing crops in Oklahoma, where summer rainfall is erratic and often lacking, is a subject of frequent discussion. Many short-time fertilizer trials in central and eastern Oklahoma have indicated that fertilization of cotton on soils capable of producing a half bale or more per acre is unprofitable in many seasons.

The experiments reported herein were continued 15 to 25 years or more. Consequently, the duration of these experiments should include most of the climatic extremes likely to be encountered in the area.

The experiments were conducted on three important soils of the area:

(a) A Kirkland silt loam on the Station's Agronomy Farm immediately west of Stillwater.

(b) Norge loam on the Station's Perkins Farm ten miles south of Stillwater; and

(c) Durant loam near Lone Grove in the south central portion of the state.

All three of these soils are low in available mineral phosphate, but contain enough organic matter to provide the nitrogen required for a high yield of cotton under the average climatic conditions of the area. All are high in exchangeable potassium.

Experimental Procedure and Results

Agronomy Farm; Stillwater

In the experiment at Stillwater, the same fertilizer treatments were applied on:

(1) Cotton planted on the same area every year;

(2) Cotton two years, followed by a summer-growing legume for one year; and

(3) Cotton on the same area every year, with a cover crop during the winter.

The experiment was started in 1927 and continued through 1956.

The Soil

The plots were located on Kirkland silt loam. This is a gently sloping claypan soil that developed under the influence of prairie grasses. The subsurface and subsoil layers are high in clay content, and water moves into these layers very slowly except where deep cracks are formed as a result of subsurface moisture loss during dry weather. Table VII shows the pH and the percentages of organic matter, total nitrogen, total phosphorus, available phosphorus and exchangeable potassium in composite soil samples collected from unfertilized plots in 1927 and 1958.

The Fertilizer Treatments

The same fertilizer treatments were used with all three cropping systems, with one exception: where sweet clover was grown, Treatments B, C and D were limed and Treatment D did not receive phosphorus and potash.

THE FERTILIZER TREATMENTS were:

Treatment A—No fertilizer. Unlimed.

Treatment B—300 pounds of 0-16-0 per acre annually from 1927 through 1932, and thereafter 200 pounds of 0-20-0 per acre annually, applied in the row at planting time. Unlimed (except where sweet clover was grown).

Treatment C—Same as Treatment B, plus 100 pounds of muriate of potash per acre broadcast annually from 1927 through 1940. Thereafter, same as Treatment B. Unlimed (except where sweet clover was grown).

Treatment D—Same as Treatment C (except where sweet clover was grown), plus two tons of agricultural limestone per acre applied in 1926.

In Treatments C and D, it was apparent by 1940 that muriate of potash was having no effect on the yield of cotton on this high-potash soil, hence the potash application was discontinued.

Where sweet clover was grown, there were two departures from the above pattern: (1) All plots except the unfertilized checks (Treatment A) were limed; and (2) Treatment D was replaced by plots which were limed but not fertilized.

Cotton Yields

Continuous Cotton

WITHOUT A WINTER COVER CROP

Table I shows the yields of seed cotton in relation to the different fertilizer treatments when cotton was planted every year and no other crops were grown. The slight average increase from phosphorus fertilization was not statistically significant.

WITH A WINTER COVER CROP

Table II shows cotton yields in relation to the different fertilizer treatments when a winter cover crop was grown and used as a green manure.

The cover crops compared were hairy vetch, Austrian winter peas, and Abruzzi rye. They were drilled between the cotton rows after the first picking, usually in early October. When fall rainfall was low, forage yields the following spring usually were low. The cover crop was disked or plowed into the soil about mid-April. When spring rainfall was low, the cotton seedbed on these plots was very cloddy, especially where rye had been grown.

Cotton yields on the phosphated plots (Treatment B) were reduced in some seasons by the effect of a terrace ridge constructed across this area in 1927.

In Rotation With Summer Legumes

Three summer-growing legumes were grown in a three-year rotation with cotton in this study. The legumes used were annual sweet clover, cowpeas, and either soybeans or Golden mungbeans. The mung-

beans were planted occasionally when the young soybeans were severely damaged or destroyed by jackrabbits.

Tables III, IV and V show the average annual yields of seed cotton for the different fertilizer treatments when the legume grown was annual sweet clover, cowpeas, and soybeans (or mungbeans), respectively.

Forage Yields of Summer Legumes And Winter Cover Crops

Table VI shows the average annual forage yields of the winter cover crops and the summer-growing legumes grown in different cropping systems with the cotton. The residual effect of the superphosphate applied on the cotton increased the forage yields of all winter cover crops.* The forage yields of the summer legumes in the years they were grown exceeded the average annual yields of the winter crops, but the average amount of forage returned to the soil per acre over a three year period was lower.

Perkins Farm; Perkins

Two experiments were started in 1931 to study the effect of various fertilizer treatments on the yields of cotton planted every year on the same area. Both experiments were located adjacent to another set of experimental plots where cotton was being grown in an alfalfa rotation; and this circumstance made it possible to compare yields obtained from the continuous cotton plots with those obtained from cotton grown once in eight years in a rotation with alfalfa.

In Experiment I, a 4-12-4 fertilizer was applied at five different rates. In Experiment II, nitrogen, phosphorus and potassium were used in different combinations.

Conditions of the Experiments

The soil is a Norge loam with a profile approximately seven feet deep. The surface soil when the experiments were started was low in easily soluble phosphorus and contained an average of 1.8 percent organic matter and 0.87 percent total nitrogen. It was high in exchangeable potassium (240 pounds per acre in the top 6 inches).

Cotton yields in all experiments on the Perkins Farm were low

* The forage yield of Austrian winter peas on Treatment D plots was seriously reduced during several seasons by henbit (*Lamium amplexicaule*).

in 1935 because of a wet spring and the coldest May and June during the 28 years included in this study. Yields were also low in 1950 when excessive rainfall in July kept the soil so wet that mechanical equipment could not be used to apply insecticides to control leaf hoppers and boll weevils.

Experiment I: Varying Rates of 4-12-4

In Experiment I, a 4-12-4 fertilizer was applied in the row at planting time. Rates per acre are shown in Table VII, which also reports the average annual yields of seed cotton. In general, yields increased with the rate of fertilization up to and including 300 pounds per acre.

The yield increase for each rate of fertilization, and the increase per pound of fertilizer applied, are shown at the bottom of Table VII.

Experiment II: Different Combinations of Nitrogen, Phosphorus, and Potassium

In Experiment II, 40 pounds of phosphoric acid per acre was applied alone and with 20 pounds of nitrogen and/or potassium. In addition, one treatment included the nitrogen and potassium, but no phosphorus. Table VIII shows the fertilizers applied, and the average annual yields of seed cotton obtained for each treatment.

The increase from phosphorus alone, and from nitrogen when used with phosphorus, were statistically significant. Yields were still further increased when potash was added to provide a complete fertilizer, but this increase was not significant.

Comparison With Cotton in An Alfalfa Rotation

Experiments I and II were both located adjacent to plots used for another experiment in which cotton was planted every eighth year in an eight-year alfalfa rotation. This made it possible to compare the cotton yields in the rotation with those obtained with continuous cotton in these experiments. This comparison is shown in Table IX.

Cotton yields in the rotation were similar to those obtained on the more heavily fertilized of the plots in Experiments I and II. Cotton in the rotation benefited from the nitrogen added to the soil by the alfalfa and also from the residual effect of superphosphate applied to the alfalfa.*

* See Okla. Agri. Exp. Sta. Bul. 565, "Effect of Fertilization and Lime on Yields of Alfalfa and of Crops Grown with it in an Eight-Year Rotation," by Horace J. Harper (October, 1960).

Southern Soil Improvement Station; Lone Grove

Four cotton fertility experiments were conducted on the Southern Oklahoma Soil Improvement Station* near Lone Grove from 1931 through 1945. In all four experiments, cotton was planted every year on the same land. The objectives of the experiments were to determine the effects of—

Varying rates of application of 4-12-4. (Experiment I.)

Varying ratios of nitrogen, phosphoric acid and potassium in mixed fertilizer applied at the rate of 400 pounds per acre. (Experiment II.)

Different combinations of fertilizer treatments and winter cover crops. (Experiment III.)

Different rates of nitrogen in a mixed fertilizer applied to cotton grown with and without a winter cover crop (hairy vetch). (Experiment IV.)

Conditions of the Experiments

The soil on which these experiments were conducted is a Durant loam. This soil developed under the influence of prairie grasses, and the subsurface is more permeable than that of the Kirkland soil at Stillwater. The soil was deficient in available phosphorus and contained about two percent of organic matter when the experiments were started.

Summer drought was severe during most of the years from 1931 through 1939.

Experiment I: Varying Rates of 4-12-4

In Experiment I, a 4-12-4 fertilizer was applied at rates of 200, 300, 400, 600, 800 and 1,000 pounds per acre. The results are shown in Table X. No appreciable increase in yield of seed cotton was obtained from rates above 400 pounds per acre. The fertilizer was applied in shallow furrows before the cotton was planted.

Experiment II: Varying Rates of N, P, and K

In Experiment II, mixed fertilizer was applied on all plots at the rate of 400 pounds per acre. The proportions of nitrogen, phosphoric

* This farm was operated as a special station of the Oklahoma Agricultural Experiment Station from 1929 through 1951.

acid, and potassium were varied as shown in Table XI, which also shows the results. Figure 1 shows the average yields associated with the different proportions of each of the three plant nutrients in the mixture.

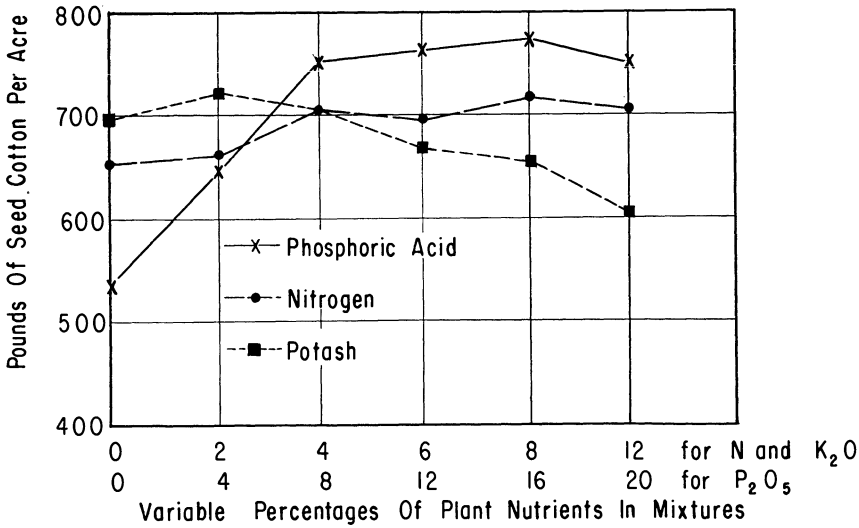
The effect of phosphate fertilization on this low-phosphate soil is strikingly apparent in Figure 1. Increasing the percentage of phosphoric acid in the fertilizer from 0 to 4 percent increased the yield of seed cotton about 100 pounds per acre, and the increase from 4 to 8 percent gave an additional increase of about 100 pounds of seed cotton.

The decrease in yield with increasing potassium content in the fertilizer was associated with increased vegetative growth and delayed fruiting at the higher percentages of potash in the fertilizer. The plants in these plots were more susceptible to injury from summer drought and insects.

Experiment III: Various Fertilizer Treatments With Winter Cover Crops

Experiment III involved three factors:

(1) Fertilizer ratio. Two levels of nitrogen were used, 0-12-6 and 4-12-6, each applied at the rate of 300 pounds per acre annually.



Basic treatment, 0-12-6 for nitrogen, 6-12-0 for potash and 6-0-6 for P_2O_5, 400 pounds per acre.

Figure 1.—Average yields of continuous cotton in relation to varying percentages of nitrogen, phosphorus and potassium in a mixed fertilizer; Southern Soil Improvement Station, Lone Grove, 1931-1945.

(2) Kind of cover crop. Three were used: Rye, hairy vetch, and Austrian winter peas.
(3) Crop on which fertilizer was applied. Three variations were compared:
    (a) Applying all the fertilizer on the cover crop;
    (b) Applying half the fertilizer on the cover crop and half on the cotton; and
    (c) Applying all the fertilizer on the cotton.

On plots where no cover crop was grown, all the fertilizer was applied in the row when the cotton was planted.

Results of the foregoing comparisons are presented in Table XII. Where no cover crop was grown, the 4-12-6 fertilizer produced a statistically significant increase in seed cotton yield — 687 pounds per acre as compared to 509 pounds per acre. Winter cover crops did not increase cotton production on this soil.

Experiment IV: Varying Rates of Nitrogen With and Without A Winter Cover Crop

In Experiment IV, mixed fertilizers containing varying percentages of nitrogen were applied on continuous cotton grown with and without vetch as a winter cover crop. The fertilizers were applied in the row when the cotton was planted at the rate of 300 pounds per acre.

The results of this comparison are shown in Table XIII. The average yield where a fertilizer containing no nitrogen was used was slightly higher where no vetch was grown than it was where vetch was plowed under each spring.

Discussion

Effect on Soil Fertility of Continuous Cotton Without Fertilization

Although considerable loss of fertility occurred during 32 years of continuous cropping to cotton without fertilization (Table XIV), the unfertilized plots at Stillwater had enough potential fertility remaining in 1958 to produce a bale of cotton per acre when summer rainfall was favorable for cotton production.

At Perkins, after 26 years of continuous cotton from 1931 through 1956, a composite sample of soil collected in May 1958 from four unfertilized plots contained 0.75 percent organic matter, 0.038 percent of nitrogen, 0.010 percent of total phosphorus, 11 parts per million of

phosphorus soluble in 0.2 normal sulfuric acid, and 120 parts per million of exchangeable calcium; and the pH value was 5.9. No soil samples were taken at the beginning of the experiment.

Chemical data were not obtained on the soil at Lone Grove.

Summer Legumes and Alfalfa As Sources of Nitrogen

On these soils, where organic matter was already high enough to provide sufficient nitrogen for a high yield of cotton when rainfall was adequate, little increase in yield was obtained from summer legumes (Tables III, IV, and V), or from winter cover crops plowed under as a green manure (Tables VI, XII, and XIII). Cotton yields following alfalfa on limed and fertilized plots were similar to yields obtained from a complete fertilizer applied to plots on which cotton was planted every year.

Although cotton yields were increased slightly in rotations with a summer legume, the increases were not great enough to recommend this practice except under a crop allotment system which restricts the acreage of cotton.

Where alfalfa can be grown, cotton in a rotation with this crop receives the benefit of nitrogen added to the soil by the alfalfa and the residual effect of phosphate or other fertilizers applied to the alfalfa. This method of fertilizing cotton is superior to fertilization of cotton at time of planting in a region where summer rainfall is frequently too low to produce a profitable return from the fertilizer applied.

Winter Cover Crops as Green Manure

Cotton yields were often reduced rather than increased by use of winter cover crops plowed under as a green manure. When spring and summer rainfall did not replace subsoil moisture removed during the winter by the green manure crop, cotton yields were limited by lack of moisture. When fall rainfall was low, cover crops often did not begin to grow until late October or early November, and produced very little growth the following spring. When early spring rainfall was low, the surface soil was dry when the green manure crops were turned under in mid-April. Poor stands of cotton were obtained during some years because of the cloddy seedbed, especially where rye had been grown.

Where soil organic matter and nitrogen are adequate, the only effect of a winter cover crop would be to improve the physical condition of the soil for water absorption and root development.

A winter cover crop is not needed for prevention of water erosion in central Oklahoma because winter rainfall is low. However, it may be needed to prevent wind erosion on sandy land.

The loss of income from reduced cotton yields could have been offset during many seasons by grazing the winter cover crops in March and early April.

Financial Return from Fertilization

The financial return from fertilization was computed for several of the experiments. In these computations, a yield of 480 pounds of seed cotton per acre (about 160 pounds of lint) was used as the break-even point – that is, the yield required to pay production and harvesting costs, including a rental charge for the land, but no allowance for cost of fertilizer or the farm operator's labor. Thus, any yield above the break-even point plus fertilizer cost was income to labor. For convenience, this is sometimes termed "profit" in the following discussion.

Using 4-12-4 Fertilizer

Figure 2 shows the average net labor income from the use of 4-12-4 fertilizer in Experiment I at Perkins. (See Table VII.) All rates of application were profitable as an average of the 26-year period, with the largest profit being from the 200- and 300-pound rates. However, the greatest number of profitable crops was from the 100-pound rate, and the next greatest from the unfertilized cotton. The reason for this is explained by the data in Table XV.

At Lone Grove, 6 of the 16 cotton crops grown in Experiment I were not profitable where no fertilizer was applied and where 300 pounds of 4-12-4 was applied per acre. Ten of the 16 crops were not profitable where 600 pounds of 4-12-4 was applied.

These results indicate the hazard involved in applying high rates of fertilizer to increase cotton production in this area.

With Phosphorous Fertilization

At Perkins (Table VIII, Treatment 0-20-0) the average annual profit from fertilization for the 26-year period was $4.61 per acre. However, the increase in cotton yield from fertilization did not pay the cost of the treatment in 9 of the 26 years. Cotton was not a profitable crop during 8 of the 26 years on unfertilized soil. Average production of cotton on this soil was about one-half bale per acre.

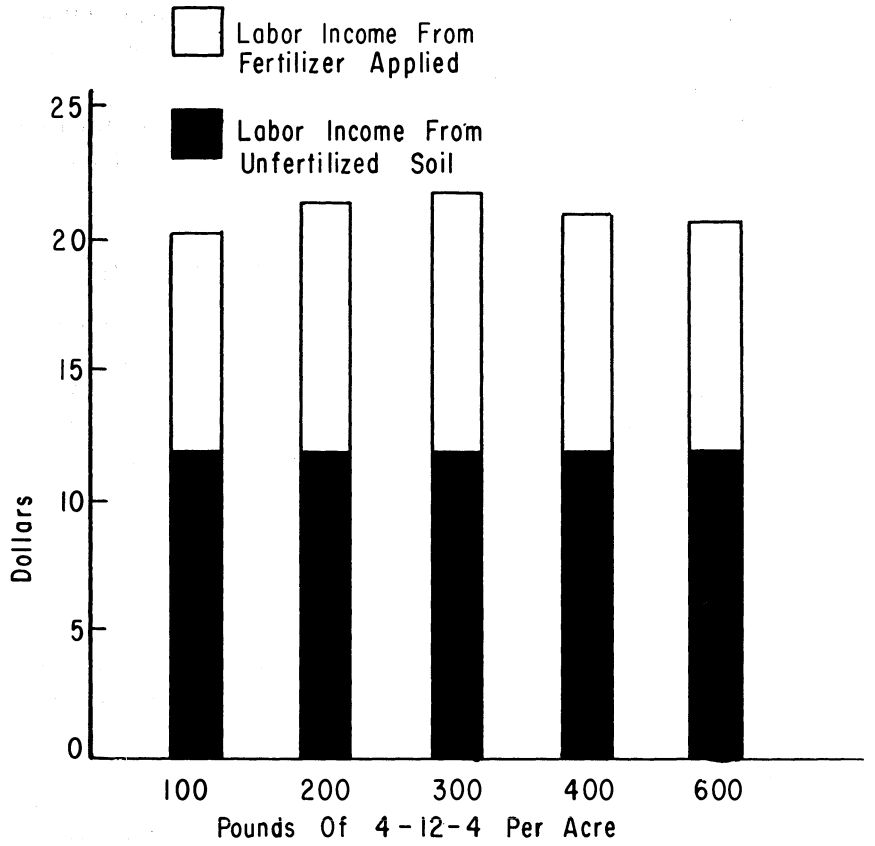


Figure 2.—Average net labor income from 4-12-4 fertilizer applied to cotton; Perkins Farm. 1931-1956.

Summary

Experiments involving the fertilization of cotton were conducted for periods ranging from 15 to 30 years at three locations in central Oklahoma. The periods of time covered by these experiments were such that the average annual data reported herein represented most of the climatic extremes likely to be encountered in central Oklahoma.

The soils on which the experiments were conducted were Kirkland silt loam at Stillwater, Norge loam near Perkins, and Durant loam near Lone Grove. These soils are all low in available mineral phosphate, but contain enough organic matter and exchangeable potassium to produce high cotton yields when rainfall is favorable.

Response to phosphate fertilization was least on the Kirkland soil at Stillwater. However, superphosphate produced a statistically significant increase in the yield of cotton grown in a three-year rotation with summer legumes. At Perkins, 40 pounds of P_2O_5 per acre gave statistically significant increases. At Lone Grove, seed cotton production increased rapidly with increasing rates of phosphate fertilization up to 32 pounds of P_2O_5 per acre.

Potash did not significantly increase cotton yields at either Stillwater or Perkins. At Lone Grove, increasing the percentage of potash in the fertilizer delayed fruiting and caused a decrease in cotton yields.

Summer legumes grown every third year at Stillwater increased the yields of cotton the other two years, but not enough to warrant use of this system except when cotton acreage is restricted.

Cotton production was nearly as high where it was planted every year and fertilized moderately as it was when grown every eighth year in an eight-year alfalfa rotation.

Winter cover crops plowed under as a green manure reduced cotton yields on both fertilized and unfertilized plots at both Stillwater and Lone Grove. No winter legumes were grown at Perkins.

Average annual labor income was computed on the basis of data obtained in some of the experiments, using a yield of 480 pounds of seed cotton per acre as the break-even point. The results indicate the hazard involved in applying high rates of fertilizer to cotton in this area unless irrigated water is available to supplement summer rainfall.

Table I.—Average yields of continuous cotton, in relation to various fertilizer treatments; Agronomy Farm, Stillwater, 1927-1956.*

(Pounds of seed cotton per acre)

Year	Treatment A No fertilizer; unlimed	Treatment B** Phoshorus; unlimed	Treatment C† Phosphorus and potash; unlimed	Treatment D†† Phosphorus and potash; limed
1927	1640	1860	1930	1756
28	980	1070	970	1100
29	610	597	685	625
30	301	395	427	411
1931	809	1003	973	947
32	833	947	913	987
33	1363	1502	1500	1497
34	124	153	155	159
35	138	197	196	142
1936	27	67	60	61
37	97	125	117	125
38	1096	1154	1203	1219
39	860	858	881	805
40	1415	1442	1432	1359
			—(potash discontinued)—	
1941	957	1091	1125	1043
42	1271	1314	1355	1352
43	592	569	554	573
44	504	559	536	621
45	779	742	731	742
1946	425	467	504	522
47	542	475	415	430
48	1313	1593	1523	1453
49	952	1047	1079	953
50	199	401	348	272
1951	585	675	643	585
52	490	525	537	513
53	1271	1231	1362	1314
54	91	101	112	80
55	1105	962	943	962
56	195	210	200	190
Avg. 1927-56	719	779	780	760
Avg. 1927-32	862	978	983	971
Avg. 1933-56	683	760	729	705
Avg. 1927-40	735	812	817	799

*Yields shown are averages of three replications, except 1928 and 1935 are averages of two replications for all treatments.

**300 pounds of 0-16-0 per acre applied from 1927 to 1932; 200 pounds 0-20-0 per acre applied from 1933 to 1956.

†C plots same as B plots except 100 pounds of muriate of potash from 1927 to 1940.
††D plots same as C plots plus 2 tons of limestone in 1926.

Table II.—Average yields of continuous cotton, with a winter cover crop plowed under for green manure, in relation to various fertilizer treatments and green manure crops, Agronomy Farm, Stillwater, 1927-1956. (Pounds of seed cotton per acre)

	Yield when winter cover crop was —.											
	Hairy Vetch				Austrian Winter Peas				Rye			
Year	Treatment A; unfertilized; unlimed	Treatment B; Phos.* unlimed	Treatment C; P and K,** unlimed	Treatment D; P and K, limed	Treatment A; unfertilized; unlimed	Treatment B; Phos.,* unlimed	Treatment C; P and K,** unlimed	Treatment D; P and K, limed	Treatment A; unfertilized; unlimed	Treatment B; Phos.* unlimed	Treatment C; P and K,** unlimed	Treatment D; P and K, limed
1927	1824	1682	1972	1596	--	--	--	--	1540	1792	1964	1604
1928	810	800	780	840	1140	940	840	1200	890	940	800	920
1929	500	510	620	715	490	500	600	630	410	605	645	715
1930	440	452	460	484	282	402	402	470	256	390	432	484
1931	640	880	880	920	720	880	640	760	680	560	640	912
1932	520	880	960	960	340	380	640	560	320	540	800	680
1933	940	990	1065	1130	955	1285	1135	1285	765	685	750	1065
1934	50	28	78	101	90	62	50	123	95	56	129	190
1935	67	62	84	101	53	67	104	90	48	70	112	112
1936	16	44	30	30	28	28	16	22	28	16	16	18
1937	78	112	45	56	123	106	62	95	140	45	56	106
1938	964	1213	1196	1351	1065	1360	1220	1400	1008	1095	1244	1328
1939	467	584	514	715	490	682	448	810	424	395	440	524
1940	1326	1296	1375	1511	1253	1433	1405	1544	1061	928	847	1147
1941	1000	992	1212	1080	1192	1024	1184	1136	1164	1024	1156	1084
1942	1244	1120	1240	1332	1148	1128	1276	1304	888	736	960	1076
1943	550	600	616	636	460	496	612	670	464	346	448	482
1944	531	503	587	656	503	531	601	685	475	447	531	606
1945	640	557	584	723	528	752	778	890	528	334	640	862
1946	335	231	209	324	290	342	324	504	211	304	311	342
1947	520	381	471	510	420	353	487	521	314	308	364	481
1948	1300	1520	1340	1720	1420	1640	1580	1768	1380	1140	1292	1440
1949	744	744	872	980	604	712	892	1004	536	584	684	820
1950	322	472	409	397	248	571	496	422	260	372	422	322
1951	445	519	618	568	420	544	568	494	371	371	914	618
1952	270	315	402	490	315	420	490	490	245	270	350	420
1953	1051	1156	944	1121	1155	1295	1332	1297	1050	1013	1155	1191
1954	48	48	32	48	32	48	32	24	48	32	64	32
1955	623	702	819	741	662	780	780	868	702	780	819	868
1956	90	75	60	90	60	30	60	45	60	60	30	45
Average	612	649	682	731	568	648	654	728	545	541	634	683

* B plots, 300 lbs. of 0-16-0 per acre 1927-1932; 200 lbs. of 0-20-0 per acre 1933-1956.
** C Plots, same as B plots plus 100 lbs. muriate of potash 1927-1940. D plots same as C plots plus 2 tons limetone in 1926.

Table III.—Average yields of cotton planted two years, with annual sweet clover grown the third year, with various fertilizer treatments; Agronomy Farm, Stillwater, 1927-1956.*

(Pounds of seed cotton per acre)

Year	Treatment A No fertilizer; unlimed	Treatment B Phophorus; limed**	Treatment C† Phosphorus and potash; limed	Limed; no fertilizer
1927	1311	1486	1531	1413
28	990	1210	1210	1100
29	695	795	856	682
30	440	492	470	446
1931	1144	1320	1312	1272
32	810	1120	1130	860
33	1172	1595	1485	1415
34	170	224	232	254
35	124	130	138	96
1936	30	64	66	72
37	53	111	109	137
38	1280	1287	1221	1222
39	885	973	945	978
40	1458	1508	1627	1565
			—(potash discontinued)—	
1941	994	990	928	1050
42	1358	1482	1530	1458
43	698	762	716	761
44	674	747	798	826
45	778	876	848	751
1946	566	634	568	616
47	714	765	703	636
48	1460	1767	1670	1806
49	1228	1236	1206	1256
50	168	347	298	210
1951	853	877	790	679
52	612	962	858	805
53	1452	1445	1500	1534
54	112	145	145	177
55	1210	1204	1462	1326
56	202	255	255	285
Avg. 1927-1940	754	879	881	822
Avg. 1941-1956	817	906	892	886
Avg. 1927-1956	788	893	887	856
Percent of continuous cotton	73.0	77.0	75.7	

* Average of two replications for all years.

** Treatment B plots reported in this table were limed for the production of sweetclover; no other Treatment B plots were limed.

† Liming of Treatment C plots for sweetclover made them equivalent to Treatment D plots with continuous cotton and other legume rotations. Omission of potash from Treatment C plots in 1941 and thereafter made them equivalent to Treatment B.

Table IV.—Average yields of cotton planted two years, with cowpeas grown the third year, with various fertilizer treatments; Agronomy Farm, Stillwater, 1927-1956.*

(Pounds of seed cotton per acre)

Year	Treatment A unlimed	Treatment B Phosphorus; unlimed	Treatment C** Phosphorus and potash; unlimed	Treatment D** Phosphorus and potash; limed
1927	1336	1747	1550	1437
28	1045	970	1150	1130
29	695	855	825	705
30	313	530	413	377
1931	934	1092	900	1084
32	950	1200	1060	1000
33	1502	1587	1610	1257
34	170	207	193	202
35	160	198	170	107
1936	34	67	62	60
37	109	126	165	159
38	1050	1164	1164	1073
39	945	1026	1082	805
40	1391	1559	1633	1378
			—(potash discontinued)—	
1941	940	1166	1184	1144
42	1332	1378	1280	1288
43	683	741	663	653
44	644	692	806	626
45	862	932	859	779
1946	542	609	604	560
47	580	635	485	423
48	1466	1846	1705	1370
49	1280	1312	1194	1069
50	322	507	360	298
1951	754	791	791	619
52	525	604	683	590
53	1378	1548	1666	1293
54	136	160	177	120
55	975	1014	1111	878
56	180	218	240	180
Avg. 1927-1940	759	881	855	769
Avg. 1941-1956	787	884	863	743
Avg. 1927-1956	774	883	859	755
Percent of continuous cotton	71.8	75.6	73.5	66.2

* Average of two replications for all years.

** Potash applied from 1927 to 1940 inclusive.

Table V.—Average yield of cotton planted two years with soybeans or mungbeans grown every third year; Agronomy Farm, Stillwater, 1927-1956.*

(Pounds of seed cotton per acre)

Year	Treatment A unlimed	Treatment B** Phosphorus; unlimed	Treatment C† Phosphorus and potash; unlimed	Treatment D†† Phosphorus and potash; limed
1927	1623	1827	2019	1782
28	927	1047	1207	1177
29	633	610	650	610
30	457	409	498	408
1931	894	1012	1160	1020
32	720	1190	980	1090
33	1343	1410	1348	1505
34	145	159	170	211
35	93	174	122	112
1936	27	62	50	63
37	95	126	190	131
38	1100	1199	1277	1093
39	853	854	833	778
40	1403	1526	1551	1410
			—(potash discontinued)—	
1941	994	1112	1212	1124
42	1254	1170	1298	1300
43	583	602	632	612
44	578	627	637	637
45	820	695	626	918
1946	541	537	638	547
47	543	443	378	470
48	1190	1390	1456	1316
49	1036	1116	1198	1120
50	351	416	323	310
1951	717	729	606	667
52	543	543	543	700
53	1275	1535	1414	1412
54	112	129	120	104
55	975	975	975	936
56	180	203	180	203
Avg. 1927-1940	736	829	857	813
Avg. 1941-1956	731	764	765	773
Avg. 1927-1956	733	794	808	792
Percent of continuous cotton	68.0	67.9	69.1	69.5

* Average of two replications.

** 300 lbs. of 0-16-0 per acre applied through 1932, then 200 lbs. of 0-20-0 per acre.

† 100 lbs. of muriate of potash applied through 1940 and none thereafter.

†† Same as Treatment C except 2 tons of lime per acre applied in 1926.

Table VI.—Average yields of dry forage produced by five legumes and Abruzzi rye grown as winter cover crops in rotation with cotton, 1927-1956. Agronomy Farm, Stillwater.

Crop	No. of yrs. crop yields were obtained	Average yield of dry forage, pounds per acre.* Treatment A No fertilizer; unlimed	Treatment B Phosphorus; unlimed	Treatment C Phosphorus and potash; unlimed	Treatment D Phosphorus and potash; limed
Winter cover crops (annually)					
Austrian winter peas	15	535	897	950	887
Hairy vetch	15	862	1456	1514	1621
Abruzzi rye	15	1202	1936	2053	2277
Summer-growing legumes					
Annual sweet clover**	9	2047	3157***	2937***	3597***
Cowpeas**	7	1468	1696	1676	1609
Soybeans**	6	1576	2059	2490	2109

* No fertilizer applied when legumes were planted.

** Grown on each plot every third year.

*** Sweet clover plots were limed. No P and K on treatment D.

Table VII.—Average yields of continuous cotton in relation to varying rates of application of 4-12-4 fertilizer; Perkins Farm, Perkins, 1931-1958.

(Pounds of seed cotton per acre)

Year	Average yield* when 4-12-4 was applied as follows:					
	None	100 lb./A	200 lb./A	300 lb./A	400 lb./A	600 lb./A
1931	645	724	818	855	847	855
32	687	870	1005	975	915	1155
33	1067	1150	1160	1260	1348	1350
34	167	184	213	174	150	171
35	407	440	385	407	428	448
1936	210	276	265	248	208	253
37	403	452	447	420	368	384
38	1111	1204	1295	1282	1339	1305
39	988	1106	1076	1083	1010	990
40	1494	1380	1881	1875	1833	1902
1941	1201	1328	1472	1506	1569	1548
42	887	876	942	1002	981	993
43	486	489	528	536	526	568
44	895	940	930	935	950	898
45	869	1043	1090	1341	1254	1271
1946	448	575	625	616	556	619
47	523	730	641	826	757	850
48	926	1400	1691	1680	1609	1543
49	713	986	1140	1138	1146	1193
50	17	57	95	137	170	201
1951	798	993	1063	1119	1133	1168
52	747	980	1082	1125	1123	1112
53	1279	1483	1631	1700	1633	1772
54	594	740	779	798	718	753
55	999	1157	1124	1192	1147	1148
1956	172	222	213	209	200	196
57**	620	704	898	757	890	1070
58**	1859	1704	1867	2135	2486	2428
Avg. 1931-1956	720	838	907	940	920	949
Increase from fertilizer	---	118	187	220	200	229
Pounds of cotton per pound of fertilizer	--	1.18	.93	.73	.50	.38

* Average of duplicate plots, except none is an average of three plots.

** No fertilizer applied in 1957 or 1958.

Table VIII.—Average yields of continuous cotton,* in relation to different combinations of nitrogen, phosphorus and potassium; Perkins Farm, Perkins, 1931-1956.

(Pounds of seed cotton per acre)

Year	Yield when ratio of fertilizer, applied at rate of 200 pounds per acre, was—					
	No fertilizer	0-20-0	10-20-0	0-20-10	10-0-10	10-20-10
1931	765	810	933	840	773	930
32	657	975	1170	870	840	1110
33	935	1212	1165	1180	968	1293
34	181	166	175	164	171	191
35	456	500	503	459	398	572
1936	242	338	332	327	414	316
37	522	504	494	510	494	447
38	983	1151	1164	1136	1193	1215
39	977	1087	1135	1126	1123	1122
40	1419	1593	1680	1737	1677	1818
1941	1171	1323	1400	1385	1325	1505
42	866	950	858	961	886	928
43	423	450	458	493	492	518
44	865	898	853	895	863	870
45	763	847	1000	1030	958	1266
1946	483	617	597	585	495	614
47	448	547	681	732	520	835
48	943	1285	1457	1321	1132	1164
49	815	966	1217	1050	1044	1322
50	13	35	58	64	37	123
1951	827	902	1076	993	1013	1142
52	829	1058	1074	1006	860	1202
53	1294	1509	1683	1676	1457	1847
54	741	761	852	852	791	901
55	926	1065	1097	985	877	1088
56	210	242	199	211	166	233
Avg.	721	838	896	869	806	945

* Average of duplicate plots, except "None" is average of three replications.

Table IX.—Comparison of cotton yields in an alfalfa rotation with yields of continuous cotton in Experiments I and II; Perkins Farm, 1938-1956.

Cropping System, and Fertilizer Treatment	Yield of Seed Cotton (Lbs. per acre)
Continuous Cotton	
In Experiment I:	
No fertilizer	797
300 lbs. of 4-12-4 per acre	1058
In Experiment II:	
No fertilizer	789
200 lbs. of 10-20-10 per acre	1037
Cotton in Rotation With Alfalfa (Fertilizer applied to alfalfa; none on cotton)	
No fertilizer	893
Limed; no fertilizer	999
200 lbs. of 0-20-0 per acre; unlimed	1121
200 lbs. of 0-20-0 per acre; limed	1136

Table X.—Average yields of continuous cotton* in relation to varying rates of application of 4-12-4 fertilizer; Southern Soil Improvement Station, Lone Grove. 1930-1945.

(Pounds of seed cotton per acre)

Year	Yield when rate of application of 4-12-4 (per acre) was—						
	None	200 lbs.	300 lbs.	400 lbs.	600 lbs.	800 lbs.	1000 lbs.
1930	269	333	349	342	369	370	357
31	1008	1313	1393	1453	1455	1335	1490
32	549	740	741	785	737	750	777
33	523	578	555	608	560	735	822
34	294	275	261	267	285	216	269
35	286	338	473	495	428	435	429
1936	343	436	449	396	383	330	403
37	658	867	860	826	809	777	820
38	726	828	869	840	881	879	795
39	343	379	327	345	347	341	362
40	895	1460	1590	1757	1578	1698	1548
1941	713	863	923	923	855	863	878
42	761	837	818	908	1030	923	995
43	345	360	357	395	384	399	359
44	603	771	731	810	794	804	881
45	651	1070	1230	1172	1038	1055	1343
Avg.	560	715	745	770	746	745	783

* Average of duplicate plots except "None" which is average of five replicates.

Table XI.—Average yields of continuous cotton, in relation to varying fertilizer ratios;* Southern Soil Improvement Station, Lone Grove. 1931-1945.

(Pounds of seed cotton per acre)
With Nitrogen Varying

Year	Yield without fertilizer	Yield when phosphorus and potash were held constant at 0-12-6, and percentage of nitrogen was:					
		Zero	2%	4%	6%	8%	12%
1931	1171	1347	1318	1369	1357	1362	1370
1932	712	734	771	800	750	797	733
1933	492	580	547	562	522	573	539
1934	384	312	377	385	316	359	462
1935	334	372	413	410	505	490	516
1936	357	372	406	427	401	436	443
1937	564	698	711	754	787	776	780
1938	540	698	756	752	675	723	702
1939	366	430	404	438	387	461	457
1940	1025	1202	1280	1391	1363	1379	1377
1941	465	738	660	710	666	651	633
1942	552	731	788	893	882	773	611
1943	352	413	410	463	451	455	398
1944	520	641	654	672	729	680	661
1945	722	552	405	549	683	773	846
Average	563	655	660	705	698	713	702

With Phosphorus Varying

Year	Yield without fertilizer	Yield when nitrogen and potash were held constant at 6-0-6, and percentage of phosphoric acid was:					
		Zero	4%	8%	12%	16%	20%
1931	995	1082	1231	1516	1416	1464	1413
1932	572	717	742	799	829	832	844
1933	460	581	518	564	583	603	612
1934	320	347	412	492	470	468	396
1935	458	498	390	435	444	499	537
1936	290	317	396	432	461	419	350
1937	635	544	710	779	765	859	745
1938	539	548	765	785	855	813	800
1939	380	386	422	500	510	453	424
1940	669	570	968	1358	1382	1379	1506
1941	600	525	510	648	716	735	735
1942	770	668	783	743	891	885	897
1943	345	351	448	543	553	506	524
1944	496	452	672	670	719	759	711
1945	492	405	666	999	860	897	777
Average	540	533	642	757	763	770	747

Table XI—Continued

With Potash Varying

Year	Yield without fertilizer	Yield when nitrogen and phosphoric acid were held constant at 6-12-0 and percentage of potash was:					
		Zero	2%	4%	6%	8%	12%
1931	1178	1308	1423	1386	1388	1297	1286
1932	649	884	869	868	864	745	754
1933	541	566	589	651	555	554	504
1934	303	374	367	305	322	344	296
1935	275	449	535	571	521	471	422
1936	337	361	361	334	299	321	296
1937	648	772	784	722	808	791	711
1938	611	771	848	771	689	638	621
1939	320	397	386	382	369	400	375
1940	725	1328	1379	1349	1345	1221	943
1941	569	672	735	720	683	596	608
1942	720	795	684	719	756	711	644
1943	296	460	464	494	407	458	321
1944	533	684	748	665	685	696	609
1945	503	642	651	594	653	585	705
Average	535	698	722	702	670	655	607

* Rate of application, 400 pounds per acre.

Table XII.—Average yields of continuous cotton in relation to (1) two different percentages of nitrogen in a mixed fertilizer, (2) winter cover crop grown, and (3) crop on which fertilizer was applied; Southern Soil Improvement Station, Lone Grove, 1931-1945.

Fertilizer Ratio*	Winter Cover Crop	Crop Fertilized	Yield of Seed Cotton (lbs. per A.)
No fertilizer	None	----	509
0-12-6	Rye	Rye	664
"	"	Half on each	614
"	"	Cotton	647
"	Austrian winter peas	Peas	690
"	" " "	Half on each	641
"	" " "	Cotton	681
"	Hairy vetch	Vetch	703
"	" "	Half on each	701
"	" "	Cotton	656
4-12-6	None	Cotton	687
"	Rye	Rye	653
"	"	Half on each	633
"	"	Cotton	673
"	Austrian winter peas	Peas	691
"	" " "	Half on each	661
"	" " "	Cotton	705
"	Hairy vetch	Vetch	700
"	" "	Half on each	733
"	" "	Cotton	668

* Fertilizers applied at a rate of 300 pounds per acre.

Table XIII.—Average yields of continuous cotton in relation to varying proportions of nitrogen in a mixed fertilizer, with and without a winter cover crop (hairy vetch); Southern Soil Improvement Station, Lone Grove, 1931-1945.

Fertilizer* Ratio	Yield of Seed Cotton (pounds per acre)	
	Without Winter Cover Crop	With Winter Cover Crop (Hairy Vetch)
No fertilizer	544	--
0-12-6	683	658
2-12-6	702	672
4-12-6	694	709
6-12-6	670	682
8-12-6	692	678
12-12-6	635	653

* 300 pounds per acre on cotton; in row at planting time.

Table XIV.—Changes in the chemical composition of surface soil during 32 years of continuous cropping to cotton without fertilization; Agronomy Farm, Stillwater, 1927-1958.*

Year	Organic matter (percent)	Nitrogen (percent)	Phosphorus (percent)	Available phosphorus (ppm)	Exchangeable potassium (ppm)	pH Value
1927	2.12	.085	.028	19	**	5.5
1958	1.29	.066	.016	14	130	5.6

*Treatment A on continuous cotton.
**No data obtained in 1927.

Table XV.—Yield increase per pound of fertilizer, and number of profitable cotton crops during 26 years, in relation to rate of application of 4-12-4 fertilizer; Perkins Farm, 1931-1956.

Rate of fertilizer application lbs./A.	Average yield (lbs. seed cotton per acre)	Yield increase from fertilization (lbs. seed cotton)	Lbs. seed cotton per-lb. of fertilizer	Number of profitable crops in 26 years*
None	720	---	---	19
100	838	118	1.18	21
200	907	187	.93	18
300	940	220	.73	9
400	920	200	.50	5
600	949	229	.38	15

*All treatments were profitable from 1945 to 1955.

11-60/2M