Long-Term Fertilizer Studies on Kirkland-Bethany Silt Loam

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Contents

ACKNOWLEDGEMENT

This bulletin is dedicated to Dr. H. F. (Pat) Murphy, former Head of the Department of Agronomy.

Dr. Murphy was a conscientious and dedicated researcher who made a lasting contribution to Agronomy. Many of the basic principles in improving and maintaining soil productivity evolved as a result of the research that he started many years ago. Dr. Murphy had a storehouse of knowledge learned through his keen observations and thorough research. This publication was made possible because of his carefully kept notes and detailed records.

Dr. Murphy was the leading authority on soil management in dryland agriculture. He knew the principles that had to be adhered to for stabilized crop production in semi-arid agriculture. Dr. Murphy had been persuaded by many of his colleagues to record this knowledge in publication form. He intended to write a book on the principles of dryland agriculture. With his untimely passing, this knowledge cannot be published but it will be used and extended by the large number of students he taught.

Acknowledgement is extended to C. D. Haston, W. C. Elder, Orville Stout and Harold Myers the station superintendents who supervised the planting and harvesting of these plots through the years.

Long-Term Fertilizer Studies on Kirkland-Bethany Silt Loam[1]

H. F. Murphy and B. B. Tucker[2]

Section I

Fertility Studies on Kirkland-Bethany Silt Loam

Some Wheat Rotation Studies

In 1916 a quadruplicate set of three plots receiving none, manure and manure and rock phosphate was established on the Agronomy farm near Stillwater on land then mapped as Kirkland loam. It has since been mapped essentially Bethany silt loam, however it joins with Kirkland silt loam. The line of demarcation between this Bethany and the Kirkland is not distinct. The rotation used was kafir, wheat, wheat and cowpeas. Manure and rock phosphate were applied every four years; namely, in 1917, 1921, 1925 and 1928. Manure was applied equivalent to that which would have been produced if the feed crops had been fed to livestock. Rock phosphate was applied at the rate of 1000 pounds per acre at the time the manure was applied. A summary of the average annual yields is reported in Table 1.

The value of farm manure is quite evident. Rock phosphate in connection with manure gave slight increases in yield except for cowpea

[1] The material reported in this publication is from work done under Station Projects: H-57D, S-719, S-720, S-974 and H-1184.

[2] Formerly Head of Department of Agronomy (now deceased—see acknowledgement) and Professor, Agronomy respectively.

Table 1. Influence of manure and rock phosphate on yield of crops grown in a rotation.

Treatment	Cowpea hay[1] (12 yrs)	1st yr-wheat[2] after cowpeas		2nd yr wheat after cowpeas		Kafir[3]	
		Grain (14 yrs)	Straw (14 yrs)	Grain (14 yrs)	Straw (14 yrs)	Grain (10 yrs)	Forage (10 yrs)
None	2356	13.19	1909	10.65	1769	14.88	2735
Manure	2766	16.58	2264	15.73	2004	16.87	3454
Manure and rock phosphate	2656	18.40	2574	15.91	2416	17.65	3678

[1] Does not include data for the years, 1917, 1920, 1926 and 1932.
[2] The first year wheat followed cowpeas was in 1919.
[3] Chinchbugs destroyed the crop in 1917, 1922, 1925, 1926, 1930, and 1931. These insects came from adjoining fields hence the results for these years are not included in the averages.

hay. There is a considerable drop in the yield of wheat the second year following cowpeas indicating that the major effect of cowpeas on the succeeding crop is secured the first year.

The cropping system and fertilizer plans were changed beginning with the 1933 cropping season and extending to 1948. Instead of the original set of four units of none, manure, and manure and rock phosphate, two units of none, manure, and manure and rock phosphate were established. These treatments were set up on the original plots the only difference being that superphosphate was used on two of the plots that originally received rock phosphate. The rotation was changed to 4 years of alfalfa and 4 years of wheat. Manure was applied at the rate of 8 tons per acre preceding the planting of alfalfa. Rock phosphate was applied at the rate of 1600 pounds per acre with the manure. Superphosphate was applied each year at the rate of 100 pounds per acre on the alfalfa.

No fertilizers were applied on the wheat. In Table 2 the average annual yields for the alfalfa and wheat are given.

Some lodging of wheat occurred following the alfalfa crop when climatic conditions for vegetative growth were favorable. Usually the extra growth was not extremely excessive except on the plots which had received the phosphate treatments. Any heavy rain, especially when accompanied with wind at heading time, increased the seriousness of the lodging. It was found that a wider row spacing was helpful.

In the fall of 1948 a new block of land adjoining the original site of the experiment was added to the test area. It allowed for another complete set of the two different treatments, namely none, manure, manure and rock phosphate, none, manure, and manure and superphosphate. Alfalfa was planted on these plots. Hence the rotation was changed to alfalfa 4 years and wheat 8 years. The fertilizer treatments were also modified. Manure was applied at the rate of 5 tons per acre, rock phos-

Table 2. Influence of manure and phosphate treatments on the yield.

Treatment	Alfalfa hay[1] pounds per acre	Wheat grain[2] bushels per acre	Wheat straw[2] pounds per acre
None	1450	13.60	1629
Manure	4298	19.85	2426
Manure, rock phosphate	5061	24.18	3028
None	2306	17.78	2044
Manure	4251	20.41	2371
Manure, superphosphate	4753	25.11	3190

[1] Average yield of alfalfa for 1933-1948, (16 years).
[2] Average yield of wheat for 1937-1948, (12 years).

phate at the rate of 450 pounds per acre, and superphosphate at the rate of 300 pounds per acre. All of the fertilizer applications were made at the time of preparing the land for the seeding of alfalfa. No fertilizers were applied on the wheat. The average annual yields for alfalfa hay and wheat from 1949 to 1961 inclusive are given in Table 3.

There were some very unfavorable seasons for alfalfa during this period, especially from 1953 to 1956, hence the average yields for the several treatments were low. With all crops the effect of manure is prominent. There is considerable difference in the yield of wheat between the first four years and the second four years following alfalfa. It appears from these data that a shorter rotation, so far as the number of years to follow alfalfa with wheat on this soil is concerned would be better.

Alfalfa Fertility

An alfalfa fertility experiment was established on the Agronomy Station in 1913. The soil was mapped later as Kirkland silt loam. Recently it has been mapped as Kirkland-Bethany silt loam. This upland soil is medium acid, deficient in available phosphorus, on the border line with respect to available potassium, and has a slowly permeable subsoil. Originally one-half of the area received 2.5 tons of agricultural limestone per acre; the other one-half was left untreated. The average yield of alfalfa for the 1916-1928 (13 years) period was 1704 pounds of oven dried alfalfa hay per acre on the unlimed area and 2575 pounds on the limed area.

In the winter of 1929 the plan of the experiment was changed to include commercial fertilizers. The applications were made at right angles to the original unlimed-limed treatments. The treatments were nitrate of soda (16 pounds of nitrogen per acre), superphosphate (48 pounds of P_2O_5 or approximately 21 pounds of P per acre), and muriate of potash (32 pounds of K_2O or approximately 26.5 pounds of K per

Table 3. Influence of fertilizer treatments on average yields of alfalfa and wheat.

Treatment	Alfalfa hay lbs/a	Wheat (1-4)[1] bu/a	Wheat (5-8)[2] bu/a
None	1267	16.63	12.99
Manure	2645	22.57	14.79
Manure and rock phosphate	3116	25.70	19.76
None	1362	17.60	12.39
Manure	2584	22.50	16.84
Manure and super-phosphate	3090	26.14	20.97

acre). Some combinations of the above were used. These fertilizers were applied each year by broadcasting about February 15-March 1. One-half of each plot was limed at the rate of 2 tons per acre every 4 years in 1929, 1933, 1937, 1941 and 1945. The data for these treatments are presented in Tables 4 and 5. The yields are for air-dried alfalfa hay.

In 1937 an additional treatment of superphosphate alone, with and without limestone, was added to the experiment. The data in Table 5 covers the period, 1937 to 1948 inclusive where this treatment was included.

During the 1937-1948 period there were two years of failure which accounts for the slightly lower averages than for the preceding period. In 1940 the plots which had not received phosphate were practically taken over with grass, hence the data are non included. In 1944 aphids killed the alfalfa early in the spring.

Table 4. Nineteen year average yield in pounds per acre (1930-1948).

Treatment	Average yield	Equivalent acres of untreated land	Acres of treated land needed to produce as much hay as one acre of untreated land
None	1840	1.00	---
Limestone	2682	1.45	0.69
PK	3899	2.11	0.47
PKL	4599	2.50	0.40
NP	3891	2.11	0.47
NPL	4509	2.45	0.41
N	1897	1.03	0.97
NL	2655	1.44	0.69
NK	1867	1.01	0.99
NKL	3090	1.68	0.60

Table 5. Twelve year average yield in pounds per acre (1937-1948).

Treatment	Average yield	Equivalent acres of untreated land	Acres of treated land needed to produce as much hay as one acre of untreated land
None	1599	1.00	---
Limestone	2515	1.57	0.63
PK	3360	2.10	0.47
PKL	3921	2.45	0.41
NP	3187	1.99	0.50
NPL	3827	2.39	0.42
N	1552	0.97	1.03
NL	2461	1.54	0.65
NK	1438	0.90	1.11
NKL	2859	1.79	0.56
P	3149	1.97	0.51
PL	3703	2.31	0.43

In January 1947 the untreated soil had a pH of 5.5, a very low available phosphorus content, a nitrogen content of 0.107 percent and an available potassium content of 55 ppm. Where only limestone had been applied the pH was 7.5, the available potassium was 72 ppm, and the nitrogen and available phosphorus were practically the same as in the unlimed soil. The yield data clearly indicate the need of agricultural lime for the growing of alfalfa on this soil. Whether lime was used alone or in combination with fertilizers it always had a favorable influence on alfalfa yields. Phosphorus and limestone were the major nutrients needed with some slight need for potassium. The highest alfalfa yield was on land receiving phosphorus, limestone and potash. The use of these three nutrients more than doubled the yield of alfalfa.

The soil in the wheat rotation studies, the results of which are reported in the first part of this publication, is essentially the same as the soil in this alfalfa fertility study. A review of the alfalfa yields especially on the untreated soil in the wheat-alfalfa rotation clearly indicates the similarity of production of the two soils. The pH of the untreated soil in the wheat-alfalfa rotation was approximately 5.85 in 1947. These were the contributing factors to the low yield of alfalfa on this soil.

Comments

The data clearly indicate that this soil was deficient in available phosphorus, and for higher crop yields a phosphorus fertilizer is essential. The data further indicate the need for limestone where this soil is to be used for alfalfa.

The rotation studies indicate that the influence of an annual legume such as cowpeas does not extend over about one year. Wheat yields were lower the second year after cowpeas than they were immediately following cowpeas.

Wheat yields in a four-year alfalfa-eight year wheat rotation were considerably better the first four years after alfalfa than they were the second four years.

Unless this soil is supplied with phosphorus one cannot secure the full benefit from a nitrogen application. This is particularly important in the use of this soil for wheat production. Wheat production is the major use of this soil in Oklahoma.

The data presented may have an application for those farmers who have similar soils, and those faced with the problem of wheat allotments. These soils are not alfalfa soils but with proper management they may be used in the allotment program for alfalfa production. Some of

the acreage taken out of wheat production with some reasonable fertility treatments may be used to bring an additional income through the use of a wheat-alfalfa crop sequence. The extra phosphorus needed to supplement this soil for alfalfa production will increase the efficiency of any nitrogen applied for the wheat crop both with respect to yield and protein content.

Section II

A 42-year Fertilizer-Rotation Study on Kirkland Silt Loam

In 1916 a rather comprehensive series of fertilizer-rotation experiments were outlined for some research studies on what was then mapped as Kirkland loam soil (later mapped as Kirkland silt loam, 0 to 2 percent slope) on the Agronomy farm near Stillwater. These experiments were initiated in 1917. The early results of these experiments were published in Oklahoma Agricultural Experiment Bulletins 155, 188 and 189. Section II of this publication will summarize all the data on one of these experiments.

General Fertilizer Plan and Results, 1916-1928

At its inception this experiment consisted of a rotation of cotton, darso, cowpeas and oats. Four areas of Kirkland soil were each divided into 28 one-tenth acre plots with appropriate borders. Every third plot was used as a no treatment (check) plot. The rest of the plots were fertilized.

Farm manure was applied every four years at a rate estimated to be equivalent to that which would have been produced if the feed crops had been fed to livestock. Cottonseed was considered a feed. For the first 12 years the average rate of farm manure application was approximately 9.39 tons per acre per rotation. Rock phosphate was applied annually at a rate of 125 pounds per acre for all crops. Likewise nitrogen, potash and gypsum were applied annually for all crops. The usual rate of nitrogen was 200 pounds per acre of nitrate of soda, while potash was applied as kainit at the rate of 100 pounds per acre. Gypsum was applied at the rate of 400 pounds per acre.

The crop residues consisted of oat straw, darso stalks and cowpea vines. Cotton stalks were left on all plots. The crop residues were returned each year and either plowed under or used as top dressings after plowing. Limestone was applied at the rate of 1 ton per acre for the limed plots in 1916, and at the rate of 2 tons per acre in 1921, and again in 1925. Although modifications in the rates of application, time of ap-

plication, and sources of nitrogen and potash have been made during the intervening years (1929-1958), the plot plans have remained as originally set forth. These plans are given in Table 6.

The average yield per acre for each of the crops and the ranking by individual crop products for the several treatments during the first 12-year period (1917-1928) are presented in Table 7. Table 8 persents the rank for the several treatments considering the total crop products.

General Fertilizer Plan and Results, 1929-1948

In 1929 two of the original 4 blocks were set aside for a residual study of the previously applied fertilizers. The other two blocks were subdivided so as to retain the fertilizer plan of the original experiment in each subdivision. This reduced the size of each individual plot to one-twentieth of an acre. The original rotation of cotton, darso, cowpeas and oats was continued. This portion of the publication reports the results of the plots which continued to receive fertilizer. The data from the residual fertilizer study is reported in Section III.

The fertilizer plan for each of the plots continued as for the 1917-1928 period except the farm manure applications for each of the 3 rounds of the rotation for the 12 years, 1929-1941 averaged 14.77 tons per acre. From 1942 to 1948 the rate of farm manure was changed to

Table 6. Treatments employed in the experiment.[1]

Plot		Treatment	Plot		Treatment
1		None	15	(NL)	Nitrogen, Limestone
2	(M)	Manure	16		None
3	(ML)	Manure, Limestone	17	(NL Rp)	Nitrogen, Limestone,
4		None			Rock Phosphate
5	(ML Rp)	Manure, Limestone, Rock	18	(NL Sp)	Nitrogen, Limestone,
		Phosphate			Superphosphate
6	(ML Sp)	Manure, Limestone,	19		None
		Superphosphate	20	(NLK)	Nitrogen, Limestone,
7		None			Potassium
8	(R)	Residues	21	(NLK Rp)	Nitrogen, Limestone,
9	(R L)	Residues, Limestone			Potassium, Rock
10		None			Phosphate
11	(R L Rp)	Residues, Limestone,	22		None
		Rock Phosphate	23	(L)	Limestone
12	(R L Sp)	Residues, Limestone,	24	(G)	Gypsum
		Superphosphate	25		None
13		None	26	(GM)	Gypsum, Manure
			27	(GM Rp)	Gypsum, Manure,
					Rock Phosphate
14	(N)	Nitrogen	28		None

[1] Plot 1 is at the top of the slope (0 to 2%), while plot 28 is at the lower end. Due to this slight slope variation the plots on the lower part of the slope may have a very slight advantage.

Table 7. The rank of the treatments with the yields in pounds per acre for the several crops (12 yr. avg. 1917-1928).[1]

Treat.	Seed Cotton	Treat.	Oat Grain	Treat.	Oat Straw	Treat.	Darso Grain	Treat.	Darso[2] Forage	Treat.	Cowpea Hay
None[3]	717	None[3]	1091	None[3]	1288	None[3]	1502	None[3]	2504	None[3]	2064
GM Rp	866	GM Rp	1374	ML Sp	1731	ML	1766	ML	2881	ML Rp	2410
GM	864	NL Sp	1360	GM Rp	1630	GM Rp	1714	M	2870	GM Rp	2369
RL Sp	829	GM	1343	RL Sp	1517	ML Rp	1708	ML Rp	2868	ML Sp	2368
ML Sp	805	ML Sp	1332	NL Sp	1615	M	1691	GM Rp	2800	ML	2336
NL Sp	801	RL Sp	1317	GM	1557	ML Sp	1670	ML Sp	2779	GM	2294
NL Rp	776	MKL	1241	ML Rp	1493	RL Sp	1624	RL	2638	RL Sp	2269
NKL	755	ML Rp	1240	RL Rp	1425	RL	1592	NKL Rp	2616	NKL	2226
RL Rp	755	M	1218	R	1387	GM	1567	L	2609	RL	2206
ML Sp	747	NKL Rp	1216	ML	1380	L	1542	GM	2540	M	2198
G	746	ML	1210	NL Rp	1380	R	1540	R	2537	R	2158
NKL Rp	741	NL Rp	1185	NL	1379	RL Rp	1497	RL Rp	2479	NL Sp	2149
RL	739	RL	1168	RL	1377	G	1472	ML	2445	RL Rp	2121
NL	719	R	1156	M	1373	MKL Rp	1464	RL Sp	2438	NL Rp	2111
L	707	L	1134	NKL	1340	NL Sp	1448	G	2422	G	2076
M	705	NL	1130	L	1301	N	1422	NL Sp	2387	ML	2075
R	702	G	1120	NKL Rp	1282	NL	1415	NKL	2337	N	2066
ML	700	RL Rp	1110	N	1269	NKL	1368	NL Rp	2305	L	2019
N	684	N	1060	G	1201	NL Rp	1349	N	2179	NKL Rp	2011

[1] The 18 treatments are divided into 3 brackets (lower, medium and upper) based on the average yield data.
[2] Eleven-year average omitting one year (1923) where excessive fall rains interfered with forage harvest.
[3] Average of 8 plots. The two outside no-treatment plots were discarded due to possible border influences.

Table 8. The rank of the treatments when the total average annual yields of all crop products are considered (1917-1928 inclusive).[1]

Treatment	SC	OG	OS	DG	DF	CH	Total	Rank
GMRp	866	1374	1630	1714	2800	2369	10753	1
MLSp	805	1332	1731	1670	2779	2368	10685	2
MLRp	747	1240	1493	1708	2868	2410	10466	3
ML	700	1210	1380	1766	2881	2336	10273	4
GM	864	1343	1557	1567	2540	2294	10165	5
M	705	1218	1373	1691	2870	2198	10055	6
RLSp	829	1317	1517	1624	2438	2269	9994	7
RL	739	1168	1377	1592	2688	2206	9770	8
NLSp	801	1360	1615	1448	2387	2149	9760	9
R	702	1156	1387	1540	2537	2158	9480	10
RLRp	755	1110	1425	1497	2479	2121	9387	11
NKLRp	741	1216	1282	1464	2616	2011	9330	12
L	707	1134	1301	1542	2609	2019	9312	13
NKL	755	1241	1340	1368	2331	2226	9261	14
None	717	1091	1288	1502	2504	2064	9166	15
NL	719	1130	1379	1415	2445	2075	9163	16
NLRp	776	1185	1380	1349	2305	2111	9106	17
G	746	1120	1201	1472	2422	2076	9037	18
N	684	1060	1269	1422	2179	2066	8680	19

[1] SC = seed cotton; OG = oat grain; OS = Oat straw; DG = darso grain; DF = darso forage; CH = cowpea hay.

5 tons per acre to be applied every 4 years. The last lime was applied in 1941. The limed plots had an approximate pH of 7.65 at that time. It was decided not to lime these plots as long as the pH was 6.0 and over. In 1958 the pH was still above this figure. (In 1960 the limed plots had an average pH of 6.8). Ammonium sulfate was used as a source of nitrogen. It was applied at the annual rate of 100 pounds per acre for each crop. Muriate of potash was used to supply potassium. It was applied at the annual rate of 100 pounds per acre for all crops. Gypsum was applied at the rate of 2 tons per acre in 1929, 1933, 1937, 1941 and 1945. Rock phosphate and superphosphate were applied as in 1917-1928. The crop residues were applied annually.

The average data by periods for each crop and treatment including the first 12 years of the experiment, the next 20 years of the experiment and the combined data for the entire 32-year period are shown in Table 9. Table 10 gives a summary of the ranking by treatments for all crops based on (1) the numerical ranking of a treatment by crops and (2) the ranking by the average annual yield of all crop products. The treatment with the lowest total is ranked highest when the numerical method No. 1 is used. The treatment with the highest total crop product is ranked highest by method No. 2.

Table 9. The rank of treatments with the average yields in pounds per acre for the several crops by periods, (1917-28), (1929-48), and the combined period, 1917-1948. Treatments underlined within a bracket occurred in this same bracket for each of the time periods of the experiment.

SEED COTTON

General Group	Treatment	1917-28	Treatment	1929-48	Treatment	Entire Period 1917-48
Upper	GMRp	866	GMRp	998	GMRp	948
	GM	864	GM	956	GM	921
	RLSp	829	MLRp	927	RLSp	884
	MLSp	805	RLSp	971	MLSp	869
	NLSp	801	MLSp	908	MLRp	860
	NLSp	776	ML	883	NLSp	849
Medium	MKL	755	NLSp	878	RLRp	825
	RLRp	755	RLRp	867	NLRp	819
	MLRp	747	NLRp	846	ML	814
	G	746	RL	844	RL	805
	NKLRp	741	M	841	M	790
	RL	739	NL	814	NKL	783
Lower	NL	719	NKLRp	805	MKLRp	781
	None	717	NKL	800	NL	778
	L	707	R	800	R	763
	M	705	L	770	L	746
	R	702	None	742	G	737
	ML	700	G	732	None	732
	N	684	N	712	N	702

OAT STRAW

Upper	MLSp	1731	GMRp	2039	GMRp	1886
	GMRp	1630	MLSp	1900	MLSp	1837
	RLSp	1617	MLRp	1825	GM	1715
	NLSp	1615	GM	1810	MLRp	1701
	GM	1557	NLSp	1690	NLSp	1662
	MLRp	1493	ML	1583	RLSp	1569
Medium	RLRp	1425	RLSp	1540	ML	1507
	R	1387	M	1468	M	1432
	ML	1380	NLRp	1317	NLRp	1340
	NLRp	1380	RLRp	1280	RLRp	1334
	NL	1379	RL	1265	RL	1310
	RL	1377	NL	1257	NL	1303
Lower	M	1373	NKLRp	1204	NKLRp	1233
	NKL	1340	NKL	1117	NKL	1201
	L	1301	L	1090	R	1198
	None	1288	R	1084	L	1169
	NKLRp	1282	N	1064	N	1141
	N	1269	None	1033	None	1129
	G	1201	G	891	G	1007

OAT GRAIN

Table 9 (Continued).

General Group	Treatment	1917-28	Treatment	1929-48	Treatment	Entire Period 1917-48
	GMRp	1374	MLSp	1602	MLSp	1501
	NLSp	1360	NLSp	1524	NLSp	1462
	GM	1343	RLSp	1495	GMRp	1438
Upper	MLSp	1332	GMRp	1477	RLSp	1428
	RLSp	1317	MLRp	1471	GM	1394
	NKL	1241	GM	1424	MLRp	1384
	MLRp	1240	ML	1340	M	1294
	M	1218	M	1339	ML	1292
	NKLRp	1216	NLRp	1327	NLRp	1274
Medium	ML	1210	RL	1302	RL	1252
	NLRp	1185	RLRp	1291	NKLRp	1250
	RL	1168	NKLRp	1271	RLRp	1223
	R	1156	NL	1242	NKL	1211
	L	1134	NKL	1193	NL	1200
	NL	1130	L	1184	L	1165
Lower	G	1120	R	1127	R	1138
	RLRp	1110	N	1111	None	1095
	None	1091	None	1098	N	1092
	N	1060	G	983	G	1034

COWPEA HAY

	MLRp	2410	GMRp	2541	GMRp	2477
	GMRp	2369	GM	2475	GM	2407
	MLSp	2368	MLSp	2370	MLSp	2369
Upper	ML	2336	ML	2327	ML	2330
	GM	2294	MLRp	2280	MLRp	2329
	RLSp	2269	NLSp	2242	RLSp	2250
	NKL	2226	RLSp	2239	NLSp	2207
	RL	2206	M	2150	M	2168
	M	2198	RLRp	1948	RLRp	2013
Medium	R	2158	NLRp	1925	RL	2001
	NLSp	2149	RL	1878	NLRp	1995
	RLRp	2121	NL	1828	NKL	1924
	NLRp	2111	NKLRp	1827	NL	1921
	G	2076	L	1770	NKLRp	1896
Lower	NL	2075	NKL	1742	R	1889
	N	2066	G	1741	G	1866
	None	2064	R	1727	L	1864
	L	2019	None	1726	None	1853
	NLKRp	2011	N	1672	N	1820

Table 9 (Continued).

DARSO GRAIN

General Group	Treatment	1917-28	Treatment	1929-48	Treatment	Entire Period 1917-48
	ML	1766	NLSp	1391	GMRp	1469
	GMRp	1714	RLSp	1361	RLSp	1460
	MLRp	1708	GM	1336	MLRp	1444
Upper	M	1691	GMRp	1323	MLSp	1434
	MLSp	1670	NLRp	1314	GM	1423
	RLSp	1624	RL	1301	NLSp	1412
	RL	1592	MLSp	1293	RL	1410
	GM	1567	MLRp	1285	ML	1402
	L	1542	RLRp	1273	RLRp	1357
Medium	R	1540	NL	1271	M	1357
	None	1502	G	1233	L	1333
	RLRp	1497	NKLRp	1221	NLRp	1327
	G	1472	L	1204	NL	1325
	NKLRp	1464	NKL	1204	G	1322
	NLSp	1448	ML	1184	NKLRp	1312
Lower	N	1422	None	1171	None	1295
	NL	1415	M	1156	R	1287
	NKL	1368	R	1143	NKL	1265
	NLRp	1349	N	1077	N	1206

DARSO FORAGE

	ML	2881	MLSp	3135	MLSp	3005
	M	2870	NLSp	3101	ML	2959
	MLRp	2868	RLSp	3051	MLRp	2905
Upper	GMRp	2800	ML	3004	GMRp	2855
	MLSp	2779	NLRp	2994	NLSp	2839
	RL	2688	MLRp	2927	RLSp	2826
	NKLRp	2616	GM	2901	M	2788
	L	2609	GMRp	2887	GM	2769
	GM	2540	G	2866	NKLRp	2754
Medium	R	2537	NL	2854	RL	2746
	None	2504	NKL	2834	NLRp	2741
	RLRp	2479	NKLRp	2834	NL	2704
	NL	2445	RL	2779	G	2703
	RLSp	2438	RLRp	2755	L	2690
	G	2422	M	2740	RLRp	2654
Lower	NLSp	2387	L	2736	NKL	2652
	NKL	2337	None	2720	None	2641
	NLRp	2305	R	2695	R	2637
	N	2179	N	2521	N	2395

The 1949-1958 Period for the Continuously Fertilized Soil

In 1949 the cropping plan on the continuously fertilized plots since 1917 was modified. A vetch-rye combination replaced cowpeas. Winter (fall seeded) oats with a spring interplanting of Korean lespedeza replaced spring seeded oats. Cotton and darso continued as the other two major crops in the rotation.

Table 10. A Summary of Treatment Rankings

Treatment	Method No. 1 Summation of ratings for all crops (1917-48)[1]							Rank
	SC	OG	OS	DG	DF	CH	TOTAL	
GMRp	1	3	1	1	4	1	11	1st
MLSp	4	1	2	4	1	3	15	2nd
GM	2	5	3	5	8	2	25	3rd
MLRp	5	6	4	3	3	5	26	4th
RLSp	3	4	6	2	6	6	27	5th
NLSp	6	2	5	6	5	7	31	6th
ML	9	8	7	8	2	4	38	7th
M	11	7	8	10	7	8	51	8th
RL	10	10	11	7	10	10	58	9th
NLRp	8	9	9	12	11	11	60	10th
RLRp	7	12	10	9	15	9	62	11th
NKLRp	13	11	13	15	9	14	75	12th
NL	14	14	12	13	12	13	78	13th
NKL	12	13	14	13	16	12	85	14th
L	16	15	16	11	14	17	89	15th
R	15	16	15	17	18	15	96	16th
G	17	19	19	14	13	16	98	17th
None	18	17	18	16	17	18	104	18th
N	19	18	17	19	19	19	111	19th

[1] SC = Seed Cotton; OG = Oat Grain; OS = Oat Straw; DG = Darso Grain; DF = Darso Forage; CH = Cowpea Hay.

Treatment	Method No. 2 Summation of annual yields in pounds per acre for all crops, 1917-1948 average[1]							Rank
	SC	OG	OS	DG	DF	CH	TOTAL	
GMRp	948	1438	1886	1469	2855	2477	11073	1st
MLSp	869	1501	1837	1437	3005	2369	11015	2nd
GM	921	1394	1715	1423	2769	2407	10629	3rd
MLRp	860	1384	1701	1444	2905	2329	10623	4th
RLSp	884	1428	1569	1460	2826	2250	10417	6th
NLSp	849	1462	1662	1412	2839	2207	10431	5th
ML	814	1292	1507	1402	2959	2330	10304	7th
M	790	1294	1432	1357	2788	2168	9829	8th
RL	805	1252	1310	1410	2746	2001	9524	9th
NLRp	819	1274	1340	1327	2741	1995	9496	10th
RLRp	825	1223	1334	1357	2654	2013	9406	11th
NKLRp	781	1250	1233	1312	2754	1896	9226	13th
NL	778	1200	1303	1325	2704	1921	9231	12th
NKL	783	1211	1201	1265	2652	1924	9036	14th
L	746	1165	1169	1333	2690	1864	8967	15th
R	763	1138	1198	1287	2637	1889	8912	16th
G	737	1034	1007	1322	2703	1866	8669	18th
None	732	1095	1129	1295	2641	1853	8745	17th
N	702	1092	1141	1206	2395	1820	8356	19th

[1] SC = Seed Cotton; OG = Oat Grain; OS = Oat Straw; DG = Darso Grain; DF = Darso Forage; CH = Cowpea Hay.

Some modification was also made in the fertilizer plan. Rock phosphate was applied at the rate of 500 pounds per acre and gypsum at 150 pounds per acre once in the rotation. Superphosphate was applied at the rate of 150 pounds per acre for the rye-vetch and also for cotton. Ammonium nitrate was used as the source of nitrogen and was applied at the rate of 100 pounds per acre for the oat crop only. Muriate of potash was applied at the rate of 100 pounds per acre for cotton and also for rye-vetch. Farm manure continued to be applied once in the rotation at the rate of 5 tons per acre. No limestone was applied since the soil on the previously limed plots was still near neutrality. This rotation-fertilizer plan continued through the 1958 season. The average annual results are given in Table 11.

In reviewing the cropping years for the three periods, namely 1917-1928, 1929-1948, and 1949-1958 by crops where yield data are available, it was found that for this 42-year period, yield data were secured for seed cotton every year. For the other crops a few years are missing as explained the footnotes to Table 11.

Table 11. A Summary of the Average Annual Yields of Crops on Continuously Fertilized Plots since 1917 for the 1949-1958 period.

	Average Annual Yield in Pounds Per Acre							
Treatment	SC[1]	OG[2]	OS[3]	DG[4]	DF[5]	Rye-vetch[6]	Total	Rank
GMRp	987	965	1302	963	3300	2494	10011	1
ML	967	838	1161	801	3794	2312	9873	2
MLRp	925	834	1143	881	3803	2178	9764	3
MLSp	910	797	1142	966	3698	2183	9696	4
NLSp	814	1136	1450	998	3144	2131	9673	5
GM	971	902	1136	947	3124	2391	9471	6
NLRp	760	913	1253	1055	3371	1746	9098	7
RLSp	864	899	1028	979	3225	1888	8883	8-9
M	866	783	975	677	3397	2185	8883	8-9
RLRp	768	860	1066	1060	2976	1606	8336	10
NKLRp	766	850	1037	1005	3222	1389	8269	11
RL	810	818	996	919	2847	1686	8076	12
NKL	691	805	1021	902	2840	1563	7822	13
NL	700	814	986	929	2655	1691	7775	14
L	658	737	840	825	2873	1411	7344	15
R	742	709	766	743	2804	1423	7187	16
NONE	693	698	737	796	2869	1322	7115	17
G	667	677	666	850	2837	1194	6891	18
N	640	715	750	778	2776	1083	6742	19

[1] Ten year average. Seed Cotton.
[2] Nine year average; Differential damage by greenbug in 1951 prevented usage of data for that year. Oat Grain.
[3] Seven year average; Differential damage by greenbugs in 1951; Straw data were not taken in 1957 and 1958. Oat Straw.
[4] Eight year average; 1952 data were not complete; Bird damage in 1958. Darso Grain.
[5] Nine year average; Forage weights were not recorded for 1957. Darso Forage.
[6] Seven year average; Data not complete for 1956, 1957, and 1958.

Table 12 gives the total of the average annual yields for the respective crops by sub-periods and for the entire period. It also shows the average annual yield of each crop for the entire time with the omissions indicated.

The average annual yields as shown in the several sections of Table 13 of each of the crops are brought together in Table 14.

Table 12. Total crop years where data are available for the several crops used in the rotation.

Crops	Sub-Period			
	1917-28	1929-48	1949-58	TOTAL
Cotton	12	20	10	42 years
Darso Grain	12	20	8[3]	40
Darso Forage	11[1]	19[2]	9[4]	41
Oat Grain	12	20	9[5]	41
Oat Straw	12	20	7[6]	39
Cowpea Hay or Rye-Vetch	12	20	7[7]	39

[1] Wet fall weather in 1923, forage rotted in field so accurate weights could not be taken.
[2] Weights lost (good yield however) in 1942; omitted.
[3] Differential damage to plots by birds in 1952 and 1958 occurred, hence data for these years are not included.
[4] Forage weights were not available for 1957.
[5] Greenbug damaged some plots so could not use the 1951 data.
[6] Weights not recorded in 1957 and 1958; greenbugs 1951.
[7] Weights not complete in 1956, 1957, and 1958.

Table 13. A summation of the total yields in pounds per acre by sub-periods where fertilizers were used continuously.

SEED COTTON

Treatment	Sub-Periods			Total (42 yrs.)	Annual Average
	1917-28 (12 yrs.)	1929-48 (20 yrs.)	1949-58 (10 yrs.)		
NONE	8599	14833	6933	30365	723
M	8465	16819	8662	33946	808
ML	8405	17650	9667	35722	851
MLRp	8969	18541	9252	36762	875
MLSp	9658	18153	9096	36907	879
R	8425	15997	7417	31839	758
RL	8870	16878	8099	33847	806
RLRp	9055	17339	7675	34069	811
RLSp	9953	18345	8639	36937	879
N	8211	14240	6402	28853	687
NL	8633	16277	6998	31908	760
NLRp	9307	16911	7604	33822	805
NLSp	9607	17554	8136	35297	840
NKL	9060	16005	6914	31979	761
NKLRp	8893	16098	7658	32649	777
L	8484	15397	6580	30461	725
G	8952	14634	6674	30260	720
GM	10362	19113	9709	39184	933
GMRp	10386	19964	9865	40215	957

Table 13 (Continued).

OATS GRAIN

Treatment	Sub-Periods 1917-28 (12 yrs.)	1929-48 (20 yrs.)	1949-58 (9 yrs.)	Total (41 yrs.)	Annual Average
None	13090	21956	6281	41327	1008
M	14612	26788	7044	48444	1182
ML	14525	26809	7539	48873	1192
MLRp	14877	29416	7505	51798	1263
MLSp	15982	32048	7177	55207	1347
R	13870	22546	6378	42794	1044
RL	14020	26047	7365	47432	1157
RLRp	13320	25825	7743	46888	1144
RLSp	15810	29895	8090	53795	1312
N	12719	22217	6438	41374	1009
NL	13555	24841	7330	45725	1115
NLRp	14225	26538	8218	48981	1195
NLSp	16320	30473	10223	57016	1391
NKL	14890	23854	7247	45991	1122
NKLRp	14592	25422	7652	47666	1163
L	13609	23674	6629	43912	1071
G	13439	19659	6093	39191	956
GM	16120	28477	8116	52713	1286
GMRp	16492	29540	8683	54715	1334

OAT STRAW

Treatment	Sub-Periods 1917-28 (12 yrs.)	1929-48 (20 yrs.)	1949-58 (7 yrs.)	Total (39 yrs.)	Annual Average
None	15460	20669	5156	41285	1059
M	16472	29367	6826	52665	1350
ML	16560	31652	8126	56338	1444
MLRp	17917	36508	8000	62425	1601
MLSp	20767	38008	7993	66768	1712
R	16650	21685	5362	43697	1120
RL	16630	25291	6970	41921	1075
RLRp	17095	25602	7462	50159	1286
RLSp	19405	30791	7195	57391	1472
N	15234	21274	5252	41760	1071
NL	16550	25141	6905	48596	1246
NLRp	16555	26333	8772	51660	1325
NLSp	19380	33808	10152	63340	1624
NKL	16080	22347	7148	45575	1169
NKLRp	15385	24078	7258	46721	1198
L	15609	21803	5881	43293	1110
G	14409	17815	4662	36886	946
GM	18680	36207	7954	62841	1611
GMRp	19557	40784	9112	69453	1781

Table 13 (Continued).

DARSO GRAIN

Treatment	Sub-Periods 1917-28 (12 yrs.)	1929-48 (20 yrs.)	1949-58 (8 yrs.)	Total (40 yrs.)	Annual Average
NONE	18024	23416	6370	47810	1195
M	20291	23127	5413	48831	1221
ML	21186	23686	6404	51276	1282
MLRp	20498	25695	7046	53239	1331
MLSp	20041	25861	7728	53630	1341
R	18485	22685	5940	47110	1178
RL	19103	26021	7350	52474	1312
RLRp	17968	25457	8479	51904	1298
RLSp	19489	27224	7832	54545	1366
N	17058	21544	6223	44825	1121
NL	16978	25422	7430	49830	1246
NLRp	16190	26283	8443	50916	1273
NLSp	17371	27820	7984	53175	1329
NKL	16412	24080	7219	47711	1193
NKLRp	17565	24421	8036	50024	1251
L	18576	24081	6607	49264	1232
G	17659	24654	6797	49110	1228
GM	18800	26725	7578	53103	1328
GMRp	20565	26458	7702	54725	1368

DARSO FORAGE

Treatment	Sub-Periods 1917-28 (11 yrs.)	1929-48 (19 yrs.)	1949-58 (9 yrs.)	Total (39 yrs.)	Annual Average
NONE	27545	51674	25825	105044	2693
M	31575	52052	30577	114204	2928
ML	31691	57073	34147	122911	3152
MLRp	31552	55610	34231	121393	3113
MLSp	30571	59570	33285	123426	3165
R	27906	51211	25234	104351	2676
RL	29571	52800	25626	107997	2769
RLRp	27266	52340	26782	106388	2728
RLSp	26815	57968	29025	113803	2918
N	23968	47895	24984	96847	2493
NL	26890	54236	23897	105023	2693
NLRp	25351	56893	30343	112587	2887
NLSp	26254	58912	28296	113462	2909
NKL	25712	53850	25559	105121	2695
NKLRp	28776	53847	28995	111618	2862
L	28703	51983	25858	106544	2732
G	26638	54451	25529	106618	2734
GM	27937	55119	28120	111176	2851
GMRp	30805	54846	29701	115352	2958

Table 13 (Continued).

Treatment	Cowpeas Rye-Vetch				
	Sub-Periods				
	1917-28 (12 yrs.)	1929-48 (20 yrs.)	1949-58 (7 yrs.)	Total (39 yrs.)	Annual Average
NONE	24772	34518	9254	68544	1758
M	26372	42999	15294	84665	2171
ML	28028	46532	16173	90733	2326
MLRp	28915	45599	15243	89757	2301
MLSp	28414	47399	15278	91091	2336
R	25895	34541	9960	70376	1805
RL	26477	37560	11800	75837	1945
RLRp	25448	38969	11240	75657	1940
RLSp	27228	44776	13214	85218	2185
N	24793	33437	7580	65810	1687
NL	24897	36562	11840	73299	1879
NLRp	25335	38503	12220	76058	1950
NLSp	25784	44843	14920	85547	2194
NKL	26716	34850	10940	72506	1859
NKLRp	24130	36549	9720	70399	1805
L	24226	35409	9880	69515	1782
G	24906	34812	8360	68078	1746
GM	27531	49499	16760	93790	2405
GMRp	28430	60827	17460	96717	2480

Table 14. A summary of the average yields in pounds per acre of the several crops (1917-1958) inclusive).

Treatment	Seed Cotton	Oats Grain	Oats Straw	Darso Grain	Darso Forage	Cowpea or Rye-vetch Forage
None	723	1008	1059	1195	2693	1758
M	808	1182	1350	1221	2928	2171
ML	851	1192	1444	1282	3152	2326
MLRp	875	1263	1601	1331	3113	2301
MLSp	879	1347	1712	1341	3165	2336
R	758	1044	1120	1178	2676	1805
RL	806	1157	1075	1312	2769	1945
RLRp	811	1144	1236	1298	2728	1940
RLSp	879	1312	1472	1366	2918	2185
N	687	1009	1071	1121	2483	1687
NL	760	1115	1246	1246	2693	1879
NLRp	805	1195	1325	1273	2887	1950
NLSp	840	1391	1624	1329	2909	2194
NKL	761	1122	1169	1193	2695	1859
NKLRp	777	1163	1198	1251	2862	1805
L	725	1071	1110	1232	2732	1782
G	720	956	946	1228	2734	1746
GM	933	1286	1611	1328	2851	2405
GMRp	957	1334	1781	1368	2958	2480

In order to get a better perspective, these yields were rearranged into the upper, medium and lower groups as was done in some of the preceding tables. These data by crops are shown in Table 15.

Table 15. The average annual yields in pounds per acre for each of the respective crops arranged into upper, medium, lower yield groups for the entire period of the experiment (1917-1948).

Treatment	Seed[1] Cotton	Treatment	Oat[2] Grain	Treatment	Oat[3] Straw	Treatment	Darso[4] Grain	Treatment	Darso[5] Forage	Treatment	Cowpea or[6] Rye-Vetch	Treatment	Total of all Averages	Rank
GMRp	957	NLSp	1391	GMRp	1781	GMRp	1368	MLSp	3165	GMRp	2480	GMRp	10878	1
GM	933	MLSp	1347	MLSp	1712	RLSp	1366	ML	3152	GM	2405	MLSp	10780	2
MLSp	879	GMRp	1334	NLSp	1624	MLSp	1341	MLRp	3113	MLSp	2336	MLRp	10484	3
RLSp	879	RLSp	1312	GM	1611	MLRp	1331	GMRp	2958	ML	2326	GM	10414	4
MLRp	875	GM	1286	MLRp	1601	NLSp	1329	M	2928	MLRp	2301	NLSp	10287	5
ML	851	MLRp	1263	RLSp	1472	GM	1328	RLSp	2918	NLSp	2194	ML	10247	6
NLSp	840	NLRp	1195	ML	1444	RL	1312	NLSp	2909	RLSp	2185	RLSp	10132	7
RLRp	811	ML	1192	M	1350	RLRp	1298	NLRp	2887	M	2171	M	9660	8
M	808	M	1182	NLRp	1325	ML	1282	NKLRp	2862	NLRp	1950	NLRp	9435	9
RL	806	NKLRp	1163	RLRp	1285	MLRp	1273	GM	2851	RL	1945	RLRp	9207	10
NLRp	805	RL	1157	NL	1246	NKLRp	1251	RL	2769	RLRp	1940	RL	9064	11
NKLRp	777	RLRp	1144	NKLRp	1193	NL	1246	G	2734	NL	1879	NKLRp	9056	12
NKL	761	NKL	1122	NLK	1169	L	1232	L	2732	NKL	1859	NL	8939	13
NL	760	NL	1115	R	1120	G	1228	RLRp	2728	NKLRp	1805	NKL	8799	14
R	758	L	1071	L	1110	N	1221	NKL	2695	R	1805	L	8652	15
L	725	R	1044	RL	1075	None	1195	NL	2693	L	1782	R	8581	16
None	723	N	1009	N	1071	NKL	1193	None	2693	None	1758	None	8436	17
G	720	None	1008	None	1059	R	1178	R	2676	G	1746	G	8330	18
N	687	G	956	G	946	N	1121	N	2483	N	1687	N	8058	19

[1] Seed Cotton: Entire 42 years.
[2] Oat Grain: 41 years; Greenbugs damaged some plots so could not use the data in 1951.
[3] Oat Straw: 35 years; Greenbug damage (noted above) in 1951; Weights not recorded in 1957 and 1958.
[4] Darso Grain: 40 years; Irregular bird damage in 1952 and 1958 so data are not included.
[5] Darso Forage: 39 years; Forage rotted in field due to wet weather in the fall of 1923; Weights lost in 1942 (yield was good); Forage weights were not recorded in 1957.
[6] Cowpea or rye-vetch hay: 39 years; Weights were not complete for 1956, 1957 and 1958. Data for these years were not used.

Discussion of the Results for the Entire Period, 1917-1958

The three treatments gypsum-manure-rock-phosphate, manure-lime-superphosphate, and manure-lime-rock phosphate are found in the upper group for yields in each of the crops. In each of the top treatments manure and lime are common additives. The treatments gypsum-manure, and residues-limestone-superphosphate each occurred in the upper group for 5 or 6 crop products, nitrogen-lime-superphosphate occurred in the upper bracket for 4 of the 6 crop products. In each case these latter treatments; namely, gypsum-manure, residues-lime-superphosphate, and manure-lime when they were not in the upper group, they were in the upper part of the medium group. With but two exceptions, residue-lime-rock phosphate on darso forage and nitrogen-potassium-lime-rock phosphate on cowpeas and vetch-rye, all of the phosphate treatments were in the upper or medium groups.

In general, the treatments which gave low yields for one group were consistently in the low group for other crops. Five treatments were categorized as being in the low group for each crop; namely nitrogen-potassium-lime, residues, lime, none, and nitrogen. The absence of phosphorus in this group is quite striking. Gypsum was in this low group for 5 of the 6 crop products.

As an overall total of the averages for each of the treatments, the top treatments were: gypsum-manure-rock phosphate, manure-lime-superphosphate, manure-lime-rock phosphate, gypsum-manure, nitrogen lime-superphosphate, manure-lime, and residues-lime-superphosphate. As has been previously pointed out, the gypsum-manure-rock phosphate and gypsum-manure plots had a slight positional advantage in the experiment, but when allowances are made for this they are still in the upper group.

It is noted that each of the top treatments furnished calcium either in the form of limestone, gypsum, or in the phosphorus carriers; namely, superphosphate or rock phosphate. The untreated soil was medium acid and the correcting of acidity or a supplemental supply of calcium was apparently desirable. All of the top treatments included superphosphate and those plots which received gypsum in combination with either manure or manure and rock phosphate. It is of further interest and quite surprising that the plots on which the residues were returned to the soil were generally in the upper brackets only if phosphate and calcium were present.

Phosphorus is the major fertility need of this soil. Nitrogen by itself was of no value. Only when the soil phosphorus was supplemented by a phosphorus fertilizer was additional nitrogen effectively used. This has

been found to be a very important factor to consider and applies to many (Oklahoma) soils in Central and Eastern Oklahoma.

There was some indication that sulfur may be needed under certain conditions. Gypsum is a source of sulfur but used alone on this soil without reinforcements supplying other nutrients it was quite unsatisfactory. Only when it was used with manure or manure-rock phosphate did it give favorable results. Gypsum alone averaged next to the lowest total yield for any treatment, being slightly less than the check or no treatment plots.

Farm manure is an excellent fertilizer, but only a few farmers today have access to a satisfactory supply. When it is reinforced with phosphate fertilizers, its value is increased as is shown by the data in this experiment.

Section III

The Residual Value of Fertilizers on Kirkland Soil

In 1916 a four year rotation involving several fertilizer treatments was set up on Kirkland silt loam on the Agronomy farm near Stillwater. The rotation consisted of cotton, oats, cowpeas and darso. The results of this experiment through 1928 were published in Oklahoma Experiment Station Bulletins 155 and 188.

In 1929 the land area used for this experiment was divided into two equal parts hereafter designated as Part I and Part II. Each part consisted of duplicate treatments of previously applied fertilizers. Part I was set aside for a study of residual effects of the fertilizers which had been applied during the 1916-1928 period. This study continued from 1929 to 1948 inclusive.

Residual Effects of Fertilizers, 1929-1948 (Part I)

The duplicate blocks used in this experiment were subdivided into two parts for replication purposes. Cotton, barley, oats, darso and cowpeas were grown and harvested by plots according to the original fertilizer plan. The original treatments are indicated in Table 16. A brief resume of the fertilizer treatments is given on pages 5 and 6 of this publication.

During some seasons between 1929 and 1948 the yield data were not complete hence only those years where complete data are available were used in securing the averages given in Table 16. The data shown

Table 16. The average annual yield of crop products grown on land previously fertilized (1916-1928). The data are given in pounds per acre and are for yields obtained during 1929-48.

Previous[1] Treatment	Block 5100W[2]	Block 5100E[3]	Block 6100W[4]	Block 6100E[5]	Total	Rank	Rank[6] Fertilizer 1917-1948
GMRp	2148	2317	2622	2956	10043	1	1
MLSp	2178	2121	2584	3103	9986	2	2
MLRp	2378	2053	2468	3043	9942	3	4
ML	2460	1968	2233	3017	9678	4	7
GM	2048	2218	2526	2860	9652	5	3
RLSp	2233	1974	2146	2867	9220	6	6
NKLRp	1962	2119	2276	2855	9212	7	13
NLSp	2201	1879	2043	2873	8996	8	5
M	2213	1881	2141	2745	8980	9	8
RLRp	2134	1917	2105	2809	8965	10	11
L	1983	2138	2133	2704	8958	11	15
NKL	1950	1745	2169	2949	8813	12	14
G	1853	2092	2199	2660	8804	13	18
NLRp	2076	1670	2117	2922	8785	14	10
RL	2076	1798	2181	2716	8771	15	9
R	2034	1658	2018	2782	8492	16	16
NONE	1960	1849	1980	2638	8427	17	17
NL	1913	1794	1885	2615	8207	18	12
N	1915	1767	1781	2456	7919	19	19

[1] G—gypsum; M—manure; Rp—rock phosphate; Sp—superphosphate; R—residues; L—limestone; N—nitrogen; K—potassium; None—no treatment.
[2] Seven year average including 2 years cotton, 1 year oats, 2 years darso, and 2 years cowpeas.
[3] Seven year average including 2 years cotton, 2 years oats, 1 year darso and 2 years cowpeas.
[4] Nine year average including 3 years cotton, 2 years barley, 2 years oats, 1 year darso, and 1 year cowpeas.
[5] Nine year average including 3 years cotton, 2 years barley, 1 year oats, 2 years darso, and 1 year cowpeas.
[6] This column shows the rank of the treatments based on total crop product yields where the land was continuously fertilized from 1917 to 1948 (32 years).

are the annual averages for all crop products including seed cotton, oats (grain and straw), darso (grain and forage), cowpea hay, and barley (grain and straw).

Next to the last column in Table 16 gives the ranking of the fertilizer treatments for their residual effects where the use of fertilizers was discontinued in 1929. The last column in Table 16 gives the rank of these same treatments where the fertilizer usage was continued through 1948 (32 years). It is interesting to observe the rather close agreement in these rankings. No plot which had received superphosphate during the first 12 years (1916-1828) fell below eighth place in residual yields. During the period of regular fertilization (1917-1948) the lowest rank for the superphosphate treatments was sixth place. Any plot which had received farm manure continued to show good residual effects. The five high plots in this residual study had received farm manure combinations during the preceding fertilizer period.

Continuously Fertilized from 1916 through 1948 (Part II)

The regular fertilizer and rotation plans were continued on Part II until the end of the 1948 cropping season. The last column in Table 16 shows the ranking of these continuously fertilized plots. Additional data are published in section II of this bulletin.

Part I was again included in the fertilizer plan in 1949. From 1949 until the end of the 1958 harvest season fertilizers were applied to the several plots in both Parts I and II as described below.

At the end of the 1958 cropping season all fertilizer applications were terminated and the rotations were discontinued. Wheat was selected as the crop to use on Part I to study the residual effects of previously applied fertilizers. Sorghum (Sumac 1712) was planted in eight inch spacing with a drill on Part II.

Continuous Wheat Starting in the Fall of 1958 (Part I)

During the previous experimental period (1917-1958), when fertilizers were applied from 1916 to 1928 and from 1949 to 1958 with a lapse of treatments from 1929 to 1948 inclusive, each of the rock phosphate (Rp) plots received a total of 4500 pounds of rock phosphate per acre. The superphosphate (Sp) plots each received a total of 2250 pounds of superphosphate per acre. The rock phosphate was applied either at rates of 500 or 1000 pounds per acre every 4 years. Superphosphate was applied in annual applications usually at a rate of 125 pounds per acre.

During the 1916-1928 period farm manure (M) was applied every 4 years at a rate calculated to be equivalent to that which would have been produced had the feed crops been fed to livestock. This amounted to approximately 9.39 tons per acre per application. During 1949-1958 manure was applied at the rate of 5 tons per acre every 4 years. Limestone (L) was applied at the rate of 1 ton per acre in 1916 and at the rate of 2 tons per acre in 1921 and again in 1925. No limestone has been applied since 1925. Gypsum (G) was originally applied at the rate of 400 pounds per acre annually, however during 1949-1958, it was applied at the rate of 150 pounds per acre for the fall oats-sweet clover crop only. The rotation used during 1949-1958 was cotton, fall oats-sweet clover, sweet clover, and darso. Originally nitrogen was applied as nitrate of soda, but later as ammonium nitrate at a rate of 100 pounds per acre. Potash was originally applied as kainit, but later as muriate of potash at the rate of 100 pounds per acre.

At the beginning of the experiment potash and nitrogen were applied each year for all crops. During 1949-1958 potash was applied for

the oats and cotton, and nitrogen as a top dressing on oats only. All of these treatments followed the plot designed as originally established in 1916. In this design every third plot was a no treatment or check plot. The full design with fertilizer designations are shown in Table 17. This applies to both Parts I and II.

Continuous Forage Sorghum Starting in 1959 (Part II)

The same fertilizer plan was used on this area as was followed on Part I during 1916-1928. This plan was continued on Part II through 1948 except that no limestone was applied after 1941. The limed plots in 1941 had an average pH of 7.65. The rate of farm manure averaged 14.77 tons per acre every four years from 1929 through 1940. In 1941 this was changed to 5 tons per acre every four years. This rate was used throughout the remainder of the experiment (1941-1958). A total of 8000 pounds of rock phosphate was applied to the rock phosphate plots during 1916-1948. Superphosphate was applied annually to each crop at the rate of 125 pounds per acre during this same period.

In 1949 the original rotation of cotton, oats, cowpeas and darso was changed to cotton, rye-vetch, fall oats-lespedeza, and darso. The rock phosphate rate of application was 500 pounds per acre per rotation. Superphosphate was applied at the rate of 150 pounds per acre twice dur-

Table 17. The residual effect of previous fertilizer usage on wheat grain and sorghum forage yields.

	Wheat in pounds per acre				Sorghum forage in pounds per acre			
	Average			Gain or[2]	Average			Gain or[2]
Plot[1]	1959	1960	Total 1959-60	loss for 2 years	1959-	1960	Total 1959-60	loss for 2 years
None	Used for border because of fence row					____	____	____
M	1120	2414	3534	962	17341	8574	25915	6796
ML	1015	2327	3342	770	16768	9340	26108	6989
None	823	1828	2651	___	13974	6365	20339	____
MLRp	1173	2629	3802	1230	17224	8095	25309	6190
MLSp	1374	2594	3968	1396	16522	8537	25059	5940
None	823	2003	2826	____	15896	5924	21820	____
Res[3]	718	1815	2533	— 39	13752	6912	20664	1545
Res L	805	1710	2515	— 57	14738	7423	22161	3042
None	726	1557	2283	____	14180	5942	20122	____
Res L Rp	1181	2393	3574	1002	15764	7330	23094	3975
Res L Sp	1208	2305	3513	941	14973	5787	20760	1641
None	709	1601	2310	____	14150	4934	19084	____
N	770	1535	2305	—267	12482	6067	18549	—570

[1] Fertilizer applications were discontinued in 1958 with no fertilizer applied for the 1959 and 1960 crop years.
[2] The yield compared to check plots where no treatment had previously been applied.

ing the rotation of rye-vetch and for cotton. A total of 1500 pounds of rock phosphate per acre was applied during 1949-1958 making a grand total of 9500 pounds of rock phosphate per acre for the entire period, 1916-1958. During the 1949-1958 period, 900 pounds of superphosphate were applied, making a grand total of 4525 pounds of superphosphate per acre for the entire 1917-1958 period. Muriate of potash was applied for the rye-vetch and for cotton at the rate of 100 pounds per acre. Ammonium nitrate was applied as a top dressing on the oats at the rate of 100 pounds per acre. Gypsum was applied once during the rotation for rye-vetch, at the rate of 150 pounds per acre.

Results

The residual effects of the fertilizer treatments as measured by wheat grain and sorghum forage yields on some of the plots are shown in Table 17 for the years 1959 and 1960. A portion of the residual yield data was lost after averages were computed. These yearly yields are in each case (of) the average of quadruplicate plots.

Comments on wheat data: The residual effect of the phosphate treatments on the yield of wheat is quite evident. The average yearly increase for all rock phosphate plots over the plots receiving the same treatment except for the rock phosphate is about 6.47 bushels per acre. Similarly the average yearly increase of all superphosphate plots is about 6.26 bushels per acre. The favorable residual effect of farm manure is quite evident. The past use of crop residues does not show a favorable influence on the wheat. It is recognized that under our present methods of farming, farm manure is normally not available. Also, under our present combine harvesting methods, wheat straw is left on the land as a crop residue. The use of nitrogen with wheat straw may be the solution to the residue problem on these soils. Soils which are low in available phosphorus give little or no response to added nitrogen (see Table 18 and Table 19). The importance of supplying low phosphorus soils with phosphate fertilizer in order to secure good efficiency to added nitrogen in wheat production needs to be stressed.
It is essential that phosphate be applied to these low phosphorus soils if the benefits from any applied nitrogen are to be secured.

Comments on sorghum forage data: The data on the residual effects of the fertilizers on sorghum forage are not as clear cut as for wheat. The effect of farm manure is quite evident, however. Also, the residual effect from the previously applied rock phosphate is considerably more pronounced than that from the superphosphate. As has been indicated

much more rock phosphate than superphosphate has been applied, however, on a monetary basis the difference in cost is not so wide.

Sorghums grow during the summer months when the decomposition of organic residues is greatest. Hence during their growth, they may acquire more nutrients from the decomposing residues than can wheat which makes its largest vegetative growth before the soil temperature is as favorable to residue decomposition.

Table 18. Wheat—The effect of top dressing previously fertilized plots with nitrogen (1961).

Soil Data (Fall 1960) before applying any nitrogen top dressing.

Treatment	Total N[1] %	Total P[1] lbs/a	Total P[2] Subsurface lbs/a	Available P[3] lbs/a	pH
None	----	---			
M	.0675	363		13	6.7
ML	.0692	349		10	6.5
None	.0728	366	316	10	6.3
MLRp	.0694	552	341	99	6.2
MLSp	.0842	459	324	34	6.4
None	.0697	383		8	5.9
Res	.0710	365		7	5.7
Res L	.0687	351		6	6.0
None	.0680	354	308	4	5.7
Res L Rp	.0701	520	351	78	5.9
Res L Sp	.0745	420	337	13	5.9
None	.0645	377		5	5.6
N	.0630	363		7	5.6
NL	.0709	348		6	5.9
None	.0707	351	321	5	5.7
NLRp	.0687	538	353	63	5.9
NLSp	.0730	440	348	14	5.9
None	.0708	386		6	5.7
NLK	.0697	380		4	6.1
NLK Rp	.0718	543		59	6.0
None	.0635	398		6	5.7
L	.0707	393		7	5.7
G	.0718	399		7	5.6
None	.0721	408		8	5.5
GM	.0769	425		9	5.5
GMRp	.0740	529		62	5.6
None	.0659	405		6	5.3
Ave. All Plots	.0704	---		--	--
Ave. all "none"	.0686	381		6+	--
Ave. all Rp	.0708	532		72	--
Ave. all Sp	.0772	440		20	--

[1] Average of 4 areas — From each area the composite sample was from 10 locations surface 0-6 in.
[2] Calculated on a 2,000,000 pounds basis.
[3] Soluble (leaching procedure) in 0.1 N acetic Acid.
[4] This plot had some border moisture addition.

Table 18. Continued

Wheat Data for the 1961 Season

Treatment	Wheat yield (1961) pounds per acre Top Dressed with N	No N	Protein (%) Top Dressed with N	No N
None	----	----	----	----
M	1599	1437		
ML	1338	1219		
None	977	815	15.26	11.92
ML Rp	1599	1213	13.12	10.26
ML Sp	1506	1120	12.39	10.55
None	1126	784	14.93	11.75
Res	852	859		
Res L	746	746		
None	672	690	15.51	13.47
Res L Rp	1201	864	12.76	10.78
Res L Sp	1095	877	13.67	11.03
None	653	709	15.15	12.62
N	610	747		
NL	641	815		
None	753	678	15.44	12.24
NL Rp	1350	1045	12.67	10.25
NL Sp	1219	890	13.20	10.93
None	840	734	14.24	11.77
NLK	890	809		
NLK Rp	1512	952		
None	983	647		
L	1076	777		
G	1095	778		
None	1126	934		
GM	1406	921		
GM Rp	1867	939		
None	970	1076 (4		
Ave. all "none"	900	789	15.12	12.30
Ave. all Rp	1506	1013	12.85	10.43
Ave. all Sp	1273	962	13.09	10.84

Laboratory Data, Land Use and Treatment After the 1960 Harvest

During the last summer and fall of 1960 soil samples were collected from each of the plots and analyzed for total phosphorus (perchloric acid digestion method), available phosphorus (leached with 0.1 normal acetic acid in the ratio of 1 part of soil to 40 parts of acid), pH (paste, using glass electrode), and total nitrogen.

The total phosphorus was determined in the plowed zone (0 to 6 inches), and at a depth of 9 to 12 inches. The 6 to 9 inch zone was discarded as a possible zone of admixture due to tillage operations primarily. The object of the phosphorus tests was to find out about the previous movement of applied phosphorus in the profile, and to secure an idea as to the availability of any accumulated phosphorus.

In 1916 the average nitrogen content of the plowed zone was 0.108 percent. The nitrogen data in 1960 indicate an average of approximately 0.06 percent for the no treatment soil plots.

Nitrogen Top Dressing Effects

The same respective areas used for wheat and sorghum in 1959 and 1960 were used in 1961 for a nitrogen top dressing study. However, instead of having quadruplicate plots, two complete sets of plots for each

Table 19. Forage Sorghum — The effect of top dressing previously fertilized plots with nitrogen (1961).

Soil Data (Fall 1960) before applying any nitrogen as a top dressing.

Treatment	Total N %[1]	Total P[1] 0-6 ins. lbs/a[2]	Total P[2] subsurface lbs/a	Available P[3] lbs/a	pH
None	----	---		--	---
M	.0721	485		21	6.5
ML	.0737	502		29	7.2
None	.0693	366	322	20	6.4
ML Rp	.0729	839	331	374	7.1
ML Sp	.0801	594	314	136	7.1
None	.0622	363		16	6.1
Res	.0717	378		8	6.0
Res L	.0654	346		14	6.8
None	.0638	360	319	13	6.0
Res L Rp	.0664	739	288	300	6.8
Res L Sp	.0726	496	334	62	6.8
None	.0627	359		14	6.0
N	.0703	348		14	6.0
NL	.0652	329		10	6.9
None	.0627	340	310	12	5.9
NL Rp	.0715	684	323	268	6.9
NL Sp	.0705	476	328	63	6.9
None	.0682	395		14	6.4
NLK	.658	380		24	6.8
NLK Rp	.0640	652		238	6.9
None	.0659	389		26	6.1
L	.0646	366		17	6.8
G	.0739	403		12	6.2
None	.0637	391		9	5.6
GM	.0774	519		32	6.1
GM Rp	.0730	836		306	6.1
None	.0703	446		29	5.5
Ave. all "none"	.0654	379		17	
Ave. all Rp	.0696	650		---	
Ave. all Sp	.0744	522		---	

[1] Average of 4 composites — each composite was made from 10 different locations; surface 0-6 in.
[2] Calculated on a 2,000,000 pounds basis.
[3] Soluble (leaching procedure) in 0.1N acetic acid.
[4] Due to wet soil conditions the harvest was not made until December; air-dried weights.

Table 19. Continued

Sorghum Data for the 1961 Season

Treatment	Sorghum forage lbs/A[4]		Nitrogen (%) in forage Ave. Sept. 18- Oct. 9		Ave. Oct. 28	
	Top dressed with N	No N	Top dressed with N	No N	Top dressed with N	No N
None	----	----	---	---	---	---
M	6666	4630	1.11	0.57	0.55	0.54
ML	7137	3888	0.92	0.52	0.53	0.40
None	5634	3253	1.15	0.55	0.51	0.45
ML Rp	5809	5281	0.86	0.49	0.50	0.28
ML Sp	6130	5084	0.95	0.51	0.61	0.37
None	7235	3183	1.05	0.70	0.62	0.49
Res	5335	2404	0.91	0.57	0.47	0.27
Res L	6079	3292	0.92	0.52	0.63	0.44
None	3713	3673	1.21	0.58	0.68	0.43
Res L Rp	7650	2509	0.81	0.51	0.64	0.44
Res L Sp	6515	3488	0.86	0.48	0.53	0 44
None	3433	2479	Not Determined		0.89	0.43
N	2324	2434	Not Determined		0.87	0.51
NL	3053	4238	Not Determined		0.77	0.29
None	3356	2505	1.23	0.62	0.85	0.43
NL Rp	4546	3964	1.01	0.72	0.76	0.33
NL Sp	6479	3595	0.88	0.47	0.63	0.35
None	3489	3538	Not Determined		0.84	0.32
NLK	3361	3204	1.05	0.67	0.70	0.59
NLK Rp	4632	4101	1.11	0.62	0.69	0.43
None	3035	2628	1.39	0.67	0.92	0.48
L	3930	3339	Not Determined		0.69	0.42
G	3374	2687	Not Determined		0.30	0.30
None	4146	2969	Not Determined		0.54	0.47
GM	5433	4459	Not Determined		0.59	0.35
GM Rp	7556	4731	1.23	0.64	0.76	0.34
None	6124	4603	1.44	0.56	---	---
Ave. all "none"	4463	3203	1.24	0.61	0.76	0.44
Ave. all Rp	6938	4117	1.00	0.60	0.67	0.36
Ave. all Sp	6375	4055	.90	0.49	0.59	0.39

of these crops were top dressed with ammonium nitrate. This left for checking purposes duplicate plots of all former treatments for each crop. Ammonium nitrate was applied at the rate of 125 pounds per acre to the wheat on February 15, 1961. The wheat was barely starting its spring vegetative growth at this time. This same fertilizer was applied at a rate of 200 pounds per acre to the 8-inch drilled sorghum on July 18, 1961. The sorghum at this time was about 12 inches in height, and had a slightly yellow color.

Plot data including analytical data on the soil, crop yields, protein content of the wheat grain from certain treatments, and nitrogen content of sorghum forage are recorded in Tables 18 and 19.

Summary

Comments on Wheat Data

The average increase in wheat yield on the "no treatment" plots due to top dressing of nitrogen was not sufficient to pay the cost of the fertilizer on this low available phosphorus soil.

The use of a nitrogen fertilizer on the old residue plots without phosphorus had no effect on the wheat yield.

A top dressing with nitrogen increased the wheat yield in all cases where the soil had accumulated phosphorus from previous phosphate applications. This average increase amounted to slightly over 7 bushels of wheat per acre.

Nitrogen top dressing increased the yield of wheat on land previously treated with rock phosphate 8.2 bushels per acre. (The total previous application of rock phosphate was 4500 pounds per acre).

Nitrogen top dressing increased the yield of wheat on land previously treated with superphosphate 5.2 bushels per acre. (The total previous application of superphosphate was 2250 pounds per acre).

The residual effect of the previously applied phosphate fertilizers with other materials and without a top dressing of nitrogen, was appreciable. The increase in wheat yields in these plots over the no treatment plots average 3.4 bushels per acre.

Phosphorus decreased the percentage of protein in the wheat.

While a decrease in protein in the wheat occurred whether or not a top dressing of nitrogen was applied to the previously phosphated plots, the top dressing with nitrogen brought the average protein up to 12.97 percent compared with 10.64 percent where no nitrogen top dressing was made.

The average protein content of "previous no treatment plots" was 12.30 percent compared with 15.12 percent where these no treatment plots received a top dressing of 125 pounds of ammonium nitrate per acre.

Comments on Sorghum Data with Observational Notes

A top dressing of nitrogen rapidly changed the slightly yellow color of the sorghum foliage to a darker green color.

The use of nitrogen as a top dressing (200 pounds of ammonium nitrate per acre) increased the yield of sorghum forage on all previously treated plots except for those where only nitrogen or nitrogen and lime had been applied.

The average increase of sorghum forage yield due to a top dressing

of nitrogen over otherwise untreated plots was 1260 pounds per acre. Whether this is economical depends on the need for the forage. The cost of the ammonium nitrate treatment was approximately $8.50 per acre.

Sorghum forage yields on previously phosphated land top dressed with nitrogen were increased approximately one ton per acre over the yields secured from the same treatments without the top dressing with nitrogen.

The use of a nitrogen top dressing increased the nitrogen content of the forage (the nitrogen data are on oven dried material), especially with early harvested forage.

The Effect of Previously Applied Fertilizer on Some Soil Conditions

The results of some analytical work done on the soils collected in 1960 are of interest. The pertinent data are summarized from Tables 18 and 19 and presented in Table 20.

Land which was fertilized with rock phosphate or superphosphate accumulated phosphorus in the plowed zone. The slight increase of total phosphorus in the subsurface with the use of superphosphate, and in the wheat series (Part I) with rock phosphate, are of little significance. The wheat series (Part I) received during the preceding 42 years slightly less than one-half the total amount of phosphorus as did the soil in Part II. This is reflected in the accumulated phosphorus in the two areas. Much of the phosphorus applied to Part I was during the first twelve years of the 42 year period (1916-1958) while fertilization of Part II was continued throughout the whole of this period of time. It is reasonable to assume that this accounts in a large measure for the difference in the percentage of increase in availability of the accumulated phosphorus due to phosphate fertilization in the two areas. Some phosphorus accumulation has occurred where manure has been used continuously throughout the 42 year period. The availability of the phosphorus is somewhat better where manure was used than where no manure was applied.

The use of limestone on Part II every 4 years from 1916 to and including 1941 is reflected in the higher pH of the limed plots over that of the limed plots in Part I. Liming was discontinued in Part I in 1925.

None of the treatments maintained the nitrogen content of the soil. The superphosphate combinations appear to be slightly better than the other treatments in this respect, however.

Table 20. Soil Data from Previously Treated Plots.

Treatments	pH	Nitrogen[1] %	Total P[1] lbs/a	Available[3] lbs/a	Increase in Total P[1] lbs/a	Increase in Available P lbs/a	% of P increase available	Total P in subsurface lbs/a[2]
Land used for wheat in 1959-61 and designated as Part I in the text.								
No treatment	5.7	.0686	381	6	-----	----	----	315
No manure								
+ No P	5.6*	.0686*	376*	7*	-----	----	----	---
	5.9(L)	.0700(L)	368(L)	6	-----	----	----	---
Manure+No P	6.1*	.0722*	394*	11*	-----	5	----	---
	6.5(L)	.0692(L)	349(L)	10(L)	-----	4	----	---
All plots with Rp	---	.0708	532	72	151	66	43.7	348
All plots with Sp	---	.0722	440	20	59	14	23.7	336
Land used for sorghum in 1959-1961 and designated as Part II in text.								
No treatment	6.0	0.654	379	17	-----	----	----	317
No manure								
+ No P	6.1*	0.720*	376*	11*	-----	----	----	---
	6.8(L)	0.653(L)	373(L)	16(L)	-----	----	----	---
Manure+No P	6.3*	0.747*	502*	27*	123*	10*	8.1*	---
	7.2(L(	0.737(L)	502(L)	29(L)	123(L)	12(L)	9.6(L)	---
All plots with Rp	---	.0696	750	297	371	280	75.4	314
All plots with Sp	---	.0744	522	87	143	70	49.0	325

[1] In the surface 2,000,000 pounds of soil.
[2] In 2,000,000 pounds of subsurface soil.
[3] As removed by 0.1 normal acetic acid leaching.
[4] No distinction was made between limed and unlimed since the last liming was in 1925. Very little difference in pH values between the limed and unlimed plots existed.
*Unlimed; (L) limed.