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Soil Fertility Studies For Improved Wheat Production In Eastern Oklahoma, 1957-1960

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Contents

Acknowledgments

Experiments reported in this bulletin were conducted at the Shi Ketchem farm near Liberty in Tulsa County; at the A. A. Jeffry farm near Wagoner in Wagoner County; and at the Vocational Agriculture Demonstration Farm near Vinita and the Vocational Agriculture Demonstration Farm near Welch, both in Craig County. The authors gratefully acknowledge the cooperation and assistance of these farmer cooperators, the County Agents, and the Vocational Agriculture Departments at Liberty, Vinita, and Welch.

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Soil fertility is a principal limiting factor for hard red winter wheat production in eastern Oklahoma. Wheat in this area is generally grown on permeable upland prairie soils and associated claypan soils. Climatic conditions are usually favorable for small grain and winter pasture production if adequate plant nutrients are supplied by proper fertilization.

Experiments were designed to determine fertilizer responses on typical eastern prairie permeable upland and claypan soils. Studies were initiated on some soils that had previously been managed with soil-improving practices, and some with soil-depleting practices. Kinds of fertilizer, rates and time of application, and residual and cumulative effects from fertilizer application are reported in this bulletin.

Procedure

Field experiments were established on Dennis silt loam in Tulsa and Wagoner counties, and on Parsons silt loam at two locations in Craig County. Brief descriptions of the soil characteristics are presented with the data tables.

Wheat was fall planted at the four locations. Phosphorus and potassium fertilization treatments were applied at planting . Time and method of nitrogenous fertilizer applications were as indicated by the experimental plan at each location. Randomized block experimental designs were used at all sites. Ammonium nitrate (33.5% N), superphosphate (20% P_2O_5)* and muriate of potash (60% K_2O)* were used as plant nutrient sources in these studies.

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* Plant nutrient composition of fertilizers are expressed in this report as oxides rather than on an elemental basis.

P_2O_5 contains approximately 43.7% P

K_2O contains approximately 83% K

Research reported herein was done under Oklahoma Agricultural Experiment Station Project Number 898.

Experiments on Dennis Silt Loam

Tulsa County, near Liberty

Studies were located on Dennis silt loam that had been farmed continuously for over 50 years. No commercial fertilizer had been used during that period. One ton of lime per acre had been applied approximately ten years before the start of the experiments.

Phosphorus rates of 0, 20, 40 and 80 lbs. P_2O_5 per acre,* and potassium rates of 0 and 60 lbs. K_2O** were applied at time of planting. Nitrogen treatments include 0, 20, 40 and 80 lbs. N per acre applied in February or March, topdressed on the established stand. Details of the fertilizer treatments and yields for the four-year period of 1957 to 1960 are presented in Table 1. Yield responses are shown in Figure 1.

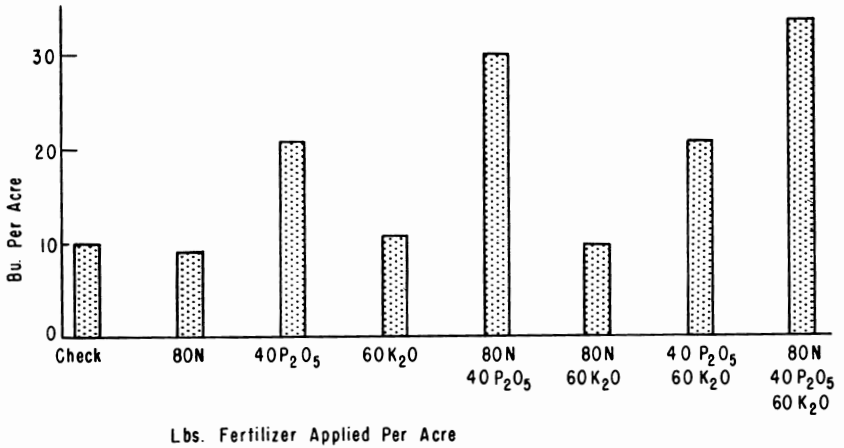

Figure 1. Yield response of Concho wheat to fertilization. Dennis silt loam, near Liberty, Tulsa County. 1957-1960. Wheat yields increased when adequate phosphorus was applied. The results indicated the importance of a proper balance of N, P_2O_5 and K_2O.

Phosphorus was the first limiting plant nutrient on this soil, and other fertilizer treatments were ineffective for increasing wheat yields unless adequate phosphorus was present. When adequate phosphorus was applied, nitrogen was the next limiting factor. Potassium increased yields after phosphorus and nitrogen were supplied in the fertilizer treatment.

*Twenty lbs. P_2O_5 per acre supplies about 8¾ lbs. P; 40 lbs. P_2O_5 per acre supplies about 17½ lbs. P; 80 lbs. P_2O_5 per acre supplies about 35 lbs. P.

**Sixty lbs. K_2O per acre supplies about 50 lbs. K.

Table 1.—Effect of Various Soil Fertility Treatments on Yields of Concho Wheat. Dennis Silt Loam at Liberty, Tulsa County, 1957-1960.

Treatment (lbs./A)			Yield (bushels per acre)[1]				
N	P_2O_5	K_2O	1957	1958	1959	1960	Four-Year Average
0	0	0	8.8	8.3	9.8	12.2	9.8
80	0	0	9.7	5.8	9.1	12.0	9.2
0	40	0	13.9	21.9	17.4	30.4	20.9
0	0	60	9.6	9.8	12.5	11.3	10.8
80	40	0	18.9	38.3	25.6	37.9	30.2
0	40	60	14.1	24.2	18.3	28.2	21.2
80	40	60	20.9	39.4	29.9	45.8	34.0
80	0	60	8.4	8.6	12.5	11.6	10.3
20	40	60	17.3	30.3	25.0	28.3	25.2
40	40	60	19.1	39.6	26.8	36.9	30.6
80	20	60	17.5	29.2	28.1	30.9	26.4
80	80	60	18.6	36.4	31.7	45.8	33.1
Error Mean Square			1.68	2.27	2.08	2.31	
Treatment F**			7.47	33.94	15.65	32.11	

** Indicates F value statistically significant at the one percent level.

[1] Yields are means from three replications. Phosphorus and potash fertilization was applied at planting, nitrogen fertilization was applied in February or March as topdressing to the established stand.

Dennis silt loam is a major upland prairie soil of central and eastern Oklahoma. This soil occupies gentle to moderate slopes, has good surface drainage and is often damaged by erosion when placed under cultivation. Soil fertility is usually a limiting factor for the production of both cool and warm season crops on this soil. Non-fertilized Dennis silt loam in this field is acid in reaction, pH 5.6 to 5.9. It has a low level of available phosphorus, 2 to 12 pounds per acre; a medium content of exchangeable potassium, 80 to 140 pounds per acre; and a medium to low content of organic matter, 2 to 3 percent. A detailed description of this soil under its previous name of Bates very fine sandy loam is found in the *Soil Survey of Tulsa County, Oklahoma.* E. W. Knobel and O. H. Brensing, USDA Series 1935, No. 22. February, 1942.

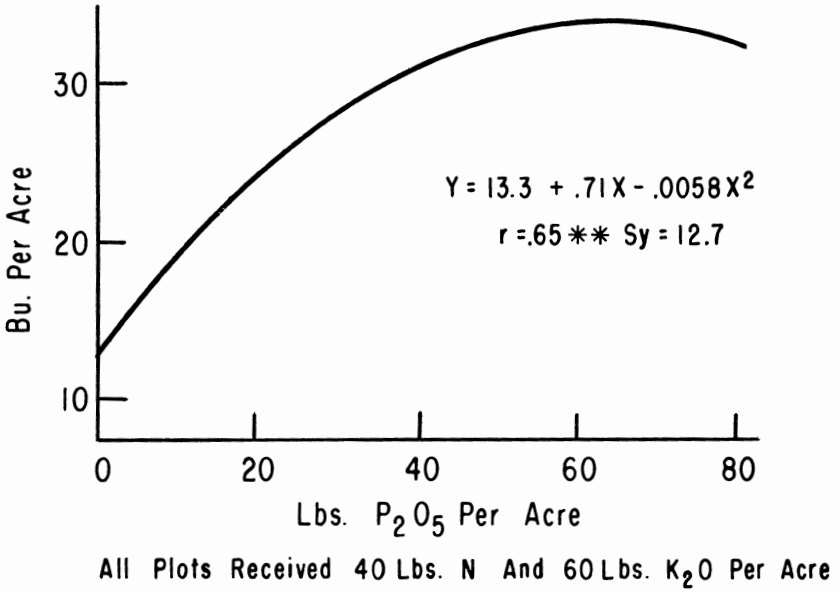

Figure 2. Yield response of Concho wheat to increased rates of phosphorus, when adequate nitrogen and potassium were applied. Dennis silt loam, near Liberty, Tulsa County. 1957-1960.

The highly significant yield response to rates of phosphorus when adequate nitrogen and potassium were applied is shown in Figure 2. Highest yields were indicated between 40 and 80 lbs. P_2O_5 applied per acre. The four-year average was 10.3 bushels per acre when 80 lbs. N and 60 lbs. K_2O per acre were applied without phosphorus. An average yield of 26.4 bushels was obtained when 20 lbs. P_2O_5 was combined with these N and K_2O treatments. Forty pounds P_2O_5 per acre with these N and K_2O rates gave an average yield of 34.0 bushels. An average of 33.1 bushels was obtained with the 80 lbs. P_2O_5 per acre rate combined with these N and K_2O rates.

The highly significant yield response obtained for rates of nitrogen application when combined with adequate phosphorus and potassium is shown in Figure 3. Largest yield increases per pound of N were obtained up to the 40 lb. per acre rate. A four-year average of 21.2 bushels was obtained when 40 lbs. P_2O_5 and 60 lbs. K_2O per acre were applied with no nitrogen. Nitrogen combined with 40 lb. P_2O_5 and 60 lb. K_2O yielded an average of 25.2 bushels at the 20 lbs. per acre rate, 30.6 bushels at the 40 lb. per acre rate, and 34.0 bushels at the 80 lb. per acre rate.

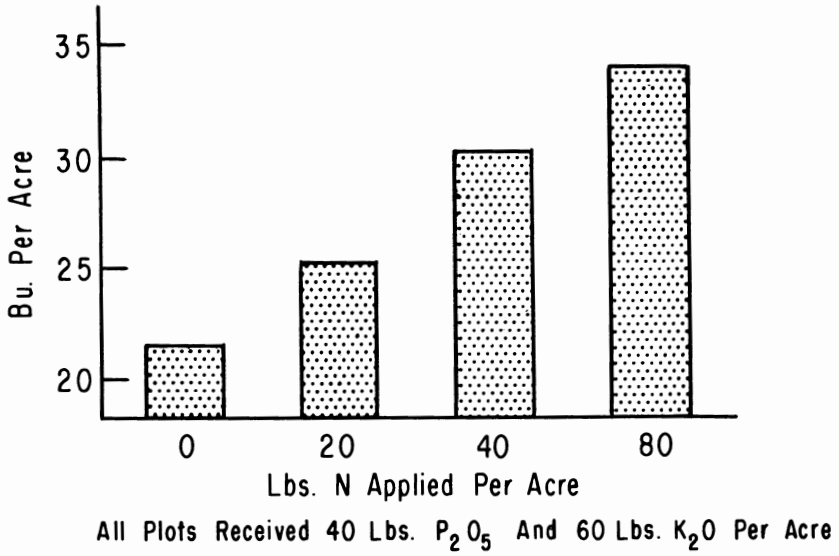

Figure 3. Yield response of Concho wheat to increased rates of nitrogen, when adequate phosphorus and potassium were applied. Dennis silt loam, near Liberty, Tulsa County. 1957-1960. The nitrogen fertilizer was topdressed in the spring on the established wheat crop.

Wagoner County, near Wagoner

The field of Dennis silt loam in which this experiment was established had been well managed to improve the active organic matter level, with frequent legume crops and plant residue returned to the soil. The field had been limed and fertilized, and crop rotations used with rye and vetch, lespedeza and soybeans. Plot samples were taken in 1957 for yield measurements. However, unusually wet weather throughout May and June of that year prevented combine harvest of the field. The entire residue of that wheat crop was plowed under.

Soil fertility treatments in this study included three nitrogen rates of 0, 40 and 80 lbs. per acre, three phosphorus rates of 0, 40 and 80 lbs. P_2O_5 per acre, and two potassium rates of 0 and 40 lbs. K_2O per acre. All possible combinations of these treatments were used. Phosphorus and potassium fertilizer were applied at planting. Nitrogen fertilization was topdressed in early spring on the wheat stand. Details of the treatments and yields for 1957, 1958 and 1959 are presented in Table 2.

Table 2.—Effects of Various Soil Fertility Treatments on Yields of Concho Wheat. Dennis Silt Loam at Wagoner, Wagoner County. 1957-1959.

Treatment (lbs./A)			Yield (bushels per acre)[1]			
N	P_2O_5	K_2O	1957	1958	1959	Three-Year Average
0	0	0	8.9	16.8	23.8	16.5
0	0	40	11.3	22.6	26.5	20.1
40	0	0	9.7	17.3	26.6	17.9
40	0	40	9.5	20.1	33.8	21.1
80	0	0	10.3	14.1	24.7	16.4
80	0	40	8.8	16.6	28.7	18.0
0	40	0	10.5	31.4	40.3	27.4
0	40	40	11.9	35.9	44.2	30.7
40	40	0	11.5	25.7	37.8	25.0
40	40	40	12.8	36.5	43.6	31.0
80	40	0	8.4	26.2	36.3	23.7
80	40	40	10.3	29.2	43.9	27.8
0	80	0	12.8	34.3	47.9	31.7
0	80	40	7.3	38.0	44.8	30.0
40	80	0	9.1	31.7	42.4	27.7
40	80	40	10.4	37.8	43.6	30.6
80	80	0	11.7	24.8	39.4	25.3
80	80	40	9.8	34.1	51.0	31.7
Error Mean Square			1.11	2.14	4.0	
Treatment F**			1.18(n.s.)	11.19	4.43	

** Indicates F value statistically significant at the one percent level.

[1] Yields for each year are means from three replications. Phosphorus and potassium fertilizer treatments were applied at planting. Nitrogen fertilization treatments were applied as top-dressing to the established stand in February or March.

A brief description of this soil type is presented with Table 1. Samples of non-fertilized Dennis silt loam in this field were similar to the Liberty area soil in reaction with pH 5.4-5.8; slightly higher in available phosphorus, 10 to 20 pounds per acre; similar content of exchangeable potassium, 90 to 150 pounds per acre; and the same in range of organic matter, 2 to 3 percent. A more detailed description of this general soils area can be found in *Soils of Wagoner County, Oklahoma,* H. M. Galloway, F. Gray and H. F. Murphy, Okla. Agr. Exp. Sta. Misc. Pub. MP 42. February, 1955. A detailed soil survey for this county will be published in the near future.

Consistent response to potassium fertilization was apparent on this field throughout the experiment. Figure 4 shows the increase in yield of 3 bushels per acre as a result of 40 lbs. K_20 per acre applied with 40 lbs. N per acre. Yields were increased six bushels per acre when 40 lbs. K_20 were combined with 40 lbs. N and 40 lbs. P_20_5 per acre. A three bushel increase was obtained when 40 lbs. K_20 was combined with 40 lbs. N and 80 lbs. P_20_5 per acre.

Figures 5 and 6 show that largest increases in yield were obtained with applications of phosphorus in all N and K_20 combinations. Adequate phosphorus applications were necessary for significant yield increases. The important interaction influence of potassium on this

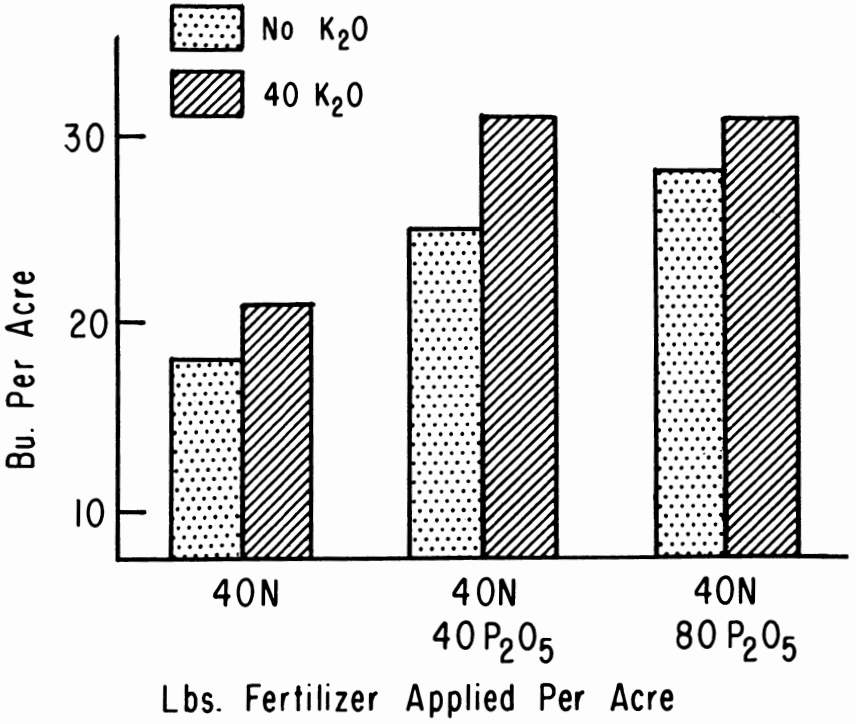

Figure 4. Yield response of Concho wheat to increased rates of potassium. Dennis silt loam, near Wagoner, Wagoner County. Three-year average, 1957-1959. Phosphorus and potassium fertilizer were applied at planting. Nitrogen fertilization was topdressed in early spring on the established wheat stand.

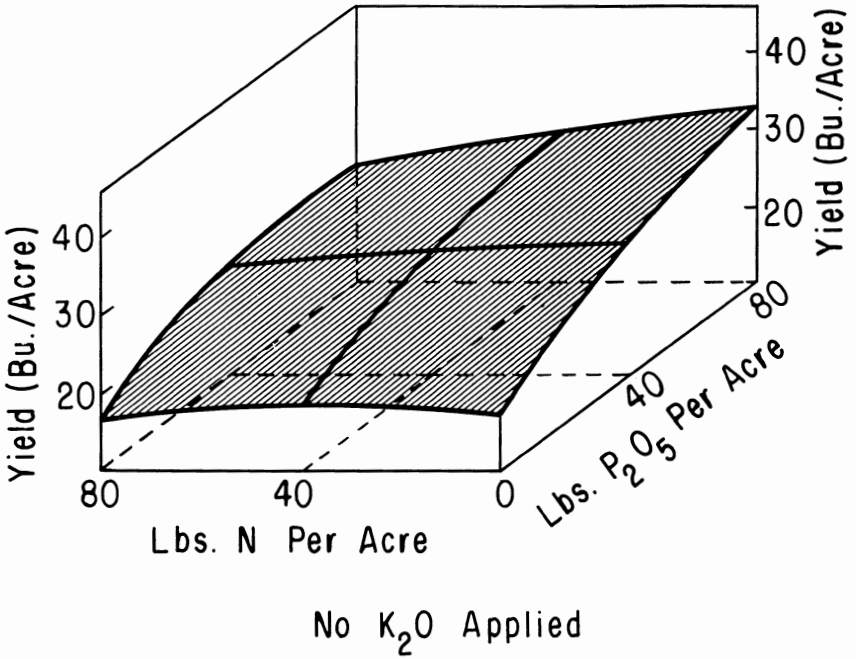

Figure 5. Yield response of Concho wheat to increased rates of phosphorus and nitrogen, when no potassium was applied. Well-managed Dennis silt loam, Wagoner County. Three-year average, 1957-1959. Yields increased as rates of phosphorus were increased; however, with no potassium included in the treatment, additional nitrogen did not increase yields at any phosphorus level.

well managed soil is shown when comparing the three-dimensional diagrams. Note that no increases were obtained with N application at any of the P_2O_5 combinations when no K_2O was applied (Figure 5). With the application of 40 lbs. K_2O (Figure 6), yields were increased with all rates of nitrogen when combined with 40 and 80 lbs. P_2O_5 per acre.

Experiments on Parsons Silt Loam

Craig County, near Welch

Experiments were continued on Parsons silt loam, a claypan soil, located at the Welch Vocational Agriculture demonstration farm.

Results from experiments conducted at this location for the years 1953, 1954 and 1955*, indicate that phosphorus was the first limiting

* Oklahoma Agricultural Experiment Station Bulletin, B-488, *Wheat Fertilization on Claypan Soils in Northeastern Oklahoma,* O. H. Brensing and J. Q. Lynd. 1957.

factor, with significant yield increases obtained only when nitrogen application was combined with phosphorus fertilization. Increased yields with potassium application were obtained when combined with nitrogen and phosphorus fertilization. The time of nitrogen application made no significant difference.

Similar results of yield response to nitrogen, phosphorus and potassium fertilization were obtained in 1958, 1959 and 1960. Details of the treatments and yields are presented in Table 3. Superphosphate at 40 lbs. P_2O_5 per acre resulted in the highest yield increase for a single plant nutrient addition. The check (0-0-0) yield for the three-year period was 18.4 bushels per acre. A three-year average yield of 42.2 bushels was obtained when 40 lbs. P_2O_5 (0-40-0) per acre were applied. This was a highly significant yield increase of 23.8 bushels per acre.

Adequate phosphorus application was necessary on this soil before response to potassium was obtained. The three-year average for the 60 lbs. K_2O (0-0-60) per acre was 19.0 bushels. However, when K_2O at

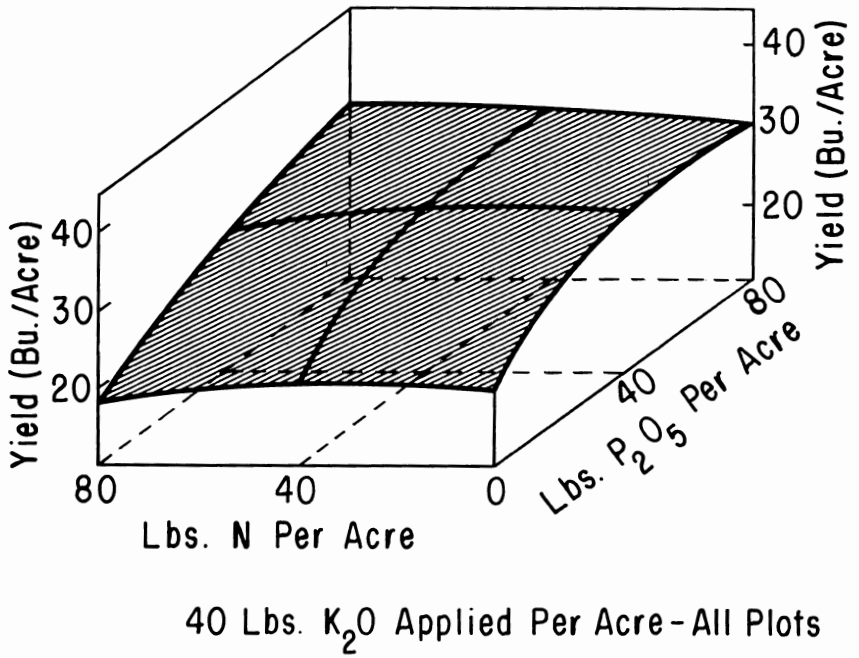

Figure 6. Yield response of Concho wheat to increased rates of phosphorus and nitrogen when 40 lbs. per acre of potassium was applied. Well-managed Dennis silt loam, Wagoner County. Three-year average, 1957 to 1959. Nitrogen applications increased yield when combined with adequate phosphorus and potassium.

Table 3.—Effects of Various Soil Fertility Treatments on Yields of Triumph Wheat. Parsons Silt Loam at Welch, Craig County. 1958-1960.

Treatment (lbs./A)			Yield (bushels per acre)[1]			
N	P_2O_5	K_2O	1958	1959	1960	Three-Year Average
0	0	0	18.4	24.0	12.7	18.4
80	0	0	21.4	28.6		25.0
0	40	0	42.9	51.9	32.1	42.2
0	0	60	18.6	24.2	14.2	19.0
80	40	0	44.6	51.2	44.7	46.8
80	0	60	21.4	32.1	13.5	23.5
0	40	60	43.7	51.0	32.6	42.4
80	40	60	40.4	52.4	39.5	43.1
20	40	60	50.1	59.0	41.9	50.3
40	40	60	43.6	52.2	38.8	44.8
80	20	60	42.7	50.3	35.0	42.7
80	80	60	47.7	59.5	41.9	49.7
20[2]	40	60	45.3	52.0	42.5	46.6
40[2]	40	60	49.9	53.3	42.1	48.4
80[2]	40	60	43.2	56.2	48.4	49.3
Error Mean Square			2.33	2.87	4.72	
Treatment F**			25.36	18.85	10.80	

** Indicates F value statistically significant at the one percent level.

[1] Yields for each year are means from four replications. Phosphorus and potassium fertilizer treatments were applied at planting.

[2] Nitrogen fertilizer treatments were applied at planting. All other nitrogen fertilizer treatments were applied to the straw of the preceding crop prior to plowing in the summer months before fall planting.

Parsons silt loam is located on nearly level prairies, with poor surface drainage and heavy clay subsoil, giving the term claypan soils. Parsons is very slowly permeable and internal drainage is a major problem for production of cultivated crops. Samples of the unfertilized plots in this field were strongly acid in reaction, pH 4.8 to 5.2; have a low content of available phosphorus, 10 to 20 pounds per acre; a medium content of exchangeable potassium, 75 to 120 pounds per acre; and low organic matter content of 1 to 2 percent. A detailed description of this soil is found in *Soil Survey of Craig County, Oklahoma.* A. C. Anderson, A. W. Goke, O. H. Brensing, R. E. Penn and C. B. Boatright, USDA Series 1931, No. 24.

this rate was combined with 40 lbs. P_2O_5 (0-40-60), the three-year average was 42.4 bushels per acre.

A study was conducted to determine if applying nitrogenous fertilizers to wheat straw before plowing it under would improve humus formation to store nitrogen for later use by the growing crop. Varying rates of nitrogen were applied to the straw before plowing it under. The same nitrogen rates were applied to wheat on other plots at fall planting. Adequate phosphorus and potassium were applied to all plots used in the comparison.

Results from this study were similar during the three years (Figure 7). Both methods of applying nitrogen appeared about equal in effectiveness for supplying nitrogen to the growing crop. These data indicate that straw fertilization with nitrogen offers a possibility for permanent soil fertility improvement with continuous wheat cropping on claypan soils of this area.

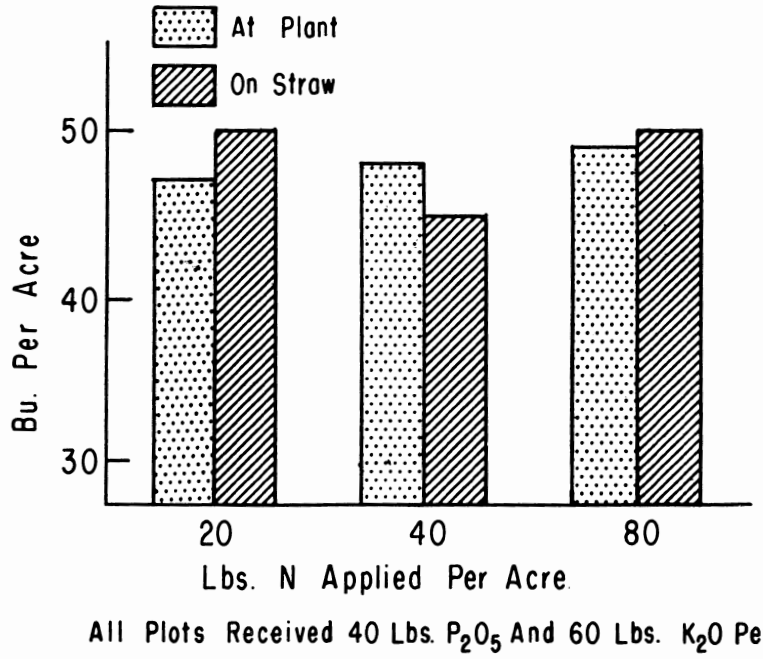

Figure 7. Yield response of Triumph wheat when nitrogen was applied to wheat straw and stubble before plowing, compared to application at time of planting. Parsons silt loam, Welch, Craig County. Three-year average, 1958 to 1960.

Rates and methods of nitrogen fertilization remain of great practical significance for increasing yields and improving soil productivity through soil organic matter and biological activity.

Craig County, near Vinita

A study was made to evaluate the residual effect from fertilizers applied to crops that fail. This experiment was established on Parsons silt loam at the Vocational Agricultural demonstration farm located near Vinita. Previous years of fertilization and soil management of crop residues resulted in a moderately high fertility level for this soil type. Barley plantings in soil fertility experiments on the field had been lost in previous years due to poor soil drainage. Details of the experiment, fertilizer treatments and yield data are presented in Table 4. Wheat yields were compared on plots that received continued fertilization and plots that were not fertilized at planting (Figure 8).

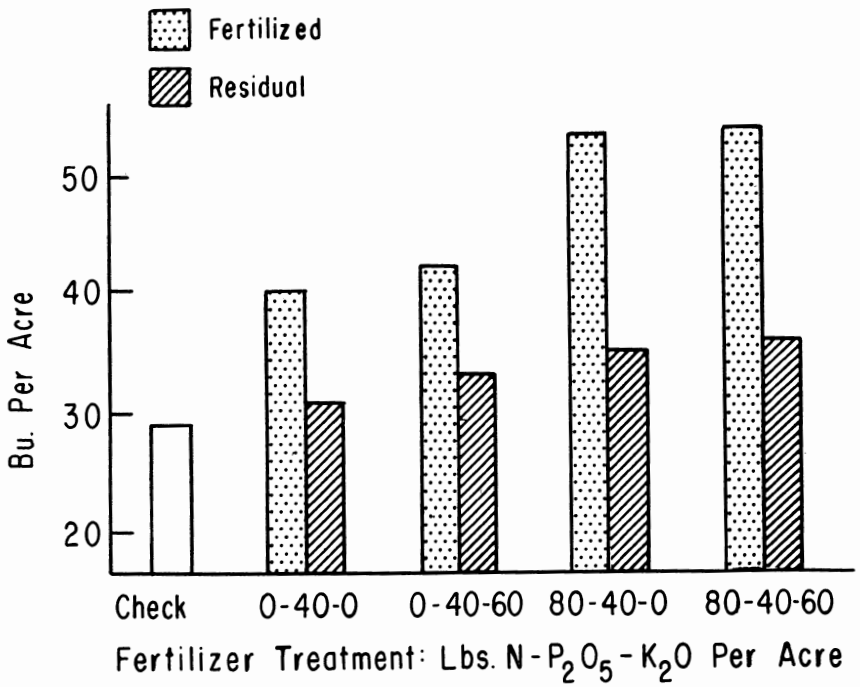

Figure 8. Yield response of Concho wheat which received continual N—P_2O_5—K_2O fertilizer treatment, compared to fertilizer applied to barley crops that had failed in 1957 and 1958. Parsons silt loam, Vinita, Craig County. Two-year average, 1959 and 1960.

Check (0-0-0) yields averaged 29 bushels per acre. Average yields from 40 lbs. P_2O_5 (0-40-0), 40 lbs. P_2O_5 plus 60 lbs. K_2O (0-40-60), 80 lbs. N plus 40 lbs. P_2O_5 (80-40-0), and 80 lbs. N plus 40 lbs. P_2O_5 plus 60 lbs. K_2O (80-40-60), were 40, 42, 54 and 55 bushels, respectively. Average yields from plots that had received these same treatments applied only with the barley plantings were 31, 33, 36 and 37 bushels, respectively.

Significant increases in wheat yield were obtained with nitrogen and phosphorus fertilization, and with potassium applications when combined with nitrogen and phosphorus.

Table 4.—Effect of Annual Fertilization on Yields of Concho Wheat and the Residual Effects of Previous Soil Fertility Treatments. Parsons Silt Loam at Vinita, Craig County. 1959-1960.

Treatment (lbs./A)			Yield (bushels per acre)[1]					
			Fertilized Annually			Residual from 1957 and 1958 Fertilization		
N	P_2O_5	K_2O	1959	1960	Average	1959	1960	Average
0	0	0	36.1	21.8	29.0			
80	0	0	46.2	26.0	36.1	40.2	19.2	29.7
0	40	0	55.4	24.0	39.7	44.6	17.8	31.2
0	0	60	38.0	21.4	29.7	40.8	18.6	29.7
80	40	0	64.5	43.4	53.9	47.8	23.2	35.5
0	40	60	54.0	29.4	41.7	46.0	20.0	33.0
80	40	60	66.6	43.3	54.9	47.1	26.7	36.9
80	0	60	47.8	31.8	39.8	44.4	17.9	31.2
20	40	60	57.2	39.9	48.6	45.1	21.4	33.3
40	40	60	55.3	37.6	46.4	45.1	21.6	33.4
80	20	60	59.9	38.6	49.3	45.3	19.6	32.5
80	80	60	63.2	41.5	52.4	45.5	20.7	33.1
80	160	60	59.0	45.5	52.3	52.4	26.2	39.3
Error Mean Square			3.66	3.39		3.18	1.82	
Treatment F**			6.7	6.7		1.7 (n.s.)	5.11	

** Indicates F value statistically significant at the one percent level.

[1] Yields for each year are means from four replications, except the check (0-0-0), which had eight replications. All fertilizer treatments were applied at planting. Barley plantings were lost in 1957 and 1958 and no crops were harvested those years. Plots were then split with one half of each plot receiving no further fertilizer applications and termed residual plots for 1959 and 1960.

This soil type is briefly described with Table 3. Soil samples from the non-fertilized areas in this field were characterized by a soil reaction of pH 4.95 to 5.3, available phosphorus of 1.6 to 4.5 pounds per acre; exchangeable potassium of 80 to 100 pounds per acre; and an organic matter content of 1 to 2.5 percent.

Summary

This bulletin reports results from field experiments conducted to determine wheat yield response to various fertilization practices in eastern Oklahoma from 1957 to 1960.

Findings from these studies include the following:

- Highly significant and profitable increases in wheat yields were obtained with proper rates and combinations of nitrogen (N), phosphorus ($P_2 0_5$), and potassium ($K_2 0$) fertilization on upland permeable and claypan prairie soils. Results showed the need for proper balance of these plant nutrients.

- Response to various fertilization combinations varied with the soil type and previous soil management. However, the first limiting plant nutrient for wheat yields at all field experiment locations was phosphorus, and highest yields were obtained only when adequate phosphorus was applied.

- Wheat yields increased with nitrogen fertilization when the N treatments were combined with adequate phosphorus and potassium. The magnitude of response to nitrogen additions was influenced greatly by previous soil treatments. Yields were not increased on well-managed Dennis silt loam to various N and $P_2 0_5$ combinations unless combined with applications of 40 lbs. $K_2 0$ per acre.

- Results from this and previous studies have shown no significant difference in yields from different times of applying nitrogen fertilizer to the wheat crop. Nitrogen fertilizer applied on Parsons silt loam to the wheat stubble and straw just prior to plowing was as effective as the same N rates applied at planting.

- Residual effects from nitrogen, phosphorus and potassium fertilization applied to crops that failed on claypan prairie soils gave significant increases in wheat yields.

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