Grain Sorghum Fertilization in Northwestern Oklahoma

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by
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Next to wheat, sorghum is the most important crop on the sandy soils of northwestern Oklahoma, and sorghum and wheat together usually occupy about 90 percent of the cropped land. The relations of cultural practices to grain sorghum production were studied at the Southern Great Plains Field Station from 1915 to 1948 (1).

Research reported herein was made to determine the fertilizer and moisture needs of continuously cropped grain sorghum on sandy soils in northwestern Oklahoma.

Two experiments, one started in 1954 the other in 1957, were involved. The 1954 experiment was designed to study moisture use by different sorghum varieties, and a fertilizer variable was added in 1958. The 1957 experiment was designed to determine the nitrogen, phosphorus, and potassium needs of grain sorghums.

Precipitation and Soils

Table 1 shows that precipitation was above the longtime average in the test area for five consecutive years in which fertilizer variables were studied. As a result, grain yields and response to fertilizer were above average during this period. Precipitation was below average only in 1962 and 1963.

The major part of the fertilizer study was located on Enterprise fine sandy loam and the remainder on Woodward fine sandy loam soil. In 1957, the soil contained 0.84 percent organic matter, 0.038 percent nitrogen, 9 pounds of $NaHCO_3$-extractable P_2O_5 per acre, 314 pounds of exchangeable potassium per acre, and had a pH of 7.15.

Soil analysis data are not available for the Pratt and Carmen fine sandy loam soils at the site on which the moisture-use study was conducted; however, soil from the same general area contained 0.41 percent organic matter, 0.029 percent nitrogen, 25 pounds of $NaHCO_3$-extractable P_2O_5 per acre, and 210 pounds of exchangeable potassium per acre.

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TABLE 1.—Monthly and annual precipitation, Woodward, Oklahoma, 1957-1963

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
						Inches							
1957	0.80	1.17	5.54	5.38	11.41	7.88	T	0.70	3.95	4.35	1.56	0.11	42.85
1958	.91	.17	2.76	1.71	1.06	6.82	8.20	2.74	2.13	.02	1.11	.65	28.28
1959	.76	.43	1.96	2.49	6.23	2.72	1.48	4.37	3.75	2.52	.45	2.01	29.17
1960	1.83	4.28	1.60	.74	3.15	3.84	2.82	2.90	4.21	2.81	.18	1.30	29.66
1961	.09	1.31	2.64	.68	4.33	3.04	2.95	5.05	1.13	2.63	1.43	1.00	26.28
1962	.98	.10	.44	2.34	2.44	4.74	2.48	1.30	3.92	.70	.69	.91	21.04
1963	T	.24	.62	.89	2.59	3.51	3.61	1.96	3.06	.77	.74	.43	18.42
Average 1957-63	.77	1.10	2.22	2.03	4.46	4.65	3.08	2.72	3.16	1.97	.88	.92	27.96
Average 1914-63	.71	.94	1.42	2.31	3.82	3.14	2.35	2.41	2.38	2.24	1.09	.76	23.57

Procedure

Fertilizer Study

Table 2 shows the seven treatments which were studied in the fertilizer experiment. The treatments were arranged in a randomized block design on plots 16 feet wide by 110 feet long, and were replicated four times. The experiment was located on the same site and treatments were placed on the same plots each year.

Sources of fertilizer were: nitrogen, ammonium nitrate (33.5% N); phosphate, treblesuperphosphate (45% P_2O_5)[2]; and potash, muriate of potash (60% K_2O)[2] Nitrogen and potassium were broadcast on the soil surface before planting. Phosphorus was applied with a combination grain and fertilizer drill on 14-inch centers, at seed level and seven inches to the side of the seed. In 1959 and 1961 it was necessary to plant with a deep furrow drill because of dry surface soil, thus, phosphorus was applied on the surface with the nitrogen and potassium. In 1963, no fertilizer was applied but plots were planted and harvested to measure residual effects of previous fertilizer treatments.

Grain sorghum, variety Wheatland, was grown in 14-inch rows on stubble-mulch tilled soil. The seeding rate was approximately 4 pounds per acre and was sown in late June or early July each year. The crop was not cultivated after planting. At bloom stage, leaf samples were collected from each plot. Each sample consisted of the next-to-top leaf of 15 randomly selected plants. The samples were air-dried, ground, and analyzed for nitrogen, phosphorus, and potassium by methods outlined by Jackson (2).

Harvesting was done with a 7-foot self-propelled combine. Yields were taken from single 7-foot swaths through each plot. Only the grain was removed from the plots.

After harvest, the stubble was allowed to stand through the winter and until the weeds started growth in the spring. It was then undercut with a large, V-shaped blade (Noble).[3] Further cultivation before planting was with a weeder blade on the Noble plow, or with a rod weeder.

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[2] Plant nutrient composition of phosphorus and potassium 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

[3] Noble Cultivators Limited, Nobleford, Alberta, Canada. Reference to brand name does not infer endorsement or preferential treatment of the product listed by the U. S. Department of Agriculture.

TABLE 2.—Effects of fertilizer treatments on grain sorghum yields, Woodward, Oklahoma, 1957-1963

	Fertilizer Treatment							
N	0	60	0	30	60	60	60	
P_2O_5	0	0	60	60	30	60	60	
K_2O	0	0	0	0	0	0	120	
	Bushels							Avg.
1957	25.2 a[1]	26.4 a	27.3 a	29.9 a	27.7 a	31.5 a	28.9 a	28.1
1958	39.5 b	49.6 ab	40.3 b	50.4 ab	60.1 a	65.1 a	63 0 a	52.6
1959	28.4 b	47.7 a	17.7 c	41.8 a	48.9 a	46.1 a	48.8 a	39.9
1960	19.6 b	30.1 a	19.1 b	29 7 a	30.3 a	36.1 a	30.7 a	27.9
1961	39.7 bc	43.6 bc	33.3 c	49.8 abc	51.7 abc	58.5 ab	71.4 a	49.7
1962	12.8 c	17.4 bc	19.5 abc	29.3 a	27.3 ab	28.8 a	28.6 a	23.4
Six-Year Average	27.6 c	35.8 b	26.2 c	38.5 ab	41.0 ab	44.3 a	45.2 a	36.9
1963 Residual Yields	19.1 bc	15.6 c	16.4 c	23.9 ab	18.7 bc	27.8 a	16.6 c	20.3

[1] Means followed by the same letter are not significantly different at the .05 level.

Moisture Use Study

Sorghum varieties were grown in 42-inch rows on clean-tilled soil in the moisture-use study. From 1954-1957, Wheatland, Dwarf Yellow milo, and Sugar Drip sorgo were grown. In 1958, Texas 660 hybrid grain sorghum was substituted for Sugar Drip sorgo. Plots were split in this and succeeding years, and half of each plot was fertilized with 60 pounds of nitrogen and 60 pounds of P_2O_5 per acre per year. In 1962, Wheatland was grown on all plots and no fertilizer was applied. Plots were planted and harvested to measure residual effects of previous fertilizer treatments.

Results

Grain yields for the fertilizer experiment are presented in Table 2 and average yields of selected treatments in Figure 1. Fertilizer treatments produced significant yield increases in 5 of the 6 years. Average data for the six years show that all treatments receiving nitrogen or nitrogen and phosphorus produced significantly higher yields than the unfertilized check or phosphorus alone. The treatment that received potassium made the highest average yield but did not produce significantly higher yields than treatments receiving both nitrogen and phosphorus.

The 60-60-0 treatment outyielded the 30-60-0 and 60-30-0 treatments by averages of 5.8 and 3.3 bushels per acre, respectively. Though these increases are not statistically significant, they definitely indicate that the higher rates of nitrogen and phosphorus are required to produce maximum yields when soil moisture conditions are not limiting.

It is apparent that both nitrogen and phosphorus are required for maximum grain yields (Figure 1). The fact that nitrogen alone outyielded both phosphorus alone and the unfertilized (check) treatment

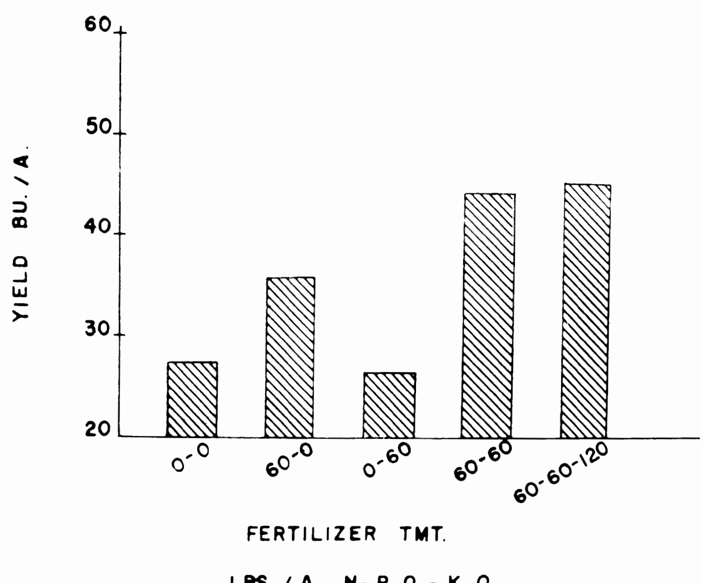

Figure 1.—Grain yields of selected treatments, grain sorghum fertilization study, Woodward, Oklahoma, 1957-62.

indicates that nitrogen was the first limiting factor in grain sorghum production on this soil. When applied with nitrogen, phosphorus also increased yields; thus, phosphorus may be termed the second limiting factor in grain sorghum production. Yields were below average in 1963 and only one previously fertilized treatment (60-60-0) yielded significantly more than the check treatment. The average yield level (20.3 bushels per acre) indicates that low moisture rather than soil fertility level limited yields in 1963. If so, little or no indication of residual fertilizer could be expected.

Grain yields from the moisture-use experiment are shown in Table 3. Yields from 1954-1957 are included to show the results obtained during a drouth period. Profitable fertilizer response cannot be expected with such low yield levels.

During 1958-1961, however, fertilizer produced an average yield increase of 26.8 bushels per acre for 60 pounds of nitrogen and 60 pounds of P_2O_5 per acre.

Even though yields were quite low in 1962 because of drouth, previously fertilized plots averaged 1.7 times the production as previously unfertilized plots. This was a remarkable response for such a dry year. It indicates that some of the fertilizer not used in one season remains in the soil for use the following season.

TABLE 3.—Average yields of fertilized and unfertilized grain sorghum[1] in the moisture-use experiment, Woodward, Oklahoma, 1954-1962

	1954	1955	1956	1957	Avg.	1958	1959	1960	1961	Avg.	1962
						Bu/Acre					
Unfertilized	2.9	9.3	9.2	4.4	6.5	30.2	19.2	32.9	32.2	28.6	9.9
Fertilized[2]	--	--	--	--	--	50.4	43.0	53.3	75.0	55.4	17.0

[1] 1954 through 1957, yields are averages for Wheatland and Dwarf Yellow milo; 1958 through 1961, yields are averages for Wheatland, Dwarf Yellow milo and Texas hybrid 660. Wheatland was grown on all plots in 1962.

[2] Fertilized with 60 pounds nitrogen and 60 pounds P_2O_5 per acre in 1958, 1959, 1960, and 1961. No fertilizer applied in 1962.

Average yields on fertilized treatments were significantly greater (5% level) than those on unfertilized treatments, 1958 through 1962

Leaf Analysis

Literature regarding the use of plant analysis as an aid to the solution of nutritional problems of plants growing under field conditions has been reviewed by Ulrich (3).

Leaf analysis data were collected to gain preliminary information on the effects of the various fertilizer treatments on nutrient levels in grain sorghum plants and to acquire preliminary information on the relation between nutrient levels in grain sorghum plants and grain yields. No "critical levels" can be established from the limited data collected in this study; however, there were trends.

Nitrogen content of the leaves at bloom stage (Table 4) was significantly increased by nitrogen applications in four of the five years in which leaf nitrogen data were collected. In these years, nitrogen content of leaves increased with increasing increments of applied nitrogen. Grain

TABLE 4.—Effects of fertilizer treatments on nitrogen content of grain sorghum leaves at bloom stage, Woodward, Oklahoma, 1957-1962

	Fertilizer Treatment							
N	0	60	0	30	60	60	60	
P_2O_5	0	0	60	60	30	60	60	
K_2O	0	0	0	0	0	0	120	
	PERCENT NITROGEN							Avg.
1957	2.50 a[1]	2.61 a	2.45 a	2.43 a	2.57 a	2.48 a	2.45 a	2.49
1958	1.55 d	2.29 a	1.41 d	1.82 c	2.19 ab	2.16 ab	2.04 b	1.92
1959	1.52 d	2.71 a	1.46 d	2.04 c	2.46 b	2.46 b	2.38 b	2.15
1960	(no data)[2]							
1961	1.78 bc	2.57 a	1.74 c	2.00 b	2.47 a	2.39 a	2.44 a	2.20
1962	1.60 c	2.40 a	1.55 c	1.98 b	2.42 a	2.33 a	2.35 a	2.09
Five-Year Average	1.79 e	2.52 a	1.72 f	2.05 d	2.42 b	2.36 bc	2.33 c	2.17

[1] Means followed by the same letter are not significantly different at the .05 level.
[2] Samples were inadvertently destroyed before nitrogen determinations were made.

yields were increased by nitrogen applications in four of the six years, and the initial increment of nitrogen (30 pounds per acre) was sufficient to produce yields that were not significantly different from those produced by 60 pounds of nitrogen per acre (compare 0-60-0, 30-60-0, and 60-60-0 treatments, Table 2). It appears that, under the conditions of this experiment, near maximum grain yields were obtained when the leaves contained about 2 percent of nitrogen at bloom stage.

Phosphorus content of the leaves at bloom stage (Table 5) was significantly increased by phosphorus applications in five of the six years. Phosphorus content of leaves increased with increasing increments of applied phosphorus in all five years. Though there were marked trends toward increased yields from applied phosphorus in most years, they were statistically significant only in 1962 (Table 2). This marginal response to phosphorus indicates an incipient phosphorus deficiency. Under these

TABLE 5.—Effect of fertilizer treatments on phosphorus content of grain sorghum leaves at bloom stage, Woodward, Oklahoma, 1957-1962

	Fertilizer Treatment							
N	0	60	0	30	60	60	60	
P_2O_5	0	0	60	60	30	60	60	
K_2O	0	0	0	0	0	0	120	
			PERCENT PHOSPHORUS					Avg.
1957	.182 a[1]	.186 a	.186 a	.191 a	.175 a	.187 a	.198 a	.186
1958	.161 de	.140 e	.206 c	.217 bc	.175 d	.236 b	.270 a	.201
1959	.169 cd	.162 d	.196 bcd	.241 ab	.208 bc	.276 a	.224 b	.211
1960	.186 cd	.166 d	.232 a	.235 a	.199 bc	.233 a	.221 ab	.210
1961	.207 e	.195 e	.260 bc	.301 bc	.295 bc	.389 a	.337 b	.283
1962	.134 c	.145 c	.194 b	.223 ab	.197 b	.243 a	239 a	.196
Six-year Average	.173 d	.166 d	.212 c	.235 b	.208 c	.261 a	.248 ab	.215

[1] Means followed by the same letter are not significantly different at the .05 level.

circumstances of marginal response, it is difficult to arrive at a leaf phosphorus level that might approximate a "critical level" for phosphorus. The critical leaf phosphorus level at bloom stage was between 0.166 and 0.208 percent, the levels obtained on the 60-0-0 and 60-30-0 treatments, respectively.

Average potassium content of the leaves from the 60-60-60 treatment was 1.70 percent as compared with 1.68 percent from the 60-60-0 treatment. These potassium contents, and the lack of yield response to potassium, indicate that the soil furnished adequate potassium for maximum yields.

Discussion

The data presented here were obtained during a period of above average precipitation and above average yields. They may present an overly optimistic picture regarding response to fertilizer; however, it is evident that the use of fertilizer in grain sorghum production is a profitable practice on these soils during wet years. Certain adjustments in fertilizer practices may be in order during dry periods. For instance, if yields are low because of drouth in one season, lower rates or perhaps no fertilizer may be required in the following season.

In all seasons, the best cultural and moisture conservation practices must be used in conjunction with fertilizers if maximum returns are to be obtained. Fertilizer will not compensate for poor stands, too thick stands, uncontrolled weeds, etc. It will give maximum response only under the best management practices.

Summary

Seven crops of wheatland grain sorghum were grown on a fertilizer experiment in which rates of nitrogen, phosphorus, and potassium were studied.

Precipitation for the period was above average, and yields were above average for the soil type involved.

Yields were increased by the use of nitrogen combined with phosphorus and to a lesser extent by nitrogen alone. Phosphorus alone did not increase yields.

Potassium combined with nitrogen and phosphorus did not increase yields above those from the same amounts of nitrogen and phosphorus without potassium. Applied nitrogen and phosphorus increased the respective nitrogen and phosphorus contents in leaf samples taken at bloom stage. Applied potassium did not affect potassium contents of the leaves.

In a moisture-use study, a fertilizer treatment consisting of 60 pounds of nitrogen and 60 pounds of P_2O_5 per acre per year increased yields an average of 193 percent during four consecutive years.

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