Manure and Inorganic Fertilizer Effects on Sorghum and Sunflower Growth on Iron-Deficient Soil[1]

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ABSTRACT

Iron chlorosis occur in grain sorghum [*Sorghum bicolor* (L.) Moench] and other Fe-inefficient crops on calcareous soils in spots throughout the Great Plains. Economical control of Fe deficiency in these crops will allow them to be grown in places where they are otherwise not adapted.

Grain sorghum ('Dekalb E-59') and sunflower (*Helianthus annuus* L. 'Hybrid 896') crops were grown on Arch fine sandy loam (Ustochreptic Calciorthid of the fine-loamy, mixed thermic family) to compare their growth on calcareous soil and to study the effects of soil treatments with beef feedlot manure (11 and 33 metric tons of dry matter/ha), and inorganic N, P, and Fe (168-56-22) kg/ha) fertilizer. Sunflower seed yield was not changed significantly by any of the treatments. In 1977, the second year of the study, sorghum grain yield where N + P was applied was about half that of the check plot. However, in 1978 forage yield was reduced only about 10% below the check by N + P. Iron-deficiency symptoms in sorghum were very severe on both check and N + P treatments; many sorghum plants died and others did not produce heads. When 22 kg/ha Fe was added with the N + P, grain yield was increased 66% over the check in 1977, and forage yield was twice that of check in 1978. Sorghum grain yield where manure was applied was three times the yield on check plots in 1977, indicating that manure keeps both Fe and P available for use by grain sorghum on calcareous soil. The study also showed that sunflower is not highly sensitive to iron deficiency and could serve as an alternative crop for iron-deficient soils.

Additional index words: **Calcareous soil, Fe chlorosis, N, P, Oil yield and content.**

IRON chlorosis in grain sorghum [*Sorghum bicolor* (L.) Moench], soybeans [*Glycine max* (L.) Merr.], and cowpeas [*Vigna sinensis* (L.) Endl.] occurs on calcareous soils in spots throughout the Great Plains. Bailey County, Tex., alone has 13,000 ha of soil classified in the Arch (Ustochreptic Calciorthid of the fine-loamy, mixed thermic family), Gomez (Aridic Ustochrepts of the coarse-loamy, mixed thermic family), and Likes (Typic Ustipsamments of the mixed thermic family) series (5). These soils are high in lime and relatively high in pH. Their organic matter content and cation exchange capacity is low compared with the other series in the county.

Iron-deficient plants may result from various soil conditions or from ionic interactions in solution or within the plant. The Fe deficiency may be related to low Fe content of soil (14), high lime content of soil (1), low Fe/Mn ratio of soil extracts (14, 2) or antagonistic effects of Zn, P, and Fe in solution culture, or in the plant (21, 15). Interaction between Fe and P may inactivate the Fe in the plant and cause Fe chlorosis. Also, competition between Fe, Zn, Cu, and Mn may reduce the uptake and translocation of Fe.

Iron deficiency in plants has been corrected by adding ferrous sulfate (1, 10), synthetic chelates (20), sulfuric acid (12), and livestock manure (18) to the soil. Ferrous sulfate, when applied to soils in sufficient amounts, temporarily increased the available Fe. Chelates kept the Fe available for uptake and translocation by plants. Sulfuric acid reduced the pH of the soil so that Fe was available from the application zone. Manure supplied Fe as an organic complex available to plants. Tan et al. (17) found that extracts from poultry litter complexed Fe and other ions. Miller et al. (13) demonstrated that poultry manure was beneficial for correcting Zn as well as Fe deficiencies in plants.

The ability of plant species to extract Fe from soils varies widely. Raju and Marschner (16) and Kashirad and Marschner (8) showed that sunflower (*Helianthus annuus* L.) plants reduced the pH of solutions and thus overcame Fe chlorosis. However, corn (*Zea mays* L.) plants did not reduce the pH and failed to utilize precipitated ferric compounds to overcome Fe chlorosis.

We conducted field experiments on Arch fine sandy loam near Muleshoe, Tex., and greenhouse experiments on soil from the same field at the USDA Conservation and Production Laboratory, Bushland, Tex. The objectives of the field experiment were 1) to compare the efficiency of beef feedlot manure with ferrous sulfate and commercial fertilizer for correcting Fe-deficiency chlorosis of grain sorghum and 2) to compare growth of sorghum and sunflower on Fe-deficient calcareous soil. The greenhouse experiment was conducted to determine whether a deep soil horizon with available Fe was responsible for regreening of sorghum late in the season.

MATERIALS AND METHODS

Field Study

The experiment was conducted on Arch fine sandy loam in Bailey County, Tex. Chemical and physical properties of Arch soil taken from the check plot in March 1978 are shown in Table 1. Soil treatments for grain sorghum 'DeKalb E-59' and sunflower 'Hybrid 896' were: check, N + P (168-56 kg/ha), N + P + Fe (168-56-22 kg/ha), manure (11 and 33 metric tons/ha dry weight), and manure (11 and 33 metric tons/ha) plus Fe (22 kg/ha). The N, P, and Fe were applied as ammonium nitrate, treble superphosphate (20% P), and ferrous sulfate. The manure was from a beef cattle feedlot. Three replications of these treatments were applied in a randomized block split plot design with soil treatments as main plots and crops subplots. Manure and commercial fertilizer were surface applied and incorporated by disking on 16 Mar. 1976, 3 May 1977, and 8 May

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Table 1. Chemical and physical properties of Arch fine sandy loam.

Depth	Extractable cations: 1 N NH_4Ac CEC	Na	K	Ca	DTPA extract Mg	Fe	Mn	Zn	P	pH	$CaCO_3$ Eq.	Sand	Silt	Clay
cm	meq/100 g				ppm						%			
0–25	7.1	0.13	0.49	22.6	3.4	1.9	3.3	0.5	8.0	7.83	9.0	78	9	13
25–71	8.0	0.27	0.29	24.9	4.5	1.7	0.8	0.1	3.7	7.96	19.0	68	10	22
71–102	7.4	0.23	0.33	24.0	5.5	1.0	0.9	0.6	1.5	8.16	19.6	67	11	22
102–178	9.7	0.38	0.35	22.4	5.8	2.2	0.9	0.4	1.8	8.24	16.4	64	15	21

1978. The soil was listed in 1-m spaced rows, pre-irrigated and crops planted on the lister beds. Eight rows of sorghum and eight rows of sunflowers were planted on plots 15 m long. Sorghum and sunflowers were rotated each year. The crops were planted on 13 May 1976, 1 June 1977, and 9 June 1978. The sunflowers were harvested 30 Aug. 1976, 6 Sept. 1977, and 7 Sept. 1978. The sorghum was harvested 12 Oct. 1976, 26 Sept. 1977, and 18 Oct. 1978. Samples were harvested by hand from a 10-m^2 area to determine yields.

This experiment was on a farmer's field and irrigation was not a controlled part of the experiment. The crops were irrigated with a solid-set sprinkler system. In 1976 and 1977, irrigation was near optimum; in 1978, however, irrigation was inadequate during July.

Soil samples were taken before the experiment in March 1976, in March 1978 from a check plot, and after the experiment in June 1979. Extracts were made with 1 *N* ammonium acetate at pH 7.0 for determination of Na, K, Ca, and Mg, and with DTPA (9) for determination of Fe, Mn, and Zn. Cation exchange capacity was determined by the sodium acetate method (7). Phosphorus was determined by the sodium bicarbonate method (7). The pH was determined on a 1:1 soil-water mixture and the calcium carbonate equivalent was determined by weight of CO_2 loss from 10 g of soil in 3 *N* HCl.

Manure was analyzed (Table 2) for N, P, K, Ca, Mg, and Mn on H_2SO_4-H_2O_2 digest (19). Nitrogen and P were determined on this digest by the Technicon AutoAnalyzer Industrial Method No. 334-74W/B+, revised March 1977. Samples for Fe analysis were digested with nitric, sulfuric, and perchloric acids. Potassium Ca, Mg, Fe, and Mn were determined by absorption spectrophotometry. Grain samples were analyzed for N and P by the method of Thomas et al. (19); the oil content of sunflower seed was determined by nuclear magnetic resonance (6).

Greenhouse Study

Sorghum was grown in a greenhouse experiment in 12 kg pots of Arch fine sandy loam taken from the soil horizons shown in Table 1. Three replications of the treatments—Check, N + P (300-50 ppm), N + P + Fe (300-50-20 ppm), and manure (2% dry weight) were used in a completely random design. These pots were watered to 20% by weight to maintain adequate water for plant growth. The pots were planted on 12 Apr. 1978, thinned to three plants per pot after emergence, and harvested 26 May 1978.

RESULTS AND DISCUSSION

Field Experiment

Although the growth responses to soil treatments observed in 1976 and 1978 were similar to those in 1977, bird damage was especially severe on the early maturing plots. The early maturing plots were those that had responded most to treatment. Therefore, harvested grain yields did not represent treatment responses in 1976 or 1978. Sorghum grain yields for 1977 are presented in Fig. 1. In 1978, sorghum forage yields represented treatment effects better than grain yields, so they are presented in Fig. 2. Grain sorghum yields are not presented for 1976.

Table 2. Analysis of the beef feedlot manure applied to experimental plots each year during the study (elements expressed on dry-weight basis).

Year	H_2O	N	P	K	Ca	Mg	Fe	Mn	Na
	%								
1976	19.5	2.9	1.0	1.9	2.2	0.7	0.6	0.02	0.8
1977	27.8	2.5	0.8	2.3	2.0	0.5	0.4	0.02	0.8
1978	26.0	2.0	0.5	2.3	2.9	1.3	0.3	0.01	0.8

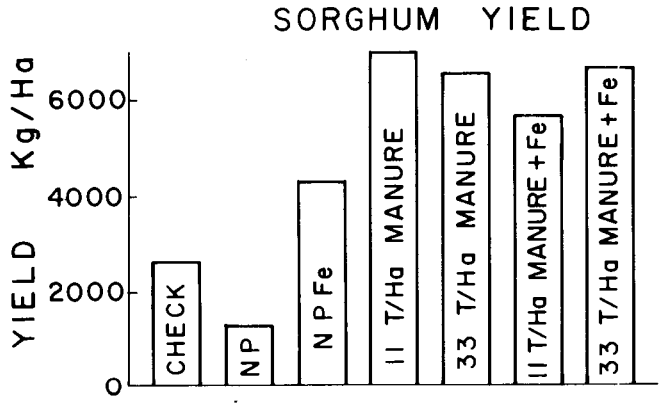

Fig. 1. Sorghum grain yield in 1977 on Arch fine sandy loam as affected by soil treatments of N, P, and Fe at 168, 56, and 22 kg/ha and manure at 11 and 33 metric tons/ha. $\overline{Sx}$ = 792.

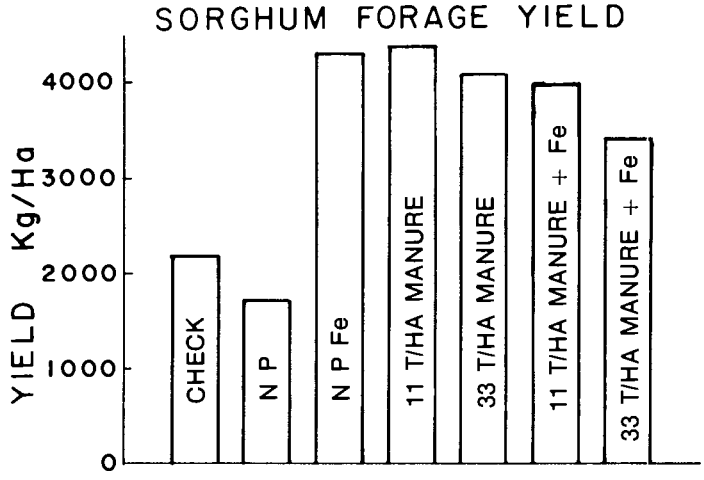

Fig. 2. Sorghum forage yield in 1978 on Arch fine sandy loam as affected by soil treatments of N, P, and Fe at 168, 56, and 22 kg/ha and manure at 11 and 33 metric tons/ha. $\overline{Sx}$ = 597.

Sorghum grain yields in 1977 (Fig. 1) and forage yields in 1978 (Fig. 2) show that N + P, without Fe, decreased yields. Sorghum growth was good every year on manured plots. Manure seems to be a good fertilizer on calcareous soils that are low in Fe and Zn, and that require P and N to produce high yields. This result is attributed to manure's slow release of plant nutrients and to its chelating of ions, keeping them in available forms.

Without fertilizer, grain sorghum growth was severely limited by Fe deficiency. On plots that did not receive Fe or manure the plants were chlorotic and stunted, and many died. Field observations indicated that soil manure treatments completely corrected the Fe deficiency symptoms in grain sorghum. Annual soil applications of ferrous sulfate (22 kg/ha Fe) with N and P caused a significant greening and increase in growth the second year (Fig. 3) and forage yields equal to the highest yields the third year (Fig. 2). This effect of Fe treatment appears to be cumulative since the increased growth was not observed until the second year and was seen to a greater extent the third year. Sorghum and sunflowers were rotated each year so a crop sequence effect was possible. The crop sequence

Table 3. Soil chemical properties (0–15 cm depth) one year after three annual applications of manure or commercial fertilizer.

Treatments		K	Ca	Mg	Na	P	Fe	Zn	Mn
	kg/ha	meq/100 g				ppm			
Check		0.57 d*	24.26	3.89	0.19 c	15 d	1.9 d	0.3 b	2.1
N + P	(168-56)	0.60 cd	25.23	3.97	0.20 ac	25 bd	2.1 d	0.4 b	1.9
N + P + Fe	(168-56-22)	0.54 d	25.13	3.84	0.19 bc	20 cd	2.1 cd	0.3 b	1.6
Manure (11 metric tons/ha)†		0.86 bc	24.92	3.99	0.21 ac	34 b	2.4 bc	0.6 ab	2.0
Manure (33 metric tons/ha)		1.27 a	23.58	3.94	0.24 a	69 a	2.7 b	0.8 a	2.1
Manure (11 metric tons/ha) + Fe	(22)	0.88 b	24.60	3.90	0.21 ac	29 bc	2.4 bc	0.6 ab	2.2
Manure (33 metric tons/ha) + Fe	(22)	1.24 a	24.55	4.13	0.23 ab	70 a	3.2 a	0.9 a	2.2

* Values in a column followed by the same, or no letter are not significantly different at the 5% level as determined by Analysis of Variance and Duncan's Multiple Range test. † Dry weight basis.

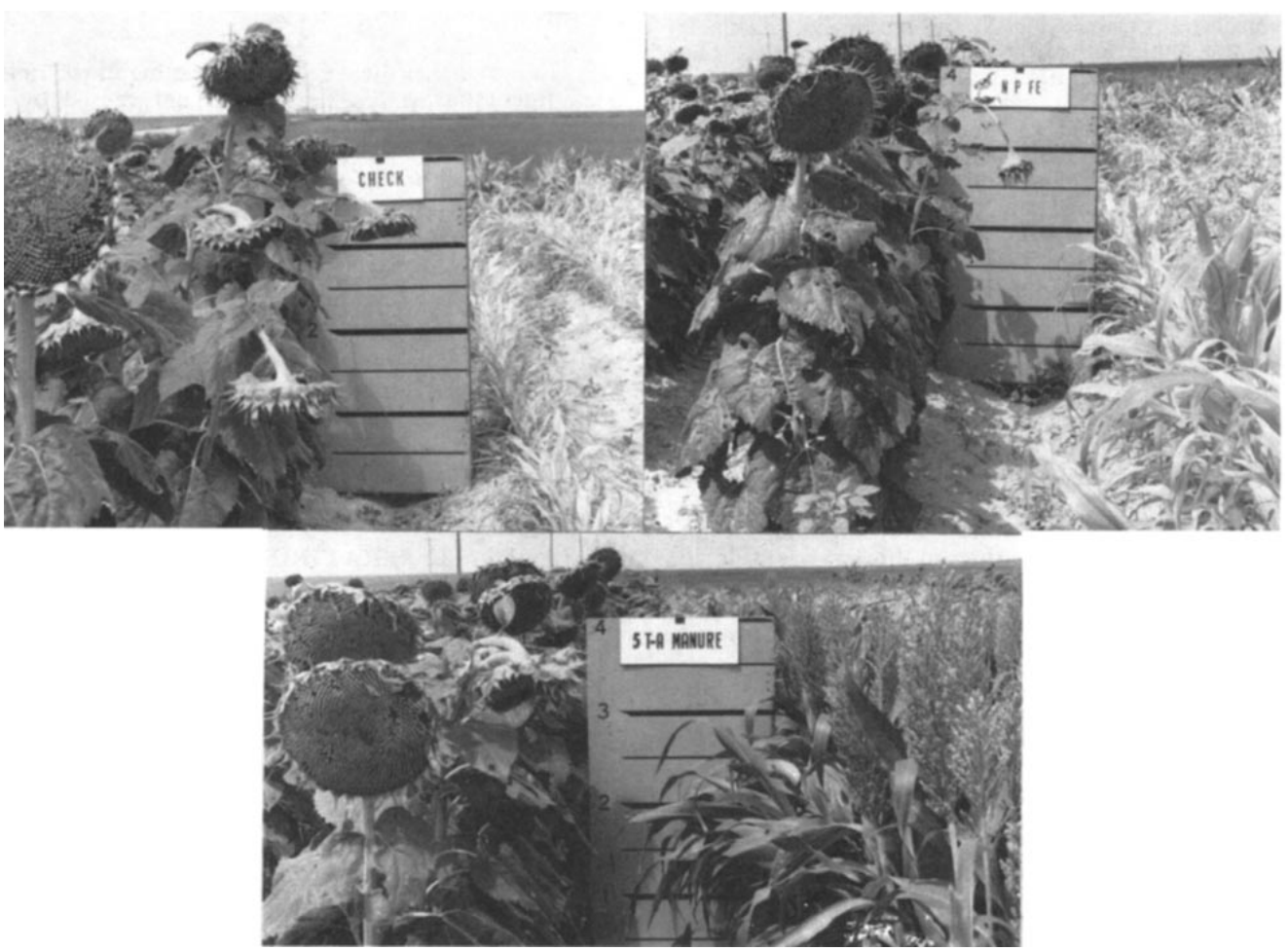

Fig. 3. Sorghum and sunflower growth on Arch fine sandy loam as affected by N + P + Fe and manure soil treatments. Pictures taken 2 Sept. 1977.

Table 4. Sunflower seed yield, percent oil, and oil yield on Arch fine sandy loam as affected by soil treatments.

Treatments		Seed yield			Percent oil			Oil yield		
		1976	1977	1978	1976	1977	1978	1976	1977	1978
	kg/ha	kg/ha			%			kg/ha		
Check		1,446	2,170	979	42.7 a	45.2 a	45.9	579	890 a*	586
N + P	(168-56)	1,479	2,106	1,157	39.5 b	42.7 b	40.3	543	818 abc	626
N + P + Fe	(168-56-22)	1,398	1,855	1,033	39.3 b	39.8 de	45.3	516	674 c	573
Manure (11 metric tons/ha)†		1,301	2,288	1,290	38.7 b	42.4 bc	43.0	472	885 ab	841
Manure (33 metric tons/ha)		1,395	1,984	885	38.9 b	40.4 cde	42.4	511	729 bc	674
Manure (11 metric tons/ha) + Fe	(22)	1,384	1,876	996	38.2 b	41.6 bcd	41.2	497	711 c	496
Manure (33 metric tons/ha) + Fe	(22)	1,644	1,871	863	39.7 b	39.7 e	39.9	612	677 c	492

* Values in a column followed by the same or no letter are not significantly different at the 5% level as determined by Analysis of Variance and Duncan's Multiple Range test. † Dry weight basis.

effect was not observed on the NP growth plots, however, so we attribute the increased growth to additional Fe applied.

Soil analysis data in Tables 1 and 3 show that manure treatments increased the available Fe, P, and K. The higher manure treatment (33 metric tons/ha) also significantly increased the Zn and Na extracted from this soil. However, these analysis show that Fe is still below the critical level (4.5 ppm) for sorghum, as observed by Lindsay and Norvell (9). Therefore, sorghum would be expected to respond to further applications of manure.

Sunflower growth (Fig. 3) and seed yield (Table 4) were not significantly affected by soil treatments. The N requirement of sunflower is lower than that of many crops. Massey (11) found that 56 kg N/ha increased sunflower seed yield in Georgia, but additional N produced no further increase in yield. Zubrinski and Zimmerman (22) found that 112 kg N/ha increased seed yield of sunflower in North Dakota but oil yield was not significantly higher on 112 than on 56 kg N/ha treatments. In France, Gachon (4) found that 150 kg N/ha was required to produce 9 metric tons/ha of sunflower dry matter. In southeast Bulgaria, Delibaltov and Ivanov (3) found that 100 kg N/ha produced the greatest economic return from sunflowers. In addition, on our plots, sunflower was grown where sorghum produced very low yields on check plots the previous year. Consequently, there was enough N even in the check plots to produce good sunflower seed yields.

Since Fe chlorosis was observed on sorghum but not on sunflower, it follows that sunflower was able to extract enough Fe for good growth through some mechanism, probably by lowering the pH around the roots, as discussed by Raju and Marschner (16) and Kashirad and Marschner (8). Apparently, it is possible to grow sunflower where sorghum, soybean, cowpea, and other Fe-inefficient crops cannot be grown without soil treatments to supply Fe.

Greenhouse Study

Table 5 shows the dry matter yield of sorghum grown in the greenhouse on soil horizons taken from untreated plots of the experimental field. Without treatment, sorghum growth was very limited on all soil horizons. Only the 2% manure treatment significantly increased yield on all soil horizons. Plants on all other treatments exhibited severe Fe-deficiency.

Table 5. Sorghum dry-matter yield as affected by N + P, N + P + Fe, and manure treatments in the greenhouse on selected horizons of Arch fine sandy loam.

Treatments		Soil depth, cm			
		0-25	25-71	71-102	102-178
	ppm	g/pot			
Check		0.98 e*	0.21 e	0.23 e	0.19 e
N + P	(300-50)	1.31 de	0.36 e	0.37 e	0.52 e
N + P + Fe	(300-50-20)	2.81 d	0.56 e	0.53 e	0.67 de
Manure (2%)		7.64 bc	5.99 c	8.63 b	12.39 a

* Values followed by the same letter are not significantly different at the 5% level as determined by Duncan's Multiple Range test.

This indicates that the sorghum regreening in the field experiment late in the season was not caused by a Fe-sufficient horizon in the top 178 cm of this plot. Sorghum either rooted deeper than 178 cm or began utilizing Fe by some other mechanism in the later stages of growth.

CONCLUSIONS

1. Beef cattle feedlot manure was effective in supplying Fe to sorghum grown on Fe-deficient calcareous soil.
2. Sunflower acquired sufficient Fe from soil where sorghum was very Fe-deficient.
3. Repeated applications of ferrous sulfate had a cumulative effect on sorghum growth on Fe-deficient calcareous soil.

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