EFFECTS OF IRON FERTILIZERS
ON SOYBEANS

By

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CHAPTER I

INTRODUCTION

The research reported in this thesis is prepared as a manuscript for publication in a professional journal.

Iron deficiency has been reported for a number of crops grown on soils of the Southern Great Plains. The sensitivity of Forrest soybeans to Fe deficiency on soils in south central Oklahoma provided a stimulus for the research reported here. It provided an opportunity to investigate an Fe inefficient variety such as Forrest, under higher soil pH and other environmental conditions as experienced in 1981. To improve the uniformity of soil pH in this study, 14 treatments included lime applications to bring soil pH values to 8.

The use of both inorganic and organic Fe fertilizers, applied to soil or foliar, have shown promise in the correction of Fe deficiency for various crops and conditions. In recent years, combinations of macronutrient and various Fe fertilizers have received considerable attention. This has been particularly true of ammonium polyphosphate (APP) and Fe fertilizers, applied together in a band at planting. The apparent sequestering of the Fe by the APP has provided an increase in Fe availability and utilization by the plant in some cases.

Primary objectives of this study were (a) to measure the effect of APP plus three different Fe fertilizers banded with the seed at planting, and (b) to measure the effects of two different Fe fertilizers foliar applied with and without urea-N on the development and yield of Forrest soybeans. Evaluations were based on yield and nutrient content of grain plus chlorophyll and nutrient analysis in leaves.

CHAPTER II

ABSTRACT

Forrest soybeans (Glycine max (L.) Merrill) have been a consistent, high yielding variety for most areas of Oklahoma. Recently, Forrest soybeans have been recognized as being Fe inefficient and developing chlorosis on soils in south central Oklahoma.

Forrest soybeans were grown near Chickasha, Oklahoma in 1981 in an experiment to measure the extent of Fe chlorosis, and to study possible methods of correction. Research on other crops in the Great Plains has shown a beneficial response from the combination of Fe fertilizers and ammonium polyphosphate (APP). Both inorganic and organic Fe fertilizers applied alone to the soil or foliage have also shown a beneficial response. In this experiment, lime was applied pre-plant to improve the uniformity of soil pH within the study areas. Three Fe fertilizers with fluid APP were banded with the seed at planting. Two granular urea phosphate fertilizers, one with Fe and one without Fe, were banded with the seed at planting also. Two Fe fertilizers were applied to the foliage with and without urea-N in two applications in 1981 due to the development of visual Fe chlorosis symptoms. All fertilizers banded with the seed at planting caused severe inhibition of germination and emergence. Deleterious effects of fertilizers applied to the soil were observed in grain and leaf tissue analysis as well as in grain yield. Foliar applications of Fe fertilizers did not produce significant increase in chlorophyll or nutrient content of leaf tissue and grain or in

yield of grain.

It was concluded that fertilizers at moderate to high rates should not be applied in contact with soybean seeds. Further investigations into the occurrence and methods of correction of Fe chlorosis on soybeans in south central Oklahoma are needed.

Additional Key Words for Indexing: ammonium polyphosphate, Urea-N, Southern Great Plains, *Glycine max* (L.) Merrill).

REVIEW OF LITERATURE

Iron (Fe) deficiencies have been reported in 25 states in the United States on at least 47 different plants (14). Iron deficiencies are most commonly associated with arid regions and alkaline soils. Within the Great Plains region of the United States, Fe deficiencies are commonly found on a wide variety of crops (3.19).

In Oklahoma, Fe chlorisis has been reported on several agronomic and horticultural plants. The nature of the development of Fe chlorosis in this case is usually associated with high soil pH. Research has been conducted in an effort to elucidate and correct chlorosis on grain sorghum (*Sorghum bicolor* (L.) Mench), and winter wheat (*Triticum aestivum* (L.) Thell), in Oklahoma, particularly for production in the central and western parts of the state where soil conditions are more conducive to the development of Fe chlorosis (16, 17, 26).

The correction of Fe chlorosis has often been accomplished by using inorganic Fe materials and chelated Fe sources. Iron fertilizers have been applied both in the soil and by foliar methods with good results (25).

In recent years, the use of Fe fertilizers mixed with a macronutrient fertilizer has given positive results (22, 24). Ammonium polyphosphate (APP) has been applied with both inorganic and chelated Fe materials and has been reported to be capable of correcting iron chlorosis under some conditions. When APP and iron fertilizers have been used successfully in the correction of iron deficiencies, it is usually when applied together in a band either in direct contact or in close proximity to the seed at planting.

Rogers (27), Heizer (16), and Hilliard (17) each reported in Oklahoma APP plus Fe fertilizer ($FeSO_4 \cdot 7H_2O$) was successful in the correction of Fe chlorosis when banded with the seed at planting. Rogers (27) decreased chlorosis in winter wheat with 29 kg P/ha as 10-15-0 (10-34-0 oxide form) plus 6 kg Fe/ha as $FeSO_4 \cdot 7H_2O$ banded with seed at planting.

Hilliard (17) did not observe a yield increase from 10-15-0 (20 kg P/ha), plus $FeSO_4$ (9 kg Fe/ha), when banded with the seed of grain sorghum. However, increases in yield from the application of Iron-Sul at 112 kg/ha (36 kg Fe/ha) when banded to the side and below the seed were observed. Highest yields were obtained in grain sorghum from treatments of 10-10-0 (20 kg P/ha) plus Sequestrene-138 (a chelate Fe source, 6% Fe), at a rate of 2 kg Fe/ha when banded with the seed.

Heizer (16), Hilliard (12), and Rogers (27) each also reported a positive response to a band application of APP alone. In Kansas, Adriano and Murphy (1) obtained success with APP (10-15-0) at 40 kg P/ha applied in a band to corn (Zea mays L.). Mortvedt and Giordano (23) obtained an enhancement in the effectiveness of $FeSO_4$ applied alone on grain sorghum grown in a calcareous soil.

There is considerable information available on the influence of polyphosphate materials placed directly with the seed of soybeans.

Clapp and Small (13) reported in North Carolina that the use of high rates of fertilizer placed near the seed of soybeans would reduce germination. They also found that all rates of "pop-up" fertilizer reduced soybean stand and grain yield. Their conclusion was that liquid or granular fertilizers containing, N , P, or K should not be placed in contact with soybean seeds at planting.

Foliar applications of Fe fertilizers have also been very promising. Although efficiency of Fe applications may be improved by foliar methods, it is still most often not economically feasible on most crops (15, 25). The success of foliar fertilizer applications appears to be dependent on several factors such as molecular size and type of the material, stomatal development of the plant species, as well as the time of application (2, 15, 28).

A plant's particular physiological response to certain conditions has also been shown to be very important in Fe soil-plant relationships. A number of investigators have pointed out the importance of recognizing differences between plant species and varieties within species in terms of Fe utilization (4, 5, 6, 21, 29).

Forrest soybeans have proven to be one of the best, consistent yielding varieties in most areas of Oklahoma. However, Forrest soybeans have exhibited Fe chlorosis and reduced performance in the South Central Oklahoma Research Station field trials (27).

The differential response of soybean varieties and isolines to Fe nutrition has been investigated previously (7, 8, 9, 10, 11, 12, 20). The case of Fe chlorosis on Forrest soybeans grown on high pH soils in south central Oklahoma has not been investigated and neither has the possible means of correction been reported.

A field experiment was initiated at the South Central Research Station at Chickasha, Oklahoma, in 1981. The objectives of the study were: (a) to determine a possible method for correction of Fe chlorosis for Forrest soybeans; (b) to measure the effects of Fe fertilizers with fluid ammonium polyphosphate applied to the soil and, (c) to measure the effects of Fe fertilizers applied to the foliage with and without urea-N.

MATERIALS AND METHODS

A field experiment was conducted on the South Central Research Station at Chickasha, Oklahoma. The soil type was a McClain silty clay loam, Pachic Argiustoll (fine, mixed, thermic). Eighteen treatments were arranged in a randomized complete block design with four replications.

Twenty soil cores 0 to 15 cm. deep were taken at random from the Ap horizon in each plot within the study area on April 29, 1981 prior to establishment of the experiment. Initial soil test indexes (Table 1) were determined according to standard Oklahoma State University Soil Testing Laboratory procedures which included: a 1:1 paste for pH, specific ion electrode for NO_3^--N, Bray P-1 with a 1:20 soil-extractant ratio, 1 N ammonium acetate extract for K, Mg, Ca, and DTPA for Fe, Zn, and Mn (2). Results of soil analysis (Table 1) indicated the fertility status of the soil in the study area was satisfactory for all nutrients including Fe and uniform within the study area. No elements were found to be present in an excessive or toxic amount.

Samples were also titrated with 0.04N $Ca(OH)_2$ to determine lime requirements to bring soil pH values in 14 treatments to pH 8.0. The remaining four treatments were not limed to provide comparisons. Lime was applied at a rate of 5.6 Mg ECCE/ha and the soil was disked twice for thorough incorporation.

Soil samples were taken again on June 22, 1981, prior to planting. Soil samples were analyzed for N, P, K, Mg, Ca, Fe, Zn, Mn, and pH as previously described (Table 1). Treflan herbicide was applied pre-plant and furrow irrigation was provided on an as needed basis.[1/]

[1/] Mention of company name of trademark does not constitute endorsement of a particular product by OSU over any others that may be commercially available.

TABLE 1

SOIL TEST INDEXES

Date	pH	NO_3-N	P	K	Ca	Mg	Fe	Zn	Mn
		kg/ha					ppm		
4-29-81	7.2	49	216	834	5,945	1,119	23	81	19
6-22-81	7.6	41	196	833	6,568	2,270	11	79	21

Forrest soybeans were inoculated and planted on June 22 and 23, 1981 in 102 cm. rows at a rate of 43 seeds per linear meter with a 4-row John Deere 71 flex planter.[1/] There were six rows per plot with two border rows. The interior four rows were regarded as "treatment rows". All plots were 12 m. long.

A total of 18 treatments were in the experiment (Table 2). Six fertilizer treatments were banded with the seed at planting (Treatments 4-9). Six treatments (Treatments 10-15) were applied to the foliage as iron chlorosis developed throughout the growing season. There were also three limed and three unlimed check plots included (Treatments 1-3 and 16-18, respectively).

Soil applied treatments included 10-15-0 (10-34-0 oxide form) fluid ammonium polyphosphate (APP) in four treatments. APP was applied at a constant rate of 20 kg P/ha. Iron fertilizers included $FeSO_4 \cdot 7H_2O$ (20% Fe, 11% S), Sequestrene 138[1/] (6% Fe) from Geigy Chemical Co., Inc., and Iron-Sol[1/] (20% Fe, 30% S), a by-product of the copper mining industry from Duval Corporation. Also, two experimental fertilizers were supplied by TVA (Tennesseee Valley Authority). Both were urea phosphate materials, one with Fe and one without (15-17-0-4 Fe and 18-19-0-0, respectively).

Foliar applied treatments consisted of two Fe fertilizers; $FeSO_4 \cdot 7H_2O$ and Sequestrene-330 (10% Fe) also from Geigy Chemical Co., Inc. These materials were applied with and without urea-N (45% N). One foliar treatment consisted of Sequestrene-330 applied to soybeans grown on an unlimed plot (Treatment 15). All other treatments (soil and foliar applied) were on plots that had been limed.

[1/] Mention of company name of trademark does not constitute endorsement of a particular product by OSU over any others that may be commercially available.

TABLE 2

TREATMENTS USED IN EXPERIMENT
(ELEMENTAL FORMS)

	Treatment	Lime	N	P	S	Fe
		Mg ECCE/ha	kg/ha			
1.	Check	5.6	0	0	0	0
2.	Check	5.6	0	0	0	0
3.	Check	5.6	0	0	0	0
4.	10-15-0	5.6	13	20	0	0
5.	10-15-0 + $FeSO_4$	5.6	13	20	5	9
6.	10-15-0 + Sequestrene-138	5.6	13	20	0	2
7.	10-15-0 + Iron-Sul	5.6	13	20	33	22
8.	15-17-0-4 (Fe)	5.6	17	20	0	4.5
9.	18-19-0-0	5.6	18	20	0	0
10.	urea-N*	5.6	0.9	0	0	0
11.	$FeSO_4$*	5.6	0	0	3	5.5
12.	urea-N + $FeSO_4$*	5.6	0.9	0	3	5.5
13.	Sequestrene 330*	5.6	0	0	0	0.2
14.	Urea-N + Sequestrene 330*	5.6	0.9	0	0	0.2
15.	Sequestrene 330*	0	0	0	0	0.2
16.	Check	0	0	0	0	0
17.	Check	0	0	0	0	0
18.	Check	0	0	0	0	0

*Foliar treatments applied at 190 liters/ha

Plant stand counts were determined in 0.609 m. (2 ft.) of row selected at random from the four treatment rows within a plot.

Tissue samples were taken and foliar fertilizers applied (Table 3) on July 14 and August 22, 1981 due to the development of Fe chlorosis. Plants had three to five fully developed trifoliate leaves at the time of the first tissue sampling (July 14). Soybean plants were in early, full bloom at the time of the second tissue sampling (August 22).

Tissue samples were acquired by removing the topmost fully developed trifoliate leaf of the plants at random from the four treatment rows of each plot. Approximately 25 leaves from each plot were collected. Tissue samples were dried, ground, and saved for nutrient analysis.

Soybeans were harvested from the interior 3m x 12m area of each plot with a self-propelled combine on November 17, 1981. Grain yield was recorded from each plot. Grain samples were obtained and saved for nutrient analysis.

All plant tissue and grain samples were analyzed for K, Mg, Fe, Zn, Mn, and Cu by atomic absorption after a nitric-perchloric acid digestion. Total P was determined colorimetrically after nitric-perchloric acid digestion. Total N in leaf tissue samples was determined by micro-kjeldahl. Grain samples were analyzed for total N using macro-kjeldah. Chlorophyll content was determined on all leaf tissue samples by a methanol extraction procedure outlined by Johnson (18).

Soil samples were taken as previously described again on December 11, 1981. pH (1:1 H_2O) was determined for each soil sample.

Concentration ratios for leaf tissue and grain samples were calculated on a basis of elemental composition expressed as ppm.

TABLE 3

CONCENTRATIONS OF FOLIAR TREATMENTS

Treatment	Concentration (%)
10. Urea-N	0.5 N
11. $FeSO_4$	3.0 Fe + 1.6 S
12. Urea-N + $FeSO_4$	0.5 N + 3.0 Fe + 1.6 S
13. Sequestrene-330	0.012 Fe
14. Urea-N + Sequestrene-330	0.5 N + 0.012 Fe
15. Sequestrene 330*	0.012 Fe

*Treatment did not include soil lime application.

RESULTS AND DISCUSSION

Germination and seedling emergence were greatly inhibited by band placement of APP with the seed at planting. Border rows and other treatments that were not fertilized with APP were not adversely affected. Stand counts were taken on all treatments (Table 4) on July 2, 1981. The absolute cause of the problem was not determined. Accumulation of ammonium salts from the dissolution of the APP in close proximity to the seeds and the apparent sensitivity of soybean seeds to salt concentrations probably resulted in the poor stands observed (13, 24).

Some seedlings did survive but were obviously under considerable stress for some time afterward. The occurrence of two light rainshowers during the establishment period seemed to relieve the severity of the condition on surviving plants. Although stands in these plots were extremely poor, plant health and vigor improved slightly as the growing season progressed.

TABLE 4

INFLUENCE OF FERTILIZER BANDED WITH THE SEED ON SOYBEAN STAND, JULY 2, 1981

Treatment	Stand, plants/m/row (ave.)
Check	29
10-15-0	3.2
10-15-0 + $FeSO_4$	3.2
10-15-0 + Sequestrene-138	3.2
10-15-0 + Iron-Sul	3.2
15-17-0-4 (Fe)	9.7
18-19-0-0	9.7

Reductions in plant stand for plots receiving soil applied fertilizers with the seed were very similar to reductions in soybean stand reported by Clapp and Small (13) in North Carolina.

Nodulation and healthy growth patterns were observed July 2 throughout the remainder of the study area.

Plant Tissue Analysis

Significant differences in total chlorophyll content existed in tissue samples taken July 14 (Figure 1). Soil applied treatments of APP and APP + Iron-Sul were significantly lower in chlorophyll than other treatments. Lower values of chlorophyll in leaf tissue from soil applied treatments were probably closely associated with the salt problems encountered earlier. There were no significant differences in chlorophyll content in leaf tissue due to foliar applications at this date.

Chlorophyll data from the second tissue sampling date on August 22, revealed a similar pattern to data from July 14 (Figure 2). Chlorophyll in leaves from soil applied APP and APP + Iron-Sul treatments were significantly lower than checks and several foliar applications. Significant differences were found between APP alone, APP + Sequestrene 138, and APP + Iron-Sul when each treatment is compared to each of the foliar applied treatments: $FeSO_4$, Urea-N + Sequestrene-330, or Sequestrene-330 (unlimed). However, chlorophyll in leaves of foliar applied treatments were not significantly different than values observed in checks. Depression of chlorophyll levels in leaves of soil applied treatments was most likely an expression of the continued stress imparted earlier by soil applied treatments.

Further analysis of the tissue samples taken July 14, showed no significant differences among treatments for N, P, Fe, Zn, Mn, or Cu (Table 5). However, K and Mg was significantly lower in leaves in soil applied treatments of APP and APP + Iron-sul than in all other treatments (Figures 3 and 4). The other two treatments which included the use of APP did not result in a significant depression of K and Mg content in the leaf tissue at this date. This appears to indicate the relative severity of these two treatments. Lack of K and Mg in the leaf tissue is likely due to the stress exerted upon the plants and the subsequent

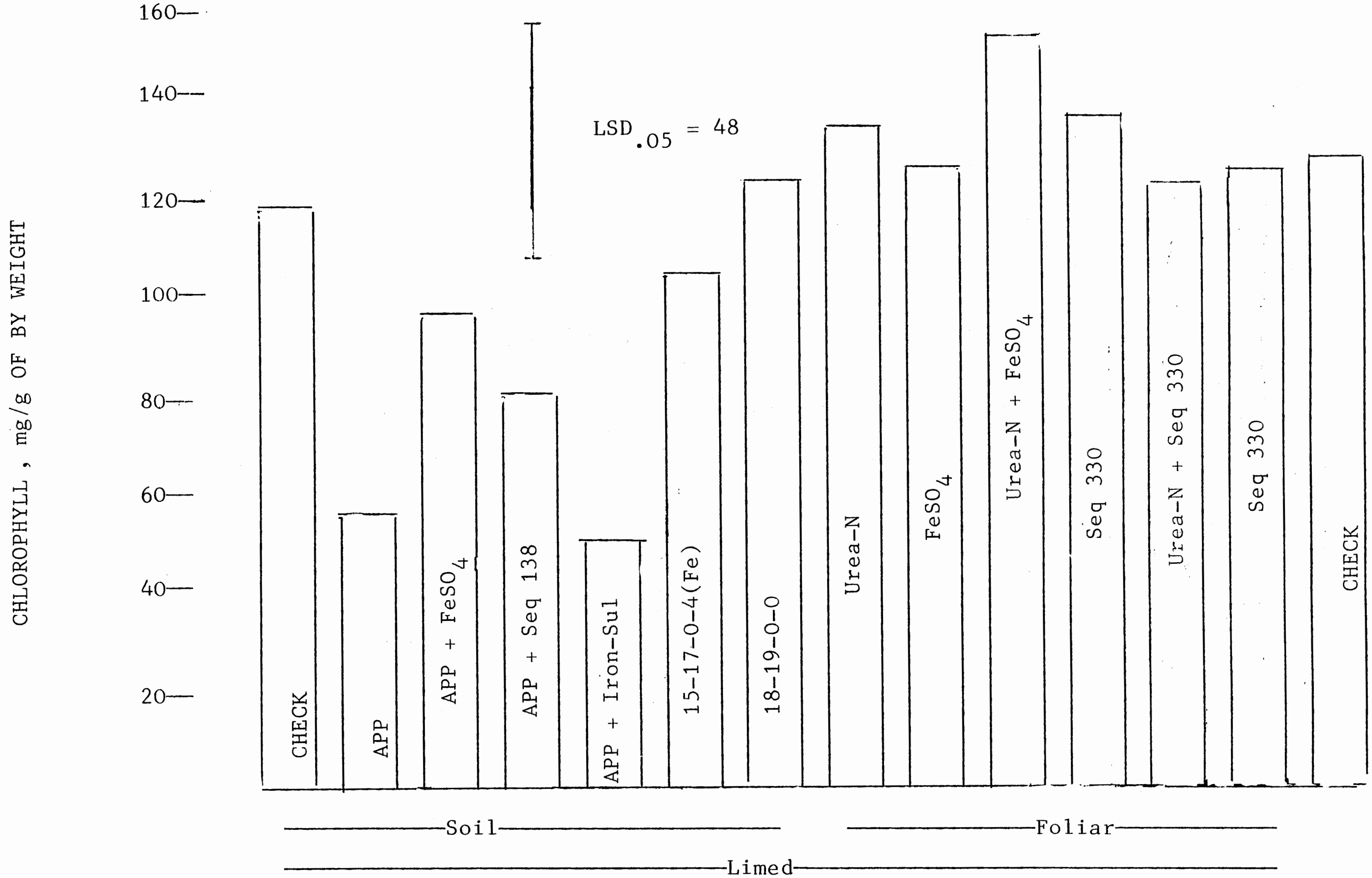

Figure 1. Chlorophyll Content in Leaf Tissue, July 14, 1981.

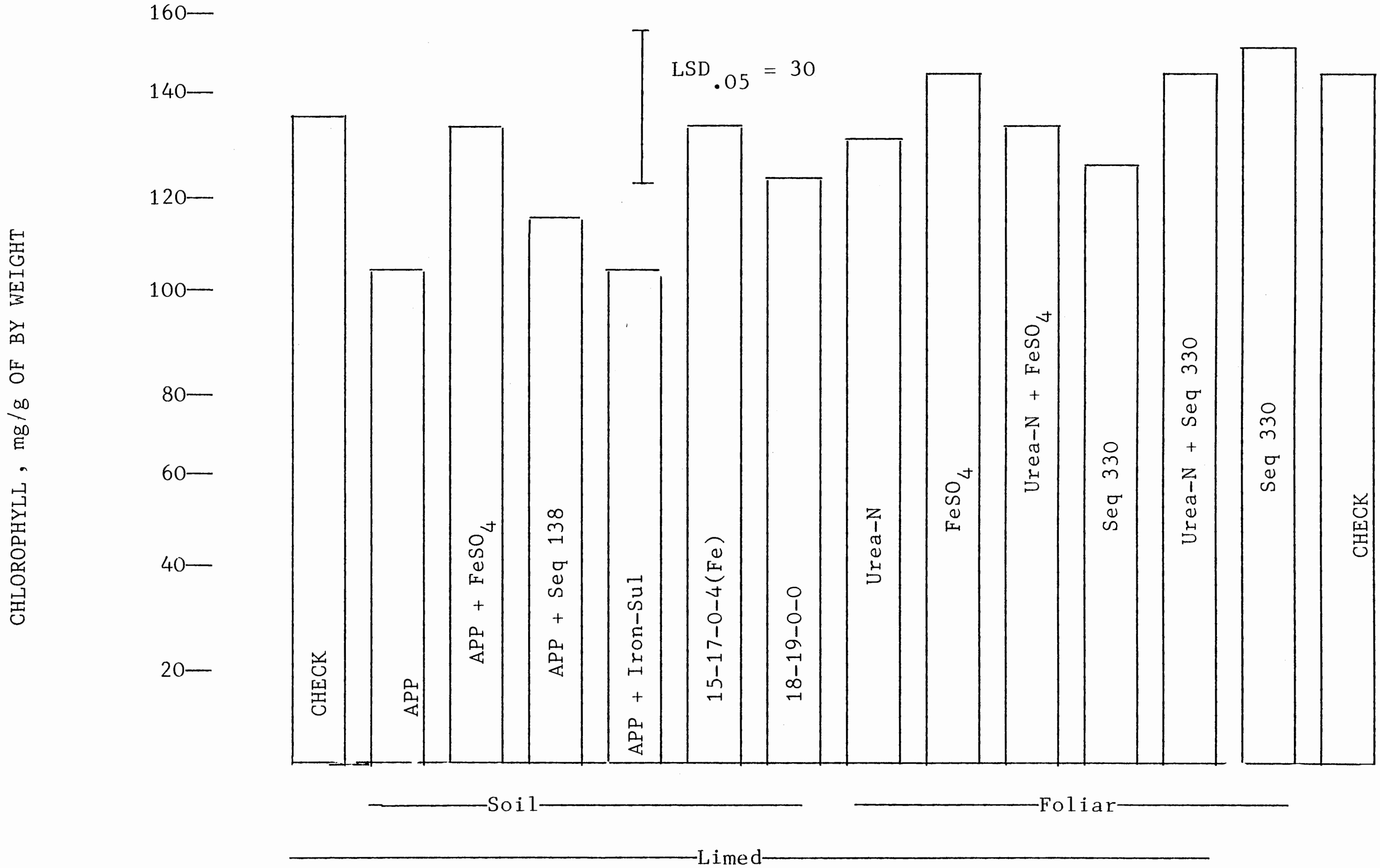

Figure 2. Chlorophyll Content in Leaf Tissue, August 22, 1981.

TABLE 5

NUTRIENT COMPOSITION OF SOYBEAN LEAVES
JULY 14, 1981

		Treatment	N	P	K	Mg	Fe	Zn	Mn	Cu	Chl.
			%				ppm				mg/g
		Check	5.7	.52	1.90	.20	364	61	82	9.5	129
		Check	5.8	.51	1.86	.20	357	54	86	9.3	114
		Check	5.4	.50	1.80	.20	385	76	86	8.8	116
		APP	2.6	.32	0.91*	.10*	233	47	51	4.0	55*
		APP + $FeSO_4$	4.1	.41	1.40	.15	341	54	74	6.6	97
	Soil	APP + Seq.-138	3.6	.42	1.30	.15	296	68	49	5.4	81
		APP + Iron-Sul	3.2	.32	0.89*	.10*	191	29	55	4.0	51*
Limed		15-17-0-4 (Fe)	5.5	.53	1.90	.20	369	66	89	8.6	104
		18-19-0-0	5.6	.55	1.94	.20	332	58	86	8.0	122
		Urea-N	5.5	.05	1.84	.20	514	46	82	8.8	133
		$FeSO_4$	5.5	.52	1.90	.20	312	52	86	9.0	123
	Foliar	Urea-N + $FeSO_4$	5.1	.49	1.90	.20	652	61	84	10.0	154
		Seq.-330	5.5	.49	1.90	.20	326	65	76	7.2	135
		Urea-N + Seq.-330	5.3	.50	1.90	.20	284	73	85	6.8	126
		Sequestrene-330	5.6	.50	1.92	.20	268	89	89	7.7	128
		Check	5.6	.51	1.90	.20	284	60	84	7.4	147
		Check	5.6	.51	1.90	.20	331	61	88	7.5	112
		Check	5.8	.47	1.80	.20	343	73	82	5.8	129
		LSD .05	--	--	.65	.06	--	--	--	--	51

*Significant at the .05 level

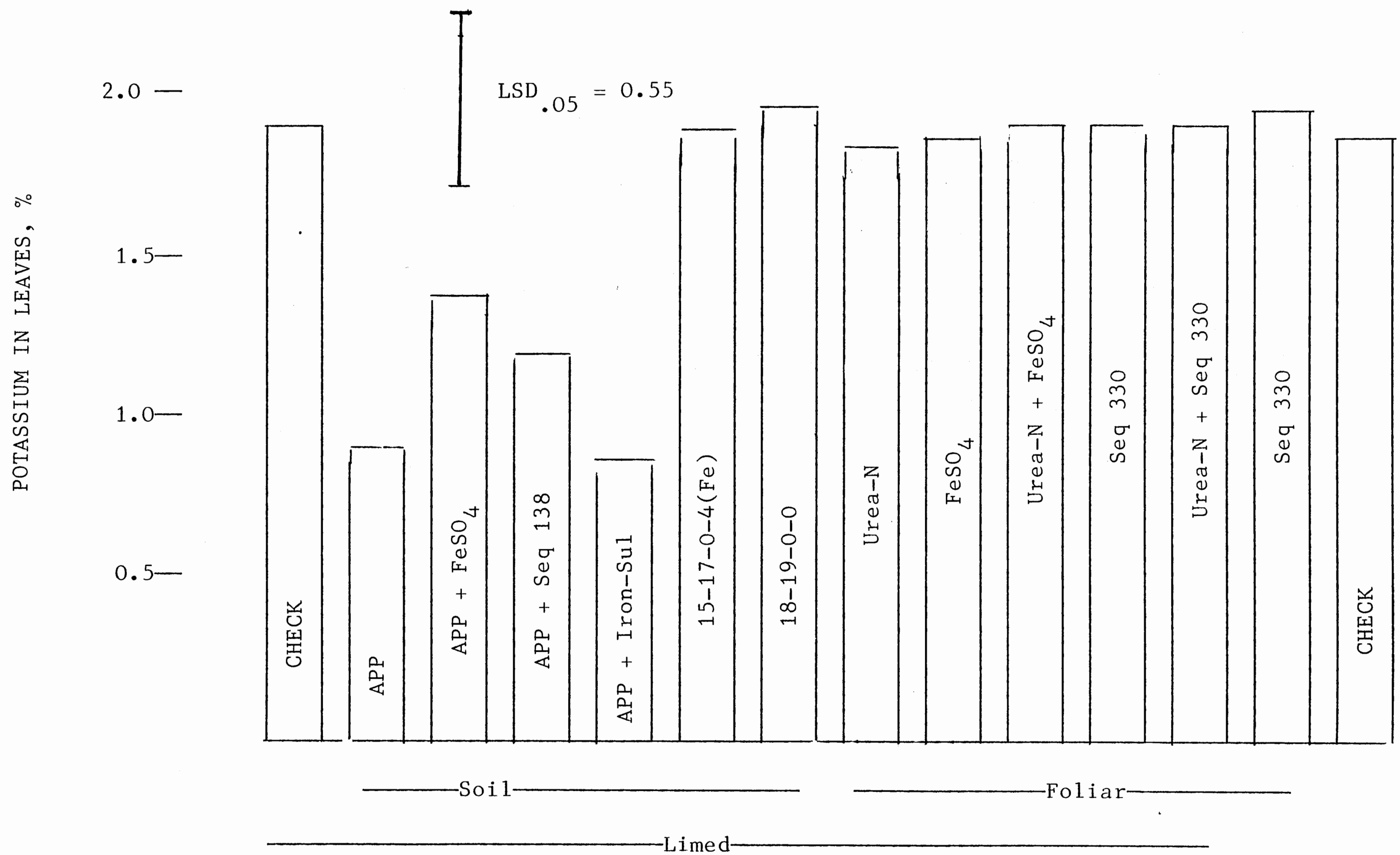

Figure 3. Potassium Content in Soybean Leaves, July 14, 1981.

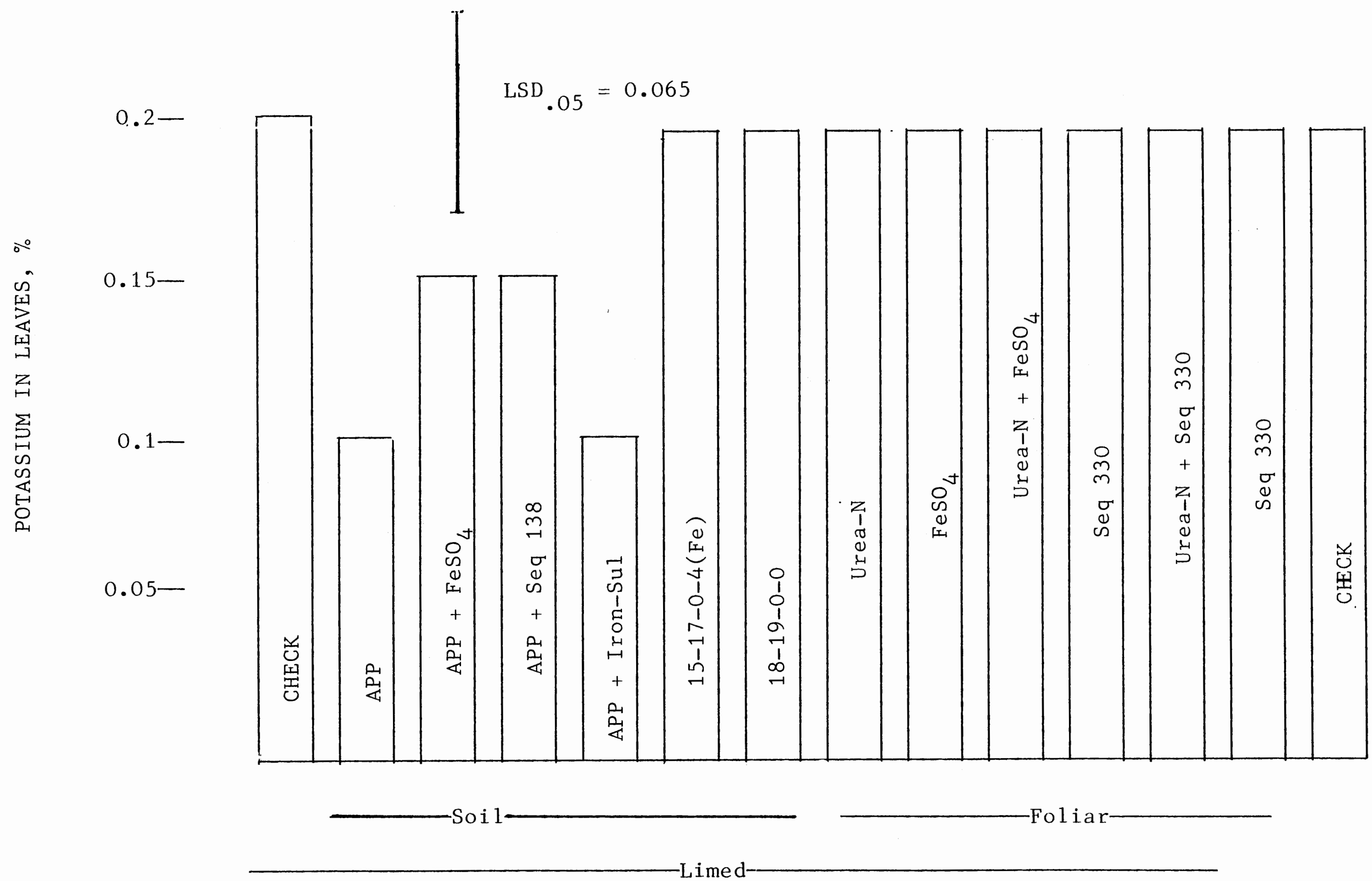

Figure 4. Magnesium Content in Soybean Leaves, July 14, 1981.

metabolic depression.

Chemical analysis of tissue samples taken August 22, revealed no significant differences between treatments for the elements N, K, Mg, Fe, Zn, Mn, or Cu (Table 6).

Soil applied treatments of APP, APP + $FeSO_4$, APP + Iron-Sul, and APP + Sequestrene-138 had significantly higher total P levels than did any of the check plots or any of the foliar applied treatments (Figure 5). Higher total P values in leaves were generally associated with lower chlorophyll content.

Other investigators (9, 10, 31) have recognized a relationship between P content and Fe content of plant tissue. Higher P values are often related to lower Fe levels in the plant. This type of interrelationship has also been suggested for Fe with other ions such as Zn^{+2}, Mn^{+2}, and Cu^{+2} (14, 31). Comparison of concentration ratios (P:Fe, Zn:Fe, Mn:Fe, Cu:Fe) for each of the tissue sampling dates (Table 7) did not reveal significant differences among treatments for Zn:Fe, Mn:Fe, or Cu:Fe. However, there were significant differences for P:Fe on the August 22 sampling (Figure 6). A concomitant increase in the P:Fe concentration ratio in leaf tissue occurred in the August 22 samples with increased P concentration.

Significant differences for the P:Fe ratios existed between leaves of soil applied treatments and leaves from foliar applied treatments. The P:Fe ratios in leaves from soil applied treatments were not significantly higher than observed in limed check plots. Watanabe et al., (31) identified a detrimental effect on Fe utilization when P:Fe concentration ratios of pinto beans (Phaseolus vulgaris) exceeded 60. This type of magnitude in P:Fe concentration ratios was not experienced in

TABLE 6

NUTRIENT COMPOSITION OF SOYBEAN LEAVES
AUGUST 22, 1981

		Treatment	N	P	K	Mg	Fe	Zn	Mn	Cu	Chl.
			%				ppm				mg/g
Limed		Check	4.9	.60	1.7	.18	404	66	79	6.8	145
		Check	4.8	.68	1.7	.18	341	71	136	7.4	129
		Check	5.1	.60	1.6	.18	378	55	122	8.2	131
	Soil	APP	5.3	.93*	1.8	.18	396	80	149	8.4	101*
		APP + $FeSO_4$	5.3	.78*	1.7	.18	394	65	138	8.2	129
		APP + Seq.-138	5.3	.78*	1.8	.18	343	53	99	8.8	113
		APP + Iron-Sul	5.3	.84*	1.8	.18	359	61	102	7.9	102*
		15-17-0-4 (Fe)	5.0	.68	1.7	.18	348	64	132	8.9	130
		18-19-0-0	4.8	.70	1.9	.18	383	62	93	8.9	122
	Foliar	Urea-N	5.0	.64	1.8	.18	411	45	90	8.0	131
		$FeSO_4$	4.8	.62	1.7	.18	448	64	91	8.8	144
		Urea-N + $FeSO_4$	4.9	.60	1.7	.18	520	28	89	8.4	131
		Seq.-330	5.1	.59	1.8	.17	432	74	110	7.7	123
		Urea-N + Seq.-330	5.0	.66	1.7	.17	438	38	136	8.2	144
		Sequestrene-330	4.9	.61	1.7	.17	444	56	132	8.0	154
		Check	4.7	.54	1.7	.17	515	69	94	8.0	133
		Check	4.9	.55	1.8	.17	480	65	90	7.0	134
		Check	5.0	.54	1.7	.17	452	52	112	7.0	148
		$LSD_{.05}$	--	.09	--	--	--	--	--	--	30

*Significant at the .05 level

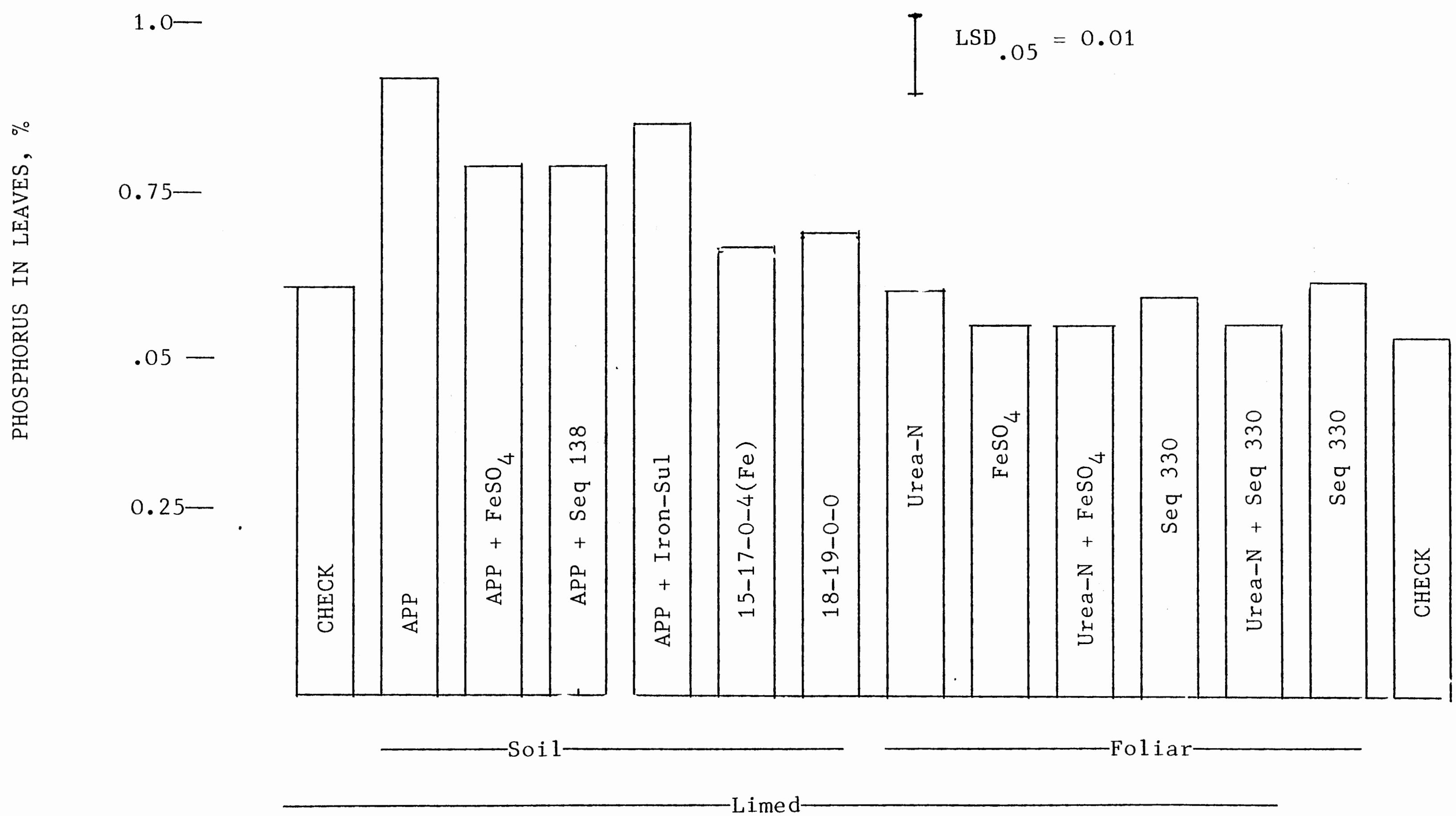

Figure 5. Phosphorus Content in Soybean Leaves, August 22, 1981.

TABLE 7

CONCENTRATION RATIOS IN SOYBEAN LEAVES

Date		Treatment	P:Fe	Zn:Fe	Mn:Fe	Cu:Fe
7-14-81		Check	15.8	.18	.24	.03
		Check	16.5	.18	.28	.03
		Check	13.5	.20	.23	.02
	Soil	APP	14.5	.22	.24	.02
	Soil	APP + $FeSO_4$	13.0	.18	.23	.02
	Soil	APP + Seq.-138	14.4	.23	.17	.02
	Soil	APP + Iron-Sul	16.5	.10	.29	.02
	Soil	15-17-0-4 (Fe)	14.5	.18	.24	.02
	Soil	18-19-0-0	16.9	.18	.27	.02
	Foliar	Urea-N	10.4	.10	.17	.02
	Foliar	$FeSO_4$	17.2	.17	.28	.03
	Foliar	Urea-N + $FeSO_4$	10.3	.13	.17	.02
	Foliar	Seq.-330	16.2	.24	.26	.02
	Foliar	Urea-N + Seq.-330	22.4	.35	.39	.02
	Foliar	Sequestrene-330	19.3	.35	.34	.03
		Check	19.6	.20	.32	.03
		Check	18.4	.24	.32	.02
		Check	16.2	.28	.28	.02
		$LSD_{.05}$	---	---	---	---
8-22-81		Check	16.9	.16	.21	.02
		Check	21.2	.20	.42	.02
		Check	17.7	.15	.35	.02
		APP	24.9	.19	.40	.02
		APP + $FeSO_4$	20.5	.17	.36	.02
		APP + Seq.-138	24.1	.17	.30	.03
		APP + Iron-Sul	25.2	.18	.32	.03

TABLE 7 (Continued)

Date	Treatment	P:Fe	Zn:Fe	Mn:Fe	Cu:Fe
Soil	15-17-0-4 (Fe)	20.0	.18	.38	.03
	18-19-0-0	20.1	.17	.29	.03
Foliar	Urea-N	16.8	.10	.26	.02
	$FeSO_4$	16.0	.15	.28	.02
	Urea-N + $FeSO_4$	13.9	.06	.17	.02
	Seq.-330	16.4	.23	.30	.02
	Urea-N + Seq.-330	15.4	.09	.32	.02
	Sequestrene-330	15.6	.13	.34	.02
	Check	11.3	.14	.21	.02
	Check	15.0	.16	.22	.02
	Check	15.4	.15	.32	.02
	$LSD_{.05}$	6.9	---	---	--

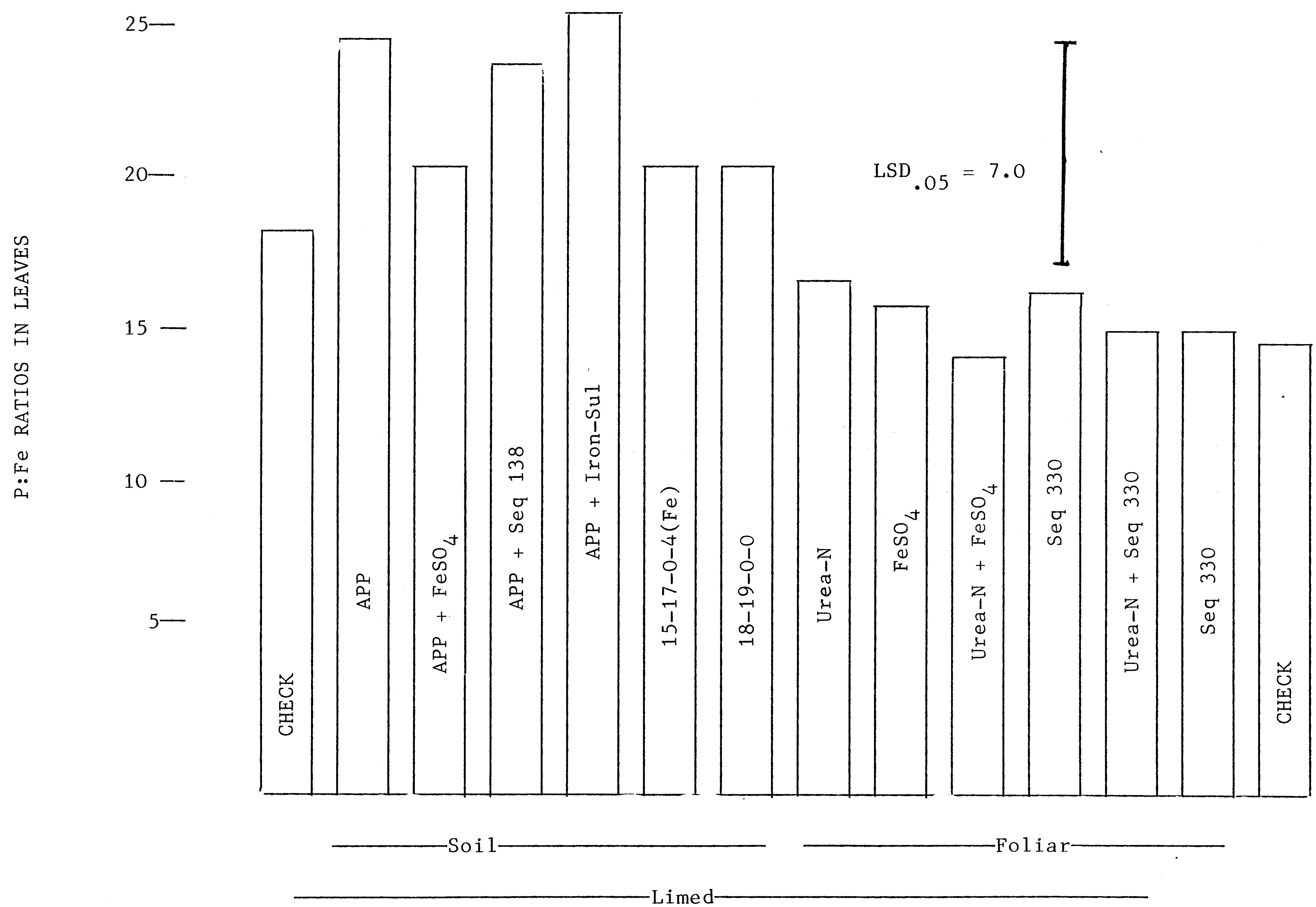

Figure 6. Phosphorus: Iron Concentration Ratios in Soybean Leaves, August 22, 1981.

the case of this study with Forrest Soybeans. It has also been recognized that the critical range for such concentration ratios are going to be largely dependent upon plant species (9, 10, 31) and possibly varietal lines within species as well as other influencing factors.

Abnormal tendencies in regards to any measured variable associated with soil applied treatments might very well be linked to the stress these plants were subjected to by the application of APP. It is interesting to note that treatments found to be high in total P content on the August 22 sampling date were treatments that included APP.

Grain Yield and Analysis

Grain samples of soybeans collected at harvest (November 17, 1981) revealed no significant differences in N, P, K, Mg, Fe, Zn, Mn, or Cu content (Table 8), or in P:Fe, Zn:Fe, MN:Fe, and cu:Fe ratios (Table 9).

Grain yield of soybeans did reveal significant differences among treatments (Figure 7). Application of APP resulted in significantly lower yield of grain (Figure 7) than other treatments. Ammonium polyphosphate applied with the seed appears to inhibit the growth and yield of soybeans.

Grain yield for all treatments that included APP and urea phosphate (18-19-0-0, elemental form) were significantly lower than the checks. Urea phosphate with Fe (15-17-0-4, elemental form) did not significantly increase grain yield above the checks but did produce grain yields that were significantly higher than urea phosphate without Fe (18-19-0-0, elemental form). This might indicate some potential for such a fertilizer with Fe applied in some manner other than direct seed contact.

Soil samples were taken post-harvest on December 11, 1981 and pH

TABLE 8

NUTRIENT COMPOSITION IN SOYBEAN GRAIN

	Treatment	N	P	K	Mg	Fe	Zn	Mn	Cu
		%				ppm			
	Check	5.9	.21	1.2	.27	62	19	34	16
	Check	6.0	.22	1.3	.33	73	18	33	16
	Check	5.9	.20	1.2	.28	60	18	30	15
Soil	APP	5.9	.22	1.4	.29	58	15	30	18
Soil	APP + $FeSO_4$	5.3	.22	1.3	.29	49	23	36	21
Soil	APP + Seq.-138	5.8	.26	1.2	.27	71	18	40	18
Soil	APP + Iron-Sul	7.3	.24	1.3	.26	75	19	33	16
Soil	15-17-0-4 (Fe)	5.8	.24	1.2	.28	69	19	33	18
Soil	18-19-0-0	5.8	.24	1.3	.27	65	21	30	16
Foliar	Urea-N	5.8	.23	1.3	.27	68	22	36	17
Foliar	$FeSO_4$	5.7	.22	1.3	.26	63	15	36	18
Foliar	Urea-N + $FeSO_4$	6.0	.21	1.3	.26	65	18	34	17
Foliar	Seq.-330	5.8	.21	1.3	.27	56	23	42	17
Foliar	Urea-N + Seq.-330	6.0	.24	1.2	.28	61	21	32	17
Foliar	Sequestrene-330	5.8	.23	1.3	.26	74	23	31	17
	Check	5.9	.22	1.3	.27	56	29	29	16
	Check	5.9	.24	1.3	.28	59	26	32	17
	Check	5.7	.24	1.2	.27	57	23	31	20
	$LSD_{.05}$	--	--	--	--	--	--	--	--

TABLE 9

CONCENTRATION RATIOS IN SOYBEAN GRAIN

Date		Treatment	P:Fe	Zn:Fe	Mn:Fe	Cu:Fe
11-71-81		Check	33.4	.31	.55	.27
		Check	37.3	.28	.53	.25
		Check	33.5	.32	.52	.26
	Soil	APP	41.5	.29	.62	.35
	Soil	APP + F eSO$_4$	56.7	.96	.66	.87
	Soil	APP + Seq.-138	41.4	.26	.62	.27
	Soil	APP + Iron-Sul	32.9	.25	.44	.21
	Soil	15-17-0-4 (Fe)	36.3	.27	.49	.26
		18-19-0-0	37.8	.33	.49	.25
	Foliar	Urea-N	38.5	.37	.59	.27
	Foliar	FeSO$_4$	35.3	.25	.58	.28
	Foliar	Urea-N + FeSO$_4$	32.2	.28	.52	.27
	Foliar	Seq.-330	42.4	.50	.78	.39
	Foliar	Urea-N + Seq.-330	40.5	.39	.57	.31
	Foliar	Sequestrene-330	37.2	.40	.49	.29
		Check	39.3	.56	.54	.31
		Check	42.7	.46	.57	.30
		Check	47.1	.48	.62	.41
		LDS$_{.05}$	---	---	---	---

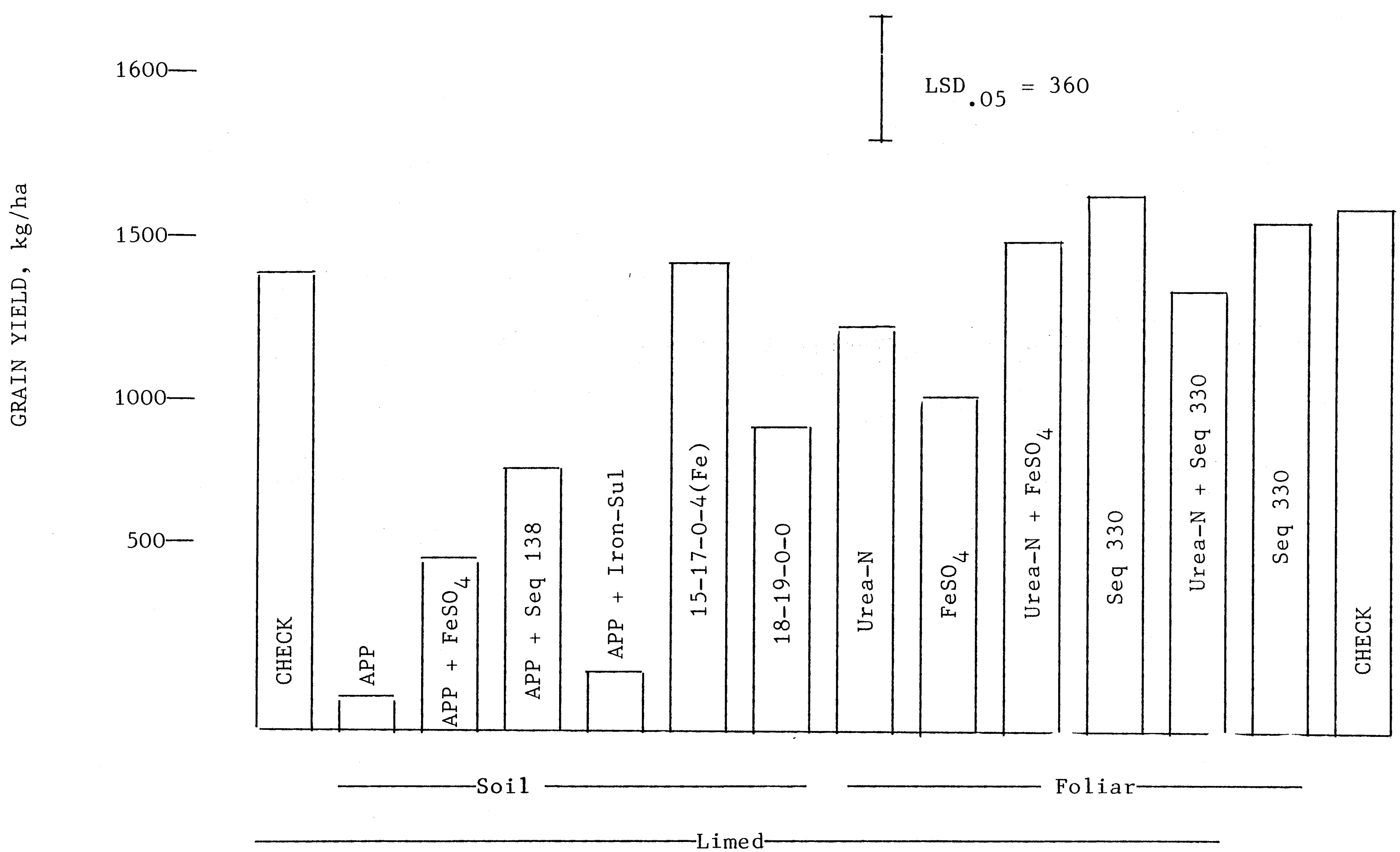

Figure 7. Soybean Grain Yield at Chickasha, Oklahoma, November 17, 1981.

(1:1 H_2O) was determined (Figure 8). Soil pH values increased from previous values (Table 1) but did not attain a uniform level of pH 8. The increase in pH values determined from the June 22 soil sampling to the December 11 sampling indicate a continuation of the equilibration process following lime applications in the 1981 growing season. The degree of uniformity attained after lime applications in 1981 is illustrated in Figure 8.

The soil pH values of this range are often considered capable of producing Fe chlorosis in many plants, particularly those that are considered to be Fe inefficient such as Forrest soybeans (14, 19, 30). In this experiment, the degree of chlorosis (based upon chlorophyll measurements) did not seem to be affected by the various Fe fertilizers employed. Soil pH is certainly an important factor in the expression of Fe chlorosis for many plants but it is not independently responsible in most cases for this condition. It must be emphasized that Fe nutrition is a dynamic relationship between a plant and many factors in its environment from both the soil and the atmosphere (12, 14, 26). Annual fluctuations in the severity of this type of abnormality is not unique for the case of Forrest soybeans grown in south central Oklahoma. In recognition of this, modification of this experiment will be implemented and research continued in an effort to determine effective means of evaluation and control of Fe chlorosis under these conditions.

Conclusions concerning the use of fertilizers in direct contact with soybean seeds would tend to reinforce those of Clapp and Small (13). Fertilizers should not be placed in contact with soybean seeds. Soybeans obviously have a much greater sensitivity to such fertilizer materials than does corn, sorghum, or wheat. This may be a direct

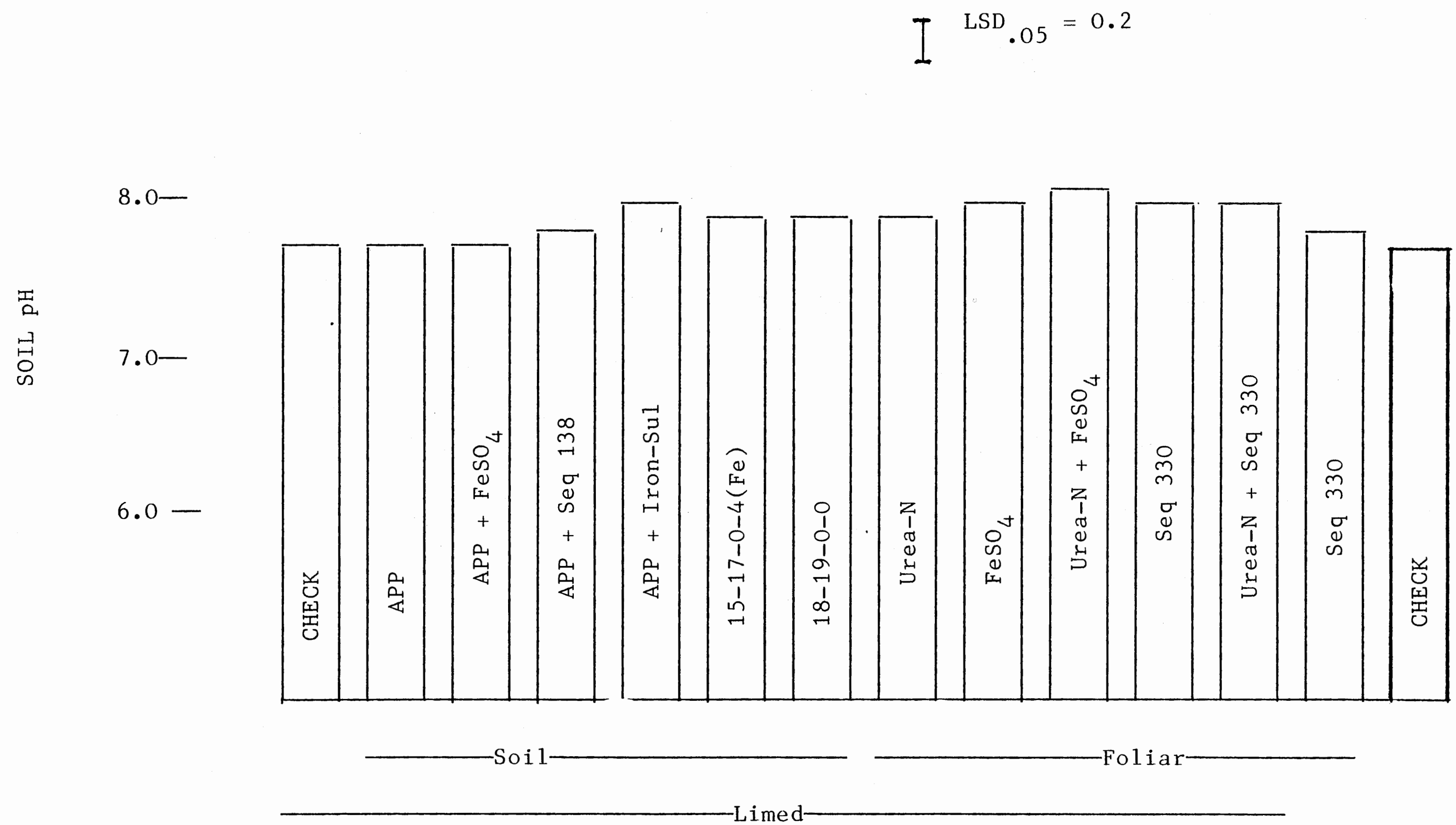

Figure 8. Soil pH Values for Experimental Area, December 11, 1981.

function of seedling salt tolerance, or in effect, drought tolerance.

Alternative methods of fertilizer placement will need to be incorporated in continuing soybean research.

Summary

A field experiment was conducted at the South Central Research Station at Chickasha, Oklahoma to investigate the occurrence and correction of Fe chlorosis on Forrest soybeans during the 1981 growing season, and also, to measure the effects of soil applied fertilizers and foliar applied fertilizers on the nutrient content of tissue and grain as well as yield of grain.

Results of this experiment indicate that the use of a macronutrient fertilizer applied in direct contact with the seed at planting is detrimental to emergence and establishment of soybean plants. An alternative method of application such as banding of the fertilizer to the side and below the seed may provide more beneficial results from the use of macronutrient fertilizers in combination with Fe fertilizers.

The use of foliar applied Fe fertilizers with or without the inclusion of urea-N may provide benefits in the correction of Fe chlorosis under the conditions of some growing seasons but they did not significantly alter the chlorophyll and nutrient content of the leaves or the yield and nutrient composition of grain of Forrest soybeans in 1981.

The results of the 1981 experiment are not conclusive in regards to cause-effect relationships nor the correction of Fe chlorosis in south central Oklahoma. However, this information will be of considerable benefit when utilized in the evaluation of subsequent research of this type.

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