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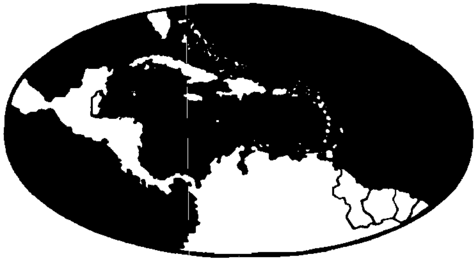

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LACK OF RESPONSE OF SOYBEANS GROWN ON AN ULTISOL TO BROADCAST RESIDUAL AND BANDED P-FERTILIZERS

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INTRODUCTION

Soybeans are an extremely important and valuable crop in the United States where over 40 million acres are planted in 30 States. Yields range from 1000 kg/ha to 2200 kg/ha with a yearly average for the United States of 1466 to 1800 kg/ha over a 10-year period.

The possibilities of producing soybeans under tropical conditions have hardly been explored. Tropical areas offer a year round growing season that might permit more than one crop during a year, but also have a wide range of pest and soil fertility problems. The great deal of technology in soybean production readily available in temperate areas must be adapted to the tropical envoronment. Being a legume, soybeans have the ability to supply their own N needs, provided the strain of Rhizobium bacteria is present, that the soil has an adequate supply of other essential elements and that the soil pH is not too low.

Since soybeans require a relatively high available soil P for maximum yields and Ultisols and Oxisols in the humid tropics are in general low in available phosphorus, P fertilization requirements of soybeans in these soils need to be studied in order to attain maximum economic yields in these areas. For example, it is necessary to know if it is more efficient and economical to make a large, initial broadcast P application or more frequent, smaller banded application or a combination of these practices. Torres soil was chosen since it had a low available P content (5.4 ppm by Bray No. 2) and was thought to be representative of large areas of Ultisols in the humid tropics.

This study offered also a good opportunity to study the potential for soybean production in the humid tropics.

MATERIALS AND METHODS

The experiment was located at Cidra, 450 m above mean sea level. The soil has been classified as Torres, one of the Orthoxic Palehumults, clayey, oxidic, isohyperthermic. The experiment followed a randomised block layout with 5 replications. On May 23, 1973, seeds of cultivar Hardee were planted at the rate of 100 kg/ha in rows 46 cm apart at a distance of 2.5 cm between plants with a plant population of approximately 864,500 plants/ha. This experiment was the fourth successive crop planted at this site. Plots of 416 m^2 (4.57 m x 9.1 m) included 10 rows each. The experiment was totally replanted on June 29, 1973, due to very poor germination resulting from the low available soil moisture during late May and early June. Prior to replanting, Gramoxone was applied at the rate of 4.6 1/ha to kill the remaining soybean plants from the first planting. Seeds were planted at a depth of 2 cm with a small 2-row planter. The seeds were inoculated.

For seven of the treatments, P was initially broadcasted on November 1971, before planting corn while P in the banded treatments was applied to each individual crop in the sequence at planting. Treatments were as follows: Unlimed, broadcast P at the rate of 1120 kg/ha; Limed to bring the soil pH to 5.5-6.0 *, but without P; Limed an initial and broadcast P at rates of 90, 179, 359 and 1120 kg/ha; Limed and banded P to each crop at rates of 22, 45, 90 and 179 kg/ha; and Limed + 359 kg/ha broadcast P plus 22 kg/ha P banded.

A blanket fertilizer application of 224 kg/ha K as K_2SO_4; 56 kg/ha Mg as $MgSO_4.7H_2O$ and 17 kg/ha Zn as $ZnSO_4$ (35% Zn) was broadcasted and ploughed in prior to planting. No nitrogen was applied since it was expected that the inoculated soybeans would fix N. Observations were recorded when the plants were at full-bloom on plant vigor, rooting colour and nodulation.

One week after germination Bugeta pellets, at the rate of 28 kg/ha were applied to control snails and slugs which were causing damage

* A total of 16.8 metric tons/ha of lime had been applied prior to planting the soybean experiment; 7.8 tons before planting the first corn crop and 9 tons after harvesting the first corn experiment.

to the stems of the young plants. Weekly sprays consisting of a mixture of Diazinon AG-500 (1.3 1/ha) or Malathion (9.5 1/ha) + Dithane M-45 (2.2 kg/ha) were initiated one month after planting to control leafworms and prevent fungal diseases. Diazinon and Malathion sprays were alternated weekly so as to prevent insects from possibly developing resistance to the pesticides. Spraying continued on a weekly basis until the pod filling stage at which time, Sevin powder, 5% strength, was applied twice a week to control the stink bug and other insects in the lower branches of the plants.

Weeds were controlled mainly by hand during the first 2-3 weeks after the seed was sown. Later on, when the crop had closed in, weeds were shaded out by the dense soybean canopy.

The third, fully developed trifoliate leaves were sampled at the early flowering, 42 days after sowing.

The experiment was harvested on October 24, 1973, 117 days after sowing. Sub-plots of 1.83 x 7.62 meters were selected from the 4 middle rows of each plot for yield calculations. Plants were cut with machetes at ground level and then threshed. Grain, stalks and shells were oven dried for yield calculations. Small samples of grain, stalks and shells were taken and sent to the laboratory for P determinations.

Soil samples (a total of 6 cores per plot) were taken prior to planting from the control (Treatment 2) and the P- broadcast plots (Treatments 1, 3-6) and immediately after harvesting, when the experimental area was clean from stover. Samples were taken from the 0-15 cm depth. Soil from the first samples were analysed for pH, available P and Mn, and exchangeable K, Ca, Mg and Al. Samples taken after harvesting were analysed for pH and available P only using the Bray No. 2 and Olsen's methods of soil extracts.

RESULTS AND DISCUSSION

Soil Nutrient Status

Results of selected chemical analyses of the soils taken prior to planting are shown in Table 1. In the unlimed plots the pH was 3.89 while the mean value of all the limed plots was 4.97. Exchangeable aluminum was only measured in the unlimed plots. Manganese extracted with unbuffered 1NKCl was three times higher in the unlimed plots than in all other plots. The Bray No. 2 extractable contents P analyses are not particularly well correlated with the amount of P applied in 1971 except that the highest level of P applied (1120 kg/ha) resulted in 4 to 5 times more extractable P than for the other P levels.

Samples taken after the soybeans were harvested showed a pH of 4.43 in the unlimed plots (Table 2) with a mean value of all the limed plots of 5.20. The quantity of P applied in 1971 was fairly well reflected in the Bray No. 2 and Olsen's P analyses. The amount of Bray No. 2 extracted dropped by an average of 40% during the growth of the crop. All but the treatments with 1120 kg/ha P were below the 20 ppm which is considered too low in Alabama*. It is interesting to note that after only two years the residual effect of 359 kg/ha P raise the extractable P levels only a few ppm.

Leaf Nutrients

Less than a month after planting all plants from the no-lime, high P treatment plots (No. 1) exhibited chlorotic spots in the first, fully developed trifoliate leaves. Some of the upper leaves in smaller plants were also crinkled, arousing suspicion of a Mn toxicity. At a more advanced growth stage, the upper leaves appeared to be distorted in shape, crinkled with marginal cupping and necrotic spots. The affected plots could be easily picked out from a distance. However, it soon became apparent that plant height was not affected by this condition.

Results from the spectrographic analyses of the leaves taken at the early flowering stage, revealed a mean Mn content of 898 ppm for the unlimed plots (Table 3). This is the toxic range for soybeans (2, 3, 6) and confirmed the visual Mn toxicity symptoms. On the other hand, aluminum leaf levels in this no lime treatment fall within the non-toxic range of 200 ppm. It appears, from data in Table 3, as though there is sufficient P for soybeans even in the O-P plots (treatment No. 2). Sufficiency P levels reported by the Ohio Plant Analysis Laboratory range between 0.26 - 0.50 per cent P.

It might be worthwhile to indicate that, in general, the Mo content in the leaves was very low and hence, probably deficient. An examination of several plants when they were in full-bloom, revealed a nearly complete absence of root nodules. However, the vigorous plant growth and dark green colour indicated that the plants were not N deficient. The soil in this site had a very high N supplying power and it is probable that this high N limited nodule formation. However, the low Mo concentration in the leaves indicates that this element may have been insufficient for nodule formation.

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*Pearson, R.W., Personal communication, Auburn, Alabama, 1975.

Except for the high Mn in the unlimed plots, low Mo and perhaps high Zn, the conditions prevailing at the experimental area appear suitable for the growth of soybeans.

Grain and Stover Yield and Total P-Uptake

A field wide grain yield average of 3698 kg/ha was obtained with no statistical differences among treatments (Table 4). This yield was almost twice as high as the average soybean yield in the continental US in 1973 and demonstrates a potential for growing soybeans in the tropics. Yields exceeding 4000 kg/ha have been obtained previously in the Corozal Substation with the same cultivar.

The quantity of P absorbed by the soybean plants was not consistently related to the amount or method of P applied. However, applications of 359 kg/ha broadcast P or over in 1971 or 179 kg/ha banded P to each of 3 crops (2 corn crops and a soybean crop) significantly increased stover (Stalks plus pods) yields over that of the check treatment. The only treatments which resulted in significantly more P uptake than the check were the 1120 kg/ha broadcast + lime (Treatment 6) and the 3* x 179 kg/ha banded treatment. These two treatments absorbed significantly more P than all except the 359 kg/ha braodcast and the 3 x 45 kg/ha banded P treatments.

Adding lime to the plots treated with 1120 kg/ha broadcast P significantly increased the P uptake by the plants. This increase may have been due more to the increased growth in the limed plots than to the increased P availability since the Bray No. 2 available P was relatively high and about the same at the beginning of the experiment (Table 2). Perhaps more dramatic P responses were not obtained in spite of the low available P because of the rapid mineralization of organic P in the soil. Fox *et al.*, reported that sufficient N was mineralized in an adjacent site where there was no N fertilizer response by corn in 2 successive trails in 1971 - 72. To clarify the response of crops to P-fertilizers further field and greenhouse experiments are necessary.

The high yields of soybeans in this experiment suggest the possibilities that this crop can be produced on large scale basis on the acid, relatively infertile soils of the hot humid tropics if limed and fertilized adequately. There is a large acreage of these soils in the Amazon Basin, in Africa and in other parts of the world which offer a vast production potential. Furthermore, because of their high protein content, soybeans offer possibilities of providing more balanced diets in areas where the

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* **Refers to P applied to previous two corn crops planted at this site and the soybean crop.**

high carbohydrate foods are staples (rice, root and tuber crops). In addition, soybeans, because of their N fixing capability can be produced with very little N or no N inputs which can be very important in keeping production costs at a low level as the high energy needs for producing inorganic fertilizer N has sharply increased the price of this fertilizer in the world market.

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TABLE 1. Selected chemical properties of soil samples taken prior to planting soybeans from several treatments at the P experiment, Torres clay, Cidra, April 1973.

Treatment No.	Lime	P Broadcast in 1971 (residual) kg/ha	pH	Exchangeable 1/ (Meq.) Ca^{2+}	Mg^{2+}	K^{+}	Al^{3+}	Mn^{2+} 2/	P 3/ p.p.m.
1	0	1120	3.89	2.86	.63	.44	2.75	7.4	86
2	16.8 tons/ha, 1971	0	5.00	5.82	.54	.56	-	2.7	13
3	"	90	5.03	6.42	.82	.50	-	2.2	17
4	"	179	4.84	5.97	.55	.48	-	1.9	13
5	"	359	5.08	6.42	.93	.51	-	2.7	21
6	"	1120	4.92	6.42	.60	.46	-	2.6	96

1/ Ca, Mg + K determined with IN NH_4O Ac, pH 7.0, Al, with unbuffered IN KCl (overnight extraction)

2/ Mn^{+} determined with unbuffered IN KCl

3/ Bray No. 2

TABLE 2. Selected chemical properties of soil samples taken after harvesting soybeans from several treatments at the P experiment, Torres clay, Cidra, November 1973.

Treatment No.	Lime	P Broadcast kg/ha	pH	P - Bray No. 2 p.p.m.	P - Olsen p.p.m.
1	0	1120	4.43	55	33
2	16.8 tons/ha, 1971	0	5.25	7	14
3	"	90	5.21	7	13
4	"	179	5.16	11	20
5	"	359	5.18	12	24
6	"	1120	5.18	57	46

TABLE 3. Leaf nutrient composition of soybean plants, variety Hardee, 42 days after planting, August, 1973.

Treatment No.	Lime	P: Broadcast in 1971 (residual) kg/ha	P: Banded[1] kg/ha	Percent of the indicated element, parts per million[2]: P	K	Ca	Mg	Mn	Al	Mo	Cu	Zn
1	0	1120	0	.40	2.67	1.04	.49	898	172	1.2	16	115
2	16.8 tons/ha, 1971	0	0	.32	2.74	1.22	.36	355	151	0.7	22	84
3	"	90	0	.34	2.73	1.17	.35	308	137	0.2	21	78
4	"	179	0	.37	2.65	1.23	.39	351	116	0.4	21	83
5	"	359	0	.39	2.97	1.07	.35	317	101	0.7	18	71
6	"	1120	0	.42	2.67	1.22	.40	338	124	0.1	17	74
7	"	0	22	.34	2.85	1.11	.37	308	133	0.9	18	85
8	"	0	45	.40	2.97	1.07	.35	360	128	0.9	19	79
9	"	0	90	.46	3.29	1.13	.42	304	122	0.5	24	74
10	"	0	179	.43	2.87	1.13	.38	270	124	0.5	16	61
11	"	359	22	.39	2.80	1.16	.36	353	116	0.3	19	74

[1] Banded at planting time

[2] Small and Ohlorogge sufficiency ranges for soybeans: P 0.26-0.50%; K 1.71-2.50%; Ca 0.36-2.00; Mg 0.26-1.00; Mn 21-100 ppm; Cu 10-30 ppm; Zn 21-50 ppm; and Mo 1.0-5 ppm (6)

TABLE 4. Soybean grain and stover yields and total plant P-uptake, Torres clay, Cidra, Puerto Rico Autumn, 1973.

	P applied				
Treatment No.	Banded	Broadcast in 1971 (residual) kg/ha	Grain Yield (13% H_2O), kg/ha	Stover Yield, kg/ha	Total Plant P[3] kg/ha
1	0	1120[1]	3573	1435 abcd[2]	24.35 c
2	0	0	3680	1181 d	24.03 c
3	0	90	3311	1258 abcd	26.29 bc
4	0	179	3577	1455 abcd	24.51 c
5	0	359	3645	1459 ab	25.28 bc.
6	0	1120	4378	1547 abc	32.86 a
7	22	0	3475	1171 cd	24.43 c
8	45	0	3830	1407 abc	27.09 bc
9	90	0	3499	1389 bcd	22.88 c
10	179	0	4229	1628 a	31.43 ab
11	22	359	3480	1479 ab	28.49 abc
		Mean	3698	1401	26.58

[1] No lime treatment

[2] Numbers followed by the same letter are not significantly different at the 5% probability level using Duncan's Multiple Range Test

[3] Grain P + Stover P (Stalks + Shells)