11-2. EFFECTS OF LIMING AND PHOSPHORUS FERTILIZATION ON STATUS OF MINERAL NUTRIENTS IN SOYBEAN PLANTS GROWN IN THE CERRADO SOIL.

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INTRODUCTION

It is well known that the cerrado soils are weathered intensively, very poor in most of nutrients, particularly phosphorus (P), low in pH and high in exchangeable aluminum (Al) content. Therefore, liming and P-fertilization are essential practices. Lobato, & Goedert (7) researched on the effects of liming and P-fertilization on the productivity of the cerrado soils, and recommended the rates and methods of liming and P-application.

Plant growth depends on many factors. These factors include the ability of soil to supply nutrients, the rate of absorption, the mobility of the nutrients within the plants and the nutrients interactions. The authors are interested in changes in micronutrient status by fertilization. It is the purpose of this paper to point out the influences of liming and P-fertilization on macro - and micronutrient absorption and mobility within the soybean plant grown in experimental field.

MATERIALS AND METHODS

Sample: Samples of soybean plants were collected from the experimental field at the Cerrado Agricultural Research Center (CPAC/EMBRAPA) in a dark-red latosol on Feb. 21, 1980 (flowering stage). The field experiment was designed as follows:

Liming t/ha	P-fertilization (P_2O_5) kg/ha		
	160	778	1374
0.5	C_1P_1	C_1P_2	C_1P_3
1.5	C_2P_1	C_2P_2	C_2P_3
4.5	C_3P_1	C_3P_2	C_3P_3

Lime and P-fertilizer (Triple superphosphate) were applied in 1975 at the rates described above. Banded application of 20 kg/ha N as Urea were made at planting 3 weeks after planting, and at the flowering stage. Potassium Chloride (30 kg/ha K_2O) was band-applied at planting.

The varieties of soybean were (1) VX5-281.5, (2) Lo75-2760 and (3) Lo75-1237, and were planted on Nov. 28 to Dec. 3, 1979.

The plants were washed with tap water and separated into leaves, stems (including branches and petioles) and roots, oven-dried at 60°C, and ground.

Analytical method:

The dried, ground materials were digested with sulfuric acid and hydrogen-peroxide on a hot plate.

The digested solutions were analyzed for Ca, Mg, Fe, Zn, Cu and Mn with the Shimadzu UV-201A Atomic absorption spectrophotometer, P by phosphomolybdate colorimetric method and Al by aluminon colorimetric method shich was described in a previous paper(4) in detail. The ground samples were ashed in a muffle furnace and analyzed for Mo by dithiol colorimetric method. The procedure was described in a previous paper (4)

Plant heights (from ground level to shoot apex) were measured for estimation of plant growth on March 3, 1980.

RESULTS AND DISCUSSION

As shown in Fig. 1, both liming and P-fertilization influenced beneficial effects on plants growth. When comparing the former with the latter, however, it is evident that the effects of the former on plant growth is very weak. The difference of growth among the varieties is not clear.

Calcium and Magnesium: Results of analysis for nutrients are shown in Table 1 - 10. Ca concentrations in leaves, stems and roots are increased with increasing levels of both lime and P-application (Table 1). Mg concentrations show the same tendency as Ca in relation to liming, but the effect of P-application on Mg status is not clear (Table 2).

Iron: Fe concentrations in leaves and stems are decreased with increasing of liming and P-applications (Table 3). Some samples of roots show extremely high concentrations of Fe probably due to soil contamination, so the data on roots are omitted. The sufficient range of Fe in scybean leaves is considered to be from 50 to 200(6), but Fe toxicity has not been reported for soybean growing under natural conditions. Therefore, it is not possibile to decide whether the Fe concentrations in those samples exceed the toxic level.

Zinc (Zn): Zn deficiency occurs when the leaf concentration is less than 20 ppm in dry matter. The normal concentration is 25 to 150 ppm(6). As shown in Table 4, Zn concentration in most of leaf sample is from 50 to 150 ppm and effects of liming and P-fertilization were not clear. But Zn concentration in stems and roots are decreased with increasing of liming and P-application. "P induced Zn deficiency" has been well known(8) This disorder in plant growth commonly is considered to be associated with large application of P and the formation of less soluble complexes of P and Zn in the soil. But, it is reasonable to consider that decreases of Zn concentration caused by P-application to the cerrado soil are a simple dilution effect on Zn concentration in the plant owing to the growth response of P. The effect of liming on Zn concentration in soybean plants is also evident in Table 4. Uptake of heavy metals by plants is generally decreased with increasing of pH. But the relation between pH and availability of heavy metals is not simple under natural conditions. The phenomena mentioned above also may be a simple dilution effect owing to the growth response of liming or amendment of acidity. Appearance of these dilution effects shows that the ability of the cerrado soil to supply Zn is not adequate and that Zn deficiency may very possibly occur when the productivity shall be increased in the future.

Copper (Cu): The normal range of Cu concentration in plant is about 5 to 20 ppm. When the Cu concentration in plants is less than 4 ppm in the dry matter, Cu deficiencies are likely to occur(6) The Cu concentrations in Table 5 are the normal range. Liming and P-fertilization do not seem to effect Cu concentration in the soybean plants grown in the cerrado soil.

Manganese (Mn): As shown in Table 6, the Mn concentrations can be considered to decrease with increasing of liming. The effects of P-fertilization on the Mn concentrations in leaves is not clear, but the concentrations in stems and roots are decreased with P-fertilization. Mn deficiency generally occurs when Mn concentration in plants is less than 20 ppm. Levels in excess of 500 ppm are probably toxic for soybean plant(6). Therefore, it should be considered that the Mn concentrations in Table 6 are ate the normal level.

Phosphorus (P): The effect of liming on P-concentration is obscure in Table 7. P-concentration increased with increasing of P-fertilization.

Molyvdenum (Mo): Mo deficiency usually occurs in most plants when the Mo concentration is less than 0.1 ppm in dry matter(6). The toxicity levels have not been established under natural conditions. The varieties and plant parts differ widely in Mo concentration in Table 8, but they seem to be normal except for some samples of the C_2 treatment. The Mo concentrations in soybean plants receiving 4 t/ha of lime increase with increasing of P-fertilization. But when amouts of liming are equal to or less than 1.5 t/ha (C_1 and C_2 treatment), the Mo concentrations decreased with increasing of P-fertilization. It was reported that phosphorus enhanced the absorption and translocation of Mo(8). Barshad (1) suggested that P may stimulate Mo uptake because of the formation of a complex phosphomolybdate anion absorbed more readily by plants. The effects of P-fertilization on the Mo concentration in the plants receiving 4 t/ha of lime (C_3 treatment) are consistent with Barshad's (1) interpretation, but the reverse effects of P-fertilization in the C_1 and C_2 treatments can not be understood.

In order to invertigate the effects of liming on Mo concentration, the average Mo concentrations of C_1, C_2 and C_3 treatment were calculated. The average Mo concentration of the C_1 and C_2 treatment is about 0.2 ppm except in leaves of the C_2 treatment, while the average concentrations in leaves, stems and roots of C_3 treatment are 0.46, 1.03 and 0.75 ppm respectively. Therefore, it can be considered that liming increases the ability of soil to supply Mo. But is has been unsolved whether the effects of liming are caused by the increase in soil pH or by the increased supply of calcium within the limits of this experiment.

Supplemental experiment

Seed is usually not analysed to determine the nutrient status of crops. However, seed analysis is usefull in determining the Mo supply for young soybean plants. According to an experiment by one of the authors, most of molybdenum contained in roots, stems and leaves removes to the pods and accumulates in seeds at ripening stage (5). Therefore, the ability of the soil to supply Mo can be estimated by seed analysis.

In order to supplement the results described above, the seeds produced in the experimental field by Spehar and Izumiyama were analysed for Mo. From the results shown in Table 9, it is observed that the Mo concentration in the seeds produced in non-limed plots does not exceed 0.08 ppm, while the seeds produced in limed plots show high concentrations of Mo (3 - 7 ppm). From the results, it is assumed that the lime may contain a trace amount of Mo, and that liming probably plays a role in micronutrient supply, in particular Mo. One of the authors is very interested in the relation among Mo concentration in seeds, nodulation and the rate of nitrogen fixation.

Aluminum (Al): Al concentration in leaves and stems is decreased by liming and P-fertilization as shown in Table 10. Average concentrations of Al in each treatment and each plant part are calculated for comparing the effects of liming and P-fertilization. From the results in Fig. 2, it is assumed that the effects of P-fertilization are more intensive than those of liming within the limits of this experiment. The roots are excluded from consideration because of the possibility of soil contamination. It is evident that plant growth negatively correlates with the Al concentration in both leaves and stems, and that the Al concentration is an important factor which inhibits the plant growth. Although correlation coefficients were not calculated, it seems that the Al concentration in stems is more negatively correlated with plant growth than that in leaves, as shown in Fig. 3. The biochemical mechanism of Al toxicity is not exactly known, although it is assumed that Al toxicity appears to be closely associated with effects on uptake and translocation of some nutrients such as P, Ca and Mg(1, 8). Clark, R.B. reported that low Mg might be an important response in plant sensitive to Al(1). The Mg concentrations in Table 2 is seemed to depend on the Al concentration shown in Table 10, however, the relation was not examined statistically.

In order to evaluate Al toxicity exactly, the relationships among plant growth, Al concentration, and concentration of mineral nutrients should be investigated.

SUMMARY

In order to investigate the effects of liming and P-fertilization on the macro - and micronutrients absorption and their mobilities within the soybean plants grown in experimental field, concentrations of Ca, Mg, Fe, Zn, Mn, P, Mo and Al were determined and the results were summarized as follows:

1. Plant growth: Liming and P-fertilization influenced beneficial effects on plant growth.
2. Ca: The concentrations were increased with increasing of both lime and P-application.
3. Mg: The concentrations were increased by liming, but effect of P was not clear.
4. Fe: The concentrations were decreased with increasing of liming and P-fertilization.
5. Zn: The concentrations in stems and roots were decreased by liming and P-fertilization, but in leaves their effects on Zn were not clear.
6. Cu: Liming and P-fertilization do not effect on Cu concentration.
7. Mn: The concentrations were decreased by liming and P-fertilization except in leaves, and the effects of P-fertilization were not clear.
8. P: P concentrations were increased with increasing of P-fertilization; however, the effects of liming is obscure.
9. Mo: When 4 t/ha of lime was applied, the Mo concentrations were increased by P-fertilization. But when 1.5 t/ha and 0.5 t/ha of lime were applied,

they were decreased. Liming was seem to increase the ability of soil to supply Mo.

10. Al: The concentrations were decreased by liming and P-fertilization. The plant growth negatively correlated with the Al concentration in leaves and stems.

REFERENCE

1. BARSHAD, I. Factors affecting the Mo content of pasture plants. 2. Effect of soluble phosphates, available nitrogen and soluble sulfate. **Soil Sci.,** 71:387-398, 1951.
2. CLARK, R.B. Effect of Al on growth and mineral elements of Al tolerant and Al-intolerant corn. **Plant and soil,** 47:653-662. 1977.
3. FOY, C.D. & BROWN, J.C. Toxic factor in acid soils. II Differential aluminum tolerance of plant species. **Soil Sci. Soc. Amer. Proc.,** 28:27-30. 1964.
4. ISHIZUKA, J. & MESQUITA FILHO M.V. de Re-examination of analytical methods for Al and Mo in plant material (in preparation).
5. ISHIZUKA, J. **Personal notes.** 1980.
6. JONES, Jr., J.B. Plant tissue analysis for micronutrients. In: MORTVEDT, J.J.; GIORDANO, P.M. & LINDSAY, W.L. **Micronutrients in Agriculture.** Madison, Wis, SSSA, 1972. p. 319-45.
7. LOBATO, E. & GOEDERT, W.J. Increasing the productivity of Brasilian cerrado soils. In: INTERNATIONAL SEMINAR ON SOIL ENVIRONMENT AND FERTILITY MANAGEMENT IN INTENSIVE AGRICULTURE, 1., Tokyo, 1977. **Proceedings. . .** Tokyo Society of the Science of Soil and Manure, 1977. p. 464-471.
8. OLSON, S.R. Micronutrient Interactions. In: MORTVEDT, J.J.; GIORDANO P.M. & LINDSAY, W.L. **Micronutrients in Agriculture.** Madison, Wis, SSSA, 1972. p. 243-64.

TABLE 1 – Ca concentration (%)

Treatment	Part / Variety*	Leaf			Stem			Root		
		1	2	3	1	2	3	1	2	3
C_1	P_1	0.30	0.29	0.25	0.35	0.38	0.29	0.17	0.19	0.29
	P_2	0.36	0.46	0.40	0.46	0.58	0,60	0.25	0.35	0.40
	P_3	0.65	0.72	0.51	0.63	0.58	0.78	0,43	0,31	0.57
C_2	P_1	0.31	0.50	0.50	0.45	0.45	0.53	0.32	0.35	0,37
	P_2	0.42	0.74	0.53	0.36	0.71	0.49	0.46	0.38	0.44
	P_3	0.38	0.75	0.61	0.48	0.64	0.61	0.37	0.37	0.44
C_3	P_1	0.56	0.79	0.75	0.42	0.83	0.62	0.54	0.43	0.60
	P_2	0.68	0.73	0.91	0.44	0.77	0.78	0.41	0,46	0.49
	P_3	0.84	1.14	0.97	0.64	0.94	0.79	0.49	0.45	0.52

TABLE 2 – Mg concentration (%)

Treatment	Part Variety*	Leaf			Stem			Root		
		1	2	3	1	2	3	1	2	3
C_1	P_1	0.16	0.17	0.15	0.13	0.12	0.09	0.08	0.06	0.09
	P_2	0.16	0.18	0.18	0.17	0.23	0.21	0.12	0.22	0.13
	P_3	0.18	0.16	0.17	0.21	0.23	0.20	0.21	0.21	0.23
C_2	P_1	0.28	0.32	0.31	0.17	0.22	0.24	0.09	0.20	0.17
	P_2	0.30	0.28	0.23	0.24	0.36	0.24	0.21	0.35	0.27
	P_3	0.17	0.21	0.23	0.20	0.26	0.33	0.12	0.28	0.23
C_3	P_1	0.41	0.47	0.40	0.26	0.49	0.36	0.27	0.33	0.34
	P_2	0.38	0.31	0.36	0.36	0.44	0.45	0.28	0.34	0.41
	P_3	0.43	0.41	0.34	0.43	0.59	0.53	0.30	0.49	0.49

* Variety 1..VX5-281.5, 2..Lo75-2760, 3..Lo75-1237

TABLE 3 – Fe concentration (ppm)

Treatment	Part Variety*	Leaf			Stem			Root		
		1	2	3	1	2	3	1	2	3
C_1	P_1	589	542	338	1000	1000	690			
	P_2	328	452	338	514	380	766			
	P_3	240	278	221	461	176	322			
C_2	P_1	497	282	278	1000	347	676			
	P_2	286	306	476	329	274	204			
	P_3	219	289	215	434	244	153			
C_3	P_1	314	494	273	428	1000	546			
	P_2	199	604	177	125	1000	324			
	P_3	275	298	269	401	448	236			

TABLE 4 – Zn concentration (ppm)

Treatment	Part / Variety*	Leaf			Stem			Root		
		1	2	3	1	2	3	1	2	3
C_1	P_1	85.0	86.9	103.3	62.3	60.0	75.5	134.7	74.9	120.8
	P_2	74.6	99.4	86.0	37.0	33.3	49.9	59.4	65.8	82.4
	P_3	85.4	153.1	99.2	28.3	44.3	38.3	59.4	57.4	71.6
C_2	P_1	89.9	112.7	86.3	91.9	37.2	42.5	113.3	106.4	83.2
	P_2	78.2	132.2	86.0	26.1	36.4	24.7	49.5	68.6	45.4
	P_3	78.3	190.4	87.3	29.2	39.3	25.1	80.2	121.8	54.5
C_3	P_1	54.4	67.7	62.5	22.0	46.2	28.6	82.4	54.1	71.6
	P_2	46.8	80.2	61.5	11.3	27.1	18.0	31.7	86.0	29.3
	P_3	46.7	63.3	59.3	15.1	23.2	16.7	51.7	42.9	38.3

* Variety 1..VX5-281.5, 2..Lo75-2760, 3..Lo75-1237

TABLE 5 – Cu concentration (ppm)

Treatment	Part / Variety*	Leaf			Stem			Root		
		1	2	3	1	2	3	1	2	3
C_1	P_1	11.0	8.9	11.8	5.6	5.0	5.7	12.3	8.3	9.3
	P_2	7.3	10.6	10.1	4.9	6.3	6.2	6.1	8.9	8.2
	P_3	9.0	8.6	8.7	5.5	5.9	5.1	8.1	6.4	7.2
C_2	P_1	7.8	10.0	8.8	4.7	5.7	5.5	12.4	11.9	8.8
	P_2	6.1	8.6	11.8	4.8	5.9	6.5	6.9	8.8	7.7
	P_3	5.9	11.1	8.4	4.0	6.6	5.6	8.7	10.3	6.5
C_3	P_1	8.1	9.6	10.0	5.1	7.3	6.4	13.2	11.3	12.2
	P_2	6.9	10.1	8.2	4.8	7.3	5.9	6.8	11.0	8.4
	P_3	7.6	6.9	6.9	5.3	5.5	5.0	6.4	8.7	7.4

TABLE 6 – Mn concentration (ppm)

Treatment	Part / Variety*	Leaf			Stem			Root		
		1	2	3	1	2	3	1	2	3
C_1	P_1	133	162	125	147	165	157	59	60	72
	P_2	128	150	121	84	70	108	27	39	93
	P_3	108	196	141	56	77	77	33	29	46
C_2	P_1	80	83	76	105	36	67	39	35	28
	P_2	50	86	85	26	36	37	18	20	30
	P_3	122	164	92	76	49	39	33	34	20
C_3	P_1	38	65	45	17	41	24	23	19	22
	P_2	33	60	33	11	24	13	9	22	9
	P_3	36	48	38	14	19	13	13	17	11

* Variety 1..VX5-281.5, 2..Lo75-2760, 3..Lo75-1237

TABLE 7 – Concentration of P (%)

Treatment	Prat / Variety*	Leaf			Stem			Root		
		1	2	3	1	2	3	1	2	3
C_1	P_1	0.21	0.17	0.24	0.08	0.08	0.08	0.12	0.07	0.08
	P_2	0.18	0.23	0.23	0.10	0.12	0.11	0.07	0.09	0.09
	P_3	0.28	0.28	0.23	0.13	0.14	0.09	0.10	0.06	0.08
C_2	P_1	0.15	0.17	0.15	0.06	0.07	0.08	0.06	0.08	0.07
	P_2	0.12	0.19	0.20	0.07	0.09	0.08	0.06	0.08	0.06
	P_3	0.16	0.27	0.24	0.09	0.11	0.10	0.11	0.10	0.07
C_3	P_1	0.14	0.17	0.16	0.06	0.09	0.07	0.08	0.09	0.08
	P_2	0.21	0.23	0.25	0.07	0.13	0.11	0.06	0.10	0.08
	P_3	0.31	0.32	0.32	0.13	0.19	0.11	0.08	0.11	0.13

TABLE 8 – Concentration of Mo (ppm)

Treatment	Part / Variety*	Leaf			Stem			Root		
		1	2	3	1	2	3	1	2	3
C_1	P_1	0.20	0.45	0.10	0.49	0.13	0.23	0.17	0.29	0.22
	P_2	0.15	0.40	0.08	0.17	0.09	0.20	0.29	0.17	0.10
	P_3	0.14	0.06	0.05	0.20	0.10	0.13	0.17	0.28	0.13
C_2	P_1	0.34	0.07	0.06	0.29	0.36	0.49	0.07	0.20	0.16
	P_2	0.11	0.06	0.05	0.24	0.21	0.17	0.19	0.23	0.19
	P_3	0.06	0.08	0.05	0.14	0.08	0.15	0.32	0.23	0.21
C_3	P_1	0.06	0.10	0.14	0.73	0.33	0.19	0.55	0.22	0.31
	P_2	0.23	0.25	0.58	1.16	0.29	1.34	0.37	0.42	1.13
	P_3	1.38	0.60	0.81	2.42	1.50	1.29	1.10	0.98	1.68

* Variety 1..VX5-281.5, 2..Lo75-2760, 3..Lo75-1237

TABLE 10 – Concentration of Al (ppm)

Treatment	Part / Variety*	Leaf			Stem			Root		
		1	2	3	1	2	3	1	2	3
C_1	P_1	615	780	425	1230	1040	790	4825	2950	3825
	P_2	480	560	405	980	500	665	1625	2715	1827
	P_3	385	365	360	520	300	460	2500	2410	2635
C_2	P_1	540	380	480	1065	435	625	3075	3720	4235
	P_2	340	395	355	350	515	370	1300	2865	1273
	P_3	300	380	270	165	150	280	3030	2920	1356
C_3	P_1	340	640	290	515	1250	435	3135	2515	3120
	P_2	290	585	250	265	775	415	2575	2730	2510
	P_3	230	350	256	415	350	350	2350	2450	1750

* Variety 1..VX5-281.5, 2..Lo75-2760, 3..Lo75-1237

TABLE 9 – **Effects of liming and P-fertilization on Mo concentration in soybean grain.**

Liming t/ha	P-fertilization kg/ha (P_2O_5)		
	50	200	350
	ppm	ppm	ppm
0	0.08	0.03	0.02
3	4.35	3.26	4.03
6	7.02	5.04	4.82

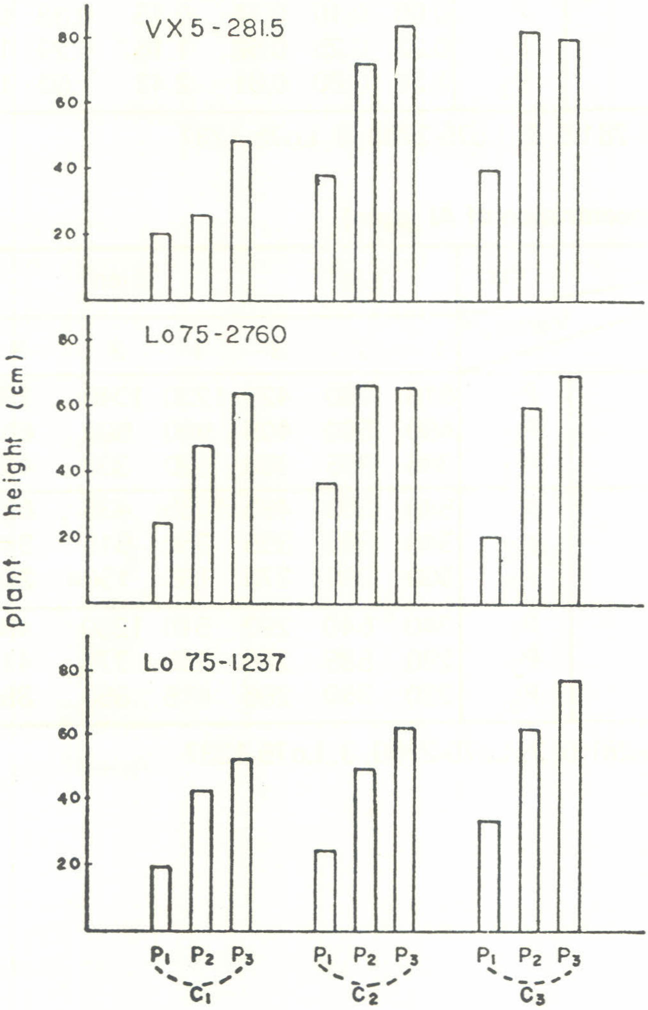

Fig. 1. Effects of limings and P-fertilization on plant growth (march 3, 1980)

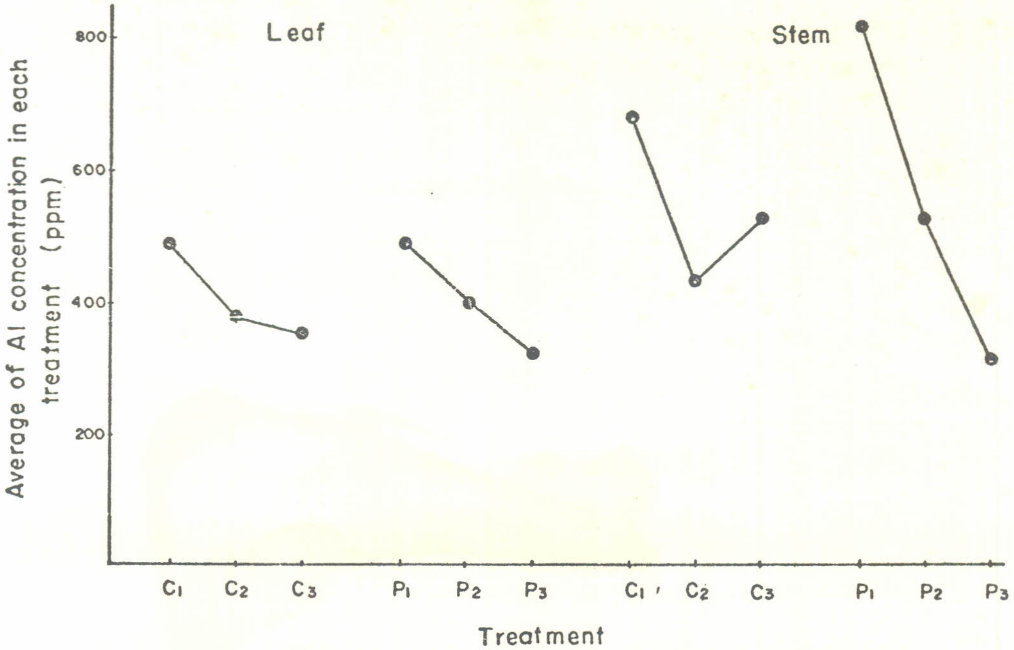

Fig. 2. Effects of liming and phosphorus fertilization on Al concentration in leaves and stems of soybean plants.

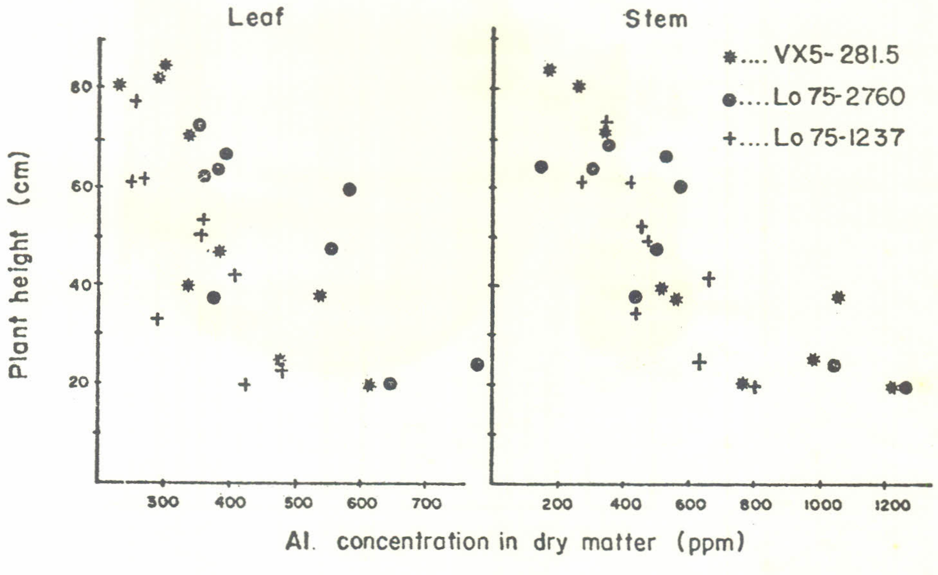

Fig. 3. Relation between plant growth and Al concentration.