EFFECT OF GYPSUM APPLICATION ON GROWTH AND BORON UPTAKE BY PLANTS GROWN ON SODIC SOIL

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ABSTRACT

Green house experiments were conducted on an alkali soil to study the effect of different levels of gypsum (0, 50 and 100 percent of the total gypsum requirement of the soil) on the tolerance of maize and oats to different levels of soluble B (0.0, 2.75, 6.25, 12.50, 21.25, 43.75 and 60 ppm) adjusted in an alkali soil. Gypsum application, at both the rates, significantly increased the dry matter production of both the crops irrespective of the levels of soluble B in the soil. Increasing levels of B depressed the average dry matter yield of both the crops irrespective of gypsum treatments. Application of gypsum improved plant growth and their B tolerance. A 50 per cent reduction in dry matter yield (B tolerance index) of oats occurred at 13.0 ppm B only where gysum was not applied, but with gypsum treatment (at both levels) the yield did not decrease to this level. In the case of maize the B tolerance indices were 20, 28, and 52 ppm at 0, 50, and 100 percent levels of gypsum application, respectively. Gypsum application at 50 and 100 percent of gpysum requirement treatments decreased the average B content of plants by 40.0 and 53.7 per cent, respectively in oats, and 24.4 and 74.6 per cent respectively, in maize. At 0, 50, and 100 per cent levels of gypsum the average Ca:B ratios in plants were 24.6, 53.1, and 73.6 respectively in oats, and 12.4, 25.4, and 72.3 respectively in maize. Incubation studies carried out in the laboratory indicated that gypsum application also decreased the soluble B content of alkali soils.

INTRODUCTION

Sodic soils generally contain high concentration of soluble B (Poonia, 1966; Ahuja, 1968) which often exceeds the toxic limits fixed for most of the crop plants. In saline sodic soils of Sangrur district of the Punjab State, Mair (1965) reported upto 70 ppm soluble B, and its content increased with increase in exchangeable sodium percentage of the soil. Therefore, to utilize these soils the concentration of soluble B has also to be reduced along with those of other salt constituents, either by leaching it below the root zone or by rendering it insoluble. Leaching of B is difficult (Kanwar & Singh, 1961), and even may not be feasible in areas where subsoil water—having high B concentration—is the only source of irrigation. The solubility of B has been reported to decrease with the application of $CaCO_3$ (Gupta, 1972) in acid soils. In alkali soils, on the other hand, gypsum is commonly recommended for their reclamation. But much work does not seem to have been done on the effect of applied gypsum on growth and B uptake by plants and soluble B content of the sodic soils. Therefore, the objectives of the investigation reported in this paper were to study the effect of gypsum application—1.—on growth and B uptake by plants grown on a sodic soil varying in soluble B content and 2.—on the soluble B content of the soil.

MATERIAL AND METHODS

Two green-house experiments and a laboratory study were conducted on a noncalcareous alkali soil, which tested loamy sand in texture, pH 9.6, electrical conductivity of the saturation extract 1.5 mmhos/cm at 25°C, cation exchange capacity 5.0 me/100 g, exchangeable sodium percentage 42 and soluble B 0.49 ppm (in saturation extract). The soil was adjusted approximately to 2.5, 5, 10, 20, 40, and 60 ppm soluble B, by the method outlined by HATCHER, BLAIR AND BEER (1962). The actual levels of soluble B obtained in the soil were—0.49, 2.75, 6.25, 12.50, 21.25, 43.75, and 60.0 ppm (referred to as B_0, B_1, B_2, B_3, B_4, B_5, and B_6, respectively).

In the pot experiments, Oats (*Avena sativa* L.) crop was grown during rabi 1973-74, in soils having B_0, B_1, B_2, B_3, B_4, and B_5 levels of soluble B, whereas maize (*Zea mays* L.) was grown during Kharif 1974 in soils having B_0, B_2, B_3, B_4, B_5, and B_6 levels of B. Three kg soil was taken in each alkathene-lined earthen pot (22 cm×30 cm). Gypsum was applied at the rate of 0, 50, and 100 per cent (referred to as G_0, G_{50}, and G_{100}, respectively) of the total gypsum requirement (SCHOONOVER, 1952) of the soil. Twenty seeds of both the crops were sown when the soil was in optimum moisture condition. Before sowing, a basal dose of 100 ppm N, 50 ppm P, 50 ppm K, and 5 ppm Zn was given through urea, KH_2PO_4, KCl, and Zinc sulphate, respectively. When the germination became constant the plants of oats and maize were thinned to 8 and 10 per pot, respectively. During the growth period, the crops were irrigated with tube-well water (electrical conductivity 315 micro mhos/cm and B content of 0.07 ppm) and moisture stress was never allowed to occur. Moisture was replenished (up to field capacity) when half of the available water had been depleted.

Oats and maize plants were harvested after 70 and 45 days of growth, respectively. The plants were washed with distilled water, dried in an air oven at 60°C to constant weight, weighed, ground and stored for determining total B (HATCHER & WILCOX, 1950) and Ca (CHENG & BRAY, 1951) contents.

In the laboratory experiment the effect of gypsum application on soluble B content of the soil was studied. The soils used for growing Oats (B_0, B_1, B_2, B_3, B_4 and B_5 levels of soluble B) were used. Gypsum was applied to 500 g soil at the rate of 0, 50, and 100 percent of the total gypsum requirement of the soil and incubated at room temperature for 1, 2, and 4 weeks at a moisture content of field capacity. After each incubation period the saturation extract was analysed for soluble B content (HATCHER & WILCOX, 1950). All other soil characteristics were determined by the methods outlined in *U. S. D. A. Hand-Book No.* 60 (1954).

RESULTS AND DISCUSSION

Increasing levels of soluble B and gypsum significantly altered the growth in terms of dry matter production of both oats and maize crops, as is evident from the multiple regression equations, the models (Y) of which are given below:

Oats $Y=0.361916+0.598988\ G-0.017648\ B-0.120417\ G^2+0.000264B^2+0.000578\ GB$

Maize $Y=0.610764-0.013300\ G-0.012941\ B+0.606668\ G^2+0.000091\ B^2-0.005637\ GB.$

(Where—G and B represent gypsum and boron levels respectively).

Relationships between calculated and observed yields were highly significant (the values of coefficients of determination, R^2 were 0.968 for oats and 0.938 for maize). The calculated dry matter yields of oats and maize at various levels of B in soils as affected by gypsum application are shown in Text-fig. 1. Gypsum application significantly increased the dry matter production of both the crops irrespective of the levels of soluble B in the soil. The mean observed yields in terms of dry matter production at G_0, G_{50} and G_{100}

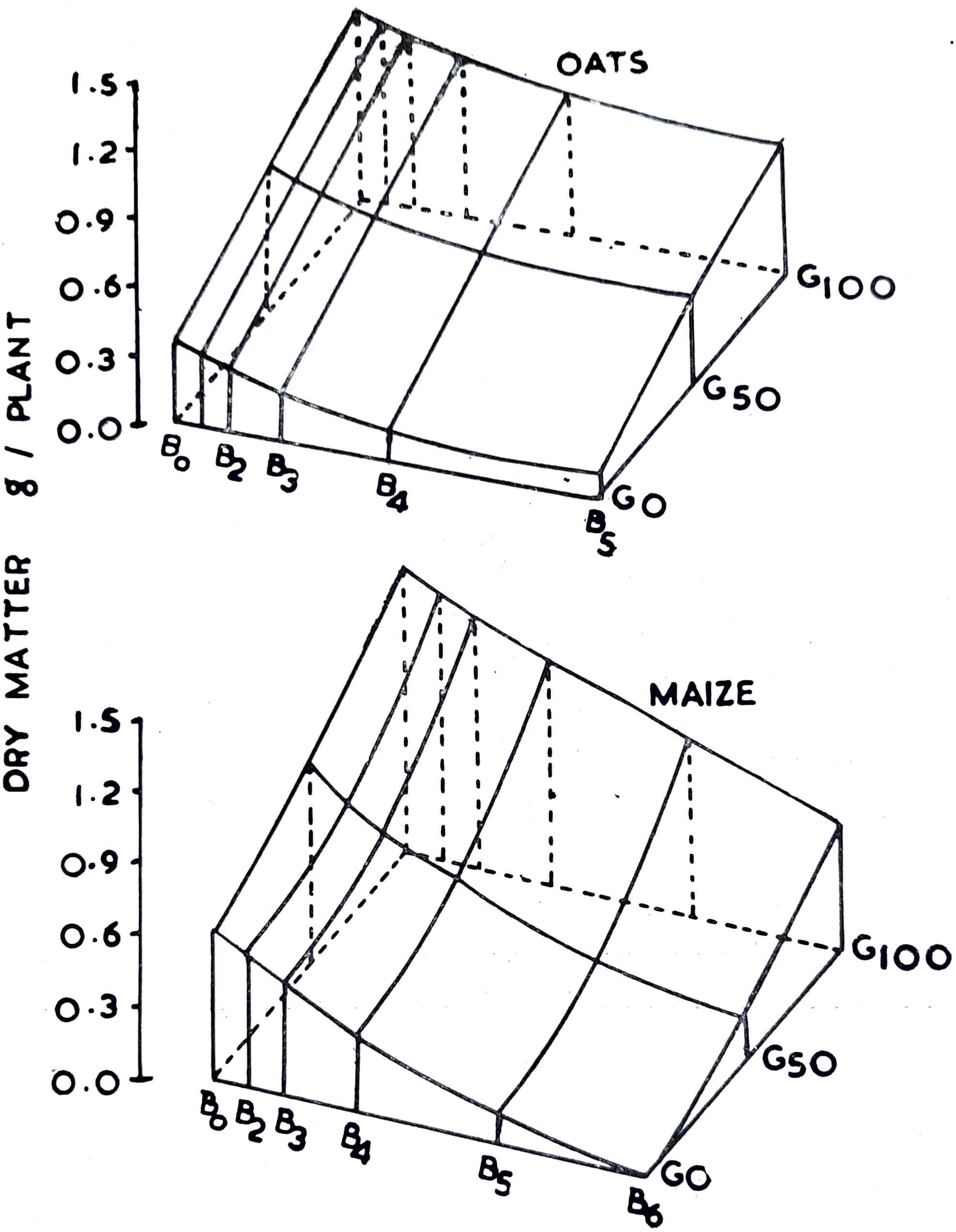

FIG. 1. DRY MATTER PRODUCTION OF OATS AND MAIZE AT DIFFERENT LEVELS OF B AND GYPSUM.

were 0.26, 0.50 and 0.72 g per plant, respectively, for oats and 0.40, 0.49 and 0.87 g per plant, respectively, for maize. On the other hand increasing levels of boron significantly depressed the dry matter production of both the crops over the entire range investigated, irrespective of the rates of gypsum application. The mean observed dry matter yields of oats at B_0, B_1, B_2, B_3, B_4 and B_5 levels of soluble boron in the soil were 0.64, 0.56, 0.51, 0.44, 0.40 and 0.33 g per plant, respectively, and that of maize at B_0, B_2, B_3, B_4, B_5 and B_6 levels of soluble boron were 0.92, 0.78, 0.60, 0.52, 0.41 and 0.19 g per plant, respectively. Fifty per cent reduction in the average expected total dry matter yield (B tolerance index) of oats and maize crops indicated that oats plants were relatively more tolerant to high levels of soluble B. The difference between the two crops may be ascribed to the differences in the rates of boron accumulation (Text-fig. 3) by both the crops (OERTLI & KOHL, 1961; REISENAVER & COX, 1971). The inverse relationships between growth of both the crops and boron content in plants support the findings of SCHUMAN (1969).

The relationships between relative growth per cent of both the crops and various levels of soluble boron in the soil at different levels of gypsum application are shown in Text-fig. 2. The rate of depression in dry matter production with increasing levels of boron was considerably reduced with the application of gypsum. In absence of gypsum application, the levels of B at which 50 per cent decrements in yields of oats and maize crops occurred were 13 and 20 ppm boron, respectively. When gypsum was applied, the yield of oats did not decrease below 50 per cent at any level of soluble boron tried in this study. However, in the case of maize, 50 per cent reduction in dry matter production at G_{50} and G_{100} occurred at 28 and 52 ppm boron levels, respectively. These data suggested that applied gypsum helped the plants to grow even when the soils had initially high levels of soluble boron. This may be attributed to the significant depression in the accumulation of B (Text-fig. 3) and increase in Ca: B ratio in plants (Table 1) with the application of gypsum, irrespective of the levels of soluble B in the soil.

Table 1—Ca : B ratio in Oats and Maize plants at various levels of soluble boron in soil as affected by gypsum application

Boron Levels (ppm)	Levels of Gypsum (Per cent of the total gypsum requirement of the soil)			Mean
	G_0	G_{50}	G_{100}	
		Oats		
B_0	56.5	95.9	132.1	94.8
B_1	39.9	91.3	117.7	82.9
B_2	19.6	79.5	74.6	57.9
B_3	10.1	31.0	72.5	37.9
B_4	7.3	14.2	35.0	18.8
B_5	4.3	7.1	10.0	7.1
Mean	24.6	53.1	73.6	49.9
		Maize		
B_0	29.5	47.2	188.5	88.4
B_2	20.9	32.1	72.4	41.8
B_3	6.3	29.8	66.7	34.3
B_4	7.0	16.0	39.2	20.7
B_5	7.0	15.2	31.0	17.7
B_6	3.9	12.3	35.9	17.4
Mean	12.4	25.4	72.3	36.7

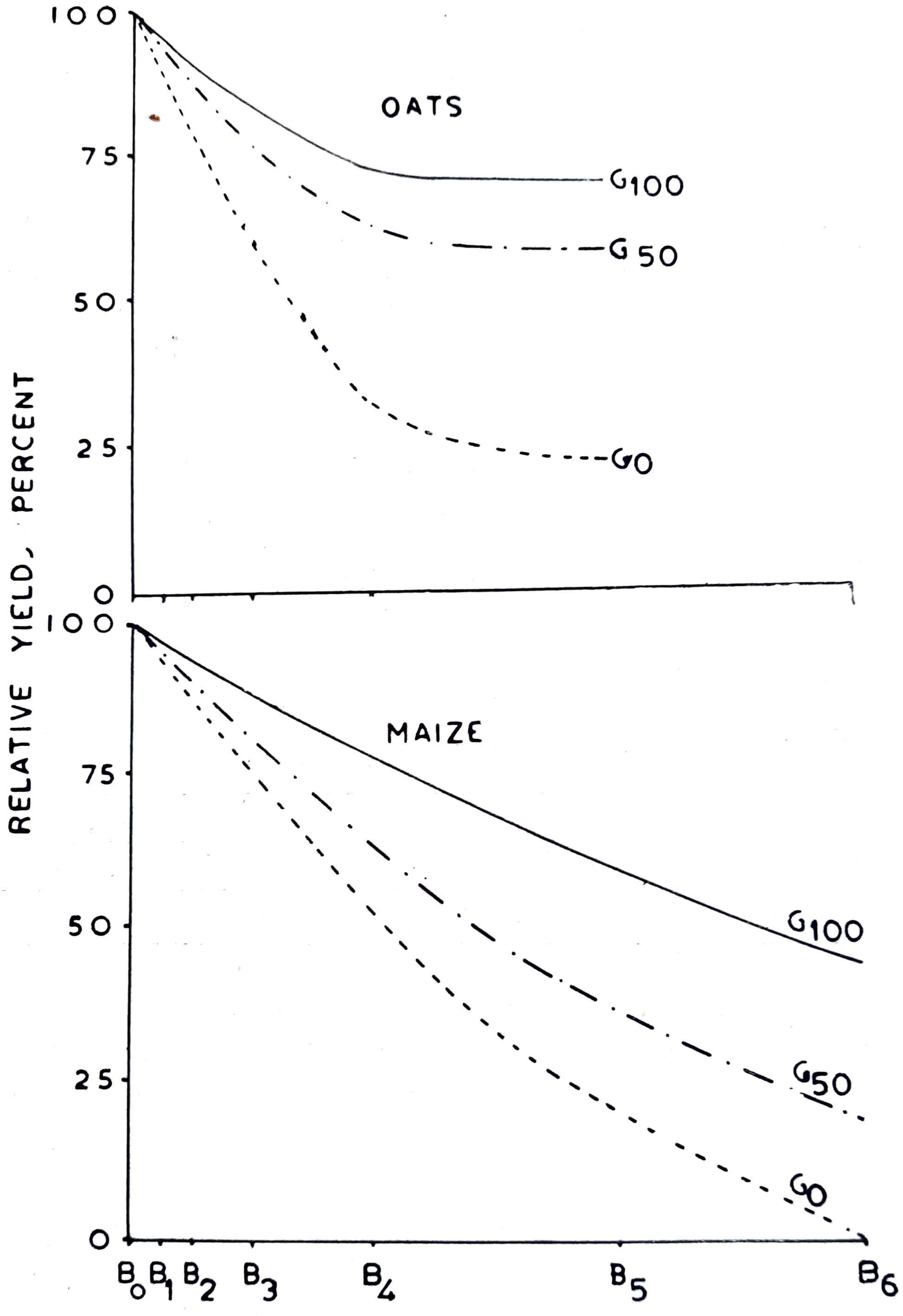

FIG. 2. RELATIVE YIELD PERCENT OF OATS AND MAIZE AT DIFFERENT LEVELS OF B AND GYPSUM.

There was a progressive increase of soluble boron and decrease of total calcium concentration in the plants with the increase of soluble boron in the soils. On an average, Ca : B ratios were 94.8, 82.9, 57.9, 37.9, 18.8, and 7.1 at B_0, B_1, B_2, B_3, B_4, and B_5 levels of B, respectively—in oats, and 88.4, 41.8, 34.3, 20.7, 17.7, and 17.4 at B_0, B_2, B_3, B_4, B_5 and B_6 levels of B, respectively—in maize. The accumulation of boron by the plants was considerably higher at higher levels of soluble boron in the soil as compared to those grown in soils having relatively lower levels, which may be due to its large passive absorption at higher concentration in the substrate. Application of gypsum significantly depressed the rate of boron accumulation (Text-fig. 3), and increased the Ca : B ratio (Table 1) in the plants. Compared with control, the treatments G_{50} and G_{100} decreased the average B content in plants by 40.0 and 53.7 per cent respectively,—in oats, and 35.1 per cent and 74.6 per cent, respectively—in maize. At G_0, G_{50} and G_{100} average Ca : B ratios were 24.6, 53.1, and 73.6, respectively—in oats, and 12.4, 25.4 and 72.3, respectively—in maize. Gupta and Cutcliffe (1972) also reported decrease in B uptake and increase of Ca : B ratio in plants with the application of Ca through $CaCO_3$ in acid soils.

Application of gypsum decreased the soluble boron content of the soil (Table 2). However, there was no appreciable difference between the two rates of gypsum application. The decrease in soluble boron content was also progressive with the increase in incubation time but maximum rate of depression was observed after 1 week of incubation. This may be due to the formation of borates of calcium which are relatively less soluble than borates of sodium—the form in which boron exists in sodic soils. Gupta & Chandra, (1972) also reported decrease in soluble boron content with the application of gypsum.

Table 2—Effect of gypsum application on the soluble B content of soil, at different periods of incubation

Original levels of Soluble B in soil (ppm)	Levels of Gypsum					
	G_{50}			G_{100}		
	Incubation period (Weeks)			Incubation period (Weeks)		
	1	2	4	1	2	4
0.49	Traces	..	..	..	..	..
2.75	1.00	0.75	..	Traces	..	..
6.25	2.75	2.15	0.35	2.70	1.50	0.30
12.50	9.50	9.00	5.50	8.00	7.20	5.25
21.25	15.00	12.50	12.50	13.00	12.50	11.75
43.75	36.50	28.25	26.25	30.00	28.00	25.00

(Average of 2 replications)

These observations suggest that gypsum, applied for the reclamation of sodic soils, would also reduce the boron hazard, particularly when the soil contains up to moderately high levels of soluble boron. At very high levels of soluble boron, although gypsum application enhanced crop growth, the responses to gypsum were inhibited by the direct adverse effects of boron in the soil. In such soils, in addition to the application of gypsum, leaching of boron should also be attempted so that crops may grow satisfactorily.

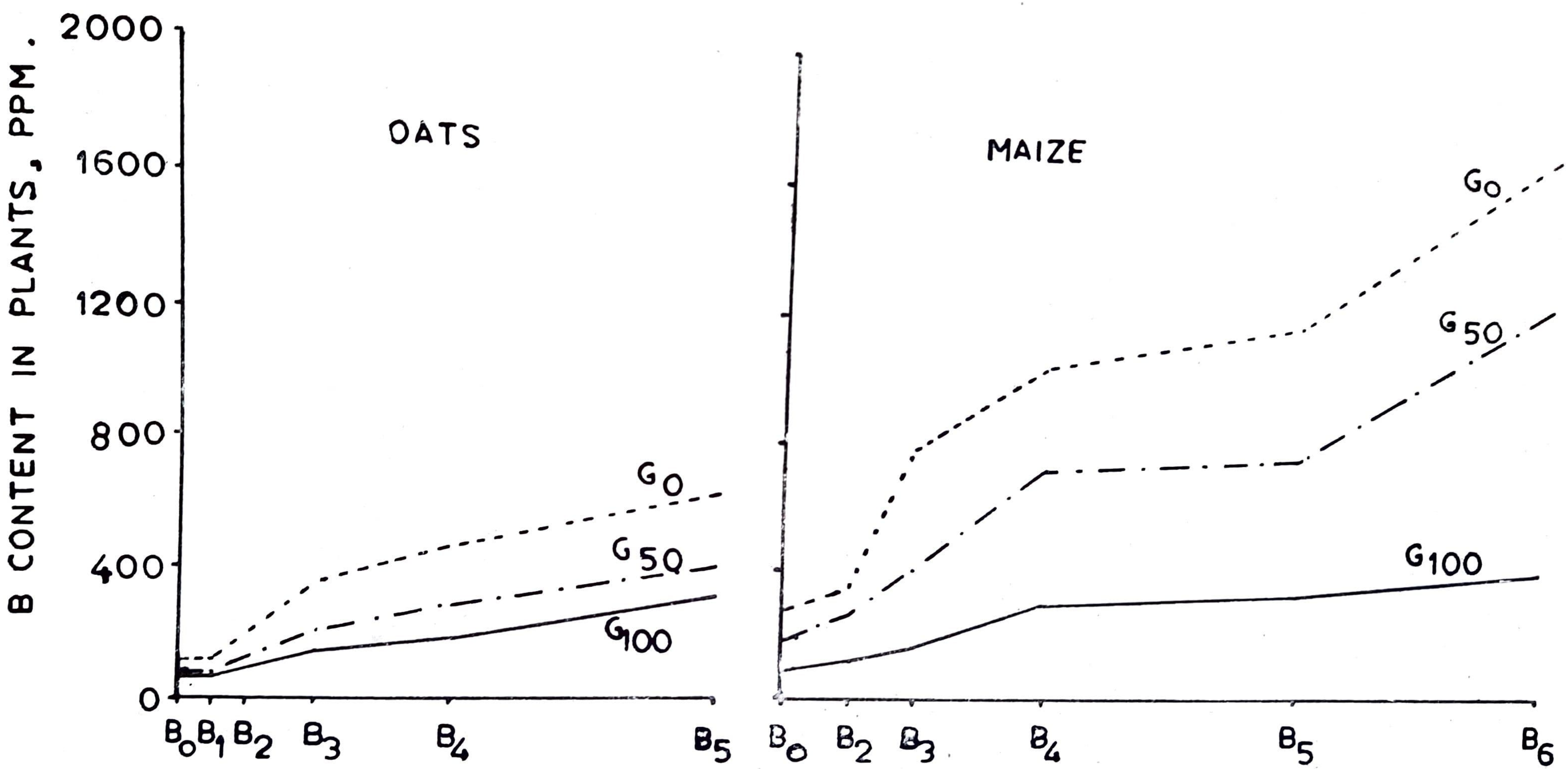

FIG 3. BORON CONTENT OF OATS AND MAIZE PLANTS AT DIFFERENT LEVELS OF BORON AND GYPSUM.

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