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SUNFLOWER RESPONSE TO LIME AND BORON ([1])

J.A. Quaggio ([2,3]), M.R.G. Ungaro ([2,3]), P.B. Gallo ([2]) & H. Cantarella ([2,2])

SUMMARY

A field experiment was carried out on a Red Yellow Podzolic soil, in order to determine the sunflower response to liming, boron and their interactions. A randomized complete block design (Split-plot) was used with four replications. In the main plots, limestone was broadcasted at rates of 0, 2, 4, 6, and 8 t/ha and in the sub-plots boron was applied banded at planting time, at rates of 0, 1 and 2 kg/ha as boric acid. The results showed that sunflower is very susceptible to soil acidity, manganese toxicity and boron deficiency. Liming increased plant height, head diameter, phosphorus uptake and grain yield, mainly when it was associated with boron fertilization. There was no effect of treatments on seed oil content. The grain yield was also correlated with soil testing and leaf analysis. It was concluded that the aluminum criterion was inadequated for determining lime requirement for sunflower. Otherwise, better agreement was obtained with the method based on the correlation between pH and soil base saturation.

INTRODUCTION

Sunflower grown in the acid soils of the tropics has frequently presented problems with seed germination, death of seedlings, reduced plant growth, and shallow, thick and little-branched root system. These symptoms were described by Blamey (1975) for the conditions of acid soils of South Africa and later confirmed by Ungaro et al. (1984) for sunflower cultivated on acid soils of the State of São Paulo, Brazil. These symptoms have been associated with the presence of toxic concentrations of exchangeable aluminum to which sunflower is highly sensitive (Hortenstine & Fiskell, 1961). However, Foy et al. (1974) have shown different degrees of tolerance to aluminum among various cultivars.

Blamey and Nathanson (1978) suggested that the exchangeable aluminum criterion, as proposed by Kamprath (1970), is adequate for estimating the lime requirement for sunflower. On the other hand, Ungaro et al. (1984) concluded that the aluminum criterion underestimates the amounts of lime needed by the sunflower crop because they obtained yield responses up to 32% above those observed with lime rates calculated to neutralise the soil exchangeable aluminum. Moreover, the seed yields were linearly correlated with the soil base saturation (r=0.92) or with the soil pH (r=0.95) up to pH values of 6.5 (Ungaro et al., 1984).

Besides being affected by the soil acidity conditions, sunflower is highly sensitive to boron deficiency, of (Blamey, 1976; Blamey et al., 1978). However, boron is less available for plants in soils with ligh pH values, as substantiated by Evans & Sparks (1983) in a recent literature review on the issue.

The objectives of this work were to study the response of sunflower to lime and boron application, and the effect of the interaction between these treatments on the yield of sunflower seeds.

([1]) Contribution from Instituto Agronômico do Estado de São Paulo, 13.100 Campinas-SP, Brazil.

([2]) Research scientists ([3]) with research grants from the National Council for Scientific Development (CNPq).

MATERIALS AND METHODS

At two-year field experiment was carried out on a Red-Yellow Podzolic soil at the Mococa Experimental Station of the State of São Paulo, Brazil, with two consecutive crops of sunflower grown on the same plots in 1982/83 and 1983/84.

A randomized complete block design (in split-plot) with four replications, was employed. The main plots, with dimensions of 4 x 21m, contained the calcinated limestone treatments, applied at the rates 0, 2, 4, 6, and 8 metric tons per hectare, and incorporated into the soil by plowing and disking, three months before planting. In the sub-plots, with dimensions of 4 x 7m the boron treatments, at the rates of 0, 1, and 2 kg/ha of B, as boric acid, were applied in the seed furrow, mixed with the planting fertilizers. The limestone treatments were applied only in the first crop in 1982/83, and the boron treatments were applied in both years.

The variety of sunflower used was IAC-Anhandy, with a cycle of approximately 100 days, planted both years in October (rainy season), spaced 0.25m in rows 0.80m apart. Each year the crop was fertilized at planting with 500 kg/ha of the N-P_2O_5-K_2O formula 4-16-12 plus 20 kg/ha of zinc sulfate. Nitrogen was also sidedressed 35 days after emergence at the rate of 50 kg/ha of N, as ammonium sulfate. Soil samples were taken in 1982/83 and 1983/84, at 6 and 18 months, respectively, after liming. Exchangeable aluminum was determined by titrating with NaOH a soil extract obtained with 1N KCl. All other determinations were made by the methods described by Raij & Quaggio (1983).

At the flowering stage, samples composed of 30 topmost mature leaves were taken from each sub-plot (Blamey, 1976). The leaf samples were rinsed with deionized water, dried at 70°C, and analyzed by the methods described by Bataglia et al. (1983).

RESULTS AND DISCUSSION

Seed yields obtained in the two consecutive crops of sunflower are shown in Table 1. On the first crop (1982/83) the average yield of the experiment was low mainly due to the climatic conditions which favored the attack of Alternaria helianti. The chemical control of this disease was not efficient. However, there was a marked response to lime application up to the rate of 4 t/ha, and a less pronounced response to boron, although statistically significant, up to the rate of 1 kg B/ha.

In the first crop, unlimed plots had poor seed germination and death of seedling contributing to the high coefficient of variation observed in the experiment. Therefore, in the following year, these plots were treated with 1 t/ha of limestone in order to assure a good plant stand.

The climatic conditions were good for the 1983/84 crop and as a consequence, average yield of the experiment was high. The yield responses to both lime and boron rates were linear and more marked than those obtained in 1982/83. On the second-year experiment the response to lime was more pronounced in the presence of high rates of applied boron, showing a synergistic effect of these factors.

Although the application of lime and boron presented a marked effect on seed yield, these treatments had no influence on the seed oil content or on its fatty acids composition.

Liming contributed to increase plant height and head diameter. With the data of the 1983/84 crop the following regression equations were calculated: $Y = -382.3 - 989.6x^{-1}$ ($r = -0.97$) were Y is the plant height (cm) and x is the soil pH value; and $Y = 21.8 - 38.1x^{-1}$ ($r = -0.88$), where Y is the head diameter (cm) and x is the soil pH value. On the other hand, no effect of boron application on these parameters was observed.

Table 1. Sunflower response to liming and boron rates, in two consecutive crops.

Boron	Limestone, t/ha					Average 1/
	0	2	4	6	8	
kg/ha	kg/ha					
			1982/83			
0	370	503	739	662	702	595 *a*
1	478	654	898	836	857	745 *b*
2	426	708	852	777	872	727 *b*
Average(1)	424 *a*	527 *ab*	830 *b*	759 *b*	810 *b*	684
			1983/84			
0	852	1337	1851	1773	2343	1631 *a*
1	737	1540	2101	2096	2508	1797 *ab*
2	1112	1714	2223	2296	2617	1992 *b*
Average(1)	900 *a*	1513 *b*	2058 *bc*	2055 *c*	2490 *c*	1803

1/ Duncan test ($p < 0.05$).

The effect of liming on some chemical properties of the soil are presented in Table 2. The soil originally had a relatively low content of exchangeable aluminum, on which was almost totally neutralized with the application of 2 t/ha of lime. Both soil pH and soil base saturation increased linearly with liming, even in the first soil samples, taken six months after liming. Results of the second soil sampling show that some calcium and magnesium moved downward in the soil profile causing an increase in the content of these elements and a partial neutralization of the soil acidity in the subsoil (Table 2). The observed leaching of bases was probably the reason for the slight decrease of the soil pH of the surface layer (0-20cm) in relation to the values obtained in the previous year.

Table 2. Results of soil analysis for samples taken in 1982/83 and 1983/84 at two depths.

Lime applied	P-resin	pH in $CaCl_2$	Exchangeable cations				Base saturation
			Ca	Mg	K	Al	
t/ha	g/cm^3		meq/100cm^3				%
			182/83 (0-20cm)				
0	19	4.2	0.5	0.3	0.16	0.7	17
2	19	5.0	1.8	0.5	0.18	0.1	46
4	22	5.5	2.4	0.6	0.18	0.0	60
6	22	6.4	4.4	1.0	0.15	0.0	80
8	26	6.4	4.5	1.1	0.19	0.0	82
			1983/84 (0-20cm)				
0	21	4.3	1.3	0.5	0.25	0.7	34
2	26	4.6	2.5	0.4	0.28	0.2	45
4	33	5.3	2.9	0.7	0.25	0.0	64
6	35	5.5	3.6	0.7	0.25	0.0	74
8	37	5.7	4.7	0.9	0.23	0.0	81
			1983/84 (20-40cm)				
0	7	4.2	1.4	0.4	0.08	0.9	28
2	8	4.2	1.3	0.4	0.08	0.9	29
4	6	4.5	1.5	0.6	0.06	0.3	42
6	9	4.5	1.6	0.5	0.05	0.5	40
8	7	4.9	2.5	0.8	0.09	0.1	59

It is worth mentioning that the increasing rates of applied lime caused a linear increase in the concentration of soil phosphorus, extracted by the method of the ion exchange resin (Raij & Quaggio, 1983), especially in the second sampling (1983/84) which included the contribution of the phosphorus fertilizer applied in the previous year. The enhanced levels of soil phosphorus brought about an increase in the concentration of phosphorus in the leaves of the sunflower plants, as shown in Figure 2.

The boron concentration in the leaves of sunflower are shown in Table 3. On the first year crop, the concentration of boron in the leaves was affected only by the application of this element on the soil, but no effect of liming was observed. In the second year, the leaf boron concentration decreased in boron untreated plants: in relation to the first crop, which did not occur in plants that received it. These data suggest that there is a loss of boron from the surface layer of the soil, where leaching may be playing an important role.

Table 3. Effects of rates of lime and boron applied to soil on boron concentration of sunflower leaves, in two consecutive crops.

Boron	Limestone, t/ha					Average 1/
	0	2	4	6	8	
kg/ha	ppm					
			1982/83			
0	52.2	69.0	55.5	63.5	60.5	60.1 *a*
1	76.0	71.7	67.2	86.2	79.2	76.1 *b*
2	85.5	85.5	87.5	85.0	75.5	83.8 *b*
Average 1/	71.2 *a*	75.4 *a*	70.0 *a*	78.0 *a*	71.7 *a*	73.3
			1983/84			
0	39.0	38.3	46.0	47.1	43.0	42.0 *a*
1	59.1	73.1	78.2	81.0	82.1	74.5 *b*
2	80.2	84.0	88.3	91.2	102.3	89.1 *c*
Average 1/	59.6 *a*	64.8 *a*	69.7 *ab*	73.0 *ab*	75.7 *b*	68.6

1/ Duncan test ($p < 0.05$).

The hypothesis that boron was leached down in the soil is supported by the fact that in the 1983/84 crop the leaf boron increased linearly with the increasing liming rates, even in plants without boron, fact not observed in the 1982/83 crop. In that case, the effect of liming may be indirect because, in the 1983/84 crop, there was enough time for partial neutralization of the soil acidity at the 20-40cm layer of soil (Table 2) and, therefore, better conditions, for root growth. This might not have been possible in the first crop to which lime was applied only 3 months before planting. With a deeper root system, the plant is capable a exploring a larger volume of soil and hence, to absorb boron from the deep layer.

The results of the two crops were interpreted jointly by using the concept of relative yield. Figure 1 shows the relationship between soil pH, determined in a 0.01M $CaCl_2$ solution, and the relative yield of seeds. The data indicated that the maximum yield of sunflower occurred at pH around 6.0, whereas the exchangeable aluminum is neutralized at pH around 4.8 (in 0.01M $CaCl_2$) in the soils of the State of São Paulo (Quaggio, 1983a). Therefore, these results are in disagreement with the conclusions of Blamey & Nathanson (1978), who suggested that the exchangeable aluminum criterion (Kamprath, 1970) is adequate for lime recommendation for sunflower.

The need for a high soil pH for maximizing the yield of sunflower in the soil used can be better understood by observing the relationship between soil pH and concentration of manganese in the leaves, shown in Fig. 2. At low pH values the concentration of manganese in the leaves reached toxic levels. The rate of

2 t/ha of lime corresponds approximately to the amount of lime that would be recommended by the exchangeable aluminum criterion which is enough to eliminate the toxicity caused by this ion, but is insufficient to suppress the toxicity brought about by manganese excess (Fig. 2).

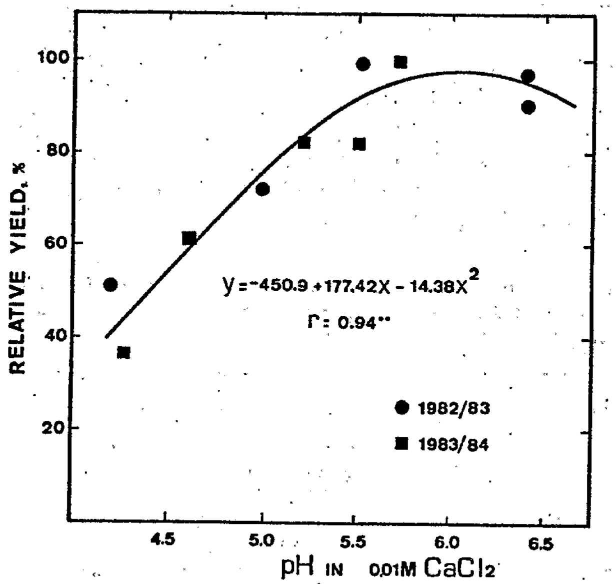

Figure 1. Relationship between soil pH values and relative yield of sunflower in two consecutive crops.

Besides the foliar concentration of phosphorus and manganese, liming affected the concentration of zinc in sunflower leaves. Therefore, it was possible to calculate the regression equation $Y = 111.6 - 9.1x$ ($r = -0.97$), where Y represents the average value of leaf zinc concentration (ppm) for the crops grown in both years, and x is the average soil pH values for the two sampling dates. Liming reduced linearly the zinc concentration in the leaves of sunflower without, however, affecting seed yield, because enough of this

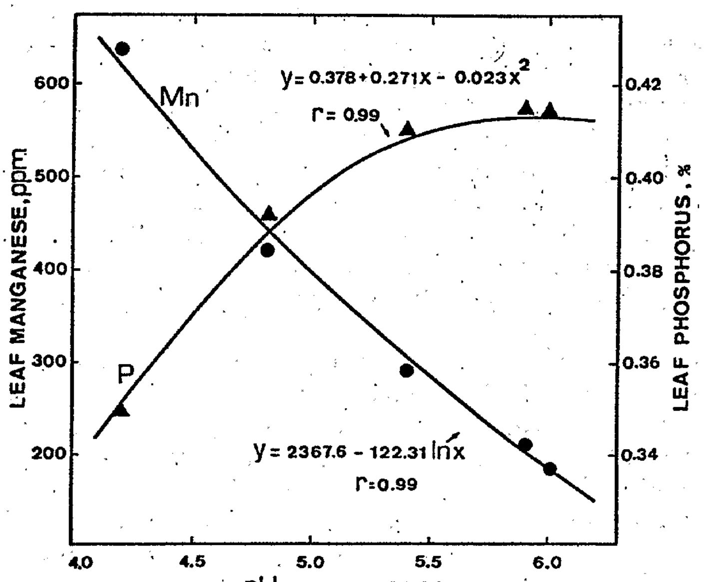

Figure 2. Relationship between soil pH values and the foliar concentration of manganese and phosphorus in sunflower (average of two crops).

micronutrient was applied to the soil each year. Other macro and micronutrients were little affected by the treatments and will not be further discussed.

Simple and multiple regression techniques were used to establish relationships between some soil chemical characteristics and leaf analytical data and yield of seeds on the second crop. The equations calculated are presented in Table 4. The coefficients of determination of the equations show that either the soil pH or the soil base saturation similarly accounts for 86% of the yield variation observed, being more efficient in this regard than the soil exchangeable aluminum, which accounts for 77% of the yield variation. As the foliar concentration of manganese is closely related to soil pH (Fig. 2), the first is equivalent to the latter in explaining sunflower yield variation.

Table 4. Regression equations and coefficients of determination calculated for sunflower seeds (Y) as a function of parameters of soil and leaf analysis, for the 1983/84 crops.

Independent variables	Regression equation	r^2 or R^2
Soil pH (pH)	Y=3183,9+982,4x	0.86
Base saturation	Y=21,2+29,5x	0.86
Aluminum saturation (Al%)	Y=2129,0+52,6x	0.77
Leaf manganese	Y=2869,5+3,0x	0.88
pH(x_1) vs leaf boron(x_2)	$Y = -3295,6+902,4x_1+7,5x_2$	0.93
Al%(x_1) vs leaf boron(x_2)	$Y=1508,6+48,0x_1+8,6x_2$	0.87
pH(x_1) vs leaf boron(x_2) vs P-resin(x_3)	$Y=1264,0-1047,2x_1+7,4x_2+176,1x_3$	0.96

The values of soil pH combined with the foliar concentration of boron account for 93% of the observed yield. This figure is slightly improved when the values of soil phosphorus are added to the equation. Exchangeable aluminum, even when associated with leaf boron, is less effective than soil pH to account for yield variation.

The results (Table 1) indicate that, in the soil used, the contribution of boron to yield increase was small compared to that of lime. Therefore, this soil is able to supply presently the boron needed to optimize sunflower yield without considering the depletion process that may occur along the years. The critical level of leaf boron (57 ppm) proposed by Blamey et al.(1978) seems to be adequate to the conditions of this experiment because, in the first crop, in the treatments without boron, the foliar concentration of this nutrient was about 60 ppm, and in the second year, when yield responses to boron were enhanced, the leaf boron concentration reduced to approximately 40 ppm in plants that did not receive boron (Table 3).

The results obtained showed that liming affected several soil chemical properties that are important for crop growth and production, thus making it difficult to explain yield variations as being only due to elimination of exchangeable aluminum, as proposed by the lime recommendation criterion based on the stoichiometric neutralization of this ion. In this sense, the soil pH is a more efficient criterion because it better reflects the physical-chemical changes that occur in the soil due to acidification or lime application. However, it is difficult to calculated lime requirement, based only on soil pH. Soil base saturation, which is highly correlated with soil pH, allows calculation, with satifactory precision, of the amount of lime to be applied to soils, taking into account the crop needs (Quaggio, 1983b).

CONCLUSIONS

The results obtained for the conditions of this experiment allowed the following conclusions:

a) Sunflower was very sensitive to soil acidity, requiring soil pH around 6.0 for maximum yield.

b) The lime requirement to pH 6.0 was probably associated with the high sensitivity of sunflower ro excess manganese.

c) Liming increased the efficiency of boron uptake by sunflower.

REFERENCES

BATAGLIA, O.C., A.M.C. FURLANI, J.P.F. TEIXEIRA, P.R. FURLANI, J.R. GALLO. 1983. Métodos de análise química de plantas. Instituto Agronômico, Campinas 48p. (Boletim nº 78)

BLAMEY, F.P.C. 1975. Amelioration of an acid Avalon medium sandy loam and effects on the growth of sunflower (Helianthus annuus L). Crop Production, 4:75-79.

BLAMEY, F.P.C. 1976. Boron nutrition of sunflowers (Helianthus annuus L) on an Avalon medium sandy loam. Agrochemophysica, 8:5-10.

BLAMEY, F.P.C. & K. NATHANSON. 1978. Relationships between aluminum toxicity and sunflower yield on an Avalon medium loam. Sunfl. Newsletter, 2:6-12.

BLAMEY, F.P.C., D. MOULD & K. NATHANSON. 1978. Relationship between B deficiency symptoms in sunflower and the B and Ca/B status of plant tissues. Agronomy Journal, 70:376-380.

EVANS, C.M. & D.L. SPARKS. 1983. On the chemistry and mineralogy of boron in pure and in mixed: A Review. Communications in Soil science and plant analysis, 14:827-846.

Foy, C.D., G.R. ORELLANA, J.W. SCHWARTZ & A.L. FLEMING: 1974. Response of sunflower genotypes to aluminum in acid soil and nutrient solution. Agronomy 66:293-296.

HORTENSTINE, C.C. & J.G.A. FISKELL. 1961. Effect of aluminum on sunflower growth and uptake of boron and calcium from nutrient solution. Soil Science Society American Proc., 25:304-307.

KAMPRATH, E.J. 1970. Exchangeable aluminum as a criterion for liming leached mineral soils. Soil Science Society American Proc., 34:252-254.

QUAGGIO, J.A. 1983a. Critérios para calagem em solos do Estado de São Paulo. Tese de mestrado. Piracicaba, SP. E.S.A. "Luiz de Queiroz" USP. 76f.

QUAGGIO, J.A. 1983b. Métodos de laboratório para a determinação da necessidade de calagem em solos. In: RAIJ, B.van, BATAGLIA, O.C. & SILVA, N.M. Eds., Acidez e Calagem no Brasil. Sociedade Brasileira de Ciência do Solo, Campinas, p.33-48.

RAIJ, B.VAN, J.A. QUAGGIO. 1983. Métodos de análise de solo para fins de fertilidade. Instituto Agronômico, Campinas, 31p. (Boletim nº 81).

UNGARO, M.R.G., J.A. QUAGGIO, P.B. GALLO, S.C.F. DECHEN, F. LOMBARDI NETO & O.M. CASTRO. 1984. Comportamento do girassol em relação a alguns parâmetros da acidez do solo. Bragantia. (In. Press).