

HIGH SAR (SODIUM ADSORPTION RATIO) IRRIGATION AND BORON PHYTOTOXICITY IN SUGARBEET

N.K. MEHROTRA, S.A. KHAN AND S.C. AGARWALA

Batany Department, Lucknow University, Lucknow-226 007

ABSTRACT

A pot-culture study on boron toxicity to sugarbeet plants (*Beta vulgaris* L.) under irrigation with graded sodic water (SAR 0.5, 20 and 40) was conducted. Plants of cv 'Ramonskaya' were grown at three levels of applied boron (B), 1 ppm (normal), 10 ppm (phytotoxic) and 20 ppm, in a loamy-sand alluvial soil amended with N, P, K, Fe, Mn, Cu, Zn and Mo. Visible effects of B toxicity developed in the plants at 0.5 SAR given excess B (10 and 20 ppm) at 15-week growth and the symptoms intensified with age. The boron phytotoxicity was associated with an increase in the available soil-B, leaf-B and top/root ratio of tissue B and decrease in root and total plant yield and tissue ratios, more so in top than in root, of Na/B and Ca/B. The excess B effects were markedly reduced at high (20 and 40) SAR. This was associated with a marked reduction in the high SAR-induced decrease in available soil B, root and total plant yield, ratios of top/root of tissue B and Ca/B, both in top and root, at excess (20 ppm) as compared to normal (1 ppm) level of B application. Results indicate antagonistic relationship between levels of soil B application and SAR of irrigation waters.

INTRODUCTION

Salt affected soils have high available boron, often in the phytotoxic range (Agarwala et al., 1976, 1979). The observation of a high degree of positive correlation of soluble boron with SAR (sodium adsorption ratio) as well as EC (electrical conductance) of irrigation waters indicates the likelihood of saline sodic soils produced in western Uttar Pradesh and Rajasthan through high SAR-EC water irrigations to suffer from boron phytotoxicity. However, plants growing in the salt affected fields of Uttar Pradesh neither exhibit any visual effects nor contain tissue boron in the range indicative of its phytotoxicity (Agarwala et al., 1979). This suggests that some edaphic factors present in such soils limit the availability of B to plants. The present study was undertaken to identify such edaphic factors.

MATERIAL AND METHODS

Sugarbeet (*Beta vulgaris* L.) cv 'Ramonskaya' plants were directly raised from seeds in pot-culture on a Gomti upland alluvial loamy-sand soil (coarse sand 0.5%, fine sand 71%, silt 20.5% and clay 4%). The soil was neutral in reaction (pH 6.95)

and marginal in hot-water soluble boron (0.43 ppm). It had 0.72% CaCO_3 , 0.83% organic matter, 0.45 m mhos cm^{-1} ECe (in water saturation extract) at 25°C and 4.1 m eq 100 g^{-1} cation exchange capacity. Before sowing, the homogenised soil was amended with N, P, K, Fe, Mn, Cu, Zn, B and Mo at 25, 11.1, 20.25, 10, 10, 2.5, 5, 1 and 0.5 ppm (w/w), respectively, and filled in 22-cm diameter clay pots, inside surfaces of which were painted twice with bitumen and lined with cleaned alkathene. Additional N, P and K at 25, 11.1 and 20.25 ppm (w/w), respectively, were top-dressed at week 13, and 12.5 ppm N each again at weeks 18 and 22. Amendments of Fe, Mn, Cu and Zn were made through their analytical reagent (AR) grade sulphate salts, of boron through AR $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$ and of Mo through AR $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24} \cdot 4\text{H}_2\text{O}$.

At 91 days, the pots were divided into three lots; while the first lot with 1 ppm applied boron (w/w) was left to serve as control, soils in the other two lots were drenched with additional boron solution to raise the levels of applied boron to the phytotoxic levels of 10 and 20 ppm (w/w). Each SAR-B treatment had four pots.

The graded levels of SAR in de-ionised irrigation water were obtained by the addition of $\text{CaCl}_2 + \text{MgSO}_4$ at a fixed rate of 5.12 meq l^{-1} and NaHCO_3 at a variable rate. The salt solutions used to supply N, P and K (by NH_4NO_3 , KH_2PO_4 and K_2SO_4 , respectively) and for the preparation of graded levels of SAR (by CaCl_2 , MgSO_4 and NaHCO_3) were purified against micronutrients by standard phosphate adsorption and dithizone extraction techniques.

Initially 10 seeds were sown in each pot but only 5 plants/pot were allowed to grow after emergence. The pots were irrigated @ 100 ml/pot with de-ionised water daily except Sunday upto day 95, then with waters prepared of graded SAR (0.5, 20 and 40) upto the day 124; then on alternate days upto day 156. Thereafter, the plants were watered with de-ionised water. Thus, each pot received 40 irrigations with water of the requisite SAR. Supplemental irrigation with limited de-ionised water was done, if needed, to avoid wilting. The experiment was continued upto 24 weeks.

Plants uprooted at day 126 and 166, separated into tops and roots, were dried in a forced draught oven at 70°C for 48 h for dry matter estimation. Before drying, 126-day old fresh plant samples were successively washed with a solution of detergent, 0.01 N HCl, de-ionised water and finally with distilled water. The nitric-perchloric acid (10:1) wet-digests of the oven dried plant material (for day 126) were analysed for by colorimetrically B (Wolf, 1971) and P (Wallace, 1951) and for Na, K and Ca by flame photometry.

After harvest, composite soil samples, drawn separately from each treatment, were analysed for pH (1:2.5), SAR in water saturation extract and 1:2 hot-water soluble B after decolorizing the soil extracts by purified activated charcoal using Azomethine-H (Wolf, 1971).

RESULTS AND DISCUSSION

Growth, visual symptoms and yield

Plant growth at the high levels of applied boron (10 and 20 ppm) was perceptibly reduced within 15 days of the treatment (106-day growth), the effect being relatively more marked at SAR 0.5 than at SAR 20 and 40. The symptoms of toxicity were the development of patchy chlorotic discolorations in the upper half of old leaves, which gradually increased in size, coalesced with each other and spread toward leaf apices and margins (cf. Vlamis and Ulrich, 1973). Affected leaf apices, curling inwards, became necrotic (Figs. 1a & b). The effects, being found related to the level of B supply, gradually advanced with an increase in the age of plants. An increase in SAR from 0.5 to 40 markedly decreased the severity of symptoms even at 20 ppm of applied boron (Fig. 1c).

At SAR 0.5, an increase in applied boron from 1 to 20 ppm decreased the dry matter yield of both tops and roots, the reduction being 45% with 20 ppm of applied boron at 126 days (Table 1). Patel and Golakiya (1986) also reported a reduction of B phyto-toxicity due to adsorption of boron on the surfaces of precipitated CaCO_3 , a feature common in high sodic water irrigated soils (Bower, 1961). Higher requirement of boron for optimising the growth and yield of sugarbeet under conditions of high SAR irrigation are well documented (Mehrotra et al., 1988).

Available soil boron

An increase in the level of applied boron from 1 to 20 ppm increased available soil boron but an increase in SAR from 0.5 to 40 markedly decreased it (Table 1). Reduced availability of soil boron at high SAR could be attributed to the high pH effect due to the adsorption of boron on the precipitated CaCO_3 (Patel and Golakiya 1986) or of polyborate ions on the soil adsorption sites (Gupta, 1980).

Tissue B

At SAR 0.5, 10 and 20 ppm soil application of B increased the tissue concentration of B, both in top and root (Table 2) to its phytotoxic levels (637 ppm). On the other hand, irrespective of B application, an increase in the SAR decreased the tissue concentration of B and also decreased the top/root ratio of tissue B. Thus high SAR irrigation decreased the B phytotoxicity in sugarbeet by decreasing both the uptake and translocation of boron from root to top. Decreased availability of B to various plants under conditions of high sodicity or high pH soil conditions has also been earlier reported by several workers (Agarwala et al., 1976).

Tissue concentration and total contents of Na, K, Ca and P in plant top and root

An increase in SAR increased the tissue concentration and total content of Na, both in top and root, the former being more marked in root. Soil application of 10



Fig. 1 Visual effects of B phyto-toxicity in 118-day old sugarbeet plants irrigated with 19 sodic irrigations : Phyto-toxicity effects SAR 0.5 : (a) 10 ppm (b) 20 ppm of boron applied in soil, with irrigation water of (c) Comparison of pots with 10 ppm applied B receiving waters of SAR 0.5 (left) and SAR 40 (right)

Table 1. Effect of applied boron on the available soil boron content, dry matter yield and fresh root yield of sugarbeet cv 'Ramonskaya' raised with sodic waters of graded SRA

| Boron applied (ppm) | SAR level in irrigation water | | | LSD (p < 0.05) |
|-------------------------------------------------------|-------------------------------|-------|-------|----------------|
| | 0.5 | 20 | 40 | |
| 1 : 2 hot-water extractable boron (ppm) | | | | |
| 1 | 1.12 | 0.68 | 0.51 | |
| 10 | 2.28 | 1.12 | 0.63 | |
| 20 | 2.60 | 2.32 | 1.53 | 0.23 |
| With 25 irrigations; at 126 days age of plants | | | | |
| Dry matter yield (g/plant) | | | | |
| 1 | Top | 2.89 | 2.85 | 1.76 |
| | Root | 2.67 | 3.05 | 1.90 |
| | Whole plant | 5.56 | 5.90 | 3.66 |
| 10 | Top | 1.78 | 2.09 | 1.80 |
| | Root | 1.57 | 1.53 | 2.03 |
| | Whole plant | 3.35 | 3.62 | 3.83 |
| 20 | Top | 1.27 | 1.95 | 2.52 |
| | Root | 0.79 | 1.23 | 1.74 |
| | Whole plant | 2.06 | 3.18 | 42.6 |
| Fresh root yield (g/plant) | | | | |
| 1 | 24.3 | 19.8 | 19.0 | |
| 10 | 20.8 | 26.6 | 18.5 | |
| 20 | 15.8 | 15.7 | 15.1 | 5.6 |
| With 40 irrigations at 166 days age of plants | | | | |
| Dry matter yield (g/plant) | | | | |
| 1 | Top | 4.02 | 4.82 | 2.76 |
| | Root | 6.75 | 3.90 | 3.80 |
| | Whole plant | 10.77 | 8.72 | 6.56 |
| 10 | Top | 3.65 | 4.10 | 3.46 |
| | Root | 5.47 | 6.45 | 3.50 |
| | Whole plant | 9.12 | 10.55 | 6.96 |
| 20 | Top | 2.15 | 3.67 | 2.55 |
| | Root | 3.76 | 3.87 | 3.50 |
| | Whole plant | 5.91 | 7.54 | 6.05 |

Table 4. Effect of applied boron on the Na/B, Ca/B, Na/K, Na/Ca and P/B ratios in sugar-beet cv 'Ramonskaya' raised with sodic waters of graded SAR, at 126 days growth;

| Boron supply (ppm) | Plant part | SAR level in irrigation water | | |
|-----------------------|------------|-------------------------------|------|-------|
| | | 0.5 | 20 | 40 |
| Na/B ratio | | | | |
| 1 | Top | 318 | 540 | 610 |
| | Root | 178 | 293 | 345 |
| 10 | Top | 53 | 96 | 185 |
| | Root | 287 | 324 | 362 |
| 20 | Top | 45 | 52 | 68 |
| | Root | 114 | 260 | 298 |
| Ca/B ratio | | | | |
| 1 | Top | 84 | 71 | 48 |
| | Root | 69 | 30 | 31 |
| 10 | Top | 6 | 10 | 14 |
| | Root | 24 | 53 | 26 |
| 20 | Top | 3 | 6 | 4 |
| | Root | 15 | 28 | 34 |
| Na/k ratio | | | | |
| 1 | Top | 2.57 | 4.72 | 5.86 |
| | Root | 0.57 | 1.02 | 1.50 |
| 10 | Top | 3.31 | 3.22 | 5.08 |
| | Root | 0.98 | 1.04 | 1.66 |
| 20 | Top | 2.47 | 4.22 | 6.28 |
| | Root | 0.60 | 1.41 | 1.88 |
| Na/Ca ratio | | | | |
| 1 | Top | 3.78 | 7.65 | 12.75 |
| | Root | 2.80 | 9.75 | 11.40 |
| 10 | Top | 8.33 | 9.73 | 13.0 |
| | Root | 11.75 | 6.11 | 13.6 |
| 20 | Top | 13.80 | 8.50 | 18.29 |
| | Root | 7.50 | 2.29 | 8.78 |
| P/B ratio | | | | |
| 1 | Top | 42 | 29 | 25 |
| | Root | 217 | 195 | 176 |
| 10 | Top | 4 | 6 | 9 |
| | Root | 189 | 229 | 117 |
| 20 | Top | 4 | 3 | 3 |
| | Root | 179 | 120 | 117 |

deficiency (Gupta and Cutcliffe, 1972; El-Damaty et al., 1974). Thus high SAR at high B levels mitigated many of the nutrient ratio imbalances in sugarbeet plants.

ACKNOWLEDGEMENTS

The authors thank Professor C. P. Sharma, Head of the Botany Department, Lucknow University, Lucknow for the facilities and to Drs. B. K. Dube and V. K. Khanna for help in plant and soil analyses during the course of the study.

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