Effects of salinity and varying boron concentrations on boron uptake and growth of wheat

F.T. BINGHAM, J.E. STRONG,
Department of Soil and Environmental Sciences, University of California, Riverside, CA 92521, USA

J.D. RHOADES
United States Salinity Laboratory, Riverside, CA 92501, USA

and R. KEREN
Institute of Soils and Water, ARO, The Volcani Center, Bet-Dagan, Israel

Received 7 March 1986. Revised June 1986

Key words Boron toxicity Leaf boron Mean concentration Salinity response Time integrated Toxicity criteria Wheat

Summary Two sandculture experiments were conducted with wheat (Triticum aestivum) to determine the effects of (1) osmotic potential (Ψs) and (2) fluctuating boron (B) concentrations on B availability (toxicity), shoot growth and leaf concentrations of B of wheat. The first experiment consisted of growing wheat to the spike emergence stage in sandcultures irrigated with a complete nutrient solution containing 1.0, 7.5, and 15.0 mg B l⁻¹ and having Ψs values of −0.02, −0.07, −0.12, and −0.17 MPa produced by CaCl₂-NaCl additions. Statistically, shoot weight was independently influenced by the B and Ψs treatments but not by their interaction. Only the B treatment had a significant effect on leaf boron concentrations; the B × Ψs interaction was nonsignificant with respect to leaf B concentrations.

The second experiment was designed to determine if growth and B uptake of wheat responds to the time integrated mean (TIM) concentration of B. This experiment consisted of four fixed-B concentrations and four fluctuating-B concentrations designed to produce two TIM concentrations (3.9 and 7.4 mg B l⁻¹) approached low to high and vice versa. With respect to shoot weight, there was no statistical difference among treatments having the same TIM concentration during the 10 week experiment. However, shoot B concentrations differed greatly; they were higher when the B concentration was progressively increased over the 10 week period. Leaf B concentrations (Y leaf at flowering), while not as high as the shoot B concentrations, were also higher under the treatment of increasing B concentration, indicating B uptake rates are higher for mature plants than for seedlings.

Introduction

Because of its moderately high tolerance to salinity⁸,⁹, wheat (Triticum aestivum) is frequently recommended as a crop to grow following the reclamation of salt-affected soils. Although wheat is moderately salt tolerant, it is sensitive to relatively low concentrations of boron (B); the B threshold concentration varies from 0.5 to 1.0 mg B l⁻¹ in soil solution⁵,⁸. Because B is removed more slowly than salinity during leaching¹⁰, it may still be excessive in some reclaimed soils and exist in various proportions with salinity. How crops respond to various combinations
of salinity and B is relatively unknown. For example, it is not known whether salinity enhances or reduces the phytotoxicity of B. It is also unknown how crops respond to B concentrations in soil solution (B_{soil}) which vary throughout the growing season. Possibly crops respond to the TIM concentration as they do to salinity.\(^2,6\)

With these questions in mind, two experiments were conducted with wheat. The first consisted of testing the effect of salinity on the availability of excessive concentrations of B to wheat. The second tested wheat's response to the manner in which the B concentrations were varied during its growth up to the flowering stage. This latter experiment was specifically designed to ascertain whether wheat responds to the TIM concentration of B. The results of these two experiments provide the basis of this paper.

**Materials and methods**

The two sandculture experiments were conducted in a temperature controlled glasshouse equipped with filters to remove smog from the incoming air. Each sandculture unit consisted of a 1201 reservoir tank, a cover supporting 2 sand-filled buckets containing approximately 10 kg of quartz sand, an air lift to pump nutrient solution from the reservoir onto the pots, and a manifold to distribute the solution to each pot. The air lift was activated by a timer which controlled time and length of irrigations. The solution percolated through the sand-filled pots back into the reservoir for 15 min 6-times daily.\(^5\) The irrigation solutions contained the following salt additions per liter: 0.5 mmol KH\(_2\)PO\(_4\), 2.1 mmol Ca(NO\(_3\))\(_2\), 1.2 mmol KNO\(_3\), 0.17 mmol Mg(NO\(_3\))\(_2\), 0.5 mmol MgSO\(_4\), 0.16 \(\mu\)mol CuSO\(_4\), 4.6 \(\mu\)mol MnSO\(_4\), 0.05 \(\mu\)mol H\(_3\)BO\(_4\), 0.38 \(\mu\)mol ZnSO\(_4\), and 89 \(\mu\)mol Fe from Fe-EDDHA. Additional details concerning boron and chloride salt additions are given separately for each experiment.

**Salinity-boron interaction experiment**

Wheat (*Inia* 66R — a short statured spring wheat with an early maturing semi-hard red grain\(^8\)) was seeded directly into each sandulture and thinned to two plants per pot when approximately 10 cm in height. Boron was added as orthoboric acid two days later to the respective sandculture solutions producing concentrations of 1.0, 7.5 and 15.0 mg B\(^-\)\(^1\). During the next three days, the B-treated sandcultures were salinized with CaCl\(_2\)-NaCl salts (1:1 molar solution) to lower the osmotic potentials (\(\Psi_s\)) of the nutrient solutions — 0.02, — 0.07, — 0.12 and — 0.17 MPa. These \(\Psi_s\) values correspond to electrical conductivities (EC) of approximately 0.6, 2.0, 3.4 and 4.8 dS m\(^-1\). The \(\Psi_s\) values were calculated from the EC values with the relation \(\Psi_s = 0.036EC\) expressed in dS m\(^-1\). These twelve combinations of B and \(\Psi_s\) were replicated six-fold in a randomized complete block design. The sandculture solutions were maintained at a volume of 1201 with deionized water during the growth period. In addition, the pH values of the solutions were kept within the range of 5.5 to 6.0 by addition of KOH or H\(_2\)SO\(_4\).

Leaf samples consisting of the Y-leaf and the first leaf below the Y-leaf were collected at the spike emergence stage for boron analysis by the azomethine-H procedure.\(^3\) The shoots (above sand portion of the plant) were harvested immediately after collecting the leaf samples, dried in a forced draft oven maintained at 65°C and weighed. Analysis of variance (ANOVA) was conducted on the data pertaining to the dry shoot weights, and concentrations of B (mg kg\(^-1\)) in the leaf samples. This experiment was conducted during the winter season 1983.

**Time integrated boron experiment**

The following winter the second experiment was conducted in the following manner. Wheat (*Inia* 66R) was planted and germinated directly in the sandcultures as described above except that the