JOURNAL OF PLANT NUTRITION, 24(2), 273–281 (2001)

EFFECTS OF SALINITY AND MACRONUTRIENT LEVELS ON MICRONUTRIENTS IN WHEAT

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ABSTRACT

It is unclear how salinity and macronutrients affect the micronutrient composition of plants. The objective of this study was to investigate interactive effects of salinity and macronutrients on micronutrient concentration in leaves, stems, and grain of spring wheat (*Triticum aestivum* L. cv. Lona) grown in hydroponics in growth chambers. Eight salinity levels from 0 to 150 m*M* NaCl, and 1, 0.2, and 0.04 strength Hoagland macronutrient solutions were used. It was found that the effects of salinity on the concentrations of Mn, Zn, Fe, and B in plants were complex. The changes in Mn, Zn, Fe, and B concentrations under saline conditions depended upon the levels of macronutrients and salinity, and the organs of plants. There was no significant correlation between yield parameters and Mn, Zn, Fe, and B in wheat, regardless of the macronutrient levels. This finding suggests that the micronutrient concentration in plants is probably not much affected by salinity.

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INTRODUCTION

Salinity can change the micronutrient concentrations in plants, depending upon the type of crop species and levels of salinity (1). Salinity increased the Mn and Zn concentrations in the shoots of barley (2), tomato (3), and rice (4), but decreased in corn (5). Salinity increased the Fe concentration in the shoots of pea (6), tomato (3), and rice (4), but decreased its concentration in the shoots of barley and corn (2,5). Concentrations of B in the shoots at anthesis and in the grain of wheat were decreased by increasing salinity (7). There is often an interaction between macronutrients and micronutrients in the root medium and in plants (8). Therefore, the composition of micronutrients in plants probably becomes more complex under the conditions of macronutrients and salinity, and it is necessary to investigate the interaction of salinity and macronutrients on the micronutrient composition in plants.

The growth of salinized plants could be improved by inorganic fertilization management (9–13). Studies on the interactive effects of salinity and nutrients have been concerned with one or two macronutrients. Wheat is a major food crop in most of the countries where salinity is a threat, and is moderately tolerant to salinity (14). The interactive effects of salinity and macronutrient level on the growth of wheat and uptake and distribution of macronutrients were reported by Hu et al. (15) and Hu and Schmidhalter (16). The results showed that the growth of wheat was enhanced by increasing the level of macronutrients at low fertility and a given salt level, and the macronutrient concentrations in leaves and stems were closely correlated to the grain and straw dry weight, irrespective of the levels of macronutrients. However, it is unclear how salinity and macronutrients affect uptake, pattern, and distribution of micronutrients in plants. The objective of this study was to investigate the interactive effect of salinity and macronutrients on the micronutrient concentrations in leaves, stems, and grain of spring wheat.

MATERIALS AND METHODS

Plant Growth

Growth conditions are described by Hu et al. (15). Spring wheat (*Triticum aestivum* L. cv. Lona) was grown in hydroponics in growth chamber until maturity. Eight levels of salinity, 0, 20, 40, 60, 80, 100, 125, and 150 m*M* NaCl, were established and 1, 0.2, and 0.04 strength Hoagland macronutrient solution (×HS) were used as the level of nutrient supply. At grain maturity, plants were harvested and separated into leaves, stems, roots, and ears. Samples were dried at 105°C for 1 h and at 65°C for 48 h. Dried ears were threshed and then the grain redried at 65°C for 24 h.

Nutrient Analysis

Dried flag and second leaves from the top of plant, stems, and grain of each plant were ground with a centrifugal mill to pass through a 0.5-mm diameter sieve. Plant samples (250 mg) were ashed at 560°C for 6 h and were digested with 2 mL of 20% HCl at 60°C for 5 min. The concentrations of Mn, Zn, Fe, and B were determined with an inductively coupled plasma emission spectrometer (ICP model Liberty 200).

Statistical Analysis

Data were analysed for the correlations between the micronutrient concentrations in various tissues and the yield parameters. Data were also analysed by using analysis of variance (ANOVA) to test for significance of main effects and interactions, and terms were considered significant at $P < 0.05$.

RESULTS AND DISCUSSION

The effects of salinity on the concentrations of Mn, Zn, Fe, and B in plants were complex (Figs. 1–4). The change in the Mn, Zn, Fe, and B concentrations in plants under saline conditions depended upon the levels of macronutrients and salinity and the organs of plant (Figs. 1–4). Hu and Schmidhalter (16) have shown that the macronutrient concentrations in leaves and stems of wheat were closely correlated to the grain and straw dry weight, whereas there was no significant correlation between these yield parameters and Mn, Zn, Fe, and B concentrations in wheat, irrespective of the macronutrient levels. Furthermore, as compared with the effect of salinity on nitrate, Cl and K in wheat (16), the micronutrient concentration in plants is probably not much affected by salinity, which is in agreement with the effect of salinity on the micronutrients of sorghum (17) and of maize (18). The growth of wheat leaves is most sensitive to salinity and the growth reduction of leaves occurs in the elongation zone (19). Therefore, the effects of salinity or other stresses on growth of wheat should be much more closely associated with metabolic/nutritional changes within the growing tissues of leaves than in whole or nongrowing leaf tissues. However, the results from Hu et al. (20) showed that salinity did not much affect the micronutrients in the growing zone of wheat as well.

Depending on the type of plant, tissue, salinity and micronutrient concentration in soils, the reports in literature also demonstrated that the effect of salinity on the micronutrients in plant is complex. Salinity increased the Mn concentration in the shoots of barley (2), rice (4), sugar beet (21), and tomato (3), but decreased

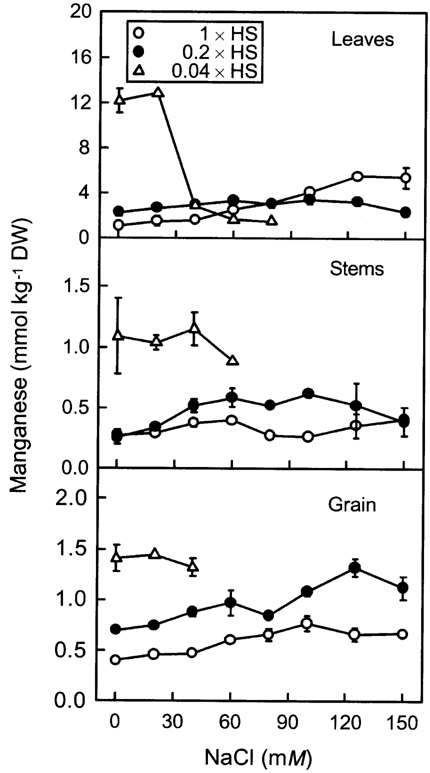

Figure 1. Interactive effects of salinity and macronutrients on the Mn concentrations in leaves, stems, and grain of wheat. Error bars represent standard deviations. Error bars fit within the plot symbol if not shown.

its concentration in the shoots of squash (3), pea (6), and corn (5). Zn concentration has been found to be increased in shoots of salt-stressed barley (2), soybean, squash, tomato (3), and in the grain of rice (4), but decreased in shoots of corn (5) and mesquite (22). Salinity increased the Fe concentration in the shoots of pea (6), tomato, soybean (3), and in the grain of rice (4), but decreased its concentration in the shoots of barley and corn (2,5). Holloway and Alston (7) reported that concentrations of B in the shoots at anthesis and in the grain of wheat were decreased by increasing salinity. Two main reasons may be responsible for these complex patterns. First, salinity changes the available concentration of these elements in soils due to an increase in the solubility of micronutrients under saline conditions (1). Hassen et al. (2) reported that salinity decreased the pH of the soil in their experiment which in turn enhanced the solubility of Zn and Mn. Therefore, the complex patterns of micronutrients in plants under saline conditions as reported in

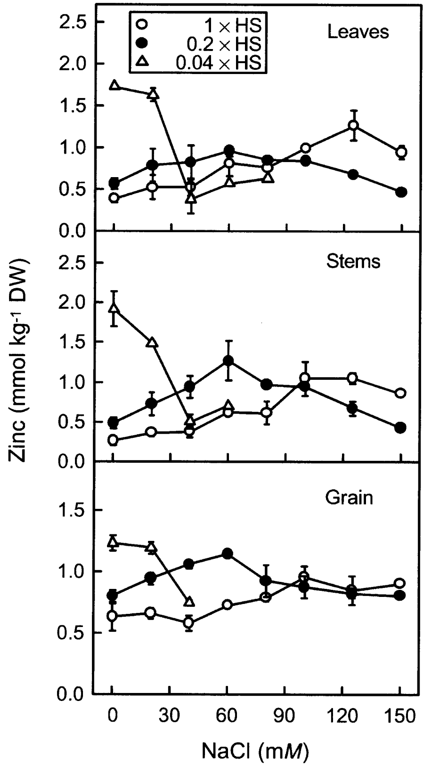

Figure 2. Interactive effects of salinity and macronutrients on the Zn concentrations in leaves, stems, and grain of wheat. Error bars represent standard deviations. Error bars fit within the plot symbol if not shown.

literature might be due to the different soils used by different researchers. Second, it is known that genotypes of plants vary widely in their ability to metabolize micronutrients efficiently (8). Also, different varieties of the same species may differ in uptake efficiency of micronutrients as well. Thus, it is no wonder that reports on the micronutrients in different species are so variable.

When the macronutrient level was increased in the growth medium, the results showed either a decrease or no change in Mn, Zn, Fe, and B concentrations in leaves, stems, and grain at a given level of salinity (Figs. 1–4), although Hu et al. (15) reported that the tolerance of plants to salinity was increased by increasing the levels of macronutrients from 0.04 to 0.2 × HS. The changes in micronutrient composition in plants were generally greater from 0.04 to 0.2 × HS than from 0.2 to 1 × HS. It is known that an increase in P and Ca concentrations in the growth medium decreases the uptake of Mn, Zn, and B (8). The higher micronutrient

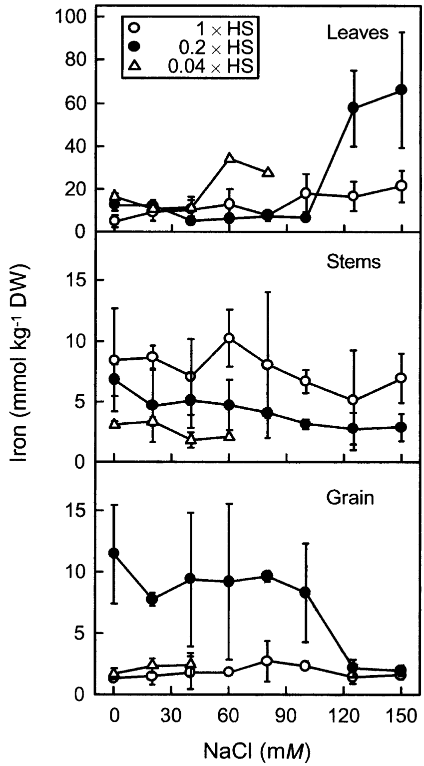

Figure 3. Interactive effects of salinity and macronutrients on the Fe concentrations in leaves, stems, and grains of wheat. Error bars represent standard deviations. Error bars fit within the plot symbol if not shown.

concentration in plants at the lower level of macronutrients may be related to the low concentration of P and Ca in the growth medium. Mn can replace Mg in plants at low Mg concentration in the growth medium. This may cause an increase in the Mn concentration at 0.04 × HS, due to a low concentration of Mg in nutrient solutions. Because the uptake of micronutrients is depressed by an increase in the macronutrient concentration in the growth medium, caution must be taken when increasing the macronutrients under saline conditions, especially at a low level of fertility.

As discussed above, the results, together with the reports in the literature, suggest that salinity did not exhibit any serious detrimental effects on micronutrients in plant parts. Therefore, the most severe growth-limiting factors under saline conditions should be considered for successful management. According to Hu et al. (15), the macronutrient supply significantly improved wheat growth at

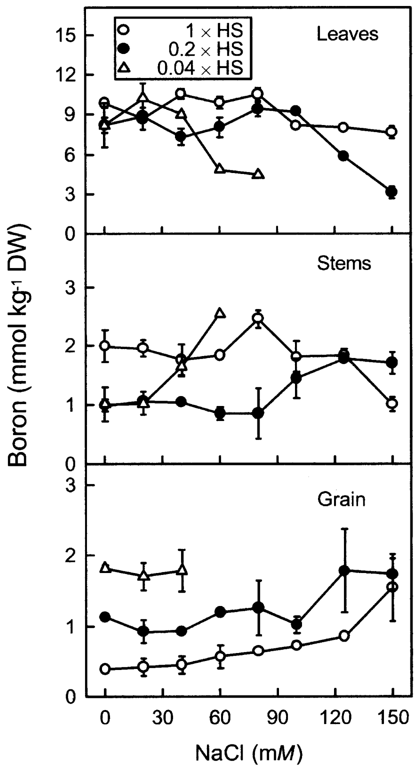

Figure 4. Interactive effects of salinity and macronutrients on the B concentrations in leaves, stems, and grain of wheat. Error bars represent standard deviations. Error bars fit within the plot symbol if not shown.

low fertility levels. The early stages of wheat development are most sensitive to salinity, and serious effects of salinity on early growth may cause tiller reduction and irreversible yield reduction (23,15). Thus, reducing salt concentration in the root zone at germination, at the seedling stage, and at early tillering will ensure the establishment of tillers. Furthermore, increasing seeding densities will achieve a higher total plant population per area, and replace lost tillers on main stems as well (24).

In conclusion, changes in the Mn, Zn, Fe, and B concentrations under saline conditions depend upon the levels of macronutrients and salinity, and the organs of plants. There was no significant correlation between the yield parameters and Mn, Zn, Fe, and B concentrations in wheat, irrespective of the macronutrient levels. The results suggest that the changes in concentration of Mn, Zn, Fe and B in plants are not a limiting factor of plant growth under saline conditions.

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