Pak. J. Bot. 33 (special issue) 2001

INFLUENCE OF GIBBERELLIC ACID (GA_3) ON GROWTH AND ION ACCUMULATION OF TWO ELITE SPRING WHEAT CULTIVARS UNDER SALINE CONDITIONS

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Abstract

A greenhouse experiment was conducted to assess whether gibberellic acid (GA_3) could alleviate the adverse effects of salt stress on growth and ion accumulation of two spring wheat cultivars. Barani-83 (salt sensitive) and SARC-1 (salt tolerant). Three week-old plants of both the cultivars were exposed to 0, 100 and 200 mol m^{-3} NaCl in Hoagland's nutrient solution. After three weeks of initiation of salt treatments, half of the plants of each cultivar were sprayed fully with 100 mg L^{-1} GA_3 solution. Plants were harvested 3 weeks after the application of GA_3. Fresh and dry weights of shoots and roots, plant height and leaf area were decreased with increasing supply of salt, but gibberellic acid treatment caused a significant ameliorative effect on both the cultivars with respect to these growth attributes. However, GA_3 caused a slight reduction in grain yield but increased grain size in both the cultivars. Saline growth medium caused a marked increase in the concentrations of Na^+ and Cl^- in shoots and roots of both the lines. However, with the application of GA_3, accumulation of Na^+ and Cl^- was enhanced in both shoots and roots of both wheat lines, but more ions accumulated in salt sensitive Barani-83 than in salt tolerant SARC-1. Overall, GA_3 treatment stimulated the vegetative growth of both cultivars of wheat under salt stress, but it caused a slight reduction in grain yield. GA_3 treatment enhanced the accumulation of Na^+ and Cl^- in both shoots and roots of wheat plants under salt stress.

Introduction

Soil salinity is one of the major stress factors responsible for low agricultural productivity all over the world. However, different biological means are being employed for attaining optimum growth under saline conditions in addition to many management practices (Kingsbury & Epstein, 1984; Ashraf, 1994; Shannon & Grieve, 1999). In addition, different types of phytohormones are being extensively used to alleviate the adverse effects of salinity stress on crop growth. Of them, gibberellins have been the main focus of most of the plant scientists (Basalah & Mohammad, 1999; Hisamatsu *et al.*, 2000). For example, GA_3 application has been reported to be helpful in enhancing wheat growth under saline conditions (Parasher & Varma, 1998). Final seed germination, growth and grain yield of wheat were decreased with increasing salinity levels, but were relatively increased by seed treatment with gibberellic acid (GA_3) (Kumar & Singh, 1996). In another study, wheat seeds after treatment with various growth regulators including gibberellic acid showed highest percent germination when treated with 20 mg L^{-1} GA_3 (Nayyar *et al.*, 1995). It was ascribed to the enhanced plastid development in germinating wheat seed due to gibberellic acid.

On the basis of these reports, it was hypothesized that GA_3 treatment could alleviate the adverse effects of salt stress on growth of spring wheat. Thus the principal objective of the present study was to determine up to what extent GA_3 could ameliorate the effect of salt stress on wheat growth. Since the two cultivars under test have different degree of salt tolerance, it was also one of the facets of the major objective that how these cultivars differing in slat tolerance responded to combination of salinity and gibberellic acid (GA_3) with respect to their ion accumulation in different plant parts.

Materials and Methods

The seed material of two spring wheat (*Triticum aestivum* L.) cultivars/lines, i.e., Barani-83 (salt sensitive) and SARC-I (salt tolerant) were obtained from the Saline Agricultural Research Cell of the University of Agriculture, Faisalabad, Pakistan. The experiment was conducted in a netting house under natural environmental conditions during the winter/spring of 1999-2000 with average day/night temperatures 28 ± 8 °C and 12 ± 5 °C, respectively and photoperiod ranging from 10-13.5h. The earthen pots of 30 cm diameter lined with polythene sheet were filled with 10 kg of pure river sand. The pots were arranged in a completely randomized design with three factor factorial arrangement and four replications. The sand was washed well with tap water and then two litres of Hoagland's nutrient solution was applied to each pot.

Ten pre-germinated seeds of each cultivar/line were sown in each pot. Salt (NaCl) treatment was started stepwise in aliquots of 50 mol m^{-3} NaCl three weeks after transplantation. Three weeks after the initiation of salt treatment, GA_3 was sprayed.

The salt and GA_3 treatments were as follows:

T_0	=	0 mol m^{-3} NaCl + without GA_3 spray
T_1	=	0 mol m^{-3} NaCl + 100 mg L^{-1} GA_3 spray
T_2	=	100 mol m^{-3} NaCl + without GA_3 spray
T_3	=	100 mol m^{-3} NaCl + 100 mg L^{-1} GA_3 spray
T_4	=	200 mol m^{-3} NaCl + without GA_3 spray
T_5	=	200 mol m^{-3} NaCl + 100 mg L^{-1} GA_3 spray

Two liters of appropriate treatment solution were applied every week to each pot. This volume was sufficient to flush through the salts already present in the sand. Evapotranspiration loss was daily compensated by adding 200 mL of distilled water to each pot.

The data for different growth parameters were recorded three weeks after the application of GA_3 (at the start of the boot stage) already experiencing varying concentrations of NaCl for three weeks. Four plants from each pot were randomly harvested and their roots and shoots were separated. All the plant samples were washed well with distilled water and their fresh weights recorded. They were then oven-dried at 65 °C up to constant dry weight after which time their dry weights were recorded.

Determination of Na^+, K^+, Ca^{2+}, N and P in shoots and roots: The dried plant material was ground in a grinder so as to pass through 2 mm sieve. The dried material (0.1 g for shoot and 0.05 g for root) was digested with digestion mixture (sulfuric acid – hydrogen peroxide) according to the method of Allen *et al.* (1986). Na^+, K^+ and Ca^{2+} were determined with a flame photometer (Sherwood model 410, Japan). Nitrogen was estimated by Kjeldahl method. Phosphorus in the plant extracts was determined following Yoshida *et al.* (1976). For Cl^- determination, 0.05-0.1 g dry ground material of roots and shoots was heated at 80 °C for 4 h and

Cl^- content in the extracts was determined with a chloride meter (Central Kagaku Corp., Japan).

Chlorophyll content: The chlorophylls a and b were determined according to the method of Arnon (1949). The fresh leaves were cut into 0.5 cm segments and extracted overnight with 80% acetone at −10°C. The extract was centrifuged at 14000 x *g* for 5 min and the absorbance of the supernatant was read at 645 and 663 nm using a spectrophotometer (Hitachi-U-2001).

At maturity of the crop, data for the grain yield and yield components were recorded.

Results

From the mean data of fresh and dry weights of shoots and roots, plant height and leaf area (Fig. 1 a-f), it is evident that although all these growth characters declined consistently with increase in NaCl level of the growth medium, application of GA_3 was found to have alleviated the effect of salt stress on both the varieties. There was not much difference between the lines with respect to fresh weights of shoots and roots, but on the basis of dry weights of shoots and roots, SARC-I was superior to Barani-83 at all external NaCl levels. In Barani-83, plant height was more adversely affected by NaCl than in SARC-I, but the reverse was true for leaf area per plant.

Salt stress had a significant effect on the concentrations of Na^+ and Cl^- in shoots and roots of both the lines since these ions increased consistently with increase in salt level of the growth medium. With the application of GA_3, accumulation of Na^+ and Cl^- was enhanced in both shoots and roots of both wheat lines, but the more accumulation of these ions was observed in salt sensitive Barani-83 than in salt tolerant SARC-1 (Fig. 2 a-d). Although K^+ in shoots and roots of both lines decreased markedly due to salt stress, no significant effect of GA_3 was observed on the accumulation of this cation in either shoots or roots, except in SARC-1, K^+ accumulation in the shoots of SARC-1 increased under non-saline and at 100 mol m^{-3} NaCl with hormone application (Fig. 2 e & f). In contrast, shoot Ca^{2+} decreased in Barani-83 and increased in SARC-1 due to hormone application, but such effect of the hormone was not observed on root Ca^{2+} concentration (Fig. 3 a & b). Although shoot N and P decreased consistently in both wheat lines with increase in external salt level, GA_3 application promoted the uptake of N in both shoots and roots and P in only shoots of SARC-1 (Fig. 3 c-f).

Contents of chlorophyll a and b and total chlorophyll generally decreased consistently with increase in NaCl of the growth medium (Fig. 4 a-c). However, growth regulator treatment was found to be effective in enhancing both the pigments in only Barani-83, but total chlorophyll in both the lines.

Grain yield per plant and number of grains per spike decreased significantly under salt stress in both the cultivars but more adverse effect of salt was observed on Barani-83 than on SARC-1 with respect to these two yield attributes. However, application of hormone caused a slight decrease in these two yield parameters in both the cultivars (Figs. 4 d & e). 1000 grain weight was increased at the highest salt level in both the cultivars and the growth regulator effectively enhanced the grain weight at the same level in both the lines (Fig. 4 f).

Discussion

From the data for different growth attributes and seed yield and yield components presented here for two spring wheat lines differing in salt tolerance, it is evident that although GA_3 was effective in enhancing biomass of both the cultivars under both saline and non-saline conditions, it caused a slight reduction in grain yield in both the lines. However, grain weight was markedly increased in both the lines with hormone treatment. These results can be explained in view of the phenomenon that when vegetative growth of a grain crop is promoted by the application of growth promoting hormone, it would result into reduction in grain yield (Guoping, 1997). In contrast, Kumar & Singh (1996) reported a decrease in growth and grain yield due to salt stress, but GA_3 treatment to seeds increased both the growth and grain yield under salt stress. Long ago, Coombe (1970) was of the view that foliar or whole plant treatments with GA_3 after anthesis generally has little effect on fruit set but increases fruit or grain size. In our study the plants were treated with GA_3 well before anthesis, but this treatment effectively caused an increase in grain size. These results are quite parallel to what earlier have been observed by Liuling *et al.* (1995) that 60 mg/L GA_3 spray on wheat plants increased grain weight.

Uptake and accumulation of toxic ions such as Na^+ and Cl^- in crop species including wheat are enhanced under saline conditions (Wyn Jones, 1981; Ashraf & O'Leary, 1996). However, GA_3 treated plants had more accumulation of Na^+ and Cl^- in both shoots and roots than the untreated plants. In addition, the effect of GA_3 was more pronounced on the salt sensitive cultivar Barani-83 as compared to the salt tolerant SARC-1. These results do not agree with those of Aldesuquy (1995) who reported that GA_3 reduced the accumulation of Na^+ in flag leaves of wheat under saline conditions. But the contradiction in the two studies could be due to the difference in plant growth stage at which GA_3 was applied, since in the latter, the grains were pre-soaked with GA_3 before sowing whereas in the present study GA_3 was applied just at the booting stage.

Barani-83 had higher chlorophyll a than that in SARC-1 under saline conditions but the reverse was true for chlorophyll b. GA_3 treatment caused a significant increase in both chlorophyll a and b but more pronounced effect of the growth regulator was observed on Barani-83 than on SARC-1. The significant increase in chlorophyll a and b of Barani-83 due to GA_3 could be one of the major factors responsible for its higher photosynthetic efficiency compared with that of SARC-1. Similarly, Munjal & Goswami (1995) reported that salinity caused a decrease in chlorophyll a and carotenoids contents in cotton, whereas GA_3 treatment caused a significant increase in these pigments. In another study, Radi *et al.* (1989) reported that in maize chlorophyll a and b, and carotenoids were increased by salt stress, but GA_3 treatment caused a further increase in these pigments. In contrast, in safflower the same authors observed that salt stress reduced the pigments whereas GA_3 increased them.

In conclusion, GA_3 treatment stimulated the vegetative growth of both cultivars of wheat under salt stress, but it caused a slight reduction in grain yield. GA_3 treatment enhanced Na^+ and Cl^- contents in both shoots and roots of wheat plants under salt stress.

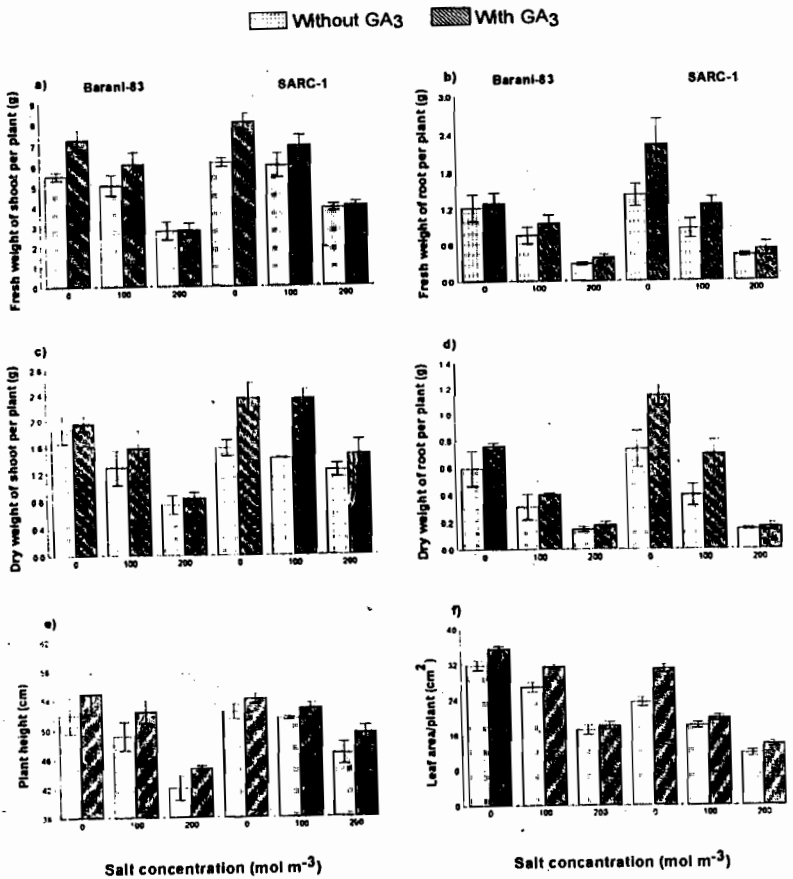

Figure 1. (a) Fresh weight of shoot, (b) fresh weight of root, (c) dry weight of shoot, (d) dry weight of root, (e) plant height, (f) leaf area per plant of two spring wheat lines differing in salt tolerance when plants were harvested 3 weeks after the application of GA_3, and six weeks after NaCl treatment.

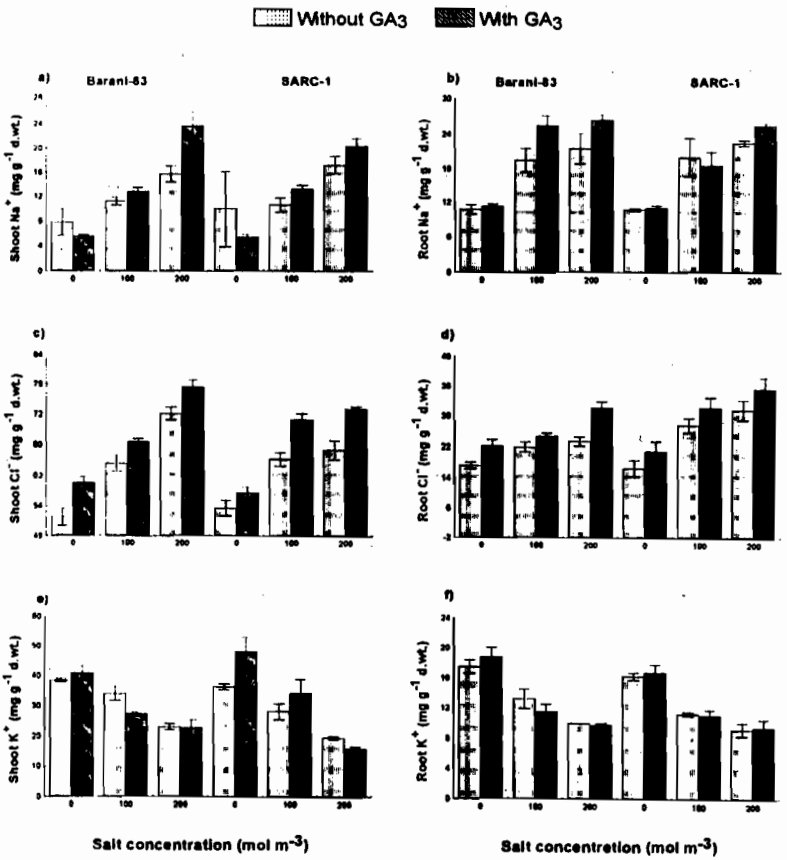

Figure 2. (a) Shoot Na^+, (b) root Na^+, (c) Shoot Cl^-, (d) root Cl^-, (e) shoot K^+, (f) root K^+ of two spring wheat lines differing in salt tolerance when plants were harvested 9 weeks after the applivation of GA_3, and six weeks after NaCl treatment.

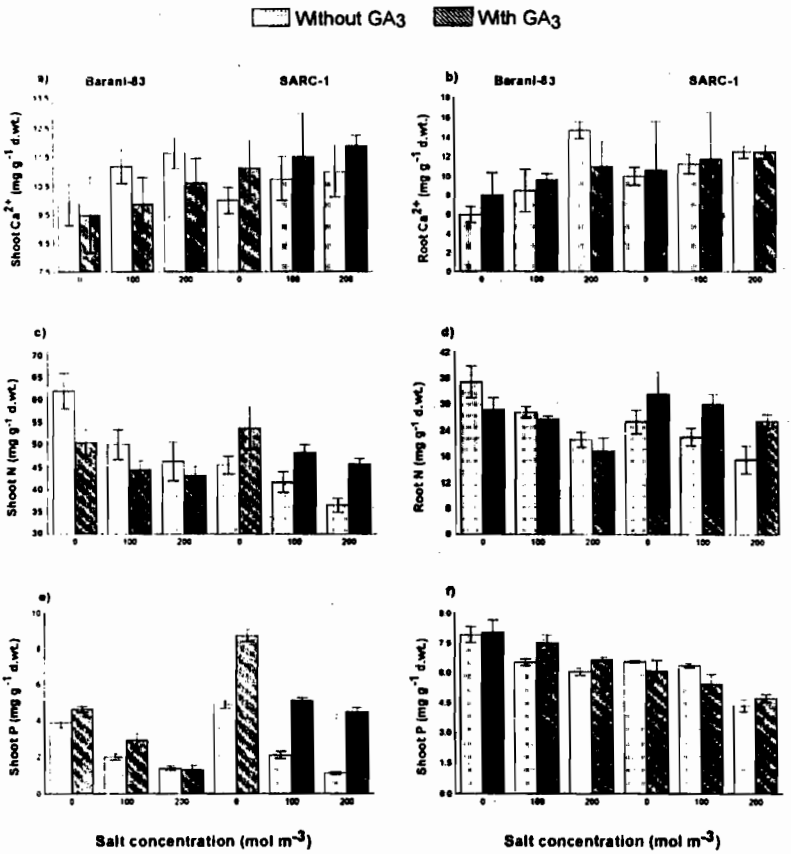

Figure 3. (a) Shoot Ca^{2+}, (b) root Ca^{2+}, (c) shoot N, (d) root N, (e) shoot P, (f)root P of two spring wheat lines differing in salt tolerance when plants were harvested 3 weeks after the application of GA_3, and six weeks after NaCl treatment.

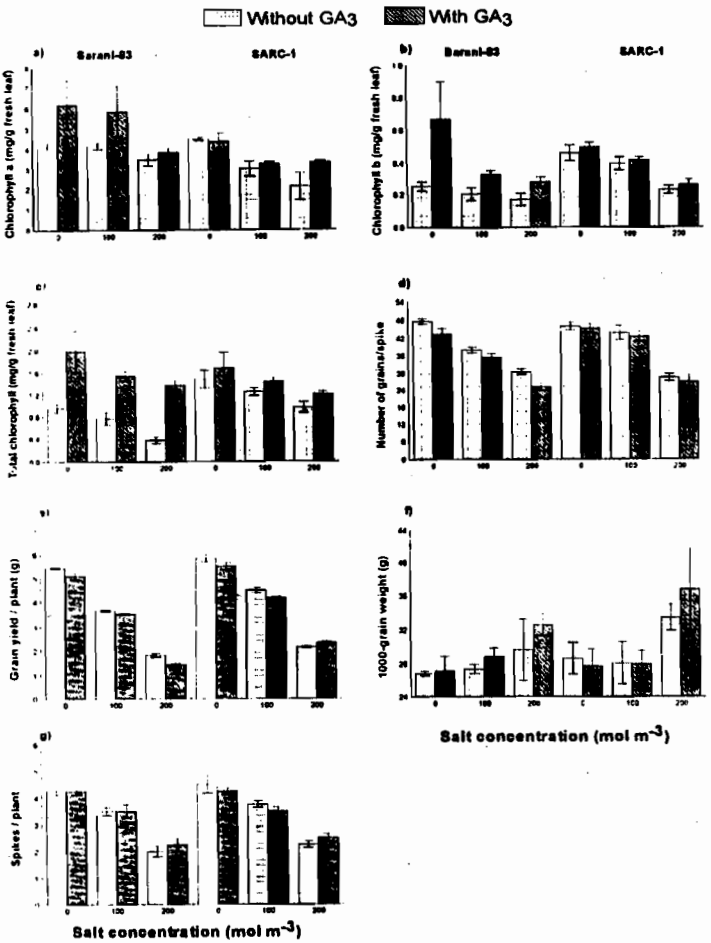

Figure 4. (a) Chrolophyll a, (b) chlorophyll b, (c) total chlorophyll of two spring wheat lines differing in salt tolerance when plants were harvested 3 weeks after NaCl treatments, (d) number of grains per spike, (e) grain yield per plant, (f) 1000-grain weight of two spring wheat lines differing in salt tolerance at maturity of crops.

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