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Research Article

Combined Effect of Drought and Salinity Stresses on Plant Growth and Nutrient Status of Wheat (*Triticum aestivum* L.) Crop

Fozia Parveen[1], Abdul Qadeer[1], Muhammad Aamer Maqsood[1] and Muhammad Sanaullah[1*]

[1] Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad-38040, Pakistan

*****Correspondence: sanasial@gmail.com; msanaullah@uaf.edu.pk

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Abstract

Increasing levels of drought and salinity stresses due to climate change are problematic for plant growth and yield. It was hypothesized that combined effects of drought and salinity stresses retard the plant growth and plant nutrient uptake from soil. For this purpose, a pot experiment was carried out to examine the individual as well as combined impact of drought and salinity on the growth, nitrogen (N) and phosphorus (P) uptake in wheat crop. Pre-germinated wheat seedlings were transferred into pots, filled with 5 kg soil. All plants were grown at optimum moisture (70% water holding capacity (WHC)) for four weeks and then half of the plants were subjected to drought stress (30% WHC). While salinity stress was applied for both moisture levels by maintaining two ECe levels: 2 dS m^{-1} as control and 8 dS m^{-1} as salinity stress. The results indicated that growth parameters like shoot and root dry weights were significantly reduced ($P < 0.05$) due to combined effects of drought and salinity stresses as compared to individual stress. Chlorophyll contents were significantly lower ($P < 0.05$) under combined and individual stresses of drought and salinity. Phosphorus and potassium (K) concentrations in plant root and shoot were significantly decreased under combined and individual stress of drought and/ or salinity. Sodium (Na) concentration in plant root and shoot was significantly higher ($P < 0.05$) under individual salinity stress and combined drought and salinity stress. It was concluded that N and K uptake in wheat plants were reduced under drought and salinity stresses. To increase the nutrient uptake in wheat plants and its growth, drought and salinity stresses should be avoided.

Keywords: Drought; Salinity; Wheat crop; Plant nutrition; Phosphorus; Potassium; Sodium

1. Introduction

Climate change causes water scarcity and prevailing drought conditions in many regions of the world (Gude, 2017). Drought stress is an inevitable and recurring feature of global agriculture. In 2025, 65% people will be facing water-stress and 1.8 billion people will face the water shortage (Jia et al., 2021). Water shortage for crop growth badly affects the world population (Fahad et al., 2017) by reduced yield of crops. Desertification in arid and semi-arid region, which are becoming drier due to changing rainfall pattern and water shortage, has increased. Drought is multivariate and complex in its occurrence and it is influenced by varied biological and physical methods. Such complication prevents basic justifications of effect and cause, make examinations of changing climate and drought an interesting task (Cook et al., 2018). Drought periods could alter the mineralization of organic materials and thus recycling of nutrients in soil ecosystem and to the plants (Feyen and Dankers, 2009). It has become interesting concern to study nutrients cycling in soil and then nutrient uptake plants due to environmental variables (Nair, 2019). Increase in temperature under global warming causes evaporation losses from soil leaving the salts on soil surface, results in soil salinity. Soil salinity occurs under arid and semi-arid climatic conditions (Foster et al., 2018). About 800 million hectares (Mha) area (6%) of the world's land is salt affected (Shahid et al., 2018). It is reported that 6.14 Mha of Pakistan area has been damaged by salinity and sodicity, out of which 3.9 mha (80%) is located in Punjab, 0.6 mha in Sindh and 0.2 Mha in Baluchistan province (Ghafoor et al., 2016). About 56% area out of total salt affected area of Pakistan is saline sodic. Sheikh et al. (2022) reported that nearly 10 mha area is badly affected by salinity, comprising 12.9% of country land. Under salinity stress, low osmotic potential and ion toxicity causes less availability of moisture in soil which reduces microbial activity for mineralization and nutrient cycling (Marschner and Rengel, 2012). Soil microbial functioning related to mineralization and nutrient cycling under salinity have been less studied but there are adverse effects of salinity on the soil microbes (Zhao et al., 2017). There is prerequisite to detect the influence of climatic factors on nutrient cycling, nutrient uptake and plant growth.

Wheat (*Triticum aestivum* L.) is a cereal crop used by more than 35% of world's population (Tyagi *et al.*, 2014). Wheat crop under rain-fed conditions often suffers from drought stress (He *et al.*, 2020) and cause significant reduction in yield. When saline conditions

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prevail in rain-fed and irrigated areas, water in the roots is pulled out back into the soil, depriving the plants of any available moisture and causing potential loss in growth and productivity. Salinity induces ion toxicity, osmotic stress, and nutrient deficiency and thus limits water uptake from soil. Cations of aluminum, copper and iron precipitate the P and this reduces the phosphate availability to the plants (Zhang *et al.*, 2018). Sodium can accumulate in the cell wall of the plants which may lead to loss in osmotic potential of cell and ultimately causes cell death (Flowers *et al.*, 2015). Many studies indicated that salinity and drought harms plant growth, however extent of harm is yet to be discovered. Therefore, present study is aimed to evaluate the combined as well as individual effects of drought and salinity stresses on plant growth parameters, N and P uptake in wheat crop.

2. Materials and Methods

2.1. Collection and preparation of soil

Samples of soil were collected from top layer (0-20 cm) from field area of University of Agriculture, Faisalabad, Pakistan. After sampling of soil, it was air dried, bigger soil clods were completely crushed, visible straw particles, and small pebbles were removed from the soil, while sieving the soil carefully by using 2 mm sieve. The soil had sandy clay loam texture (sand 50%, silt 35%, clay 15%), organic matter 0.66%, pH 7.7, ECe 2 dS m^{-1}, field capacity 24%, Olsen P 7.7 ppm, extractable K^+ 206 ppm.

2.2. Experimental setup

First, wheat seeds were kept on moist filter paper for germination under dark conditions for three days and then three days old seedling were transferred into pots having 5 kg soil (sandy clay loam, pH 7.9). Recommended doses of NPK (80,70 and 90 kg ha^{-1}) fertilizers were applied before sowing. All plants were grown at optimum moisture for four weeks and drought treatments were maintained at 30% WHC. Salinity stress was maintained at two (EC_e) levels: 2 dS m^{-1} (control) and 8 dS m^{-1} (salinity stress). There were total four treatments arranged under complete randomized design (CRD) including drought, salinity, combined drought and salinity and a control with four replicates of each.

2.3. Plant physiological and biochemical parameters

Chlorophyll contents were recorded at 8, 15, 21, 26, 30 and 35 days time interval. After harvesting, plant shoot and root samples were separated and roots were gently washed with distilled water. The fresh weights of plant shoots and roots were recorded and then these plant samples along with soil samples were oven dried at 65 °C. Plant shoot and root dry weights were recorded after oven drying. All oven dried plant materials were ground and used for chemical analysis. Phosphorus concentration in plant shoot and root was analyzed at UV-visible spectrophotometer (Shimadzu UV-1201) by following vanadate-molybdate method (Chapman and Pratt, 1961). Potassium and Na^+ in the digested material was determined by Jenway PFP-7 flame photometer after running standards of K^+ and Na (Gee and Bauder, 1986).

2.4. Statistical analysis

The significance difference between treatments were tested by using two-way analysis of variance (ANOVA) followed by least significance difference (LSD) test at 5% probability level, depending upon data distribution and its normality tests by using software Statistix version 8.1 (Steel *et al.*, 1980). The pearson correlation coefficient test was used to test the correlation among the different parameters.

3. Results

3.1. Plant biomass

Under salinity stress shoot and root dry weights were significantly reduced (2±04, 0.5±0 g) ($P < 0.05$) as compared to control treatment (Fig. 1). Drought stress reduced root dry weight and had no impact on shoot dry weight as compared to control treatment. Due to combined stresses of drought and salinity, shoot and root dry weights were reduced (1.4±0.1, 0.4±0 g) significantly ($P < 0.05$) as compared to control as well as individual stresses of salinity and drought (Fig. 1).

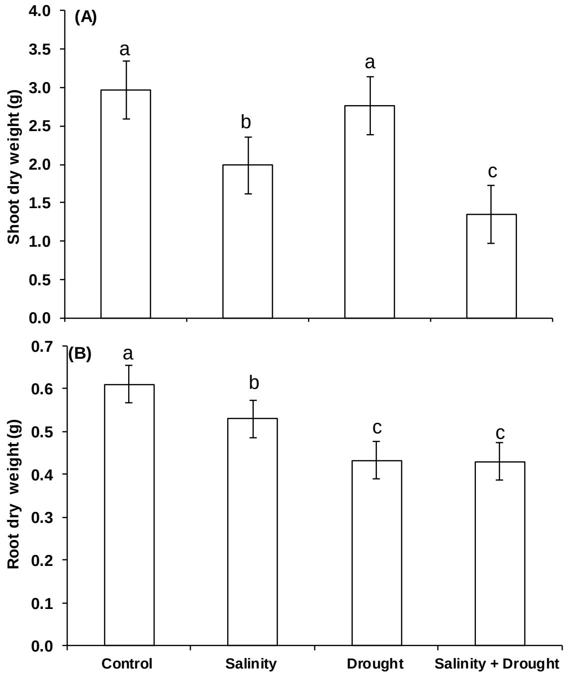

Figure 1. The effects of individual and combined stresses of drought and salinity on (A) shoot dry weight and (B) root dry weight. Data represented by the bars is mean ± SD (n=3). Letters above the bars indicate significant differences between treatments according to LSD test ($P < 0.05$).

3.2. Chlorophyll contents

At controlled conditions, chlorophyll contents (SPAD values) of wheat crop were significantly increased with increasing growth time (Fig. 2A). While under salinity stress, there was no significant changes in chlorophyll contents with growth period (Fig. 2B). Under drought stress, there was significant decrease (35.8±2) in SPAD values from day 8 to 35 (Fig. 2C) and in combined stress of salinity and drought, similar trend was observed as that of drought stress (Fig. 2D).

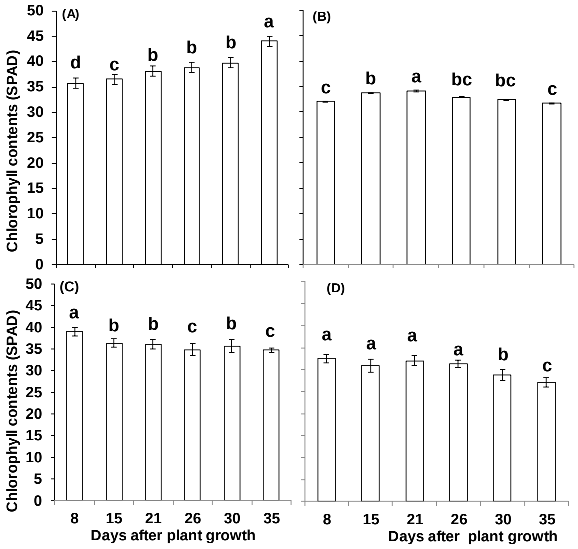

Figure 2. Chlorophyll contents of the plants measured after different time intervals in four treatments as (A) control, (B) salinity stress, (C) drought stress and (D) combined salinity and drought stresses. Data represented in the bars is mean ± SD (n=3). Letters above the bars indicate significant differences between treatments according to LSD test ($P < 0.05$).

3.3. Nutrient uptake

Under individual abiotic stresses of drought and salinity, there was significant ($P < 0.05$) decrease in P and K^+ uptake by plant shoot and root as compared with control (Fig. 3 and 4). Combined stresses of drought and salinity further reduced P (2236±232, 1544±33 ppm) and K^+ (155±14, 55±1 ppm) concentration in plant shoot and root as compared to individual stresses (Fig. 3 and 4). Sodium concentration was significantly increased in plant shoot and root under salinity stress either individual or combined with drought stress (Fig. 5).

4. Discussion

4.1. Effect of drought and salinity stresses on plant growth

In this study, plant shoot and root dry weights were reduced due to individual and combined stresses of drought and salinity in line with our hypothesis. The plant biomass reduction under water stress reduces the photosynthates production (Cao *et al.*, 2018). Under stress conditions plants were unable to continue their normal growth and development processes because water stress during growing period disrupted the photosynthesis in plants and reduced the production of photo-assimilates towards growing parts of plants due to which plant height was reduced. So, the fresh and dry biomass of plants was negatively affected (Sharif *et al.*, 2018). Plant biomass is dependent on plant height and higher salt concentrations reduce the leaf area index of plants due which plant height is reduced and thus plant biomass is also reduced.

Moisture stress reduces the chlorophyll contents (Rostampour *et al.*, 2012) which harvest the light energy and convert in biochemical energy for enhancing plant growth. Under low moisture plant cells are disrupted because during drought stomata of leaves are closed, carbon dioxide is reduced while electron transfer and light reaction continue at normal state. In such condition NADP is limited and electron accepting is limited which can be regulated by reactive oxygen species produced under stress condition and thus disrupts the lipids, sugars, nucleic acid and proteins. Salinity stress is a cause of disruption of hormones and limiting the activity of chlorophyll degrading enzyme such as chlorophyllase, limiting precursors chlorophyll synthesis, destroying photosynthetic apparatus and chloroplasts structure (Neocleous and Vasilakakis, 2007). The nutrient uptake by plants is condensed due to reduction in transpiration rates (Alsaeedi *et al.*, 2019) and thus diffusion rates drop due to decline in soil moisture contents. Salinity combined with drought induces ion toxicity, osmotic stress, nutrient deficiency and thus plants are unable to continue their growth and development (Arif *et al.*, 2020).

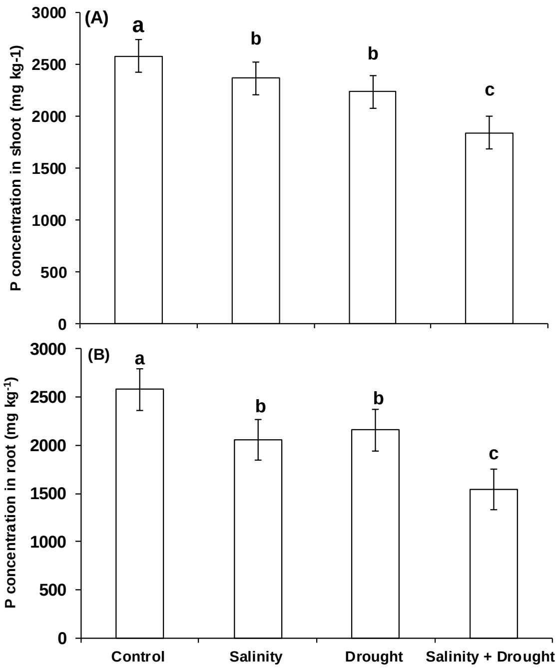

Figure 3. The effect of individual and combined stresses of drought and salinity on P concentration in plant (A) shoot

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and (B) root. Data represented in the bars is mean ± SD (n=3). Letters above the bars indicate significant differences between treatments according to LSD test (P < 0.05).

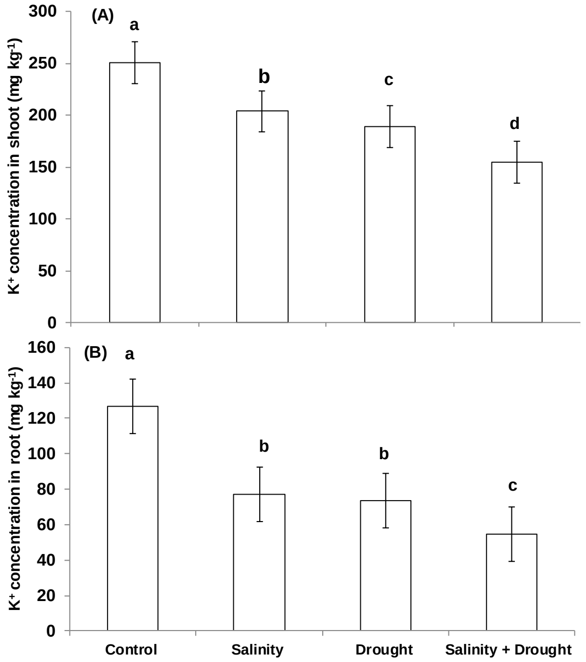

Figure 4. The effect of individual and combined stresses of drought and salinity on K^+ concentration in plant (A) shoot and (B) root. Data represented in the bars is mean ± SD (n=3). Letters above the bars indicate significant differences between treatments according to LSD test (P < 0.05).

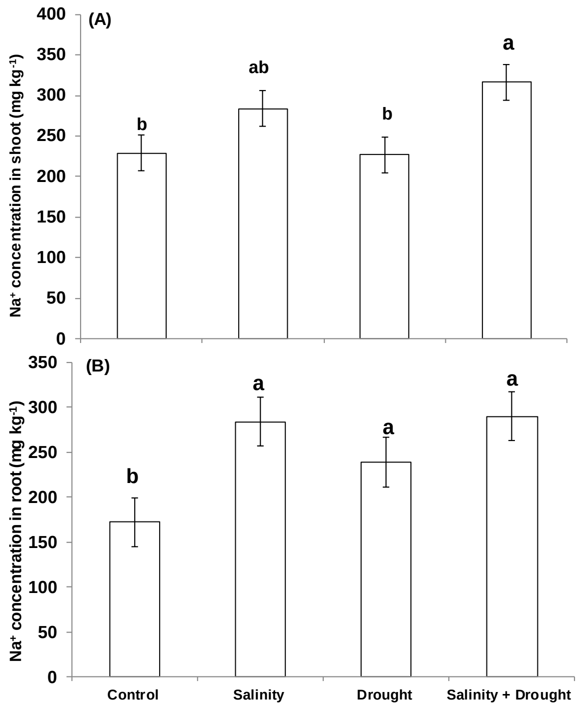

Figure 5. The effect individual and combined stresses of drought and salinity on Na^+ concentration in plant (A) shoot and (B) root. Data represented in the bars is mean ± SD (n=3). Letters above the bars indicate significant differences between treatments according to LSD test (P < 0.05).

4.2 Effect of drought and salinity on nutrient uptake

Our results regarding P uptake in wheat shoot and root show negative effects of drought and salinity stresses. Phosphorus concentration in plants decreased due to water stress conditions as described by (Young and Ross, 2018) and uptake of P by plants is reduced severely in dry soils as explained by (Ge *et al.*, 2012). Salinity stress limits the normal uptake and distribution of P in plants. Balanced absorption of P is disrupted due to excess salts in the external soil solution (Jouyban, 2012). Combined stresses of drought and salinity were even more lethal for P uptake in plant shoot and root because calcium ions of salts precipitate P thus reducing P uptake and P availability to the plants (Bano and Fatima, 2009). Phosphorus becomes insoluble under stress conditions due which not available in soil solution and unavailable for plant uptake. Potassium concentration was less observed in plant shoot and root due to drought stress owing to increasing water deficiency. Potassium influx transporters mediate sodium influx into root cells (Wakeel, 2013). When water level insides the plants reduced then the stomata are closed and transpiration rate is tremendously reduced (Saud *et al.*, 2017). Under drought conditions the K^+ concentration in plants reduced significantly that depressed the photosynthetic rate and diffusion rate also decreased which causes reduction in K^+ uptake (Ahanger *et al.*, 2016). As physiochemical properties of Na^+ and K^+ are similar, uptake of K^+ is affected by high Na^+ level. Under drought conditions K^+ uptake not reduced much as P (Huseynova *et al.*, 2016). However, salinity increased the Na^+ concentration in plants which causes to reduce the plant growth which is due to lower Na^+/K^+ ratio in plants (Kaushal and Wani, 2016).

Plants show certain toxicity symptoms towards some elements which cause salinity stress. Drought effect was less severe on sodium uptake in plants as compared to effects of salinity. Sodium was accumulated in the cell wall of the plants which may lead to loss in osmotic potential of cell and ultimately causes cell death (Munns, 2002). Potassium and Ca^{2+} uptake decreased than Na^+ under salt stress (Bavei *et al.*, 2011). Combined effect of drought and salinity and individual effect of salinity results in Na^+ uptake in plant shoots and roots but reduced the plant growth. Balanced absorption of nutrients was disrupted due to excess salts in the external soil solution (Farooq *et al.*, 2015). Interference of excess Na^+ in root cells of plant occurs as Na^+ competes with K^+ for uptake and causes ionic imbalance (Hussain *et al.*, 2021). Thus, nutrient imbalance due to drought and high salinity limits the plant growth and production.

5. Conclusion

Our study concluded that individual stresses of drought and salinity reduced the plant growth and nutrient uptake in wheat crop. Combined drought and salinity stresses were even more harmful for plant growth and nutrient uptake by wheat crop than the individual stresses of drought and salinity. Growth parameters were also significantly reduced under single and combined stresses. Same negative results were observed for chlorophyll contents and nutrient uptake by plant as P and K+ concentration in plant shoots and roots were significantly reduced under separate and combined stresses of drought and salinity. Drought and salinity stresses are detrimental for wheat growth, N and P uptake. Increase in wheat growth, production and nutrient uptake is possible, if drought and salinity stresses would be avoided.

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Author Contributions

Conceptualization, M.S.; methodology, F.P. and AQ; investigation, M.S.; resources, M.S. and M.A.M.; data curation, A.Q. and M.S.; writing—original draft preparation, A.Q. and F.P.; writing—review and editing, M.S and M.A.M.; funding acquisition, M.S. All authors have read and agreed to the published version of the manuscript."

Conflict of Interest

The authors declare no conflict of interest.

Ethics Approval

All authors have read and agreed to the published version of the manuscript.

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