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FOLIAR APPLICATION OF POTASSIUM UNDER WATER DEFICIT CONDITIONS IMPROVED THE GROWTH AND YIELD OF WHEAT (*TRITICUM AESTIVUM* L.)

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ABSTRACT

Study to find out the response of wheat (*Triticum aestivum* L.) cultivars (Lasani-2008, Auqab-2000) to foliar application of 1 % potassium at different growth stages (tillering, flower initiation and milking) was carried out under water limited environment, at the Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad during 2008-09. The wire house experiment was laid out in completely randomized design. Data regarding various agronomic traits (plant height, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight and grain yield per plant) of crop were recorded using standard procedures. The data so collected were analyzed statistically by using the Fisher's analysis of variance technique and LSD at 5% probability was used to compare the differences among treatments' means. Drought stress at all three critical growth stages adversely affected plant height, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight and grain yield of wheat plant. Foliar application of K at all three critical growth stages improved the drought tolerance of plants and improved the growth and yield components, however, grain filling stage was found more responsive.

Key words: Wheat; drought tolerance, potassium foliar spray.

INTRODUCTION

Major threat to reduce growth and yield of a plant is drought stress (Souza *et al*., 2004). This shortage of water occurs in region of low rainfall, and most wheat is cultivated in such semi arid regions (Deng *et al*., 2004). Nutritional status of the plant is the indicator of its response to environmental stress. Cakmak (2005) reported that potassium enhanced drought tolerance in plants by mitigating harmful effects by increasing translocation and by maintaining water balance. Crop can more easily take nutrients when applied foliarly and in return crop yield increased (Arif *et al*., 2006). El-Ashry *et al*. (2005) reported that the negative effect of drought on growth of wheat can be decreased by spraying K; plants translocate this K to all its parts, in turn yield per plant increased. Average wheat yield increased in K fertilized plots (Pettigrew, 2008). Potassium has the major role in osmoregulation, photosynthesis, transpiration, stomatal opening and closing and synthesis of protein etc. (Cakmak, 2005; Milford and Johnston, 2007). The growth of the crop is reduced when K is not applied sufficiently (Hermans *et al*., 2006).

Various adaptive (resistance) mechanisms in the plants have been developed under stress conditions to survive under unfavorable conditions. According to IPI-OUAT-IPNI Intern Symposium (2009) mineral-nutrient status of plants has major role in its adaptation to stress. K plays a vital role in improving the plant resistance. K regularizes physiological processes like photosynthesis, translocation of cations into sink organs, regulation of turgor pressure and enzymes activation (Mengel and Kirkby, 2001). Cakmak (2005) reported that plant suffering from drought stress required more internal K. During stress condition, ROS formation was induced and oxidative damage to cells occurred and requirement for K was increased (Foyer *et al.*, 2002). This enhanced need for K by plants suffering from drought stress showed that K is required for photosynthetic and CO_2 fixation, because water deficit caused stomatal closure and decreased the CO_2 fixation. By the studies of Jiang and Zhang (2002) it is documented that the impairment in photosynthesis increased the ROS production and carbohydrate metabolism was also disturbed. Mengel and Kirkby (2001) observed that due to low K concentration, ROS production was induced during water deficit which caused disturbance in stomatal opening. In legumes damaging effects of drought can be diminished by ample K supply (Sangakkara *et al*., 2000). Low grain yield resulting from water deficit could be overcome by increasing K supply (Damon and Rengel, 2007). Results reviewed in this section indicate that under water limited conditions, yield losses can be minimized by the sufficient supply of K.

MATERIALS AND METHODS

The experiment was carried out during 2008-09 in pots (wire house) at Nuclear Institute for Agriculture and Biology (NIAB), Faisalabad, Pakistan (latitude = 31^0

N, longitude = 73^0 E, and an altitude of 184.4 meters above the sea level).

The experiment consisted of two wheat cultivars (Lasani-2008 and Auqab-2000) and seven K application/drought induction schedules viz., K_0 (no drought and no K spray), K_1 (drought at tillering stage without K spray), K_2 (drought at tillering stage with K spray), K_3 (drought at flower initiation stage without K spray), K_4 (drought at flower initiation stage with K spray), K_5 (drought at milking stage without K spray) and K_6 (drought at milking stage with K spray). Ten seeds were sown per pot, each containing 7 kg dry soil. After 14 days of germination, plants were thinned to four plants per pot. Drought stress was created by withholding irrigation at different growth stages (as per treatment) and then potassium @ 1% was sprayed. Carboxymethyl cellulose (5% solution) was used as a sticking agent, whereas Tween-20 (0.1% solution) was used as a surfactant for foliar spray.

The experiment was laid out in completely randomized design (CRD) with factorial arrangement and replicated thrice. Data on various growth and yield parameters (plant height, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight and grain yield per plant) were collected using standard procedures. The collected data were analyzed by using Fisher's analysis of variance technique and LSD test at 5% probability was used to compare the differences among treatments' means (Steel *et al*., 1997).

RESULTS

Plant height (cm): The analyzed data (Table 1) regarding plant height of wheat showed significant effect of drought and potash spray on this parameter. Although tallest plants were produced in K_0 (no drought and no spray of potash), however it was at par with K_5 (drought at grain filling stage without potash spray) and K_6 (drought at grain filling stage with potash spray) where crop faced drought at grain filling stage with or without K spray. Data showed that drought significantly reduced plant height when it was applied either at vegetative stage or at flowering stage and K ameliorated this negative effect to a significant level when it was sprayed at vegetative stage. Varieties also differed significantly with respect to plant height, recording more in Lasani-2008 than Auqab-2000. Furthermore, interactive effect of varieties (V) and exogenous applications of potassium (K), V x K, was also non-significant on plant height of wheat. Significant orthogonal contrast was only drought vs no drought.

Spike length (cm): Yield potential of wheat crop is determined by its spike length. More number of grains per spike is due to more spike length. The analyzed data (Table 1) regarding spike length exhibited that drought stress badly affected the ear length. Spikes with maximum length were produced from well-watered control (K_0), while minimum ear length was recorded when crop faced water stress at flowering (K_3), however, it was similar with that where crop faced water stress at vegetative stage (K_1). Foliar application of K under drought significantly improved the spike length when it was sprayed either at vegetative (K_2) or at flowering stage (K_4) but it failed to improve it when it was applied at grain filling stage (K_5 vs K_6). Varieties also differed significantly with respect to ear length; Lasani-2008 produced longer spikes than Auqab-2000. Interactive effect of varieties (V) and applications of potassium (K), V x K, was non-significant (Table 1).

Number of spikelets per spike: Number of spikelets per spike has the vital importance in the production potential of a crop. Water deficit adversely affected the number of spikelets per spike. Less number of spikelets per spike was obtained when water deficit occurred at flowering than at vegetative stage. Foliar application of K under drought improved the number of spikelets per spike. The analyzed data (Table 1) indicate that highest number of spikelets was taken at K_0 (no drought, no spray), however it was at par with that where plants were sprayed with K under drought at grain filling stage (K_6) or at vegetative stage (K_2). The ameliorating effect of K spray (on drought stressed crop) was non-significant at flowering stage (K_3 vs K_4). Varieties did not differed significantly with respect to spikelets per spike. The interaction between varieties and K was also non-significant (Table 1).

Number of grains per spike: Production potential of any crop depends on its number of grains per spike that play vital role in the economic yield of the crop. Drought stress badly affected the number of grains per ear. Both meaningful orthogonal contrasts i.e. drought vs no drought and K spray vs no K spray were significant. Maximum decrease in number of grains per spike was observed when water deficit occurred at flowering stage. Potash spray under drought at all growth stages of wheat ameliorated the adverse effects of stress by improving the number of grains per spike to a significant level. Among various treatments, K_6 (drought at grain filling stage with K spray) showed number of grains per spike, statistically similar to the well watered crop (K_0), (Table 1). The varieties as well as their interaction with K spray were non-significant.

1000-grain weight (g): The 1000-grain weight is an important component contributing towards the final yield of wheat. The analyzed data (Table 1) showed that the drought stress had significant effect on 1000-grain weight. Exogenous application of potassium significantly improved the 1000-grain weight. The crop produced heaviest grains when it faced no water deficit at any growth stage (K_0) however it is at par with K_1 (no spray of K and drought at vegetative stage), K_2 (spray of K under drought at vegetative stage) and K_6 (spray of K under drought at grain filling stage) and lowest grain weight was produced when crop suffered with water stress and no K was sprayed at grain filling (K_5). The varieties showed non-significant response. Interaction between varieties (V) and exogenous applications of potassium (K), V x K, for 1000-grain weight was also non-significant. Meaningful orthogonal contrasts viz. drought vs no drought and K spray vs no K spray were significant with respect to 1000-grain weight.

Grain yield per plant (g): The final grain yield is the expression of the effects of various yield components developed under the particular set of environmental conditions. Data (Table 1) indicate that water stress badly affected the grain yield (per plant). Significantly highest grain yield was obtained when crop was grown with standard irrigations, K_0 (no water stress). Drought imposed at any stage (K_1, K_3 and K_5) significantly reduced grain yield and foliar spray of K at any stage failed to make up this deficiency. However, comparison of K_1 vs K_2 (drought at vegetative stage with K spray vs drought at vegetative stage without K spray), K_3 vs K_4 (drought at flowering stage with K spray vs drought at flowering stage without K spray) and K_5 vs K_6 (drought at grain filling stage with K spray vs drought at grain filling stage without K spray) indicated that foliar application of K under drought at any critical crop growth stage significantly increased wheat grain yield. Comparing the efficiency of K spray at different growth stages (K_2 vs K_4 vs K_6) indicated that maximum grain yield was produced when K was applied under stress at grain filling stage (K_6). Among all treatments means, minimum grain yield was recorded in K_3 where crop faced drought at flowering stage without K spray, however it was at par with K_1 (drought at vegetative stage without K spray). The varieties showed non-significant response. Interactive effect of varieties (V) and foliar applications of K (K), V x K, on grain yield was non-significant. Meaningful orthogonal contrasts of drought vs no drought was significant while that of K spray vs no K spray was non significant (Table 1).

Table 1: Effect of potash spray under drought on wheat growth and yield.

Treatments	Plant height (cm)	Spike length (cm)	Number of spikelets/ spike	Number of grains/ spike	1000-grain weight (g)	Grain yield/ plant (g)
V_1 (Lasani-2008)	72.53^a	9.05^a	12.40	24.71	36.31	0.84
V_2 (Auqab-2000)	69.49^b	8.33^b	11.82	24.14	35.75	0.79
LSD	2.73	0.57	-	-	-	-
Drought and potash application (K)						
K_0 = Control (no drought and no K spray)	76.70^a	10.03^a	13.61^a	29.50^a	41.52^a	1.22^a
K_1 = Drought at tillering without K spray	67.01^c	7.81^c	12.10^b	21^d	39.12^a	0.66^d
K_2 = Drought at tillering with K spray	72.20^b	8.88^b	12.92^a	27.50^b	40.96^a	0.87^c
K_3 = Drought at flower initiation without K spray	66.47^c	7.47^c	10.45^c	18.50^e	30.02^c	0.57^{de}
K_4 = Drought at flower initiation with K spray	67.34^c	8.77^b	11.01^c	24^c	35.29^b	0.82^c
K_5 = Drought at milking without K spray	73.50^{ab}	8.93^b	11.87^b	22^{cd}	25.52^d	0.53^e
K_6 = Drought at milking with K spray	74.90^{ab}	9.02^b	13.01^a	28^{ab}	39.78^a	1.04^b
LSD	3.18	0.74	0.82	1.58	2.90	0.10
Drought vs. no drought	*	*	*	*	*	*
K vs. no K	NS	NS	NS	*	*	NS

Means not sharing the same letters within a column differ significantly at 5% probability.
* = Significant NS = Non-significant

DISCUSSION

Water deficit is a common abiotic stress adversely affecting crop production; meaningful orthogonal contrasts of drought vs no drought (Table 1) confirmed the same. Our study observed that foliar application of K to wheat plant under water deficit condition on either growth stage (vegetative, flowering or grain filling) enhanced crop growth and development.

In present study plant height was decreased under water deficit condition; same was reported by Khan *et al.* (2001). Water deficit, either at vegetative or at flowering stage reduced the plant height, however comparatively more adverse effect was observed at flowering stage (13.33%). Plant height may be reduced due to dehydration of protoplasm; decrease in relative turgidity associated with turgor loss and decreased cell expansion and cell division (Hussain *et al.*, 2008). During vegetative stage the growth is that of the leaves and tillers mainly, whilst the stem elongates very slowly and it gains its maximum height at the time of onset of floral initiation a possible reason for much reduced plant height with drought at flowering stage than at vegetative or grain filling. It was reported by Zhao *et al.* (2006) that drought affected plant height due to hormonal imbalance (cytokinin, abscisic acid) that affected growth due to changes in cell wall extensibility. The adverse effect of water stress may also be decreased by increasing the availability of water to the plant due to reduction in transpiration by partial closure of stomata (Alfredo and Setter, 2000; Hoad *et al*., 2001). It has been suggested that plants mineral nutrient status plays a vital role in improving the resistance of plant to stress conditions (Yadov, 2006). Of the mineral nutrients, potassium plays a key role in improving the plant tolerance to stress conditions. For many physiological processes such as activation of enzymes, photosynthesis, maintenance of turgescence, translocation of photosynthates, K is essential element (Mengel and Kirkby, 2001). The exogenous application of K improved the plant height. It was found more effective in increasing the plant height when sprayed under drought at vegetative stage (7.18%) than at flowering (1.2%) or grain filling stages (1.87%).

Spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight and grain yield were severely affected under drought stress at any growth stage (tillering, flowering and grain filling). More reduced spike length (25.52%), number of spikelets per spike (23.31%) and number of grains per spike (37.93%) was recorded when drought stress was imposed at flowering stage. The 1000-grain weight and grain yield were proved to be sensitive under drought at both stages (flowering and grain filling), however drought stress at grain filling reduced these two parameters to a greater extent (38.53 and 56.55% over control, respectively). Giunta *et al*. (1993) reported that the spike length was adversely affected by water deficit between stem elongation and ear formation stage. The reduced ear length at anthesis is due to reduced number of nodes and less node to node distance on the rachis (data not shown). Moreover it was also observed by Yadav *et al.* (2004) that under environmental stress conditions the spike length remains stable. Reduced canopy was developed when crop faced water stress before grain filling or at flowering stage (Hammadeh *et al*., 2005) that can be improved by enhancing plant's stress tolerance by CMS (cell membrane stability) (Daneshian *et al*., 2005). The decrease in number of spikelets per spike at flowering stage was highest; it may be due to reduced root growth about the time of spike formation that resulted in reduced nutrient uptake. Taiz and Zeiger (1991) reported that reduced number of spikelets per ear may be due to limited photosynthetic activity before spike emergence because spikelets per spike are determined before spike emergence Drought stress at flowering or grain filling stage adversely affected the plant production by causing drastic decrease in number of grains per spike (Rad *et al*., 2005; Nasri, 2005). Richards *et al.* (2001) also reported that the numbers of grains per spike were decreased adversely under water stress. The flowering stage proved to be the most sensitive to water deficit and produced the decreased number of grains per spike Dejan *et al.* (2002) and less number of flowers to set seed. The reduced number of grains may be due to low number of spikelets per spike and spike length Plaut *et al.* (2004) under drought. Decreased 1000-grain weight was reported by Plaut *et al.* (2004) under drought at flowering stage due to less efficient and disturbed nutrient uptake and limited photosynthetic translation within the plant which hastened maturity producing shriveled kernels. Drought stress either at vegetative or flowering stage considerably decreased grain yield and yield components in wheat (Nasri *et al*., 2005). Plant's fresh and dry biomass reduced under water deficit conditions (Zhao *et al.*, 2006). It was reported by Manivannan *et al*. (2007) in sunflower and by Sankar *et al*. (2007) in lady finger (bhindi), that fresh weight and dry weight of crop plants reduced under drought stress. This reduced biomass may create the disorder in the remobilization of the assimilates from source to mature grain (sink) that resulted in short and shriveled kernel or it may be due to disturbed grain growth pattern or its improper position between and within the spikelets under drought stress showing assimilate limitation (Yang *et al.*, 2003). Drought reduced plant yield components (Anjum *et al.*, 2011), especially grain weight (Nasri, 2005). This decrease was due to reduced production of photosynthates under water deficit conditions (Anjum *et al*., 2003; Wahid and Rasul, 2005). The loss in kernel weight and number may also be due to water stress condition (Setter *et al*., 2001). More reduced 1000-grain weight was observed when water deficit occurred at anthesis stage than at vegetative stage (Brevedan and Egli, 2003; Sinaki *et al*., 2007). The decrease in yield components was maximum due to drought at flowering stage (Saleem, 2003). Gupta *et al*. (2001) also observed decreased grain yield per plant due to drought stress at flowering stage. Drought reduced photosynthesis and ultimately resulted in reduced 1000-grain weight, grain yield, number of grains per spike and other yield contributing components (Foulkes *et al*., 2001; O'Connell *et al*., 2004; Brisson and Casals, 2005). Weight per 1000 grains under drought stress can be improved by increasing plants stress tolerance (Liu *et al*., 2005). More reduced 1000-grain weight was observed when drought was imposed at anthesis stage than at vegetative stage (Brevedan and Egli, 2003; Sinaki *et al*. 2007).

Normal required number of irrigations is compulsory for ideal crop growth and production but when there is limited water available, it is necessary to identify growth stage of the crop where irrigation could be skipped with minimum loss in grain yield. Final grain yield of wheat depends on its efficient use of water (Sun *et al*., 2006). Normal water at flowering increased photosynthetic rate and also enhanced duration of grain filling (Zhang *et al*., 1998). Due to water stress at heading reduced weight of 1000-grains was reported by Royo *et al*., (2000).

Exogenous application of K on wheat plants under drought mitigated the negative effects of water deficit. In the present study, foliar application of K improved the grain yield and other yield components. The foliar application of K was more effective at flowering stage under water stress than other stages and improved the spike length and number of grains per spike by 14.82% and 25%, respectively. Whereas foliar application of K at grain filling stage was more effective in alleviating the adverse effect of water deficit on number of spikelets per spike, 1000-grain weight and grain yield and improved these by 8.76%, 35.84% and 49.03%, respectively. This increase in number of grains per ear by exogenous application of K was due to increase in number of spikelets and similar response was observed in wheat where photosynthesis and root respiration increased grain yield under drought (Liu *et al*., 2005). It was indicated by many investigators that potassium played a key role in the osmotic adjustment (stomatal opening) of plants under water stress and yield may be improved due to foliar potassium application to plants (Foyer *et al.*, 2002).

Conclusion: Water deficit at any critical crop growth stage severely restrained the growth and yield of wheat. Foliar application of K at all critical stages improved all the yield components; grain filling stage being more responsive.

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