DOI: 10.1515/cerce-2017-0011 **Original Article**
Available online: www.uaiasi.ro/CERCET_AGROMOLD/
Print ISSN 0379-5837; Electronic ISSN 2067-1865

Cercetări Agronomice în Moldova
Vol. L , No. 2 (170) / 2017: 5-20

NUTRIENT UPTAKE AND YIELD OF WHEAT VARIETIES AS INFLUENCED BY FOLIAR POTASSIUM UNDER DROUGHT CONDITION

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Received: Jan. 05, 2017. Revised: May 05, 2017. Accepted: May 12, 2017. Published online: June 30, 2017

ABSTRACT. Water stress experienced by a wheat crop during growth is recognized to have accumulative effect stated as a decline in total biomass over well water potential. The yield and nutrient uptake performance of two wheat (*Triticum aestivum* L.) varieties (Pirsabak-2013 and Atta Habib) to foliar feeding of 2% potassium (K) at three various growth phases (Zadoks GS-22, Zadoks GS-60 and Zadoks GS-73) was explored under water restricted environment in a wire house trial at the Agriculture Research Station, Harichand, Charsadda. The target was to find out the preeminent K application stage for enhancement in the drought tolerance potential. Drought stress was generated by suppression of irrigation at the three growth phases and then K was sprayed with the carboxymethyl cellulose as a sticking agent, however Tween-20 was used as a surfactant for foliar spray. Data about several agronomic characters (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 documented via standard techniques. Moreover, at maturity, aboveground nitrogen, phosphorus, K, sodium and calcium uptakes by the crop were determined. The results point out that drought stress at all three acute growth phases unfavorably affected plant height, spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight, grain yield and nutrient uptake of the wheat plant. The exogenous K application under drought stress at all three acute growth phases boosted tolerance of wheat by decreasing noxious nutrient's uptake and augmenting the yield and yield characters. In this concerns, both varieties exposed undeviating behavior. Extreme enhancement in all the documented yield parameters and nutrients uptake was attained when K was practiced at grain filling stage of both varieties.

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Keywords: macro nutrients uptake; water stress; potassium; yield, wheat.

INTRODUCTION

Drought is known to be the most overwhelming abiotic stress factor affecting growth and performance of different crops. As compared to other environmental stresses, drought is adversely reduced the crop productivity (Pennisi, 2008; Farooq *et al.,* 2008). However, related to drought stress, many techniques have been reported. Drought stressed plant illustrate numerous physiological, biochemical and molecular adaptations to blossom under water stress (Arora *et al.,* 2002). Longer spells of drought mostly occur in arid and semi-arid environments, as compared to other factors, which results in decline in crop yield and development (Ashraf *et al.,* 1995). It has now become the well-known fact that yield of wheat is diminished by water stress irrespective of the growth stage at which the drought occurs. When plant agonize from water stress the decline in production and impaired growth of crop are caused (Farooq *et al.,* 2008). Perception about drought tolerance is one of the most indistinct in literature (Blum, 2005). Several mechanisms of tolerance have been developed, several of which are: the dehydration tolerance level *via* genetic engineering procedures under laboratory situations (Jenks *et al.,* 2007; Nelson *et al.,* 2007), reclamation of reactive oxygen species under condition of stress (Zhu *et al.,* 2007; Yang *et al.,* 2003) and assisting the drought avoidance mechanism with hormonal stability (Rivero *et al.,* 2007).

Several adaptation mechanisms in the plants have been established under stress condition to persist under hostile conditions. Nutritional position of the plants is the sign of its feedback to environmental stress. K boosted drought tolerance in plants by extenuating detrimental effects by elevating translocation and by keeping water stability. When nutrients are applied foliarly crop take it easily and as a consequence yield is increased (Arif *et al.,* 2006). By showering K, the detrimental effect of drought on the growth of wheat can be decreased, this K is translocated to the all parts of the plant, as a consequence yield of crops can be increased (El-Ashry *et al.,* 2005). Potassium plays a significant role in osmoregulation, photosynthesis, transpiration, opening and closing of stomata and protein synthesis etc (Milford and Johnston, 2007). When K is not applied appropriately, the yield and growth of crops are diminished (Hermans *et al.,* 2006). Plant suffering from water stress required more internal K (Cakmak, 2005). Yield restricting effect of water stress might be overwhelmed by elevating K supply (Damon and Rengel, 2007). ROS formation was induced during drought stress and oxidative injury to cells happened and K requirement was augmented (Foyer *et al.,* 2002). This improved need for K by plants distressing from drought stress exhibited that K is obligatory for photosynthetic and CO_2 fixation, because water scarcity caused stomatal cessation and declined the CO_2 fixation. Carbohydrate metabolism was disturbed due to the increased ROS production, caused by impairment in photosynthesis (Jiang and Zhang, 2002). Mengel and Kirby (2001) documented that disturbance in stomatal opening under water stress induced ROS production due to low K concentration. By increasing K supply stumpy grain yield due to water stress can be overwhelmed (Damon and Rengel, 2007).

The purpose of current work was to assess the promising role of K applied on wheat foliage at various growth stages under drought, in alleviation of stress in terms of yield and nutrients uptake.

MATERIALS AND METHODS

The role of foliar potassium in alleviating the impact of drought on nutrient uptake and yield characters of wheat cultivars was orchestrated in pots (screen house) at Agriculture Research Station Harichand, Pakistan (34^0 8’ 43’’ North, 71^0 43’ 53’’ East, 282 m above sea level), during 2015 - 2016. The trial was laid down in a wire house in order to evade any insect/birds outbreak on the plants and intermission by rainfall. Physico-chemical analysis of the investigational soil exhibited that it comprised: sand 21%, silt 14%, clay 66%, organic matter 0.85%, total nitrogen (N) 0.32 mg kg^{-1} dry soil, phosphorous (P) 4.9 mg kg^{-1} dry soil, K 136 mg kg^{-1} dry soil, and calcium (Ca) 103 mg kg^{-1} dry soil; the pH of the soil was 7.8.

The trial comprised of two wheat cultivars (Pirsabak-2013 and Atta Habib) and seven foliar K application and drought introduction schedules viz., K_0 (No water stress no K spray), K_1 (water stress at Zadoks GS-22 without K spray), K2 (water stress at Zadoks GS-22 with K pray), K3 (water stress at Zadoks GS-60 without K spray), K4 (water stress at Zadoks GS-60 with K spray), K5 (water stress at Zadoks GS-73 without K spray), K6 (water stress at Zadoks GS-73 with K spray). Pots were filled from 7 kg of soil and in each pot twelve seeds were sown and consequently the suggested doses of N and P (120 g pot^{-1}) was practiced. The plants were thinned to five plants per pot after 15 days of germination. The water stress was generated by withholding irrigation at various growth phases and then potassium at the rate of 2% was showered. Cellulose gum (5%) solution was used as a sticking agent, while surfactant for foliar spray Tween-20 (0.2%) solution was practiced.

The trial was carried out in completely randomized design (CRD) with factorial arrangement having three repeats. Using standard methods data on different growth and yield attributes (plant height, grains number per spike, length of spike, 1000-kernel weight and grain yield per plant) were compiled.

Nutrient uptake

The plant’s shoot material with leaves at maturity was dried in oven at 75^0C and crushed in Wiley Micro Mill to pass easily through a sieve of 2 mm. The dried crushed material (0.5 g) was absorbed in sulphuric acid and hydrogen peroxide (Wolf, 1982). The absorbed samples were read on flame photometer to find out sodium (Na), Ca and K. An ordered series of standards of these ions were prepared and standard curves was drawn. From standard curve of each ion the concentration of Na, Ca and K in plant samples from flame photometer were determined. Micro-Kjeldhal's method was used for estimation of total N content (Bremner, 1965). Spectrophotometer was used for estimation of total P content.

Statistical analysis

Treatment impacts on yield characters and nutrient uptake was analyzed using Fisher's analysis of variance technique and difference between the treatments means were compared using LSD test at 5% probability (Steel *et al.,* 1997).

RESULTS

Agronomic traits

The data analyzed for plant height of wheat depicted significant impact of water stress and potash spray**.** Though tallest plants were noted in K0 (no water stress and no K spray), nevertheless it was statistically comparable with K5 (water stress at grain filling phase without K spray) and K6 (water stress at grain filling phase with K spray), where crop encountered water stress at grain filling phase with or without K spray. The data illustrated that water stress significantly diminishes the height of plants when it was established either at tillering stage or booting stage and potash spray bettered this adverse effect to a substantial level, when sprinkled at tillering stage. The cultivars also varied with respect to plant height, recording more in Pirsabak-2013 over Atta Habib. Furthermore, interaction between varieties (V) and foliar feeding of potash (K), V x K, was also not-significant on plant height of wheat. Water stress vs. no water stress was significant orthogonal contrast.

Wheat crop yield potential is expressed by its spike length. Higher number of grains per spike is owed to lengthy spike. The scrutinized data (*Table 1*) about spike length demonstrated that drought stress critically affected the spike length. Lengthy spikes were documented from well watered control (K0), whereas minimum spike length was documented when crop encountered water stress at flowering (K3); nevertheless, it was comparable with that when crop confronted water stress at vegetative phase (K1). Foliar feeding of K under drought expressively enhanced the spike length, when it was showered either at vegetative (K2) or at flowering phase (K4), but it failed to enhance it when it was practiced at grain filling phase (K5 vs. K6). Varieties also varied considerably with respect to spike length; Pirsabak-2013 produced lengthy spikes than Atta Habib. Interaction among varieties (V) and applications of potassium (K), V x K, was insignificant (*Table 1*).

Number of spikelets per spike has the dynamic rank in the production potential of a crop. Water scarcity badly affected the number of spikelets per spike. Fewer number of spikelets per spike was achieved when water shortage happened at flowering over vegetative phase. Foliar feeding of K under drought enhanced the number of spikelets per spike. The evaluated data (*Table 1*) point out that uppermost number of spikelets was taken at K0 (no drought, no spray), nonetheless it was at similarity with that when plants were showered with K under drought at grain filling phase (K6) or at vegetative phase (K2). The enhancing effect of K feeding (on drought stressed crop) was insignificant at flowering phase (K3 vs. K4). Varieties did not diverged considerably with respect to the spikelets per spike. The interactive effect among varieties and K was also insignificant (*Table 1*).

Table 1 - Influence of drought and foliar potash spray on plant height (cm), spike length (cm), number of spikelets/spike, number of grains/spike, 1000-grain weight (g) and grain yield/plant (g)

Treatments	Plant height	Spike length	Number of spikelets/spike	Number of grains/spike	1000-grain weight	Grain yield/plant
K_0= (No drought no K spray)	78.72a	10.05a	14.62a	32.51a	43.53a	1.24a
K_1= (Drought at Zadoks GS-22 without K spray	69.03c	7.83c	13.11b	23d	41.13a	0.68d
K_2= (Drought at Zadoks GS-22 with K spray	74.22b	8.9b	13.93a	29.5b	42.97a	0.89c
K_3= (Drought at Zadoks GS-60 without K spray	68.49c	7.49c	11.46c	20.51e	32.03c	0.59de
K_4= (Drought at Zadoks GS-60 with K spray	69.36c	8.79b	12.02c	26c	37.3b	0.84c
K_5= (Drought at Zadoks GS-73 without K spray	75.52ab	8.95b	12.88b	24cd	27.53d	0.55e
K_6= (Drought at Zadoks GS-73 with K spray	76.92ab	9.04b	14.02a	30ab	41.79a	1.06b
Meaningful Orthogonal Contrasts						
Drought vs. no drought	*	*	*	*	*	*
K vs. no K	NS	NS	NS	*	*	NS
Pirsabak-2013 vs. Atta Habib	*	*	NS	NS	NS	NS

Means not carrying the similar letters within a column vary significantly at 5% probability.
* = significant; NS = non significant

Number of grains per spike has the vibrant position in the production potential of any crop and play vigorous role in the profitable yield of the crop. Drought stress severely affected the number of grains per spike. Both meaningful orthogonal contrasts, i.e. drought vs. no drought and K spray vs. no K spray were significant. Fewer number of grains per spike was perceived when water shortage happened at flowering phase. Potash spray under drought at all growth phases of wheat upgraded the hostile effects of stress by enhancing the number of grains per spike to a noteworthy level. Amongst numerous treatments, K6 (drought at grain filling stage with K spray) exhibited number of grains per spike, statistically analogous to the control (K0), (*Table 1*). The varieties and their interaction with application of K were insignificant.

The 1000-grain weight is an imperative factor donating towards the concluding yield of wheat. The scrutinized data (*Table 1*) exposed that the drought stress had noteworthy effect on 1000-grain weight. External application of potassium considerably enhanced the 1000-grain weight. The crop formed densest grains when it confronted no water shortage at any growth phase (K0), nevertheless it is at similarity with K1 (no spray of K and drought at vegetative phase), K2 (spray of K under drought at vegetative phase) and K6 (spray of K under drought at grain filling phase) and lowermost grain weight was formed when crop agonized with water stress and no K was sprayed at grain filling (K5). The varieties presented insignificant reaction. Interaction among varieties (V) and external 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 in terms of 1000-grain weight.

The concluding grain yield is the countenance of the effects of numerous yield components established under the specific set of environmental situations. Data (*Table 1*) point out that water stress desperately affected the grain yield (per plant). Considerably utmost grain yield was achieved when crop was grown with normal irrigations, K0 (no water stress). Drought executed at any phase (K1, K3 and K5) considerably declined grain yield and foliar feeding of K at any phase failed to recover this scarcity. Though, evaluation of K1 vs. K2 (drought at vegetative phase with K spray vs. drought at vegetative phase without K spray), K3 vs. K4 (drought at flowering phase with K spray vs. drought at flowering phase without K spray) and K5 vs. K6 (drought at grain filling phase with K spray vs. drought at grain filling phase without K spray) point out that foliage applied K under drought at any serious crop growth phase considerably augmented wheat grain yield. Linking the effectiveness of K spray at diverse growth phases (K2 vs. K4 vs. K6) point out that augmented grain yield was documented when K was practiced under stress at grain filling phase (K6). Amongst all the treatments means, slightest grain yield was noted in K3, when crop confronted drought at flowering phase without K spray; nevertheless, it was at similarity with K1 (drought at vegetative phase without K spray). The varieties exhibited insignificant reaction. Interactive effect of varieties (V) and foliage applied potassium (K), V x K, on grain yield was insignificant. Meaningful orthogonal contrasts of drought vs. no drought was significant whereas that of K spray vs. no K spray was not-significant (*Table 1*).

Nutrient uptake

The contrasts (drought vs. no drought) expressed it clear that drought considerably influenced nutrients uptake by wheat (*Table 2*) and K foliage application under drought enhanced most of these attributes. The composed data concerning N, P, K, Ca and Na uptake (*Table 2*) point out that both the varieties Pirsabak-2013 and Atta Habib exhibited constant behavior to the K feeding. The foliage applied K on wheat varieties upgraded the drought tolerance in the plants.

Table 2 - Influence of drought and foliar potash spray on nutrient uptake (mg g^{-1})

Treatments	Nitrogen uptake	Phosphorous uptake	Potassium uptake	Sodium uptake
K_0= (No drought no K spray)	0.029c	1.83a	6.34d	8.29d
K_1= (Drought at Zadoks GS-22 without K spray	0.034c	0.81cd	6.79cd	10.82b
K_2= (Drought at Zadoks GS-22 with K spray	0.036b	0.98bc	7.65bc	9.03c
K_3= (Drought at Zadoks GS-60 without K spray	0.037ab	0.71d	7.04cd	11.62a
K_4= (Drought at Zadoks GS-60 with K spray	0.039a	0.82cd	8.50ab	10.92b
K_5= (Drought at Zadoks GS-73 without K spray	0.035bc	0.74d	7.20cd	11.35ab
K_6= (Drought at Zadoks GS-73 with K spray	0.039a	1.14b	9.18a	8.96c
Meaningful Orthogonal Contrasts				
Drought vs. no drought	*	*	*	*
K vs. no K	NS	NS	NS	*
Pirsabak-2013 vs. Atta Habib	NS	NS	*	NS

Means not carrying the similar letters within a column vary significantly at 5% probability.
* = significant; NS = non significant

Amongst drought treatments, higher enhancement in all the documented growth, yield and nutrient uptake parameters was attained when K was practiced at grain filling phase (K6) over other critical phases (*Table 2*). While crop got maximum value for all the characters in control treatment (no drought); nonetheless, it was at similarity with the treatment when crop challenged drought at grain filling phase, but K was used. Nutrient uptake is foremost factor donating to the concluding yield of the crop. Well watered plants (K0) exhibited the utmost P and Ca uptake, whereas N, K and Na uptake were the lowermost in this case (*Table 2*). Drought generated at most of these phase (K1, K3 and K5) considerably abridged P and Ca uptake, whereas augmented the N, K and Na concentrations.

Nevertheless, comparison of K1 vs. K2, K3 vs. K4 and K5 vs. K6 exposed that foliage applied K at any precarious crop growth phase considerably augmented wheat N, P, K and Ca uptakes and declined Na uptake. Linking the effectiveness of K spray at diverse growth phases (K2 vs. K4 vs. K6) point out that nutrient uptake was affected supreme, when K was practiced under water stress at grain filling phase (K6).

DISCUSSION

Water shortage is a common abiotic stress badly distressing crop production; meaningful orthogonal contrasts of drought vs. no drought (*Table 1*) established the same. Our work perceived that foliage applied K to wheat plant under water discrepancy condition on either growth phase (vegetative, flowering or grain filling) boosted crop growth and expansion.

In current study, plant height was diminished under water scarcity condition; similar was described by Khan *et al.* (2001). Water shortage, either at vegetative or at flowering phase diminished the plant height; nevertheless, relatively more hostile effect was perceived at flowering phase (14.34%). Plant height might be declined due to desiccation of protoplasm; diminution in relative turgidity related with turgor injury and declined cell extension and cell separation (Hussain *et al.*, 2008). During vegetative phase, the growth is that of the leaves and tillers primarily, whereas the stem extends very gradually and it increases its supreme height at the time of beginning of floral commencement, a probable reason for much abridged plant height with drought at flowering phase over at vegetative or grain filling. It was stated by Zhao *et al.* (2006) that drought affected plant height due to hormonal discrepancy (cytokinin, abscisic acid), that affected growth due to deviations in the cell wall extensibility. The contrary effect of water stress may possibly also be diminished by augmenting the accessibility of water to the plant owed to lessening in transpiration by fractional cessation of stomata (Alfredo and Setter, 2000; Hoad *et al.*, 2001). It has been proposed that plants mineral nutrient position plays a vital role in enhancing the resistance of plant to stress situations (Yadav, 2004). Of the mineral nutrients, potassium plays a crucial role in enhancing the plant tolerance to stress situations. For several physiological processes, such as stimulation of enzymes, photosynthesis, preservation of turgescence, translocation of photosynthates, K is indispensable element (Mengel and Kirby, 2001). The external application of K enhanced the plant height. It was found more operative in swelling the plant height when sprayed under drought at vegetative phase (8.19%) than at flowering (1.3%) or grain filling stages (1.98%).

Spike length, number of spikelets per spike, number of grains per spike, 1000-grain weight and grain yield were rigorously affected under drought stress at any growth phase (tillering, flowering and grain filling). More abridged spike length (25.52%), number of spikelets per spike (23.31%) and number of grains per spike (37.93%) was documented when drought stress was enforced at flowering phase. The 1000-grain weight and grain yield were demonstrated to be sensitive under drought at both phases (flowering and grain filling); nevertheless, drought stress at grain filling abridged these two traits to a larger level (39.54 and 57.56% over control, respectively). Giunta *et al.* (1993) described that the spike length was badly affected by water shortage among stem elongation and spike establishment phase. The declined spike length at anthesis is due to less number of nodes and fewer node to node distance on the rachis (data not presented). Furthermore, it was also perceived by Yadav *et al.* (2004), that under environmental stress situations the spike length remains constant. Small canopy was established when crop encountered water stress earlier grain filling or at flowering phase (Hammadeh *et al.*, 2005), that can be enhanced by augmenting plant's stress tolerance by CMS (cell membrane stability) (Daneshian *et al.*, 2005). The diminution in number of spikelets per spike at flowering phase was uppermost; it could be due to compact root growth approximately the time of spike establishment, that ensued in compact nutrient uptake. Taiz and Zeiger (1991) stated that compact number of spikelets per ear could be due to inadequate photosynthetic activity earlier spike emergence as spikelets per spike are determined earlier spike emergence Drought stress at flowering or grain filling phase badly affected the plant production by triggering severe diminution in number of grains per spike (Rad *et al*., 2005; Nasri, 2005). Richards *et al.* (2001) also described that the numbers of grains per spike were diminished badly under water stress. The flowering phase ascertained to be the most profound to water shortage and formed the diminished number of grains per spike (Dejan *et al.*, 2002) and fewer number of flowers to the set seed. The compact number of grains might be due to little number of spikelets per spike and spike length (Plaut *et al.*, 2004) under drought. Diminished 1000-grain weight was described by Plaut *et al.* (2004) under drought at flowering phase due to less proficient and distressed nutrient uptake and restricted photosynthetic transformation within the plant, which accelerated maturity generating desiccated kernels. Drought stress, whichever at vegetative or flowering phase, noticeably dwindled grain yield and yield constituents in wheat (Nasri, 2005). Plant's fresh and dry biomass abridged under water shortage situations (Zhao *et al.*, 2006). It was described 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 abridged under drought stress. This declined biomass may possibly generate the syndrome in the remobilization of the assimilates from source to mature grain (sink), that ensued in diminutive and desiccated kernel or it could be due to distressed grain growth configuration or its inappropriate position among and within the spikelets under drought stress displaying assimilate restriction (Yang *et al.*, 2003). Drought declined plant yield constituents (Anjum *et al.*, 2011), particularly grain weight (Nasri, 2005). This diminution was due to abridged production of photosynthates under water shortage situations (Anjum *et al*., 2003; Wahid and Rasul, 2005). The loss in kernel weight and number may possibly also be due to water stress situation (Setter *et al.*, 2001). More compact 1000-grain weight was perceived when water shortage happened at anthesis phase over at vegetative phase (Brevedan and Egli, 2003; Sinaki *et al.*, 2007). The diminution in yield constituents was supreme due to drought at flowering phase (Saleem, 2003). Gupta *et al.* (2001) also witnessed diminished grain yield per plant due to drought stress at flowering phase. Drought abridged photosynthesis and eventually resulted in compact 1000-grain weight, grain yield, number of grains per spike and other yield donating components (Foulkes *et al.*, 2001; O'Connell *et al.*, 2004; Brisson and Casals, 2005). Weight per 1000 grains under drought stress can be upgraded by elevating plants stress tolerance (Liu *et al.*, 2005). Lighter 1000-grain weight was perceived when drought was enforced at anthesis phase over at vegetative phase (Brevedan and Egli, 2003; Sinaki *et al.* 2007).

Normal prerequisite number of irrigations is obligatory for ultimate crop growth and production, but when there is inadequate water accessible, it is obligatory to recognize growth phase of the crop where irrigation might be avoided with slightest loss in grain yield. Concluding grain yield of wheat depends on its proficient use of water (Sun *et al.*, 2006). Normal water at flowering augmented photosynthetic rate and also heightened duration of grain filling (Zhang *et al.*, 1998). Due to water stress at heading abridged weight of 1000-grains was stated by Royo *et al.*, (2000).

Exogenous K application on wheat plants under drought diminished the deleterious effects of water scarcity. In the current study, foliage applied of K upgraded the grain yield and other yield traits. The foliage applied K was more operative at flowering phase under water stress over other phases and upgraded the spike length and number of grains per spike by 15.82% and 26%, correspondingly. While foliar feeding of K at grain filling phase was more operative in lessening the hostile effect of water scarcity on number of spikelets per spike, 1000-grain weight and grain yield and upgraded these by 9.76%, 36.84% and 50.03%, respectively. This upsurge in number of grains per ear by exogenous K application was due to upsurge in number of spikelets and comparable reaction was perceived in wheat, where photosynthesis and root respiration augmented grain yield under drought (Liu *et al.*, 2005). It was point out by numerous investigators that potassium played a strategic role in the osmotic adjustment (stomatal opening) of plants under water stress and yield could be upgraded due to foliar potassium feeding to plants (Foyer *et al.*, 2002).

Drought stress affected the crop growth and development considerably by affecting the physiological and biochemical traits triggering diminution in the concluding yield of wheat. Foliar feeding of K to wheat under water shortage situation on either growth phase (tillering, flower initiation and grain filling) considerably affected nutrients uptake of both wheat cultivars.

Nutrients (N, P, K, Ca and Na) uptake in the plant was noticeably affected by the drought stress. Under drought stress the concentration of N, K and Na augmented. Uppermost N (28%) and Na (32%) contents were perceived in plants where drought stress was enforced at grain filling phase, whereas uppermost K uptake (14%) was perceived with drought at flower initiation phase. The plants under water shortage have great N concentration, which is because of the free amino acids accretion, that are not manufactured into protein (Alam, 1994) since under drought stress nitrate reductase (enzyme accountable for absorption of nitrate into amino acid) is badly affected (Sinha and Nicholas 1981).

Consequently, the growth was repressed under water shortage and plants mostly leaves complemented by nitrate accretion in plant tissue were affected (Sarwar *et al.*, 1991). During K insufficiency, ion is conveyed from older leaves to the younger leaves and then to meristematic areas due to great movement of K (Wignarajah, 1995), thus plants could have accrued K contents in emerging ears for osmotic adjustment, so abridged K contents were perceived in straw at maturity because awns comprise chloroplasts and stomata and can photosynthesize (Arnon, 1972). Augmented Na concentration in plants (due to drought) could cause ion injuriousness; with the application of K ion harmfulness may possibly be abridged because K is involved in osmotic regulation, preservation of cell turgor pressure and can effectually contend with Na (Ashraf and Foolad 2005). Under augmented drought stress K contents augmented as described by Ashraf (1998) and Khondakar *et al.* (1983). Exogenous K application abridged the hostile effect of drought by decreasing the extreme uptake of Na by the plant under drought. Foliar applied K sustained the turgor pressure and interior water equilibrium of the leaves. Exogenous K spray on plants under drought at grain filling phase was most operative and it diminished the uptake of Na by 23% and augmented the uptake of N and K by 10 and 24%, respectively.

Water shortage has resilient detrimental effect on the plants and it declined the uptake of P and Ca by plants. Declined P and Ca (62 and 34%, respectively) uptake was documented in the plants, where drought was generated at flower commencement and at tillering phase, respectively. Water stress has the hostile effect on P uptake, that has diminished with declining soil moisture in wheat genotypes (Ashraf, 1998) and similar reaction was described by Turner (2001) in pepper. P paucity performed in little to judicious level of drought stress (Alam, 1994). Kidambi *et al*. (1990) perceived no effect of water stress on P uptake. On the other hand, greater P uptake in wheat plants was described under water stress by Khondakar *et al.* (1983). Foliar feeding of K upgraded the hostile effect of drought on plants and enhanced the uptake of P by 37% and Ca by 19% in plants under water shortage at grain filling phase

CONCLUSION

Water shortage at any critical crop growth phase rigorously controlled the growth, yield and nutrient uptake of wheat. Foliar feeding of K at all critical phases enhanced all the yield attributes and nutrient uptake, but declined Na uptake, grain filling phase being quick to respond. All these conclusions lead us to endorse that for wheat crop under drought farmers would spray the crop with 2% K to diminish the deleterious effect of drought. This can have a twofold advantage: by enhancing the physiological performance of wheat and quantity of K nutrient to plants.

REFERENCES

Alam, S.M. (1994). Nutrient by plants under stress conditions. In: *Handbook of Plant and Crop Stress*, M. Pessarakli (Ed.), Marcel Dekker, New York, pp. 227-246.

Alfredo, A.C.A. & Setter, T.L. (2000). Response of cassava to water deficit: Leaf area growth and abscisic acid. *Crop Sci.,* 40(1): 131-137.

Anjum, F., Yaseen, M., Rasul, E., Wahid, A. & Anjum, S. (2003). Water stress in barley. II. Effect on chemical composition and chlorophyll contents. *Pak. J. Agri. Sci.,* 40(1-2): 45-49.

Anjum, S.A., Wang, L.C., Farooq, M., Hussain, M., Xue, L.L. & Zou, C.M. (2011). Brassinolide application improves the drought tolerance in maize through modulation of enzymatic antioxidants and leaf gas exchange. *J. Agron. Crop Sci*., 197(3): 177-185.

Arif, M., Khan, M.A., Akbar M.A.H. & Ali, S.(2006). Prospects of wheat as a dual purpose crop and its impact on weeds. *Pak. J. Weed Sci. Res.,* 12 (1-2): 13-17.

Arnon, I. (1972). Crop production in dry regions. In: Polunin, N. (ed), Leonard Hill Book, Vol. 1, pp. 203-211, London.

Arora, A., Sairam, R.K. & Srivastava, G.C. (2002). Oxidative stress and antioxidative systems in plants. *Curr. Sci.,* 82(10): 1227-1238.

Ashraf, M.Y. & Naqvi, S.S.M. (1995). Studies on water uptake, germination and seedling growth of wheat genotypes under PEG-6000 induce water stress. *PJSIR,* 38: 103-133.

Ashraf, M.Y. (1998). Yield and yield components response of wheat (*Triticum aestivum* L.) genotypes grown under different soil water deficit conditions. *Acta Agronomica Hungarica,* 46: 45-51.

Ashraf, M., Foolad, M.R. (2005). Pre-sowing seed treatment -a shotgun approach to improve germination, plant growth, and crop yield under saline and non-saline conditions. *Adv. Agron*., 88, 223-271.

Blum, A. (2005). Drought resistance, water-use efficiency, and yield potential: are they compatible, dissonant, or mutually exclusive? *Aust. J. Agric. Res*., 56(11), 1159-1168.

Bremner, J.M. (1965). Inorganics forms of nitrogen, pp. 1179-1237. In: *Methods of Soil Analysis*, C.A. Black (Ed.), American Society of Agronomy, Madison, Wisconsin, USA.

Brevedan, R.E. & Egli, D.B. (2003). Short periods of water stress during seed filling, leaf senescence and yield of soybean. *Crop Sci.*, 43(6): 2083-2088.

Brisson, N. & Casals, M.L. (2005). Leaf dynamics and crop water status throughout the growing cycle of durum wheat crops grown in two contrasted water budget conditions. *Agron. Sustain. Dev.,* 25, 151-158.

Cakmak, I. (2005). The role of potassium in alleviating detrimental effects of abiotic stresses in plants. *J. Plant Nutr. Soil Sci.,* 168:521-530.

Damon, P.M. & Rengel. Z. (2007). Wheat genotypes differ in potassium efficiency under glasshouse and field conditions. *Aust. J. Agric. Res.,* 58(8):816-823.

Daneshian, J., Farrokhi, E., Khani, M. & Rad, A.H.S. (2005). Evaluation of sunflower hybrids, CMS and restorer lines to drought stress. Interdrought-II, the second International Conference on integrated approaches to sustain and improve plant production under drought stress; Rome, Italy, September, 24-28 p.137.

Dejan, D., Quarrie, S. & Stankovic, S. (2002). Characterizing wheat genetic resources for responses to drought stress. *Euphytica,* 307-318.

El-Ashry, M. Soad & El-Kholy, M.A. (2005). Response of wheat cultivars to chemical desiccants under water stress conditions. *J. Appl. Sci. Res.,* 1 (2): 253-262.

Farooq, M., Basra, S.M.A., Wahid, A., Cheema, Z.A., Cheema, M.A. & Khaliq, A. (2008). Physiological role of exogenously applied glycinebetaine to improve drought tolerance in fine grain aromatic rice (*Oryza sativa* L.). *J. Agron. Crop Sci.,* 194: 325-333.

Foulkes, M.J., Scott, R.K. & Sylvester-Bradley, R. (2001). The ability of wheat cultivars to withstand drought in UK conditions: formation of grain yield, *J. Agri. Sci.*, 138(2), 153-169.

Foyer, C.H., Vanacker, H., Gomez L.D. & Harbinson, J. (2002). Regulation of photosynthesis and antioxidant metabolism in maize leaves at optimal and chilling temperatures: review. *Plant Physiol. Biochem.,* 40:659-668.

Giunta, F., Motzo, R. & Deidda, M. (1993). Effect of drought on yield and yield components of durum wheat and triticale in a Mediterranean environment. *Field Crops Res.,* 33(4): 399-409.

Gupta, N.K., Gupta, S. & Kumar, A. (2001). Effect of water stress on physiological attributes and their relationship with growth and yield of wheat cultivars at different stages. *J. Agron. Crop Sci.,* 186: 55-62.

Hammadeh, I., Maury, P., Debaeke, P., Lecoeur, J., Nouri, L., Kiani, S.P. & Grieu, P. (2005). Canopy nitrogen distribution and photosynthesis during grain filling in irrigated and water stressed sunflower genotypes. Interdrought-II, the second International Conference on integrated approaches to sustain and improve plant production under drought stress; Rome, Italy, September 24-28, p. 94.

Hermans, C., Hammond, J.P., White, P.J. & Verbruggen, N. (2006). How do plants respond to nutrient shortage by biomassallocation. *Trends Plant Sci.,* 11(12):610-617.

Hoad, S.P., Russell, G., Lucas, M.E. & Bingham, I.J. (2001). The management of wheat, barley and oats root systems. *Adv. Agron.,* 74: 193-246.

Hussain, M., Malik., M.A., Farooq, M., Ashraf, M.Y. & Cheema, M.A. (2008). Improving drought tolerance by exogenous application of glycinebetaine and salicylic acid in sunflower. *J. Agron. Crop Sci.,* 194: 193-199.

Jenks, M.A., Hasegawa, P.M. & Mohan, S.J. (Eds.) (2007). Advances in molecular breeding toward drought and salt tolerant crops, p. 817, Springer, Dordrecht, The Netherlands.

Jiang, M.Y. & Zhang, J.H. (2002). Involvement of plasma-membrane NADPH oxidase in abscisic acid- and water stress-induced antioxidant defense in leaves of maize seedlings. *Planta,* 215: 1022-1030.

Khan, M.A. & Ungar, I.A. (2001). Alleviation of salinity stress and the response to temperature in two seed morphs of *Halopyrum mucronatum (Poaceae)*. *Aust. J. Bot.,* 49: 777-783.

Khondakar, Z.H., Aslam, A., Rehman, A.S. & Khan, T.H. (1983). Influence of soil moisture stress on yield, grain quality, availability and uptake of N, P and K by wheat. *Int. J. Trop. Agric.,* 1: 211-220.

Kidambi, S.P., Matches, A.G. & Bolger, T.P. (1990). Mineral concentration in alfalfa and rainfoin as influenced by soil moisture level. *Agron. J.,* 82: 229-236.

Liu, H.S. & Li, F.M. (2005). Root respiration, photosynthesis and grain yield of two spring wheat in response to soil drying. *Plant Growth Regul.,* 46: 233-240.

Manivannan, P., Jaleel, C.A., Kishorekumar, A., Sankar, B., Somasundaram, R., Sridharan, R. & Panneerselvam, R. (2007). Changes in antioxidant metabolism of *Vigna unguiculata* (L.) Walp. by propiconazole under water deficit stress. *Colloids Surf., B*., pp. 5769-5774.

Mengel, K. & Kirby, E.A. (2001). Principles of plant nutrition. 5th edn., Dordrecht: Kluwer Academic Publishers, 849 p.

Milford, G.F.J. & Johnston, A.E. (2007). Potassium and nitrogen interactions in crop production. *International Fertiliser Society,* p.24.

Nasri, M. (2005). Interaction of nutrient elements and drought stress in cultivars of *Brassica napus*. The second international conference on integrated approaches to sustain and improve plant production under drought stress. Rome, Italy, September 24-28, p. 109.

Nelson, D. *et al.* (2007). Plant nuclear factor Y (NF-Y) B subunits confer drought tolerance and lead to improved corn yields on water-limited acres. *Proc. Natl. Acad. Sci. USA,* 104(42): 16450-16455.

O'Connell, M.G., O'Leary, G.J., Whitfield, D.M. & Connor, D.J. (2004). Interception of photosynthetically active radiation and radiation-use efficiency of wheat, field pea and mustard in a semi-arid environment. *Field Crop. Res.,* 85: 111-124.

Pennisi, E. (2008). The blue revolution, drop by drop, gene by gene. *Science,* 320(5873): 171-173.

Plaut, Z., Butow, B. J., Blumenthal, C.S. & Wrigley, C.W. (2004). Transport of dry matter into developing wheat kernels and its contribution to grain yield under post-anthesis water deficit and evaluated temperature. *Field Crops Res.,* 86: 185-198.

Rad, A.H.S., Daneshian, J. & Valadabadi, A.R. (2005). Water deficit stress effect at grain filling seed stages of rapeseed. The second international conference on integrated approaches to sustain and improve plant production under drought stress. Rome, Italy, September 24-28, p. 243.

Richards, R.A., Condon, A.G. & Rebetzke, G.J. (2001). Traits to improve yield in dry environments Mexico DF, CIMMYT, pp.88-100.

Rivero, R.M., Kojima, M., Gepstein, A., Sakakibara, H., Mittler, R., Gepstein, S. & Blumwald, E. (2007). Delayed leaf senescence induces extreme drought tolerance in a flowering plant. *Proc. Natl. Acad. Sci. USA,* 104(49): 19631-19636.

Royo, C., Abaza, M., Blanco, R. & Garcia del Moral, L.F. (2000). Triticale grain growth and morphometry as affected by drought stress, late sowing and simulated drought stress. *Aust. J. Plant Physiol.,* 27: 1051-1059.

Saleem, M. (2003). Response of durum and bread wheat genotypes to drought stress: biomass and yield components. *Asian J. Plant Sci.,* 2(3):290-293.

Sankar, B., Jaleel, C.A., Manivannan, P., Kishorekumar, A., Somasundaram R. & Panneerselvam, R. (2007). Drought-induced biochemical modifications and proline metabolism in *Abelmoschus esculentus* (L.) Moench. *Acta Bot. Croat.*, 66: 43-56.

Sarwar, M., Ahmad, N., Nabi, G. & Yasin, M. (1991). Effect of soil moisture stress on different wheat varieties. *Pak. J. Agri. Res.*, 12, 275-280.

Setter, T.L., Flannigan, B.A. & Melkonian, J. (2001). Loss of kernel set due to water deficit and shade in maize: carbohydrate supplies, abscisic acid and cytokinins. *Crop Sci.,* 41: 1530-1540.

Sinaki J.M., Heravan, E.M., Rad, A.H.S., Noormohammadi, G. & Zarei, G. (2007). The effect of water deficit during growth stages of canola. *American-Eurasian J. Agric. Environ. Sci.,* 2(4): 417-422.

Sinha, S.K. & Nicholas, D.J.D. (1981). Nitrate reductase. In: *The Physiology and Biochemistry of Drought Resistance in Plants.* L.G. Paleg & D. Aspinall (Eds.). Academic Press, Sydney. pp. 145-169.

Steel, R.G.D., Torrie J.H. & Dickey, D.A. (1997). Principles and procedures of statistics: A biometrical approach. 3rd Ed., McGraw Hill Book Co., Inc. New York, USA.

Sun, Y.H., Liu, C.M., Zhang, X.Y., Shen Y.J. & Zhang, Y.Q. (2006). Effects of irrigation on water balance, yield and water use efficiency (WUE) of winter wheat in North China plain. *Agric. Water Manag.,* 85: 211-218.

Taiz, L. & Zeiger, E. (1991). Plant physiology. Redwood City, Calif.: Benjamin/Cummings, 559 p.

Turner, N.C., Wright, G.C., Siddique, K.H.M. (2001). Adaptation of grain legumes (pulses) to water limited environments. *Adv. Agron.,* 71: 123-231.

Wahid, A. & Rasul, E. (2005). Photosynthesis in leaf, stem, flower and fruit. In: Pessarakli M. (Ed). *Hand book of Photosynthesis*, 2nd ed., CRC Press, Florida, pp: 479-497.

Wignarajah, K. (1995). Mineral nutrition of plants. In: Pessarakli, M. (Ed). *Handbook of Plant and Crop*

Physiology, Marcel Dekker, New York, pp. 193-222.

Wolf, B. (1982). A comprehensive system of leaf analysis and its use for diagnosing crop nutrient status. *Comm. Soil Sci. Plant Anal.,* 13(12), 1035-1059.

Yadav, R.S., Hash, C.T., Bidinger, F.R., Devos K.M. & Howarth, C.J. (2004). Genomic regions associated with grain yield and aspects of post flowering drought tolerance in pearl millet across environments and tester background. *Euphytica,* 136(3): 265-277.

Yang, J.C., Zhang, J.H., Wang, Z.Q., Liu, L.J. & Zhu, Q.S. (2003). Postanthesis water deficits enhance grain filling in two-line hybrid rice. *Crop Sci.,* 43(6): 2099-2108.

Zhang, H., Oweis, T.Y., Garabet, S. & Pala, M. (1998). Water use efficiency and transpiration efficiency of wheat under rain-fed and irrigation conditions in a Mediterranean-type environment. *Plant Soil,* 201(2): 295-305.

Zhao, T.J., Sun, S., Liu, Y., Liu, J.M., Liu, Q., Yan, Y.B. & Zhou, H.M. (2006). Regulating the drought responsive element (DRE)-mediated signaling pathway by synergic functions of trans-active and transinactive DRE binding factors in *Brassica napus*. *J. Biol. Chem.,* 281(16): 10752-10759.

Zhu, J.M. *et al.* (2007). Cell wall proteome in the maize primary root elongation zone. II. Region-specific changes in water soluble and lightly ionically bound proteins under water deficit. *Plant Physiol.,* 145: 1533-1548.