

Field Performance of Three Wheat Cultivars under Drought Stress and Potassium Foliar Application Treatments

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Abstract

The effects of drought stress and potassium foliar application on grain yield and some physiological traits of three wheat (*Triticum aestivum* L.) cultivars, was studied through field experiments conducted during growing season of 2011-2012 at two locations, 1. Seed and Plant Certification and Registration Research Institute (SPCRI), Karaj- Iran 2. Agricultural and Natural Resources Research Center Yazd- Iran. The experiments were carried out using a split plot factorial based on a randomized complete blocks design with three replications. The experimental treatments included three irrigation regimes; normal, mild stress (water withheld at the grain filling phase) and severe stress (water withheld at the ear emergence phase); potassium foliar treatments included, 0, 1.5% and 3.0% K₂O applications and three wheat cultivars (Marvdasht, Pishtaz and WS-82-9). Leaf stomatal conductance, transpiration rate, chlorophyll, biological yield and grain yield were measured. The results indicated that water stress through withholding at the ear emergence and grain filling phases reduced the above mentioned traits at the both locations. Also these traits showed significant increase by increasing potassium foliar application.

Keywords: Wheat, Grain yield, Stomatal conductance, Transpiration, Drought stress, Potassium foliar application.

1. Introduction

The relative decreases in maximum crop potential yield (*i.e.*, yields under ideal conditions) associated with abiotic stress vary between 54-82% [4]. The greatest fear of global climatic change is drought and among the environmental stresses, drought is one of the most severe stresses for plant growth and productivity [7]. During grain filling in wheat, plants are subjected to some unfavorable conditions such as low winter rainfall, shortage of irrigation water and the need to withholding irrigation for saving water and early land evacuation for cultivating the following crop [10]. Although, drought

can affect all growth stages of wheat plant, grain filling is considered to be one of the most sensitive growth stages to water deficit stress [6]. With increased drought stress lower growth and yield were determined in barely and corn [16, 8]. Understanding of physiological mechanisms that enable plants to adapt to water deficit and maintain growth and productivity during stress period could help in screening and selection of tolerant genotypes and using these traits in breeding programs [25].

The response of a plant to environmental stress is determined by its nutritional status. One of the mechanisms for improving plant tolerance to drought is to apply K which seems to have a beneficial effect in overcoming soil moisture stress [20]. Available moisture and nutrition during grain development are the two main factors influencing grain development. Application of NPK to the plant influence grain composition which can also affect embryo development [21]. Increased application of K has been shown to enhance photosynthetic rate, plant growth and yield in different crops under water stress conditions [9, 24].

The objective of this study was to find out the effects of drought stress and potassium foliar application on grain yield and some physiological traits of three wheat cultivars in Iran.

2. Materials and Methods

Two field experiments were conducted during 2011-2012 at two locations: 1- Seed and Plant Certification and Registration Research Institute (SPCRI), Karaj- Iran, 2- Natural Resources Research Center, Yazd- Iran. Chemical and physical traits of experimental soil are represented in Table 1. The experiments were carried out using a split plot factorial based on a randomized complete blocks design with three replications. Three irrigation regimes, control (normal irrigation), mild stress (water withhold at the grain filling phase) and severe stress (water withhold at the ear emergence phase), potassium foliar application, without foliar application (K0), 1.5% K₂O (K1) and 3.0% K₂O (K2) and three wheat cultivars (Marvdasht, Pishtaz and WS-82-9) comprised the experimental

factors. Leaf stomatal conductance, transpiration rate, chlorophyll (after grain filling stage), biological yield and grain yield were measured. Seeds were sown on 15 and 19 November at Yazd and Karaj, respectively. Sowing density was 400 seeds m^{-2} by planting 500 seeds on each row. Plots were 5 m long and 2 m wide, with eight rows 0.25 m apart. All plants received irrigation until the imposition of treatments. Drought treatments imposed by withholding irrigation after ear emergence and grain filling phases. Plastic cover was used to protect from effective rainfall on plots under drought water stress. Urea, potassium sulphate and super phosphate were applied according to results of soil analysis. All plots received one-third of urea and all super-phosphate at sowing. Other two-third of urea was applied at the start of stem elongation, and before flowering, respectively. Plots for potassium foliar application treatments were assigned to three

levels of treatments *i.e.* control treatment (without spraying), 1.5% and 3.0% K_2O in the form of potassium sulphate (48 % K_2O). The foliar solution was prepared at both rates and applied using hand sprayer at stem elongation stage. The youngest fully-expanded leaf (third from the apex), intact and full sunlit leaves per plot was used for measurements. Leaf stomatal conductance and transpiration rate were measured by the CI-340 Ultra-Light Portable Photosynthesis System. Measurements obtained by using Leaf Chamber attachments in conjunction with the CI-340. It contains a pump along with a mass airflow sensor. A built-in microprocessor regulates the airflow rate, which is set by the user. SPAD value or leaf chlorophyll content was measured by (SPAD-502, Minolta Co Ltd, Osaka, Japan). At harvest, a 3 m^2 area was harvested from the center of each plot for grain yield.

Table 1. Some chemical and physical traits of experimental soil at both locations.

Location	K (mg/kg)	P (mg/kg)	T.N. (%)	OC (%)	Sand (%)	Silt (%)	clay (%)	Tex (%)	pH	EC (Mmhos)
Karaj	149.9	8.09	0.221	0.78	38.4	47	14.6	Loamy	7.01	2.4
Yazd	100	10.74	0.021	-	-	-	-	Sandy loam	7.44	5.12

Analysis of variance was carried out using SAS software. Treatment means were compared using Duncan's test at the 5% and 1% levels of significance and graph drawing was performed by means of Excel 2003 software. Bartlett test was used to test homogeneity of variances. Data expressed as percentages were transformed prior to analysis of variance by using arc sin transformation.

3. Results and Discussion

The results obtained from combined analysis of variance across two locations revealed significant difference ($P < 0.01$) among different levels of drought stress, potassium foliar application, cultivars and their interactions (Table 2).

Chlorophyll

Interaction effects of location and drought stress and potassium foliar application was significant on chlorophyll (Table 2). Results showed that the efficiency of potassium fertilizer was different at both locations. For example, differences between chlorophyll in highest level and no potassium application at Yazd was 2.4% more than Karaj. Maximum chlorophyll content was attained under normal water use and spraying with 3.0% K_2O at the both locations (44.3%) and minimum chlorophyll content was observed under severe stress and no potassium application treatments at Yazd (27.9%)

(Figure 1). Improvement in chlorophyll due to potassium foliar application may be ascribed to the role of potassium in improving many physiological growth processes and delay plant leaves senescence as well as increasing photosynthetic activity. Numerous studies have shown that the application of potassium fertilizer mitigates the adverse effects of drought on plant growth in barley, sunflower and rice that confirmed result of this study [3, 17, 20]

Leaf stomatal conductance

Interaction effects of location and drought stress was significant on leaf stomatal conductance (Table 2). Results showed that drought stress had more negative effect on leaf stomatal conductance at Yazd area so that, this decrease was 53.36% and 78.6 $mmol\ m^{-2}\ s^{-1}$ at Karaj and Yazd area, respectively (Figure 2).

In a study on wheat, results showed that water deficit significantly decreased Stomatal conductance both at the vegetative and anthesis stages. Stress induced reductions in stomatal conductance were 60% and 50% for vegetative and anthesis drought, respectively as compared with the control treatment [22]. In other experiment on oil seed species (*Brassica napus*), leaf stomatal conductance consistently decreased under water stress in both species and sampling stages [13].

Table 2. Grain yield and some physiological traits of three wheat cultivars in response to drought stress and potassium foliar application at two locations.

Source of variance	Means of square				
	Chlorophyll	Leaf stomatal conductance	Transpiration rate	Grain yield	Biological yield
Location (L)	165.70 ^{ns}	1.77 ^{ns}	1.02 ^{ns}	85869056.40*	603858474.69*
Error (R/L)	75.67	57.27	1.74	2184294.50	42055150.6
Drought stress (D)	2243.45**	554.54**	7.95**	129867031.52**	212389974.69**
LxD	110.49**	73.81**	0.18 ^{ns}	442717.11 ^{ns}	18180159.87 ^{ns}
Error a	38.26	11.40	0.34	2415328.20	19461354.32
Potassium (K)	127.27**	192.91**	10.70**	35074179.00**	8371743.21 ^{ns}
(LxK)	4.31 ^{ns}	65.41**	1.17**	8860185.19**	3186558.02 ^{ns}
(DxK)	11.15 ^{ns}	1.48 ^{ns}	0.06 ^{ns}	1473942.41 ^{ns}	9153437.65 ^{ns}
(LxDxK)	98.95**	5.48 ^{ns}	0.009 ^{ns}	1533739.80 ^{ns}	4237326.54 ^{ns}
Cultivar(C)	143.46**	3.07 ^{ns}	0.06 ^{ns}	68981012.02**	46560076.54**
(LxC)	112.53**	4.12 ^{ns}	0.08 ^{ns}	5770482.54*	78356372.84**
(DxC)	4.34 ^{ns}	5.52 ^{ns}	0.20 ^{ns}	5179890.79**	34061493.21**
(LxDxC)	39.91 ^{ns}	4.43 ^{ns}	0.07 ^{ns}	3337126.51*	4353530.24 ^{ns}
(KxC)	9.86 ^{ns}	4.82 ^{ns}	0.07 ^{ns}	662812.02 ^{ns}	590331.17 ^{ns}
(LxKxC)	8.14 ^{ns}	2.39 ^{ns}	0.18 ^{ns}	996012.89 ^{ns}	10686442.28 ^{ns}
(DxKxC)	7.40 ^{ns}	2.61 ^{ns}	0.03 ^{ns}	1589613.50 ^{ns}	6773685.34 ^{ns}
(LxDxKxC)	13.78 ^{ns}	1.67 ^{ns}	0.11 ^{ns}	852624.71 ^{ns}	6358870.52 ^{ns}
Error b	22.56	3.37	0.09	1295258.92	7205311.00
CV%	13.06	20.3	18.76	18.63	11.24

* and **, significant at the 0.05 and 0.01 levels of probability, respectively

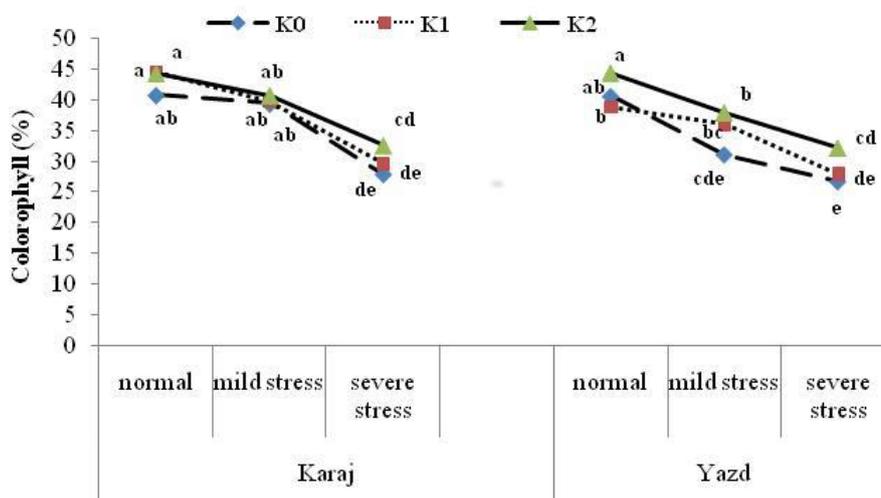


Figure 1. Mean comparison of interaction location × drought stress × potassium for chlorophyll

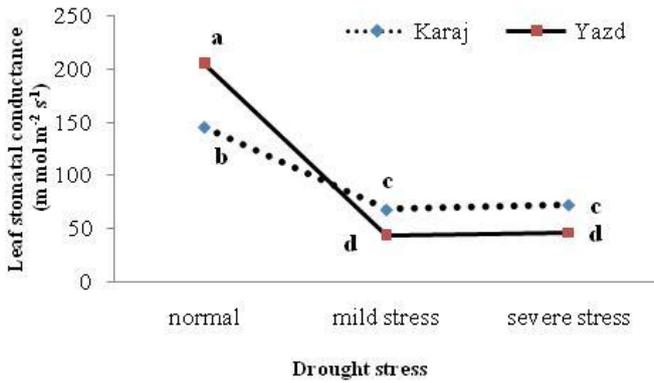


Figure 2. Mean comparison of interaction location × drought stress for leaf stomatal conductance

Spraying wheat plants with 3.0% K₂O caused the highest value of leaf stomatal conductance followed by spraying plants with 1.5% K₂O; while control treatment (without potassium foliar application) gave the lowest values of this character (Figure 3). It was reported that potassium control water loss from the plant through osmotic adjustment and positive role in closing of stomata [15]. When K⁺ is deficient, the stomata can not function properly and water losses from plant may reach damaging levels [14].

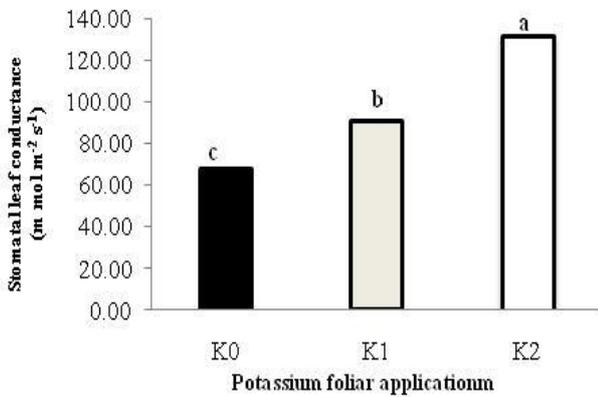


Figure 3. Means comparison of potassium for stomatal leaf conductance

Transpiration rate

Results indicated that drought stress significantly affected on transpiration rate (Table 2). Transpiration rate was 4.57 and 2.28 mmol m⁻²s⁻¹ in normal and severe water stress treatments, respectively (Figure 4). Similar results on mungbean (*Vigna radiata* L.) revealed that water deficit significantly decreased transpiration rate both at the vegetative and anthesis stages. Stress induced reductions in transpiration rate were 43% and 62% for mild and severe drought stress, respectively as compared with the control treatment [18].

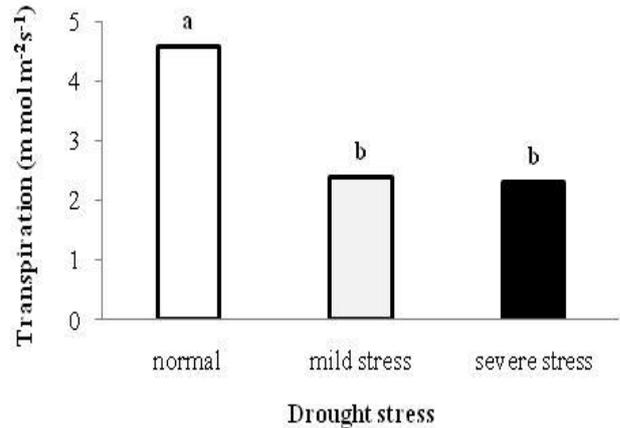


Figure 4. Mean comparison of drought stress for transpiration rate

Interaction effects of location and potassium foliar application was significant on transpiration rate (Table 2). Results showed that the efficiency of potassium fertilizer was different at both locations so that, differences between transpiration rate in highest level and no potassium application at Yazd was 80.2% more than Karaj (Figure 5). The function of stomata is to control water loss from the plant via transpiration. Improvement in transpiration rate due to potassium foliar application may be ascribed to the role of potassium in improving many physiological growth processes and delay plant leaves senescence. These results are in line with those stated by other researchers [1, 11].

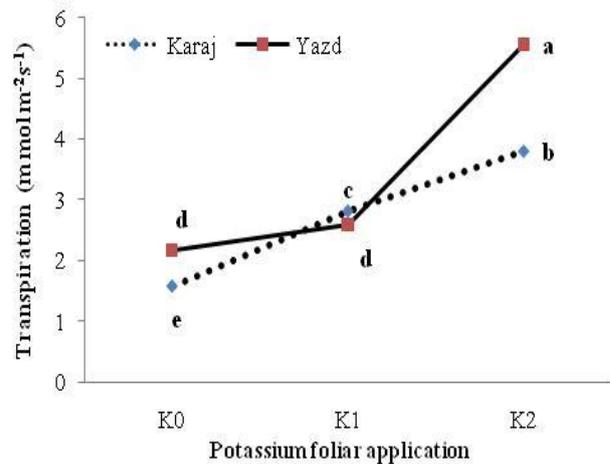


Figure 5. Mean comparison of interaction location × Potassium for transpiration rate

Biological yield

Significant interaction effects of drought stress and cultivar on biological yield showed that reaction of cultivars under drought stress conditions was different. Results showed under drought water stress, biological yield reduction in WS-82-9 was less than other cultivars (Figure 6).

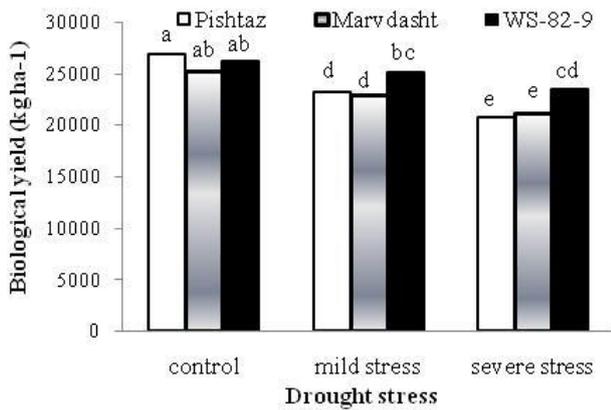


Figure 6. Means comparison of interaction drought stress for biological yield

In similar study was reported that biological yield of drought stress treatment was 21.5% lower than control [12]. Also they concluded that under drought stress, maximum and minimum values of biological yield were found with Kohdasht (13610 kg ha⁻¹) and Cham-4 cultivars (10070 kg ha⁻¹), respectively.

Grain yield

Interaction effects of location and drought stress and cultivar was significant on grain yield and

harvest index (Table 2). Results showed that reaction of cultivars under drought stress conditions at both locations was different. By increasing drought stress the reduction of grain yield was approximately similar in three wheat cultivars at Karaj, but under severe stress at Yazd, yield decrease in WS-82-9 than Marvdasht was least that can be associated to its physiological characteristics. The highest value of grain yield was produced in WS-82-9 under normal water use at Karaj (9310 kg ha⁻¹), while the lowest value of grain yield was observed in Marvdasht cultivar under severe drought stress at Yazd (2220 kg ha⁻¹) (Figure 7). The results of a study on sorghum reported that grain yield of drought stress treatment were 36.6% lower than control. Also, they resulted that under drought stress, maximum and minimum values of grain yield were attained with M5 (3680 kg ha⁻¹) and M3 lines (2830 kg ha⁻¹), respectively [5]. This effect of water stress during grain filling on grain yield may be due to the reduction in rate and duration of filling processes and causing small grain size consequently reducing yield components (number of spikes per m², number of grains per spike and 1000-grain weight) [19].

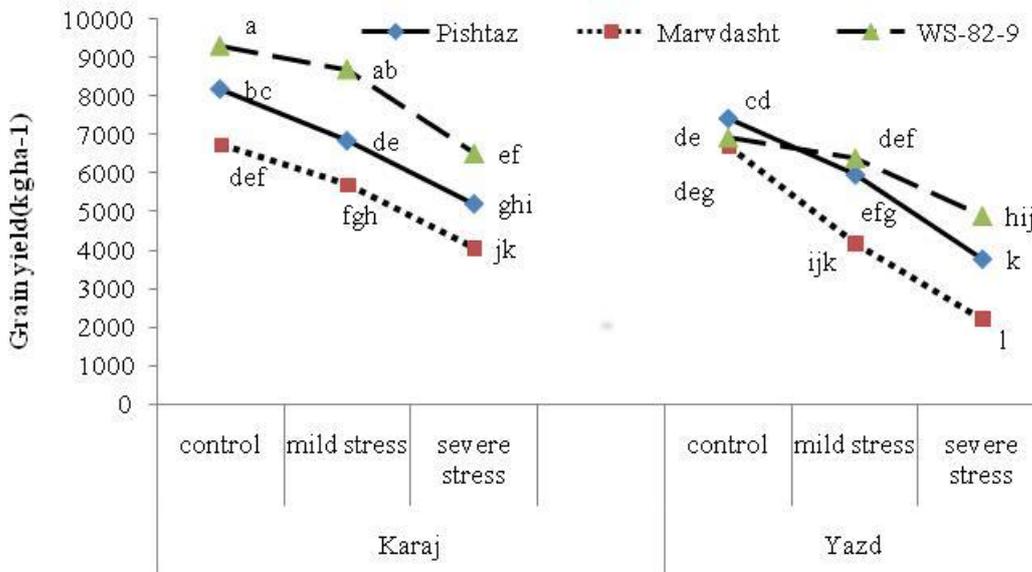


Figure 7- Mean comparison of interaction location × drought stress × cultivar for grain yield

Potassium foliar application significantly increased grain yield at both locations. Results showed that the efficiency of potassium fertilizer at Yazd was much more than Karaj. For example, differences between grain yield in highest level and no potassium application at Yazd was 1616 kg ha⁻¹ more than Karaj (Figure 8). Results of a study showed that under drought stress, high and low values of grain yield were produced with spraying 2.0 %K₂O and 2.0% urea (781.2 g/m²) and no application potassium and urea (636.7 g/m²),

respectively [2]. These increases may be ascribed to the role of foliar spray with potassium on increasing photosynthetic activity which accounts much for high translocation of photoassimilates from leaves to the grains. The other studies have shown that the application of potassium fertilizer mitigates the adverse effects of drought on plant growth in faba beans and sugar cane that confirmed result of this study [23].

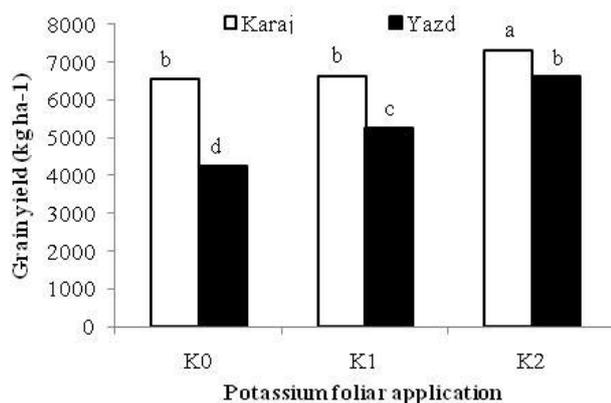


Figure 8. Means comparison of interaction location \times potassium for grain yield

Conclusion

Results showed that drought stress significantly affected on leaf stomatal conductance, transpiration rate, chlorophyll, biological yield and grain yield. Potassium foliar application mitigates the adverse effects of drought on plant growth and improved grain yield and physiological traits. The highest decrease in these traits was observed at Yazd area, because of unfavorable conditions. It is concluded that maximum values of grain yield could be achieved from wheat cultivar WS-82-9 giving normal irrigation and sprayed with 3.0% K₂O.

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