Yield, yield components and some physiological traits of three wheat (*Triticum aestivum* L.) cultivars under drought stress and potassium foliar application treatments

Abbas Zareian1*, Hosein Heidari Sharif Abad2, Aidin Hamidi2

1, 2Department of Agronomy, Science and Research branch, Islamic Azad university, Tehran, Iran
3Seed and Plant Certification and Registration Institute (SPCRI), Karaj, Iran

**Key words:** Wheat, Grain yield, Physiological traits, Drought stress, Potassium foliar application.

http://dx.doi.org/10.12692/ijb/4.5.168-175 Article published on March 10, 2014

**Abstract**

In order to evaluate the effects of drought stress and potassium foliar application on grain yield, its components and some physiological traits of three wheat (*Triticum aestivum* L.) cultivars, field experiment was conducted during growing season of 2011-2012 at Seed and Plant Certification and Registration Research Institute (SPCRI), Karaj- Iran. The experiment was 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 withhold at the grain filling phase) and severe stress (water withhold 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). Relative water content (RWC) and net photosynthesis were measured after grain filling stage. Also the number of spikes per area, number of grains per spike, 1000-grain weight and grain yield were measured. Results showed relative water content and net photosynthesis were significantly decreased by drought stress. These traits showed significant increase by increasing potassium foliar application. Also results indicated that water stress through withholding at the ear emergence and grain filling phases reduced grain yield and its components. Foliar application of potassium at the rate of 3.0% K2O gave the highest values of all studied wheat characters followed by 1.5% K2O as compared with control treatment. 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.

*Corresponding Author: Abbas Zareian E-mail: a_zareyan52@yahoo.com
Introduction

Wheat is one of the main cereal crops, cultivated to meet great demands of the population for human feeding. It is the most important staple for bread flour in Iran (Nour-mohamadi et al., 2009). 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 (Deng et al., 2004). According to Bray et al., (2000) the relative decreases in maximum crop potential yield (i.e., yields under ideal conditions) associated with abiotic stress vary between 54-82%.

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 (Bradford, 1994). Drought during grain filling could be limiting the rate and duration of filling processes, causing small grain size, earlier physiological maturity, reduce number of grains, low grain weight and grain yield of wheat (Gupta et al., 2001). With increased drought stress lower growth and yield were determined in barely (Jamieson et al., 1995) and in corn (Earl and Davis, 2003). Plant response to water stress include physiological and biochemical changes and later as water stress become more severe to functional damage and loss of plant parts (Sangtarash, 2010). The degree of adaptations to the decrease of water potential caused by drought may vary considerably among species (Save et al., 1995). Researchers linked various physiological responses of plant to drought with their tolerance mechanisms such as; pigment content and stability and high relative water content (Clarke and McCaig, 1982). Pasban-Eslam et al., (2000) have revealed that water potential and relative water content of leaves of all tested genotypes significantly decreased due to water stress, But genotypes with the highest osmotic adjustment ability under stress, appeared to have the least decrease in water potential and relative water content.

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 (Marchner, 1995; Reddy et al., 2004). Increased application of K has been shown to enhance photosynthetic rate, plant growth and yield in different crops under water stress conditions (Tiwari et al., 1998; Egilla et al., 2001). Spraying wheat plants with K before subjecting the plants to drought treatment diminished the negative effects of drought on growth and in turn increases yield per plant (El-Ashry and El-Kholy, 2005).

Therefore, the aim of this study was to find out the effects of drought stress and potassium foliar application on grain yield, its components and some physiological traits of three wheat cultivars in Iran.

Materials and methods

Field experiment was conducted in 2011-2012 at Seed and Plant Certification and Registration Research Institute (SPCRI), Karaj- Iran.

Experimental design and crop managements

Chemical and physical traits of experimental soil is representing in Table 1. The experiment was 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, Pishat and WS-82-9) comprised the experimental factors. Relative water content and net photosynthesis were measured after grain filling stage. Also the number of spikes per area, number of grains per spike, 1000-grain weight and grain yield were measured. Seeds were sown on 19 November. 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 prevent of 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% K₂O in the form of potassium sulphate (48% K₂O). The foliar solution was prepared at both rates and applied using hand sprayer at stem elongation stage.

Measurement
Measurement of net photosynthesis was made at a fix time of day between 9.00 to 12.00 h after withholding water at grain filling stage. The youngest fully-expanded leaf (third from the apex), intact and full sunlit leaves per plot was used for measurement. Net Photosynthesis was measured by the CI-340 Ultra-Light Portable Photosynthesis System. Measurement obtained by using Leaf Chamber attachments in conjunction with the CI-340. Relative water content was determined by the method described by Barrs and Weatherley, (1962). The first fresh weights of leaf samples were recorded. Then they was taken and kept in double distilled water in a petridish for two hours to make the leaf tissue turgid. The turgid weights of the leaf materials were taken after carefully soaking the tissues between the two filter papers. Subsequently this leaf material was kept in a butter paper bag and dried in oven at 65°C for 24 hours and their dry weights were recorded. The RWC was calculated by using the formula:

\[
RWC (\%) = \frac{(\text{Fresh weight} - \text{Dry weight})}{(\text{Turgid weight} - \text{Dry weight})} \times 100
\]

At harvest, a 3 m² area was harvested from the center of each plot for grain yield. Also a 1 m² area was harvested for measuring the yield components.

Statistical analysis
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.

Results and discussion
The results revealed significant difference \((P<0.01)\) among different levels of drought stress, potassium foliar application and cultivars. (Table 2).

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

<table>
<thead>
<tr>
<th>K</th>
<th>P</th>
<th>T.N.</th>
<th>OC</th>
<th>Sand</th>
<th>Silt</th>
<th>clay</th>
<th>Tex</th>
<th>pH</th>
<th>EC</th>
</tr>
</thead>
<tbody>
<tr>
<td>(mg/kg)</td>
<td>(mg/kg)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(%)</td>
<td>(Mmhos)</td>
<td></td>
</tr>
<tr>
<td>149.9</td>
<td>8.09</td>
<td>0.221</td>
<td>0.78</td>
<td>38.4</td>
<td>47</td>
<td>14.6</td>
<td>Loamy</td>
<td>7.01</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Net photosynthesis
Net photosynthesis significantly decreased by increasing drought stress and this reduction was %66 (Table 3). Spraying wheat plants with 3.0% K₂O produced the highest value of net photosynthesis; while control treatment (without potassium foliar application) gave the lowest value of this character (Table 3). This improvement in net photosynthesis 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. These results are in line with those stated by Abou El-Defan et al. (1999) and El-Sabbagh et al. (2002).

Effect of water stress (low, mild and severe) and K supply (0.2, 2.0 and 6.0 mM) on net photosynthesis in wheat leaves was studied by Gupta et al., (1989). Result showed under water stress, the photosynthetic efficiency of plants was reduced drastically (61%) as a consequence of chloroplast dehydration. Also, in drought stress conditions, spraying plants with K application in three levels 0.2, 2.0 and 6.0 mM, photosynthesis rate increased %17.3, %75 and %92.8, respectively. In wheat experiments, Pier and
Berkowitz, (1987) observed 66-13 higher photosynthetic rates in plants fertilized with above normal K+ than those under standard fertilization, indicating that leaves of plants grown in very high internal K+ levels have partially reversed the dehydration effects on photosynthesis. Significant impact of wheat cultivars on net photosynthesis was observed (Table 2). Pishaz cultivar produced the highest net photosynthesis compared to the other cultivars (Table 3). Difference between cultivars in net photosynthesis was reported by other researcher (Siddique, et al., 1999).

### Table 2. Grain yield, its components and some physiological traits of three wheat cultivars in response to drought stress and potassium foliar application treatments.

<table>
<thead>
<tr>
<th>Source of variance</th>
<th>Mean of square</th>
<th>Source of variance</th>
<th>Mean of square</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Net photosynthesis</td>
<td>Relative water content</td>
<td>Number of spikes per area</td>
</tr>
<tr>
<td>Block</td>
<td>1.1297</td>
<td>168.695</td>
<td>59337.679</td>
</tr>
<tr>
<td>Drought stress</td>
<td>14.7126**</td>
<td>1896.542**</td>
<td>23159.308</td>
</tr>
<tr>
<td>Error a</td>
<td>1.48</td>
<td>221.92</td>
<td>12121.38</td>
</tr>
<tr>
<td>Potassium foliar application (K)</td>
<td>4.5814**</td>
<td>169.815</td>
<td>10391.753</td>
</tr>
<tr>
<td>Cultivar (C)</td>
<td>1.5002*</td>
<td>63.647</td>
<td>32017.975*</td>
</tr>
<tr>
<td>(D×K)</td>
<td>0.1652</td>
<td>102.187</td>
<td>2386.567</td>
</tr>
<tr>
<td>(C)</td>
<td>0.4818</td>
<td>42.419</td>
<td>1486.123</td>
</tr>
<tr>
<td>(K)</td>
<td>0.3564</td>
<td>162.751</td>
<td>5811.456</td>
</tr>
<tr>
<td>(D×K×C)</td>
<td>0.3983</td>
<td>66.938</td>
<td>16181.827</td>
</tr>
<tr>
<td>Error b</td>
<td>0.3284</td>
<td>206.884</td>
<td>6556.148</td>
</tr>
<tr>
<td>CV%</td>
<td>27.07</td>
<td>18.98</td>
<td>14.45</td>
</tr>
</tbody>
</table>

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

**Relative water content (RWC)**

Results indicated that drought stress significantly affected on relative water content (Table 2). Relative water content was 85.44 and 70.53 in normal and severe water stress treatments, respectively (Table 3). Water stress is generally characterized by decrease in relative water content and water potential, resulting in wilting, stomatal closure and reduced growth (Lawlor and Cornic, 2002). Fanai et al., (2009) on canola reported that the highest relative water content was found in control treatment. Their results showed that relative water content decreased with increasing drought stress and was attained 22 and 9 at %50 at flowering and %100 siliques formation stages, respectively. Similar results was reported by Unyayar et al., (2004), who concluded that under drought stress decreased the leaves relative water content.

**Number of spikes per area**

Results indicated that cultivars were different in number of spikes per area (Table 2). Minimum number of spikes per m² was observed in WS-82-9 (521.59) that can be associated with agronomical characteristics especially its low tillering capacity (Table 3). Difference between wheat cultivars in this character was recorded by Emam et al., (2007) who reported that under drought stress, high and low value of spikes per m² were attained with Niknejad (601) and Giza 164 cultivars (481), respectively.

**Number of grains per spike**

Results indicated that drought stress, potassium foliar application and cultivar significantly affected on number of grains per spike (Table 2). In this study high value of grains per spike was observed under normal water use (50.93) (Table 3). Also results showed that spraying with 3.0% K₂O increased number of grains per spike by 8.2 (Table 3). EL-Abady et al., (2009) on wheat reported that the highest value of grains per spike was found in control treatment and number of grains per spike decreased
with increasing drought stress by %13. Also they reported that under drought stress, high and low values of grains per spike were observed with spraying 3.0% K2O (65.5) and no application potassium (59.95), respectively.

Table 3. Means comparison of grain yield, its components and some physiological traits of three wheat cultivars in response to drought stress and potassium foliar application treatments.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Traits</th>
<th>Net photosynthesis (µmol CO2/m²/s)</th>
<th>Relative water content (%)</th>
<th>Number of spikes per area</th>
<th>Number of grains per spike</th>
<th>Grain weight (g)</th>
<th>1000-grain weight (g)</th>
<th>Grain yield (kg ha⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drought stress</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>K0</td>
<td>9.27 ± 4.23 a</td>
<td>85.44 ± 4.4 a</td>
<td>593.59 ± 4.9 a</td>
<td>50.93 ± 4.5 a</td>
<td>35.35 ± 4.9 a</td>
<td>8073.5 ± 8.4 a</td>
<td>7244.4 ± 8.4 a</td>
</tr>
<tr>
<td></td>
<td>K1</td>
<td>71.35 ± 5.72 b</td>
<td>76.49 ± 5.9 a</td>
<td>559.15 ± 4.9 a</td>
<td>49.91 ± 4.5 a</td>
<td>28.86 ± 4.9 a</td>
<td>6643.8 ± 8.4 b</td>
<td>7321.0 ± 8.4 b</td>
</tr>
<tr>
<td></td>
<td>K2</td>
<td>3.09 ± 2.8 b</td>
<td>70.53 ± 4.9 a</td>
<td>538.48 ± 4.9 a</td>
<td>46.81 ± 4.5 a</td>
<td>22.70 ± 4.9 a</td>
<td>5189.7 ± 8.4 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Potassium foliar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Marvdasht</td>
<td>7.18 ± 2.8 b</td>
<td>77.85 ± 4.9 a</td>
<td>580.48 ± 4.9 a</td>
<td>49.08 ± 4.5 a</td>
<td>33.50 ± 4.9 a</td>
<td>7321.0 ± 8.4 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pishtaz</td>
<td>6.33 ± 5.4 b</td>
<td>76.73 ± 4.9 a</td>
<td>587.52 ± 4.9 a</td>
<td>46.46 ± 4.9 a</td>
<td>28.68 ± 4.9 a</td>
<td>6744.0 ± 8.4 b</td>
<td></td>
</tr>
<tr>
<td></td>
<td>WS-82-9</td>
<td>4.38 ± 4.23 ab</td>
<td>74.01 ± 4.9 a</td>
<td>521.59 ± 4.9 a</td>
<td>48.18 ± 4.9 a</td>
<td>37.25 ± 4.9 a</td>
<td>8275.3 ± 8.4 b</td>
<td></td>
</tr>
</tbody>
</table>

Means with the same letter in each column have not statistically significant difference.

1000-grain weight
Effects of drought stress, potassium foliar application and cultivar on 1000-grain weight was significant (Table 2). Results showed that low value of 1000-grain weight was observed under severe stress treatments (22.70 g) (Table 3). Also WS-82-9 produced a greater significantly 1000-grain weight (37.25 g) and Marvdasht cultivar produced the lowest value of 1000-grain weight (24.92 g) (Table 3). It may be concluded that, difference among cultivars for this trait was due to their various genetic potential and WS-82-9 was superior in this character. Difference between wheat cultivars in grain weight was recorded by Emam et al., (2007) who reported that under drought stress, high and low values of 1000-grain weight were observed in Seymareh (27.9 g) and Gahar cultivars (24.1 g), respectively. The reduction in yield components due to water stress during grain filling might have been due to the inhibition in photosynthesis efficiency under insufficient water conditions (Siddique et al., 1999). The mean comparison of potassium on 1000-grain weight showed that difference between 1000-grain weight in spraying with 3.0% K2O and no potassium application was 5.00 g (%14.9) (Table 2). These results are in line with those stated by Fusheng, 2006 who reported that grain from potassium deficient plants are small, shriveled and are more susceptible to diseases, while suitable amount of K can be improved grain quality and quantity.

Grain yield
Results indicated that drought stress, potassium foliar application and cultivar significantly affected on grain yield (Table 2). In this study high value of grain yield was produced under normal water use (8073.5 kg ha⁻¹) (Table 3). Spraying wheat plants with 3.0%K2O produced the highest value of grain yield (7321.9 kg ha⁻¹); while control treatment (without potassium foliar application) gave the lowest value of this character (Table 3). Also maximum value of grain yield was observed in Marvdasht cultivar (5488.3 kg ha⁻¹) (Table 3). Beheshti and Behboodi fard (2010) on sorghum reported that grain yield under 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. In other study, Alizadeh et al., (2014) concluded that the lowest grain yield was obtained from maize under drought stress at the end of pollination compared to normal irrigation and drought stress at silk emergence conditions. Compared to the maize under normal irrigation condition, this represents a yield decrease of %41. 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). Similar results were detected by Saint Pierre et al., (2008). Amal et al., (2011) reported 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. 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. Numerous studies have shown that the application of potassium fertilizer mitigates the adverse effects of drought on plant growth in barley (Anderson et al., 1992) sunflower (Lindhauer, 1985) faba beans (Abdelvahab and Abdalla, 1995) sugar cane (Sudama et al., 1998) and rice (Reddya et al., 2004) that confirmed result of this study.

**Conclusion**

Our results showed that application of potassium under water stress affects on grain yield, yield components and some physiological traits of wheat. Drought adversely affected grain yield and physiological traits in contrast with increasing potassium consumption, negative effect of water stress on grain yield and its components modified and consequently improved them. Due to high sensitive of Marvdasht to drought stress, grain yield and its components noticeably decreased, While WS-82-9 showed superior characteristics, therefore produced high grain values.

**References**


http://dx.doi.org/10.1007/BF00231694


http://dx.doi.org/10.12692/ijb/4.2.244


http://dx.doi.org/10.2134/agronjl20070166


