Original Article

Study on Drought Tolerance of 12 Varieties of Bread Wheat (*Triticum Aestivum*) in East Part of Iran

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ABSTRACT

In order to study the drought tolerance of 12 varieties of bread wheat an experiment was conducted in research farm of Islamic Azad University of Shirvan. The experiment was performed under two separated irrigated and dryland conditions using a randomized complete block design with three replications. The length and width of each plot was 5 and 1.5 m, respectively. Plant density was 500 seeds/m², in both experiments. At the early grain filling stage, leaf sample provided from each plot to determine the leaf electrolyte leakage and leaf relative water content. Number of spikes/m², grain weight and yield were measured after harvesting. Stress tolerance index (STI) and stress susceptibility index (SSI) were estimated according to grain yield of any variety in both dryland and irrigated conditions. The results of combined analysis showed that Chamran and Cross-Sabalan, produced 2005 and 2310 kg/ha seed yield in irrigated condition that were higher than other varieties. In dryland condition, the yield of Chamran and Cross-Sabalan were 648 and 551 Kg/ha that were higher than other varieties as well. Cross-Sabalan and Chamran also showed higher drought tolerance index compared with other varieties. Drought tolerance index in these two varieties were 6.8 and 6.6, respectively. Cross-Sabalan also showed relatively high drought susceptibility index but Chamran showed higher drought tolerance index and lower drought susceptibility index compared with the other varieties. Thus according to results of this study two varieties of Cross-Sabalan and Chamran are advisable to plant in regions with limited source of water.

Key word: Stress susceptibility index, stress tolerance index, electrolyte leakage, relative water content, wheat and yield.

Introduction

Water is one of important component of plant tissues and it is needed for all chemical process, photosynthesis and for cell enlargement. Cell enlargement is dependent to water and will decreases with water deficit. Most of physiological process that are interfere with plant growth decreases with water deficit as well. Severe water deficit my destroy the plant.

By decreasing relative cell turgidity to 83 and 85 %, plant growth will reduce to half. However in some plant spices plant growth will continue to relative turgidity of 62% that is very near to wilting point [21]. Tolerance of plant to drought is a total of complex mechanism and their reaction. A number of scientist proposed that plants only have two mechanism include, stress toleration and stress avoidance. Plants may complete their growth stage before of drought occurrence and prevent stress damage to their tissues. This action named escape from drought. Plants may tolerate to drought through retaining water in their tissues. This action occur by deep and extensive root system and reduction of transpiration. This thick and impermeable cuticle and close stomata during hot period of day will decrease plant transpiration. Closing of stomata may reduce sever drought but because of increasing stomata resistance to CO2 conductivity, photosynthesis and finally yield will decrease. Because of drought avoidance, this kind of plants can tolerate drought condition. In spite of lower internal moisture, plants may remain alive. This mechanism is named drought toleration and the plants that have this mechanism can regrow after improving water condition [21].

Accessibility to variety that produced more yield in drought stress condition is one of the important
aim to crop selection. Several methods proposed to study drought. That include, measurement of plant temperature as a factor to show plant water potential [7], Resistance against gas transmitting [13], Osmotic adjustment of leaves and measurement of proline amino acid [12], Amount of photosynthesis and carbon sequestration [9,14] and measurement of leaves growth reduction [6].

Based on several studies, [14] proposed that relative leaf water content can use as an index for rate of stress and wilting. [19] in a study on two varieties of wheat used the relative leaf water content as a stress index [24], proposed amount of electrolyte seepage in plant leaves under stress condition. [25], showed that cell membrane damage on plant which were under stress condition was lower than other. [10] proposed stress susceptibility index to determine drought tolerant variety. Lower stress susceptibility index indicated higher toleration to drought. The selected varieties by this way have lower yield potential but in drought condition they will produce higher yield. [8] proposed another index as a drought tolerance index to determine drought tolerant variety. Higher drought tolerance index show more toleration to drought. The variety that show higher drought tolerance index will produce higher yield in stress and non stress condition. [11] used cell size to determine drought toleration in plant and he reported that the rate of cell volume to cell surface can indicate drought toleration. When this rate is low drought toleration is high.

The aim of this experiment was to study and comparing 12 varieties of bread wheat to determine drought tolerant varieties. Four methods include, drought tolerance index [8], drought susceptibility index [10], leaf relative water content [14] and electrolyte leakage [24] used to select drought tolerant varieties.

Materials and methods

This experiment was conducted in Islamic Azad University of Shirvan during 2007-2008 growing season in two separated irrigated and dry land condition as a complete block design with 3 replications and 12 varieties of bread wheat. In irrigated condition irrigation was done in 5 stages include, immediately after planting, at beginning of jointing, at enlargement of the boot, at flowering and seed filling stage. Amount of irrigation in each stage was equal to 60mm. Each plot had 6 rows and the distance between rows was 20 cm and length of each rows was 5 meter. Seeding depth was 5cm. Fertilizer application was based on soil chemical analysis. The varieties of this experiment were, Koohdasht, Marvdasht, Cross Arvand, Cross sablan, Chamran, Zagros, Sablan, Alvand, Toos, Sayonz, Pastor and Azar-2. Seed density was 500 seed/m². Planting date in both condition was mid November. Relative leaf water content and electrolyte leakage determined in early seed filling stage. Number of ear/m² also was measured with sample unite of 1m². After crop harvesting, number of seed per ear, thousand kernel weight and seed yield determined as well.

The data were analyzed with MSTATC software as a randomized complete block design. The mean comparison was done by Duncan multiple test.

Four method used to study on drought tolerant genotypes as below:
1- Measurement of leaf electrolyte leakage (E. L). for measuring leaf electrolyte leakage at flowering stage 20 diskette samples provided from top branch leaves of plant. These samples transfer to distilled water for 48 hour. after this time electrolyte leakage was measured at laboratory temperature by Ec meter. Plants that show lower electrolyte leakage indicated lower cell membrane damage from drought stress. [24].
2- measurement of relative leaf water content (RWC):

For measuring relative leaf water content we used top branches leaves. At flowering stage in each plot 10 samples selected and immediately preliminary wet weight of samples determined, Leaves transfer to bowl containing distilled water. After 24 hour saturation weight of samples obtained and theses samples transfer to oven for 24 hour at 105C. After 24 hour dry weight of samples obtained and relative leaves water content calculated and relative leaves water content computed by following equation [14]:

\[
RWC = \frac{(leaves \ preliminary \ weight - dry \ weight)}{(leaves \ preliminary \ weight)}
\]

3- Stress susceptibility index (SSI):

Stress susceptibility index computed based on [10]. In this method drought intensity computed as below:

\[
D = 1 - YD/YP
\]

\[
SSI = \frac{1 - YD/YP}{YD/YP}
\]

D= drought intensity

SSI = stress susceptibility index

4- Stress tolerance index (STI):

Stress tolerance index computed through Fernandez (1993) method as below:

\[
STI = \frac{YP*YSi}{YPi}
\]

STI= Stress tolerance index

YPi= yield of any genotype in non stress condition

YP= total mean yield under non stress condition

YSi= yield of any genotype in stress condition

YP= total mean yield under stress condition

Results and Discussion
As shown in Table 1, effect of location on number of ear/m², number of seed per ear and seed yield was significant at 1% level of probability. Effect of location on electrolyte leakage was significant at 5% level of probability as well. Effect of variety on T. K. W and seed yield was also significant at 1% level of probability. Interaction of location and variety on T. K. W and electrolyte leakage was significant at 1% level of probability as well.

Table 1: Analysis of variance of yield and yield components of wheat.

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>D.F</th>
<th>Ear/m²</th>
<th>Seed/ear</th>
<th>T.K.W</th>
<th>Seed/h</th>
<th>E.L</th>
<th>R.W.C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>1</td>
<td>1542646**</td>
<td>2688**</td>
<td>24.267ns</td>
<td>29509122**</td>
<td>304200*</td>
<td>37.224ns</td>
</tr>
<tr>
<td>Error</td>
<td>4</td>
<td>20729.81</td>
<td>116.98</td>
<td>11.128</td>
<td>499260.3</td>
<td>36544</td>
<td>45.716</td>
</tr>
<tr>
<td>Variety</td>
<td>11</td>
<td>17580.65ns</td>
<td>58.03ns</td>
<td>35.812**</td>
<td>456564**</td>
<td>20288*</td>
<td>23694ns</td>
</tr>
<tr>
<td>Loc*V</td>
<td>11</td>
<td>9482.79ns</td>
<td>36.071ns</td>
<td>17.409*</td>
<td>261013ns</td>
<td>36728**</td>
<td>41.493ns</td>
</tr>
<tr>
<td>error</td>
<td>44</td>
<td>24454.21</td>
<td>155692.7</td>
<td>7.392</td>
<td>155692</td>
<td>10353</td>
<td>22.671</td>
</tr>
</tbody>
</table>

**, ns., In order significant at the level of 1%, 5% of probability and not significant.

Fig. 1: Drought tolerance index and seed yield in different varieties of wheat.

Average of seed yield in varieties of Cross Sablan, Cross Arvand, Marvdasht and Chamran in order were 1431, 1340, 1333 and 1326 Kg/h that were higher than other varieties. The varieties of Zagros and Toos with 511 and 717 Kg/h seed yield produced the lowest (table 2).

In dry land condition the varieties of Chamran and Cross Sablan in order produced 648 and 551 Kg/h seed yield that were higher than other varieties. Cross Sabalan with seed yield of 2310 Kg/h in irrigated condition also produced the most seed yield (table 2). The highest average of T. K. W (irrigated and dryland) was 39.5 gr that belonged to Sabalan that was more than others. In irrigated condition T. K. W of Cross Sabalan and Cross Arvand were more than others and in order were 41and 40 gr. In dryland condition the highest T. K. w belonged to Cross Sabalan, Sabalan and Alvand that were 38, 37 and 37 gr respectively (table 2).

Electrolyte leakage:

Average of electrolyte leakage in varieties of Chamran, Toos, Sayons and Pastor in order were 22.6, 21.5, 23.4 and 22.0 ds/cm that were lower than other varieties. Zagros with average of 38.7 ds/cm showed the highest electrolyte leakage. In dry land condition because of water stress, electrolyte leakage almost in all varieties were higher that indicated more damage from drought stress. Zagros with 63.2 ds/cm in dry land condition showed the highest electrolyte leakage that indicated the highest damage from drought stress (table 2).

Relative leaf water content:

Average of relative leaf water content was not significant among different varieties of wheat, but totally, relative leaf water content in dry land condition and irrigated condition showed significant different. As expected in irrigated condition all varieties retain more water compared with dry land condition. The varieties of Chamran and Toos in both irrigated and dryland condition showed the same water content (table 2). There was no positive or
negative relationship between relative leaf water content and seed yield in this experiment. The varieties that their water potential were the same their seed yield were different.

Table 1: Seed yield, thousand kernel weight, electrolyte leakage and relative water content in different varieties of wheat in two irrigated and dry land condition

<table>
<thead>
<tr>
<th>Environment</th>
<th>Varieties</th>
<th>Relative leaf water content(%)</th>
<th>Electrolyte leakage(ds/cm)</th>
<th>Thousand kernel weight(gr)</th>
<th>Seed yield(Kg/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigated</td>
<td>Azar-2</td>
<td>17</td>
<td>27 cdef</td>
<td>34 efgh</td>
<td>1512 cde*</td>
</tr>
<tr>
<td></td>
<td>Pastor</td>
<td>23</td>
<td>19.7 abcde</td>
<td>36 cdef</td>
<td>1614 cd</td>
</tr>
<tr>
<td></td>
<td>Sayons</td>
<td>25</td>
<td>23.4 abcdef</td>
<td>35 defg</td>
<td>1789 bcd</td>
</tr>
<tr>
<td></td>
<td>Toos</td>
<td>18</td>
<td>28.1 bcdef</td>
<td>32 gh</td>
<td>1098 ef</td>
</tr>
<tr>
<td></td>
<td>Alvand</td>
<td>17</td>
<td>23.4 defg</td>
<td>38 abcd</td>
<td>1962 abc</td>
</tr>
<tr>
<td></td>
<td>Zagros</td>
<td>22</td>
<td>14.3 fg</td>
<td>34 efgh</td>
<td>760 fg</td>
</tr>
<tr>
<td></td>
<td>Chamran</td>
<td>17</td>
<td>13.1 g</td>
<td>34 efgh</td>
<td>2005 abc</td>
</tr>
<tr>
<td></td>
<td>Cross-Sablan</td>
<td>20</td>
<td>13.2 g</td>
<td>41 a</td>
<td>2310 a</td>
</tr>
<tr>
<td></td>
<td>Cross-Arvand</td>
<td>24</td>
<td>24.4 defg</td>
<td>40 ab</td>
<td>2257 ab</td>
</tr>
<tr>
<td></td>
<td>Marvdasht</td>
<td>18</td>
<td>23.4 defg</td>
<td>34 efgh</td>
<td>2225 ab</td>
</tr>
<tr>
<td></td>
<td>Sabalan</td>
<td>17</td>
<td>30.7 bcde</td>
<td>38 abcd</td>
<td>1640 cd</td>
</tr>
<tr>
<td></td>
<td>Koohdasht</td>
<td>22</td>
<td>24.6 defg</td>
<td>39 abe</td>
<td>1420 de</td>
</tr>
<tr>
<td>Mean</td>
<td>20</td>
<td></td>
<td>22.10</td>
<td>36</td>
<td>1695</td>
</tr>
<tr>
<td>Dry land</td>
<td>Azar-2</td>
<td>14</td>
<td>39.7 be</td>
<td>34 efgh</td>
<td>492 g</td>
</tr>
<tr>
<td></td>
<td>Pastor</td>
<td>20</td>
<td>24.3 defg</td>
<td>31 h</td>
<td>347 g</td>
</tr>
<tr>
<td></td>
<td>Sayons</td>
<td>18</td>
<td>23.5 defg</td>
<td>31 h</td>
<td>519 g</td>
</tr>
<tr>
<td></td>
<td>Toos</td>
<td>18</td>
<td>15 fg</td>
<td>35 defg</td>
<td>337 g</td>
</tr>
<tr>
<td></td>
<td>Alvand</td>
<td>16</td>
<td>40.8 b</td>
<td>37 bcde</td>
<td>354 g</td>
</tr>
<tr>
<td></td>
<td>Zagros</td>
<td>15</td>
<td>63.2 a</td>
<td>34 efgh</td>
<td>264 g</td>
</tr>
<tr>
<td></td>
<td>Chamran</td>
<td>17</td>
<td>32.1 bcde</td>
<td>33 fg</td>
<td>648 fg</td>
</tr>
<tr>
<td></td>
<td>Cross-Sablan</td>
<td>14</td>
<td>41.5 b</td>
<td>38 abcd</td>
<td>551 g</td>
</tr>
<tr>
<td></td>
<td>Cross-Arvand</td>
<td>13</td>
<td>31.6 bcde</td>
<td>36 cdef</td>
<td>424 g</td>
</tr>
<tr>
<td>Mean</td>
<td>16</td>
<td></td>
<td>35.12</td>
<td>35</td>
<td>435</td>
</tr>
</tbody>
</table>

* In each column the figures which have at least a common letter are not significant at the 5% level of probability.

Drought tolerance index:

As shown in fig 1 based on seed yield and drought tolerance index varieties divided in four groups. In this fig no variety located in group A. The varieties that located in group B showed lower seed yield and drought tolerance index. The varieties that located in group D produced higher seed yield and showed lower drought tolerance index but the varieties that showed higher seed yield and drought tolerance index located in group C. The varieties of Chamran, Cross Sabalan, Cross Arvand, Marvdasht compared with other varieties produced the most seed yield. Among these varieties the highest seed yield belonged to Cross sablan. Beside of more seed yield the varieties of Cross sablan and Chamran showed higher drought tolerance index. Two varieties of Cross Arvand and Marvdasht also produced more seed yield but drought tolerance index in these varieties was lower than Cross sablan and Chamran. Among All varieties ,Pastor, Toos, Zagros and Koohdasht showed lower seed yield and drought tolerance index. As shown Zagros produced the lowest seed yield and showed the lowest drought tolerance index. Electrolyte leakage in this varieties in dry land condition were more than other varieties that indicated the most damage from drought stress.

Drought susceptibility index:

As shown in fig 2 the varieties according to drought susceptibility index and seed yield located in four groups. Varieties that located in group A showed higher drought susceptibility index and
lower seed yield. The varieties that located in group B show lower seed yield and drought susceptibility index. The varieties that located in group C showed higher seed yield and drought susceptibility index but varieties that located in group D showed higher seed yield and lower drought susceptibility index. Thus in order to select the variety with higher seed yield and lower drought susceptibility index we have to look for them in group D. The varieties of Cross Sabalan, Cross Arvand and Marvdasht that located in group C in spite of more seed yield showed higher drought susceptibility index. That make them susceptible to drought stress. The variety of Chamran that located in group D produced seed yield equal with Cross Arvand and Marvdasht but its drought susceptibility index was lower than these two varieties. In addition of higher seed yield and lower drought susceptibility index the Variety of Chamran showed higher drought tolerance index that total of these traits make this variety acceptable for planting in dry area. Electrolyte leakage of Chamran compared with other variety was lower as well.

![Fig. 2: Seed yield and drought susceptibility index in different varieties of wheat.](image)

**Discussion:**

As mentioned average of seed yield in varieties of Chamran, Cross Sabalan, Cross Arvand and Marvdasht in order were, 1326, 1431, 1340 and 1333 Kg/h that were more than other varieties but In dry land condition the most seed yield belonged to two varieties of Chamran and Cross Sabalan that were 648 and 551 Kg/h respectively. In irrigated condition, varieties of Chamran, Cross Sabalan, Cross Arvand and Marvdasht produced 2004, 2310, 2256 and 2224 Kg/h seed yield respectively that were more than other varieties.

Although seed yield is one of important index to select drought tolerant variety [2,15,1,18,22] but when seed yield tested with other index it will be more valuable.

Average of electrolyte leakage in varieties of Pastor, Sayons, Toos and Chamran in order were, 22, 22.4, 21.5 and 22.6 ds/cm that were lower than other varieties. In dry land condition also these varieties and Koohdasht showed lower electrolyte leakage that indicated lower damage of cell membrane from drought stress. [25] reported that the drought tolerable variety showed less cell membrane damage. [15] applied this method to select drought tolerant genotypes of lentil. Electrolyte leakage also used to select drought tolerant varieties of barley [20]. Water stress in susceptible protoplast will damage cell membrane and breaks the continuity of plastid membrane, mitocondri, nucleus, plasmalema and dictosom membrane. Membrane permeability to salts, improve this theory that membrane will damage in stress condition and this is why that through evaluation of electrolyte leakage (measuring electrical conductivity) can understand plant susceptibility to drought to some extent [4,5,23,16,26,18,21].

Considering to drought tolerance index and seed yield, the varieties of Cross Sabalan, Chamran, Cross Arvand and Marodasht produced more seed yield and showed higher drought tolerance index. The most seed yield and most drought tolerance index observed in variety of Cross sabaalan. Among four varieties that produced highest yield and showed highest drought tolerance index the variety of Chamran in addition to higher seed yield and drought tolerance index showed lowest drought susceptibility index. Drought tolerance index and drought susceptibility index applied by several scientist to select crop for dry land condition. [18] used these index to select drought tolerant genotypes of Safflower, [15] for lentil [3,20] for barley.
According to results of this experiment two varieties of Cross Sabalan and Chamran are suitable to plant in low rainfall area. Variety of Cross Sabalan in both irrigated and dry land condition produced acceptable seed yield. In spite of high drought susceptibility index, drought tolerance index in this variety was much more than other varieties. Average of electrolyte leakage in this variety was more than Chamran and less than most of other varieties.

Although average of seed yield in Chamran was less than Cross Sabalan but its seed yield in dry land condition was more than other varieties. Average of electrolyte leakage of this variety was equal with Toos and Pastor but was less than other varieties. drought tolerance index of Chamran was equal with Cross Sabalan and more than other varieties and drought susceptibility index of Chamran was equal with Azar-2 and less than other varieties.

Relative leaf water content in different varieties did not showed a clear trend but relative leaf water content in Chamran in both irrigated and dry land conditions was equal and this is another reason for advantages of Chamran for planting in low rainfall condition because this variety can retain cell turgidity in drought stress condition. Finally according to the results of this experiment two varieties of Cross Sabalan and Chamran are advisable to plant in dry regions.

References