Effects of supplemental irrigation and source limitation on grain quality of Iranian bread wheat genotypes

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Abstract

The wheat’s bread is one of the main foods to supply daily diet that its quality is affected by different stress and environmental conditions. This study was carried out to investigate the effects of different irrigation treatments (supplemental irrigation at anthesis and grain filling stages and non-irrigation as control) and source limitation (current photosynthetic limitation) at 14 days after anthesis on traits related to baking quality of bread wheat genotypes (Karim, Cross Albourz, Sivand and Pishhtaz). The results showed that the effects of irrigation, source limitation and genotypes were significant on the gluten index, total gluten, wet gluten and strong gluten. Also the falling number was affected by treatments except genotypes. The supplementary irrigation had positive effect on bread wheat traits and between the genotypes Sivand and Cross Albourz had highest amount of gluten index and strong gluten. The most appropriate falling number was related to Karim genotype and without source limitation condition.

Key words: Gluten Index, Falling number, Wet gluten, Wheat.

Introduction

Nowadays increasing of food demand and water deficit has created a challenge for food security in the world (Zwart and Bastiansen, 2004). Among the crops, wheat is a strategic cereal in the world and it is also a major food cereal and a cheapest source of the people in Iran that provides more than 40-45 and 50 percent of the daily calories and protein (respectively) of people (Iran-Nejad and Shahbaziyan, 2005). The mainly consuming of wheat is in the form of bread. The bread quality can be affected by grain genetic and environmental effects like soil condition, irrigation, weather, seed storage and seed content (Finney et al., 1987). Also in relation to quality of wheat flour: grain protein content, wet gluten value, gluten index (which describes the ratio of strong gluten to total gluten) and alpha amylase activity are factors that affect on it (Huebner et al., 1997). The gluten is formed about 78-85 percent of total protein in wheat grain, which is composed of gliadin and glutenin. Dough with high glutenin content has good stability and elasticity. In fact, the ratio of glutenin to gliadin determines the quality of dough/bread (Hamada et al., 1982).

Water deficit has significant effect on many biochemical changes in wheat grain (Ashraf, 2010). Genotypes with tolerance to drought stress have higher values of traits related to baking quality. Water deficit and high temperature during post-anthesis and grain filling stages can be reduced accumulation of starch and increase the concentration of protein in the grains that are growing (Sowers et al., 1994; Zhang et al., 2010). There are two sources to supply assimilate for grain filling: (I): Current photosynthesis of leaf, which is the major source and (II): remobilization of storage matter at late period of gain filling. Assimilate availability directly has relationship with leaf photosynthetic activity and decreasing in leaf photosynthesis can be caused the quality and quantity of grain (Kumar et al., 2010). This experiment was conducted to investigate the effects of post-anthesis current photosynthetic limitation and supplemental irrigation on some characteristics related to baking quality in some bread wheat genotypes.

Results

Effects of supplemental irrigation

According to the results, the effect of supplemental irrigation was significant on baking quality traits (P < 0.01) (Table 1). Application of supplemental irrigation reduced the falling number value (9.5%) but increased the amount of parameters related to gluten (Table 2).

Effects of source limitation

All of the baking quality traits were affected by limitation of leaf current photosynthesis (P ≤ 0.01) (Table 1). As be showed (Table 2), under normal photosynthesis conditions the values of baking quality are higher than limited current photosynthesis (Table 2).

Situation of traits between genotypes

The amount of gluten and other traits related to it were differ between genotypes but the falling number had not significant difference between the genotypes (Table 1) (Table 2). The correlation between quantity and quality of gluten (total gluten and gluten index, respectively) was positive and significant (P < 0.94). Also, the falling number had negative correlation with other traits (Table 3).
Discussion

As regards, duration of grain filling has an important role in quality bread of wheat so that using of supplemental irrigation in addition to increasing quantity of wheat (increasing in yield components and final harvested grain), enhances the quality of wheat grain and flour as well. This effect is due to an increase in the grain filling period. Increasing in duration of grain filling causes a rise in the transport of assimilates to grains. Gudeira et al., (2002) and Mary et al., (2001) reported that the water stress has played a key role to reduce the moisture percentage, while it increased protein and gluten contents. Erekul et al., (2012) reported that supplemental irrigation increased the yield of some common wheat cultivars to 58% and also gluten index increased with supplemental irrigation. However, in both trail years the values of protein, gluten index were highest under without supplemental irrigation conditions. The highest falling number values were found for all varieties with non-supplemental irrigation. Moinian et al., (2011), reported that a significant difference was observed between irrigation treatments for seed gluten content. The highest percentage of grain gluten was obtained in treatment severe stress treatment with 9.47% while the lowest percentage of grain was 7.4% in normal irrigation treatment. Norka et al., (2009) stated that although drought has negative effects on yield and yield components, but low amount of aggregation especially during reproductive stages increase gluten percentage. Gutieri et al., (2005) observed that genotype, nitrogen fertilizer and irrigation affected grain protein concentration which differed significantly in their optimum nitrogen levels for grain yield. However, in our previous study we found that water deficit after anthesis reduced gluten index and total gluten between different genotypes and increased falling number values (Jalali-Honarmand et al., 2013). Grain quality is related to supply of assimilates at anthesis and stage after it (Rotundo et al., 2009; Seebauer et al., 2009) and availability of assimilate directly is correlated with photosynthesis activity (Kuanar et al., 2010). This relation is showed in our result. Under limitation of photosynthesis which was applied by spraying

![Figure 1](https://example.com/fig1.png)

**Figure 1.** Relationship between the ratio of wet gluten to total protein content and gluten index.

| Table 1. Analysis of variance for genotypes of bread wheat under supplemental irrigation and source limitation for traits related to baking quality (MS). |
|-----------------|-------|-------|-------|-------|-------|-------|
| S. O. V         | df    | Falling number | Gluten index | Total gluten | Wet gluten | Strong Gluten |
| Supplemental Irrigation | 1     | 13872.0** | 67.7** | 0.36** | 36.7** | 0.63** | 0.52** |
| Error (E_a)     | 2     | 721.0    | 0.4    | 0.01   | 1.0    | 0.002  | 0.16** |
| Source limitation | 1     | 11718.7** | 180.1** | 2.43** | 243.0** | 3.46** | 0.86** |
| Genotypes       | 3     | 911.7**  | 885.6** | 5.78** | 578.7** | 10.26** | 2.49** |
| Supplemental Irrigation * Source limitation | 1     | 4961.3** | 9.2**  | 0.03** | 3.0**  | 0.06** | 0.04** |
| Supplemental Irrigation*Genotypes | 3     | 5835.4** | 0.7**  | 0.007** | 0.7**  | 0.0007** | 0.04** |
| Source * limitation Genotypes | 3     | 4909.7** | 5.2**  | 0.02** | 2.0**  | 0.026** | 0.03** |
| Supplemental Irrigation *Source limitation* Genotypes | 3     | 8266.7** | 1.2**  | 0.02** | 2.0**  | 0.004** | 0.10** |
| Error (E_b)     | 28    | 1289.4   | 4.0    | 0.04   | 4.2    | 0.04   | 0.06   |
| CV (%)          | -     | 10.0     | 3.0    | 4.1    | 4.1    | 5.6    | 7.14   |

ns, * and ** not significant and significant at the 0.05 and 0.01 percent levels of probability, respectively.
of sodium chlorate not only yield and yield components were decreased (not shown), but also quality parameters of grains were decreased. According to the result, the range of wet gluten to protein was between 2.9 (for cv. Karim) to 3.8 (cv. Cross Albourz and Sivand) with gluten index (Fig. 1). In fact, the cultivar of Sivand with highest value of gluten index had highest wet gluten/protein ratio. This result is true for supplemental irrigation and non-source limitation to drought stress and source limitation conditions. This means that not only under well conditions (irrigation and no limitation of photosynthesis) the ratio of wet gluten/protein is high, but also this ratio has positive relationship with quality of flour (gluten index). However, Šimic et al., (2006) reported opposite result. They found that cultivars with highest strong gluten had lowest ratio of wet gluten to protein which the relationship between gluten index and this ratio was positive.

Materials and Methods

Experimental site

The field experiment was conducted as split-plot factorial based on randomized complete block design with three replications in 2012-13 cropping season at Sararod Dryland Research Station, Kermanshah, Iran. The main factors were included: supplemental irrigation at anthesis and grain filling stages and non-supplemental irrigation as control and sub-plots were included: source limitation (current photosynthetic limitation) at 14 days after anthesis on bread wheat genotypes (Karim, Cross Albourz, Sivand and Pishtraz) with non-source limitation. Source limitation was performed by spray of 10 grams per liter of sodium chlorate.

Table 2. Mean comparisons of traits related to baking quality of different bread wheat genotypes under supplemental irrigation and source limitation

<table>
<thead>
<tr>
<th>Genotypes</th>
<th>Falling number (s)</th>
<th>Gluten Index (%)</th>
<th>Total gluten (g)</th>
<th>Wet gluten (%)</th>
<th>Strong Gluten (g)</th>
<th>Wet gluten/Protein</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sivand</td>
<td>374.5</td>
<td>80.5</td>
<td>5.6</td>
<td>56.2</td>
<td>4.5</td>
<td>3.86</td>
</tr>
<tr>
<td>Cross Albourz</td>
<td>369.2</td>
<td>79.2</td>
<td>5.5</td>
<td>55.7</td>
<td>4.1</td>
<td>3.83</td>
</tr>
<tr>
<td>Pishtraz</td>
<td>361.4</td>
<td>69.0</td>
<td>4.7</td>
<td>47.7</td>
<td>3.3</td>
<td>3.31</td>
</tr>
<tr>
<td>Karim</td>
<td>354.7</td>
<td>62.0</td>
<td>4.1</td>
<td>41.7</td>
<td>2.6</td>
<td>2.91</td>
</tr>
<tr>
<td>Lsd 5%</td>
<td>30.02</td>
<td>1.67</td>
<td>0.16</td>
<td>1.17</td>
<td>0.16</td>
<td>0.20</td>
</tr>
</tbody>
</table>

Supplemental Irrigation

+ 347.9 74.0 5.1 51.2 3.8 3.58
- 381.9 71.6 4.9 49.5 3.6 3.37
Lsd 5% 33.32 0.82 0.12 1.24 0.06 0.50

Source Limitation

+ 380.6 70.9 4.8 48.1 3.4 3.61
- 349.3 74.7 5.3 52.6 3.9 3.34
Lsd 5% 21.23 1.22 0.12 1.21 0.12 0.14

Means at least one common letter in each column, based on Least Significant Difference (LSD) test at 5% level are not significant. (+): Application and (-): no Application

Table 3. Simple correlation coefficients between the traits

<table>
<thead>
<tr>
<th>Traits</th>
<th>Falling number</th>
<th>Gluten Index</th>
<th>Total gluten</th>
<th>Wet gluten</th>
<th>Strong Gluten</th>
</tr>
</thead>
<tbody>
<tr>
<td>Falling number</td>
<td>1</td>
<td>-0.16</td>
<td>-0.18</td>
<td>-0.18</td>
<td>-0.18</td>
</tr>
<tr>
<td>Gluten Index</td>
<td>0.94</td>
<td>1</td>
<td>0.94</td>
<td>0.98</td>
<td>0.87</td>
</tr>
<tr>
<td>Total gluten</td>
<td>1.00</td>
<td>1.00</td>
<td>1.00</td>
<td>0.98</td>
<td>0.98</td>
</tr>
<tr>
<td>Wet gluten</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
<td>0.98</td>
</tr>
</tbody>
</table>

The measured traits

The measurements of baking quality traits were done in Seed Technology Laboratory at Departments of Agronomy and Plant Breeding, Campus of Agricultural and Natural Resources, Razi University, Kermansh, Iran.

A) Falling number: The amount of falling number was measured by standard method and was determined based on alpha-amylase activity. The falling number value was read by Falling Number set (1500-Perten) (AACC, 65-81B, 2000).
B) Gluten index: It was based on the Glutomatic Gluten Washer and Gluten Index Centrifuge and measured by Glutomatic System (AACC, 38-12A, 2000).
C) Total gluten (g)= weak gluten (g) + strong gluten (g)
D) Wet Gluten= total gluten x 10
Analyses were done using SAS 9.1 and MSTAT-C Softwares. Differences between means were determined by LSD test at 5% level probability.

Conclusion

Finally, although the grain protein content had not significant different between genotypes (data not shown), under well conditions earned higher yield than stress conditions (data not shown) and the quality of flour was improved.

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References