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# EFFECT OF SUPPLEMENTAL IRRIGATION ON YIELD AND BREAD-MAKING QUALITY OF WHEAT (*Triticum aestivum* L.) VARIETIES UNDER THE MEDITERRANEAN CLIMATICAL CONDITIONS

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**ABSTRACT**

**This study was conducted to determine the suitable irrigation dose (0, 40, 80 and 120 mm) to compansate yield and bread-making quality of four common wheat varieties under the Mediterranean ecological conditions for two years. Grain yields of Pamukova, Sagittario, Fiorino and Golia ranged between 2864 kg ha$^{-1}$ (Golia, 0 mm) and 6021 kg ha$^{-1}$ (Sagittario, 80 mm). The supplemental irrigation caused the grain yield to increase significantly up to 58%. The highest grain yields could be ensured with a supplemental irrigation of 80 mm. The protein content, sedimentation value and gluten index among the bread making quality parameters have been found to be at the highest levels for all varieties in both trial years when no supplemental irrigation has been applied. Increases of gluten index were observed with supplemental irrigations. Optimum levels of quality characteristics were obtained with 80 mm supplemental irrigation which is also suited to the level of the highest grain yield. Thus it could be suggested that in order to combine acceptable quality characteristics with the highest grain yield in the region, a supplemental irrigation up to 80 mm could be applied.**

**Keywords: Wheat, yield, bread-making quality, supplemental irrigation.**

## INTRODUCTION

Wheat (*Triticum spp.* L.) cultivation area has been down to 8.0 million ha in recent years (FAO, 2010). About 75% of wheat produced in Turkey is bread wheat type while the remaining part is durum type. In the Aegean region located in the Western Turkey, wheat yield is mostly higher than that of the other regions of Turkey. The area of wheat cultivation in the Aegean region is approximately 0.8 million ha and grain yield is approximately 3000 kg ha$^{-1}$ including the irrigated and non-irrigated fields. Today wheat is still a strategically important product in human nutrition especially due to its protein. In this respect, protein quality as well as protein content in the grain is highly desirable. Despite the large area of wheat cultivation in Turkey, the locally produced wheats do not always correspond to the standards of the food industry, so wheat with high quality has to be imported. Naturally little attention has been paid to the bread making quality characteristics of wheat varieties in the Aegean region mainly in the province of Aydin.

Most of the research on the climatical effects on grain yield and bread-making quality has been carried out in the temperate climates of the developed countries. Some recent studies have also been conducted on only for yield stability of the bread wheat genotypes in the Aegean region (Ilker et al., 2011a; Ilker et al., 2011b). But additional research should be conducted to study the quality potential of wheat genotypes combined with high yield under the Mediterranean climate such as the Western Turkey covering the Aegean region.

High grain yield and good bread-making quality of wheat are opposite criteria and are influenced by the environmental conditions as well as by the variety, soil, N-fertilization, and the interactions between these factors (Rao et al., 1993; Johansson et al., 2004). As shown by Debaeke et al. (1996) and Feil (1997), yield and quality are negatively correlated. Yield and protein content depend on the weather conditions during the various developmental stages of winter wheat (Johansson et al., 2003). Limited water availability and unfavourable moisture distribution during the main wheat growing period can lead to a high variability in yield and in protein content affecting the bread-making quality (Bonfil et al., 2004).

The apparent negative relationship between yield and grain protein content has been accepted for a long time. Under favorable growing conditions, starch and protein build up simultaneously. Water deficit stress and high temperature during the grain filling period hinder the accumulation of starch in the grain causing a high concentration of protein (Sowers et al., 1994). Late-season moisture stress especially during the grain filling period often prevents starch accumulation in the grain and therefore the test weight of grain declines (Gooding et al., 2003a). If the test weight is lower than 76 kg $hl^{-1}$ (in Turkey) the grains will be used for animal feed. Although sufficient amount of bread wheat is produced in Turkey, desired quality properties cannot be acquired especially in the Aegean region due to climatical effects. In the Mediterranean countries including Turkey, wheat yields are limited by the low water availability due to restricted rainfall, high evapotranspiration, heat stress and the short duration of the grain-filling period so irrigation is important for wheat production (Alexandrov and Hoogenboom, 2000; Yano et al., 2007). Water deficit is the major constraint to crop production in the Western Turkey under the Mediterranean climate. In the Western Turkey rainfall especially in May and June is considerably low and generally poorly distributed, so periods of water deficit and short periods of very high temperature (35 ºC) occur during the grain filling period of wheat. This stage usually covers the periods after flowering and especially during grain filling. Traditionally in the Western Turkey supplemental irrigation to wheat has been applied in the last week of April and in the first week of May. This type irrigation in the region is practiced on about 0.5 million hectares of wheat cultivated area. The average yield obtained in the Aegean region is approximately two times higher than the national average yield (FAO, 2010; TUIK, 2010). However there is no clear information about the amount of supplemental irrigation and on the effects of supplemental irrigation of wheat on yield and especially on bread making quality properties in the region.

The purpose of this study was to determine the effects of supplemental irrigation on yield and bread-making quality of certain wheat varieties in order to find a suitable dose to combine high yield and acceptable quality.

## MATERIALS AND METHODS

Field trial was conducted of the Research and Experimental Farm at the Adnan Menderes University located in the Western Turkey at 37º 44’ N 27º 44’ E at 65 m above sea level in the 2008-2009 and 2009-2010 growing years. The temperature and rainfall means of the growing years are shown in Table 1. Mean annual precipitation (1977–2007) is 648.9 mm and mean annual temperatures (1977–2007) is 17.6 ºC. Average monthly temperatures in the trial year of 2009-2010 were higher than the trial year of 2008-2009 except June and November.

**Table 1.** Monthly mean temperature and total rainfall and long-term mean (1977–2007) during the growing seasons of 2009 and 2010 at the study site in Aydin Province, Turkey

| | Temperature (ºC) | | | Precipitation (mm) | | |
|---|---|---|---|---|---|---|
| Month | 2008-2009 | 2009-2010 | 1977-2007 | 2008-2009 | 2009-2010 | 1977-2007 |
| November | 14.8 | 13.1 | 12.9 | 71.0 | 99.3 | 87.5 |
| December | 10.1 | 11.5 | 9.3 | 96.8 | 176.6 | 110.2 |
| January | 9.2 | 9.9 | 8.3 | 267.4 | 138.9 | 98.7 |
| February | 9.3 | 11.8 | 8.9 | 160.8 | 156.5 | 88.6 |
| March | 11.3 | 13.4 | 11.8 | 87.6 | 23.3 | 71.7 |
| April | 16.1 | 17.1 | 15.8 | 38.4 | 13.9 | 55.5 |
| May | 21.2 | 21.9 | 21.0 | 19.2 | 26.4 | 30.8 |
| June | 26.6 | 24.8 | 26.1 | 0.5 | 24.6 | 15.2 |

The soil texture is classified as sandy loam. A summary of soil chemical properties is presented in Table 2. Four bread wheat (*Triticum aestivum* L.) varieties Pamukova, Sagittario, Fiorino and Golia grown primarily in the Western Turkey were used as plant material. The field trial was arranged in a Randomized Complete Block Design with 4 replications.

**Table 2.** Chemical properties of Soil (Ap-horizon) at the study site in Aydin Province, Turkey

| | Soil Texture (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Horizon | Sand | Silt | Clay | N (%) | P (ppm) | K (ppm) | Ca (ppm) | Mg (ppm) | OM[a] (%) | pH |
| Ap | 66.5 | 23.2 | 10.3 | 0,11 | 18.5 | 363 | 3132 | 306 | 1.3 | 7.8 |

[a]Organic matter.

Additional irrigation of 0, 40, 80 or 120 mm was applied when approximately 50% of the available soil moisture was consumed in the root zone of the wheat. Closed-end furrow irrigation method was used. Irrigation water was supplied from an open channel irrigation system by a pump into the trial area and distributed to the plots through PVC pipelines. The gravimetric method was used to measure soil moisture level (Black, 1965). Plot size was 8m x 2.4 m = 19,2 $m^{-2}$ with row spacing of 20 cm. 500 seeds $m^{-2}$ were seeded by drill machine. Sowing time was between mid-November and beginning of December (05.12.2008 and 27.11.2009). For the phenological growth stages the BBCH-scale was used (BBCH Monograph, 2001). A total of 160 kg $ha^{-1}$ nitrogen fertilizer was distributed uniformly over the whole experimental period as ammonium sulfate (80 kg $ha^{-1}$ at sowing time, + 40 kg ha$^{-1}$ at BBCH 21, beginning of tillering, + 40 kg ha$^{-1}$ at BBCH 31, beginning of shooting). Standard field management (P and K fertilization, weed control and pest management) were carried out in accordance to the nutrient state of the soil and crop development in accord with regional farming practice.

Grain yield was obtained from the harvested 5.6 m$^2$ as the centre rows of the plot. At maturity, yield components (ear number m$^{-1}$, kernels per ear and 1000-kernel-weight) were determined from 1 m$^2$ samples from each plot. Grain test weight was measured on a 250 g sample taken from the harvested plot and expressed as kg hl$^{-1}$. Grain protein was determined on a dry weight basis by near-infrared reflectance spectroscopy (NIRS), using a Perten DA-7200 instrument (Perten Co., Huddinge, Sweden). Kjeldahl test was used for calibration. Quality traits were measured following the Standard Method of the International Association of Cereal Chemistry (ICC, 1986). Wet gluten and gluten index were determined by the ICC standards 137, 155 and 158 using a Glutomatic 2200 instrument (ICC, 1986). Sedimentation values were determined by the Zeleny Sedimentation Test according to the ICC standard 116 (ICC, 1986). The Falling number values were determined according to the ICC standard 107 (ICC, 1986). The data were analyzed using statistical software package SPSS Version 14.0. The Least Significant Differences among means were used at the $P<0.05$ level of probability as described by Steel et al. (1997).

## RESULTS

Grain yield was significantly influenced by the supplemental irrigation in both trial years. In the first year the grain yield depending on irrigation doses and wheat varieties ranged between 3384 kg ha$^{-1}$ (control) and 6021 kg ha$^{-1}$ (Sagittario, 80 mm) and in the second year between 2864 kg ha$^{-1}$ (control) and 5273 kg ha$^{-1}$ (Fiorino, 120 mm) (Table 3). Wheat varieties differed in response to supplemental irrigation. The highest yield was measured with 40 mm supplemental irrigation for Pamukova (5788 kg ha$^{-1}$). 80 mm supplemental irrigation was needed for Golia (5259 kg ha$^{-1}$), Fiorino (5413 kg ha$^{-1}$) and Sagittario (6021 kg ha$^{-1}$) to obtain high yield. The supplemental irrigation increased the grain yield for varieties Pamukova, Sagittario and Golia between 50% and 55%, however the increase was only 24% for the variety Fiorino. Sagittario had higher grain yield (5413 kg ha$^{-1}$) than other varieties. The highest increase of grain yield among all varieties was observed between the 0 mm and the 40 mm water doses. An increase from 40 mm to 80 mm resulted in significant yield increase only in Fiorino (5068 versus 5413 kg ha$^{-1}$) and Golia (4674 versus 5259 kg ha$^{-1}$). In the second year, the highest grain yields were obtained for Pamukova (4811 kg ha$^{-1}$) and Sagittario (5115 kg ha$^{-1}$) at the 80 mm supplemental irrigation, for Fiorino at the 120 mm and for Golia at the 40 mm doses. Beside, the highest yield increases were found to be significant between the 0 mm and the 40 mm supplemental irrigation doses (Table 3). Fiorino reacted to the supplemental irrigation positively in the second year as compared to the first year. In comparison to the previous year yield advantage of Sagittario has decreased remarkably in the second year. In general the variety Golia similar to the previous trial year has resulted in lower yield than the other varieties.

In the first trial year, ear densities ranged between 568 (Fiorino, 0 mm water) and 632 (Golia 120 mm); in the second trial year between 513 (Golia, 0 mm) and 641 (Fiorino, 40 mm) (Table 3). In the first trial year supplemental irrigation for the varieties Pamukova and Sagittario made no positive effects on ear density. But this effect was more remarkable on Golia and Fiorino. The effect of supplemental irrigations on this parameter was more remarkable in the second trial year.

**Table 3.** Grain yield and ear densities of wheat varieties at the given supplemental irrigation water levels, 2009 and 2010

| | **Grain yield (kg ha$^{-1}$)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Supplemental irrigation levels (mm) 2009** | | | | | **Supplemental irrigation levels (mm) 2010** | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 3858 e | 5788 a | 5351 bc | 4818 cd | 4954 | 3409 de | 4442 c | 4811 b | 4581 bc | 4311 |
| Sagittario | 4010 e | 5865 a | 6021 a | 5754 a | 5413 | 3337 e | 4633 bc | 5115 ab | 4976 ab | 4515 |
| Fiorino | 4367 d | 5068 c | 5413 b | 5193 bc | 5010 | 3691 d | 4784 b | 5092 ab | 5273 a | 4710 |
| Golia | 3384 f | 4674 d | 5259 bc | 4879 cd | 4559 | 2864 f | 4535 bc | 4176 c | 4291 c | 3967 |
| Mean | 3905 | 5349 | 5511 | 5161 | 4981 | 3325 | 4599 | 4799 | 4780 | 4376 |
| | LSD (0,05) = 314 | | | | | LSD (0,05) = 307 | | | | |
| | **Ear Density (ears m$^{-2}$)** | | | | | | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 605 bc | 599 bc | 609 bc | 586 c | 600 | 544 c | 612 ab | 582 bc | 590 bc | 582 |
| Sagittario | 616 ab | 625 ab | 629 ab | 622 ab | 623 | 555 c | 589 bc | 616 ab | 633 a | 598 |
| Fiorino | 568 d | 586 c | 593 c | 599 bc | 587 | 561 c | 641 a | 618 ab | 588 bc | 602 |
| Golia | 609 bc | 615 b | 623 ab | 632 a | 620 | 513 d | 552 c | 593 bc | 596 b | 564 |
| Mean | 600 | 606 | 614 | 610 | 607 | 543 | 599 | 602 | 602 | 586 |
| | LSD (0,05) = 16 | | | | | LSD (0,05) = 33 | | | | |

The highest number of kernels per ear was found in the first year for the 80 mm supplemental irrigation (25.4). The highest increases were measured between the 0 mm and the 40 mm water doses and these increases were found to be significant in all varieties with the exception of Fiorino (Table 4). The highest number of kernels per ear was found as 27.3 for Sagittario at the 80 mm irrigation dose. Decreases in all varieties observed at the 120 mm irrigation dose. In the second year of trial, the number of kernels per ear remained generally lower than the previous year and ranged between 15.9 and 24.4. The highest amount was observed for Fiorino at the 120 mm supplemental irrigation dose (24.4). Similar to the first year, the highest increases were observed between the 0 mm and the 40 mm irrigation doses and these increases were also found to be statistically significant except the variety Pamukova. With application of supplemental irrigation, the differences between the number of kernels (of the varieties) were decreased. Similar to the first year, Fiorino and Sagittario, in general, resulted in higher number of kernels than the others.

**Table 4.** Kernel number per ear and 1000-kernel weight of wheat varieties at the given supplemental irrigation water levels, 2009 and 2010

| | Kernels per ear (number of kernels) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Supplemental irrigation levels (mm) 2009 | | | | | Supplemental irrigation levels (mm) 2010 | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 18.2 d | 26.9 ab | 24.3 bc | 23.5 bc | 23.2 | 17.1 cd | 18.9 c | 22.1 b | 20.6 bc | 19.7 |
| Sagittario | 21.4 c | 26.1 ab | 27.3 a | 26.1 ab | 25.2 | 17.8 cd | 22.5 ab | 23.5 ab | 21.9 b | 21.4 |
| Fiorino | 23.7 bc | 24.1 bc | 24.7 bc | 24.3 bc | 24.2 | 18.8 c | 21.5 b | 22.7 ab | 24.4 a | 21.9 |
| Golia | 17.8 d | 22.7 c | 25.1 b | 22.5 c | 22.0 | 15.9 d | 22.0 b | 21.7 b | 21.3 b | 20.2 |
| Mean | 20.3 | 25.0 | 25.4 | 24.1 | 23.7 | 17.4 | 21.2 | 22.5 | 22.1 | 20.8 |
| | LSD (0,05) = 2.1 | | | | | LSD (0,05) = 1.9 | | | | |
| | **1000-kernel weight (g)** | | | | | | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 37.2 ab | 38.0 ab | 38.3 ab | 37.2 ab | 37.7 | 17.1 cd | 18.9 c | 22.1 b | 20.6 bc | 39.6 |
| Sagittario | 32.9 c | 38.1 ab | 37.2 ab | 37.7 ab | 36.5 | 17.8 cd | 22.5 ab | 23.5 ab | 21.9 b | 37.7 |
| Fiorino | 34.7 bc | 38.0 ab | 39.0 a | 37.8 ab | 37.4 | 18.8 c | 21.5 b | 22.7 ab | 24.4 a | 37.9 |
| Golia | 34.2 c | 35.7 bc | 35.8 bc | 36.4 b | 35.5 | 15.9 d | 22.0 b | 21.7 b | 21.3 b | 36.8 |
| Mean | 34.8 | 37.5 | 37.6 | 37.3 | 36.8 | 36.5 | 38.8 | 38.3 | 38.4 | 38.0 |
| | LSD (0,05) = 1.9 | | | | | LSD (0,05) = 1.3 | | | | |

In the first trial year 1000-kernel weight of the varieties ranged between 32.9 (Sagittario) and 39.0 g (Fiorino). The highest 1000-kernel weight was found at the 80 mm dose for Fiorino (Table 4). Only Sagittario and Fiorino showed significant increases between the 0 mm and the 40 mm irrigation doses. The supplemental irrigations as 40 mm, 80 mm and 120 mm) did not significantly increase 1000-kernel weight of the varieties. In the second year somewhat higher 1000-kernel weights as compared to first year were measured. The highest 1000-kernel weight was for Pamukova at the 40 mm dose of supplemental irrigation. Similar to the previous year the lowest 1000-kernel weight was measured for Sagittario at the 0 mm irrigation dose. In this trial year significant increases in Sagittario, Fiorino and Pamukova were observed between the 0 mm and the 40 mm irrigation doses. Pamukova resulted in significantly higher 1000-kernel weight than that of the other varieties at all supplemental irrigation.

Test weights of the varieties ranged between 78.1 kg $hl^{-1}$ (Fiorino, 40 mm) and 83.1 kg $hl^{-1}$ (Golia, control) in the first trial year (Table 5). The high test weight values were found for the supplemental applications. Golia had high test weight for the 0 mm dose and this difference in often was statistically significant. The test weights ranged between 79.6 kg $hl^{-1}$ (Fiorino the 120 mm dose) and 83.3 kg $hl^{-1}$ (Sagittario the 0 mm dose) in the second trial year. Significant differences among test weight means among the water doses for the varieties could be seen.

In the first trial year grain protein content ranged between 12.4% and 14.7% (Table 6). The highest protein content was for the 0 mm dose of supplemental irrigation. With supplemental irrigation, reductions in the protein contents are expected. Even at the same doses some significant differences among the protein content of varieties were found. In the second trial year the protein contents ranged between 11.7% and 14.9% (Table 6). Similar to the first trial year, protein contents of varieties without supplemental irrigation were found significantly higher than the values obtained from the supplemental irrigations. Similar to the first year, among same irrigation doses, significant differences among the varieties were found.

Sedimentation values of the varieties at different supplemental irrigation doses ranged between 27 ml (Pamukova the 40 mm dose) and 37 ml (Sagittario the 0 mm dose) (Table 7). A significant decrease in sedimentation values was observed between the 0 mm and the 40 mm irrigation doses. The applied supplemental

**Table 5.** Test weight of wheat varieties at the given supplemental irrigation water levels, 2009 and 2010

| | Test weight (kg $hl^{-1}$) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Supplemental irrigation levels (mm) 2009 | | | | | Supplemental irrigation levels (mm) 2010 | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 80.2 d | 78.9 ef | 79.4 e | 79.7 de | 79.6 | 81.2 c | 81.0 cd | 81.7 bc | 82.3 b | 81.6 |
| Sagittario | 82.7 ab | 81.6 c | 81.3 c | 82.2 b | 82.0 | 83.3 a | 82.4 ab | 82.4 ab | 81.9 bc | 82.5 |
| Fiorino | 79.8 de | 78.1 f | 78.5 f | 79.0 ef | 78.9 | 80.7 cd | 80.2 d | 81.1 cd | 79.6 d | 80.4 |
| Golia | 83.1 a | 82.3 b | 81.8 bc | 82.6 ab | 82.5 | 82.3 b | 81.4 bc | 81.0 cd | 81.9 bc | 81.7 |
| Mean | 81.5 | 80.2 | 80.3 | 80.9 | 80.7 | 81.9 | 81.3 | 81.6 | 81.4 | 81.5 |
| | LSD (0,05) = 0.5 | | | | | LSD (0,05) = 0.9 | | | | |

**Table 6.** Grain protein content of wheat varieties at the given supplemental irrigation water levels, 2009 and 2010

| | Grain protein content (%) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Supplemental irrigation levels (mm) 2009 | | | | | Supplemental irrigation levels (mm) 2010 | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 14.7 a | 12.9 c | 13.7 b | 13.2 bc | 13.6 | 14.3 b | 13.3 d | 13.4 cd | 13.8 c | 13.7 |
| Sagittario | 14.4 ab | 12.9 c | 13.6 b | 12.9 c | 13.5 | 14.9 a | 13.8 c | 13.2 d | 13.2 d | 13.8 |
| Fiorino | 13.8 b | 13.2 bc | 13.5 bc | 12.4 c | 13.2 | 12.9 d | 12.2 e | 12.4 e | 11.7 f | 12.3 |
| Golia | 14.3 ab | 13.7 b | 13.6 b | 13.8 b | 13.9 | 14.8 a | 13.4 cd | 13.1 d | 13.9 bc | 13.8 |
| Mean | 14.3 | 13.2 | 13.6 | 13.0 | 13.5 | 14.2 | 13.2 | 13.0 | 13.2 | 13.4 |
| | LSD (0,05) = 0.6 | | | | | LSD (0,05) = 0.4 | | | | |

irrigation doses similar to the above given two quality parameters did not show any positive effect on the sedimentation values of the varieties. Significant differences among the sedimentation values of the varieties appeared at the same irrigation doses. Especially Sagittario resulted in significantly higher sedimentation values. In the second trial year, although not significant reactions of varieties to the irrigation doses in terms of sedimentation values showed similarity to the first year (Table 7).

**Table 7.** Sedimentation value, wet gluten content and gluten index of wheat varieties at the given supplemental irrigation water levels, 2009 and 2010

| | Sedimentation value (ml) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Supplemental irrigation levels (mm) 2009 | | | | | Supplemental irrigation levels (mm) 2010 | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 31 d | 27 f | 28 ef | 28 ef | 29 | 32 b | 29 c | 29 c | 31 bc | 30 |
| Sagittario | 37 a | 35 b | 34 bc | 35 b | 35 | 35 a | 35 a | 34 ab | 33 ab | 34 |
| Fiorino | 33 c | 32 cd | 30 de | 32 cd | 32 | 33 ab | 30 bc | 31 bc | 31 bc | 31 |
| Golia | 33 c | 30 de | 29 e | 30 de | 31 | 34 ab | 32 b | 30 bc | 32 b | 32 |
| Mean | 34 | 31 | 30 | 31 | 31 | 34 | 32 | 31 | 32 | 32 |
| | LSD (0,05) =1.0 | | | | | LSD (0,05) = 2.0 | | | | |
| | **Wet gluten content (%)** | | | | | | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 30.3 c | 27.2 ef | 28.7 d | 29.4 cd | 28.9 | 29.8 c | 28.1 d | 27.8 d | 29.2 cd | 28.7 |
| Sagittario | 34.4 a | 30.9 bc | 31.2 bc | 31.7 b | 32.1 | 33.3 a | 32.7 a | 32.2 ab | 31.4 b | 32.4 |
| Fiorino | 29.0 d | 27.6 e | 26.5 f | 28.4 de | 35.2 | 29.5 cd | 28.4 d | 29.1 cd | 27.5 d | 28.6 |
| Golia | 33.7 a | 29.8 cd | 29.1 d | 30.2 c | 30.7 | 32.7 a | 30.6 bc | 29.8 c | 31.5 b | 31.2 |
| Mean | 31.9 | 28.9 | 28.9 | 29.9 | 29.9 | 31.3 | 30.0 | 29.7 | 29.9 | 30.2 |
| | LSD (0,05) = 0.9 | | | | | LSD (0,05) = 1.1 | | | | |
| | **Gluten index (%)** | | | | | | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 88 b | 89 b | 90 ab | 90 ab | 89 | 90 b | 92 a | 92 a | 91 ab | 91 |
| Sagittario | 84 d | 86 c | 86 c | 86 c | 86 | 84 d | 86 c | 85 cd | 85 cd | 85 |
| Fiorino | 82 e | 82 e | 83 de | 82 e | 82 | 80 e | 80 e | 81 e | 83 d | 81 |
| Golia | 89 b | 90 ab | 91 a | 90 ab | 90 | 90 b | 92 a | 92 a | 91 ab | 91 |
| Mean | 86 | 87 | 88 | 87 | 87 | 86 | 88 | 88 | 88 | 87 |
| | LSD (0,05) = 1.0 | | | | | LSD (0,05) = 1.0 | | | | |

The highest values of wet gluten content were found for the 0 dose similar to the previously given quality traits. Significant decreases in wet gluten contents were found between the 0 mm and the 40 mm doses for all varieties (Table 7). Even at the same irrigation dose significant differences among the varieties were found. Sagittario resulted in significantly higher wet gluten means at all irrigation doses than the remaining varieties except Golia (34,4 versus 33,7). In the second year of the study the wet gluten content of the varieties showed similarities with the first year. However decreases between the 0 mm and the 40 mm irrigation doses were not significant as the previous year. Gluten index values of the varieties ranged between 82% (Fiorino; 0, 40 and 120 mm) and 91% (Golia, 80 mm) (Table 7). The gluten indices were lower for the 0 dose. But it could be seen that gluten index, was less influenced by the irrigation doses as compared to other quality traits. Some significant differences for gluten index among the varieties were found. Pamukova and Golia produced significantly more gluten index values than Sagittario and particularly Fiorino. In the second trial year the means of the varieties at the irrigation doses showed similarities with the previous year (Table 7).

Falling number values ranged between 315 (Sagittario, 120 mm) and 384s (Fiorino the 0 dose) in the first trial year (Table 8). The effect of supplemental irrigation on this trait was not significant. Falling number values of Fiorino were found higher than those of the other varieties. In the second trial year the highest falling number values for all varieties were found for the 0 dose.

**Table 8.** Falling number of wheat varieties at the given supplemental irrigation water levels, 2009 and 2010

| | **Falling number (s)** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **Supplemental irrigation levels (mm) 2009** | | | | | **Supplemental irrigation levels (mm) 2010** | | | | |
| **Variety** | **0** | **40** | **80** | **120** | **Mean** | **0** | **40** | **80** | **120** | **Mean** |
| Pamukova | 358 b | 370 ab | 331 c | 336 bc | 349 | 372 ab | 347 bc | 359 bc | 331 cd | 352 |
| Sagittario | 343 bc | 338 bc | 347 bc | 315 c | 336 | 356 bc | 323 cd | 311 d | 338 c | 332 |
| Fiorino | 384 a | 351 bc | 363 ab | 355 bc | 363 | 393 a | 352 bc | 350 bc | 338 c | 358 |
| Golia | 370 ab | 346 bc | 333 c | 327 c | 344 | 366 b | 341 c | 310 d | 303 d | 330 |
| Mean | 364 | 351 | 344 | 333 | 348 | 372 | 341 | 333 | 328 | 343 |
| | LSD (0,05) = 24 | | | | | LSD (0,05) = 23 | | | | |

## DISCUSSION

Insufficient rainfalls during the grain filling period in the Mediterranean climates similar to the Aegean region in the Western Turkey affect grain yield negatively (Erekul et al., 2011). Also it is expected that the global warming will occur between April and September in the coming years in the Western part of Turkey (Özkul, 2009). Therefore, the impact of global warming on wheat production in the Mediterranean region of Turkey will have a great importance in the future. Due to expected global warming and the need of more irrigation for new wheat varieties will increase, the need of extra water in wheat production especially in April and May arise (Araus et al., 2002).

In this study the supplemental irrigation was applied at the beginning of May, increased the yield of the wheat varieties grown significantly. By applying the irrigation dose of 40 mm, the highest yield increase was obtained. This appeared much more remarkable as the rainfalls were much lower than the long term means particularly in March and April in 2010. Grain yield of Sagittario, in general was higher than other varieties since the conditions of growth and development are improved by the supplemental irrigation. Similar results for Sagittario were also reported by Tatar (2011). When the two years were considered under the current ecological conditions, the grain yield should be in peak values -except in 2010 Fiorino- with the supplemental irrigation of the 40 mm dose and the 80 mm dose. Thus it could be concluded that a supplemental irrigation of 40 mm and 80 mm were sufficient. The main reason apparently higher yield of all varieties without irrigation in the 2008-2009 wheat growing year as compared to 2009-2010 growing year could be high precipitation occurred especially in March and April. Our study showed that supplemental irrigation of 40 mm and 80 mm doses during the grain filling period could guarantee double the average wheat yield in Aydin province. Suitable weather conditions for wheat growing particularly after the tillering (BBCH 21), till shooting (BBCH 31) and beginning of inflorescence emergence (BBCH 51); ear densities were found at the desired levels in two trial years. However due to the decreases in rains occurred in the months of March and April in 2010, effect of the supplemental irrigation on this trait was higher than the first trial year. The reason of the reduced development of ears especially in the 0 doses in 2010 could be the water deficit stress combined with high temperatures during the period of shooting (BBCH 31), till ear emergency (BBCH 55), which is the decisive period for the reduction of plants and for the reduction of already initialized and developed tillers (Gupta et al., 2001). In the periods of spikelet and flower formation, favourable climatical conditions might cause high number of grains per ear (Wollenweber et al., 2003). The unfavourable weather conditions in 2010 during the periods of spikelet and flower formation might cause some reductions in the number of kernels per ear resulting in increase in 1000-kernel weight. Low kernel number per ear especially in the 0 dose might result in larger wheat grains due to the compensatory reactions among yield components. Pamukova might have genetic capacity to have high 1000-kernel weight even without irrigation. Golia might have some different genotypic make up so benefited less from the supplemental irrigation than the others except Pamukova. Test weight is used to indicate the density and soundness of the wheat grain. Test weights of the varieties in both trial years have been above the value of 78 kg $hl^{-1}$ suited to expected average (Mason et al., 2007).

The quality of wheat grain is a combination of some physical and chemical characteristics. Their expression depends on their genetic nature as well as the influence of environment (Johansson, 2002; Johansson et al., 2004). Without supplemental irrigation low grain yield obtained in both trial years with high protein content. Similar results were reported by Saint Pierre et al. (2008). With the application of supplemental irrigation, the protein content of the varieties begins to decrease as expected. The rainfall induced vegetative period and this resulting in shortens generative period, insufficient grain formation and reduced grain yields (Tahir and Nakata, 2005). In this study in 2010 non-irrigated plots had higher protein contents in the grain similar to earlier reports (López-Bellido et al., 1998). Also Gooding et al. (2003b) discussed that high temperatures and water stress may lead to increased grain protein content.

The sedimentation value indicating swelling capacity of gluten, exceeded well the accepted value (20 ml) for bread-making wheat in all varieties. In general, sedimentation values ranged between 28 and 37 ml. Different water doses caused considerable differences. The high sedimentation values obtained for the 0 dose plots might be due to higher protein contents and is in agreement with Saint Pierre et al. (2008). In accordance with the results of Gooding and Davies (1997) dry and hot weather (above 30 ºC) toward the end of grain filling might have affected protein fractions, resulting in low to medium sedimentation values. The genotype x environment interactions might also affect sedimentation value so they should be studied in several locations for several years in the future. Generally wet-gluten contents of approximately > 26% were in the middle to high level. In two trial years the highest wet gluten contents were measured with non supplemental irrigation similar to the previous year. Especially in the first trial year the supplemental irrigation caused sharp decreases in gluten contents. Similar results were also reported by Shahryari et al. (2011). This situation indicated that some losses certainly happen in the quality characteristics of bread wheat varieties with additional supplemental irrigation. While some decreases in wet gluten content with the supplemental irrigation were found, significant differences among the varieties were also observed in both trial years. Particularly Sagittario with comparable high values for this trait is in agreement with the results of Kahriman (2007).

Gluten-index has been introduced as a better trait for wheat processing quality, rather than the wet-gluten content (Deng et al., 2005). However the gluten index is still a new, and yet seldom used characteristics in evaluating bread-making quality; little information is available on the relationship between the gluten index and other indices, or about the influence of environment on the gluten-index (Johansson et al., 2002). Curic et al. (2001) reported optimum values between 75 and 90%. In our study the gluten index values of the varieties were found to be above 80 %. Pamukova and Golia showed gluten-index values of 90% and more. It could be concluded that this trait was affected by the variety rather than the irrigation doses. Considering the previous studies, high protein and gluten contents might cause lower gluten index values (Garrido-Lestache et al., 2004; Johansson et al., 2004). In this study high protein and high gluten contents for the 0 dose of irrigation were found, although the gluten index values were lower.

The falling numbers, representing the enzymatic state of the grain and the degree of pre-harvest sprouting and thereby estimating the expected baking volume, had the optimum range from 220–250 seconds for wheat (Gooding and Davies, 1997). This optimal range exceeded by all the tested wheat genotypes in two years and indicates a flour poor in enzymes. Values being over the 300 s in two years showed the climatic characteristic of the environmental conditions. In this study irrigation doses did not have remarkable effect on falling number values although by applying the irrigation dose 80 mm and over a decrease in falling number values was observed. This situation might be due to the high humidity caused by the microclimate formed in wheat plots as a result of high temperature in that period. Since the high rate of humidity and high rainfall during the starch formation period might cause the falling number values to decrease (Gooding et. al., 2003a). The remarkable differences obtained among the genotypes are in agreement with (Johansson, 2002).

## CONCLUSION

Insufficient rainfall especially in the late spring period limits wheat production in the Mediterranean countries. Western Turkey will have constraints in wheat production in future due to water deficits in spring and summer due to the expected climatic changes. Based on the results of this study it could be concluded that the supplemental irrigation of maximal 80 mm practiced in the beginning of May is sufficient for the high grain yields. Without additional irrigation, the lowest grain yields were obtained for tested varieties but their quality traits were high. However the results of quality characteristics indicated that yield and quality could be combined in a suitable way. The values of protein content, sedimentation value and gluten index have been found at high level for the varieties in the two trial years without supplemental irrigation. On the other hand the high values of gluten index were found at the high irrigation doses. The best yield and acceptable quality could be obtained at the 80 mm supplemental irrigation. Thus it could be concluded that in order to have the desired bread making quality characteristics combined with the high grain yield in the region, a supplemental irrigation such as the 80 mm (at flowering / beginning of grain filling period) could be recommended.

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## LITERATURE CITED

Alexandrov, V.A., G. Hoogenboom, 2000. The impact of climate variability and change on crop yield in Bulgaria. Agr. Forest Meteorol. 104:315-327.

Araus, J.L., G.A. Slafer, M.P. Reynolds, C. Royo, 2002. Plant breeding and drought in $C_3$ cereals: What should we breed for? Ann. Bot. 89:925-940.

BBCH Monograph, 2001. Growth stages of mono-and dicotyledonous plants. Federal Biological Research Centre for Agriculture and Forestry. Edited by U. Meier, 2. Edition.

Black, C.A., 1965. Methods of Soil Analysis: Part I Physical and mineralogical properties. American Society of Agronomy, Madison, Wisconsin, USA.

Bonfil, D.J., A. Karnieli, M. Raz, I. Mufradi, S. Asido, H. Egozi, A. Hoffman, A. Schmilovitch, 2004. Decision support system for improving wheat grain quality in the Mediterranean area of Israel. Field Crop Res. 89:153-163.

Curic, D., D. Karlovic, D. Tusak, B. Petrovic, J. Dugum, 2001. Gluten as a standard of wheat flour quality. Food Technol. Biotech. 39:353–361.

Deng, Z.Y., J.C. Tian, G.X. Sun, 2005. Influence of high molecular weight glutenin subunit substitution on rheological behaviour and bread-making quality of near-isogenic lines developed from Chinese wheats. Plant Breeding. 124:428–431.

Debaeke, P., T. Aussenac, J.L. Fabre, A. Hilaire, B. Pujol, L. Thuries, 1996. Grain nitrogen content of winter bread wheat (*Triticum aestivum* L.) as related to crop management and to the previous crop. Eur. J. Agron. 5:273-286.

Erekul, O., I. Bräsemann, K.P. Götz, H. Herzog, 2011. Ertragsverhalten und Qualität von mediterranen und mitteleuropäischen Weizensorten unter verschiedenen klimatischen Bedingungen. Mitt. Ges. Pflanzenbauwiss. 23:252-253.

FAO, 2010. http://faostat.fao.org/site/567/default.aspx#ancor

Feil, B., 1997. The inverse yield-protein relationship in cereals: possibilities and limitations for genetically improving the grain protein yield. Trends Agron. 1:103–119.

Garrido-Lestache, E., R.J. López-Bellido, L. López-Bellido, 2004. Effect of N rate, timing and splitting and N type on bread-making quality in hard red spring wheat under rainfed Mediterranean conditions. Field Crop Res. 85:213-236.

Gooding, M.J., W.P. Davies, 1997. Wheat Production and Utilization. CAB International, Wallingford, UK.

Gooding, M.J., R.H. Ellis, P.R. Shewry, J.D. Schofield, 2003a. Effects of restricted water availability and increased temperature on the grain filling, drying and quality of winter wheat. J. Cereal Sci. 37:295-309.

Gooding, M.J., G. Smith, W.P. Davies, P.S. Kettlewell, 2003b. The use of residual maximum likelihood to model grain quality characteristics of wheat with variety, climatic and nitrogen fertilizer effects. J. Agr. Sci. 128:135-142.

Gupta, N.K., S. Gupta, A. Kumar, 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.

Ibanoglu, S., 2001. Influence of tempering with ozonated water on the selected properties of wheat flour. J. Food Engineering, 48:345-350.

International Association of Cereal Chemistry (ICC), 1986. Standard methods of the ICC.

ICC, Vienna.

Ilker, E., O. Tatar, F.A. Tonk, M. Tosun, 2011a. Determination of Tolerance Level of Some Wheat Genotypes to Post-Anthesis Drought. Turkish Journal of Field Crops, 2011, 16(1): 59-63.

Ilker, E., H. Geren, R. Unsal, I. Sevim, F.A. Tonk, M. Tosun, 2011b. Ammi-Biplot Analysis of Yield Performances of Bread Wheat Cultivars Grown at Different Locations. Turkish Journal of Field Crops, 2011, 16(1): 64-68.

Johansson, E., (2002). Effect of two wheat genotypes and Swedish environment on falling number, amylase activities, and protein concentration and composition. Euphytica, 126: 143-149.

Johansson, E., H. Nilsson, H. Mazhar, J. Skerritt, F. MacRitchie, G. Svensson, 2002. Seasonal effects on storage proteins and gluten strength in four Swedish wheat cultivars. J. Sci. Food Agr. 82:1305–1311.

Johansson, E., M.L. Prieto-Linde, G. Svensson, 2004. Influence of nitrogen application rate and timing on grain protein composition and gluten strength in Swedish wheat cultivars. J. Plant Nutr. Soil Sc. 167:345-350.

Kahriman, F., 2007. Determination of quality and yield levels of some bread wheat cultivars. Canakkale University Institute for Natural Sciences M. Sc. Thesis, 37pp.

Karaoglu, M.M., 2011. Dough characteristics of wheat flour milled from wheat grains stored in spike form. Int. J. Food Sci. Technol. 46:1905-1911.

Larsson, H., A.C. Eliasson, 1996. Phase separation of wheat flour dough studied by ultracentrifugation and stress relaxation: influence of water content. Cereal Chem. 73:18-24.

Linlaud, N.E., M.C. Puppo, C. Ferrero, 2009. Effect of hydrocolloids on water absorption of wheat flour and farinograph and textural characteristics of dough. Cereal Chem. 86:376–382.

López-Bellido, L., M. Fuentes, J.E. Castillo, F.J. López-Garrido, 1998. Effects of tillage, crop rotation and nitrogen fertilization on wheat-grain quality grown under rainfed Mediterranean conditions. Field Crop Res. 57:265-276.

Mason, H., A. Navabi, B. Frick, J. O'Donovan, D. Niziol, D. Spaner, 2007. Does growing Canadian Western Hard Red Spring wheat under organic management alter its breadmaking quality? Renew. Agr. Food Syst. 22:157–167.

Özkul, S., 2009. Assessment of climate change effects in Aegean river basins: the case of Gediz and Buyuk Menderes Basins. Climatic Change, 97:253–283.

Özmutlu, O., G. Sumnu, S. Sahin, 2001. Assessment of proofing of bread dough in the microwave oven. Eur. Food Res. Technol. 212:487-490.

Rao, A.C.S., J.L. Smith, V.K. Jandhyala, R.I. Papendick, J.F. Parr, 1993. Cultivar and climatic effects on the protein content of soft white winter wheat. Agron. J. 85:1023-1028.

Saint-Pierre, C., C.J. Peterson, A.S. Ross, J.B. Ohm, M.C. Verhoven, M. Larson, B. Hoefer, 2008. Winter wheat genotypes under different levels of nitrogen and water stress: Changes in grain protein composition. J. Cereal Sci. 47:407-416.

Shahryari, R., M. Valizadeh, V. Mollasadeghi, 2011. Evaluation of irrigation levels and its impact on quality and quantity performance of wheat. Adv. Environ. Biol. 5:528-534.
Sowers, K.E., B.C. Miller, W.L. Pan, 1994. Optimizing grain yield in soft white winter wheat with split nitrogen applications. Agron. J. 86:1020-1025.
Steel, R.G. D., J. H. Torrie, D. A. Dickey, 1997. Principles and Procedures of Statistics. A biometrical approach. 3rd Ed., McGraw Hill Book, INC., New York, USA.
Tahir, I.S., A.N. Nakata, 2005. Remobilization of nitrogen and carbohydrate from stems of bread wheat in response to heat stress during grain filling. J.Agron.Crop Sci. 191:106-115.
Tatar, Ö., 2011. Physiological regulation of drought stress related with yield components of some wheat cultivars. Ege University Institute for Natural Sciences Ph. D. Thesis, 119 pp.
TUIK, 2010. Statistical Foundation of Turkey. http://www.tuik.gov.tr/bitkiselapp/bitkisel.zul Access date: 02 April 2012.
Wollenweber, B., J.R. Porter, J. Schellberg, 2003. Lack of interaction between extreme high temperature events at vegetative and reproductive growth stages in wheat. J. Argon. Crop Sci. 189:142-150.
Yano, T., M. Aydin, T. Haraguci, 2007. Impact of climate change on irrigation demand and crop growth in a Mediterranean Environment of Turkey. Sensors, 7:2297-2315.