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Periodic Variation of the Water Use Efficiency in Durum Wheat

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Abstract: Water Use Efficiency (WUF) of five durum wheat varieties (Khiar, Karim, Nasr, Razzak and Sobirano) cultivated in Tunisia was investigated. The experiment was conducted under rainfed field conditions, irrigated pots and test tubes at ESA Kef experiment station during the cropping season of 2010-2011. Under rainfed conditions, Khiar has the highest grain yield with 29.35 q ha^{-1}. Biological WUE ranged from 1.72-1.49 mg dry matter per g of water for Razzak and Nasr, respectively. The WUE of grain ranged from 0.81-0.48 mg grain per g of water for Khiar and Sobirano, respectively. Biological WUE showed positive correlation to grain yield and stomatal density and negatively correlated with leaf area. Periodic water use efficiency in pot and test tube trials indicated variation of wheat genotypes according to stage periods and how the experiment was conducted. Test tubes trials showed high, accurate and maximum value of water use. Therefore, we can consider that Khiar has a high WUE in the first period; germination-early tillering (6.70 mg dry matter per g water). Nasr and Sobirano valorise well had got water use during the second period; tillering (9.16 and 10.20 mg dry matter per g of water). Razzak shows a high WUE for the third period; booting-early heading (9.06 mg dry matter per g of water). Finally, Karim cultivar has the highest WUE during for the fourth period; heading-physiological maturity (22.13 mg dry matter per g of water). Periods of high WUE can be targeted for appropriate time of wheat cultivar irrigation.

Key words: Durum wheat, water use efficiency, dry matter, yield

INTRODUCTION

Water is the main limiting factor for crop production particularly in the Mediterranean region. According to Ragab and Prudhomme (2002), precipitation amounts in North Africa countries would be reduced by 20-50% compared to current averages with limited water resources for crop irrigation that can alleviate problems related to drought.

Cereals have dominated the Mediterranean region, from time immemorial (Harlan, 1992). Indeed, cereals have been important in the Mediterranean region since Biblical times with indications that inherent physiological yielding potential may not have been altered substantially over the millennia (Amir and Sinclair, 1994) of the cereals, wheat is dominant, with bread wheat for flour and durum wheat for pasta, couscous and burghoul supplying human nutritional needs (Ryan *et al*., 2009).

Wheat is a major crop species cultivated in the Mediterranean region with many cultivars that differ in their tolerance to drought expressed by continuous adjustments between available water, crop needs and its ability to develop specific water requirements (Benseddik and Benabdelli, 2000).

Regardless of tolerance strategies, some authors suggest that the maintenance of efficient water use during high decrease in soil water availability could contribute to the mechanisms of drought tolerance (McKay *et al*., 2001; Dawson *et al*., 2002; Jones, 2004). According to this hypothesis, a high efficiency of water use could then offer a significant advantage in improving crop productivity in drought-prone areas (Braatne *et al*., 1992; Araus *et al*., 2002; Condon *et al*., 2002; Rebetzke *et al*., 2002; Cao *et al*., 2007). However, the relationship between efficiency of water use and drought tolerance in wheat are still unclear and few studies have attempted to clarify it.

WUE definitions differ according to scientific disciplines:

- From the agronomic point of view, the efficiency of water use by the crop is defined as the ratio of harvested yield (grain, total biomass, sugar beet pivot, etc) and water used to achieve this production per unit area (Bouaziz and Elmourid, 1999). Thus,

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there is a conversion of water by plants biomass through photosynthesis. The WUE is the ratio of crop performance to receive rain during the crop cycle

- For crop-physiologists, Water Use Efficiency (WUE) is defined as the ratio of carbon gain to water loss (Gregory, 1988). The efficiency of water use can be studied at the ecosystem scale (this is the carbon gain of the ecosystem by evapotranspiration (Law *et al*., 2002) or the plant scale

It takes 520-700 tons of water to produce one ton of dry matter for C3 plants (wheat, peas, sunflower), while it takes 300-370 tons for the same production for C4 plants such as sorghum and amaranth (Lecoeur, 2007).

Several environmental factors such as rainfall and temperature affect wheat production in different development stages. In semi arid environments, WUE of cultivated crop species has become more appropriate to make better use of limited water resources. For this purpose, we have to evaluate and select more efficient genotypes from a limited range of variety of durum wheat varieties. The relationship between the efficiency of water use and agronomic parameters and the efficiency of water use and morphological parameters can give us an idea on wheat varieties with better potential of water use efficiency. Finding WUE periods in pots and test tubes trials can identify the best development stage to maximize variety efficiency of water consumed per gram produced.

MATERIALS AND METHODS

Durum wheat varieties used to evaluate water use efficiency are Khiar, Karim, Nasr, Sobirano and Razzak.

The field study was conducted in the Kef region, located in the northwest of Tunisia, under a Mediterranean climate, characterized by a cold and wet winter, warm and dry summer. Spring and autumn are mild intermediate for moisture rather than temperature. Area's climate is considered semi-arid with cold winters.

The rainfall in this region varies from 200 mm during dry years to 600 mm during wet years with an annual average of 460 mm (Table 1).

Water use efficiency tests for five varieties of durum wheat were conducted at ESAK under three different conditions:

Test 1: Open field under rain fed conditions
Test 2: Pots under controlled green house conditions
Test 3: Test tubes in the laboratory

The experimental design adopted for the three tests is a "randomized complete block design" with three replications (SAS Software).

Table 1: Monthly rainfall and temperature recorded at the experiment site of Boulifa during the cropping season of 2010-2011

	Months								
Parameters	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May
Rainfall (mm)	40.2	51.8	89.6	16.2	48.6	107.6	49.0	39.8	100.9
T max (°C)	29.5	25.3	18.8	16.2	14.8	13.3	16.6	22.4	25.0
T min (°C)	15.6	12.1	8.7	4.2	3.5	3.2	5.4	8.4	11.2

Meteorological office of Boulifa, Kef

Field experiment: Seeding was done on the 24th of December 2010 in the experimental plot of the College of Agriculture of Kef (ESAK). Each variety was planted in an experimental unit of 2 m^2.

Weeding was manually done. Nitrogen (NH_4NO_3) supply of 2 g per pot was twice manually, applied after emergence and jointing.

Pots experiment: Seeding was done on the 18th of December, 2010 by an average of 6 grains per pot distributed in an equidistant way. Before seeding, all pots were water saturated and allowed to drain overnight to acquire the weight to field capacity. The pots were maintained at field capacity by irrigation. The level of water in the soil was carried out by consecutive pots weighed every three days.

The quantities of water applied in each pot were equal to the water lost by evapotranspiration. This test was conducted in a green house with a temperature of 25°C and 20000 lux light during the day and 15°C at night (Fig. 1).

Test tubes: Seeds were placed on filter paper in petri dishes (Fig. 2). They were germinated in a growth chamber at a temperature between 15 and 16°C. When the coleoptile reached a length of 2-3 cm (10 days), plants were transplanted into test tubes containing 30 mL of a nutrient solution KNOP (KNO_3, $MgSO_4$, KH_2PO_4, traces of iron). To avoid the accumulation of mineral elements in the bottom of the tubes and their concentration around the roots, we have conducted a bubbling air promoting mixing of the solution and oxygen enrichment. It was also necessary to replace the solution by a new one at least once a month. Watering was done every week with a graduated pipette. This technique allows calculating with precision the exact quantities of water used by transplanted plants.

For each variety, WUE has been obtained by ratio of grain yield or biological yield to water consumption (Rezgui *et al*., 2000). All definitions share a water exchange against a production unit:

- WUE to produce biomass and grain in field conditions was determined by the ratio of biomass

Fig. 1(a-c): Pots experiment conducted in a growth chamber at different stages

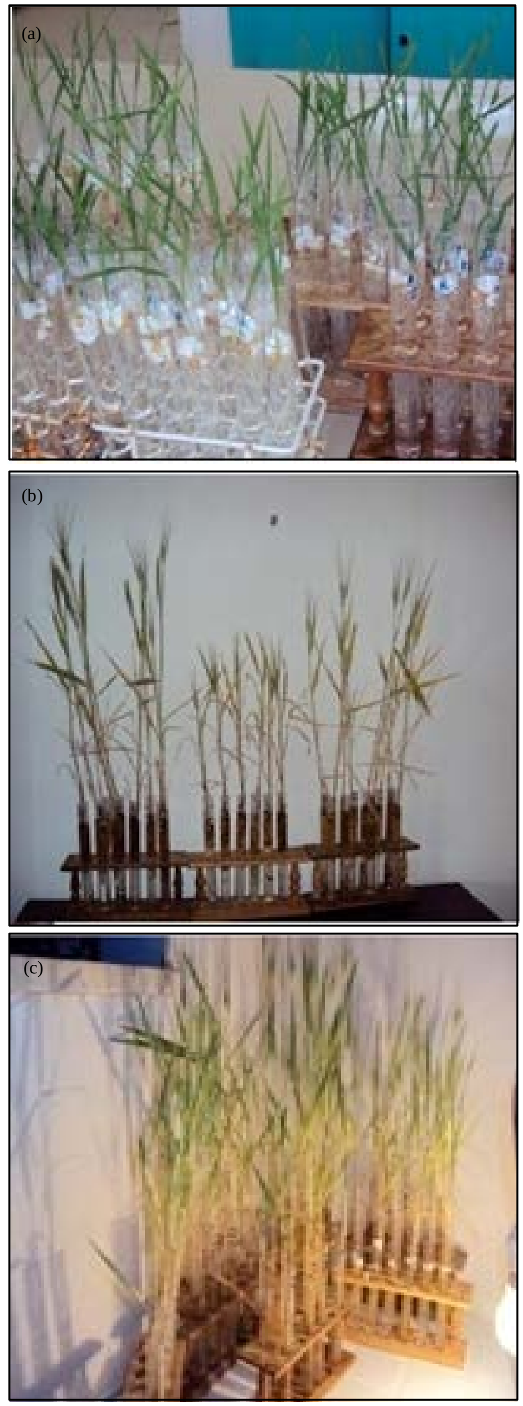

Fig. 2(a-c): Test tubes experiment, (a) Tillering, (b) and (c) Heading

and grain yield of the rainfall recorded from December to the date of physiological maturity

- WUE to produce the total biomass (aboveground and underground parts) was periodically determined by the ratio of total dry biomass of each plant in the experiment end to the water used by the plant during the same period

- Different parts of the plants (pots and test tubes) were placed in an oven at 95°C for 48 h to determine their dry weight. The different measurements are made using a precision balance

Harvest index parameter was calculated by the ratio of grain yield in relation to biological yield.

Leaf area: At anthesis, five leaves were taken at random from each experimental unit to measure leaf length and width. The length of each leaf was measured from the base to the tip of the blade L (cm). The maximum width of each blade was also measured W (cm).

Leaf area is calculated through the equation:

LA (cm^2) = L×W×K, while, K = 0.65 (Mosseddaq, 1988)

Stomatal density: The number of stomates measured per mm^2 is the average of the two faces; the underside and the upper-side of the blade. This parameter was measured on the penultimate leaf in the five durum wheat varieties. Stomatal density was determined by using the fingerprint of the epidermis. The latter was obtained by applying a thin layer of clear nail polish to the surface of the blade. Having been dried, the coating layer was removed using an adhesive tape which was placed on an object slide (Jones, 2004) to count stomata.

RESULTS AND DISCUSSION

Field trial, biological Water Use Efficiency (WUE) (dry matter): Total biological dry matter synthesis and water use were different depending on wheat genotypes (Fig. 3a). Analysis of variance revealed highly significant ($p<0.01$) differences between the five durum wheat varieties. Four genotype groups were found and biological WUE, in this trial, varies from 1.75-1.49 mg of dry matter per g of water.

Biological WUE of Karim and Razzak were the highest, while Nasr was characterized by the lowest WUE. Khiar and Sobirano have intermediate WUE values. These results show that under rainfed field conditions, Karim and Razzak used rainwater more efficiently to produce maximum biomass (straw and grain).

Water use efficiency for grains: Analysis of variance revealed that Karim and Khiar varieties have best values of water use for grain production with, respectively 0.81 and 0.77 mg of grain per g of water consumed. Razzak ranked second with an average about 0.704 mg of grain per g of water consumed, while Nasr and Sobirano (0.60 and 0.48 mg grain per g of water used) have the third and the fourth position, respectively (Fig. 3b).

Stomatal density: Figure 3c shows that stomatal density ranges between 45 and 59. The highest average (59 stomata/mm^2) was obtained for Razzak, while the lowest average (45 stomates/mm^2) was recorded in Sobirano. The other varieties showed intermediate values.

Leaf area of plants under rainfed trial: Results shown in Fig. 3d indicated that this parameter is highly affected by genotypes. The highest averages were noticed for Sobirano and Nasr, while the lowest averages were recorded in Khiar and Razzak with 13, 98 and 13, 55 cm^2, respectively. The variety Karim has an intermediate position.

Harvest index: Based on separation test averages of these genotypes, we found that the variety Khiar ranks first with a HI of 0.48 followed by Karim (0.44). Nasr and Razzak have very similar HI and came in third position. The study of this parameter has also shown that Sobirano variety is characterized by the lowest IR (Fig. 3e).

Grain yield: Grain yield is a quantitative trait highly influenced by environment and genotype. The highest yields are recorded for Khiar (29.58 q ha^{-1}) and Karim (28.26 q ha^{-1}). But the lowest was obtained for Sobirano (17.74 q ha^{-1}). The other varieties have intermediate yield with a slight superiority for Razzak (Fig. 3f).

Correlations between water use efficiency and measured parameters: The relationship between parameters studied in this trial shows that grain yield is maximized with an average leaf area around 15 cm^2 and a stomatal density of 55-60. Stomates allow gas exchange that simultaneously affects photosynthetic efficiency and WUE efficiency through transpiration.

Periodical water use efficiency in test tubes:

First period: Germination-early tillering: During the first period tested, the varieties fell into three groups.

Khiar has the highest WUE (6.70 mg of dry matter per g of water consumed), while Karim and Razzak have the lowest WUE. Nasr and Sobirano were medium for WUE; 5.16 and 5.03 mg of total dry matter per g of water consumed, respectively (Table 2).

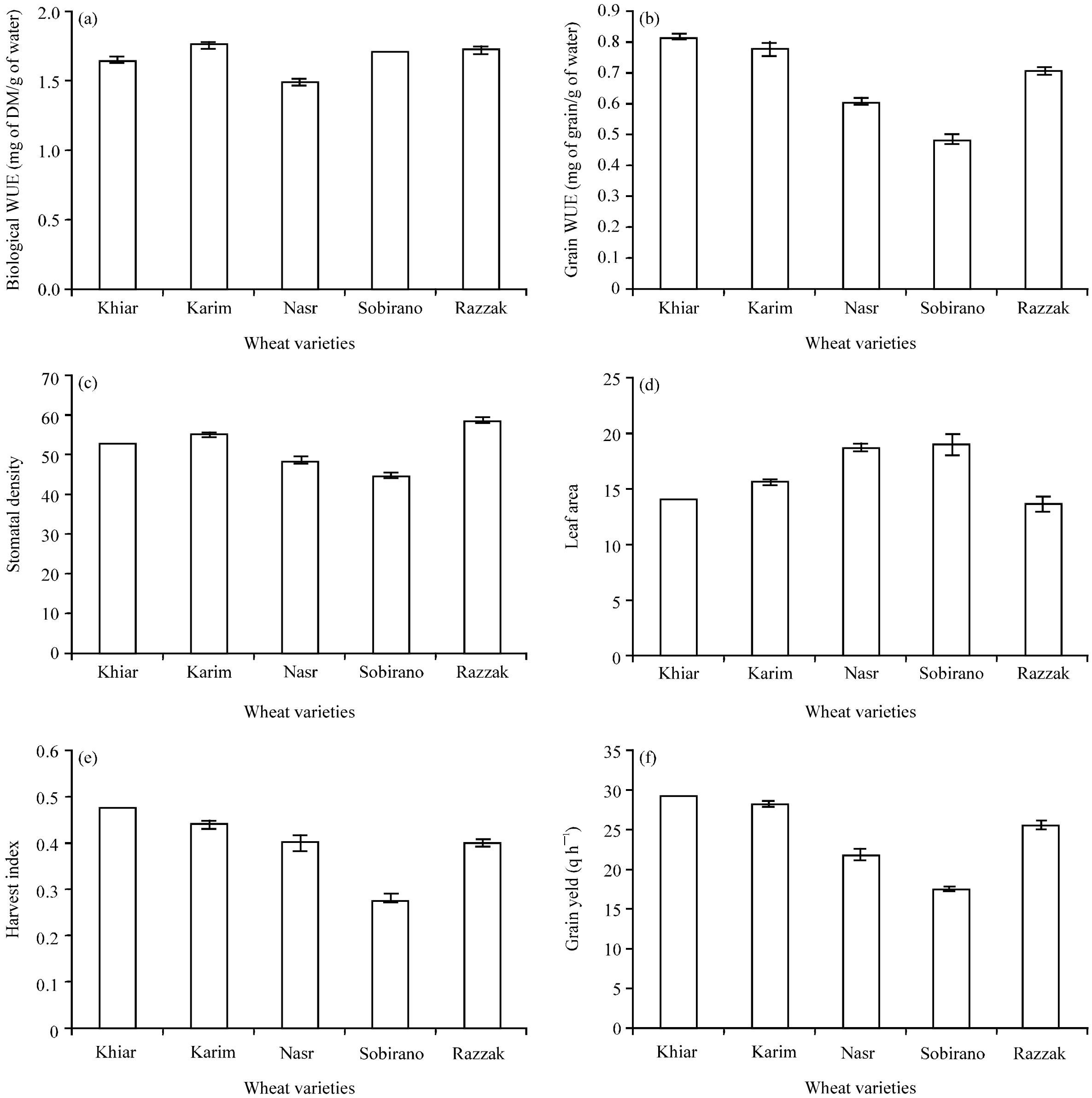

Fig. 3(a-f): Five durum wheat varieties grown in field trial, (a) Biological WUE at maturity, (b) WUE for grain yield, (c) Stomatol density, (d) Leaf area, (e) Harvest index and (f) Grain yield

Table 2: WUE (mg dry matter/g water) at different periods of five durum wheat varieties grown in test tubes

Periods	Khiar	Karim	Nasr	Sobirano	Razzak
4	13.66^{c}	22.13^{a}	7.03^{d}	19.46^{b}	12.23^{c}
3	6.41^{c}	7.73^{b}	3.43^{d}	6.70^{b}	9.06^{a}
2	2.43^{d}	2.03^{e}	9.16^{b}	10.20^{a}	8.70^{c}
1	6.70^{d}	3.83^{c}	5.16^{b}	5.03^{b}	3.81^{c}

Values in a column with same letter are not significantly different at 5% level

Second period: Tillering: WUE ranged from 2.03-10.20 of dry matter per g of water consumed. During this second period, Sobirano has the highest WUE, while Karim WUE value was the lowest. The other varieties have intermediate WUE values.

The analysis of variance for this parameter shows a highly significant difference between genotypes divided into five groups (Table 2).

Third period: Booting-early heading: During this period, Razzak was most efficient for water use (9.06 mg of dry matter per g of water used). Nasr has the lowest WUE

Table 3: WUE (mg dry matter per g water) at different periods of five durum wheat varieties grown in pots

Periods	Khiar	Karim	Nasr	Sobirano	Razzak
4	1.36^{d}	3.18^{b}	3.75	4.00^{a}	2.20^{c}
3	2.20^{b}	0.76^{c}	2.30	2.99^{a}	0.70^{c}
2	1.30^{b}	2.56^{a}	2.46	2.40^{a}	1.63^{b}
1	0.54^{c}	1.46^{a}	0.41	0.75^{b}	0.87^{b}

Values in a column with same letter are not significantly different at 5% level

(3.43 mg of dry matter per g of water consumed). Karim and Sobirano rank second with no significant difference (Table 2).

Fourth period: Heading-physiological maturity: During this fourth development period, results indicated significant differences between varieties. Four groups can be identified where Karim is first, followed by Sobirano. Khiar and Razzak were homogenous with 13.66 and 12.23 mg of dry matter per g, respectively of water used, while Nasr came in the last position (Table 2).

Periodical water use efficiency in test pots:
First period: Germination-early tillering: Ranking of genotypes in descending order of WUE during the first period, indicated that Karim was in the first position, Nasr and Khiar were last and showed no significant difference between them, while Razzak and Sobirano were in a middle position with almost similar WUE values (Table 3).

Second period: Tillering: During this second period, two groups of genotypes can be identified. A first group of varieties with best WUE in descending order; Karim, Nasr and Sobirano. The second group of less efficient varieties, where we find Razzak and Khiar, with no significant difference (Table 3).

Third period: Booting-early heading: In three groups of genotypes, Sobirano comes first. It is the most efficient variety (2.99 mg dry weight of water absorbed per g). Karim (0.76 mg dry weight per g of water) which was not statistically different from Razzak (0.70 mg dry weight per g of water). Both are less efficient. Finally, Nasr (2.30 mg dry matter per g water) is similar to Khiar (2, 20 mg dry matter per g water) and both have an intermediate position (Table 3).

Fourth period: Heading-physiological maturity: Total dry matter produced per gram of water was highest for Sobirano and Nasr; 4.00 and 3.75 mg dry matter per g of water, respectively. An intermediate WUE was recorded for Karim and Razzak, while the lowest WUE was for Khiar (1.36 mg dry matter per g of consumed water) (Table 3).

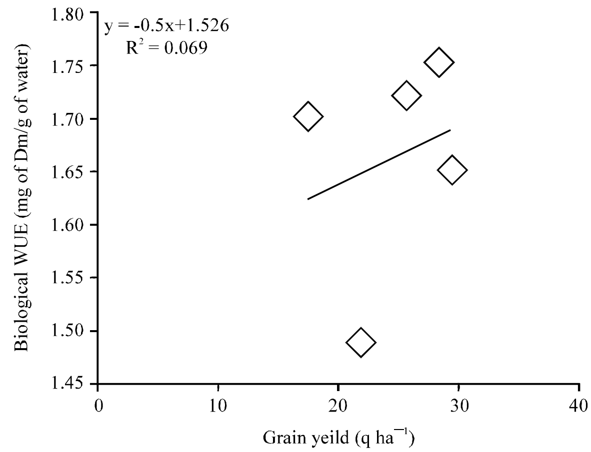

Fig. 4: Correlation between biological WUE and grain yield

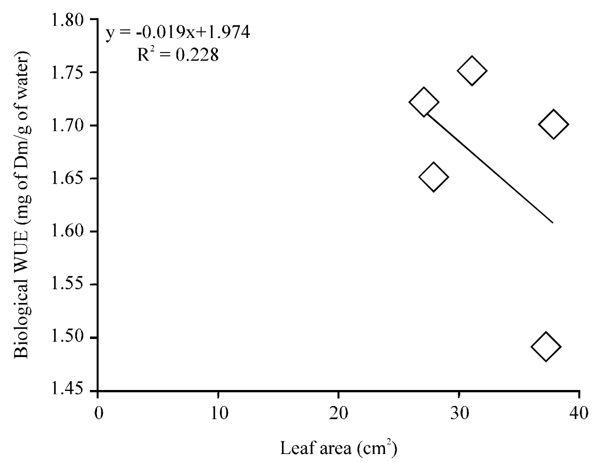

Fig. 5: Correlation between biological WUE and leaf area

Field trial: The cropping season of 2010/2011 at the experimental station of ESAK was characterized by sufficient and well distributed rainfall to allow excellent plant growth without any water deficit throughout the development life cycle of wheat.

The analysis of the relationships between agronomic and physiological parameters shows a number of strong linkages. Biological (WUE) and grain yield (Fig. 4) shows positive correlation (r = 0.26). Karim has recorded the best grain yield and the highest biological WUE. However, Sobirano WUE values were medium (1.70 mg dry matter per g of water) while, it produced the lowest grain yield (17.74 q ha^{-1}).

There was a negative relationship (Fig. 5) between biological WUE and leaf area (r = -0.06), while the latter has a significant positive correlation (Fig. 6) with grain WUE (r = 0. 94). This would indicate that genotypes with

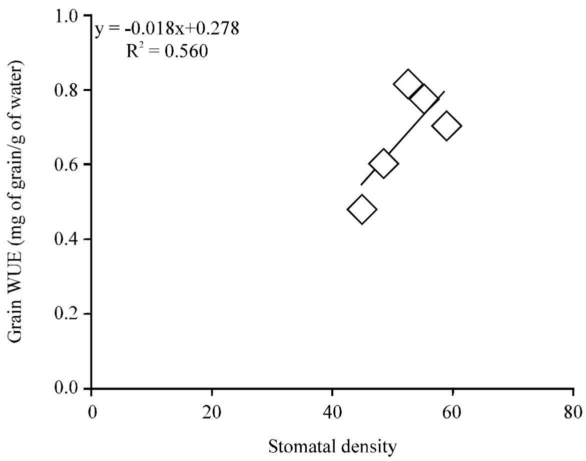

Fig. 6: Correlation between grain WUE and stomatal density

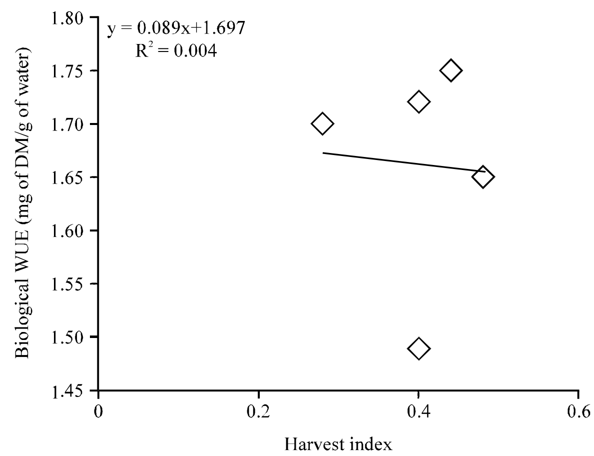

Fig. 8: Correlation between biological WUE and harvest index

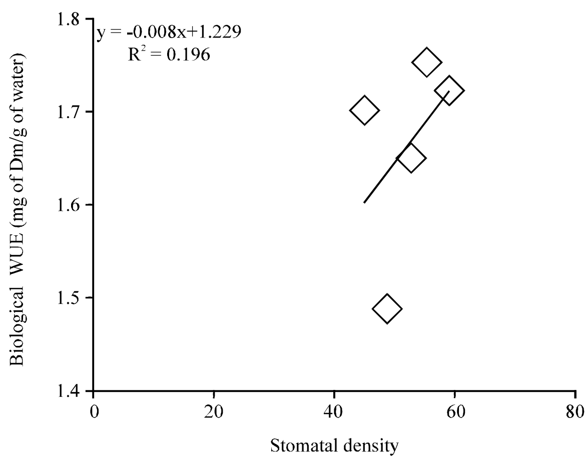

Fig. 7: Correlation between biological WUE and stomatal density

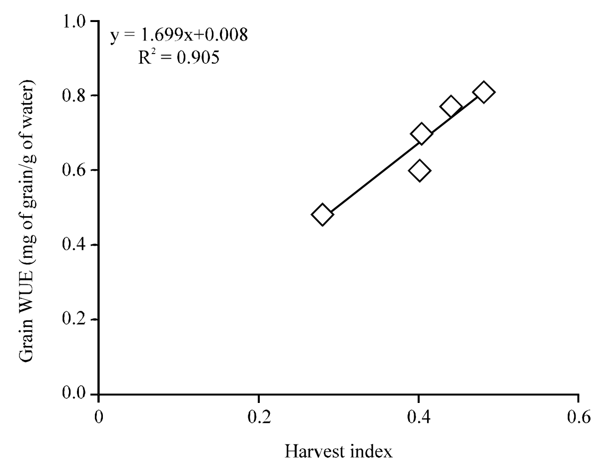

Fig. 9: Correlation between grain WUE and harvest index

high grain WUE make maximum and efficient use of water for grain production. These results can be explained by Gent and Kiyomoto (1989) who concluded that harvest index may explain the effectiveness of translocation of photosynthetic to grains.

The present trials also indicated that biological WUE was strongly correlated (Fig. 7) with stomatal density (r = 0.74). Moreover, biological WUE is positively correlated (Fig. 8) to harvested index (r = 0.44). The positive relationship between stomatal density and grain WUE (Fig. 9) under uncontrolled conditions suggests that the increased cultivar stomatal density seems to make a mechanism that makes better use of rainwater. High number of stomata does not result in high water loss from stomatal aperture control. Therefore, further investigation of stomatal conductance of these durum wheat cultivars is needed. According to Gent and Kiyomoto (1989), Sapra *et al.* (1975) and Wang and Clarke (1993), the decrease in stomatal density does not always result in a reduction of water losses by plants, because of its compensation by increasing their size. This is the case for Sobirano that has high caliber and low density of stomata compared to Razzak which has a small stomata and a high density presented in Fig. 10 and 11.

The Karim stomatal density was 55,33 stomate/mm^2 and Razzak stomatal density was (59 stomat/mm$^{2)}$). Karim and Razzak showed the highest stomatal density and ranked top position for grain yield and stomatal density, respectively. This fact confirms the results of Erchidi *et al.* (2000). Varieties characterized by high stomatal density achieved the most satisfying grain

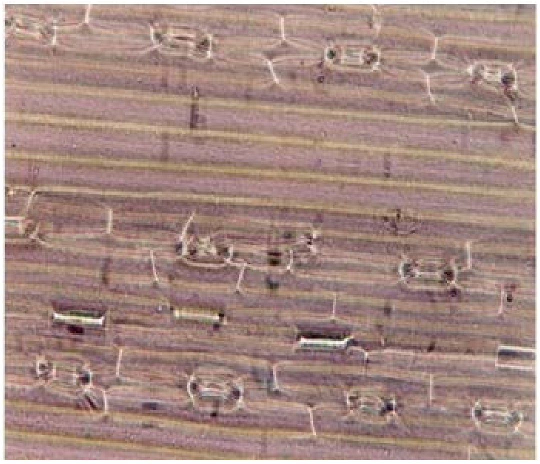

Fig. 10: Microscopic observation of Sobirano variety stomata (lower side of the leaf scale of 250X)

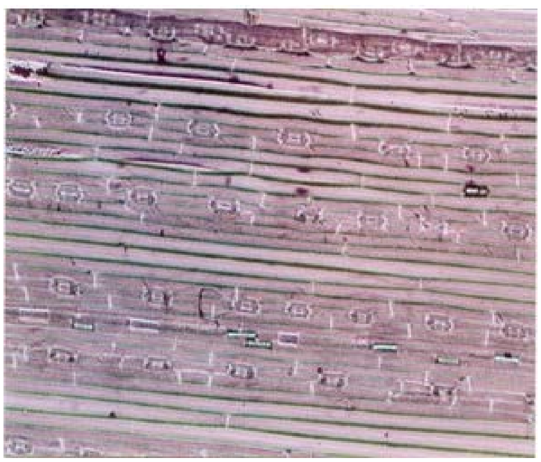

Fig. 11: Microscopic observation of Razzak variety stomata (lower side of the leaf scale of 250X)

yields, while those types with opposite behavior like Sobirano has the lowest stomatal density and were lowest for grain yield. The variety Nasr had an intermediate behavior. Biological WUE and leaf area correlation (Fig. 9) was negative (r = -0.44). Sobirano has maximum leaf area with low dry matter WUE. Razzak has the lowest leaf area associated with medium biological WUE. This biological WUE can be explained by proper use of water and reduced water loss by plants. This is in agreement with Chaudhuri *et al*. (1990) who indicated that a reduced leaf area can be advantageous in effective reduction of total water loss from the plants.

Grain WUE of Khiar (0.81 mg per g of water) is similar to that reported by Doorenbos and Kassam (1987). Karim value was found to be less than that found by Rezgui *et al*. (2005) (0.91 mg grain per g water). Grain WUE for these five wheat varieties is between 0.81 and 0.48 mg grains per g of water consumed and did not exceed in this rain fed trial a value of 1 unit which is recommended by the FOA (Doorenbos and Kassam, 1987).

WUE tested in tubes was maximum during all periods WUE measured in pots experiment (Table 3). The test-tube experiment was set to accurately calculate exact quantities of water used by plants to support them and cover needs of biomass synthesis. During this experiment, growth was well controlled, rapid and with minimal parasitic attack. These conditions and technique promote crop culture since temperature, lighting, pH, nutrients and liquid ventilation were favorable. Under these conditions, WUE of test tubes would be better than pots experiment.

Evaluation of each variety WUE at different periods is meant to improve durum wheat production with limited water amounts and targeting appropriate phenological stages for maximum values of efficient water use. According to studies of Rezgui *et al*. (2005), WUE can be useful to adopt different strategies during complementary irrigation of wheat crops.

Test tubes WUE results for the first period indicated that Khiar came in first position and Karim was last. These varieties ranking was reversed for pot experiment and Sobirano was in second position for both tests.

Khiar and Karim, in test tubes and in pots experiment, respectively, promoted good use of available water through accumulation of higher biomass. High biomass would make mulch that can reduce soil water evaporation. This stage of early tillering was critical since it incubates components affecting wheat grain yield (grain number/m^2; number of grains per fertile spikelet).

Based on controlled and accurate test tubes findings, ranking of these durum wheat varieties can indicate that Khiar can be adapted to highlands climate where water is available during this stage followed by Sobirano and Nasr. While, Karim and Razzak will not be adapted to this climate. On the overall periods, Khiar, Nasr and Sobirano showed high growth combined with maximum WUE. They require some tolerance to cold winter temperatures.

According to Bouthiba (2001) studies, good growth during early development (period 1) improves the use of winter rains and yields higher biomass at maturity.

The second period corresponds to tillering and shows differences regarding varieties classification between the two tests compared to the first period. Sobirano is the performing variety for both tests. It is ranked first followed by Nasr for test tubes. This high efficiency is expressed in a large biomass synthesis in order to promote good tillering.

Khiar and Karim have low WUE during this second period. According to Vilain (1987), it may be due to an alteration of some heat-sensitive enzymes involved in plant growth.

Plants grow rapidly during the second period when temperature and moisture permit and produce new leaves. During this period, wheat plants should be protected against insects and diseases. They should also be provided by adequate nitrogen nutrition.

The stem elongation is the time of rapid growth leading to reproductive period, during which Razzak (test tubes) presents the best WUE (9.06 mg dry matter per g of water). While, Nasr has the lowest WUE (3.43 mg dry matter per g of water). Cultivated in pots, Sobirano shows a better WUE (2.99 mg dry matter per g of water). These results can be explained by intense photosynthetic activity which maximizes grain yield. Razzak and Sobirano can be characterized by a high capacity for remobilization of assimilates stored in the stem. Translocation of assimilates effectively contributes to grain filling and therefore, increasing the average weight of grain (Belkharchouche *et al*., 2009).

This period appears to be the period most sensitive to drought during which varieties with maximum WUE such as Razzak, Karim, Sobirano and Khiar (based on the results of the test tubes) are the most tolerant to water deficit during this period known for water limiting conditions in the region (Rezgui, 1995). This is in contradiction with Levitt (1980). Stockle (1991) mentioned that the ability of plants to produce in the presence of water stress is not necessarily linked to high WUE.

The grain-filling, from heading to physiological maturity, is a reproductive stage marked by manufacture of organs and dry matter accumulation in the seeds.

In test tubes, Karim is the most preferment genotype during this fourth period by producing dry matter for grains or straw which is also true for Sobirano and Nasr grown in pots. It is also known that Mediterranean climate is characterized by low rainfall and increased evaporation during post anthesis of wheat plants (Palta and Fillery, 1995), in addition to disease development (Hossain *et al*., 1990) which induces stress during grain filling of wheat. Therefore, this period may be a crucial time for pesticides application. According to Rezgui (1995) WUE is an important component of resistance to drought, so Karim with its strong WUE may be an excellent variety suited for Mediterranean climate. This was also confirmed by Cao *et al*. (2007) who suggested that high WUE might offer a significant advantage in improving crop production areas prone to occasional droughts.

Grain yield is highly dependent on water availability during the period from anthesis to maturity (Hossain *et al*., 1990), which corresponds to the fourth period. Since this study is carried out under non limiting water, Karim can give better yields if the crop will be done in favorable weather conditions.

CONCLUSION

In open field and under rainfed conditions, Khiar presents a high grain WUE, a low biological WUE and a high harvest index. Sobirano shows a low grain WUE, a high biological WUE and low harvest index. These results show that khiar values rainwater for grain production, while Sobirano values the same amount of rainwater for straw production. Karim variety values rainwater for both grain and straw production.

There was variation between genotypes for WUE during four periods. Pots and test tubes tests under controlled conditions indicated important growth rate for some varieties. Such speed in growth can constrain growth of roots and aerial parts and disrupt possible relationship with WUE.

Khiar and Karim gave high WUE during germination-early tillering period which would produce high biomass at maturity. Sobirano, Karim and Nasr have expressed good growth coupled with better use of irrigation water during tillering. Razzak and Sobirano with their high WUE can withstand possible water stress from stem elongation to booting (early heading). Karim, Nasr and Sobirano showing good WUE can achieve good grain yield if they are given adequate quantities of water during the fourth period.

In summary, WUE can help choices of different strategies adopted in the conduct of complementary irrigation. Water supply is beneficial when irrigated at heading or flowering.

WUE is not necessarily associated with either tolerance or resistance to drought. We should take into consideration other ecophysiological traits of wheat varieties such as roots growth rate and roots depth for water accessibility, stomatal conductance and the degree of stomatal opening. Periods of the growing season and development stages, during which wheat varieties have high WUE, is very important in making expected grain and or straw harvest.

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