Growth and Yield Responses of Three Durum Wheat Cultivars Subjected to Four Levels of Available Soil Moisture

Faisal A. Al-Rjoub and Mahmoud A. Al-Samarrai*

ABSTRACT

A pot experiment was conducted in a greenhouse as rainout shelter to evaluate the performance of wheat grown under different levels of available soil moisture. Three spring wheat cultivars, Haurani 27, Acsad 65 and Omrabi 6 were grown under four levels of available soil moisture including 25% (M1), 50% (M2), 75% (M3) and 100% (M4). Cultivars differed significantly for all the traits evaluated except for the number of spikes per pot, Omrabi 6 cultivar showed superiority over the other two cultivars and outyielded Haurani 27 for biological yield, seed yield and harvest index by 9%, 32% and 19%, respectively, but it exceeds Acsad 65 by 41% for the number of kernels per spike. On the contrary, Haurani 27 exceeds significantly the other two cultivars for plant height, peduncle length and number of days to heading. The soil moisture level M3 gave superior response for biological yield, seed yield, number of spikes per pot and number of kernels per spike. On the other hand, the M4 level showed superiority for plant height, peduncle length and 1000-kernels weight. In contrast, there were no significant differences between the effects of M3 and M4 for the traits number of kernels per spike and number of days to heading. Omrabi 6 cultivar was superior for biological yield, seed yield, harvest index, number of spikes per pot and number of kernels per spike. On the contrary, Haurani 27 showed superiority for plant height, peduncle length and number of days to heading (late flowering). It seems valid to consider the level of available soil moisture as a good indicator for the performance in a wheat field.

KEYWORDS: Available soil moisture, Durum wheat, Morphological traits, Yield components, Yield.

1. INTRODUCTION

Bread and durum wheats provide the principal food source for the majority of the people in the countries of West Asia and North Africa, with an annual consumption average of more than 150Kg/person which is considered the highest level in the world (Ferrara, 1994). The semi-arid areas in the Middle East where the average annual rainfall ranges from 350-500mm, are characterized by being highly variable and unpredictable in terms of rainfall (amount and distribution) and temperature. Such variability makes shortage of soil and water which are the most serious constraints to production improvement because they affect growth, yield and the phenology of wheat (Katata, 1987). As a result, Jordan imported about 343 thousand Metric tons of wheat in 2003 with a value of about $66 million (Food Agriculture Organization, 2003).

Plant breeders on their attempts to improve drought tolerance of crop cultivars have emphasized the fact that high priority should be given to improve the efficiency of water use through the exploitation of genotypic variation and better soil management practices (Cooper et al., 1987). Also, CIMMYT is currently evaluated genotypes simultaneously under near optimum moisture conditions to take advantage of high heritability and correlated response under drought conditions to ensure the preservation of alleles for drought tolerance. Afterwards, those genotypes that perform well in both environments are selected (Calhoun et al., 1994). Many studies emphasized the importance of selecting the appropriate cultivars for rainfed conditions in which drought tolerance and yield potential can be combined. Such cultivars were recommended by Cooper et al. (1987) which have fast early growth that provides them with the best advantage of the low transpiration conditions during
the winter period with low radiation and evaporative demand.

Genotypic variability for drought tolerance and some of the physiological mechanisms related to it have been reported for wheat (Holmberg and Bulow, 1998; Nagarajan et al., 1999 and Alderfasi, 2001). Similar results reported by Moustafa et al. (1996) showed that the yields of the spring wheat cultivars Klassic and SPHE3 were less affected by the water stress treatments than those of Giza 165 and Gemmiza 1. Therefore, when stress is applied at heading, yield of Giza 165, Gemmiza 1 and SPHE3 decreases by 44%, 43% and 18%, respectively while Klassic had a yield increase of 4%. Moreover, osmotic adjustment occurred to a higher level in Klassic and SPHE3 than in Giza 165 and Gemmiza 1. Comparison between drought resistant and drought susceptible durum wheat cultivars which were exposed to early stress at tillering, mid-season stress at flowering and late-season stress at grain filling revealed that early season stress delayed the time to anthesis and physiological maturity. On the other hand, mid and late season moisture stress shortened the grain-filling period by 10 and 11 days. Also, drought-resistant cultivars reached anthesis earlier than the susceptible one. The moisture stress treatments tested resulted in low dry-matter accumulation compared to the control. Moreover, the drought-resistant cultivars Omrabi-5 and Boohai showed vigorous root development and/or a low shoot/root ratio (Simane et al., 1993).

Motzo et al. (1996) found a significant difference among seven Italian durum wheat cultivars grown under different moisture levels and soil types for the traits, days to flowering, kernels weight and rate of grain-filling. Therefore, large kernels were achieved by genotypes characterized by high rates of grain filling, irrespective of earliness. In a greenhouse experiment, Abbasi et al. (2003) examined the performance of four wheat genotypes under five irrigation levels imposed at different growth stages as terminal drought, pre-anthesis drought and post-anthesis drought. They found that genotypes show different response to water stress at almost all stages of plant growth. Moreover, plant height, fresh plant biomass and number of leaves decreased significantly depending upon the extent and degree of water stress. Based on that, they deduced that water shortage at anthesis and grain filling stage severely damage and decrease the growth of wheat plants and will finally affect the potential and stability of wheat under water stress conditions. Also, in a field study, significant differences were observed among four bread wheat cultivars tested under a package of cultural practices including the effects of four rates of Supplemental Irrigation (SI) (i.e. full SI and 1/3 and 2/3 of that amount, as well as rainfed conditions). It has been found that the addition of only limited irrigation (1/3 full SI) with 100 and 150 Kg N/ha doubled yield compared with rainfed conditions. Furthermore, though lesser, increases occurred in grain yield at the 2/3 SI level and there was no additional increase with full supplemental irrigation (Oweis et al., 1998). Abou El-Fotouh et al. (2002) studied the effect of three amounts of irrigation water on the performance of wheat cultivar Gemmiza 7 at Eastern Delta in Egypt. The levels were equal to 100% (T1), 80% (T2) and 60% (T3) of class A Pan evaporation given at weekly intervals. Results showed no significant differences between the effects of T1 and T2 for plant height, grain weight/spike 1000 grain weight and grain, and straw yields. However, T1 and T2 treatments were superior to T3 irrigation level. As a result, there is a possibility of saving about 16% of the amount of irrigation water by applying T2 level as compared with T1 level. Khater et al. (1997) studied the response of some wheat cultivars to different irrigation levels (40, 60, 80, and 100%) of field capacity at Gemmizea (Middle Delta). They revealed that irrigation at 100% and 80% of field capacity increased grain and straw yields and the yield components. Moreover, water use efficiency was the highest for the irrigation level 80% of field capacity (1.93 Kg/m³). The objective of this study was to investigate the effect of different levels of available soil moisture on the performance of three durum wheat cultivars.

2. MATERIALS AND METHODS

In an open green house used as a rainout shelter at the College of Agriculture, Mu'tah University, Jordan, the experiment was conducted using 10 kilograms capacity pots (25cm upper diameter and 30cm height). Four levels of available soil moisture (i.e. 25% (M1), 50% (M2), 75% (M3) and 100% (M4) of available soil water) and three locally adapted spring durum wheat (Triticum turgidum L.sub sp.durum) cultivars namely, Haurani 27, Acsad 65 and Omrabi 6. Twelve treatment combinations were replicated four times in a Randomized Complete Block Design (RCBD).
Haurani 27 and Acsad 65 cultivars are certified and recommended for wheat growers in Jordan, the first is a landrace originating from Lebanon (Elings, 1993) which is considered tall, the second one is an improved cultivar developed by ACSAD center and classified as semi-dwarf with early heading (Niane et al., 1999). Omrabi 6 is a promising cultivar which is still under evaluation at NCARTT in Jordan. Wheat seeds were kindly provided by Agronomist F. Al-Kateb, at Maru Agricultural Station. Soil was dug out from the depth (0-15 cm) of a field in the College of Agriculture in Al-Rabba area which was previously planted with vegetables. Soil was air-dried and sieved through 2 mm sieve. Each pot was filled with 9 kg of air dry soil then corrected to the oven dry weight by using the following equation (Marshall and Holmes, 1979):

\[
\text{Oven Dry wt. of soil sample} = \frac{\text{Air Dry wt.}}{100 + \% \text{ Initial moisture (on oven dry wt. basis)}} \times 100
\]

The pots were filled with the prepared soil and arranged according to the design on a bench in a greenhouse (the soil characteristics are shown in Table 1).

On November 20th 2003, wheat seeds treated with fungicide were sown in the pots at a rate of 6 seeds per pot. The pots were irrigated four times to the field capacity (i.e. 100% of available water) from seeding date to January 4th. Emergence was completed on December 1st, and seedlings were thinned on December 7th to three healthy plants per pot at the second leaf stage expanded. On January 4th 2004 (45 days after sowing) when the plants were at the 3rd fully expanded leaf stage, they were subjected to the different levels of available soil moisture. The moisture status was determined gravimetrically by weighing and watering the pots at regular intervals (mostly every other day) as used by Simane et al. (1993) and Moustafa et al. (1996) to maintain moisture level in the pots as required by treatments. Weeding of pots was done frequently to keep the pots free of weeds. Diammonium phosphate fertilizer (18 % N, and 46 % P₂O₅) as granules was applied twice on February 25th and March 22nd 2004 at a rate of 100 kg/ha. The fertilizer was dissolved in water and applied as 100 ml solution for each pot. Correction for plants’ weight in the pots was based on the results presented by Noggle and Fritz (1976).

Irrigation continued every other day as required by the treatments until the first of May, after that, irrigation withholds on all pots until May 17th. At this date, every plant in each pot was hand harvested and its seeds were separated from the spikes.

Data were recorded on biological yield, seed yield, harvest index, number of spikes, number of kernels per spike, 1000-kernels weight, plant height, peduncle length and heading date.

### Table 1: Physical and chemical characteristics of the soil used.

<table>
<thead>
<tr>
<th>Particle size distribution</th>
<th>%</th>
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<tbody>
<tr>
<td>Clay</td>
<td>13.3</td>
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<tr>
<td>Silt</td>
<td>18.3</td>
</tr>
<tr>
<td>Sand</td>
<td>68.4</td>
</tr>
<tr>
<td>Texture Class</td>
<td>Sandy Loam Soil</td>
</tr>
<tr>
<td>Permanent Wilting Point</td>
<td>21.5</td>
</tr>
<tr>
<td>Field Capacity</td>
<td>30.8</td>
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<tr>
<td>Saturation Capacity</td>
<td>61.7</td>
</tr>
<tr>
<td>Bulk Density</td>
<td>g/cm³ 1.60</td>
</tr>
<tr>
<td>Particle Density</td>
<td>g/cm³ 2.88</td>
</tr>
<tr>
<td>PH</td>
<td>6.03</td>
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<tr>
<td>Total Nitrogen</td>
<td>0.142 %</td>
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<tr>
<td>Available phosphorous</td>
<td>ppm 409</td>
</tr>
<tr>
<td>Available Potassium</td>
<td>ppm 610</td>
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<tr>
<td>Organic Matter</td>
<td>% 2.2</td>
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<tr>
<td>Electrical Conductivity (EC) ms/cm</td>
<td>1.83</td>
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</table>
Table 2: Yield, yield components, and phonological traits of three spring wheat cultivars as affected by four levels of available soil moisture.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Biological yield (g/pot)</th>
<th>Seed yield (g/pot)</th>
<th>Harvest index (%)</th>
<th>No. spikes/pot</th>
<th>No. of kernels/spike</th>
<th>1000 - kernels wt. (g)</th>
<th>Average peduncle length (cm)</th>
<th>Plant height (cm)</th>
<th>No. of days to heading</th>
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<tr>
<td>Cultivars</td>
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<tr>
<td>Haurani 27</td>
<td>93.28&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.40&lt;sup&gt;c&lt;/sup&gt;</td>
<td>23.08&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>31.31&lt;sup&gt;b&lt;/sup&gt;</td>
<td>53.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>21.98&lt;sup&gt;a&lt;/sup&gt;</td>
<td>101.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>115.6&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Acsad 65</td>
<td>95.97&lt;sup&gt;b&lt;/sup&gt;</td>
<td>23.81&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.85&lt;sup&gt;b&lt;/sup&gt;</td>
<td>12.62&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27.88&lt;sup&gt;c&lt;/sup&gt;</td>
<td>68.04&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.73&lt;sup&gt;b&lt;/sup&gt;</td>
<td>83.43&lt;sup&gt;b&lt;/sup&gt;</td>
<td>104.8&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Omrabi 6</td>
<td>101.70&lt;sup&gt;a&lt;/sup&gt;</td>
<td>28.14&lt;sup&gt;a&lt;/sup&gt;</td>
<td>27.55&lt;sup&gt;a&lt;/sup&gt;</td>
<td>13.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>39.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>56.53&lt;sup&gt;b&lt;/sup&gt;</td>
<td>15.68&lt;sup&gt;c&lt;/sup&gt;</td>
<td>84.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>111.1&lt;sup&gt;b&lt;/sup&gt;</td>
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<tr>
<td>Moisture Levels</td>
<td>M1</td>
<td>87.75&lt;sup&gt;c&lt;/sup&gt;</td>
<td>22.79&lt;sup&gt;b&lt;/sup&gt;</td>
<td>27.21&lt;sup&gt;a&lt;/sup&gt;</td>
<td>12.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>33.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>57.32&lt;sup&gt;c&lt;/sup&gt;</td>
<td>17.38&lt;sup&gt;c&lt;/sup&gt;</td>
<td>85.19&lt;sup&gt;c&lt;/sup&gt;</td>
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<td></td>
<td>M2</td>
<td>93.64&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>22.79&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.30&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.17&lt;sup&gt;a&lt;/sup&gt;</td>
<td>29.75&lt;sup&gt;b&lt;/sup&gt;</td>
<td>58.25&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>18.96&lt;sup&gt;b&lt;/sup&gt;</td>
<td>88.33&lt;sup&gt;b&lt;/sup&gt;</td>
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<td></td>
<td>M3</td>
<td>106.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>26.38&lt;sup&gt;a&lt;/sup&gt;</td>
<td>24.54&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>33.58&lt;sup&gt;a&lt;/sup&gt;</td>
<td>59.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>18.59&lt;sup&gt;b&lt;/sup&gt;</td>
<td>90.67&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>M4</td>
<td>99.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.76&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>24.62&lt;sup&gt;b&lt;/sup&gt;</td>
<td>11.83&lt;sup&gt;c&lt;/sup&gt;</td>
<td>34.75&lt;sup&gt;a&lt;/sup&gt;</td>
<td>62.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>20.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>94.45&lt;sup&gt;a&lt;/sup&gt;</td>
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</table>

Interaction * ** ** Ns ** ** ** ** *** **

M1 = 25%, M2 = 50%, M3 = 75% and M4 = 100% of available moisture.
* Significant at 5% and 1% probability levels, respectively; Ns = non-significant at P<0.05.
Means in each column for each of the two treatments followed by the same letter are not significantly different.

3. RESULTS AND DISCUSSION

Total Yield and Harvest Index

Analysis of variance showed significant variations between cultivars and moisture levels with respect to biological and seed yield (Table 2). Omrabi 6 cultivar exceeds Acsad 65 and Haurani 27 by 6% and 9%, respectively for biological yield and by 18% and 32% for seed yield, respectively, where there is no significant difference between Acsad 65 and Haurani 27 cultivars for biological yield. On the other hand, seed yield of Acsad 65 cultivar significantly out yielded Haurani 27 cultivar by 10% (Table 2). Such genotypic differences in wheat exposed to post-anthesis water stress for dry matter accumulation of tillers of the tall and dwarf types were observed by Nagarajan et al. (1999). The data were analyzed statistically using the Analysis of Variance (ANOVA) technique by MSTATC program model number 8 (Michigan State University, East Lansing, Mich., USA) and the significance of mean difference was tested by Duncan’s Multiple Range Test.

The effect of moisture levels indicated that the level M3 of moisture gave the highest biological and seed yields but as the moisture level lowered from M3 to M2 there was a reduction in biological yield by 14% whereas from M3 to M1 22%. On the other hand, increasing moisture level up to M4 caused reduction in biological yield and seed yield by 7.3% and 6%, respectively. Similarly, seed yield of M3 moisture level exceeds that of M2 and M1 levels by 15% and 10.5%, respectively. Similar response was reported by Alderfasi (2001) and Alderfasi et al. (1999). Moreover, the response of biological and seed yield to M2 and M1 levels is not significantly different (Table 2). This result is in agreement with Oweis et al. (1998) who found that saving in irrigation water can be achieved with little or no loss in yield. The interactions between cultivars and moisture levels were highly significant for biological and seed yield. Biological and seed yields of Omrabi 6 cultivar increased steadily as moisture level increased from M1 to M2 and from M2 to M3, by 20.5% and 18.8% for biological yield (Fig.1a) and by 12% and 26% for seed yield, respectively (Fig.1b).
Fig. 1: Interactive effects of cultivars and moisture levels on (a) biological yield, (b) seed yield and (c) harvest index.
Fig. 2: Interactive effects of cultivars and moisture levels on (a) average number of spikes/pot (b) average number of kernels/spike and (c) 1000-kernel weight.
Fig. 3: Interactive effects of cultivars and moisture levels on (a) average plant height (cm), (b) Average peduncle length (cm) and (c) Number of days from emergence to heading.
On the contrary, the biological and seed yield of Omrabi 6 cultivar did not differ significantly when moisture level increased from M3 to M4. This result could be explained that at M3 level, the conditions in the root zone particularly aeration at the upper layer of soil are more favorable for growth than those at M4 level. Such genotypic variability in response to water stress was confirmed by Mustafa et al. (1996).

Harvest index significantly affected by cultivars and moisture levels. However, Um-Rabi 6 cultivar gave significantly the highest harvesting index; next in range were Acsad 65 cultivar and Haurani 27 cultivar (Table 2). This result could be attributed to genotypic differences between Haurani 27 as a tall cultivar while the other two are semi-dwarf. Such genotypic variability for harvest index was reported in barley by Wahbi and Gregory (1989) and Cantero-Martinez et al. (1995). The response to moisture levels revealed that M1 level gave significantly the highest harvest index, this result was ascribed partly to the low biological yield produced at M1. Contrastively, harvest index obtained under the other three moisture levels did not differ significantly. This response can be attributed to the availability of adequate moisture at these levels that allows full expression of cultivars’ capabilities for remobilization and assimilation during grain filling (Loomis and Connor, 1992). Interaction results showed that the highest harvest index for the three cultivars obtained at M1 level by Omrabi 6 cultivar, even though, the response of Omrabi 6 at all the other moisture levels was not significantly different. This could be due to the consistency in seed set and Condon (1986), Cantero-Martinez et al. (1995). On the contrary, harvesting index for Haurani 27 and Acsad 65 cultivars was not significantly different as moisture level decreased from M4 to M2 (Fig.1c). This response could be attributed to the availability of moisture and absence of any canopy effect as shading. Harvest index values ranging from 32%-38% found by Nagarajan et al. (1998) study, in which two double dwarf cultivars and two tall ones were exposed to post-anthesis water stress. Their results did not show significant effect for post-anthesis water stress on harvest index of the evaluated cultivars; such finding is in agreement with our results obtained under conditions of available soil moisture.

Yield Components

For the average number of spikes/pot, it was found that there was no significant difference among cultivars (Table 2). This result contradicts that of Moustafa et al. (1996) and that of Nagarajan et al. (1999), the second authors found that the taller cultivars had higher fertile tillers number than the dwarfs when subjected to post-anthesis water stress. The highest number of spikes/pot was produced by M3 and M2, next in range were M1 and M4 (Table 2). In contrast, Moustafa et al. (1996) found that the number of spikes per plant was not affected by the water stress treatments. As moisture increased from M3 to M4, the number of spikes per pot decreased by 12%. Also, decreasing moisture level from M2 to M1 causes reduction in the number of spikes per pot only by 5% (Table 2). It seems that the extreme treatments M1 and M4 levels suppress tiller development but in different mechanisms. At M1 level, it seems that the condition in the root zone was stressful that cause reduction in number of fertile tillers. On the other hand, M4 level possibly reduced the number of fertile tillers because of the every other day irrigation in this study that leads to wetting the upper layer of the pots. Such condition enhances adventitious roots proliferation and development of high root densities that invest much of the energy resources of the plant (Loomis and Conner, 1992). The number of spikes per pot was higher but not significantly different for the three cultivars at M3 and M2 levels. The decrease in the number of spikes per pot as moisture level changed from M3 to M1 for the Haurani 27, Acsad 65 and Omrabi 6 cultivar was 7%, 4% and 11%, respectively. Similarly, increasing moisture level from M3 to M4 resulted in a decrease in the number of spikes per pot for the above cultivars by 6%, 13% and 10%, respectively (Fig.2a).

The average number of kernels/spike was affected significantly by cultivars, moisture treatments and their interaction (Table 2). The mean number of kernels/spike was 39.3, 31.3 and 27.9 for Omrabi 6, Haurani 27, and Acsad 65 cultivars, respectively. Similar response of different wheat cultivars to different moisture levels was found by Motzo et al. (1996) in which fertility ranged from 37 kernels per spike for Creso cultivar in 1987 to 61 kernels per spike for Vespro cultivar in 1986. The effect of moisture treatments did not show significant difference for the levels M4, M3 and M1 whereas M2 gave significantly the lowest value (Table 2). This observation can be explained based on the finding of Shahram et al. (2003), which indicates that apical fertility in wheat is determined by two dominant genes, and their expression is dependent on high temperature and/or the degree of water stress. It is evident that the moisture levels tested in our study was not...
sufficient to express the genes and induce apical sterility when compared to moderate water stress which was applied on wheat by withholding water for 6 days when the flag leaf is just visible. On the contrary, when Moustafa et al. (1996) applied water stress at heading by withholding water for 10 days, the number of kernels per spike decreased for all cultivars except for Klassic. Similarly, Briggs et al. (1999) found that the application of moisture stress at the heading stage reduced the average pollen fertility in all wheat cultivars tested. Based on that, fertility greatly depends on the availability of moisture during the processes of pollination and fertilization. The highest significant interaction reveals that the number of kernels /spike for Omrabi 6 cultivar declines as available moisture level decreases from M4 to M2. For Acsad 65 cultivar, M1 level gave significantly the highest number of seeds /spike, whereas there were no significant differences among the other moisture levels. On the other hand, Haurani 27 cultivar did not show consistent response to the moisture treatments (Fig.2b). A similar variable response of cultivars was reported by Briggs et al. (1999), where several of the semi-dwarf cultivars had a lower frequency of sterile florets compared with the tall cultivars when fully watered. But when moisture stress was applied at the booting stage, it increased the frequency of sterile florets in both semi-dwarf and tall wheat cultivars. Also, when the level of moisture stress increased further, the sterility level was significantly higher in semi dwarf cultivars compared to the tall cultivars.

The weight of 1000 – kernels was significantly affected by cultivars, moisture levels and their interactions (Table 2). Acsad 65 cultivar gave the highest weight (68.04 gm) followed by Omrabi 6 and Haurani 27 cultivars. Similarly, Motzo et al. (1996) reported that genotypic variability for kernel weight in wheat grown under different moisture levels ranged from 51.8 mg for Creso cultivar in 1987 to 59.5 mg of Messapia in 1986. In contrast, Moustafa et al. (1996) found that kernel weight was not affected by the water stress treatments and did not differ among cultivars. The effect of moisture treatments indicated that M4 gave significantly the highest weight. However, 1000- kernels weight decreases by 4%, 2% and 2% when available moisture levels were reduced gradually from M4 down to M1, respectively (Table 2). This result goes in parallel with that of Abou El-Fotouh et al. (2002). The significant interaction revealed that Acsad 65 cultivar showed no significant difference as moisture level decreases from M4 to M2 but there was a significant decline in weight as moisture level decreases to M1. The high kernel weights of Acsad 65 could be attributed partly to compensation effect associated with the low number of kernels per spike in Acsad 65. In this study, some of the unusual values for 1000- kernels weight in all treatments could be due to the availability of moisture, absence of any canopy effect as shading and to the second fertilizer application which coincides with heading and grain filling stage. Such high 1000-seed weight (60 gm) was reported in irrigated lentil by Turk et al. (2003).

Morphological Traits

Plant height was found to be affected significantly by cultivars, moisture levels and their interaction. Haurani 27 cultivar gave significantly the tallest plants where the other two cultivars were in par (Table 2). Similar genotypic variability for plant height was observed among ten wheat genotypes (Alderfasi et al., 2001). The response to moisture levels showed that plant height increased significantly with increasing moisture levels except between M3 and M2 where the difference was not significant. Plant height, however, decreased by 4%, 3% and 4% as moisture level decreased gradually from M4 down to M1, respectively (Table 2). Such slight decrease may be attributed to decline in cell expansion and enlargement processes that are responsible for plant elongation (Larson, 1992). This finding is in agreement with the results of Abou El-Fotouh et al. (2002) which indicated that plant height was not significantly decreased, unless the amount of water was decreased to a level equal to 60% of Class A pan evaporation. In contrast to the slight decreases found in this study, Abbasi et al. (2003) compared the average height of four wheat genotypes at control with the height they attained at different stress levels, terminal drought caused a maximum reduction of 38% followed by 20% reduction at pre-anthesis drought. The significant interaction indicated a general trend that the plant height increases as moisture level increases from M1 to M4. However, the more clear effect appeared with Haurani 27 cultivar as compared to the other cultivars (Fig.3a).

Peduncle is the section of stem between the flag leaf and the head. Peduncle length and flag leaf area in wheat was found to correlate strongly and positively with grain yield when subjected to terminal drought and different irrigation levels, respectively (Ferrara, 1994; Alderfasi, 2001). This is due to the fact that in wheat and barley, current Photosynthesis of the flag leaf, stem and head
which are the closest sources to the grain is the primary contributor to the final grain yield (Gardner et al., 1985). Results showed that the average length of peduncle was significantly affected by cultivars, moisture levels and their interaction. Haurani 27 cultivar gave significantly the longest peduncle followed by Acsad 65 and Omrabi 6 cultivars in sequence (Table 2). The effect of the moisture levels on peduncle length indicated that M4 gave significantly the longest peduncle while M1 gave significantly the shortest length. On the other hand, M2 and M3 produced plants of similar peduncle length. For Haurani 27 and Omrabi 6 cultivars, the interaction revealed that their peduncle length decreased significantly with decreasing available moisture content. This might be due to the decrease in cell expansion and enlargement at a late stage of growth (Larson, 1992). On the contrary, Acsad 65 cultivar did not show significant effect due to a decline in moisture content (Fig.3b).

The number of days to heading was affected significantly by cultivars, moisture levels and their interaction. Acsad 65 cultivar was the earliest to reach the heading stage (104.8 days), next in range were Omrabi 6 and Haurani 27 cultivars (Table 2). Related to that, Cantero-Martinez et al. (1995) found that anthesis in barley was 5-7 days later in Tina cultivar than in Dobla and Tina which reached physiological maturity 10 to 17 days later than Dobla. Similarly, the results of two experiments in a Mediterranean environment revealed that the early cultivar Messapia reached flowering between 132 and 139 days after sowing (Motzo et al., 1996). While Vespro and Creso reached flowering between 141 and 148 days. Also, Simane et al. (1993) reported that the three Ethiopian cultivars reached anthesis 5 days earlier than Omrabi-5 cultivar. The response to moisture levels revealed no significant difference among M4, M3 and M2, whereas M1 level caused slight decrease in the number of days to heading (Table 2). Different results were obtained by Simane et al. (1993), where early season stress delayed the time to anthesis and physiological maturity, while mid and late season moisture stresses did not affect the time to anthesis. The interaction effect revealed that Haurani 27 cultivar required less number of days to heading as the moisture level declined from M4 to M1, while the other two cultivars did not show such response (Fig.3c). The unusual earliness in heading date of wheat was observed in this study, which extended from middle of March to its end, was comparable with the number of days to flowering in irrigated lentil reported by Turk et al. (2003). This could be attributed to the combined effects of high temperature which prevail from 24th February to 5th March during which the average of the maximum air temperature was 24.5 °C (Rabba Meteorological Station) and to the availability of adequate moisture and nutrients during the growing season. This result is of great value in areas where high temperature during growing season can be combined with adequate moisture and nutrients because it shortens the growing season by about one month. Therefore, it is extremely important for escaping the late season drought which is common in Mediterranean environments; thus, will result in good saving in the amount of irrigation water for that period.

4. CONCLUSIONS

From the results, it has been concluded that Omrabi 6 was superior to the other two cultivars when grown at M3 moisture level for biological yield, seed yield, harvest index, number of spikes per pot and number of kernels per spike. On the contrary, the tall cultivar Haurani 27 showed superiority for average plant height, average peduncle length and number of days to heading (late heading) at the same moisture level. Therefore, Omrabi 6 behaved as a more efficient cultivar because of its better exploitation of the improved growing conditions. Fortunately, Omrabi 6 is certified by the Ministry of Agriculture in Jordan as an improved durum wheat cultivar with the name Omquais, in the growing season 2005, based on the results of their multi-location trials in several seasons (personal communication). It seems reasonable to conclude that the escape of crop failure under dry farming is possible as long as the low level of available moisture is present in the soil. Accordingly, further research is required to confirm these results under field conditions to determine the level of soil moisture at which crop failure may occur.

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