The effect of drought stress on yield and yield components of promising cultivars of sunflower

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Abstract

In order to study the effect of drought stress on the agronomical traits of different cultivars of sunflower, an experiment was conducted in 2013 at the Agricultural Research Station of Islamabad Gharb, Kermanshah province, Iran. The experiment was conducted in factorial in the form of a randomized complete block design with three replications. Drought stress was the first factor in three levels: normal irrigation after 60 mm evaporation from an A Class evaporation pan (control), irrigation after 120 and 180 mm evaporation from the pan, at the beginning of the flowering stage. Cultivar was the second factor in 12 levels: Farrokh, Ghasem, SHF-81-90, Barzegar, G5*43, G6*43, Hysun 25, Euroflor, Hysun 36, Azargol, Sumbro and Sirena. Results indicated that reducing the irrigation, especially severe drought stress, had adverse effect on the measured traits. The effect of cultivar was also significant on head diameter, 1000 grain weight and grain yield. The interaction of irrigation × cultivar had only a significant effect on 1000 grain weight. Results showed that Barzegar cultivar had the highest grain yield under normal irrigation (4767.66 kg/ha), moderate stress (3850.66 kg/ha) and extreme stress (3208.33 kg/ha).

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Introduction

Sunflower is one of the most important oil crops under cultivation all over the world. Sunflower is fairly resistant to drought stress; however, its production efficiency suffers from the stress in the way that grain yield reduces when the plant faces drought stress (Chimenti et al., 2002).

Drought is the most common abiotic stress which limits crop production in different parts of the world especially in Iran which is considered as an arid and semiarid country (Sabaghpour et al., 2006). Water deficit has major effect on grains weight in the way that 1000 grain weight significantly reduces when the interval of the irrigations increases (Goksoy et al., 2004). Drought stress reduces plant leaf area and consequently reduces photosynthesis rate and re-translocation. In addition to the reduction of the translocation of photosynthetic assimilates to the developing grains, the reduction of grain weight may be also attributed to the reduced photosynthesis rate and the defoliation of leaves at the flowering stage (Rauf, 2008; Nazarli and Zardashti, 2010). Tan et al. (2000) reported that grain oil content is affected by both environmental factors and genetic factors.

So, this experiment was conducted in order to assess the response of various sunflower cultivars to drought stress.

Materials and methods

Site and treatments

This experiment was conducted in factorial in the form of a randomized complete block design with three replications in 2013 at the Agricultural Research Station of Islamabad Gharb, Kermanshah province, Iran. The first factor was cultivar in 12 levels: Farrokh, Ghasem, SHF-81-90, Barzegar, G5*43, G6*43, Hysun 25, Euroflor, Hysun 36, Azargol, Sumbro and Sirena. The second factor was drought stress in three levels: normal irrigation after 60 mm evaporation from an A class evaporation pan (control; ET60), irrigation after 120 (ET120) and 180 mm (ET180) evaporation from the pan. For normal irrigation (ET60), plots were irrigated after 60 mm evaporation from the A class evaporation pan, from the plantation stage to the end of the plant growth period. In moderate drought stress level (ET120), irrigation was conducted after 120 mm evaporation from the pan and in extreme stress level (ET180), irrigation was conducted after 180 mm evaporation from the pan. The moderate and extreme drought stress levels were started from the eight leaves stage.

Field practices

The field preparation included moldboard plowing, disk ing, leveling, furrowing and fertilizing according to the soil analysis test. Seeds were planted manually and the field was irrigated until the full establishment of the seedlings. Each plot consisted of four planting rows each one 5 m long. Planting rows were 65 cm apart from each other and seeds were planted every 20 cm. To achieve the desired density, three seeds were planted in every planting hole and they were thinned to one seedling when plants were 15-20 cm tall. In order to prevent plants from birds attack after the flowering stage, the heads were covered by newspapers or suitable bags until the harvest stage. During the growth period, normal agronomic practices such as weeding or controlling pests were conducted.

Measurements and statistical analysis

In this experiment, the following traits were measured: head diameter, 1000 grains weight, grain yield and oil percentage. After collecting the data, they were analyzed using SAS and means were compared according to the LSD method.

Results and discussion

Head diameter

Analysis of variance showed that drought stress had significant effect on head diameter at P≤0.05 (Table 1). Mean comparison showed that the highest head diameter (15.9 cm) was related to the normal irrigation and the lowest head diameter (13.44 cm) was related to the extreme drought stress (ET180) (Fig. 1). The size of head in sunflower is an indicator of the yield potential because the fertilized flowers in head will form the grains after inoculation. Nezami et
Amjadian et al. (2008) reported the reduction of sunflower head size under drought stress; however, the moderate stress had no significant differences with the normal irrigation. Under moderate drought stress, plants tolerate the conditions through different mechanisms (Goksöy et al. 2004).

Table 1. Analysis of variance of the effect of treatments on the measured traits.

<table>
<thead>
<tr>
<th>SOV</th>
<th>df</th>
<th>Mean Squares (MS)</th>
<th>Head diameter</th>
<th>1000 grain weight</th>
<th>Grain yield</th>
<th>Oil percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>2</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
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<td>*</td>
</tr>
<tr>
<td>Cultivar</td>
<td>11</td>
<td>**</td>
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<td>**</td>
<td>ns</td>
<td>**</td>
</tr>
<tr>
<td>Drought stress</td>
<td>2</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>ns</td>
</tr>
<tr>
<td>Cultivar × Stress</td>
<td>22</td>
<td>ns</td>
<td>*</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Error</td>
<td>69</td>
<td>0.94</td>
<td>12.30</td>
<td>268186.34</td>
<td>5.06</td>
<td></td>
</tr>
</tbody>
</table>

CV (%): 6.21, 6.55, 14.64, 5.42

ns, nonsignificant; *, significant at P≤0.05; **, significant at P≤0.01.

In our experiment, cultivar had a significant effect (P≤0.01) on head diameter in the way that head diameter was the highest (16 cm) in G6*43, G5*43, Hysun 36 and Euroflor cultivars and the lowest (14.4 cm) in Ghasem cultivar (Fig. 2). It seems that the genetic variation of the cultivars is the reason for different head size. These findings are in agreement with those of Iqbal et al. (2005).

1000 grains weight

Analysis of variance showed that drought stress had a significant effect (P≤0.05) on 1000 grain weight (Table 1). The highest 1000 grain weight (55.71 g) was achieved in normal irrigation and the lowest 1000 grain weight (50.31 g) was achieved in the extreme drought stress level. 1000 grain weight was 52.5 g in the moderate drought stress level (Fig. 3). Dehkhoda et al. (2013) reported that the reduction of 1000 grain weight under drought stress is due to the reduction of the grain filling period length early aging. In fact, drought stress reduces the weight and the number of grains through reducing the leaf area. It is also possible that drought stress has negative effect on the translocation of the photosynthetic assimilates which reduces the accumulation of the assimilates in grains.

Ahmadi and Zali (2004) reported that grain weight of different cultivars reduced under drought stress because of the reduction of the photosynthetic assimilates accumulation in grains.
found a significant effect of hybrid on grain weight at P≤0.05. They reported that 100 grain weight of Hysun 33 cultivar was 3.6% and 6.7% more than Record and Armavirosky cultivars, respectively. The concluded that 100 grain weight of Hysun 33 cultivar was higher than other cultivars because there has been lower competition between fertilized florets and grains on the head of this cultivar compared with the other cultivars, to obtain the photosynthetic assimilates.

Results of our experiment also showed that the interaction of drought stress × cultivar was also significant on this trait (Table 1); the highest 1000 grain weight (64.80 g) was related to normal irrigation × Barzegar cultivar and the lowest 1000 grain weight (50.70 g) was related to the extreme drought stress level × Farrokh cultivar.

**Grain yield**

Analysis of variance showed that drought stress significantly affected grain yield at P≤0.05 (Table 1). Grain yield was the highest (4184.6 kg/ha) in the normal irrigation and the lowest (2854.3 kg/ha) in the extreme drought stress level. Grain yield was 3589.1 kg/ha in the moderate drought stress level (Fig. 5). It seems that providing balanced amount of water to plants in different growth stages such as the flowering and the grain filling stages results in the improvement of grain yield because in these stages two important components of the grain yield (the number of grains in head and 1000 grain weight) forms. In addition, sufficient irrigation in vegetative growth stage results in the development of leaf area and improvement of plant photosynthesis rate. Although sunflower is partly resistant to drought stress, or grows in rainfed farming systems; however, sufficient irrigation will significantly boost the plant’s yield (Serraj and Sinclair, 2002).

Cultivar had also a significant effect (P≤0.01) on grain yield (Table 1). The highest grain yield (4004.4 kg/ha) was related to Barzegar cultivar and the lowest grain yield (3103.4 kg/ha) was related to Ghasem cultivar (Fig. 6). The variation in grain yield of different cultivars may be attributed to their genetic variations. Rezaei Zad (2007) also observed a significant variation in grain yield of different sunflower cultivars. They reported that Azargol and Record cultivars had the highest grain yield (3908 and 3907 kg/ha, respectively) among the tested cultivars. These findings were also observed in the experiments of Soorninia et al. (2012).

**Grain oil percentage**

Results of our experiment indicated that drought stress had a significant effect on oil percentage at P≤0.05 (Table 1). Mean comparison showed that the...
highest oil percentage (42.19%) was achieved in normal irrigation and the lowest essential oil percentage (40.8%) was achieved in the extreme drought stress level (ET180). Oil percentage was 41.36% in the moderate drought stress level (Fig. 7). Anonymous (1993) reported that drought stress reduced sunflower grain oil percentage by 4% compared with the normal irrigation. The reported that this reduction is because at first, carbohydrates accumulates and then changes to oil, protein or other forms. As the result, when this period is longer, oil percentage will be higher. Regarding the results of our experiment, it may be concluded that grain filling stage is longer in normal irrigation so grain oil percentage is higher. Moreover, drought stress increases the thickness of grain cuticle and reduces the ratio of grain kernel to grain cuticle; resulting in the reduction of oil percentage.

Analysis of variance showed that cultivar had no significant effect on grain oil percentage (Table 1). However, mean comparison showed that the highest oil percentage (43.4%) was related to Sumbro cultivar and the lowest oil percentage was related to Euroflor (40.5%), G6*43 (40.46%), Farrokh (40.8%), Ghasem (40.8%) and G6*43 (40.9%) (Fig. 8). The variation in oil percentage of different cultivars may be attributed to the variation in their genetic potential. In addition, in these cultivars the length of the growth period has been low and consequently lower photosynthetic assimilates have been stored in grains; reducing the oil percentage. These findings are in agreement with those of Jabbari et al. (2008).

References


