Evaluate the effect of plant density on yield and morphology of winter safflower under irrigated and non-irrigated conditions

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Abstract:
In order to investigate the effect of plant density on morphology and yield of winter safflower (Zarghan varietie) under irrigated and non-irrigated conditions, a factorial experiment based on randomized complete block design with three replications was carried out in autumn 2013 in Ardebil. Factors include the planting of two levels (irrigated and no irrigation) and plant densities with four levels (20, 35, 50 and 65) plants per square meter. For this purpose, were studied some morphological traits and traits related to yield and yield components. The results showed that most of the traits in terms of non irrigation conditions, decreases and with increasing plant density per square meter, increased. In terms of morphological traits, the diameter and height of the plants were higher under irrigated conditions than under rain-fed conditions. The stem diameter of the plants was higher under the lowest density (i.e. 20 plants per m²). Also, the height of the first head-bearing branch from ground was the highest at the highest density (65 plants per m²) under irrigated conditions and the lowest one was obtained at the lowest density (20 plants per m²) under both irrigated and rain-fed conditions. The results were converse for the number of main branches, head number and seed number per unit area. Also can be said that according to the research, drought stress (non irrigation) have a significant effect on yield and dry conditions was reduced.

Key words: Safflower, Zarghan, irrigation and no irrigation, density, yield.

1- Introduction

Safflower (Carthamus tinctorius L.) belongs to the Asteraceae family. It has been proved to be able to grow in a wide range of climatic conditions and its wild varieties have been observed throughout Iran (Pourdad, 2006).

It seems that taller and more late-maturing genotypes of safflower produce higher seed yield under no-stress conditions (Abulhasani and Saeidi, 2003). The highest yield of safflower was obtained by control (full irrigation) and its seed yield was 4.05 and 3.74 t.ha⁻¹ for summer and winter treatments under full irrigation treatment, respectively. The highest water use efficiency under irrigated treatment was obtained only during vegetative growth stage, whereas the lowest one was obtained when the plants were irrigated only during yield stage. Irrigation can influence yield by changing yield components. The impact of the time of drought stress occurrence on seed yield can be as important as the intensity of the stress (Rostami, 2004). In a study on common bean, Ramirez-Vallejo and Kelly (1998) reported that the decrease in seed yield under drought stress conditions ranged 22-71% in the studied genotypes and that among the yield components, pod number and seed number per pod were most affected by the stress.

Istanbulluoglu (2009) evaluated the effect of irrigation and water stress at different developmental stage on seed yield per ha and 1000-seed weight and found that safflower was significantly affected by late-vegetative period stress.

The highest yield was produced at early and late vegetative growth and during seed formation period. Marita and Muldoon (1995) and Patel (1993) stated that different irrigation regimes in safflower were at the stages of rapid stem growth, flowering and seed-setting. They
also reported that the highest yield was obtained when the plants were irrigated only once at flowering stage.

Nabavicalat et al. (2004) reported that plant density significantly affected plant height, the height of the first branch from the ground, auxiliary branch number, head number, seed number per head and seed yield. The studies on the effect of plant density per unit area on different crops have showed that density variations influence agronomical traits and the yield per unit area (Kouchaki, 1996). Plant density did not significantly impact branch number per plant, head number per m², seed number per head, 1000-seed weight and seed yield per unit area. Branch number per m² increased with plant density, but head number per branch and per plant, single-plant yield and harvest index were decreased. The highest seed yield (4769 kg.ha⁻²) was obtained from inter-row spacing of 30 cm and the density of 40 plants per m². Given the optimum effect of uniform distribution of plants per unit area and the adaptation of safflower to plain sowing method, inter-row spacing of 30 cm with the density of 40 plants per m² might be appropriate for safflower production under the conditions similar to those of the current study (Azari and Khajehpour, 2003). Though, some studies on safflower did not show the effect of the increase in density on seed weight (Nasr et al. 1978; Blackshaw, 1993; Rashed Mohasel and Behdani, 1993).

Ranjbar et al. (1987) found that the optimum seeding rate (inter-row and on-row inter-plant spacing) affected yield and yield components via changing the density and environmental resources. According to the study of the effect of severe variations of optimum seeding rate on yield and yield components, plant height, branch number, seed number per head and 1000-seed weight, it significantly impacted branch number and head number per plant. The increase in inter-row spacing and the decrease in seeding rate resulted in the increase in branch number and head number per plant. The increase in seeding rate resulted in the significant loss of branch and head number per plant. The loss of single-plant seed yield essentially due to the increase in plant number per m² did not result in significant difference in seed yield. In addition, the interaction between density and inter-row spacing was not significant for any studied traits. The difference in yield was not significant as affected by plant density. Also, boll number per plant and seed number per boll were not affected by plant density (Hashemi Dezfuli, 1994).

The aim of the this study was to examine the effect of different plant densities on some morphological traits and yield of winter safflower under irrigated and rain-fed farming conditions in Ardabil, Iran.

2- Materials and Methods

In order to investigate the effect of plant density on morphology and yield of winter safflower (Zarghan varietie) under irrigated and non-irrigated conditions, a factorial experiment based on randomized complete block design with three replications was carried out in autumn 2013 in Ardebil. Factors include the planting of two levels (Irrigated and non-irrigation) and plant densities with four levels (20, 35, 50 and 65) plants per square meter. For this purpose, were studied some morphological traits and traits related to yield and yield components. The soil of the study field was sampled at the depths of 0-30 cm to determine its physical and chemical characteristics. Then, they were analyzed in Water and Soil Laboratory whose results are presented in Table 1.

<p>| Table 1. Results of soil analysis of the study field |
|-----------------|-------|---------|-------|--------|-------------|----------------|---------|</p>
<table>
<thead>
<tr>
<th>Depth</th>
<th>Saturation percentage</th>
<th>EC (ds/m)</th>
<th>pH</th>
<th>Neutralizable material</th>
<th>Organic C (%)</th>
<th>Total N (%)</th>
<th>Absorbable P (ppm)</th>
<th>Absorbable K (ppm)</th>
<th>Soil texture</th>
<th>Soil type</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-30</td>
<td>48</td>
<td>2.66</td>
<td>7.8</td>
<td>4.8</td>
<td>0.97</td>
<td>0.103</td>
<td>4.8</td>
<td>460</td>
<td>Clay</td>
<td>Loom-clay</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
The first irrigation was conducted at the same day. To study the morphology from sowing until harvesting time, three plants were randomly selected from each plot and the studied traits were measured and recorded such as final plant height, main stem basal diameter and the height of the first head-bearing branch from ground.

To determine yield and yield components, plant number per unit area, boll number per plant, seed number per boll, seed weight and plant height and to record other quantitative traits including final branch number, the plants were cut from the two middle rows after eliminating 0.5 m from the both ends of the rows. The plants were then dried separately under natural conditions. Next, their seeds were separated from other parts and the dried seeds were weighed. The analysis of variance was done by SAS software and the means were compared by Duncan Test. The graphs were drawn by MS-Excel software. At the end, the coefficients of correlation between the traits were calculated.

3- Results and Discussion
3-1- Number of Initial branch per m²

Analysis of variance (Table 2) indicated that the impact of simple effects of planting conditions and plant density was significant on the number of initial branches per m² at 1% probability level, while means comparison (Table 3) showed that the number of initial branches of the plants was higher under irrigated conditions than under rain-fed conditions. The highest number of initial branches was observed at the density of 20 plants per m² while it was higher at the density of 50 plants per m² than at the densities of 35 plants per m² under irrigated conditions and at the density of 65 plants per m² under rain-fed conditions. They were ranked in the same statistical group in both conditions. Azari and Khajehpour (2003) reported that plant density increased the number of branches per m².

3-2- Number of secondary branches

Results of analysis of variance (Table 2) showed that the main effect of plant density was significant on the number of secondary branches at 1% probability level. Also, means comparison (Table 3) indicated that neither the planting conditions nor the plant density affected it significantly. Shariciyan and Babaeiyan-jelidar (1999) found that the increase in plant density resulted in the loss of auxiliary branch number, whereas Nabavicalat et al. (2004) reported that plant density significantly influenced auxiliary branch number and some yield components. An important advantage of high plant density is the prevention of the formation of redundant auxiliary branches and the resulting prevention of the formation of late-maturing heads, which leads to uniform maturity of safflower plants (Azari and Khajehpour, 2003).

3-3- Plant height

Results of analysis of variance (Table 2) indicated that the simple effect of planting conditions was significant on plant height at 1% probability level, but the simple effect of plant density was not significant on it. According to means comparison (Table 3), mean plant height was higher under irrigated conditions than under rain-fed conditions. In the studies conducted by Shariciyan and Babaeiyan-jelidar (1999) and Nabavicalat et al. (2004), main stem height was increased as the plant density was increased. Ramachandram (1983) reported that seed yield had a positive, significant correlation with plant height. Kumar et al. (1982) found that the relation between plant height and seed yield was positive and significant.
3-4- Number of Head per m²

According to the results of analysis of variance (Table 2), the simple effect of planting conditions was statistically significant on head number per unit area at 1% probability level and the interaction between plant densities and planting conditions was significant for it at 5% probability level. Means comparison (Table 3) showed that more heads per unit area were produced under irrigated conditions than under rain-fed conditions, whereas no significant difference was observed for the main effect of plant density. The highest head number per unit area was produced by plants at the density of 35 and 65 plants per m² under irrigated conditions and the lowest one with significant differences was produced by plants at the density of 35 plants per m² under rain-fed conditions which was ranked in the same group with the densities of 20 and 65 plants per m² under rain-fed conditions. Under rain-fed conditions, the highest head number per unit area was obtained from the density of 50 plants per m² which was ranked in the same group with the all densities of irrigated conditions. Azari and Khajehpour (2003) found that plant density significantly affected head number per m². Also, Fazeli Kakhaki et al. (2006) concluded that plant density increased head number per unit area.

3-5- Seed length

As the results of analysis of variance for this trait showed (Table 2), there was statistically significant difference between the simple effects of planting conditions. Means comparison (Table 3) revealed significant differences in seed length as affected by plant density and planting conditions.

Table 2. Summary of analysis of variance for some studied traits at final harvest

<table>
<thead>
<tr>
<th>S.O.V.</th>
<th>df</th>
<th>Means of squares</th>
<th>Number of Initial branch</th>
<th>Number of Secondary branch</th>
<th>Plant height</th>
<th>Number of Head</th>
<th>Seed length</th>
<th>Seed yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Replication</td>
<td>2</td>
<td>27279.78**</td>
<td>0.86*</td>
<td>7.41**</td>
<td>1970.24**</td>
<td>0.16**</td>
<td>112927.65**</td>
<td>ns</td>
</tr>
<tr>
<td>Planting conditions (C)</td>
<td>1</td>
<td>493168.31**</td>
<td>0.14**</td>
<td>698.12**</td>
<td>33225.32**</td>
<td>0.65**</td>
<td>8258630.52**</td>
<td>ns</td>
</tr>
<tr>
<td>Plant density (D)</td>
<td>3</td>
<td>149282.64**</td>
<td>1.99**</td>
<td>12.45**</td>
<td>590.72**</td>
<td>0.21**</td>
<td>6032444.29**</td>
<td>ns</td>
</tr>
<tr>
<td>Interaction CxD</td>
<td>3</td>
<td>5630.82**</td>
<td>0.19**</td>
<td>17.28**</td>
<td>3590.97**</td>
<td>0.17**</td>
<td>700925.92**</td>
<td>ns</td>
</tr>
<tr>
<td>Error</td>
<td>14</td>
<td>13539.82</td>
<td>0.29</td>
<td>44.51</td>
<td>1448.50</td>
<td>0.15</td>
<td>369453.87</td>
<td>ns</td>
</tr>
</tbody>
</table>

Coefficient of variation (%)  
15.29  24.34  11.85  28.19  6.20  26.96

ns, * and ** show non-significance and significance at 5 and 1% level, respectively.

Table 3. Summary of means comparison for the main studied effects on some traits at final harvest using Duncan Test at 5% probability level.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Number of Initial branch (m²)</th>
<th>Number of Secondary branch</th>
<th>Plant height</th>
<th>Number of Head (m²)</th>
<th>Seed length</th>
<th>Seed yield (kg/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting conditions</td>
<td>Irrigated</td>
<td>802.31 a</td>
<td>5.16 a</td>
<td>72.29 a</td>
<td>158.27 a</td>
<td>8.81 a</td>
</tr>
<tr>
<td></td>
<td>Rain-fed</td>
<td>568.60 a</td>
<td>4.99 b</td>
<td>65.49 b</td>
<td>101.86 b</td>
<td>9.08 a</td>
</tr>
<tr>
<td>Plant density</td>
<td>20 plants/m²</td>
<td>882.27 a</td>
<td>8.26 a</td>
<td>59.13 a</td>
<td>145.65 a</td>
<td>9.00 a</td>
</tr>
<tr>
<td></td>
<td>35 plants/m²</td>
<td>685.58 b</td>
<td>5.07 b</td>
<td>58.83 a</td>
<td>132.13 a</td>
<td>9.11 a</td>
</tr>
<tr>
<td></td>
<td>50 plants/m²</td>
<td>640.97 b</td>
<td>3.78 b</td>
<td>71.01 a</td>
<td>139.72 a</td>
<td>9.02 a</td>
</tr>
<tr>
<td></td>
<td>65 plants/m²</td>
<td>589.00 b</td>
<td>3.49 b</td>
<td>70.14 a</td>
<td>144.76 a</td>
<td>8.65 a</td>
</tr>
</tbody>
</table>

Means with similar letter did not show significant differences.
3-6- Seed yield (kg.ha$^{-1}$)

Results of analysis of variance (Table 2) showed significant differences between planting conditions for seed yield at 1% probability level. Means comparison for this trait (Table 3) indicated that seed yield was higher under irrigated conditions than under rain-fed conditions and that plant density played no role in increasing or decreasing seed yield under either planting conditions. Ranjbar et al. (2004) found that the decrease in single-plant seed yield essentially caused by the increase in plant number per m$^2$ did not bring about significant differences in seed yield compared to different seeding rate. Therefore, 20 seeds per m$^2$ with inter-row spacing of 20 cm had the highest yield and 50 seeds per m$^2$ with inter-row spacing of 35 cm had the lowest one which is inconsistent with the results of the current study. But, Azari and Khajehpour (2003) reported that the increase in plant density resulted in the loss of plant size and yield components of the plants, but the resulting increase in plant number per unit area often compensated the total loss of the yield vs. single-plant yield.

Istanbulluoglu, (2009) observed the highest seed yield under full-irrigation treatment and reported that safflower seed yield of the plants treated with full irrigation was 40.5 and 3.74 t.ha$^{-1}$ under summer and winter treatments, respectively. Tavakkoli (2001) found that irrigation withdrawal at flowering stage decreased the yield which was brought about by the loss of head number per plant and seed number per head.

4- Conclusion

In terms of morphological traits, the diameter and height of the plants were higher under irrigated conditions than under rain-fed conditions. The stem diameter of the plants was higher under the lowest density (i.e. 20 plants per m$^2$). Also, the height of the first head-bearing branch from ground was the highest at the highest density (65 plants per m$^2$) under irrigated conditions and the lowest one was obtained at the lowest density (20 plants per m$^2$) under both irrigated and rain-fed conditions. The results were converse for the number of main branches, head number and seed number per unit area.

5- References