Effect of planting date and plant density on morphological traits, LAI and forage corn (Sc. 370) yield in second cultivation

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ABSTRACT: In order to study the effect of sowing date and plant density on morphological traits, LAI and forage corn yield, a split-plot experiment was carried out in the research field of Islamic Azad University, Gonabad Branch, Gonabad, Iran in 2007 based on a randomized complete block design with three replications. The sowing dates of the main plot at three levels were July 4, July 21 and August 6. The sub-plot was of plant density at four levels 50, 80, 110 and 140 thousand plants/ha. The results showed that delay in sowing from July 4 to August 6 decreased significantly the plant height, stem diameter, leaf area index, total fresh and dry yield by 15.7, 20.9, 42.1, 24.7 and 25.9%, respectively. With increasing plant density from 50000 to 140000 plants/ha, stem diameter decreased by 21.6%, but plant height increased 15.1%. Moreover leaf area index and total dry yield, increased 3.39 and 1.84 times, respectively. According to the results, the treatment of sowing date of July 4 with density of 140000 plants/ha recommended for the cultivation of forage corn in Gonabad, Iran as second cultivation.

Keywords: forage corn, sowing date, plant density, yield, LAI, morphology.

Introduction

Maize (Zea mays L.) is the world's most widely grown cereal and it is ranked third among major cereal crops (Ayisi and Poswall, 1997). Maize has a big potential in that it has a large utilization as food sources for people and animals and for industry. Sowing date and plant density are very important parameters in crop production. The optimum sowing date and plant density paves the way for better-use of time, light, temperature, precipitation and other factors. Planting date is critical in cold climates due to the potential for frost damage in late of season (Kondra, 1977; Johnson et al., 1995). Rastegar (2004) reported that delay in sowing from April 25 to June 9 decreased total yield of corn by 38%. Also, Kresovic et al. (1997) in sweet corn reported that delay in sowing from June 21 to July 11 decreased total yield of corn by second crop. There is an optimum plant density for each crop. Also, it is possible that under low plant density, although single-plant production increased, yield per unit area decreases (Gardner et al., 1984; Ghanbari and Taheri Mazandarani, 2003). On one hand, plant deficit per unit area prevents maximum usage of production parameters and on the other hand, excessive density can increase the competition and decrease the yield. Plant density is of particular importance in corn, because it does not have tillering capacity to adjust to variation in plant stand. Cox and Cherney (2001) reported that increasing plant density increased dry matter (DM) yield of corn and the difference in DM yield between the two plant densities (32000 and 47000 plants/ac) was 13.7%. However,
maximum forage corn yields have also been reported at 79000 plants ha\(^{-1}\) (Graybill et al., 1991) and 100000 plants ha\(^{-1}\) (Sparks, 1988).

Bangarwa et al. (1988) stated that generally, the yield of a single maize plant decreases with increasing plant population whereas the yield per unit area increases. Also, Rutger and Crowder (1967) and Karlen et al. (1985) reported that total dry matter increases 6 to 40% when plant density increases from about 55000 to 88000 plants ha\(^{-1}\).

Edwards et al. (2005) reported dry matter accumulation increase for corn hybrids at high than at low density due to light interception. Ayisi and Poswall (1997) reported that leaf area index is major factor determining photosynthesis and dry matter accumulation. Also, Al-Suhaibani (2011) stated that fresh and dry weights were increased at high plant density of Pearl Millet (*Pennisetum glaucum* L.) and high plant density produced the highest leaf area index.

Yarnia (2010) reported that interaction between delay sowing and increasing plant density decreased leaf area of amaranth at least 19.63 up to 97.15%. Safar1 et al. (2008) in a study to determine the best planting date and plant density on forage yield of foxtail millet stated that forage yield increased with increasing plant density. The highest forage yield obtained in 60 plants/m\(^2\) and forage yield decreased with delaying of planting date, as highest density forage yield obtained in first planting date. Also, total dry matter and leaf area index increased with increasing plant density but decreased with delay in planting date. Therefore, this research was carried out to evaluate the effect of different plant densities and planting dates on yield, LAI and morphological traits of forage corn in drought stress condition in Gonabad, Iran climate.

**Materials and Methods**

The study was carried out in the Research Station of Islamic Azad University, Gonabad Branch, Iran (Long. 58°50´ E., Lat. 34°27´ N., Alt. 985 m above sea level) in 2007. The soil was loamy with pH of 8.1, EC of 1.46 ds.m\(^{-2}\) and organic carbon content of 0.31% at the depth of 0-30 cm. The average long-time minimum and maximum temperature was -3 and 38.5°C with average annual precipitation of 136 mm and average minimum and maximum relative humidity of 20.5 and 51.6%, respectively. The regional climate was hot and arid.

It was a split-plot experiment based on a randomized complete block design with three replications. In this study, the effects of sowing date at three levels (July 4, July 21 and August 6) as the main plot and plant densities at four levels (50, 80, 110 and 140 thousand plants/ha) as the sub-plot were examined. Each plot was 3m×6m with six planting rows. The space between rows, plots and replications was 0.75, 1 and 2 m, respectively. The field had been left fallow in the previous year. According to the results of soil test, 120 kg/ha ammonium phosphate and 150 kg/ha soleplate potassium was applied to the soil before final disking. Having disinfected by fungicide carboxin thiram with the ratio of 2:1000, the seeds were dry-sown at the depth of 3-4 cm. The desired plant densities were created by changing the spacing between plants at the emergence of the three leaves. Given the local climate and soil type, the irrigation was carried out once every 6-8 days and the weeds were removed 3-4 times at each sowing date.

Nitrogen fertilizer was applied 120 kg/ha as 1/3rd at sowing, 1/3rd at 6-7 leafy and 1/3rd before appearance of tasseling in the form of urea. Weeds were controlled manually. To calculate total fresh yield, an area of 2 m\(^2\) was harvested from each plot considering the margin effect. Then, for total dry yield determination a sample of 500-gr was randomly taken from each plot and samples were oven dried at 70°C to constant weight and weighed by a 0.01-precision digital scale. To determine morphological traits including plant height, leaf number per plant and stem diameter, eight plants were selected from the middle of the plots and measured.

Leaf area index was determined by dividing leaf area over ground area at tasseling stage. At the end, the data were analyzed by statistical software MSTAT-C and the means were compared by Duncan Multiple Range Test at 5% level. The graphs were drawn by MS-Excel.

**Results and Discussion**

*Morphological traits*

The results showed that plant height and stem diameter of forage corn were significantly affected by sowing date and plant density but leaf number per plant no significantly affected by them. Also, sowing date and plant density interaction was not significant on morphology traits (Table 1).
Table 1. Mean of squares of the effect of sowing date and plant density on morphological traits, LAI and yield of forage corn

<table>
<thead>
<tr>
<th>Sources of variation</th>
<th>df</th>
<th>Mean squares</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Plant height</td>
</tr>
<tr>
<td>Replication</td>
<td>2</td>
<td>121/755</td>
</tr>
<tr>
<td>Sowing date (A)</td>
<td>2</td>
<td>1153/567</td>
</tr>
<tr>
<td>Error a</td>
<td>4</td>
<td>160/142</td>
</tr>
<tr>
<td>Plant density (B)</td>
<td>3</td>
<td>268/377</td>
</tr>
<tr>
<td>A × B</td>
<td>6</td>
<td>233/010</td>
</tr>
<tr>
<td>Error b</td>
<td>18</td>
<td>37/718</td>
</tr>
<tr>
<td>C.V. (%)</td>
<td></td>
<td>5/8</td>
</tr>
</tbody>
</table>

*ns* Non Significant at 0.05 probability level and *, ** Significant at 0.05 and 0.01 probability levels, respectively

Means comparison indicated that with the delay in sowing, plant height was decreased by 5.7 and 15.7% at the sowing dates of July 21 and August 6 as compared with the sowing date of July 4, respectively (Table 2). Also, means comparison indicated that 31-day delay in sowing from July 4 to August 6 led to the 20.9% loss of stem diameter (Table 2). The significant decrease in plant height and stem diameter traits following the delay in sowing can be associated with higher temperatures that the plants at the second and third sowing dates experienced which limited their growing period and assimilate-building because of the early maturity of plants. Thus, the plants did not have adequate opportunity for photosynthesis and their height and stem diameter capacity decreased. These results are in agreement with the results of Jafari (2010) on forage millet. Moreover, Amiri (2003) stated that with the delay in sowing date caused a decrease in stem diameter. Morin and Dormency (1993) and Imholte and Carte (1987) reported that delay of sowing caused a decline in plant height which are agreement with results of this study.

Means comparison showed that increase in plant density from 50000 to 140000 plants/m² increased plant height by 15.1% (Table 3). But increase in plant density from 50000 to 80000, 110000 and 140000 plants/m² decreased stem diameter by 16.2, 15.1 and 21.6%, respectively (Table 3). It appears that the increase in plant height following the increase in plant density was related to the increase in the inter-plant competition over light and the disruption of the balance of growth regulators. Under these conditions, plant height increases if other environmental parameters – e.g. moisture and soil fertility – do not limit the growth of plants (Imam and Ranjbar, 2000). In order words, the decrease in light penetration into middle and lower layers of canopy decreases auxin decomposition and thus, plant height increases. Also, Moosavi (2007) on forage sorghum and Mohammad Nikpoor (1995) on safflower reported the increase in plant height with the increase in plant density. They stated that the increase in internode length was the main reason for the increase in plant height. Nonetheless, Rezvani Moghaddam et al. (2005) stated that the increase in plant density had no significant effect on sesame plant height. Moreover, some researchers found that under excessively high densities, plant height do not increase and even tends to decrease because the plants compete over other growth-affecting parameters than light (Mukhopadhy and Sen, 1997).

Table 2. Effect of Sowing date on morphological traits and yield of forage corn

<table>
<thead>
<tr>
<th>Planting date</th>
<th>Plant height (cm)</th>
<th>Stem diameter (mm)</th>
<th>Leaf number per plant</th>
<th>Total fresh yield (gr/m²)</th>
<th>Total dry yield (gr/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>July 4</td>
<td>113.2 a</td>
<td>18.2 a</td>
<td>10.2 a</td>
<td>5170.48 a</td>
<td>923.3 a</td>
</tr>
<tr>
<td>July 27</td>
<td>106.8 ab</td>
<td>15.6 ab</td>
<td>9.7 a</td>
<td>4463.51 ab</td>
<td>768.2 ab</td>
</tr>
<tr>
<td>Aug 6</td>
<td>95.4 b</td>
<td>14.4 b</td>
<td>9.4 a</td>
<td>3831.90 b</td>
<td>695.1 b</td>
</tr>
</tbody>
</table>

Means followed by the same letters in each column-according to Duncan’s multiple range test are not significantly (P<0.05)
The reason for the 21.6% loss of stem diameter as plant density was increased could have been the intensified inter-plant competition on environmental parameters (light, water, space) and hence decrease of photosynthesis, assimilates production and its partitioning, that finally caused reduction of stem diameter. In other words, the lower the density is, the more active the plants are to intake nutrients to increase its vegetative growth as well as stem diameter given that the competition is mitigated too, while the conditions are different at higher densities. Aslam et al. (2011) in maize confirmed this finding. Means comparison showed that under the conditions of the current study, although delay of sowing and increase of plant density numerically decreased leaf number per plant, but different density levels for this trait situated in same statistical group (Tables 2 and 3).

<table>
<thead>
<tr>
<th>Density (plant/ha)</th>
<th>Plant height (cm)</th>
<th>Stem diameter (mm)</th>
<th>Leaf number per plant</th>
<th>Total fresh yield (gr/m²)</th>
<th>Total dry yield (gr/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50000</td>
<td>98.4 b</td>
<td>18.5 a</td>
<td>10 a</td>
<td>548.91 c</td>
<td>3075.51 c</td>
</tr>
<tr>
<td>80000</td>
<td>103.8 a</td>
<td>15.5 b</td>
<td>9.9 a</td>
<td>752.38 b</td>
<td>4208.5 b</td>
</tr>
<tr>
<td>110000</td>
<td>107.1 a</td>
<td>15.7 b</td>
<td>9.9 a</td>
<td>871.92 ab</td>
<td>4950.9 ab</td>
</tr>
<tr>
<td>140000</td>
<td>113.3 a</td>
<td>14.5 b</td>
<td>9.6 a</td>
<td>1008.9 a</td>
<td>5652.9 a</td>
</tr>
</tbody>
</table>

Means followed by the same letters in each column according to Duncan’s multiple range test are not significantly (P<0.05).

Leaf area index (LAI)
The results showed that change in sowing date and plant density significantly affected LAI at tasseling stage, but their interaction was not significant on LAI (Table 1). The mean LAIs in sowing dates of July 4, July 21 and August 6 were 2.85, 2.12 and 1.65 respectively (Fig. 1). The increase or decrease in LAI has a direct effect on plant growth rate. This index is the main tool for enhancing photosynthesis capacity and assimilates production. Also, Lizaso et al. (2003) stated that the average absorbed photosynthetic active radiation (PAR) by leaf area at reproductive stage was the determining factor of corn yield and the decrease in yield had a high correlation with the decrease in corn leaf area. Delay of sowing because shortening of the growing cycle caused reduction of LAI that is agreement with Noferesti (2006) report.

Moreover, means comparison of LAI indicated that density 140000 plants/ha had 3.4 times higher LAI than 50000 plant/ha−1 (Fig. 2). Application of optimum plant density in corn production helps for the proper utilization of solar radiation, which influences leaf area, interception and utilization of solar radiation, and
consequently corn dry matter accumulation and biomass produced. The LAI had a positive and significant correlation with forage yield (Table 4).

Increasing plant density is one of the ways of increasing the capture of solar radiation within the canopy and LAI (Moderras et al., 1998) and increasing of dry matter accumulation. Generally, in suitable plant density, plants are completely use environmental conditions (water, air, light and soil) and inter- or intra-specific competition is minimum. Also, Williams (2012) and Baron et al. (2006) reported that one of ways of increasing leaf area index is to increase plant density.

Figure 2. Effect of plant density on leaf area index of forage corn

Gan et al. (2002) showed that planting density influenced leaf area and intensity of light and thus received the soybean canopy photosynthesis. Also, Agam-Norozzi and Bahrani (1995) reported that with the increase in plant population it significantly increased LAI.

**Total fresh and dry yield**

According to the results, total fresh and dry yield of forage corn were significantly affected by sowing date and plant density, but their interaction was not significant on them (Table 1). Means comparison revealed that delay in sowing from July 4 to August 6 decreased total fresh and dry yield by 25.9 and 24.7%, respectively (Table 2). Delay of sowing and shortening of the growing cycle decreased the amount of radiation intercepted during the growing season and thus total fresh and dry yield of corn. Yield loss due to unfavorable sowing date has been reported in many researchers such as Boller et al. (1996), Amiri (2003), Rastegar (2004), Akbari (1991) and Kresovic et al. (1997) in corn.

Also, the increase in plant density had a positive effect on them, so that total fresh and dry yield were 83.8% higher under density of 140000 plant/ha than density of 50000 plant/ha (Table 3). Ayisi and Poswall (1997) suggested that high plant density increases total light interception by the crop canopy, which increased total dry matter and leaf area index. Similar results were also reported by Egli and Guffy (1997). The increase in total dry matter with the increasing of plant population indicates the favorable response of biomass produced corn to plant population. Cirilo and Andrade (1994) reported that dry matter accumulation was much in high plant densities compared to low plant densities. These findings are in agreement with those obtained by Aslam et al. (2011) and Moaveni et al. (2011) in maize and Ali (2010) in millet.
Table 4. Correlation coefficient between traits of forage corn

<table>
<thead>
<tr>
<th>Traits</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-Plant height</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-Stem diameter</td>
<td>0.081&lt;sup&gt;ns&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3-Leaf number per plant</td>
<td>0.527&lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.022&lt;sup&gt;ns&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4-LAI</td>
<td>0.615&lt;sup&gt;**&lt;/sup&gt;</td>
<td>0.512&lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.321&lt;sup&gt;ns&lt;/sup&gt;</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5-Total fresh yield</td>
<td>0.51&lt;sup&gt;**&lt;/sup&gt;</td>
<td>0.191&lt;sup&gt;ns&lt;/sup&gt;</td>
<td>0.426&lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.75&lt;sup&gt;**&lt;/sup&gt;</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6-Total dry yield</td>
<td>0.49&lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.189&lt;sup&gt;ns&lt;/sup&gt;</td>
<td>0.431&lt;sup&gt;*&lt;/sup&gt;</td>
<td>0.698&lt;sup&gt;**&lt;/sup&gt;</td>
<td>0.99&lt;sup&gt;**&lt;/sup&gt;</td>
<td>1</td>
</tr>
</tbody>
</table>

<sup>ns</sup> Non Significant and <sup>*</sup>, <sup>**</sup> Significant at 0.05 and 0.01 probability levels, respectively.

Conclusion

In total, given the results of the study, early sowing of forage corn in July 4 can be recommended for the cultivation of forage corn in Gonabad, Iran because plants have longer growth period, their growth and development coincides with favorable environmental conditions, they produce stronger vegetative parts and more assimilates. Also, higher plant density (140000 plants/ha) can be recommended because of the increase in usage of radiation and other inputs for the production of biomass per hectare.

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