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Effects of sowing date and plant density on marigold (*Calendula officinalis*) morphology and flower yield

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Abstract
For evaluation of different sowing times and plant densities effects on marigold, a factorial experiment with randomized complete block design and three replications was carried out at the Research Farm of the Faculty of Agriculture, University of Tabriz, Iran. Three sowing times (May 10, May 26 and June 10) and four plant densities (30, 40, 50 and 60 plants/m^2) were studied. The analysis of variances showed that sowing time and plant density have significant effects on leaf number, plant height, plant dry weight and flower dry weight. However, the interaction of sowing time and plant density has not any significant effect on evaluated traits. The results showed that 60 and 30 plant/m^2 density produced the highest and lowest flower dry yield, respectively. In conclusion, this study showed that sowing at May 26 and 60 plant/m^2 is suitable for producing the highest flower yield of marigold at Tabriz climate conditions.

Keywords: sowing time, plant density, plant dry weight, marigold, flower yield.

1. Introduction
The increasing tendency toward herbal medicine for curing diseases makes the necessity of cultivating various medicinal plants inevitable both in worldwide level and inside Iran (Rasam *et al.,* 2007) [13]. In past, herbal medicine collected from nature for shopping in market was enough, but a number of common species are in danger of extinction because of increasing the request of consuming and more using of natural resources. However, low yield of medicinal plants persuaded researchers to increase yield. The best and economic way is to achieve the performances in order to increasing yield, using the proper cultivars and variety, best sowing date, optimum plant density and etc. (Thomas, 2000) [15]. Plant density is dependent on the plant characters, growth period, time and method of cultivation, soil conditions, sun light and weeds. Selection of suitable sowing date has advantages in relation to assembling the raw material and other productions. It can be accomplished by choosing the right plant species, soil, sowing date, plant nutrition, harvest etc. (Cromack and Smith, 1988) [2].
Calendula Officinalis L. is an annual medicinal and oil plant. The origin is the west of Asia and Mediterranean region and it was used for many times as an ornamental plant before its medicine properties known as an herbal medicine. The leaves and flowers of marigold are used in medicine, cosmetics, perfume, pharmaceutical preparation, food and other industries (Marczal, 1987; Muusa *et al.,* 1992) [6, 11]. One of the main components of active ingredient in *C. officinalis* L. is essential oils, mostly synthesized in its orange petals (Omidbaighi, 2005) [12]. Flower essential oil is also used in food and medicine industries (Hamburger *et al.,* 2003) [3].
Study of Marisol *et al.* (2003) [7] on the influence of sowing date on the flower yield of *C. officinalis* L. during two growing seasons showed that in the first year of production the highest flower yield was obtained in the plants sown on June 4. In the second year, there was no difference in yield between sowing dates, and the average dried flower yield was 3685 kg/ha. Martin and Deo (2000) [8] reported that the highest flower yield in *C. officinalis* L. was obtained in density of 40 plants/m^2 and sowing date of April 15. Zheljazkov *et al.* (2008) [16] investigated the effect of sowing dates of May 24 and June 8 on Coriandrum sativum L. during two years in Canada and showed that the yield is higher in earlier cultivation. The current study was carried out to investigate the effect plant density of and sowing date on morphological traits and flower yield of *C. officinalis* L. in Tabriz, Iran climate.

2. Materials and methods

The field experiment was conducted at the Research Farm of the Faculty of Agriculture, Tabriz University, Iran (latitude 38.05^0 N, longitude 46.17^0 E, Altitude 1360 m above sea level). The climate is characterized by mean annual precipitation of 245.75 mm, mean annual temperature of 10 °C, mean annual maximum temperature of 16.6 °C and mean annual minimum temperature of 4.2 °C and a sandy- loam soil texture. Three sowing dates (May 10, May 26 and June 10) and four plant densities (30, 40, 50 and 60 plants/m^2) were compared in a factorial experiment based on a randomized complete block design with three replications. Plots were plowed before sowing date and disked before planting. Plots were 3 m long and 2 m wide. Seeding depth was 3 cm. All plots were irrigated immediately following planting and next irrigations were conducted once a week.

In order to determine of morphological traits including leaf number and plant height, 7 plants were randomly selected from the middle of each plot and these traits were measured. Also, for measure the plant dry weight and flower dry weight, plants were cut and after drying, plant dry weight and flower dry weight were measured. Statistical analysis of data was performed using software SAS and MSTAT-C and comparison of the means was done by Duncan multiple range test at the 5% probability level. Also, the graphs were drawn by software Excel.

3. Results and Discussion

The analysis of variances showed that sowing time and plant density have significant effects ($p< 0.01$) on leaf number, plant height, plant dry weight and flower dry weight. However, the interaction of sowing time and plant density has not any significant effect on evaluated traits (Table 1).

Table 1: Analysis of variance for the effects of sowing date and plant density on some morphological traits and flower yield of marigold.

				Mean squares	
Source of Variation	**df**	**leaf number**	**plant height**	**plant dry weight**	**flower dry weight**
Replication	2	1540.058^{**}	361.865^{**}	37061.27^{**}	7083.524^{**}
Sowing date	1	4784.703^{**}	2242.667^{**}	181922.33^{**}	47879.989^{**}
Plant density	3	522.95^{**}	$2\ 20.648^{**}$	21061.42^{**}	8998.033^{**}
Date and density	3	216.184^{ns}	10.03^{ns}	308.152^{ns}	19.748^{ns}
Error	14	126.527	10.882	1157.95	56.763
C.V (%)		19.23	7.53	9.09	4.27

ns and **: No significant and significant at p≤0.01, respectively.

As can be seen from figure (1-a) the maximum leaf number was obtained in sowing at May 26 with mean of 72.62. Leaf number in sowing date of May 26 was increased 40% compared with the June 10, because of appropriate environmental condition. The mean comparison of plant density effect on leaf number showed that the maximum leaf number per plant obtained in 30 plant/m^2 density (Figure 1-b). It seems that due to increasing competition between plants there is less space for each plant in high densities compared to lower densities (30 plants/m^2) which consequently reduced the leaf number per plant. Mohammadian *et al.* (2014) [9] reported that the effect of sowing date, plant density and their interaction on leaf number of peppermint herb were significant. However, figure 2 shows that despite the reducing in the number of leaves per plant at higher densities, the large number of plants per unit area, lead to increased number of leaves per unit area.

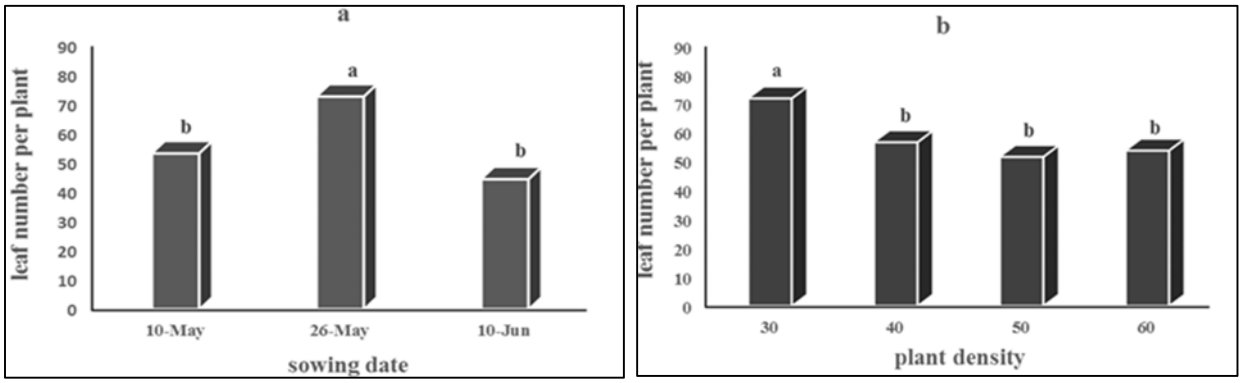

Fig 1: Effects of sowing date (a) and plant density (b) on marigold leaf number per plant.

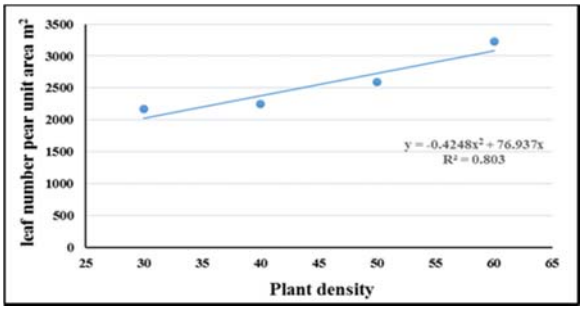

Fig 2: The relationship between plant density and number of marigold leaves per unit area.

The most plant height was obtained in May 26 which was 10.2 and 36 percent higher than sowing dates of May 10 and June 10, respectively (Figure 3-a). The significant decrease in plant height with delaying in sowing (June 10) could be attributed to shorter period of vegetative growth of plants. Imholte and Carte (1987) [4] reported that delay of sowing caused a decline in plant height. Perusal of the data presented in figure (3-b) indicated that the plant height was significantly increased with increasing of plant density. So, the highest plant height (51.01 cm) was obtained under the treatment of 60 plant/m^2 density. Such an increase in plant height with increased plant density may be explained by increasing activity of stem growth hormone due to

light deficiency. These results are in line with those of reported by Sadeghi *et al*. (2009) [14]. Also, Mohammadian *et al*. (2014) [9] Reported that the effect of sowing date, plant density and their interaction on plant height of peppermint herb were significant.

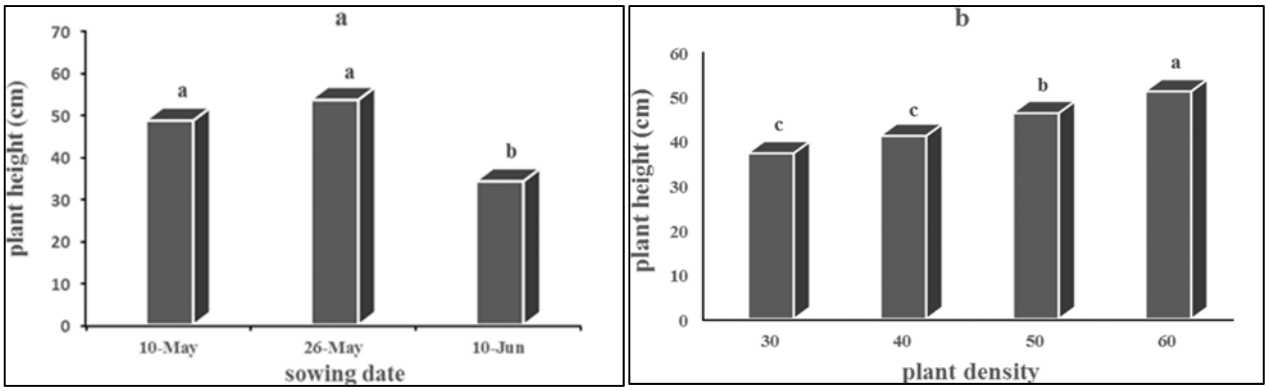

Fig 3: Effects of sowing date (a) and plant density (b) on plant height of marigold.

Means comparison revealed that delay in sowing from May 26 to June 10 decreased plant dry weight by 37.7% (Figure 4-a). Delay of sowing and shortening of the growing cycle decreased the amount of radiation intercepted during the growing season and thus plant dry weight of marigold. As shown in figure (4-b), the increase in plant density had a positive effect on plant dry weight, so that plant dry weight were 30.6% higher under density of 60 plants/m^2 than density of 30 plants/m^2. Bavec and Bavec (2002) [1] suggested that high plant density increases total light interception by the crop canopy, which increased total dry matter and leaf area index. Also, Moosavi *et al.* (2012) [10] reported that the increase in plant density had a positive effect on plant height.

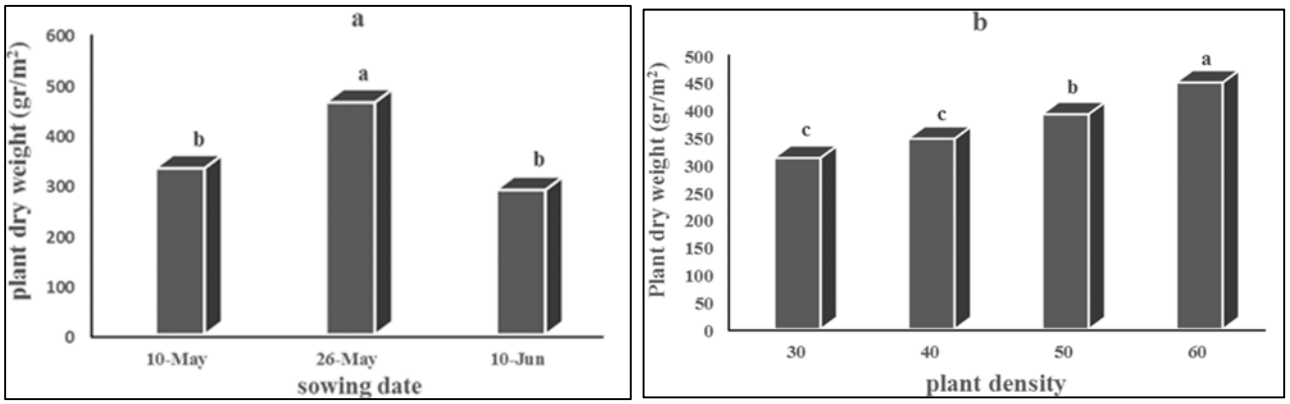

Fig 4: Effects of sowing date (a) and plant density (b) on plant dry weight of marigold.

At the second sowing date (May 26), plants had the highest flower dry weight (Figure 5-a). Also, as shown in figure (5-b), the increase in plant density had a positive effect on flower dry weight. So that 60 plants/m^2 was with a mean of 211.19 gr/m^2 of the highest flower dry weight than other treatments. Studies of Lotfi Jalalabadi *et al.* (2006) [5] on *C. officinalis* L. showed that the effect of plant density on the dry weight of flower was significant at 0.05 level of probability. Also, the results of Martin and Deo (2000) [8] are consistent with these results.

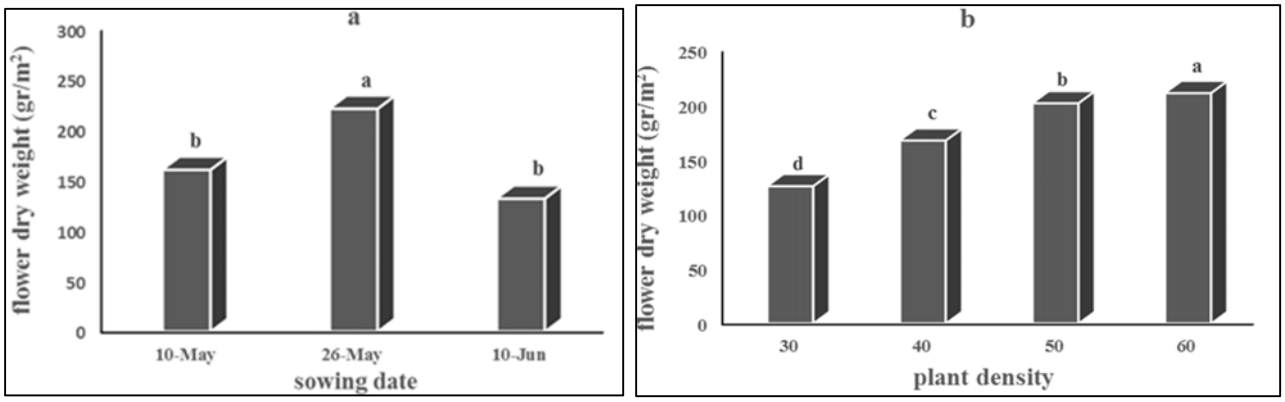

Fig 5: Effects of sowing date (a) and plant density (b) on flower dry weight of marigold.

4. Conclusion

In total given the results of the study, the sowing date of May 26 and 60 plant/m2 density is suitable for producing the highest flower yield of marigold at Tabriz climate conditions. It recommends carry out the experiment under soil types and other conditions for two or more years.

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