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Full Length Research Paper

Effect of planting date and plant density on morphological traits, yield and water use efficiency of *Plantago ovate*

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In order to study the effect of planting date and plant density on morphological traits, yield and water use efficiency (WUE) of *Plantago ovata*, an experiment was conducted as a split-plot based on a Randomized Complete Block Design with three replications at experimental field of Islamic Azad University, Birjand Branch, Birjand, Iran in 2008. The main plot was planting dates (April 19, May 9 and May 30) and the sub-plot was plant densities (16.6, 22.2 and 33.3 plants/m^2). Means comparison indicated that retarding the planting from April 19 to May 30 decreased significantly plant height, spike length, leaf number/plant, husk, leaf and grain yield, and WUE for grain production by 24.5, 29.9, 18.2, 65.4, 60.2, 60.2 and 46.9%, respectively. As the results showed, with the increase in plant density from 16.6 to 33.3 plants/m^2, plant height, grain yield and water use efficiency were increased significantly by 7.8, 82.8 and 82.1%, respectively, but leaf number per plant, spike length and tiller number per plant were decreased by 24.8, 5.9 and 28.9%, respectively. The highest husk and leaf yield, and WUE for biomass production were obtained at the density of 33.3 plants/m^2 which was higher than those at the density of 16.6 plants/m^2 by 2.11, 2.10 and 2.06 times, respectively. In total, according to the results, the planting date of April 19 with the density of 33.3 plants/m^2 is recommended to realize maximum yield and water use efficiency in *Plantago ovata* cultivation in Birjand region, Iran.

Key words: *Plantago ovata*, planting date, plant density, yield, water use efficiency.

INTRODUCTION

Medicinal plants are valuable sources in Iranian natural resources whose understanding and scientific cultivation can play an important role in people's health, job creation, and preventing genetic erosion of invaluable medicinal herbs due to their improper harvest from natural habitats and non-oil exports. *Plantago ovata* is an important medical plant belonging to the family of plantaginaceae. Its seeds are full of mucilaginous compounds which are used in pharmaceutics, food, military, paper and oil industries (Fakhr-Tabatabaei, 1980; Zahoor et al., 2004). The leaves of various *Plantago* varieties have mucilaginous and costive property which is recommended as pain-killer and blood purifier in healing chronic diseases of lung, urinary tract and digestive tract (Franz, 1988; Handa and Kaul, 1999; Zargari, 1990; Ansari and Ali, 1996). Its oral use helps reduce blood cholesterol levels (Segawa et al., 1998). The desirable climate during its growing period is cold and dry, and prolonged coldness at nights enhances its seed yield quantitatively and qualitatively. *P. ovata*'s water requirement is low and it is drought-resistant (Levitt, 1993; Zahoor et al., 2004; Dagar et al., 2006).

P. ovata is native to Iran, India, Afghanistan, Pakistan, east of Mediterranean and Mediterranean regions of northern Africa; and today, India is the biggest producer and main exporter of *P. ovata* seeds (Zahoor et al., 2004).

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Table 1. Variance analysis for effects of planting date and plant density on morphological traits of *Plantago ovate.*

SOV	df	Plant height	Number of tiller per plant	Number of leaf per plant	Length of spike
Replication	2	13.335 ns	1.134ns	38.554 ns	0.382 ns
Planting date	2	45.466*	2.677 ns	3343.161**	1.957*
Error a	4	8.421	0.649	160.705	0.162
Plant density	2	4.103**	7.257**	1149.635**	0.1*
Planting date × plant density	4	0.54 ns	0.116 ns	4.621 ns	0.038 ns
Error b	12	0.544	0.079	36.938	0.018
CV (%)	-	4.08	5.30	7.60	5.09

ns: Non significant at 0.05 probability level; *****, ****** significant at 0.05 and 0.01 probability levels, respectively.

The crop depends largely on temperature, solar radiation, moisture and soil fertility for their growth and nutritional supplies. Plant population may affect the maximum accessibility and consumption of these factors. Therefore, it is necessary to determine the optimum density of plant population per unit area for obtaining maximum yields (Baloch et al., 2002).

Karimzadeh and Omidbaigi (2004) showed that the best time for sowing isabgol in Zanjan, Iran was 5th May. These researchers stated the sowing date had highly significant effects on plant height, number of branches and seed yield ($P < 0.001$) and swelling factor ($P < 0.01$). In a study on the effect of 6 planting dates (February 6, 16 and 26 and March 8, 18 and 28, 2005), Galavi et al. (2006) concluded that the planting date significantly affected spike length and leaf number per plant, but swelling factor and plant height were not affected by it. They stated that retarding planting from March 8 to 28 led to a significant decrease in yield. In a study on the effect of two autumn planting dates (November 6 and December 6) and three spring planting dates (March 6, April 4 and May 5) on *P. ovata*, Asgari (2002) concluded that winter chilling severely destroyed the yield at two autumn planting dates and planting date had significant effect on morphological traits including plant height, spike length, leaf number and tiller number per plant and they showed a decreasing trend with the delay in planting.

Mcenil (1991) showed that plant density had significant effect on spike length and number per unit area of *P. ovata*. Najafi and Rezvanimoghadam (2002) and Sabagh and Razmjoo (2007) reported the increase in *P. ovata* seed yield with the increase in plant density. The objective of this research was to evaluate the impacts of planting date and plant density as some traits of *P. ovate*.

MATERIALS AND METHODS

The study was carried out in research field of Islamic Azad University, Birjand Branch, Birjand, Iran (Long. 59°13´ E., Lat. 32°52´ N., Alt. 1400 m) in 2008. The soil characteristics are as follows: 0.25% organic carbon, silty loam texture and 8.6 pH. Climate of Birjand is dry and warm. It was a split-plot experiment based on a Randomized Complete Block Design with nine treatments and three replications. In this the study, the effects of three planting dates (April 19, May 9 and May 30) as main plot and three plant densities (16.6, 22.2 and 33.3 plants/m^2) as sub-plot were studied. The plots were 1.8 m × 5 m with six planting rows. The spacing was 1 m between plots and 2 m between replications. The seeds were dry-planted at the depth of about 1.5 cm. The irrigation was carried out by pressurized system using hose and contour in each plot.

To measure morphological traits including plant height, spike length, tiller number and leaf number per plant, 10 plants were randomly evaluated from the middle rows considering margin effects. To determine leaf, husk and seed yield, an area of 3 m^2 was harvested from the middle of each plot. Water use efficiency for seed and biomass production was calculated by the following equations:

WUE_{seed} = Grain yield/Total irrigation volume
$WUE_{biomass}$ = Biological yield/Total rrigation volume

To determine the swelling factor, 1 g of seed was put into beaker of 25 ml capacity and 20 ml distilled water was added. The swelling of seeds was calculated after 24 h (Sharma and Koul, 1986).

The data were analyzed by software MSTAT-C and the means were compared by Multiple Range Duncan Test at 5% probability level.

RESULTS AND DISCUSSION

Morphological traits

The results of analysis of variance showed that the planting date had significant effect on plant height, spike length and leaf number per plant, while it had no effect on tiller number per plant. Moreover, the change in plant density caused significant difference in all studied morphological traits but the interactions between planting dates and plant densities did not significantly affect these traits (Table 1).

Means comparison showed that delay in planting from April 19 to May 30 led to the decrease in plant height, spike length and leaf number per plant by 24.5, 29.9 and 18.2%, respectively (Table 2). Given the increasing trend of mean daily temperature, it appears that the delayed planting shortened growing period and so, plants

Table 2. Effect of planting date on morphological traits of *plantago ovate*.

Planting date	Plant height (cm)	Number of tiller per plant	Number of leaf per plant	Length of spike (cm)
April 19	20.66[a]	5.89[a]	101.81[a]	3.11[a]
May 9	16.97[ab]	5.17[a]	72.89[b]	2.67[ab]
May 30	16.59[b]	4.82[a]	56.28[b]	2.18[b]

Means followed by the same letter symbols in each column - according to Duncan's multiple range test - are not significantly ($P < 0.05$) different from each other.

Table 3. Effect of plant density on morphological traits of *plantago ovate*.

Density (plant/m^2)	Plant height (cm)	Number of tiller per plant	Number of leaf per plant	Length of spike (cm)
16.6	17.38[b]	6.05[a]	90.10[a]	2.70[a]
22.2	18.09[ab]	5.53[b]	82.08[b]	2.73[a]
33.3	18.73[a]	4.30[c]	67.79[c]	2.54[b]

Means followed by the same letter symbols in each column - according to Duncan's multiple range test - are not significantly ($P < 0.05$) different from each other.

Table 4. Variance analysis for effects of planting date and plant density on yield and water use efficiency of *plantago ovate.*

SOV	df	Leaf yield	Husk yield	Seed yield	Swelling factor	WUE for seed	WUE for biomass
Replication	2	15754.015[ns]	14697.266[ns]	9330.394[ns]	0.039[ns]	669.011[ns]	3390.623[ns]
Planting date	2	280222.689**	52892.648*	146253.441**	0.015[ns]	5508.738*	3248.086[ns]
Error a	4	10236.128	5276.518	5356.272	0.052	435.471	5574.735
Plant density	2	174160.394**	26582.252**	65611.753**	0.007[ns]	5184.277**	100559.48**
Planting date × plant density	4	9691.306**	2901.245**	5768.369**	0.003[ns]	244.747**	1208.856[ns]
Error b	12	932.294	298.402	483.431	0.042	33.376	556.128
CV (%)	-	7.85	11.32	7.66	2.02	7.11	7.78

ns: Non significant at 0.05 probability level; *****, ****** significant at 0.05 and 0.01 probability levels, respectively.

reproductive phase initiated earlier and thus, their potential vegetative growth was not fully realized. Delayed sowing decreased plant height of cumin in Sadeghi et al. (2009)'s study. According to the results, with the increase in plant density from 16.6 to 33.3 plants/m^2, plant height increased by 7.8%, but leaf number per plant, spike length and tiller number per plant decreased by 24.8, 5.9 and 28.9%, respectively (Table 3). Also, Kumar et al. (2007) on coriander and Mohammadi (1995) on safflower reported the increase in plant height with the increase in plant density. Probably, the increase in plant height with the increase in plant density was caused by inter-plant competition over light. Moreover, the decrease in other morphological traits can be related to this intensified inter- and intra-plant competition and resource limitations, particularly insufficient space for plants under higher densities. Nonetheless, the increase in plant density of *Plantago ovata* from 80 to 160 plants/m^2 had no significant effect on spike length in Sabagh and Razmjoo (2007)'s study and the effect of seed quantity was not significant on spike length in Najafi and Rezvanimoghadam (2002) and Asgari (2002)'s study. This disagreement can be related to the very high densities in their studies.

Yield traits

As can be seen in Table 4, the traits of leaf, husk and seed yields of *P. ovata* showed significant differences under the effect of planting date, plant density and their interactions. Means comparison showed that husk yield decreased from 233.40 to 80.87 kg/ha, leaf yield decreased from 579 to 230.45 kg/ha and seed yield decreased by 60.2% as planting was retarded from April 19 to May 30 (Table 5). It seems that at the first planting date, *P. ovate* had higher yield potential because of

Table 5. Effect of planting date on yield and water use efficiency of *plantago ovate*.

Planting date	Leaf yield (kg/ha)	Husk yield (kg/ha)	Seed yield (kg/ha)	WUE for seed (kg/m^3)	WUE for biomass (kg/m^3)
April 19	579.00^{a}	233.40^{a}	421.34^{a}	105.32^{a}	367.79^{a}
May 9	356.84^{b}	143.58^{ab}	272.12^{b}	82.48^{a}	292.89^{ab}
May 30	230.45^{b}	80.87^{b}	167.70^{c}	55.89^{b}	248.43^{b}

Means followed by the same letter symbols in each column-according to Duncan's multiple range test - are not significantly ($P < 0.05$) different from each other.

Table 6. Effect of plant density on yield and water use efficiency of *plantago ovate*.

Density ($plant/m^2$)	Leaf yield (kg/ha)	Husk yield (kg/ha)	Seed yield (kg/ha)	WUE for seed (kg/m^3)	WUE for biomass (kg/m^3)
16.6	251.31^{c}	98.18^{c}	205.72^{c}	58.33^{c}	198.71^{c}
22.2	385.52^{b}	152.79^{b}	297.46^{b}	79.16^{b}	300.33^{b}
33.3	529.47^{a}	206.87^{a}	375.97^{a}	106.20^{a}	410.07^{a}

Means followed by the same letter symbols in each column - according to Duncan's multiple range test - are not significantly ($P<0.05$) different from each other.

enjoying favorable environmental conditions and its growth termination before the hot days of late-July and August as well as having enough time for vegetative growth, while retarded planting did not give an acceptable yield due to the shortened growth period, accelerated reproductive phase and also hot regional climate during inoculation and seeds filling period. Also, Galavi et al. (2006) and Asgari (2002) reported that seed yield of isabgol decreased as planting date was retarded which was in agreement with results this study.

The results showed that the increase in plant density had positive effect on the increase in husk and leaf production, so that the density of 33.3 plants/m^2 had the highest husk and leaf yield which was 2.11 and 2.10 times as high as those under the density of 16.6 plants/m^2, respectively (Table 6).

In addition, seed yield increased by 82.8% with the increase in density from 16.6 to 33.3 plants/m^2 (Table 6). Given the small plant size of *Plantago ovata*, higher husk, leaf and seed yield at higher densities was probably due to the quick formation of canopy, the increase in leaf area index and better utilization of solar radiation and other resources. Asgari (2002) and Sabagh and Razmjoo (2007) reported similar results for *P. ovata.* Also, Rezaei (2011) showed that seed yield of cumin increased with increasing plant density.

The treatment of planting date of April 19 with the density of 33.3 plants/m^2 produced the highest husk and leaf yields (323.12 and 780.84 kg/ha, respectively) and the treatment of planting date of May 30 with the density of 16.6 plants/m^2 produced the lowest ones (50.18 and 137.96 kg/ha, respectively). Also, the treatment of planting date of April 19 with the density of 33.3 plants/m^2 had the highest seed production potential (558.99 kg/ha) (Table 7).

Swelling factor and water use efficiency

The results of analysis of variance showed that the swelling factor was not affected by planting date, plant density and their interactions (Table 4). Also, Sabagh and Razmjoo (2007) stated that the increase in plant density from 80 to 160 plants/m^2 had no significant effect on swelling factor of *P. ovata*. Mean swelling factor of different treatment ranged from 1.05 to 1.08 ml/20 ml in the present study.

Water use efficiency for seed production was significantly affected by planting date, plant density and their interactions (Table 4). The planting date of April 19 with 105.32 g/m^3 had higher WUE than planting dates of May 9 and May 30 by 27.7 and 88.4%, respectively (Table 5).

The increase in plant density was effective in improving WUE for seed and biomass production. As can be seen in Table 6, the increase in plant density from 16.6 to 33.3 plants/m^2 increased WEU for seed production by 82.1%. The treatment of planting date of April 19 and plant density of 33.3 plants/m^2 had the highest (139.73 g/m^3), and the treatment of planting date of May 9 with the density of 16.6 plants/m^2 had the lowest (39.83 g/$m^{3)}$ WUE for seed production (Table 7).

WUE for biomass production was significantly affected by plant density but not by plant date and the interactions between planting date and plant density (Table 4). Nonetheless, the results showed that the planting date of

Table 7. Effect of the interaction between planting date and plant density on yield and water use efficiency of *Plantago ovate*.

Planting date	Density (plant/m^2)	Leaf yield (kg/ha)	Husk yield (kg/ha)	Seed yield (kg/ha)	WUE for seed (kg/m^3)	WUE for biomass kg/m^3)
April 19	16.6	384.10^{cd}	147.19^{c}	295.61^{cd}	73.90^{d}	243.23^{ef}
	22.2	572.06^{b}	229.91^{b}	409.41^{b}	102.33^{bc}	361.23bc
	33.3	780.84^{a}	323.12^{a}	558.99^{a}	139.73^{a}	498.90a
May 9	16.6	231.86^{ef}	97.18^{d}	202.08^{ef}	61.27^{de}	199.70ef
	22.2	343.85^{de}	141.38^{c}	258.11^{de}	78.20^{cd}	286.53cde
	33.3	494.80^{bc}	192.12^{bc}	356.17^{bc}	107.97^{b}	392.43b
May 30	16.6	137.96^{f}	50.18^{e}	119.45^{f}	39.83^{e}	153.20f
	22.2	240.64^{ef}	87.09^{de}	170.88^{ef}	56.93^{de}	253.23de
	33.3	312.76^{de}	105.39^{cd}	212.76^{de}	70.90^{d}	338.87bcd

Means followed by the same letter symbols in each column - according to Duncan's multiple range test - are not significantly ($P < 0.05$) different from each other.

April 19 had 48% higher WUE than the planting date of May 30 (Table 5). Higher WUE of the earliest planting date for seed and biomass production means that at retarded plantings, despite the decrease in water application, WUE for seed and biomass production considerably decreased because of the severe decrease in seed and biomass yield. Barzgaran (2010) was reported that the delay in sowing from May 10 to June 20 decreased WUE for fruit and biomass production by 66.7 and 50%, respectively which confirm the results of the current study.

As shown in Table 6, the increase in plant density from 16.6 to 33.3 plants/m^2, WUE for biomass production was increased 2.06 times. According to the results, it can be concluded that at higher densities, plants use applied water more optimally in the production of seed and biomass, the reason being that the application of the same amount of irrigation water on one hand, and the increase in seed and biomass yield with the increase in plant density on the other hand. Thangwana (2009) stated that greater WUE for seed and biomass production at higher planting density could be due to greater crop biomass and grain yield, respectively. Also, the studies of Pirzad et al. (2007) on *Matricaria chamomilla* L. and Ogola et al. (2009) on chickpea (*Cicer arietinum* L.) showed that the increase in plant density increased WUE for flower or seed and biomass production which confirm the results of the current study.

Conclusion

The results indicated that the delay in planting led to the significant decrease in yield and WUE through shortening growing period and coincidence of plants sensitive growth stages with unfavorable environmental conditions as well as low density because of ineffective utilization of environmental resources. Therefore, the treatment of planting date of April 19 with minimum density of 33.3 plants/m^2 is recommended for the cultivation of *P. ovata* in Birjand, Iran. However, further studies are needed on earlier planting dates and higher plant densities.

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