Journal of Ecology and the Natural Environment Vol. 1(9), pp 201-205, December, 2009
Available online at http://www.academicjournals.org/jene
ISSN 2006- 9847 © 2009 Academic Journals

Full Length Research Paper

Effects of sowing date and planting density on quantity and quality features in valerian (*Valeriana officinalis* L.)

Elham Morteza[1], Gholam Ali Akbari[1], Sayed Ali Mohammad Modares Sanavi[2] and Hossein Aliabadi Farahani[3]*

[1]Agronomy and plant breeding Department, Abureyhan Campus University of Tehran, Iran.
[2]Agronomy, College of Agriculture, Tarbiat Modares University, Tehran, Iran.
[3]Islamic Azad University, Shahr-e-Qods Branch, Iran.

Accepted 15 November, 2009

This study was conducted as split plot field experiment in a randomized complete block design with four replications for one year planting. The main factors were the sowing dates (10 August, 1 and 20 September) and sub factors were the planting densities (4, 8 and 12 plants/m^2). Our results showed that sowing date (SD) and planting density (PD) significantly affected grain yield, essential oil yield, essential oil percentage, root length, root diameter, flowering stem number and root yield. The highest grain and root yield were achieved under the 8 plants/m^2 planting density and 10 August sowing date; the highest root length and flowering stem number were achieved under 12 plants/m^2 planting density and 10 August sowing date; the highest root diameter was achieved under 4 plants/m^2 planting density and 10 August sowing date; the highest essential oil yield was achieved under 8 plants/m^2 planting density and 20 September sowing date and the highest essential oil percentage was achieved under 4 plants/m^2 planting density and 20 September sowing date. It was thus concluded that sowing date and planting density are the main factors influencing the quantity and quality features in valerian. Our findings may give applicable advice to commercial farmers and agricultural researchers for management of planting density strategy and for estimate of sowing date carefully for increase of quantity and quality features in medicinal and aromatic plants farming. And is better that such studies be further validated by conducting them for two or more years.

Key words: Sowing date, planting density, essential oil, valerian.

INTRODUCTION

Valerian (*Valeriana officinalis*, Valerianaceae) is a hardy perennial flowering plant, with heads of sweetly scented pink or white flowers. The flowers are in bloom in the northern hemisphere from June to September. Valerian was used as a perfume in the sixteenth century and natural habitat of the plant is Europe and parts of Asia and valerian has been introduced into North America. Valerian, in pharmacology and phototherapy medicine, is the name of an herb or dietary supplement prepared from roots of the plant. Valerian is a well-known and frequently used medicinal herb that has a long and proven history of efficacy. It is noted especially for its effect as a tran-quilliser or sedatives and nervine, particularly for those people suffering from nervous overstrain (Grieve, 1984; Foster and Duke, 1990). It is used in perfumes to provide a mossy aroma (Usher, 1974; Bown, 1995), though the scent is considered to be offensive to many people (Coffey, 1993). Valerian has been shown to encourage sleep, improve sleep quality and reduce blood pressure (Chevallier, 1996). It is also used internally in the treatment of painful menstruation, cramps, hypertension, irritable bowel syndrome etc (Bown, 1995; Chevallier, 1996). It should not be prescribed for patients with liver problems (Bown, 1995). The active ingredients are called valepotriates. Research has confirmed that these have a calming effect on agitated people, but are also a stimulant in cases of fatigue (Foster and Duke, 1990).

The roots of two year old plants are harvested in the autumn once the leaves have died down and are used fresh or dried. The fresh root is about 3 times as effective

*Corresponding author. E-mail: farahani_aliabadi@yahoo.com.

Table 1. Some physical and chemical features of the experimental soil.

Soil texture	Sand (%)	Silt (%)	Clay (%)	K (mg/kg)	P (mg/kg)	N (mg/kg)	Na (Ds/m)	EC (1: 2.5)	pH	Depth of sampling (cm)
L	46	31	22	140.2	5.2	31.7	0.03	0.18	8.0	0 - 15cm
SC.L	58	24	18	120.3	2.7	26.2	0.02	0.14	7.8	15 - 30

as roots dried at 40℃ (the report does not specify if this is centigrade or Fahrenheit), whilst temperatures above 82℃ destroy the active principle in the root (Grieve, 1984; Launert, 1981; Bown, 1995). The plant yields about 1% of an essential oil from the roots (Chiej, 1984). To optimize yield of commercial essential oil, most growers use high planting densities with over 6 to 10 plants/m^2 for annual crops but not for biennial crops (Douglas et al., 1996). High plant density may increase relative humidity within the canopy and increase the duration of leaf wetness by reducing air movement and sun light penetration (Burdona and Chilvers, 1982; Tu, 1997). Thus, plant density could have significant impact on plant disease incidence (Burdona and Chilvers, 1982; Copes and Scherm, 2005). Several studies have been conducted on the effect of plant density on essential oil in medicinal plants (Ram et al., 1997; Hashemi et al., 2007; Taheri-Asghari et al., 2008; Zehtab-Salmasi et al., 2001).

Douglas et al. (1996) found optimum densities of 60000 plants/ha [6 plants/m^2] for highest essential oil in valerian. Moreover, most published studies evaluating the effect of plant density on valerian yield have traditionally used analysis of variance and means separation techniques to test differences among discrete levels of plant density (Staub et al., 1992; Widders and Price, 1989). The relationship between essential oil and sowing date has not been established. Early planting increases the total length of time that the plant is in the field and exposed to the environment and also, it is associated with increased incidences of several diseases (Bowden, 1997). Thus, early planting increases the probability of unfavorable consequences, including the quality of the essential oil. Several studies have been conducted on the effect of sowing date on essential oil in medicinal plants (Zehtab-salmasi et al., 2001; Carrubba et al., 2006). The objectives of this study were to describe relationships between sowing date and planting density on essential oil yield and determine the optimum sowing date and planting density for valerian essential oil at Iran.

MATERIALS AND METHODS

This study was carried out in the Abureyhan Campus, University of Tehran, Iran during 2005 - 2006. The field experiment was carried out in a split plot, randomized complete block design with four replications. The main factor was sowing date (10 August, 1 and 20 September) and the sub factor was planting density (4, 8 and 12 plants/m^2) and the soil consisted of 22% clay, 31% silt and 46% sand (Table 1).

The soil bulk density was 1.21 g cm^{-3}, the field was prepared in a 15 m^2 area (5 × 3 m) divided into a total number of 24 plots. Nitrogen fertilizer was added twice; first, 75 kg ha^{-1} urea at the stem elongation stage and 75 kg ha^{-1} urea at the beginning of flowering stage. Also 150 and 75 kg ha^{-1} potash (K_2O) and phosphorus (triple super phosphate) fertilizers were applied at cultivation time respectively. At the maturity, we collected 10 plants from each plot randomly for determination of plant features and selected 100 g root dry matter for determination of essential oil percentage by Clevenger. Finally, essential oil yield was determined using the formula by Aliabadi et al. (2008):

Essential oil yield = Essential oil percentage × Root yield

Data were subjected to analysis of variance (ANOVA) using Statistical Analysis System (SAS) computer software at $P < 0.05$ (SAS institute Cary, USA 1988).

RESULTS

The final results of plants features showed that PD significantly increased the grain yield, essential oil yield, essential oil percentage, root yield, flowering stem number, root diameter and root length ($P \leq 0.01$, Table 2). However, we noted longest root length under the 12 plants/m^2 PD, while other plant features were reduced under 12 plants/m^2 PD (Table 3). Highest grain yield, essential oil yield and root yield were achieved under 8 plants/m^2 PD and highest essential oil percentage, flowering stem number and root diameter were achieved under 4 plants/m^2 PD (Table 3). These findings are in agreement with the observations of Azizi and Kahrizi (2008), Khazaie et al. (2008) and Corley (1973). In addition, SD had a significant effect on all plant features ($P \leq 0.01$), but essential oil yield was not significantly affected by SD (Table 2). Therefore, our findings indicated a significant improved grain yield, root yield, flowering stem number, root diameter and root length under 10 August SD. Also, highest essential oil yield and essential oil percentage were achieved under 20 September SD (Table 3). These results were similar with the findings of Hadj et al. (2004), Zehtab-salmasi et al. (2001) and Carrubba et al. (2006). Data of interactive effect between PD and SD have been demonstrated in Table 4. Interactive effect was indicated in grain yield ($P \leq 0.01$) and other plant features were not significantly affected by interactive effect (Table 4). However, highest essential oil yield was indicated in the 20 September SD with 8 plants/m^2 PD conditions. Surprisingly, other plant features were reduced under these conditions (Table 4). Highest grain yield and root yield were achieved under 10 August SD with 8 plants/m^2

Table 2. Analysis of variance.

Sources of variation	df	Mean squares						
		Grain yield	Essential oil yield	Essential oil percentage	Root yield	Flowering stem number	Root diameter	Root length
Replication	3	27.64 *	113.55	0.007	0.37 *	0.42	0.50**	7.44
Sowing date	2	947.36 **	384.14	1.423 **	6.56 **	10.47 **	4.30**	261.58**
Error a	6	12.64	85.21	0.017	0.07	0.19	0.01	3.21
Planting density	2	234.9 **	275.06 **	1.515 **	16.9 **	30.2 **	14.48**	376.33**
Sowing date × Planting density	4	15.38 *	17.9	0.027	0.089	0.33	0.01	1.16
Error b	18	3.2	10.16	0.009	0.027	0.09	0.02	3.15
CV (%)		13.06	16.10	6.92	5.72	4.79	3.64	8.17

* and **: Significant at 5 and 1% levels respectively.

Table 3. Means comparison of main treatments.

Treatments		Grain yield (kg/ha)	Essential oil yield (kg/ha)	Essential oil percentage (%)	Root yield (kg/)	Flowering stem number (stem/plan)	Root length (cm)	Root diameter (mm)
Sowing date	10 August	36.9 a	51.43 b	1 c	5350 a	7.11 a	26.50 a	4.32 a
	1 September	25.33 b	57.81 ab	1.32 b	4640 b	6.42 b	22.08 b	3.57 b
	20 September	19.43 c	62.71 a	1.69 a	3870 c	5.27 c	17.17 c	3.14 c
Planting density	4 plant/m^2	23.27 c	54.83 b	1.74 a	3230 b	7.93 a	16.58 c	4.73 a
	8 plant/m^2	32.2 a	62.83 a	1.2 b	5370 a	6.09 b	21.41 b	3.76 b
	12 plant/m^2	26.4 b	54.28 b	1.06c	5350 a	4.87 c	27.75 a	2.54 c

Means within the same column and rows and factors, followed by the same letter are not significantly difference (P < 0.05).

PD conditions and highest root diameter and flowering stem number were achieved under 10 August SD with 4 plants/m^2 PD conditions. Also, longest root length was achieved under 10 August SD with 12 plants/m^2 PD conditions and highest essential oil percentage was achieved under 20 September SD with 4 plants/m^2 PD conditions (Table 4).

DISCUSSION

The results showed that late-planting decreased quantity and quality features in valerian. The selection of valerian planting date is one of the most important management decisions for essential oil production. Planting date affects leaf-spot by avoiding unfavorable weather conditions for disease development. Late planting date was positively associated with more necrosis because of favorable weather conditions. Early planting increases the forage production potential by extending the vegetative growth period and increasing the total length of time that the valerian is in the field and exposed to the environment. In areas with limited soil moisture, early planting can cause excessive fall in growth: this results in depletion of soil moisture for early spring growth. Early planting of valerian also breaks winter dormancy earlier in the spring as temperature increases and, thus, has a greater potential for late spring freeze injury. Valerian planted at an intermediate date has essential oil yield potential than late-planted valerian because of increased lateral stems, leaves and flowering stem. Late-planted valerian also develops under different temperature and day-length, has a shortened vegetative growth period and requires greater essential oil rate to compensate partially for reduced flowering stem development.

In a study, the effects of planting time and plant density on flower yield and active substance of chamomile (*Matricaria chamomilla* L.) were investigated. The treatments were three planting times (5, 15 and 25 March) and three plant densities (50 × 20, 50 × 30 and 50 × 40 cm). The results showed that, highest number of flower per plant, fresh flower per plant, dried flower per plant, fresh flower yield, dried flower yield, essential oil yield, chamazulene percentage and chamazulene yield were obtained by the first planting time (5 March). Also, the highest number of flower, fresh flower per plant and dried flower per plant were obtained by the lowest plant density (50 × 40 cm). The highest fresh flower yield, dried flower

Table 4. Means comparison of interactions.

Survey instance qualifications	plant/m^2	Grain yield (kg/ha)	Essential oil yield (kg/ha)	Essential oil percentage (%)	Root yield (kg/ha)	Flowering stem number (stem/plant)	Root length (cm)	Root diameter (mm)
	4	30.40c	51.55cd	1.33 c	3880 d	8.80a	21.25c	5.38a
10 August	8	43.40a	55.35bcd	0.9 ef	6200 a	7.22c	26.50b	4.38c
	12	36.90b	47.38d	0.8 f	5990 a	5.32e	31.75a	3.23e
	4	22.70ef	53.70bcd	1.69 b	3190 e	8.02b	16.50d	4.63b
1 September	8	29.00cd	63.58ab	1.18 cd	5400 b	6.25d	21.25c	3.63d
	12	24.30de	56.15bcd	1.06 de	5340 b	4.97e	28.50b	2.48f
	4	16.70g	59.23bc	2.2 a	2700 f	6.97c	12e	4.20c
20 September	8	23.60def	69.58a	1.53 b	4520 c	4.80e	16.50d	3.30e
	12	18fg	59.33bc	1.34 c	4410 c	4.02f	23c	1.93g

Means within the same column and rows and factors, followed by the same letter are not significantly difference ($P < 0.05$).

yield, essential oil yield and chamazulene yield were obtained by the highest plant density (50 × 20 cm). So, according to the results of this investigation, the highest yield was obtained by the earliest sowing and the highest plant density (Hadj et al., 2004). Also, the highest root yield was achieved by optimal plant density (8 plants/m^2), because photosynthesis increases by development of leaves areas and increases essential oil yield.

Plant population density has important effects on vegetative and reproductive development in valerian. Valerian yield is low with low plant density because of little plasticity in leaf area per plant. Additionally, valerian plants have small capacity to develop new reproductive structures in response to an increase in available resources per plant.

The plant density of red chicory (*Cichorium intybus* L. var. *foliosum* Hegi) was studied at a field in Linares, south central Chile. Four and five plants/m^2 were established, using a single or a double planting line/row. The distance between rows was 0.60 m. The treatments were 60000, 80000, 130000 and 170000 plants/ha. The average total fresh weight/plant, the marketable fresh weight/plant and head size were higher at the lower plant density. The total yield was higher at the treatment with 4 plants/m^2 and a double planting line/row. The highest marketable and export quality yield was obtained with the treatment 4 plants/m, single planting line/row. The lowest marketable yield was observed in the highest plant density treatment. The critical plant density was 0.2 m with a single row (Carrasco et al., 1998). High plant density increased essential oil yield of sweet annie (Ram et al., 1997) and cumin (Hashemi et al., 2008).

On the other hand, if plant density is too high, there is decrease in the availability of resources per plant in the period of flowering stem production. This may lead to a marked fall in yield per plant that is not offset by the increase in the number of plants. High plant density may increase relative humidity within the canopy and increase the duration of leaf wetness by reducing air movement and sun light penetration. The plant increased its shoot for increase of assimilation matters by increase of refulgence absorb for compensation of low density in this condition. Therefore, there was increased root length under planting density of 12 plants/m^2. Two experiments were conducted in Southern Italy with two cultivars of chicory, such as 'Cicoria da foglie' (leaf chicory) and "Cicoria di Galatina" ("asparagus chicory") grown at three plant densities (11.1, 5.6 and 3.7 plants/m^2). At maturity, the aerial part of the plant was excised. With the closest spacing during the second year a high seed yield, stems per plant and germination percentage were noticed. Leaving the plants *in situ* resulted in a faster germination, while the excised plants showed a decrease in seed yield, seed per plant, thousand seed weight, plant height and number of stems per plant (Bianco et al., 1994). Also flowering stem number was increased under low density because flower reproductive cells increased in this condition by low rivalry between plants. The plant increases its root length for increase of water absorb under high density by high rivalry between plants, but root diameter increases under low density because assimilation matters enough for increase of root diameter. Thus, plant density could have significant impact on plant disease incidence.

Conclusion

The investigation showed that planting density and sowing date significantly influence most of the productive features in valerian. The best combination of planting density and sowing date for achieving high biological yield in valerian was 8 plants/m^2 and 20 September sowing date while the highest essential oil percentage was achieved under a density of 4 plants/m^2 and 20 September sowing. Consequently, our findings may suggest farmers and agricultural researchers to consider carefully on estimate of sowing date in different planting density conditions as current challenge of scientist in global changes. As the results of a year study for the field experiments are not so reliable in view of climatic change, thus, it is better that such studies may be validated further by conducting them for two or more years.

ACKNOWLEDGMENTS

The authors thank Dr. Hamid Irannejad and Dr. Gholam Abbas Akbari for their field assistance and analytical support in processing the plant samples and collecting the data reported herein.

REFRENCES

Aliabadi Farahani H, Lebaschi MH, Hamidi A (2008). Effects of arbuscular mycorrhizal fungi, phosphorus and water stress on quantity and quality characteristics of coriander. J. Adv. Natur. Appl. Sci. 2(2): 55-59.

Azizi K, Kahrizi D (2008). Effect of nitrogen levels, plant density and climate on yield quantity and quality in cumin (*Cuminum cyminum* L.) under the conditions of Iran. Asian J. Plant Sci. 7(8): 710-716.

Bianco VV, Damato G, Fanizza G (1994). Plant-density and seed production of 2 cultivars of chicory *(Cichorium-Intybus* L.). Acta Horticulturae Fifth International Symposium on Seed Research in Horticulture (eds Quagliotti, L. and Belletti, P.). 362p.

Bowden RL (1997). Disease management. In: Manhattan, KS [Ed.2] Wheat production handbook. C-529. Kansas State Univ. Coo. Ext. Serv. pp.18-24.

Burdon JJ, Chilvers GA (1982). Host density as a factor in plant diseased ecology. Annu. Rev. Phytopathol. 20: 143–166.

Bown D (1995). Encyclopaedia of Herbs and their Uses. Dorling Kindersley, London

Carrasco G, Carmona C, Sandoval C, Urrestarazu M (1998). Plant density on yield of red chicory heads - Radiccio rosso – (*Cychorium intybus* L. var. *foliosum* Hegi) grown in south-central Chile. Acta Hortic. 467: 269-275.

Carrubba A, la Torre A, Calabrese I (2002). Cultivation trials of coriander *(Coriandrum sativum* L.) in a semi-arid Mediterranean environment. In Medicinal and aromatic plants—Possibilities and limitations of medicinal and aromatic plant production in the 21st century, Proc. Int. Conf. Budapest. 8–11 July (2001). Acta Hortic. 576: 237-242.

Chevallier A (1996). The encyclopedia of medicinal plants Dorling Kindersley. London.

Chiej R (1984). Encyclopaedia of medicinal plants. MacDonald.

Coffey T (1993). The history and folklore of North American wild flowers. Facts on File.

Copes WE, Scherm H (2005). Plant spacing effects on microclimate and Rhizoctonia web blight development in container-grown *Azalea*. Hortic. Sci. 40:1408–1412.

Corley RHV (1973). Effects of plant density on growth and yield of oil palm. Exp. Agric. 9: 169-180.

Douglas JA, Douglas MH, Follett JM, Heaney AJ (1996). The effect of plant density on the production of Valerian root. Acta Hortic. 426: 375-379.

Foster S, Duke JA (1990). A field guide to medicinal plants. Eastern and Central N. America. Houghton Mifflin Co.

Grieve A (1984). Modern herbal. Penguin.

Hadj Seyed, Hadi M, Noormohammadi G, Sinaki JM, Khodabandeh N, Yasa N, Darzi MT (2004). Effects of planting time and plant density on flower yield and active substance of Chamomile (*Matricaria chamomilla* L.). 4th International Crop Science Congress 280 p.

Hashemi P, Yarahmadi A, Azizi KH, Sabouri B (2007). Study of the effects of N fertilization and plant density on the essential oil composition and yield of *Cuminum cyminum* L. seeds by HS–SME. Chromatographia 67(3): 253-257.

Khazaie HR, Nadjafi F, Bannayan M (2008). Effect of irrigation frequency and planting density on herbage biomass and oil production of thyme (*Thymus vulgaris*) and hyssop (*Hyssopus officinalis*). Ind. Crops Prod. 27(3): 315-321.

Launert E (1981). Edible and medicinal plants. Hamlyn

Ram M, Gupta MM, Dwivedi S, Kumar S (1997). Effect of plant density on the yields of artemisinin and essential oil in *Artemisia annua* cropped under low input cost management in north-central India. Planta Med. 63(4): 372-374.

SAS Institute (1988). Statistics Analysis System user's guide: Statistics. SAS Inst., Cary, NC.

Staub JE, Knerr LD, Hopen HJ (1992). Plant density and herbicides affect cucumber productivity. J. Am. Soc. Hortic. Sci. 117: 48–53.

Taheri AM, Daneshian J, Valadabadi SAR, Aliabadi Farahani H (2008). Effects of water deficit and plant density on morphological characteristics of chicory (*Cichorium intybus* L). 5th International Crop Science Congress & Exhibition 26p.

Tu JC (1997). An integrated control of white mold (*Sclerotinia sclerotiorum*) of beans, with emphasis on recent advances in biological control. Bot. Bull. Acad. Sin. 38: 73–76.

Usher GA (1974). Dictionary of Plants Used by Man. Constable.

Widders IE, Price HC (1989). Effects of plant density on growth and biomass partitioning in pickling cucumbers. J. Am. Soc. Hortic. Sci. 114: 751–755.

Zehtab-Salmasi S, Javanshir A, Omidbaigi R, Alyari H, Ghassemi-golezani K (2001). Effects of water supply and sowing date on performance and essential oil production of anis (*Pimpinella anisum* L.). Act. Agro. Hun. 49(1): 75-81.