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Effect of plant density on vegetative growth, tuber yield and essential oil content in *Coleus barbatus*

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ABSTRACT

The present investigation was undertaken to assess the impact of plant density on different vegetative and economic yield of medicinal *Coleus.* A field experiment was designed in randomized block design with five treatments and four replications. The study consisted of five levels of spacing (T_1 = 30 cm × 30 cm; T_2 = 45 cm × 30 cm; T_3 = 30 cm × 45 cm; T_4 = 45 cm × 45 cm and T_5 = 60 cm × 45 cm). All traits pertinent to vegetative growth and herbage yield were significantly influenced by different plant densities. Gradual increase in all parameters with increased spacings were observed except tuber yield per plot and oil yield per plot. The maximum plant height (62.36 cm), spike length (33.51 cm) and leaf area (436 cm²) were recorded at 1,11,111 plants per ha (30 cm × 30 cm spacing) and minimum at 37,037 plants per ha, 60 cm × 45 cm spacing (44.10 cm; 25.95 cm and 264 cm²) respectively. The maximum tuber yield (24.37 q/ha), and essential oil yield (3.03 l/ha) were recorded in 1,11,111 plants/ha and minimum at 37,037 plants/ha (9.78 q/ha and 1.67 l/ha) respectively. However, marketable tuber diameter (12.61 cm) and oil yield (0.143%) were found better in spacing 60 cm × 45 cm compared to T_3 (11.03 cm; 0.122%) and T_4 (11.70 cm; 128%).

Key words: Plant density, spacing, tuber yield, essential oil, *Coleus barbatus*.

INTRODUCTION

Medicinal *coleus, Coleus barbatus* (Andr) Benth., syn. *Coleus forskohlii* Briq., Family Lamiaceae, commonly known as *Patharchur*, *Garmar* in the state of Maharashtra, and *Mainmool* in the state of Karnataka. *Gandhmoolika* and *Makandi* in Ayurveda and Sanskrit, respectively. It is a perennial aromatic herb, about 30-60 cm height with thick carrot like tuberous root, much branched hairy, stem and fruit is nutlet. *Coleus* is economically useful and endangered root drug of Indian origin. In India, it is found naturally in Himalayan region from Garhwal to Nepal up to an altitude of 2,000 amsl and commonly grown in Gujarat, Bihar, Maharashtra, Karnataka, Tamil Nadu and parts of Rajasthan**.** It is known for its fasciculated roots, which are exclusive source of forskolin (coleonol), a labdone diterpenoid, forskolin is being developed as drug for treatment of glaucoma, congestive cardiomyopathy, asthma and certain cancers (Shah *et al*., 10). *Coleus* roots are also rich in diterpenoids like coleonos, barbatusin, cyclobarbatusin, coleosol, coleol, colenone, deoxycoleonol, j-deacetyl forskolin and 6-accetyl-7-deacetyl forskolin. The main action of forskolin is to activitate adenyl cyclase, an enzyme responsible for the conversion of ATP to cyclic adenosine monophosphate (CAMP), CAMP is one of the most important 'second messenger' a signaling hormone system in cell regulation (Anon, 1).

Because of the exclusive presence of forskolin, it enjoys the current recognition of its status as a crop of medicinal importance internationally. Since the cultivation of *Coleus* is not extended at commercial scale except in South India, most of the requirement for Indian industry is met through collection from wild forests. The indiscriminate collection of tubers from the wild, lead to inclusion of *Coleus* in the list of endangered species. Owing to the extensive chemical investigations carried out on this species cultivation aspect and genetic upgradation studies have received scant attention (Vishwakarma *et al*.,13). Looking at the high demand of shed dried root of *Coleus* and also to conserve the natural resources and biodiversity, there is an urgent need to develop agro-technology for enhances the commercial viability of this crop. The present study was therefore, undertaken to standardize the optimum plant density for maximizing the tuber and essential oil yield of *Coleus* under mid hill rainfed conditions of Garhwal Himalayas.

MATERIALS AND METHODS

The present experiment was conducted at the Medicinal and Aromatic Plant Section, Department of Horticulture, College of Forestry & Hill Agriculture, G.B. Pant University of Agriculture and Technology, Hill Campus, Ranichauri, Tehri Garhwal during year 2009-2010. The experimental site was located at

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an altitude of 1,900 amsl. The experimental block represent northern aspect of Hill Campus, Ranichauri and is located geographically under mid hill zone of Himalayas, between the latitude 30°15' North and the longitude 70°50' East. The experiment was designed in randomized block design) with five treatments and four replications. Treatment consisted of five spacing levels (T_1 = 30 cm × 30 cm; T_2 = 45 cm × 30 cm; T_3 = 30 cm × 45 cm; T_4 = 45 cm × 45 cm; and T_5 = 60 cm × 45 cm). Rooted plants of *Coleus barbatus* obtained from Department of Medicinal and Aromatic Plants, Hill Campus, Ranichauri, were procured during May, 2009. After one month, the seedlings were transplanted in the field at evening time with the different spacing levels. The seedlings were irrigated immediately after transplantation. Randomly selected ten plants were tagged and harvested from all plots. Periodic observations at monthly interval pertinent to vegetative growth and flowering (e.g. plant height, collar diameter, plant spread, leaf area, number of branches per plant, number of spikes per plant, spike length, plant biomass per plot and per plant), tuber yield contributing parameters (e.g. fresh tuber yield per plot and per plant, dry tuber yield per plot and per plant, tuber length, tuber diameter, No. of tubers per plant, marketable tuber yield ha^{-1} and harvest index) were recorded to find out the percent increase in the growth and yield parameters.

Beside these biochemical parameters (essential oil yield ha^{-1}, essential oil yield $plot^{-1}$ and per cent essential oil content) were also estimated in ten randomly selected plants in each treatment combinations. The leaf area was measured with the help of leaf area meter (Model Epsilon, 1800) and the harvest index percentage was calculated by formula given by Sastry *et al*. (10). The data on essential oil content of tubers were determined by using Clevenger's apparatus. The hydrodistillation methonol was carried out using cut tuber and water in 3:1 ratio for 3 h. The temperature was set initially 100°C and when boiling started, it was reset at 40°C for rest of period. The oil was collected in the vials and stored in the refrigerator, so that oil could easily separate from water and the pure oil was collected and sealed properly. Analysis of experimental data was done by method described by Cochran and Cox (5) following randomized block design (RBD).

RESULTS AND DISCUSSION

In this study, significant differences were recorded among the treatments with respect to different vegetative growth, tuber growth and essential oil yield parameters. It was evident that there was an enhancement in these parameters decreased in plant density from 1,11,111 to 37,037 plants per ha (Table 1). The present work is in confirmation with findings of Anwar and Maurya (2) in gladiolus. It is a known fact that at lower plant density, good growth is noted due to availability of more space and less competition among the adjacent plants, which helped the individual plant to utilize more water, nutrition, air and light. However, maximum plant height, tuber yield per hectare and essential oil yield were recorded under T_5 (Table 1). Per cent increase in plant height was significantly influenced by different plant densities. Maximum increase in plant height was recorded in the highest plant density (T_1) followed by T_2 and T_3, while minimum at plant spacing of 45 cm × 45 cm (T_4). The general mean value of plant height was found to be 52.76 cm (range 45.74 to 62.67 cm). The plant height was recorded maximum in T_1 with the plant density of 1,11,111 plant/ha and spacing of 30 cm × 30 cm. A possible reason behind this trend may be the fact that due to high plant density/ha, plants have to compete with each other for the resourses resulting in poor photosynthesis. Moreover, increase in plant height with higher plant density may also be attributed to the increased concentration of endogenous auxin in closely spaced plants leading lanky growth (Nadukeri and Kattimani, 6).

The minimum collar diameter was found in T_1 (30 cm × 30 cm), whereas, maximum in T_5 (60 cm × 60 cm) plant spacing. The maximum increase in the collar diameter was found for T_4, having plant density of 49,383/ha and spacing of 45 cm × 45 cm followed by T_5 and T_3. Earlier, Shivanna *et al*. (11) also supported the findings that under wider spacing, collar diameter tends to increase. Maximum increase in plant spread was found under the lowest plant density (T_5) followed by T_3 and T_4. These findings are in accordance with the earlier findings of Rao and Reddy (8), in *Coleus*. This effect can be explained in the light of the statement that closer spacing result in high competition among plants for nutrition, moisture, space and light resulting in poor plant growth and development. Leaf area per plant was found to decrease with the increase in plant density. The highest leaf area was found with the minimum plant density, *i.e*., 37,037 plants/ha in T_5. On the other hand under plant density of 1,11,111/ha (T_1) resulted in the lowest leaf area. The results are in accordance with the findings of Umesha *et al*. (12) in *Clocimum*. Wider spaced plants lead to higher availability of nutrients and also facilitate better penetration of sunlight thereby influencing leaf area. However, lower leaf area observed in closer spacing may be attributed to overcrowding and shading. Number of branches and spikes per plant was found to be significantly influenced by plant density. The highest per cent increase in number of spikes per plant was

Table 1. Vegetative characters of *Coleus barbatus* under different planting densities.

Treatment	Plant height (cm)			Collar dia. (cm)			Plant spread (cm)			Spike length (cm)			No. of branches/plant			No. of spikes/plant		
	Initial	Final	% Increase	Initial	Final	% Increase	Initial	Final	% Increase	Initial	Final	% Increase	Initial	Finall	% Increase	Initial	Final	% increase
T_1	23.49	62.67	167.36	0.71	0.91	28.16	22.16	34.84	57.22	20.80	33.51	61.18	6.67	19.50	192.36	13.00	22.25	71.15
T_2	22.79	54.70	140.41	0.73	0.95	30.13	22.23	35.17	58.20	21.13	34.10	61.38	6.15	22.50	265.85	11.75	21.25	80.85
T_3	22.42	53.59	139.02	0.71	0.93	30.98	22.66	38.07	68.45	19.29	28.50	47.74	5.57	23.00	312.92	12.20	21.00	72.13
T_4	21.95	45.74	108.38	0.72	1.01	40.27	25.76	42.62	65.45	16.97	27.10	59.69	5.90	27.00	357.62	17.00	28.75	69.11
T_5	19.84	47.10	137.39	0.78	1.07	37.17	27.99	48.59	73.59	18.70	25.90	38.50	7.42	31.75	327.78	18.00	30.60	70.00
$CD_{0.05}$	2.48	2.84	0.13	0.51	0.10	0.82	2.40	3.77	0.74	2.66	4.46	0.32	1.85	3.46	48.67	3.88	3.29	1.85

found in T_2 (80.85), which were followed by T_3 and T_5 however minimum (69.11) was in T_4. The maximum number of spike per plant was found in T_5, while it was minimum in T_3. The spike length was higher in T_2 (45 cm × 30 cm), while minimum for T_5. Maximum per cent increase in spike length was also found in T_2 followed by T_1, while minimum in T_5 (Table 1). Plant biomass yield per plot was maximum in closer spacing of 30 cm × 30 cm (T_1), which was at par with spacing of 45 cm × 30 cm (T_2), whereas, it was minimum in widest spacing 60 cm × 45 cm (Table 2). Similar findings have also been reported by Nadukeri and Kattimani (6), who reported more herbage yield with the closer spacing in *Coleus.* However, plant biomass yield per plant increased with the wider spacing. It was found maximum in the spacing of 60 cm × 45 cm (T_5) and minimum in the spacing of 30 cm × 30 cm (T_1). It is evident from results obtained from present study that the per cent harvest index is significantly affected by the plant density. The harvest index showed an increasing trend with higher plant density since, at wider spacing, the dry matter production efficiency was more than the narrow ones. It was clear from the data that the harvest index was maximum in T_2, which was at par with spacing of 45 cm × 45 cm (T_3), while it was minimum in T_1.

Plant density had significant affect on length, diameter and yield of tuberous roots. The maximum length of tuberous root was recorded in T_5 (13.16 cm). whereas; the minimum was recorded in T_3 (8.91 cm), Patil and Hulamani (7) also reported maximum tuberous root length in widest plant spacing and minimum in close spacing. This might be due to good availability of nutrition, moisture, light and space for each plant resulting in good plant growth and root growth. Similarly, maximum tuber diameter was found in T_5 (60 cm × 60 cm), whereas, minimum was found in T_1 (30 cm × 30 cm). It was observed that the tuber diameter increased slightly with an increase in plant spacing. The tuber yield per hectare was found maximum (24.37 q/ha) in T_1 (30 cm × 30 cm), and minimum (9.78 q/ha) in T_4 (60 cm × 45 cm) with plant density of 37,037 plants/ha (Table 2). Minimum number of tuberous roots/plant (10.47) was found in T_1, while the maximum number of tuberous roots/plant (21.30) was found for widest spacing (T_5). Thus, the number of tubers per plant showed a positive response to decreased plant density. The results of the present investigation are in accordance with the findings of Patil and Hulamani (7). A significant increase in the tuber yield per plot was found the higher plant density. It was found maximum in the spacing of 30 cm × 30 cm (T_1) and minimum in the spacing of 60 cm × 45 cm (T_5). The findings of the present investigations on tuber yield per plot are in

Table 2. Tuber yield and essential oil yield contributing parameters of *Coleus barbatus* under different planting densities.

Treatment	Leaf area (cm^2)	Plant biomass/ plot (g)	Plant biomass/ plant (g)	Tuber length (cm)	Tuber dia. (cm)	No. of tubers/ plant	Fresh tuber yield/plot (g)	Fresh tuber yield/plant (g)	Dry tuber yield/plot (g)	Dry tuber yield/ plant (g)	Tuber yield (q/ha)	Essential oil yield/ ha (l)	Essential oil content (%)	Harvest index (%)
T_1	264.53	1923.0	34.46	10.09	11.57	10.47	1170.00	21.06	155.25	4.61	24.37	3.03	0.100	49.75
T_2	378.54	1742.0	46.78	9.25	10.15	10.49	842.0	21.04	104.00	4.83	20.33	2.67	0.101	67.50
T_3	327.07	1457.0	36.55	8.91	11.03	12.15	816.00	24.78	115.87	4.75	17.12	2.73	0.122	63.25
T_4	339.55	1127.0	49.96	11.29	11.70	18.80	782.00	27.09	65.12	6.00	11.08	1.98	0.128	66.25
T_5	436.89	902.00	50.22	13.16	12.61	21.30	778.00	31.95	47.32	6.77	9.78	1.67	0.143	62.25
$CD_{0.05}$	98.99	646.42	16.74	1.32	1.60	2.55	196.64	6.42	42.41	1.46	4.20	0.17	0.28	10.05

conformity with results reported by Bharathi *et al*. (3) in *Coleus*. The main reason behind this increase in fresh tuber yield per plot is the increase in number of plants per unit area under high planting density leading to higher fresh tuber yield. Significant effect of different plant density on the oil yield per hectare and oil yield per plot were observed. The oil yield per hectare was found maximum (3.03 l/ha) in the spacing 30 cm × 30 cm and minimum (1.67 l/ha) in a spacing of 60 cm × 45 cm. The results are well in tune to those of Patil and Hulamani (7), who also found similar results. The essential oil content of tuber was found maximum in plants at wider spacing than at narrow spacings. Similar results were also reported by Bukhbinder *et al*. (4) in geranium.

Hence, it may be concluded plant density of 1,11,111/ha (30 cm × 30 cm) was ideal for obtaining maximum tuber and essential oil yield per hectare under the agro-climatic conditions of Garhwal Himalayas. As far as the plant growth and essential oil content is concerned, it was also found satisfactory with the spacing of 60 cm x 45 cm having a plant density of 37,037/ha.

REFERENCES

1. Anonymous. 2009. Forskohllin, http://www. wikipedia, the free encyclopedia.com. visited on Sept. 12, 2009.

2. Anwar, D. and Maurya, K.R. 2005. Effect of spacing and corm size on growth, flowering and corm production in gladiolus. *Indian J. Hort*. **62**: 419-21.

3. Bharathi, L.K., Medhi, R.P., Venkatesh, A. and Damodaran, V. 2004. Effect of different plant densities on growth and yield of Chinese potato (*Salenostemon rotundifolius*). *J. Root Crops*, **30**: 157-58.

4. Bukhbinder, A.A. 1982. Spacing in relation to the yield of herbage and essential oil of geranium grown on the alluvial soils of the Kolkhida lowland. *Subtropicheskie-kul-Tury*, **5**: 84-86.

5. Cochran, W.G. and Cox, M.G. 1992. *Experimental Designs*, John Wiley Sons Inc., New York, pp. 106-17.

6. Nadukeri, S.V. and Kattimani, K.N. 2008. Effect of organic and inorganic fertilizers on growth, tuber yield and essential oil content in *Coleus* (*Coleus forskohlii* Briq.) under dry zone of Karnataka. *Indian Perfumer*, **52**: 44-47.

7. Patil, S. and Hulamani, N.C. 1999. Effect of

different plant densities on growth, yield and essential oil content of *Coeus forskohlii. J. Root Crops*, **25**: 143-46.

8. Rao, C. and Reddy, N. 2005. Studies on the effect of plant density, type of cutting and method of planting on growth and yield of medicinal *Coleus. Indian Perfumer*, **39**: 52-55.

9. Sastry, K.P., Kumar, P., Saleem, S.M. and Singh, S.P. 1989. Effect of different spacing on the growth and flower yield of pyrethrum, *Chrysanthemum cinerarifolium*. *J. Appl. Hort*. **17**: 98-100.

10. Shah, V., Bhat, S.V., Bajwa, B.S., Darnauer, H. and De Souza, N.J. 1980. The occurrence of forskolin in Labiatae. *Planta Med.* **39**: 183-85.

11. Shrivanna, J.S., Srinivas, K., Sreeram, L. and Lakshmipathiah, O.R. 2007. Effect of spacing on growth, yield and active principle content in Jeevanthi (*Leptadenia reticulata* Wight and Aru.). *Mysore J. Agric. Sci.* **41**: 157-61.

12. Umesha, K., Bajappa, K.M., Farooqui, A.A. and Suresh, N.S. 1990. Influence of plant density on growth and yield of clocimum (*Ocimum gratissimum* L.). *Indian Perfumer*, **34**: 173-75.

13. Vishwakarma, R.A., Tyagi, B.R., Ahmad, B. and Hussain, A. 1988. Variations in forskolin content in the roots of *Coleus forskohlii*. *Planta Med*. **54**: 471-72.

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