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Effect of spacing and rhizome diameter on different growth parameters and oil content of *Bergenia ciliata* L. under temperate conditions of Kashmir Valley

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Abstract

Bergenia ciliata L. is a rhizomatic herb with fleshy leaves, growing up to 30 cm tall has medicinal values, and is used for the treatment of different diseases under traditional and ayurvedic systems since ages. Although *Bergenia ciliata* is found growing at an altitude of 1200-3000 m in the natural forests of Kashmir Valley. An attempt was made to propagated it in open nursery beds using different diameter classes and spacings. Rhizomes planted in open nursery beds rooted and survived 100 percent during the first growing season, but there was a difference in their growth characteristics. Growth parameters showed an increasing trend with the increase in diameter class and spacing. Rhizomes of higher diameter class 2.25-3.0 cm showed better performance under field conditions at a spacing of 60 cm × 75 cm in terms of survival percentage, rooting percentage, number of leaves per plant, leaf area (cm^2), leaf fresh weight (g/plant), root length (cm), rhizome diameter (mm), above-ground biomass (g/plant), below-ground biomass (g/plant) and total biomass (g/plant). Also maximum essential oil content of (15.10 l/ ha, was extracted from leaves and Rhizomes of the harvested material planted in open from the diameter class of (2.25 to 3 cm) and planted at a spacing of (60 x 75 cm) D_4S_4 respectively. It is recommended that the diameter class (2.25-3.0 cm) and spacing of (60 cm × 75) cm should be followed to cultivate Bergenia to get a better yield of the crop and essential oil.

Keywords *Bergenia ciliate*, diameter, essential oil, spacing, yield

Introduction

The union territory of Jammu and Kashmir is a mountainous zone in the north-west Himalaya with the most complex and diverse physiography. The state is bestowed with rich floral diversity owing to the diversity in its climate and altitude, which has resulted in an ideal environment for the development of a rich variety of forests. The Kashmir Himalaya alone contributes nearly 2,000 (20%) of the plant species within just 2.15 percent (15,948 km^2) of the total land area [1].

Most of these plants have been used as a food source only, as some are still under-utilized and their knowledge is confined to the tribal and ethnic communities living in close conformity to nature [2].

In India, the major constraints in the commercial exploitation of the medicinal and aromatic plant sector include major dependence on collection from natural sources; poor harvesting and post-harvest treatment practices; domestication; improper storage; unorganized trade practices, and lack of

coordination of the plant-based drug industry. Many international agencies, research institutes, and NGOs have played an active role in promoting the sustainable use of biodiversity resources of medicinal and aromatic plants. Initiatives have been taken to increase public awareness, develop technologies for efficient utilization of resources and species cultivation, efficient management of local resources, creation of reserve forests for monitoring biodiversity change, and regular review of requirements of conservation plans. Cutting down forests at an unprecedented rate has drastically decreased the population of medicinal and aromatic plants due to their habitat destruction. The deforestation not only causes habitat loss, but also results in habitat fragmentation, diminishing patch size and core area, and isolation of suitable habitats. The shrinking populations of medicinal and aromatic plants is a matter of great concern as these plants are the backbone of our traditional medicinal system, a huge population still depends on traditional medicine. Besides, the extinction of these plant species may also lead to ecological imbalance. Plant propagation is the process of increasing the number of plants of a particular species or cultivar. Propagation can be via sexual or asexual means.

Table 1. Effect of diameter class, spacing and their interaction effect (diameter classes × spacing) on number of leaves plant-1 of *Bergenia ciliata* L.

Diameter classes	Spacing				Mean
	S_1	S_2	S_3	S_4	
D_1	3.00	4.00	4.50	5.50	4.25
D_2	6.00	6.25	6.50	7.00	6.43
D_3	7.25	7.50	8.25	9.75	8.18
D_4	8.00	8.40	9.50	10.80	9.17
Mean	**6.06**	**6.53**	**7.18**	**8.26**	
Treatment	**CD**	**Treatment**	**CD 5%**	**Treatment**	**CD 5%**
D	**1.13**	**S**	**1.14**	**D X S**	**1.13**

Over the years, Breeders have developed asexual propagation methods that use vegetative plant parts. This allows plants to be created in ways that nature cannot duplicate. The main advantage of vegetative propagation methods is that the new plants contain the genetic material of only one parent, so they are essentially clones of the parent plant. The plant produced with desirable traits can reproduce the same traits indefinitely by vegetative means, as long as the growing conditions remain similar. Thakur et al., [3] conducted field trials to study the effect of different propagation and plant techniques on the performance of *Picrorhiza kurroa*. Maximum sprouting and survival were recorded from vegetatively propagated 6 cm stolon cuttings taken from the top portion whereas; maximum rootstock yield was obtained with 10 cm stolon cuttings taken from the middle portion of the plant. It was concluded that the stolon cuttings should be planted horizontally at 7.5 cm depth with the spacing of 30 cm × 30 cm to get maximum rootstock yield/ha.

Table 2. Effect of diameter classes, spacing and their interaction effect (Diameter classes × spacing) on leaf area (cm^{-2}) of *Bergenia ciliata* L.

Diameter classes	Spacing				Mean
	S_1	S_2	S_3	S_4	
D_1	5.28	6.35	7.23	9.43	7.07
D_2	6.25	6.50	7.50	9.83	7.52
D_3	8.15	8.33	9.73	9.90	9.02
D_4	9.40	10.03	10.23	10.53	10.04
Mean	**7.27**	**7.80**	**8.67**	**9.92**	
Treatment	**CD 5%**	**Treatment**	**CD 5%**	**Treatment**	**CD 5%**
D	**NS**	**S**	**1.45**	**D x S**	**NS**

Yau and Nimah [4] studied the effect of spacing on corm and flower production of saffron. Corms planted at a spacing of 20 × 20 cm spacing gave heavier corms and flower numbers and red stigma yield per corm cluster than the other spacing densities studied.

Bergenia ciliata L. is a rhizomatic herb with fleshy leaves, growing up to 30 cm tall, having a stout creeping rhizomatous rootstock with scars and intermittent axillary buds. Plant is quite hardy and able to survive frost during winter turning reddish in color.

Table 3. Effect of diameter classes, spacing and their interaction effect (diameter classes × spacing) on root length (cm) of *Bergenia ciliata* L.

Diameter classes	Spacing				Mean
	S_1	S_2	S_3	S_4	
D_1	12.25	13.00	14.25	15.00	13.62
D_2	14.00	14.25	15.25	16.25	14.93
D_3	15.50	17.00	17.75	18.00	17.06
D_4	16.75	17.75	18.00	18.75	17.81
Mean	**14.62**	**15.50**	**16.31**	**17.00**	
Treatment	**CD 5%**	**Treatment**	**CD 5%**	**Treatment**	**CD 5%**
D	**NS**	**S**	**NS**	**D xS**	**NS**

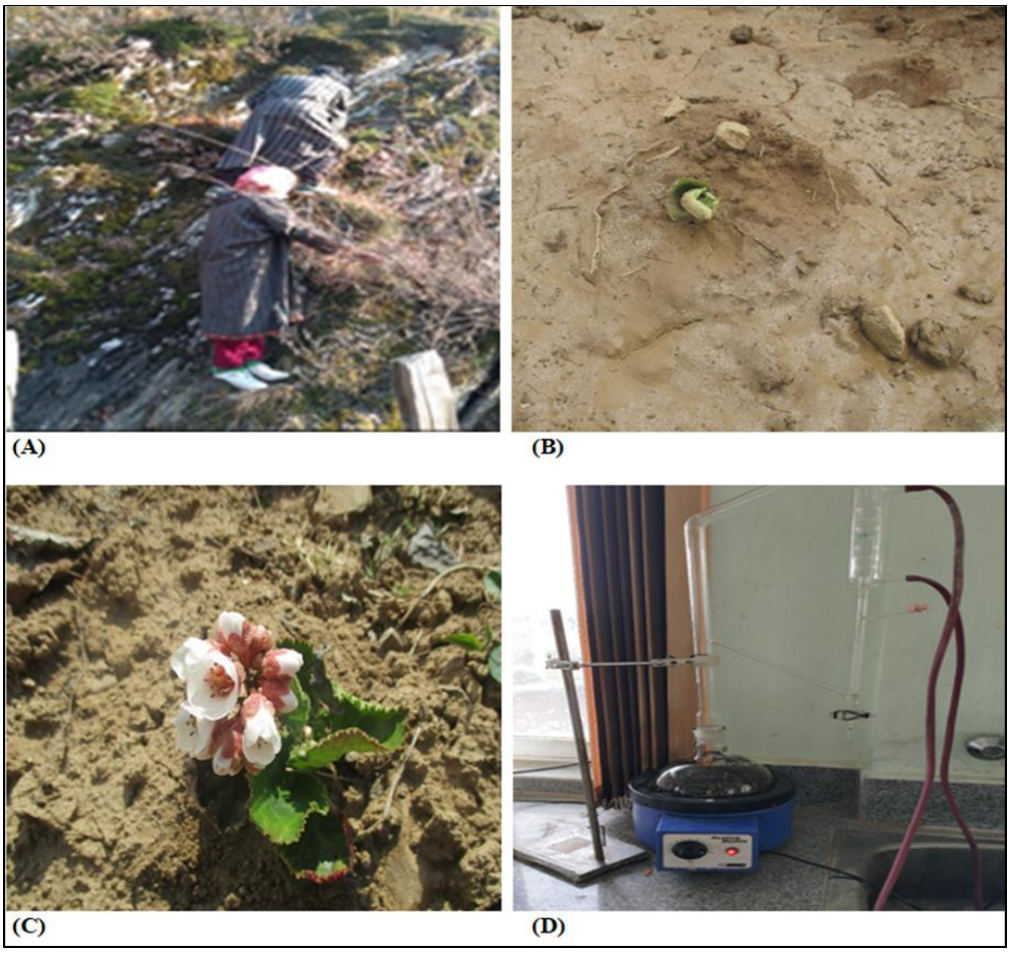

Figure 1. (A) Collection of rhizomes of *Bergenia ciliata* from forests (B) Germination of *Bergenia ciliata* L. in the Nursery (C) Flowering of *Bergenia ciliata* L. under nursery conditions (D) Estimation of oil content in laboratory

People of the valley collect this plant, use it locally for treatment of various diseases and after processing it sell in the local market as each part (rhizome, root hairs, leaves, stem, flowers, latex, and whole plant) of *Bergenia ciliata* has medicinal values and is used for the treatment of different diseases under traditional and ayurvedic system since ages. Also high cost and side effects of allopathic medicine, the use of *Bergenia ciliata* against different ailments plays a significant role in meeting the primary health care needs of the rural as well as urban communities. Bergenia based cottage industry is the 4th major component of household economy and employment after herbal medicine, agriculture, and livestock [5]. In light of the above the present study entitled. Effect of spacing and rhizome diameter on different growth parameters and oil content of *Bergenia ciliata* L. under temperate conditions of Kashmir Valley was undertaken to propagate this species under rainfed conditions in degraded lands using different rhizome diameter classes and different spacing's.

Methodology

Investigations conducted on "Effect of spacing and rhizome diameter on different growth parameters and oil content of *Bergenia ciliata* L. under temperate conditions of Kashmir Valley" were carried out in the Faculty of Forestry, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Benhama, Ganderbal during 2017-2018. Rhizome is a modified subterranean plant stem that sends out roots and shoots from its nodes. Propagation through rhizomes method was used to produce a plant identical in genotype with the mother plant. The rhizomes were collected from the natural forests and after that were divided into four different diameter classes viz D_1 (<0.75 cm,) D_2 (0.75-1.5 cm), D_3 (1.5-2.25 cm), D_4 (2.25-3.0 cm), and were sown at different spacing's viz., S_1 (60 cm × 30 cm), S_2 (60 cm × 45cm) S_3 (60 cm × 60 cm), S_4 (60 cm × 75 cm) in well prepared open nursery beds in the first week of March.

The following observations were recorded at the end of the growing season
1. Rooting percentage: It was recorded at the end of the growing season.
2 Survival percentages: It was recorded at the end of the growing season.
3. No. of leaves per plant: No. of leaves per plant were counted manually.
4. Leaf area (cm^2): It was measured by leaf area meter.
5. Root length (cm): It was measured in cm by scale.
6. Root diameter (mm): The diameter was recorded with the help of a digital caliper.
7. Above-ground biomass g/plant): leaves were harvested and weighed by using a top pan balance.
8. Below-ground biomass (g/plant): Rhizomes were harvested and weighed by using a top pan balance.
9. Total biomass (g/plant): Above ground biomass + below ground biomass.

Table 4. Effect of diameter class, spacing and their interaction effect (Diameter classes × spacing) on root diameter (mm) of *Bergenia ciliata* L.

Diameter classes	Spacing				Mean
	S_1	S_2	S_3	S_4	
D_1	2.25	2.50	3.38	4.00	3.03
D_2	3.00	4.10	4.48	4.60	4.04
D_3	4.00	4.98	5.00	5.50	4.77
D_4	4.48	5.08	5.25	5.75	5.14
Mean	**3.43**	**4.16**	**4.52**	**4.86**	
Treatment	**CD 5%**	**Treatment**	**CD 5%**	**Treatment**	**CD 5%**
D	**NS**	**S**	**0.64**	**D x S**	**0.64**

Essential oil/plant

To extract essential oil by Hydro distillation, all the plots were harvested once in the month of October. After calculating the herbage and rhizome yield both the herbage and rhizomes were subjected to Hydro distillation in the Clevenger apparatus. Essential oil content present in the rhizomes and leaves was estimated once at the time of harvest.

Statistical analysis and interpretation

The data obtained were subjected to statistical analysis using EX-Post-Facto Research Design and RBD. The observed data were analyzed in MS Excel and statistical package for social sciences (SPSS) software for meaningful interpretation.

Results and Discussion

Rhizomes collected from the forests (natural habitat of plant species) (Figure 1A.) were divided into four different diameter classes viz., D_1 (<0.75 cm,) D_2 (0.75-1.5 cm), D_3 (1.5-2.25 cm), D_4 (2.25-3.0 cm) and were sown at different spacing's viz., S_1 (60 cm × 30 cm), S_2(60 cm × 45cm) S_3 (60 cm × 60 cm), S_4 (60 cm × 75 cm) in well prepared open nursery beds in the first week of March. Germination (Figure 1B) started after 10 days of sowing and completed within four weeks. All the germinated rhizomes survived cent percent in open nursery beds (Figure 1C) during the first growing season. The different growth parameters were recorded at the end of the growing season in terms of survival percentage, rooting percentage, the number of leaves per plant, leaf area (cm^2), root length (cm), rhizome diameter (mm), above-ground biomass (g/plant), below-ground biomass (g/plant) and total biomass (g/plant) and after subjecting the data to statistical analysis results are presented in (Tables 1-7).

Table 5. Effect of diameter class, spacing on above-ground biomass (g/plant) [fresh weight of leaves] of *Bergenia ciliata* L.

Diameter classes	Spacing				Mean
	S_1	S_2	S_3	S_4	
D_1	6.76	8.26	9.00	10.00	8.50
D_2	9.80	10.00	10.96	11.76	10.63
D_3	13.26	18.00	19.00	20.70	17.49
D_4	13.76	19.26	20.00	22.76	18.94
Mean	**10.89**	**13.88**	**14.74**	**16.05**	
Treatment	**CD 5%**	**Treatment**	**CD 5%**	**Treatment**	**CD 5%**
D	**2.55**	**S**	**2.56**	**D XS**	**NS**

Hundred percent rooting and survival was recorded in all the diameter classes of rhizomes planted at four different spacing's. Data presented in Tables 1-7 indicates that the maximum average number of leaves (10.80), leaf area (10.53 cm^2) root length (17.81) cm, root diameter (5.75 mm) per plant was recorded in the rhizomes falling in the diameter class D_4 (2.25-3.0 cm) and planted at a spacing of S_4 (60 x 75cm) respectively. Minimum values for the average number of leaves (5.50), leaf area (9.43 cm^2) root length (16.25) cm, root diameter(4.0 mm) per plant was recorded in the rhizomes falling in the diameter class D_1 (<0.75 cm) and planted at a spacing of S_1 (60 x 30 cm) respectively. Also Above ground Biomass (leaf fresh weight 22.76 g/plant), below ground biomass, (rhizome fresh weight (81.00 g/plant), and total fresh biomass of (103.76 g/plant) was also recorded in the higher diameter class D_4 and higher spacing S_4 respectively. However minimum values for leaf fresh weight (10.0 g/plant), rhizome fresh weight (44.88.g /plant), and total fresh biomass of (54.88 g/plant) were recorded in the diameter class D_1 ((<0.75 cm) and planted at a spacing of S_1 (60 x 30 m) respectively.

Propagation through rhizome is used to produce a plant identical in genotype with the mother plant. We get true to type plants when we multiply plants by asexual means. Although *Bergenia ciliata* was found growing at an altitude of 1200-3000 m in the natural forests of Kashmir Valley. Rhizomes of different diameter planted in open nursery beds at different spacing are rooted and survived 100 percent during the first growing season, but there was a difference in their growth characteristics. Rhizomes of higher diameter

Table 6. Effect of diameter class, spacing on below-ground biomass (g/plant) [rhizome fresh weight] of *Bergenia ciliata* L

Diameter classes	Spacing				Mean
	S_1	S_2	S_3	S_4	
D_1	37.13	40.63	41.00	44.88	40.91
D_2	40.00	45.63	46.00	50.00	45.40
D_3	49.00	58.00	60.00	78.00	61.25
D_4	52.25	62.88	72.63	81.00	67.19
Mean	**44.59**	**51.78**	**54.90**	**63.47**	
Treatment	**CD 5%**	**Treatment**	**CD 5%**	**Treatment**	**CD 5%**
D	**NS**	**S**	**3.29**	**D X S**	**3.29**

class 2.25-3.0 cm showed better performance under field conditions at a spacing of 60 cm × 75 cm. The reason may be higher diameter class, more spacing, less competition, and maximum growth. Tiwari et al., [6] studied the effect of spacing on rhizome yield of *Acorus calamus* L. at the college of agriculture Bilaspur. Harvest of the crop after one growing season gave maximum rhizome yield at closer spacing (20 × 20 cm and 30 × 20 cm) compared to wider spacing of 40 × 40 cm. The study also illustrates the possibility of optimizing rhizome yield of *Acorus calamus* by manipulation in the time of planting and harvesting as well as maintaining proper planting space.

Gopichand et al., [7] conducted a study to determine the effect of spacing on growth and yield of *Dioscorea deltoidea*. Among the three spacing's (25 × 25 cm, 25 × 50 cm, and 50 × 50 cm) 50 × 50 cm was found to produce more biomass and rhizome yield compared to the other two spacing's. It was also found that with the increase in spacing height also increased significantly.

Nigussie et al., [8] studied the effect of plant population density (four intra-rows viz., 40, 60, 80, 100 cm and four inter-row plant spacings of 60, 80, 100, 120 cm) on growth and yield of Artemisa (*Artimesia annua* L.) and found that maximum above ground biomass (72605 kg/ha), leaf fresh weight (9510 kg/ha), leaf dry weight (5392.7 kg/ha) and essential oil yield (23.39 kg/ha) were attained due to spacing combination 40 cm intra-row and 60 cm inter-row spacing.

Table 7. Effect of diameter class, spacing) on total biomass (g/plant) fresh weight of leaves and fresh weight of rhizome] of *Bergenia ciliata* L.

Diameter classes	Spacing				Mean
	S_1	S_2	S_3	S_4	
D_1	43.89	48.89	50.00	54.88	49.41
D_2	49.80	55.63	56.96	61.76	56.03
D_3	62.26	76.00	79.00	97.70	78.84
D_4	66.01	82.14	92.63	103.76	86.13
Mean	**55.49**	**65.66**	**69.64**	**79.52**	
Treatment	**CD 5%**	**Treatment**	**CD 5%**	**Treatment**	**CD 5%**
D	**NS**	**S**	**4.49**	**D X S**	**4.49**

Extraction of oil content of Bergenia ciliata* L. *by Hydro-distillation

Essential oil (Figure 1D.) yield was extracted from leaves and rhizomes of *Bergenia ciliata* L. Results from the present study indicated a significant effect of different spacings and diameters on essential oil yield. In leaves essential oil content ranged from 0.0060 ml to 0.113 ml/plant maximum, However, maximum essential oil content extracted from leaves was recorded in the diameter class of D_4 (2.25 to 3 cm), and planted at a spacing of (60 x 75 cm) S_4 (Table 8). The essential oil content extracted from rhizomes ranged from 0.240 to 0.569 ml/plant. Maximum oil content extracted from rhizomes was (0.569 ml/plant), total average oil content (leaves + rhizomes) 0.682 ml/plant, and total average oil yield of 15.10 l/ha was also recorder in higher diameter class D_4 spacing S_4 followed by 0.499 ml/rhizome, total average oil content (leaves + rhizomes) 0.523ml/plant and total average oil yield of 13.60 l/ha was recorder in lower diameter

Table 8. Estimation of Total average oil content of *Bergenia ciliata* L. (ml/plant)

Treatments	Average Leaf Oil (ml/Plant)	Average Rhizome Oil (ml/Plant)	Average Total oil ml/plant	Oil yield/ha
D_1S_1	0.0060	0.240	0.248	13.60
D_2S_2	0.0082	0.394	0.339	14.70
D_3S_3	0.0202	0.499	0.523	14.41
D_4S_4	0.113	0.569	0.682	15.10
CD (P≤0.05)	**0.0015**	**0.030**	**0.037**	**0.40**

class D_1 spacing S_1. The present finding is in agreement with the results of Sajad [9], who reported maximum essential oil yield from spacing 40 cm x 60 cm (24.20 kg/ha) and minimum essential oil yield from spacing 100 x 120 cm (0.81kg/ha). Nigussie et al., [8] also studied the effect of plant population density (four intra-rows viz., 40, 60, 80, 100 cm and four inter-row plant spacing's of 60, 80, 100, 120 cm) on growth and yield of *Artemisa* (*Artimesia annua* L.) and found that essential oil yield (23.39 kg/ha) was attained due to spacing combination 40 cm intra-row and 60 cm inter-row spacing. The essential oil extracted from different parts of the plant was directly proportional to the essential oil yield. Rayees [10] reported that maximum essential oil yield increased as the increase in diameter class and spacing in the case of *Acorus Calmus*. Rao [11] conducted a study on essential oil yield and essential oil composition of rose-scented geranium (*Pelargonium* species) as influenced by row spacing and intercropping with corn mint (*Mentha arvensis*). The field investigation demonstrated that 60×30 cm (60 cm between the rows and 30 cm between the plants within the rows) spacing is optimum for rose-scented geranium for harvesting high essential oil yields and good quality essential oil.

Conclusion

To check the increased pressure of the locals on Bergenia, domestication, and propagation of the species should be facilitated. Propagation of *Bergenia ciliata* can be done asexually by use of rhizomes. It is recommended that the diameter class 2.25-3.0 cm and spacing of 60 cm × 75 cm should be followed to get a better yield of the crop and essential oil under rain fed and in degraded lands.

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