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Ex situ conservation of *Hedychium spicatum* Buch.-Ham. using different types of nursery beds

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***Hedychium spicatum* Buch.-Ham. belongs to family Zingiberaceae. It is known for its many medicinal uses. Due to great market potential of the plant, it is harvested in uncontrolled way causing the decline of the herb from its natural habitat. Presently, its status in nature is not good. Thus, there is need of its *in situ* as well as *ex situ* conservation and propagation. The present study was conducted on different trials with different organic fertilizers and types of nursery beds to develop a need based agro-technique for mass scale cultivation of the plant in the climatic condition of Ranikhet, Uttarakhand.**

Key words:*Hedychium spicatum* Buch.-Ham., organic cultivation, conservation, sustainable harvesting.

INTRODUCTION

Hedychium spicatum Buch.-Ham. belongs to family Zingiberaceae, commonly known as “Ginger Lily”, found in temperate and sub-temperate zones in Himalayas between 1500 to 2700 m (Naithani, 1985). It is an annual-perennial, erect herb, stem leafy, 5 to 150 cm high. Leaves broadly ovate-lanceolate, 30 to 60 × 10 to 20 cm acuminate, glabrous above, sparsely pubescent beneath. Flowers fragrant, white with an orange-yellow or red base, in dense, terminal, 15 to 25 cm long spikes; floral bracts large, green, 1-flowered. Calyx membranous: three-lobed, ovate, obtuse, shorter than bracts. Corolla tube 5 to 6.5 cm long, much longer than calyx; petals white, linear, spreading; lip white with two-elliptic lobes and orange or yellow base; filaments of stamen-red. Capsules globular: three-valved with an orange-red lining; seeds black with red aril (Gaur, 1999).

H. spicatum is highly traded from the Himalayan region under the trade name “Kapur Kachari” or “Sathi”. Its rhizome is used in Ayurvedic and Unani medicine. Aromatic rootstock contains essential oil, saccharin, albumin, starch and mucilage. The rhizomes are considered useful as stomachic, carminative and stimulant for the treatment of liver complaints, diarrhea, food poisoning and inflammation. It is useful in the treatment of asthma and bronchitis (Singh, 1983). Rhizome powder is sprinkled as an antiseptic agent and also used in various aches and pains (Thakur et al., 1989). A famous perfume ‘abir’ is obtained from the rootstocks. The rhizomes are also considered to have insect repelling properties and used for the preservation of cloth in some part of Uttarakhand. The essential oil can be used in perfumes, soaps, hair oils and in cosmetics. Locally rhizomes, are boiled and eaten with salt, powder of roasted rhizome is effective in asthma and respiratory disorders. Seeds are believed to cause abortion. Decoction of rhizome with deodar saw dust is taken for tuberculosis (Gaur, 1999). The rhizome yields an aromatic volatile oil known as ‘Kapur Kachri oil’ which has p-methoxycinnamate as major chemical constituent (Sarin, 2008).

In recent years, over exploitation of this herb due to demand of raw drugs in pharmaceutical industries has led to habitat destruction. Due to lack of management, this highly valuable species have reached near extinction

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and require immediate attention towards its *ex situ* and *in situ* conservation.

Here, we are presenting the agro-technique of this highly valuable medicinal plant which may be fruitful in future for farmers and medicinal plant growers. The main objective of our study is *ex situ* conservation of this valuable herb as well as upliftment of the economy of hill people by its cultivation.

MATERIALS AND METHODS

Germplasm of *H. spicatum* has been collected from the wild sources surrounding Ranikhet before the onset of its dormancy and the trials for this study were conducted at Medicinal Plant Garden of Central Council for Research in Ayurveda and Siddha (CCRAS), Ranikhet (29°38'60 N, 79°25'0 E). The garden is situated at an altitude of 1700 m. It is surrounded by thick pine forest, characterized by *Cedrus*, *Myrica*, *Rhododendron*, *Quercus* and Shrubs like *Berberis*, *Rubus* sp., and *Crataegus* sp. Germplasm of *Polygonatum cirrhifolium* was collected from the wild sources just before the onset of its dormancy. Before plantation, we prepared the land and applied the fertilizer as follows:

The land was dug up or ploughed twice or thrice until a fine tilth was obtained. After those different types of experimental beds namely: beds in plain, beds in slopes and beds with rows and furrows of 1 m^2 areas were prepared. Before plantation, these nursery beds were supplemented with different types of organic fertilizers. Three types of organic fertilizers namely: farmyard manure (FYM), forest litter and vermincompost were used to see their effect on the survival, growth and yield. The fertilizers were added in the beds in two doses: first before plantation (at the time of bed preparation) and second after sprouting. In order to study the effect of fertilizers and nature of nursery beds on survival, growth, yield and other related parameters the experiment was designed in randomize block design (RBD) with a total of 16 treatment combinations along with a control set and each treatment was replicated three times.

Plants can be raised by rhizomes as well as by seeds; however, plants raised by seeds can take more time for crop maturity. Hence, rhizomes are best for its propagation (Nautiyal and Nautiyal, 2004; Anonymous, 2008). Therefore, we used rhizome sections for the propagation. In morning hours, these rhizome sections were planted in the different nursery beds. Before plantation, rhizomes were washed with natural spring water of Medicinal Plant Garden and dipped in cow's urine for overnight to prevent them from soil born diseases as suggested in "Varkshayurveda" by Vijyalashmi and Shyam (1993). Rhizome sections were cut into transverse sections of about 4.00 to 5.00 cm long at the intermodal portion with at least two nodes within each section and each rhizome section was planted laterally in different types of nursery beds. A total of 432 rhizome sections were selected for plantation and total 9 rhizome sections were planted in each bed. A row-to-row and plant-to-plant distance of 30 cm was followed for sowing the rhizomes. In all the treatments, irrigation was done at regular intervals through, natural spring water (heavy metal free), depending upon weather condition and moisture requirements of soil. The crop was irrigated once a week during dry months. During the dormancy period, irrigation was done in every 20 days. The beds were kept free from weeds manually.

Data were recorded on both pre-harvest and post-harvest agronomic characters namely: days to sprout, days to flower, number of leaves, leaf length, plant height, fresh weight of rhizomes, dry weight of rhizomes and rate of fresh weight of rhizomes increased. Observations were recorded in 15 days interval. Statistical analysis was carried out to calculate mean values and correlation between different morphological traits. Analysis of variance (ANOVA) and correlation between different morphological traits was calculated by using data analysis tool of Window 2007.

To observe the yield, underground parts (rhizomes) from one replication of each treatment were uprooted at the end of each growing season for three consecutive growth seasons. These rhizomes were properly washed with running water to remove soil particles. Fresh weight was taken after removing rootlets. These rhizomes were then cuts into small slices and kept in the partial shade for drying. After complete drying, dry weight of these rhizomes was taken.

Intercultural operation

The following fertilizer doses and spacing was used to standardize the agro-technique for commercial cultivation of this herb:

(a) Design: RBD.
(b) Fertilizers: F_1, forest litter; F_2, vermi compost; F_3, FYM; F_4, control (quantity of fertilizer: 600 g per bed (60 qut /ha).
(c) Nursery beds: B_1, slope; B_2, rows; B_3, furrows; B_4, plain.
(d) No. of treatment combinations: 4 × 4 = 16

	F_1	F_2	F_3	F_4
B_1	T_1	T_2	T_3	T_4
B_2	T_5	T_6	T_7	T_8
B_3	T_9	T_{10}	T_{11}	T_{12}
B_4	T_{13}	T_{14}	T_{15}	T_{16}

(e) Replication: 3
(f) Spacing: 30 × 30 cm.
(g) Total no. of plots: 48
(h) Plot size: 1 × 1 m^2
(i) Number of rhizome cuttings planted in each bed: 9

RESULTS

Data analyzed for mean values showed that in the first year of cultivation (Table 1), *H. spicatum* takes about 181.56 to 195 days to sprout and 251.89 to 266.44 days to flower from the date of plantation. The percentage of survival was observed 100% in all type of beds. Maximum average number of leaves per plant, 7.56 in the bed T_2 (slope + vermin compost) and minimum, 5.37 in the bed T_{16} (plain + control), maximum average leaf length, 33.04 cm in the bed T_{14} (plain + vermi compost) and minimum, 21.49 cm in the bed T_{12} (forrow + control), maximum average height per plant, 76.22 cm in the bed T_{13} (plain + forest litter) and minimum, 39.81 cm in the bed T_8 (row + control), maximum fresh weight of rhizomes harvested 113.62 qt/ha in the bed T_1 (slope + forest litter) and minimum, 62.98 qt/ha in the bed T_8 (row + control), maximum dry weight of rhizomes obtained 24.50 qt/ha in the bed T_1 (slope + forest litter) and minimum, 13.90 qt/ha in the bed T_{12} (forrow + control), maximum rate of fresh weight of rhizomes increased 53.05% in the bed T_1 (slope + forest litter) and minimum, 12.03% in the bed T_8 (row + control) were observed during

Table 1. Pre-harvest and post- harvest agronomic characters of *H. spicatum* under different types of nursery beds and fertilizer treatments for first year of cultivation.

				Pre- harvest agronomic character					Post- harvest agronomic character			
Bed	Treatment	Spacing	% of survival	Days to sprout	Days to flower	Avg. no. of leaves/plant	Avg. leaf length (cm)	Avg. height /plant (cm)	Fresh weight of rhizomes planted (qt/ha)	Fresh weight of rhizomes harvested (qt/ha)	Dry weight of rhizomes obtained (qt/ha)	Rate of fresh weight of rhizomes increased (%)
T_1	Slope + Litter	30 × 30	100	181.56 ± 3.32	251.89 ± 3.69	6.96 ± 1.60	30.68 ± 10.75	61.26 ± 3.49	75.12 ± 7.66	113.62 ± 5.50	24.50 ± 1.18	53.05 ± 21.02
T_2	Slope + Vermi	30 × 30	100	182.11 ± 4.34	252.00 ± 4.53	7.56 ± 1.93	30.93 ± 7.55	68.13 ± 2.92	72.83 ± 7.52	108.04 ± 4.52	23.19 ± 0.95	49.94 ± 18.67
T_3	Slope + FYM	30 × 30	100	182.00 ± 3.57	252.22 ± 3.49	5.85 ± 1.66	26.17 ± 7.34	62.24 ± 3.33	68.37 ± 11.52	96.30 ± 6.62	20.75 ± 1.45	45.15 ± 30.27
T_4	Slope + Control	30 × 30	100	182.22 ± 3.03	252.22 ± 3.77	5.56 ± 1.85	28.32 ± 8.75	53.27 ± 2.27	65.42 ± 8.88	90.75 ± 4.54	19.49 ± 0.97	41.33 ± 22.40
T_5	Row + Litter	30 × 30	100	181.78 ± 3.31	252.00 ± 4.39	6.78 ± 1.60	27.48 ± 7.35	60.89 ± 1.93	63.58 ± 9.74	74.21 ± 4.64	15.87 ± 0.98	22.76 ± 19.06
T_6	Row + Vermi	30 × 30	100	183.33 ± 2.92	254.33 ± 3.24	7.37 ± 1.88	30.89 ± 9.14	70.85 ± 2.48	61.73 ± 8.14	75.94 ± 3.23	16.31 ± 0.76	25.08 ± 18.77
T_7	Row + FYM	30 × 30	100	188.11 ± 3.98	259.56 ± 3.17	6.41 ± 2.15	26.93 ± 5.97	57.73 ± 2.39	73.46 ± 9.38	85.84 ± 4.72	18.44 ± 1.05	19.40 ± 18.76
T_8	Row + Control	30 × 30	100	187.00 ± 3.04	257.56 ± 3.97	5.70 ± 1.68	22.18 ± 4.50	39.81 ± 2.14	59.88 ± 8.21	62.98 ± 3.28	14.24 ± 0.72	12.03 ± 12.32
T_9	Furrow + Litter	30 × 30	100	194.33 ± 4.24	266.00 ± 4.66	6.74 ± 1.46	29.88 ± 9.16	64.50 ± 2.62	73.49 ± 6.93	102.49 ± 5.42	22.00 ± 1.18	40.12 ± 9.08
T_{10}	Furrow + Vermi	30 ×30	100	187.44 ± 3.32	258.89 ± 3.89	6.19 ± 1.75	29.17 ± 8.57	69.81 ± 2.32	61.11 ± 8.12	83.37 ± 4.65	17.91 ± 0.96	39.17 ± 24.20
T_{11}	Furrow + FYM	30 × 30	100	188.00 ± 4.44	259.33 ± 3.20	5.93 ± 1.54	28.07 ± 7.25	60.23 ± 3.23	62.95 ± 9.14	78.40 ± 3.46	16.64 ± 0.73	29.24 ± 16.90
T_{12}	Furrow + Control	30 × 30	100	195.00 ± 4.24	266.44 ± 6.46	6.07 ± 1.49	21.49 ± 3.69	47.37 ± 3.56	59.26 ± 7.90	64.21 ± 3.69	13.90 ± 0.74	15.04 ± 10.03
T_{13}	Plane + Litter	30 × 30	100	186.00 ± 3.16	257.89 ± 4.48	6.74 ± 1.43	32.14 ± 8.11	76.22 ± 3.28	67.27 ± 8.47	94.47 ± 4.76	20.42 ± 1.02	42.89 ± 23.29
T_{14}	Plane + Vermi	30 × 30	100	187.67 ± 3.08	259.78 ± 3.27	6.30 ± 1.44	33.04 ± 8.86	69.58 ± 3.28	67.92 ± 7.04	95.71 ± 4.42	20.66 ± 1.01	42.39 ± 17.22
T_{15}	Plane + FYM	30 × 30	100	188.00 ± 3.57	259.89 ± 3.22	6.67 ± 1.57	31.55 ± 7.62	72.44 ± 3.17	75.28 ± 7.47	104.95 ± 5.69	22.58 ± 1.20	40.79 ± 17.77
T_{16}	Plane + Control	30 × 30	100	189.11 ± 3.37	261.33 ± 3.57	5.37 ± 1.84	24.13 ± 5.47	55.55 ± 3.06	71.57 ± 9.95	81.49 ± 3.48	17.42 ± 0.68	18.07 ± 13.35
		DF		15	15	15	15	15	15	15	15	15
ANOVA		MS		158.91	207.07	10.77	238.21	2517.78	285.80	2052.06	91.85	1553.17
		F-value		12.30***	12.80***	3.76***	4.00***	301.94***	3.88***	95.65***	92.72***	4.27***

uring first year of cultivation. In the first year of cultivation of *H. spicatum*, ANOVA was found significant for all the pre-harvest and post-harvest agronomic characters namely: days to sprout, days to flower, average number of leaves per plant, average leaf length (cm), average height per plant (cm), fresh weight of rhizomes planted (qt/ha), fresh weight of rhizomes harvested (qt/ha), dry weight of rhizomes obtained (qt/ha) and rate of fresh weight of rhizomes increased (%) with F-value (12.30, 12.80, 3.76, 4.00, 301.94, 3.88, 95.65, 92.72 and 4.27, respectively at $p <$ 0.001).

In the second year of cultivation (Table 2), the plant took about 164 to 181.11 days to sprout and 234.22 to 256.78 days to flower from the date of dormancy and 100% survival was recorded in all type of beds. Maximum average number of leaves per plant, 7.89 in the bed T_2 (slope + vermicompost) and minimum, 5.61 in the bed T_{16} (plain + control), maximum average leaf length, 33.86 cm in the bed T_{14} (plain + vermi compost) and minimum, 23.11 cm in the bed T_{12} (forrow + control), maximum average height per plant, 77.35 cm in the bed T_{13} (plain + forest litter) and minimum, 40.32 cm in the bed T_8 (row + control), maximum fresh weight of rhizomes harvested, 181.23 qt/ha, dry weight of rhizomes obtained 39.12 qt/ha and rate of fresh weight of rhizomes increased 162.62% in the bed T_1 (slope + forest litter) and minimum fresh weight of rhizomes harvested 128.37 qt/ha, dry weight of rhizomes obtained 27.58 qt/ha and rate of fresh weight of rhizomes increased 74.86% in the bed T_8 (row + control) were observed during second year of cultivation. In the second year of cultivation,

Table 2. Pre-harvest and post-harvest agronomic characters of *H. spicatum* under different types of nursery beds and fertilizer treatments for second year of cultivation.

Bed	Treatment	Spacing	% of survival	Pre-harvest agronomic character					Post-harvest agronomic character			
				Days to sprout	Days to flower	Avg. no. of leaves/plant	Avg. leaf length (cm)	Avg. height /Plant (cm)	Fresh weight of rhizomes planted (qt/ha)	Fresh weight of rhizomes harvested (qt/ha)	Dry weight of rhizomes obtained (qt/ha)	Rate of fresh weight of Rhizomes increased (%)
T_1	Slope + Litter	30 × 30	100	166.22 ± 3.07	236.89 ± 4.23	7.44 ± 1.50	32.45 ± 8.49	62.08 ± 3.43	70.32 ± 9.68	181.23 ± 8.44	39.12 ± 1.84	162.62 ± 44.11
T_2	Slope + Vermi	30 × 30	100	166.67 ± 4.21	237.78 ± 4.15	7.89 ± 1.60	32.76 ± 7.19	69.43 ± 2.84	72.32 ± 9.28	175.33 ± 7.87	37.53 ± 1.64	146.94 ± 41.54
T_3	Slope + FYM	30 × 30	100	164.00 ± 3.35	234.22 ± 4.09	6.33 ± 1.41	27.18 ± 6.15	63.02 ± 2.87	71.66 ± 9.50	173.57 ± 16.09	37.19 ± 3.45	145.89 ± 39.03
T_4	Slope + Control	30 × 30	100	167.00 ± 3.67	238.11 ± 3.59	6.00 ± 1.33	30.25 ± 9.62	53.98 ± 2.10	59.52 ± 6.71	138.72 ± 10.11	29.96 ± 2.22	135.69 ± 30.38
T_5	Row + Litter	30 × 30	100	169.56 ± 3.54	241.44 ± 4.16	7.50 ± 1.82	29.08 ± 9.07	61.62 ± 2.20	72.60 ± 9.53	144.96 ± 9.78	31.25 ± 2.10	103.56 ± 34.65
T_6	Row + Vermi	30 × 30	100	173.78 ± 3.73	248.00 ± 4.39	7.72 ± 1.32	32.62 ± 9.76	71.69 ± 3.34	71.35 ± 11.30	144.07 ± 10.97	30.97 ± 2.36	107.28 ± 41.96
T_7	Row + FYM	30 × 30	100	172.22 ± 3.80	244.56 ± 4.07	6.56 ± 1.42	28.47 ± 9.31	58.58 ± 2.61	67.24 ± 7.47	135.37 ± 11.74	29.08 ± 2.42	102.89 ± 22.23
T_8	Row + Control	30 × 30	100	174.33 ± 3.61	247.89 ± 4.04	6.00 ± 1.64	23.88 ± 5.89	40.32 ± 2.22	74.22 ± 7.63	128.37 ± 9.99	27.58 ± 2.18	74.86 ± 24.56
T_9	Furrow+litter	30 × 30	100	180.89 ± 4.54	253.67 ± 3.94	7.17 ± 1.34	31.25 ± 8.01	65.96 ± 4.68	68.46 ± 10.14	154.73 ± 10.74	33.44 ± 2.31	130.62 ± 38.64
T_{10}	Furrow + Vermi	30 × 30	100	176.22 ± 2.95	250.56 ± 3.81	6.50 ± 1.47	30.89 ± 8.94	70.90 ± 3.44	67.72 ± 8.66	145.82 ± 13.79	31.46 ± 2.94	119.39 ± 40.52
T_{11}	Furrow + FYM	30 × 30	100	177.33 ± 3.20	251.78 ± 4.38	6.39 ± 1.50	29.94 ± 6.68	60.95 ± 2.97	63.64 ± 9.63	132.87 ± 10.30	28.67 ± 2.14	113.39 ± 39.96
T_{12}	Furrow + Control	30 × 30	100	181.11 ± 4.40	254.33 ± 3.39	6.44 ± 1.42	23.11 ± 5.96	48.19 ± 2.78	69.39 ± 10.64	135.14 ± 14.62	29.09 ± 3.03	98.24 ± 31.89
T_{13}	Plane + Litter	30 × 30	100	175.78 ± 3.31	250.78 ± 3.73	7.28 ± 1.18	33.36 ± 7.55	77.35 ± 2.52	63.86 ± 8.65	153.50 ± 12.49	33.13 ± 2.70	144.27 ± 35.84
T_{14}	Plane + Vermi	30 × 30	100	174.78 ± 4.21	249.00 ± 5.07	6.56 ± 1.50	33.86 ± 7.98	70.36 ± 2.81	65.79 ± 10.12	153.51 ± 11.68	32.88 ± 2.51	137.62 ± 36.41
T_{15}	Plane + FYM	30 × 30	100	180.11 ± 4.59	254.67 ± 4.03	6.94 ± 1.21	33.00 ± 8.34	72.98 ± 2.71	67.92 ± 10.09	155.43 ± 11.71	33.42 ± 2.57	134.94 ± 50.47
T_{16}	Plane + Control	30 × 30	100	180.33 ± 4.64	256.78 ± 3.80	5.61 ± 1.69	25.27 ± 6.41	56.55 ± 3.47	67.00 ± 9.12	131.47 ± 12.24	28.25 ± 2.64	99.11 ± 29.50
			DF	15	15	15	15	15	15	15	15	15
ANOVA			MS	288.48	464.635	8.07	234.88	1715.66	134.26	2386.79	109.27	4994.29
			F-value	19.56***	28.04***	3.74***	3.73***	190.48***	1.54^{NS}	17.74 ***	17.76***	3.64***

ANOVA was found significant for days to sprout, days to flower, average number of leaves per plant, average leaf length (cm), average height per plant (cm), fresh weight of rhizomes harvested (qt/ha), dry weight of rhizomes obtained (qt/ha) and rate of fresh weight of rhizomes increased (%) with F value (19.56, 28.04, 3.74, 3.73, 190.48, 17.74, 17.76 and 3.64, respectively at $p < 0.001$), wherein found non-significant for fresh weight of rhizomes planted (qt/ha) with F-value (1.54 at $p > 0.05$).

In the third year of cultivation (Table 3), the plant took about 160 to 183 days to sprout and 229 to 259.67 days to flower from the date of dormancy and 100% survival was recorded in all type of beds. Maximum average number of leaves per plant 8.56 in the bed T_6 (row + vermicompost) and minimum 6.22 in the bed T_{16} (plain + control), maximum average leaf length 34.49 cm in the bed T_{15} (plain + FYM) and minimum 24.04 cm in the bed T_{12} (forrow + control), maximum average height per plant 78.73 cm in the bed T_{13} (plain + forest litter) and minimum 41.22 cm in the bed T_8 (row + control), maximum fresh weight of rhizomes harvested 225.48 qt/ha, dry weight of rhizomes obtained 48.72 qt/ha and rate of fresh weight of rhizomes increased 232.34% in the bed T_1 (slope + forest litter) and minimum fresh weight of rhizomes harvested 158.62 qt/ha, dry weight of rhizomes obtained 34.06 qt/ha and rate of fresh weight of rhizomes increased 123.85% in the bed T_8 (row + control) were observed during second year of cultivation. In the third year of cultivation,

Table 3. The pre-harvest and post-harvest agronomic characters of *H. spicatum* under different types of nursery beds and fertilizer treatments for third year of cultivation.

Bed	Treatment	Spacing	% of survival	Pre-harvest agronomic character					Post-harvest agronomic character			
				Days to sprout	Days to flower	Avg. no. of leaves/plant	Avg. leaf length (cm)	Avg. height /plant (cm)	Fresh weight of rhizomes planted (qt/ha)	Fresh weight of rhizomes harvested (qt/ha)	Dry weight of rhizomes obtained (qt/ha)	Rate of fresh weight of rhizomes increased (%)
T_1	Slope + Litter	30 × 30	100	160.00 ± 3.12	229.00 ± 3.50	7.89 ± 1.45	32.83 ± 4.79	62.86 ± 4.36	68.87 ± 9.37	225.48 ± 10.45	48.72 ± 2.25	232.34 ± 43.24
T_2	Slope + Vermi	30 × 30	100	163.00 ± 2.78	232.89 ± 3.69	8.44 ± 1.81	33.31 ± 5.41	69.98 ± 2.61	69.58 ± 11.00	217.33 ± 10.24	46.74 ± 2.27	220.79 ± 62.14
T_3	Slope + FYM	30 × 30	100	165.00 ± 2.69	236.00 ± 4.24	7.33 ± 1.00	27.48 ± 6.22	64.42 ± 2.16	69.90 ± 8.61	214.17 ± 19.48	46.03 ± 3.99	210.43 ± 45.20
T_4	Slope + Control	30 × 30	100	163.22 ± 3.99	232.00 ± 4.85	6.89 ± 1.27	31.08 ± 5.98	55.13 ± 1.28	68.38 ± 6.87	189.86 ± 14.19	40.74 ± 3.07	180.51 ± 39.67
T_5	Row + Litter	30 × 30	100	167.11 ± 3.22	238.89 ± 4.57	8.11 ± 1.05	29.48 ± 6.68	62.20 ± 2.58	72.57 ± 8.41	180.56 ± 12.44	38.98 ± 2.78	152.20 ± 38.14
T_6	Row + Vermi	30 × 30	100	169.22 ± 4.35	242.22 ± 3.99	8.56 ± 1.13	33.53 ± 5.21	72.00 ± 2.93	70.80 ± 8.98	177.55 ± 13.23	38.20 ± 2.88	153.77 ± 33.03
T_7	Row + FYM	30 × 30	100	174.00 ± 3.77	246.89 ± 3.86	7.33 ± 1.41	28.74 ± 5.59	59.73 ± 1.98	67.82 ± 8.07	166.63 ± 13.09	35.89 ± 2.73	148.71 ± 34.94
T_8	Row + Control	30 × 30	100	172.33 ± 3.91	244.56 ± 4.10	6.89 ± 1.17	24.16 ± 6.39	41.22 ± 2.61	72.48 ± 12.00	158.62 ± 12.46	34.06 ± 2.61	123.85 ± 37.77
T_9	Furrow + litter	30 × 30	100	176.89 ± 3.98	249.89 ± 4.43	7.78 ± 1.64	32.04 ± 4.60	67.13 ± 3.21	71.14 ± 10.27	190.85 ± 13.65	41.16 ± 2.93	172.29 ± 35.52
T_{10}	Furrow + Vermi	30 × 30	100	174.78 ± 3.31	248.78 ± 3.99	7.44 ± 1.51	30.99 ± 9.84	71.62 ± 3.43	68.77 ± 10.61	181.64 ± 17.30	39.11 ± 3.84	169.59 ± 46.86
T_{11}	Furrow + FYM	30 × 30	100	174.33 ± 3.46	247.56 ± 3.40	7.11 ± 1.69	30.57 ± 6.86	62.37 ± 2.51	64.93 ± 7.98	167.91 ± 14.08	36.26 ± 2.96	160.64 ± 26.12
T_{12}	Furrow + Control	30 × 30	100	176.67 ± 3.08	248.56 ± 4.61	7.33 ± 1.58	24.04 ± 5.86	48.83 ± 2.65	72.87 ± 10.50	168.02 ± 17.93	36.08 ± 3.85	133.71 ± 32.68
T_{13}	Plane + Litter	30 × 30	100	179.44 ± 3.71	254.44 ± 4.30	8.00 ± 1.58	33.62 ± 4.59	78.73 ± 2.89	64.39 ± 8.65	190.12 ± 15.64	40.90 ± 3.49	199.00 ± 39.11
T_{14}	Plane + Vermi	30 × 30	100	177.11 ± 3.10	251.78 ± 3.96	7.22 ± 1.20	34.34 ± 10.59	72.54 ± 2.78	67.85 ± 8.63	192.42 ± 14.42	41.43 ± 3.11	188.78 ± 48.80
T_{15}	Plane + FYM	30 × 30	100	175.89 ± 3.55	250.67 ± 4.00	7.89 ± 1.05	34.49 ± 5.77	74.20 ± 2.20	61.89 ± 6.39	171.98 ± 12.45	37.09 ± 2.70	179.88 ± 28.63
T_{16}	Plane + Control	30 × 30	100	183.00 ± 4.64	259.67 ± 3.97	6.22 ± 1.09	25.88 ± 5.95	58.16 ± 3.60	71.08 ± 9.64	164.51 ± 15.26	35.32 ± 3.26	136.65 ± 49.37
			DF	15	15	15	15	15	15	15	15	15
ANOVA			MS	397.97	683.27	3.41	109.43	869.09	86.72	3577.72	167.31	9042.56
			F-value	31.01***	40.47***	1.80*	2.61**	109.15***	1.02^{NS}	17.37***	17.55***	5.38***

Significant levels (* = P<0.05; ** = P<0.01; ***P<0.001); NS, non significant.

ANOVA was found significant for days to sprout, days to flower, average height per plant (cm), fresh weight of rhizomes harvested (qt/ha), dry weight of rhizomes obtained (qt/ha) and rate of fresh weight of rhizomes increased (%) with F-value (31.01, 40.47, 109.15, 17.37, 17.55 and 5.38, respectively at $p < 0.001$); average number of leaves per plant with F-value (1.80 at $p < 0.05$); average leaf length (cm) with F-value (2.61 at $p < 0.01$), whereas found non-significant for fresh weight of rhizomes planted (qt/ha) with F-value (1.02 at $p > 0.05$).

Correlation in morphological traits

In the first year of cultivation of *H. spicatum* (Table 4), days to sprout showed significant positive correlation with days to flower (r = 0.99 at p = 0.05). Average number of leaves per plant was significantly and positively correlated with average leaf length (cm) and average height/plant (cm) (r = 0.63 and 0.61, respectively at p = 0.05). Average leaf length (cm) showed significant positive correlation with average height/plant (cm), fresh weight of rhizomes harvested (qt/ha), dry weight of rhizomes obtained (qt/ha) and rate of fresh weight of rhizomes increased (%) (r = 0.88, 0.71, 0.70 and 0.75, respectively at p = 0.05). Average height/plant (cm) showed significant positive

Table 4. Correlation between different morphological traits of *H. spicatum* for first year of cultivation.

Parameter	Days to sprout	Days to flower	Avg. no. of leaves/plant	Avg. leaf length (cm)	Avg. height/ plant (cm)	Fresh weight of rhizomes planted (qt/ha)	Fresh weight of rhizomes harvested (qt/ha)	Dry weight of rhizomes obtained (qt/ha)	Rate of fresh weight of rhizomes increased (%)
Days to sprout	1.00								
Days to flower	0.99*	1.00							
Avg. no. of leaves/plant	-0.27	-0.26	1.00						
Avg. leaf length (cm)	-0.33	-0.27	0.63*	1.00					
Avg. height/plant (cm)	-0.21	-0.14	0.61*	0.88*	1.00				
Fresh weight of rhizomes planted (qt/ha)	-0.07	-0.05	0.30	0.44	0.36	1.00			
Fresh weight of rhizomes harvested (qt/ha)	-0.28	-0.26	0.44	0.71*	0.59*	0.84*	1.00		
Dry weight of rhizomes obtained (qt/ha)	-0.29	-0.26	0.43	0.70*	0.57*	0.83*	1.00*	1.00	
Rate of fresh weight of rhizomes increased (%)	-0.41	-0.40	0.39	0.75*	0.64*	0.51*	0.90*	0.90*	1.00

DF=14; p= 0.05; r= 0.497; * = P<0.05.

Table 5. Correlation between different morphological traits of *H. spicatum* for second year of cultivation.

Parameter	Days to sprout	Days to flower	Avg. no. of leaves/plant	Avg. leaf lengt (cm)	Avg. height/ plant (cm)	Fresh weight of rhizomes planted (qt/ha)	Fresh weight of rhizomes harvested (qt/ha)	Dry weight of rhizomes obtained (qt/ha)	Rate of fresh weight of rhizomes increased (%)
Days to sprout	1.00								
Days to flower	0.99*	1.00							
Avg. no. of leaves/plant	-0.25	-0.26	1.00						
Avg. leaf length (cm)	-0.17	-0.14	0.64*	1.00					
Avg. height/plant (cm)	0.004	0.05	0.60*	0.86*	1.00				
Fresh weight of rhizomes planted (qt/ha)	-0.19	-0.21	0.37	-0.27	-0.17	1.00			
Fresh weight of rhizomes harvested (qt/ha)	-0.55*	-0.57*	0.59*	0.54*	0.52*	0.27	1.00		
Dry weight of rhizomes obtained (qt/ha)	-0.55*	-0.57*	0.59*	0.55*	0.52*	0.26	1.00*	1.00	
Rate of fresh weight of rhizomes increased (%)	-0.44	-0.45	0.42	0.71*	0.62*	-0.25	0.86*	0.87*	1.00

DF=14; p = 0.05; r = 0.497; * = P<0.05.

correlation with fresh weight of rhizomes harvested (qt/ha), dry weight of rhizomes obtained (qt/ha) and rate of fresh weight of rhizomes increased (%) (r = 0.59, 0.57 and 0.64, respectively at p = 0.05). Fresh weight of rhizomes planted (qt/ha) showed significant positive correlation with fresh weight of rhizomes harvested (qt/ha), dry weight of rhizomes obtained (qt/ha) and rate of fresh weight of rhizomes increased (%) (r = 0.84, 0.83 and 0.51, respectively at p = 0.05). Fresh weight of rhizomes harvested (qt/ha) showed perfect positive significant correlation with dry weight of rhizomes obtained (qt/ha) (r = 1.00 at p = 0.05) and it was significantly and positively correlated with rate of fresh weight of rhizomes increased (%) (r = 0.90 at p = 0.05) and dry weight of rhizomes obtained (qt/ha) was significantly and positively correlated with rate of fresh weight of rhizomes increased (%) (r = 0.90 at p = 0.05). In the second year of cultivation (Table 5), days to

Table 6. Correlation between different morphological traits of *H. spicatum* for third year of cultivation.

Parameter	Days to sprout	Days to flower	Avg. no. of leaves/plant	Avg. leaf length (cm)	Avg. height /plant (cm)	Fresh weight of rhizomes planted (qt/ha)	Fresh weight of rhizomes harvested (qt/ha)	Dry weight of rhizomes obtained (qt/ha)	Rate of fresh weight of rhizomes increased (%)
Days to sprout	1.00								
Days to flower	0.99*	1.00							
Avg. no. of leaves/ plant	-0.39	-0.36	1.00						
Avg. leaf length (cm)	-0.17	-0.13	0.62*	1.00					
Avg. height/ plant (cm)	0.10	0.16	0.58*	0.85*	1.00				
Fresh weight of rhizomes planted (qt/ha)	-0.18	-0.21	-0.10	-0.61*	-0.58*	1.00			
Fresh weight of rhizomes harvested (qt/ha)	-0.67*	-0.65*	0.43	0.46	0.39	-0.03	1.00		
Dry weight of rhizomes obtained (qt/ha)	-0.67*	-0.65*	0.44	0.47	0.40	-0.04	1.00*	1.00	
Rate of fresh weight of rhizomes increased (%)	-0.54*	-0.52*	0.44	0.64*	0.57*	-0.38	0.93*	0.93*	1.00

DF=14; p = 0.05; r = 0.497; * = P<0.05.

sprout showed significant positive correlation with days to flower (r = 0.99 at p = 0.05). Days to flower showed significant but negative correlation with fresh weight of rhizomes harvested (qt/ha) and dry weight of rhizomes obtained (qt/ha) (r = -0.57 and -0.57, respectively at p = 0.05). Average number of leaves per plant was significantly and positively correlated with average leaf length (cm), average height/plant (cm), fresh weight of rhizomes harvested (qt/ha) and dry weight of rhizomes obtained (qt/ha) (r = 0.64, 0.60, 0.59 and 0.59, respectively at p = 0.05). Average leaf length (cm) showed significant positive correlation with average height/plant (cm), fresh weight of rhizomes harvested (qt/ha), dry weight of rhizomes obtained (qt/ha) and rate of fresh weight of rhizomes increased (%) (r = 0.86, 0.54, 0.55 and 0.71, respectively at p = 0.05). Average height/plant (cm) showed significant positive correlation with fresh weight of rhizomes harvested (qt/ha), dry weight of rhizomes obtained (qt/ha) and rate of fresh weight of rhizomes increased (%) (r = 0.52, 0.52 and 0.62, respectively at p = 0.05). Fresh weight of rhizomes harvested showed perfect positive significant correlation with dry weight of rhizomes obtained (qt/ha) (r = 1.00 at 0.05) and showed significant positive correlation with rate of fresh weight of rhizomes increased (%) (r = 0.86 at p = 0.05) and dry weight of rhizomes obtained (qt/ha) was significantly and positively correlated with rate of fresh weight of rhizomes increased (%) (r = 0.87 at p = 0.05).

In the third year of cultivation (Table 6), days to sprout showed significant positive correlation with days to flower (r = 0.99 at p = 0.05) but it showed significant negative correlation with fresh weight of rhizomes harvested (qt/ha), dry weight of rhizomes obtained (qt/ha) and rate of fresh weight of rhizomes increased (%) (r = -0.67, -0.67 and -0.54, respectively at p = 0.05). Average number of leaves per plant showed significant positive correlation with average leaf length (cm) and average height/plant (cm) (r = 0.62 and 0.58, respectively at p = 0.05). Average leaf length (cm) was significantly and positively correlated with average height/plant (cm) and rate of fresh weight of rhizomes increased (%) (r = 0.85 and 0.64, respectively at p = 0.05) but showed negative significant correlation with fresh weight of rhizomes planted (qt/ha) (r = -0.61 at p = 0.05). Average height/plant (cm) showed significant positive correlation with rate of fresh weight of rhizomes increased (%) (r = 0.57 at p = 0.05) but showed significant negative correlation with fresh weight of rhizomes planted (qt/ha) (r = -0.58 at p = 0.05). Fresh weight of rhizomes harvested showed perfect significant positive correlation with dry weight of rhizomes obtained (qt/ha) (r = 1.00 at p = 0.05) and it was significantly and positively correlated with rate of fresh weight of rhizomes increased (%) (r = 0.93 at p = 0.05) and dry weight of rhizomes obtained (qt/ha) showed significant positive correlation with rate of fresh weight of rhizomes increased (%) (r = 0.93 at p = 0.05) (Figure 1).

DISCUSSION

The implementation of plant species conservation involves two broad approaches: (i) *in situ*- protection of species within habitats (where the protected area networks play a crucial role) and (ii) *ex situ* - use of botanical gardens, arboreta and *in vitro* methods including high-tech cryopreservation.

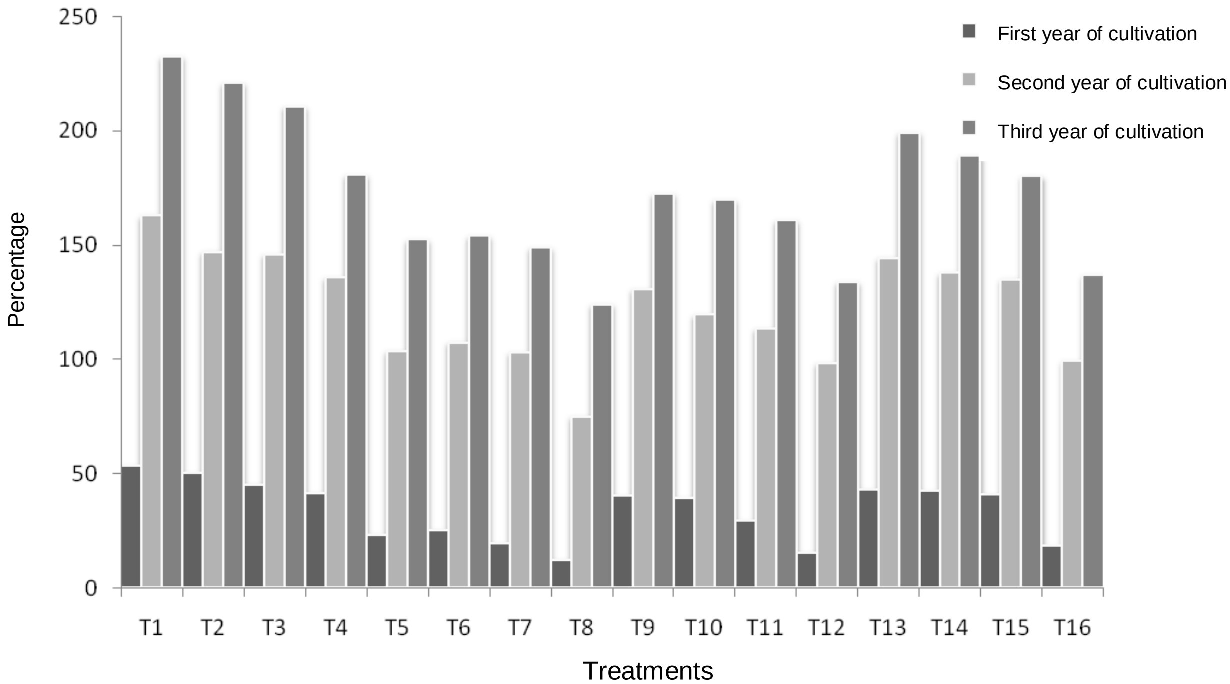

Figure 1. Showing rate of fresh weight of rhizomes increased under experimental cultivation of *H. spicatum* in different types of treatments for first, second and third year.

Ex situ cultivation of threatened plant taxa, particularly those in high demand for trade, has been seen as a practical step, not only indirectly supporting *in situ* conservation (by diverting attention from *in situ* harvesting) but also in reaching a sustainable supply of raw material.

Economic yield was found lower under control beds as compared to litter, FYM and vermicompost in all type of beds prepared in slopes, rows, furrows and plain. In control condition, minerals are not enough for proper growth and development of plants. Chauhan and Bhatt (2000) concluded that addition of 5 to 10 tons/ha of FYM resolve nutritional problems of various hill crops and deteriorating physical condition of soil. Chauhan and Nautiyal (2005) found that economic yield increased with addition of manure (FYM) in all treatments and altitudes compared to control. Application of FYM and leaf litter in cultivated field is traditional practices in Kumaun Himalaya for the better yield and production. Plants grown under different treatments showed much higher economic yield as compared to control beds. However, yield was higher at T_1 (slope + forest litter) as compared to other beds, this difference may be due to low level of mineral nutrient in alpine soil. Several workers (Patidar and Mali, 2001; Saharan et al*.,* 2001; Kasera and Sharan, 2002) also found increase in biomass production with the use of FYM in different crops, while in our study highest incensement in biomass is obtained with the use of leaf litter. Higher economic yield in manure as well as litter beds could become possible only due to availability of essential mineral nutrients, which were needed for growth and development. Addition of manure, litter and vermicompost increased moisture content of soil and retained it for quite some time. It also improved physical, chemical and microbial properties of soil and thereby its productivity. Increased soil fertility enhanced vegetative growth of plants and additional food got stored in underground rhizomes, which improved economic yield of plants. Similar observations were earlier made by Ramamurthy et al*.* (1998), Phirke (2001) and Sharma (2002) and also supported addition of bio-fertilizer for improvement of soil quality.

Spacing treatment generally does not have any significant effect on economic yield. Generally, spacing showed effect on biomass when population density increased at per unit area and plants compete for space, moisture, mineral nutrient or sunlight. But during short period of 3 years, spacing could not show significant difference in economic yield production due to low density during 3-year growth; therefore, we used same spacing during all three growth seasons. However, spacing will certainly affect economic yield in latter stages of development due to increase in above ground and below ground surface area per plant in per unit area. Such study will require long time for fruitful result due to long maturation time. Maturity stage is 7 to 8 years for high altitude species and maximum gain can be obtained by fully matured plants (Rai et al*.,* 2000; Nautiyal et al*.,*

Plate 1. Different stages of *H. spicatum*: (A) In wild. (B) Flowering. (C) In experimental beds. (D) Harvested rhizomes.

2002b) (Plate 1).

Conclusion

From the present study, it may be concluded that the maximum economic yield of rhizomes is obtained in the beds prepared in slope in comparison to beds prepared in plain, rows and furrows. However, best results are obtained in the bed prepared in slope and supplemented with forest litter. It means that the plantation in slopes supplemented with forest litter will results maximum economic yield. The observations are based on 3 years of study. This study on the cultivation technology of *H. spicatum* may help in sustainable utilization, fulfillment of pharmaceutical demand and maintenance of its population in wild.

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