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Performance of Rhizome Cuttings of *Valeriana jatamansi* Jones Populations in Garhwal Himalayas

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A B S T R A C T

Valeriana jatamansi is an important medicinal plant found in the Western Himalayas which is increasingly decreasing in its natural habitats due to its overexploitation for medicinal uses. Therefore study was conducted to identify promising populations and commercially viable morphotypes for cultivation of the species for reducing the pressure on the natural populations. In this study, the plants of *Valeriana jatamansi* were collected from ten natural populations from Tehri and Dehradun districts and their rhizome cuttings were planted in the protected as well as in field condition. The plants showed maximum survival (93.3%) in Kempty population (1391 m elevation) under protected condition, survival was obtained 80% in Kwava , Nagthat and Buranskantha accessions under field condition. In comparison to field condition, growth performance was also observed better under protected conditions like fresh (16.47g) and dry weight (1.66g) of shoots in Mathyau population, roots fresh (7.52 gm) and dry weight (1.05gm) in Kwawa population whereas in field condition, yield of fresh shoot was obtained better in Nagthat population and fresh roots weight it was good in Buranskandha accession. The dry shoot weight was recorded in Zero point population and dry roots weight was registered maximum in Nagthat population under field condition. On the basis of morphological studies promising morphotypes have been identified as Mathyau, Kwawa, Nagthat and Buranshkanda populations which can be used for further studies of genetic and phytochemical characters to isolate stable and distinct morphological features.

Introduction

Medicinal and Aromatic Plants (MAPs) are being used worldwide for different health care needs and preparation of medicines. In developing countries more than 80% people rely on traditional medicines. About 70% of modern medicines are obtained from medicinal plants (Singhal and Agarwal 2007; Bhatt *et al.*, 2012). More than 25% of pharmaceutical drugs across the world are derived from plant natural products (Schmidt *et al.*, 2008). Presently the demand of medicinal plants, both for preparing drugs by pharmaceutical industries and domestic consumption by local inhabitants is mostly

met from wild plant populations, which has resulted in rapid depletion of natural plant populations from natural habitats. Western Himalayas is a big storehouse providing a large number of valuable drug plants and is the source of raw material for around 80 percent Ayurvedic, 46 percent Unani and 33 percent Allopathic medicines (Nautiyal and Nautiyal, 1983).

One of the important medicinal and aromatic plant species of Western Himalayan region is *Valeriana jatamansi* which is facing threat for its existence due to over-exploitation (Kaul and Handa, 2000).In India *Valeriana jatamansi* Jones *(Syn. Valeriana wallichii DC)* is known by several vernacular names such as *Indian Valerian, Muskbala, Sugandbala* (Hindi) and *Tagar* (Sanskrit). It is a substitute of European Valerian (*Valeriana officinalis)* and is widely used as an ingredient in the various Indian systems of medicines (Atal and Kapoor, 1997**)**.

This species is native to Himalayan regions of India, Nepal and South-Western China. It is distributed abundantly in India in the Himalayas from Kashmir to Assam (Bhattacharjee, 2000). Indian Valerian is found in subtropical as well as temperate Himalayan regions up to an elevation of 3000 masl (Atal and Kapoor, 1997**)**.Except for Australia it is found in all temperate regions of the world (Chakraborty *et al.,* 2015). The genus Valeriana (Family-Valerianaceae) has 12 species which are present in India (Bhattacharjee, 2000) It has been listed as an endangered species by the National Medicinal Plant Board, New Delhi and is also listed in the IUCN endangered category (Naquashi and Dhar, 1982). Indiscriminate collection of the rhizomes of Indian Valerian has resulted in potential threat of its existence in localities it was previously found (Chakraborty *et al.,* 2015).

The Indian Valerian is a perennial herb up to 45cm tall with tufted stem, thick and horizontal aromatic and modular rootstock/rhizome and has a seminal root system that arises from the rhizomes of the plants (Bhattacharjee, 2000; Anonymous, 1976). Length of the roots is 6-10 cm. The roots contain major active ingredients which have preventive medicinal uses against the various diseases (Anonymous, 1976). Rhizome length is found between 3-5 cm. and width between 0.2-1.5 cm (Bounthanh *et al.,* 1981). Indian Valerian is dioecious, tetraploid, polygamous, or sometimes polygamo-monoecious (Chakraborty *et al.,* 2015 There is no stem or stem like structure found in *Valeriana jatamansi* Jones, it also does not have any branches. The inflorescence is of terminal corymb type in both hermaphrodite and female type of plants (Chakraborty *et al.,* 2015). Flowers are white tinged with pink. The seeds of the Indian Valerian have fluffs by which it spreads outside by air and the weight of the seeds was found to be 1000 seeds = 1gm, this is true for both hermaphrodite and female plants (Chakraborty *et al.,* 2015).

Valeriana jatamansi Jones has been used for a long time in Indian traditional medicinal systems such as Ayurveda and Unani systems of medicines. The roots of Indian Valerian have been used in traditional Indian medicine systems to treat ulcers, convulsions, jaundice, cardiac debility, dry cough, asthma, seminal weakness, skin diseases, leprosy, general debility and for sleep enhancements (Atal and Kapoor, 1997). It has sesqui terpenoids, valerianoids (Ming *et al.,* 1997), forty chemical constituents (Dongsheng *et al., 1994)* of essential oils and eleven jatamanins (Chakraborty *et al.,* 2015). The commercially produced alkaloid Valerian, is found in the roots (Anonymous, 1976) and is used as a sedative in Germany with the trade name of 'Valmane'. The valepotriates of Indian

Valerian has cytotoxic and anticancer activity found in the leaves and rhizomes of the plant and clinically proven (Bounthanh, *et al.,* 1981).

The Indian valerian can be propagated through seeds as well as vegetative propagation. The propagation by vegetative means i.e. cuttings is recommended for quick and large-scale propagation (Chakraborty *et al.,* 2015). *Valeriana jatamansi* Jones is propagated through rhizome cuttings. A number of plants can be propagated by cutting and splitting the rhizomes into several parts and sowing them during the monsoon season (Mukherjee, 2014).

Vegetative propagation is a useful method for asexual reproduction of plant species, which are very less in their natural habitat but are economically important and are difficult to propagate through seeds (Banday *et al.,* 2014). This method is effective and easy, and is well suited for the mass multiplication and production of true-to -type plants and it also preserves the genetic characters (Banday *et al.,* 2014). This method of propagation is ideal for rapid multiplication of a species under threat, while trying to maintain certain desired characteristics (Hartmann *et al.,* 2002; Tchoundjeu *et al.,* 2004).

The present study was undertaken to identify promising populations of Indian valerian in the Garhwal Himalaya under field and protected conditions.

Materials and Methods

Experimental Sites (Locations)

The study area consisted of 10 populations (Table 1) of natural habitat of Indian Valerian across Tehri and Dehradun districts of Uttarakhand from where germplasm of *Valeriana jatamansi* Jones was collected for evaluation at College of Forestry, Ranichauri. The other location apart from the aforementioned locations was College of Forestry, V.C.S.G Uttarakhand University of Horticulture and Forestry, Ranichauri (Tehri Garhwal), which is located around 9 km away from the hill town of Chamba, which itself is situated on the Rishikesh-Gangotri Road. College of Forestry, Ranichauri is at an altitude of approximately 1850 masl between 30° 15˚ N latitude and 78° 30˚ E longitudes in the mid hills of Uttarakhand, India. The experiment was carried out in the polyhouse and experimental field of Medicinal and Aromatic plants section. The parameters were recorded in the respective experimental sites, medicinal and aromatic plants nursery and the forestry lab.

Climate

Ranichauri campus experiences humid and temperate type of climate with chilled winter. The mean annual maximum and minimum temperature varies from 40.03°C to 13.5°C.

Experiments Details

Sl. No.	Protected Condition	Natural field condition
1	**Design of Experiment:** Randomized Block Design	**Design of Experiment:** Randomized Block Design
2	**Number of Accessions:** 10	**Number of Accessions:** 10
3	**Number of Replications:** 3	**Number of Replications:** 3
4	**Container:** Poly bags (7.5 ×15 cm)	**Type of Sowing:** Line Sowing
5	**Growing Media:** Soil + Sand + FYM (2:1:1)	**Plant to plants spacing:** 30cmx30 cm **Row to row spacing:** 45cm x 45 cm
6	**Total Number of Cuttings:** 10×3×5 = 150	**Total Number of Cuttings:** 10×3×5 = 150
7	**Propagation by: Rhizome cuttings**	**Propagated By: Rhizome cuttings**
8	**Place:** Poly house of MAP Blocks Medicinal and Aromatic Plants Block	**Place:** Experimental Field, Medicinal and Aromatic Plants Block

Observations Recorded

Survival percentage

Survival percentage of rooted cuttings was calculated 90 days after planting by using following formulae:

Survival percentage of cuttings = T-Mp/T x 100

T = Total number of rooted cuttings
Mp = Mortal plants (dried)

Root length per cutting (cm)

The root length of cuttings was recorded from randomly selected three rooted cuttings after 30, 60 and 90 days after planting of cutting and then average was calculated.

Shoot length per cutting (cm)

The length of shoot of three randomly selected cuttings was measured from the base of shoot to the shoot tip at 30, 60 and 90 days after planting.

Number of leaves per cutting

The number of leaves of three randomly selected cuttings was counted at 30, 60 and 90days after planting of cutting.

Fresh weight of roots per cutting (g)

The fresh weight of randomly selected three rooted cuttings was recorded for each treatment and mean fresh weight was recorded at 30, 60 and 90 days after planting.

Dry weight of roots per cutting (g)

Roots were dried in the oven at $35\pm^{0}$ C for 72 hours (till the constant weight obtained) and then dry weight of roots was recorded at 30, 60 and 90 days after planting.

Statistical analysis

The observations of different variable data were carried out by using the techniques of analysis of variance (ANOVA) technique to find out the degree of variation within all the treatments at 20 percent level of variability and the critical difference (CD) was calculated by using the software STPR 3.

Results and Discussion

Survival Percentage

Under poly house condition, the survival percentage was found to be highest in T_1 (Kempty) 93.3% whereas the lowest was in T_4 (Dandachali) and T_6 (Bataghat) 60% after 90 days of planting (Table 1 & Figure 1). In Field condition, the survival percentage was recorded lower than protected condition after 90 DAP (Figures 1). Survival percentage was registered highest 80 % in T_1 (Kempty), T_2 (Nagthat) and T_9 (Buranshkanda) whereas the lowest (53.30 %) was noted in T_4 (Dandachali). The differences in survival percentages in both the conditions may be due to genetic composition as well as soil and climatic adaptations or genetic heritability as reported by Salathia (2005) and Thakur (2017).

Number of Leaves

Poly house conditions: The number of leaves per plant was recorded at 30, 60 and 90 DAP. Number of leaves per plant showed significant variation with different treatment (Table 1). The number of leaves was found to be highest (6.6) in T_2 (Kwawa) and T_7 (Chakrata) at 30 DAP which was significantly superior to all other treatments except T_3 and T_4 whereas the lowest (4.6) was in T_6 and T_{10} which was at par with T_1, T_4, T_5, T_8 and T_9.At 60 DAP the number of leaves was found to be highest in T_3, which was found to be

significantly superior to all other treatments except T_8 and T_9. The least number of leaves was recorded in T_5 (7.6) which was at par with T_1, T_4, T_6 and T_{10}.At 90 DAP the highest number of leaves was found to be in Kempty, T_1 (26.3) which was significantly superior to all other treatments except T_9, T_{10} and lowest in T_6 which was at par with T_4 and T_8 (13.6).

Field conditions: Number of leaves per plant showed significant variation with different treatment (Figure 2). At 30 DAP Zero point, T_5 (6.3) showed the highest number of leaves, whereas the least number of leaves was recorded in Kwawa,T_2 (2.3).At 60 DAP the most number of leaves (18.3) was recorded in Kwawa (T_2) and Nagthat (T_3) and the lowest number of leaves (5.6) was recorded in Bataghat (T_6) and Chakrata (T_8). At 90 DAP, Nagthat (T_3) (27.6) showed the most number of leaves (27.6) which was significantly superior to all other treatments, whereas the least number of leaves (7) were recorded in Mathayau (T_8) which was statistically at par with Bataghat (T_6) and Chakrata (T_7).

Average number of leaves after 90 days of planting was almost similar in both growing conditions. The average increase in number of leaves from 30 DAP to 60 DAP was 148.05%, this rapid increase in number of leaves may be primarily attributed to better utilization of stored carbohydrates, nitrogen (Chandramouli, 2001) and end of hardening period. The average increase in number of leaves among the various populations from 60 DAP to 90 DAP was 48.04% this may be due to the increase in ambient temperatures to congenial range (23°C to 27°C) and bright sunshine hours of around 10 hours which promoted vegetative growth between 60 to 90 DAP. The increase in number of leaves in polyhouse condition may be due to genetic heritability or environmental factors (Jugran 2013 and Thakur 2017).Similar studies were carried out by Purohit *et al.,* (2008) in *Picrorhiza kurrooa* and Saara Bäck (1993) in *Fucus vesiculosus*.

Shoot length

Poly House: The shoot length was measured at 30, 60 and 90 DAP (Table 2). At 30 DAP the shoot length was found to be highest (8.4) in Chakrata (T_7) which was significantly higher than T_5, T_8 and T_9 whereas T_2, T_3, T_4, T_6 and T_{10} were statistically at par with T_7. Kempty (T_1) noted the lowest (5.7 cm) which was at par with T_3, T_5, T_8 and T_9. At 60 DAP the highest shoot length (21.7 cm) was recorded in T_1 (Kempty) which was significantly superior to all other treatments, with the lowest shoot length (9.7cm) was recorded in T_6 (Bataghat) which was at par with T_3 and T_{10}. At 90 DAP, kempty (T_1) remained the highest (47.80cm) and was significantly superior to all other treatments except T_{19} which was statistically at par T_1. The lowest shoot length (14.6 cm) was recorded in T_6 (Bataghat) which was statistically at par with T_3, T_4 and T_5.

Field Conditions: At 30 DAP shoot length was observed to be highest (6.6 cm) in Kempty (T_1) which was statically similar with T_2 and T_5 whereas Bataghat (T_6) showed the lowest shoot length (4.1cm)) which was statistically similar with T_3, T_4, T_7, and T8 (Figure 3). At 60 DAP T_2 (Kwava) showed the highest shoot length (21.7cmm) and the lowest shoot length was recorded in T_2 (6.2cm) which was statistically at par with T_8. At 90 DAP highest shoot length (51.6 cm) was recorded in T_5 (Zero point) which was statistically superior to all other treatments. The lowest shoot length(7.8 cm was observed in T_7 (Chakrata) which was statistically at par with T_1, T_6 and T_8.

The shoot length observed significant variations among the populations in both growing conditions and after 90 days of

planting filed conditions grown plants showed better seedlings growth. The average increase in shoot length between 30 DAP to 60 DAP was 178.96%, this rapid increase in number of leaves may be primarily attributed to better utilization of stored carbohydrates, nitrogen (Chandramouli, 2001) and end of hardening period. The average increase in shoot length between 60 DAP to 90 DAP was 85.21% this may be due to the increase in ambient temperatures to congenial range (23°C to 27°C) and bright sunshine hours of around 10 hours which promoted vegetative growth between 60 to 90 DAP. The shoot length variations maybe due to genetic differences (Jugran 2013) or because shoot length is a highly plastic character and varies among different populations in different environmental conditions (Thakur, 2017). Similar studies were carried out by *Said et al., (2011)* in *Pistacia atlantica and* Zaharieva *et al.,* (2003) *in Aegilops* L. species from Bulgaria.

Root length

Poly House: The root length was measured at 30, 60 and 90 DAP (Table 2). At 30 DAP root length was recorded the highest (5.2 cm) in Chakrata (T_7) which was significantly superior to all other treatments. The lowest root length (1.7 cm) was recorded in T_9 (Buranshkanda). At 60 DAP root length remained highest (15cm) in Chakrata (T_7) and was significantly superior to all other treatments except T_3 and T_7 which were at par T_7, whereas the lowest root length (5.4cm) was in T_9 (Buranshkanda). At 90 DAP, Chakrata (T_7) remained the highest root length (20.7 cm) and was significantly superior to all treatments except T_2 which was at par with T_7. The lowest root length (9.9cm) was recorded in T_9 (Buranshkanda).

Field conditions: At 30 DAP highest root length (3.9 cm) was recorded in T_8 (Mathyau) which was significantly superior to all other treatments, whereas the lowest root length (1.0cm) was recorded in T_6 (Bataghat) which was at par with T_7 (Figure 4). At 60 DAP highest root length (13.1cm) was recorded in T_9 (Buranshkanda) which was significantly superior to all other treatments, whereas the lowest root length (5.9cm) was observed in T_6 (Bataghat). At 90 DAP the highest root length (18.6cm) was recorded in T_9 (Buranshkanda) which was significantly superior to all other treatments. The lowest root length (7.9cm) was observed in T_6 (Bataghat) which was statistically at par with T_2 and T_5.

The average increase in root length among the populations from 30 DAP to 60 DAP was about 300 %, this rapid increase in number of leaves may be primarily attributed to better utilization of stored carbohydrates, nitrogen (Chandramouli, 2001) and end of hardening period as well as increase in temperature (12°C to 17°C). The average increase in root length among the various populations between 60 DAP and 90 DAP was 34.69%, this may be due to the increase in ambient temperatures to congenial range (23°C to 27°C) and bright sunshine hours of around 10 hours which promoted vegetative growth between 60 to 90 DAP. The differences in root length may be due to phenotypic plasticity or a product of heredity (Thakur 2017). Similar studies were carried out by Longton (1981) in *Bryumar genteum* and Saara Bäck (1993) in *Fucus vesiculosus*.

Fresh weight of shoots and roots

Poly house: The fresh weight of shoots and roots varied significantly among the treatments (Table 3). The fresh weight of shoots was found to be highest (16.47gm) in T_8 (Mathyau) which was significantly higher than all other treatments except T_1, T_6 and T_7 which were statistically at par with T_8. The lowest fresh weight (8.00gm) was recorded in T_3 (Nagthat).

In the case of roots, fresh weight was found the highest (7.52gm) in T_2 (Kwawa) which was significantly higher than all other treatments, whereas the lowest fresh weight (1.31 gm) was recorded in T_5 (Zero point).

Field conditions:- The fresh weight of shoots and roots varied significantly among the treatments (Figure 5). Fresh weight of shoots was found to be highest (6.2gm) in T_3 (Nagthat) which was statistically similar with T_9 and T_{10}. The lowest shoot fresh weight (1.1gm) was recorded in Kempty ($T_{1)}$ and T_6 (Bataghat).

Fresh weight of roots was recorded to be highest (3.53gm) in T_9 (Buranskanda) and the lowest root fresh weight (1.1 gm) was recorded in T_6 (Bataghat) (Figure 6).

Table.1 Details of natural populations of *Valeriana jatamansi* Jones

Accessions	Name	Altitude (metres)	Position		Aspect
			Latitude	Longitude	
T_1	Kempty	1391	30°28'57" N	78°02'34" E	0 N
T_2	Kwawa	1849	30°38'42" N	77°54'26" E	0 N
T_3	Nagthat	1884	30°34'29" N	77°57'38" E	35 NE
T_4	Dandachali	1927	30°18'4.95" N	78°24'44" E	36 NE
T_5	Zero-Point	1930	30°28'09" N	78°03'31" E	18 N
T_6	Bataghat	2093	30°27'13" N	78°06'53" E	353 N
T_7	Chakrata	2129	30°40'49" N	77°52'54" E	60 NE
T_8	Mathyau	2132	30°35'10" N	77°56'11" E	18 N
T_9	Buranshkanda	2318	30°26'30" N	78°12'35" E	330NW
T_{10}	Jwarna	2387	30°24'54" N	78°17'49" E	34 NE

Table.2 Effect of different accessions of V*aleriana jatamansi* rhizomes cuttings on survival percentage and number of leaves under poly house conditions

Accessions	Survival (%) 90 DAP	No. of Leaves/plant		
		30 DAP	60 DAP	90 DAP
T_1 (Kempty)	93.3	4.6	8.6	26.3
T_2 (Kwawa)	66.6	6.6	12.6	16.3
T_3(Nagthat)	73.3	6.3	15.6	19.6
T_4(Dandachali)	60.0	5.3	9.3	14.3
T_5(Zero-Point)	66.6	5.0	7.6	19.3
T_6(Bataghat)	60.0	4.3	8.0	13.6
T_7(Chakrata)	80.0	6.6	11.3	23.6
T_8(Mathyau)	73.3	4.6	13.3	14.3
T_9 (Buranshkanda)	86.6	5.0	13.6	24.6
T_{10}(Jwarna)	80.0	4.3	8.6	25.3
SEm ±		0.511	0.867	0.948
CD (P=0.05)		1.519	2.576	2.818
CV		16.719	13.778	8.312

Table.3 Effect of different accessions of V*aleriana jatamansi* rhizomes cuttings on shoot and root length under poly house conditions

Accessions	Shoot Length (cm)			Root Length (cm)		
	30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
T_1 (Kempty)	5.7	21.7	47.8	2.4	9.6	13.7
T_2 (Kwawa)	8.2	12.8	18.9	2.7	12.3	19.5
T_3(Nagthat)	7.4	10.5	15.7	3.6	12.2	16.1
T_4(Dandachali)	7.7	12.0	14.7	2.6	11.4	15.3
T_5(Zero-Point)	6.4	12.4	17.1	3.4	13.2	17.9
T_6(Bataghat)	8.2	9.7	14.6	2.7	11.2	18.3
T_7 (Chakrata)	8.4	13.3	28.1	5.2	15.0	20.7
T_8 (Mathyau)	6.5	12.8	18.6	4.2	14.0	16.8
T_9 (Buranshkanda)	6.5	17.9	45.7	1.7	5.4	9.9
T_{10}(Jwarna)	8.0	10.6	28.2	2.4	9.5	12.3
SEm ±	0.392	0.581	0.941	0.214	0.661	0.725
CD (P=0.05)	1.166	1.728	2.797	0.637	1.963	2.156
CV	9.253	7.603	6.533	11.942	10.016	7.813

Table.4 Effect of different accessions of V*aleriana jatamansi* rhizomes cuttings on the fresh and dry weight under poly house condition

Accessions	Shoot		Root	
	Fresh Weight (gm)	Dry Weight (gm)	Fresh Weight (gm)	Dry Weight (gm)
T_1 (Kempty)	14.99	1.58	4.75	0.81
T_2(Kwawa)	12.38	1.40	7.52	1.05
T_3(Nagthat)	8.00	1.09	2.37	0.53
T_4(Dandachali)	11.20	1.27	4.50	0.83
T_5(Zero-Point)	12.28	1.31	1.31	0.43
T_6(Bataghat)	15.31	1.61	4.23	0.75
T_7(Chakrata)	14.7	1.54	2.59	0.55
T_8(Mathyau)	16.47	1.66	5.85	0.91
T_9 (Buranshkanda)	12.56	1.33	2.57	0.55
T_{10}(Jwarna)	12.47	1.32	4.22	0.67
SEm ±	0.751	0.718	0.328	0.377
CD (P=0.05)	2.232	0.213	0.975	0.112
CV	9.984	8.793	15.910	9.179

Table.5 Effect of different growing conditions on the performances of *Valerina jatamansi*

Sl. No.	Attributes	Poly house			Field		
		30 DAP	60 DAP	90 DAP	30 DAP	60 DAP	90 DAP
1	Survival percentage (%)	-	-	73.97	-	-	68.64
2	Number of leaves	5.26	10.85	17.36	4.12	10.22	15.13
3	Shoot length (cm)	7.30	13.37	24.94	5.08	14.07	26.06
4	Root length (cm)	3.09	11.38	16.05	2.26	9.31	12.54
5	Shoot fresh weight (gm)	-	-	13.03	-	-	3.510
6	Root fresh weight (gm)	-	-	3.991	-	-	2.257
7	Shoot dry weight (gm)	-	-	1.411	-	-	0.522
8	Root dry weight (gm)	-	-	0.708	-	-	0.534

Table.6 Percent increase in vegetative growth in protected conditions over field conditions in V*aleriana jatamansi* rhizome cuttings

Sl No.	Character	Poly house	Field	Percentage increase over field (%)
1	Survival percentage	73.97	68.64	7.70
2	Number of leaves			
	30 DAP	5.26	4.12	27.6
	60 DAP	10.85	10.22	6.10
	90 DAP	17.36	15.13	14.70
3	Shoot length (cm)			
	30 DAP	7.30	5.08	43.70
	60 DAP	13.37	14.07	-4.90
	90 DAP	24.94	26.06	-4.20
4	Root length (cm)			
	30 DAP	3.09	2.26	36.70
	60 DAP	11.38	9.31	22.20
	90 DAP	16.05	12.54	27.90
5	Shoot fresh weight (gm)	13.03	3.510	271.10
6	Root fresh weight (gm)	3.991	2.257	76.80
7	Shoot dry weight (gm)	1.411	0.522	170.30
8	Root dry weight (gm)	0.708	0.534	32.50

Fig.1 Meteorological data during the experiment (February 18-May18)

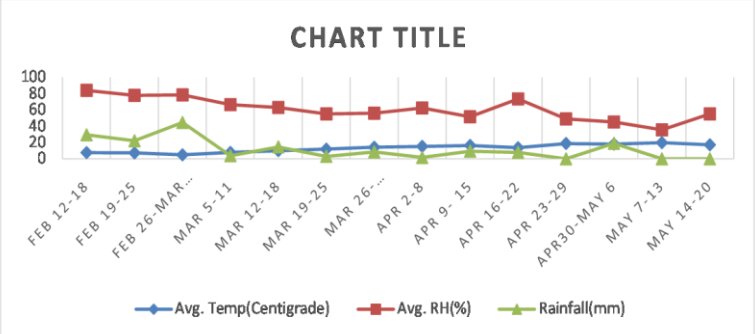


Fig.2 Survival percentage of *Valeriana jatamansi* accessions in poly house and field conditions

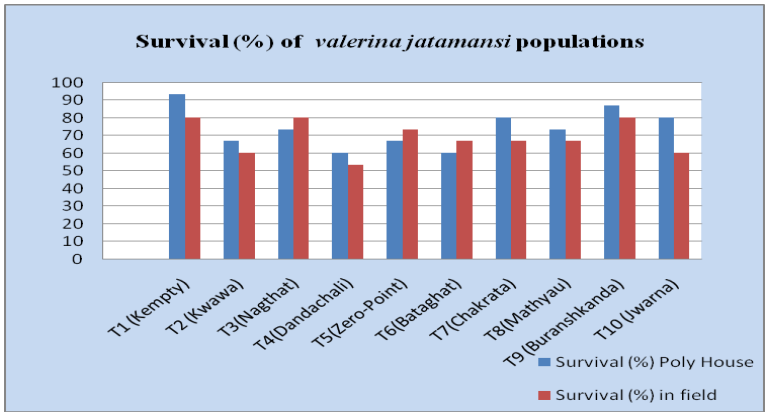
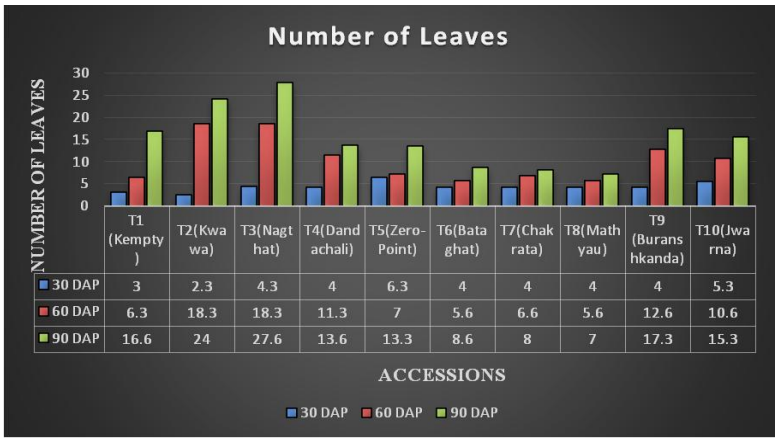
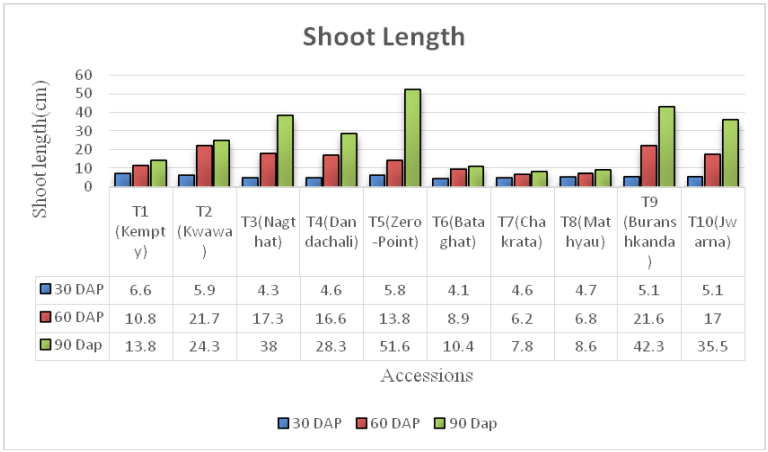


Fig.3 Effect of different accessions of *Valeriana jatamansi* rhizome cuttings on leaves number under field conditions



	T1 (Kempty)	T2(Kwawa)	T3(Nagthat)	T4(Dandachali)	T5(Zero-Point)	T6(Bataghat)	T7(Chakrata)	T8(Mathyau)	T9 (Burans hkanda)	T10(Jwarna)
30 DAP	3	2.3	4.3	4	6.3	4	4	4	4	5.3
60 DAP	6.3	18.3	18.3	11.3	7	5.6	6.6	5.6	12.6	10.6
90 DAP	16.6	24	27.6	13.6	13.3	8.6	8	7	17.3	15.3

Fig.4 Effect of different accessions of *Valeriana jatamansi* rhizome cuttings on shoot length (cm) under field conditions



	T1 (Kempty)	T2 (Kwawa)	T3(Nagthat)	T4(Dandachali)	T5(Zero-Point)	T6(Bataghat)	T7(Chakrata)	T8(Mathyau)	T9 (Burans hkanda)	T10(Jwarna)
30 DAP	6.6	5.9	4.3	4.6	5.8	4.1	4.6	4.7	5.1	5.1
60 DAP	10.8	21.7	17.3	16.6	13.8	8.9	6.2	6.8	21.6	17
90 Dap	13.8	24.3	38	28.3	51.6	10.4	7.8	8.6	42.3	35.5

Fig.5 Effect of different accessions of *Valeriana jatamansi* rhizome cuttings on root length (cm) under field conditions

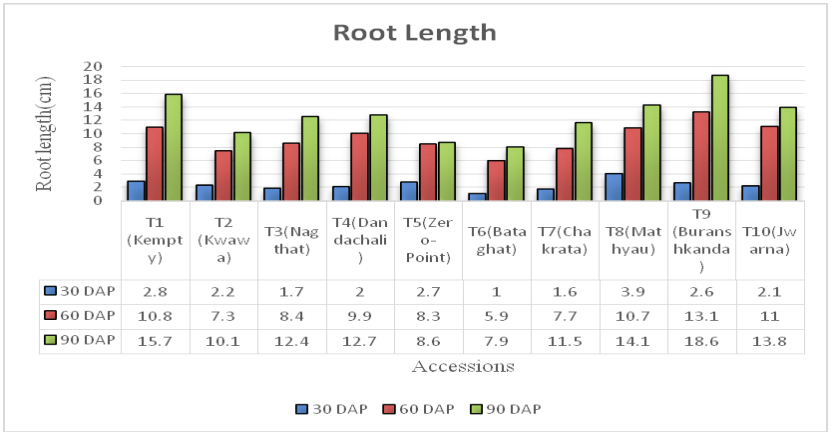


Fig.6 Effect of different accessions of *Valeriana jatamansi* rhizome cuttings on Fresh and dry weight of shoots (gm) under field conditions

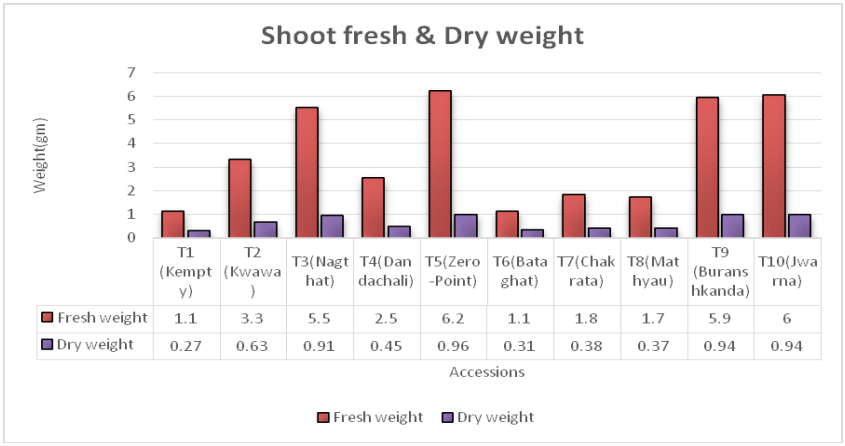
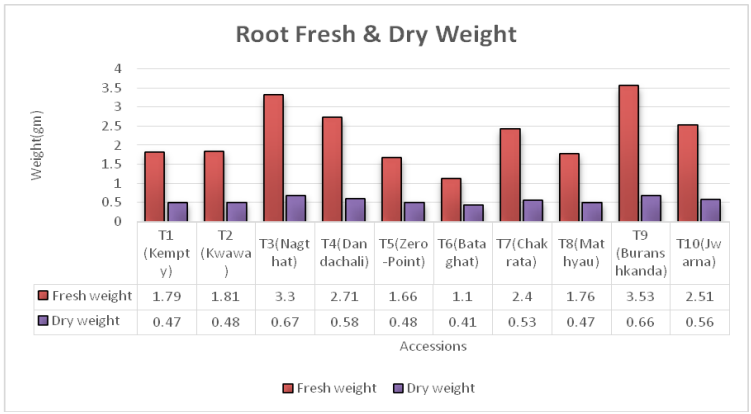


Fig.7 Effect of different accessions of *Valeriana jatamansi* rhizome cuttings on Fresh and dry weight of roots (gm) under field conditions



Dry Weight of Shoots and Roots

Poly house: The dry weight of shoots varied significantly among the treatments (Table 3). The dry weight of shoots was recorded the highest (1.66gm) in T_8 (Mathyau) which was significantly higher than all other treatments except T_1, T_6 and T_7 which were at par with T_8. The lowest (1.09 gm) shoot dry weight was recorded in T_3 (Nagthat) which was at statistically at par with T_4. In the case of root dry weight T_2 (Kwawa) showed the highest value (1.05gm) which was also significantly superior to all other treatments, whereas the lowest value (0.43gm) was recorded in Zero Point (T_5) which was statistically at par with Nagthat (T_3).

Field Condition: The dry weight of shoots and roots varied significantly (Figure 5 & 6). Dry weight of shoots was found to be highest (0.96gm) in Zero point (T_5) which were statistically at par with T_3, T_9 and T_{10}. The lowest shoot dry weight (0.27gm) was recorded in Kempty (T_1) which was statistically at par with T_7, T_8 and T_9 (Figure 5). The highest root dry weight (0.67gm) was recorded to be in Nagthat (T_3). The lowest dry weight (0.41gm) was recorded in Bataghat, T_6 (Figure 6).

The fresh and dry weights of roots and shoots recorded differed significantly among the different populations. Under poly house conditions, the highest fresh weight and dry weight of shoots was found in Mathyau, T_8 (16.47 and 1.66 gm, respectively) whereas in the case of roots fresh and dry weight were registered maximum in Kwawa,T_2(7.52gm and 1.05 gm respectively). The lowest fresh and dry weight of shoots was found in Nagthat, T_3 (8.00 gm and 1.09 gm, respectively) and in roots fresh and dry weight was in Zero point, T_5.(1.31gm and 0.43gm, respectively). From this study it may be concluded that Manthyau and Nagthat populations having the highest and lowest fresh weight of shoots and maintain same rhythm in dry weight proportion. Whereas in roots fresh and dry weight was found maximum and minimum in Kwawa and Zero point populations, respectively. However this trend was not uniform in case of populations raised under field conditions. Similar study was done by Thakur (2017) on *Valeriana jatamansi* in Himachal Pradesh and reported that the Fresh aerial biomass per plant among different morpho- variants ranged between 5.56g to 74.65g during V1 generation and Dry aerial biomass per plant among different morpho-variants ranged between 0.96g to 11.81g during V1 generation. Rootstock fresh biomass per plant among different morpho-variants ranged between 3.91g to 34.99g during V1 generation and Rootstock dry biomass per plant among different morpho-variants ranged between 1.02g to 12.01g during V1 generation.

Comparison of performance in Poly house and field study

A comparison of the various parameters of poly house and field study was done and the data is presented in Table 4. In the case of survival percentage, the overall survival percentage of plants in the poly house was higher (73.97%) as compared to the field (68.64%) after 90 DAP. The number of leaves per plant was also higher in the poly house as compared to the field at 30, 60, and 90 DAP. Shoot length was higher in the poly house at 30 DAP but it was higher in the field at 60 and 90 DAP. Root length was higher in the poly house as compared to the field at 30, 60 and 90 DAP. Shoot fresh weight was much higher in the poly house as compared to the field, root fresh weight was also higher in the poly house, similar case was observed in the shoot and root dry weight with the shoot dry weight being much higher in the poly house and the root dry weight also being higher in the poly house.

Percent increase in vegetative growth in poly house over field study

The percent increase in poly house for various morphological and yield characteristics are embodied in Table 5. It shows that survival percentage was 7.7 % higher in polyhouse as compared to the field. Number of leaves was also higher by 27.6, 6.1, 14.7 percent at 30, 60 and 90 DAP respectively. The shoot length was higher by 43.7 % at 30 DAP but was lower by -4.9 and -4.2 % at 60 and 90 DAP respectively as compared to field. Root length was 36.7, 22.2 and 27.9 percent higher than polyhouse at 30, 60 and 90 DAP respectively. The shoot fresh weight was 271.1 % higher in the polyhouse as compared to the field whereas the root fresh weight was 76.8% higher in the polyhouse as compared to the field. The shoot dry weight was 170.3% higher in the polyhose as compared to the field whereas the root dry weight was 32.5% higher in the polyhouse as compared to the field. The result shows that in all the parameters except shoot length at 60 and 90 DAP the performance was better in the polyhouse as compared to the field.

Comparison between polyhouse and field

The polyhouse growth in number of leaves and root length were higher by 27.6, 6.1, 14.7, 36.7, 22.2, 27.9 percent at 30, 60 and 90 DAP respectively as compared to the field this may be due to better ambient temperatures in the polyhouse. The shoot length was higher by 43.7% at 30 DAP but was lower by -4.9 and -4.2% at 60 and 90 DAP respectively in the polyhouse as compared to the field which may be due to the emergence of runner shoots in the field. The shoot and root fresh weight were higher by 271.1 and 76.8 percent in the polyhouse respectively. The shoot dry weight and root dry weight was higher in the polyhouse by 170.3 and 32.5 percent respectively. This may be due to the more controlled conditions in the polyhouse which may have resulted in protection of polyhouse plants from extremes in temperature and other climatic factors therefore resulting in better growth and nutrient uptake and prevent shock to the plants. Gualberto *et al.*, (1998) and Kanwar (2011) also conducted similar studies and found that yield and vegetative growth was higher in polyhouse as compared to the field.

In conclusion the populations grown under poly house conditions showed better yield as compared to populations of *Valeriana jatamansi* grown under the field condition and also have better survival percentage Mathyau population located at 2123 m under poly house condition, showed better growth performance of shoot weight both fresh (16.47gm) and dry (1.66gm) root fresh (7.52gm) and dry weight (1.05gm) was obtained in Kwawa population which is located at an elevation of 1849 m. Whereas in field conditions, better root fresh growth (3.53g) and dry weight (1.10 gm) was observed in Buranshkanda population. Further studies in terms of genetic mapping, seed and essential oil yield and composition can help to identify promising morphotypes and lines among these populations for commercial farming purposes, it may also be concluded that naturally ventilated poly houses are a good and less expensive option for *Valeriana jatamansi* cultivation in the trans-Himalayan region to obtain higher yield and a viable means to grow Indian valerian through rhizome cuttings.

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