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Ex-Situ Cultivation of Medicinal Plant Species in High Altitudes at Swat, Pakistan

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Abstract: An *ex-situ* experiment was conducted to evaluate the growth performance of six medicinal species (*Bergenia ciliata*, *Valeriana jatamansi*, *Dioscorea deltoidea*, *Paeonia emodi*, *Polygonum amplexicaule* and *Viola serpense*) from upper Swat, Pakistan. Experiments were conducted at four different locations in the upper Swat valley at altitudes ranging from 1200 to 1900 m.a.s.l. The objectives were: 1) to determine the suitability of *ex-situ* cultivation of different medicinal species, and; 2) to assess the economic geasibility of growing medicinal plants in the area. A highest mean survival of 80.7% across all locations was observed for *Viola serpense*, followed by 58.7% for *Valeriana jatamansi*. The remaining four species exhibited very poor survival rates, although *Polygonum amplexicaule*, did show encouraging signs of growth and flowered, before experiencing high mortality rates late in the trial. Altitude generally seemed to enhance the degree of sprouting for all species except *Viola serpense*. However, the productive yield of *V. serpense* was certainly not reduced, but rather slightly enhanced in the higher altitude sites. Overall, cultivation of only two of the investigated species, *Valeriana jatamansi* and *Viola serpense*, appeared successful and potentially economically viable under farmland conditions at upper Swat.

Key words: Medicinal plant; *Ex-situ* cultivation; High altitudes

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Introduction

Man has long been using various plants to cure diseases and to provide relief from health problems. Primitive peoples from all ages and in all locations had knowledge of medicinal plants, which they acquired through long experience of trial and error. The knowledge is still alive, for many plants are still used in herbal remedies and in indigenous medicine systems all over the world (Khan, 1985). A medicinal plant is any plant that contains chemical substances in one or more of its parts (roots, leaves, stems, flowers, fruits or seeds), which can be used for therapeutic purposes or serve as starting material for chemical pharmaceutical synthesis (Khan, 1991), therefore the economic values of such plants are obvious.

Lange (1998) reported that some medicinal and aromatic plants like *Lavendula* spp., *Carum carvi*, *Foeniculum vulgare*, *Thymus vulgare* and *Althaea rosea* are cultivated over an estimated area of 70 000 hm^2 in the European Union, playing a significant role in its economy. Similarly, in the Peruvian Amazon, medicinal plants are an important industry, with about 100 species currently in

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cultivation, which are processed into powders, ointments and other plant extracts (Lange, 1998). One of the largest markets for medicinal plants is Asia; Singh *et al*. (1997) reported that, at present, more than 250 species of medicinal plants are commercially cultivated on about 380 000 hm^2 in China. Given the increasing market and the threat of over-collection, these authors suggested that cultivation of medicinal plant species is the only solution for their rapid conservation.

Several workers have noted the need to conserve many threatened species of medicinal plants in sub-continental Asia. Hussain and Sher (1998) observed that substantial extraction of medicinal plants has resulted in the depletion of existing populations of many valuable species. At present most of these valuable species can only be found growing in small scattered populations in the remote areas. Khan (1989) reported that medicinal species such as *Dioscorea deltoidea*, *Saussurea lappa* and *Colchicum luteum* are rapidly becoming endangered. As a response to the looming threat of over-collection and extinction, several workers have investigated the possibility of cultivating useful plants. Zaidi (1998) studied the *ex-situ* cultivation of 14 condiments and spices in various parts of Punjab and in plains of North-West Frontier Province (NWFP). He also worked on the cultivation of *Althaea rosea* in Peshawar valley. Along similar lines, Goel *et al*. (1997) studied the *ex-situ* conservation of *Encephalortus* species in the botanical garden at Lakhnawo, India. They evaluated their economic value, horticultural importance, propagation, cultivation, ecology and conservation needs.

The fate of many medicinal plant species is typified by the findings of Joshi and Rawat (1999) who reported that medicinal and aromatic plants of alpine and sub-alpine areas of the North-West Himalayas have been rapidly depleted and are endangered due to deforestation, over-grazing, habitat loss and over-exploitation. They recommended an urgent need for conservation of threatened medicinal plant species in various parts of Swat and suggested *in-situ* and *ex-situ* cultivation of these plants as a conservation strategy for such species.

Traditionally forests and rangelands are the main sources of medicinal plants in Pakistan. In this study we examined six species; *Bergenia ciliata*, *Valeriana jatamansi*, *Dioscorea deltoidea*, *Paeonia emodi*, *Polygonum amplexicaule* and *Viola serpense*. These plants all occur naturally in the Swat district and are used as a basis for modern pharmaceuticals and, therefore, are commonly exploited commercially. Since these plants usually occur in wild form and have been collected from the forest for decades (Khan, 1989), their cultivation has been neglected in the past; hence no nurseries or protected areas for these plants exist in Swat.

Only very limited information is presently available regarding the cultivation of medicinal plant species in the Swat district. The present study was, therefore, initiated with the objectives; 1) to evaluate the cultivation prospects of the aforementioned important medicinal plant species and 2) to assess the economic feasibility of commercially cultivating such medicinal plant species under typical farming conditions.

Materials and Methods

Site and plant selection

The *ex-situ* cultivation of the six medicinal plant species was undertaken in four different locations on farmers' fields in high altitudes of the Swat valley during 2000–2001. These locations included the villages of Gurrha, Chinkoli, Shingrai and Malam at altitudes of 1200, 1400, 1600 and 1900 meters above sea level (m.a.s.l), respectively. The criteria for selection of species were; 1) they have high commercial value and have been over-exploited in the area, 2) they are becoming rare due to indiscriminate destruction of their natural habitat because of urbanization, and 3) the local people were interested in their cultivation. The criteria for selection of sites were; 1) local people in these locations were interested in cultivation of medicinal plants, 2) a nearby *in-situ* study area existed which could be used for comparison, and 3) these locations had good forest plantation management and had altitudes variation ranging from 1200 to 1900 m.a.s.l.

Plant cultivation

In September, 2000, rhizomes of *Paeonia emodi*, *Bergenia ciliata*, *Polygonum amplexicaule*, *Valeriana jatamansi* and *Dioscorea deltoidea* were collected from the Shinko alpine pasture of Madyan area, and *Viola serpense* rhizomes were collected from their natural habitat at Malam village. The rhizomes were cut into small pieces (4 to 6 cm in size), each with 2 to 3 active buds. Rhizomes were planted in experimental plots the day after they had been collected.

The experiment was conducted as randomized complete block design (RCBD) using each location as replication. The plot size for each species consisted of 3 × 3 meters at each location. Planting was done during mid-September, 2000 on a well-prepared soil using farm yard manure to improve soil fertility. For *Valeriana jatamansi* and *Viola serpense*, a plant to plant distance of 4 cm and a row to row distance of 8 cm was used. The remaining four species were planted with distance of 30 cm between rows and 15 cm between plants.

The soil of each location was analyzed in the Soil Testing Laboratory of the Agricultural Research Station, North Mingora, Swat (Table 1). The soils at Malam, Gurrha and Chinkoli were silt loams while that at Shingrai was sandy loam. Soil pH ranged from 7.0 to 7.5, while the $CaCO_3$ content of soil in four locations varied from 0.27% for Gurrha to 0.86% for Shingrai. Soil organic matter varied from 2.31% (Shingrai) to 4.91% (Chinkoli) and the N contents ranged from 3.6% (Shingrai) to 6.9% (Chinkoli). The water holding capacity of the sites were similar with extreme values of 19.11% at Malam to 23.11% at Gurrha.

Table 1 Physical and chemical properties of soils of four experimental locations at Swat during 2000–2001

S. No.	Location	Altitude (m.a.s.l)	$CaCO_3$ (%)	Organic matter (%)	pH	Textural classes	Water holding capacity (%)	N (%)	P (%)	K (%)
1	Gurrha	1200	0.27	3.61	7.3	Silt loam	23.11	5.7	4.2	5.3
2	Chinkoli	1400	0.49	4.91	7.0	Silt loam	22.24	6.9	6.9	7.0
3	Shingrai	1600	0.86	2.31	7.5	Sandy loam	21.20	3.6	3.7	4.4
4	*Malam*	1900	0.36	4.62	7.4	Silt loam	19.11	6.2	7.1	7.7

Weeds were controlled by hand weeding and hoeing in each location during December, 2000 and during April and May, 2001. Data were recorded for various parameters on each plot which included number of days to achieve 50% sprouting, sprouting percentage, survival percentage, number of days from sprouting to flowering, plant height and yield of useable plant parts (rhizomes, shoots, leaves and flowers). Harvesting of *Valeriana jatamansi* and *Viola serpense* was done during the moths of April and May, 2001 while rhizomatous species i.e. *Paeonia emodi*, *Bergenia ciliata*, *Polygonum amplexicaule* and *Dioscorea deltoidea* were harvested in September and October, 2001.

Data were analyzed using analysis of variance procedures for randomized complete block design, considering locations as replications, by MSTAT-C program. Means were compared using Least Significant Difference (LSD) test at 5% probability level (Steel and Torrie, 1980).

Economic analyses of yield data were carried out to determine the net income for each medicinal plant species, using prevailing market rates for land rent, costs of production and prices of useable plant parts relevant to the species. The most widely cultivated crops, wheat and maize among cereals and tobacco among cash crops, were included for comparison.

Results

Data regarding growth, flowering and yield parameters for six medicinal species under farm land conditions in four different locations and their means across locations is presented in Tables 2 through 7. The relative responses of the species for sprouting duration and sprouting percentage was in most cases different both between and among locations (Tables 2 and 3). Most species appeared to take longer to sprout at higher altitudes, but this was not statistically significant (Table 2). However, there was a tendency to increased sprouting at higher altitudes for all species, except for *Viola serpense*, which showed a decreased proclivity to sprout with increasing altitude (Table 3).

Table 2 Days to sprouting for six medicinal species evaluated in four different locations under farmland conditions at Swat during 2000–2001. Values with the same letter superscripts are not significantly different ($P < 0.05$)

S.No.	Species	Locations				Means
		Gurrha (1200) m.a.s.l	Chinkoli (1400) m.a.s.l	Shingrai (1600) m.a.s.l	*Malam* (1900) m.a.s.l	
		Days				
1	*Bergenia ciliata*	160	160	170	165	164^{b}
2	*Valeriana jatamansi*	35	35	25	20	31^{c}
3	*Dioscorea deltoidea*	170	170	150	190	170^{ab}
4	*Paeonia emodi*	160	165	165	175	166^{ab}
5	*Polygonum amplexicaule*	165	175	175	175	173^{ab}
6	*Viola serpense*	170	175	175	190	178^{a}
	L.S.D (0.05%)					11.58

Table 3 Sprouting percentage of six medicinal species evaluated in four different locations under farmland conditions at Swat during 2000–2001. Values with the same letter superscripts are not significantly different ($P < 0.05$)

S.No.	Species	Locations				Means
		Gurrha (1200) m.a.s.l	Chinkoli (1400) m.a.s.l	Shingrai (1600) m.a.s.l	*Malam* (1900) m.a.s.l	
		%				
1	*Bergenia ciliata*	4	5	5	20	8.5^{c}
2	*Valeriana jatamansi*	20	70	90	40	55.0^{b}
3	*Dioscorea deltoidea*	0	3	7	5	3.7^{c}
4	*Paeonia emodi*	5	5	5	10	6.2^{c}
5	*Polygonum amplexicaule*	70	80	80	90	80.0^{a}
6	*Viola serpense*	90	75	75	60	75.0^{ab}
	L.S.D (0.05%)					22.38

Valeriana jatamansi took the minimum number of days to achieve 50% sprouting (mean of 31 days)-this was significantly less than the other species in the test (Table 2).

The greatest degree of sprouting (80%) was observed for *Polygonum amplexicaule*, followed by *Viola serpense* with 75% sprouting-these were significantly higher than all other species. *Dioscorea deltoidea*, *Paeonia emodi* and *Bergenia ciliata* showed very poor sprouting with 3.7%, 6.2% and

8.5%, respectively (Table 3).

Significant differences among species for survival after sprouting were observed (Table 4). *Viola serpense* exhibited the highest survival (mean value of 80.7%) followed by *Valeriana jatamansi* (mean value of 58.7%)-significantly greater than all other species. Survival rates were assessed 10 months after planting, by which time clear trends were apparent, however, it is worth noting that after showing quite good initial growth, many *Polygonum amplexicaule* plants started to wilt and died 10 to 11 month after planting. Survival percentages of *Dioscorea deltoidea*, *Bergenia ciliata* and *Paeonia emodi* were very poor under farmland conditions with mean values of 0.2%, 1.7% and 3.7%, respectively, across locations.

Table 4 Survival percentage of six medicinal species evaluated in four different locations under farmland conditions at Swat during 2000-2001. Values with the same letter superscripts are not significantly different ($P < 0.05$)

S. No.	Species	Locations				Means
		Gurrha (1200) m.a.s.l	Chinkoli (1400) m.a.s.l	Shingrai (1600) m.a.s.l	*Malam* (1900) m.a.s.l	
		%				
1	*Bergenia ciliata*	6	0	0	0	1.75^{c}
2	*Valeriana jatamansi*	57	17	71	90	58.7^{b}
3	*Dioscorea deltoidea*	0	0	1	0	0.2^{c}
4	*Paeonia emodi*	0	0	0	15	3.7^{c}
5	*Polygonum amplexicaule*	15	10	15	20	15.0^{c}
6	*Viola serpense*	84	80	88	75	80.7^{a}
	L.S.D (0.05%)					19.19

Significant differences among species for days to flowering after sprouting (Table 5) were observed. *Valeriana jatamansi* and *Polygonum amplexicaule* took significantly longer to flower than other species. In species where survival rates allowed comparison, there was some evidence that altitude retarded flowering (e.g. for *Polygonum amplexicaule* and *Viola serpens*).

Table 5 Number of days to flowering after sprouting of 6 medicinal species evaluated in four different locations under farmland conditions at Swat during 2000-2001. Values with the same letter superscripts are not significantly different ($P < 0.05$)

S. No.	Species	Locations				Means
		Gurrha (1200) m.a.s.l	Chinkoli (1400) m.a.s.l	Shingrai (1600) m.a.s.l	*Malam* (1900) m.a.s.l	
		Number				
1	*Bergenia ciliata*	18	0	22	0	10.0^{b}
2	*Valeriana jatamansi*	35	35	35	30	33.7^{a}
3	*Dioscorea deltoidea*	0	0	0	0	0.0^{b}
4	*Paeonia emodi*	0	0	0	30	7.5^{b}
5	*Polygonum amplexicaule*	25	35	25	40	31.2^{a}
6	*Viola serpense*	10	10	10	15	11.2^{b}
	L.S.D (0.05%)					13.35

Some variation among plant heights were seen (Table 6). *Polygonum amplexicaule* had the highest mean value of 37.2 cm (though as mentioned earlier, this plant subsequently had late, high mortality rates). Generally, the greatest plant heights were observed at Shingrai across all species. However, it is difficult to ascribe any meaningful trend to this data as *Paeonia emodi* only grew successfully at Malam, where it grew to 70 cm.

Table 6 Plant height (cm) of six medicinal species evaluated in four different locations under farmland conditions at Swat during 2000-2001. Values with the same letter superscripts are not significantly different ($P < 0.05$)

S. No.	Species	Locations				Means
		Gurrha (1200) m.a.s.l	Chinkoli (1400) m.a.s.l	Shingrai (1600) m.a.s.l	*Malam* (1900) m.a.s.l	
		cm				
1	*Bergenia ciliata*	15	0	20	0	8.7^{b}
2	*Valeriana jatamansi*	13	13	19	15	15.0^{ab}
3	*Dioscorea deltoidea*	0	0	0	0	0.0^{b}
4	*Paeonia emodi*	0	0	0	70	17.5^{ab}
5	*Polygonum amplexicaule*	35	40	40	35	37.2^{a}
6	*Viola serpense*	11	15	18	14	14.5^{ab}
	L.S.D (0.05%)					23.42

Productive yield data (i.e. rhizome, flower or leaf/shoot), for the six medicinal species in the four test locations is given in Table 7. Due to poor sprouting and/or no survival, no rhizome yield for *Dioscorea deltoidea* at any of four sites was obtained. Similarly *Paeonia emodi* failed to give any rhizome yield at three of four sites. While *Bergenia ciliata* was found to have no rhizome yield at two locations. Rhizome yield of *Bergenia ciliata* showed a decrease at the higher elevation site (96 kg/hm^2 at Gurrha vs 49 kg/hm^2 at Shingrai), while *Polygonum amplexicaule* generally exhibited a rise in rhizome yield with increasing elevation. This latter species, grew quite well and developed rhizomes, yet failed to set seeds or develop fruit (and many plants subsequently died). The yield in both shoot/leaf and flowers of *Viola serpense* was certainly not reduced, but rather, generally seemed to be enhanced with increasing altitude, while no discernable trend of increased flower yield was evident for *Valeriana jatamansi*.

Table 7 Productive yield of usable plant parts in kg/hm^2 of six medicinal species evaluated in four different locations under farmland conditions at Swat during 2000-2001

S. No.	Species	Plant organ	Locations				Means
			Gurrha (1200) m.a.s.l	Chinkoli (1400) m.a.s.l	Shingrai (1600) m.a.s.l	*Malam* (1900) m.a.s.l	
1	*Bergenia ciliata*	Rhizome	96	0	49	0	72.5
2	*Valeriana jatamansi*	Flower	21	16	24	5	16.5
3	*Discorea deltoidea*	Rhizome	0	0	0	0	0.0
4	*Paeonia emodi*	Rhizome	0	0			
5	*Polygonum amplexicaule*	Rhizome	853	1066	709	1386	1003.5
6	*Viola serpense*	Flower	373	320	533	426	413.0
7	*Viola serpense*	Shoot/Leaf	1066	746	1280		

Results of economic analysis of the data indicated that only two of six medicinal species (*Valeriana jatamansi* with income of Rs. 18, 930 and *Viola serpense* with net income of Rs. 27, 810) generated higher net incomes than cereal crops, maize and wheat (Rs. 13, 440 and Rs. 15, 000, respectively). However, the estimated net annual income of these two medicinal species were lower than that of tobacco (Rs. 30, 872), due to their relatively high costs of production.

Table 8 Economic Analysis of yield data of Medicinal plants, Cereal crops and Cash crops of the experiment conducted in four different locations under farmland conditions at Swat during the year 2000-2001

S.No.	Species	Yield (kg/ha)	Sale rate (Rs/kg)	Income/ha (Rs/ha)	Cost/ha (Rs/ha)	Net income (Rs/ha)
A	**Medicinal Plants**					
1	*Bergenia ciliata*	90	30	2700	31680	-28980
2	*Valeriana jatamansi*	24	3000	72000	53070	18930
3	*Dioscorea deltoidea*	0	30	0	31680	-31680
4	*Paeonia emodi*	90	20	1800	31680	-29880
5	*Polygonum amplexicaule*	1386	20	27780	31680	-3970
6	*Viola serpense*	533*, 1280**	100#, 4.8$	59, 490	31680	27810
B	**Cereal Crops**					
1	Maize	5760	8	46080	32640	13440
2	Wheat	4800	10	48000	33000	15000
C	**Cash Crop**					
1	Tobacco	2162	30	64872	34000	30872

*: Flower Yield; **: Leaf/Shoot Yield; #: Sale Rate of Flower; $: Sale Rate of Shoot

Discussion

The major aim of this study was to examine the viability of cultivating medicinal plants under realistic field conditions, therefore, we expected some variation in results. It is extremely difficult to draw definitive autecological conclusions based on our field trails, but several trends were apparent. The variation in sprouting success and number of days from planting to sprouting of the medicinal plant species across locations indicated that a complex array of habitat factors such as altitude, temperature, soil, moisture and time of planting affect growth. Some delay in sprouting was generally observed in the highest sites, supporting the findings of Onwueme (1973) that *Dioscorea deltoidea* and *Bergenia ciliata* often sprouted late at high altitude due to snow and cool weather conditions. The present findings are also in agreement with those of Goel, *et al*. (1997) who reported that when the air and soil temperatures were low at high altitudes, *Dioscorea deltoidea*, *Colchicum luteum* and *Bergenia ciliata* sprouted in early spring. We also found that *Viola serpense* showed greatest sprouting percentage in early spring (March/April). These findings agree with those of Khan (1989) and Zaidi (1998) who reported that seed germination/sprouting of several Umbellifers and *Viola serpense* responded positively warming conditions in the early spring.

Soil chemistry and texture are also likely to be very important. Not surprisingly, Khan (1995) reported the height of the alpine medicinal plants was greatly affected by the fertility and moisture contents of the soil. Certainly, in our study most species (with the notable exception of *Paeonia emodi*, which only grew at one site) attained greatest heights in the sandier soil at Shingrai. *Valeriana jatamansi*, for example, grew tallest and sprouted most successfully at Shingrai, supporting the contention of Khan (1998) that sandy soil and dry climate is more suitable for Valerian root cultivation. Overall, however, we observed very low sprouting percentage and survival of *Dioscorea deltoidea*, *Bergenia ciliata* and *Paeonia emodi* in the farmland conditions. This starkly contrasts with Verlet and Leclereq (1997) who reported that farmland habitats are favorable for some medicinal plants like *Vale-*

riana officinale and *Rauwolfia serpentiana*. In the present study though, the farm lands were not fertile and soils were poorly developed, primarily due to mountain topography where the upper soil layers had eroded to stones and gravels. Even with some manuring these sites were not conducive for good growth of these medicinal species.

The poor survival referred to above could be due to shallow nature of the soil and/or the absence of associated species that are commonly present *in-situ*; these may help by providing shelter or perhaps creating richer, more humic soils. Joshi and Rawat (1999) observed that alpine medicinal plants such as *Colchicum luteum*, *Dioscorea deltoidea* and *Paeonia emodi* prefer to grow in the forest habitat with the humus rich soils and with high moisture content. Similarly, Khan (1989) reported that perennial medicinal plant species like *Lavetaria*, *Dioscorea*, *Saussurea* and *Podophyllum* grow best in humus rich soil with high pH values.

In the present study the medicinal plants generally flowered earlier at the lower elevation sites. Lower temperatures in higher elevations could be the plausible explanation for this delayed flowering. This phenomenon is well documented; Thakur and Bhatt (1980) reported that plants remain dormant and exhibit delayed flowering primarily due to low temperatures in higher elevations, and similarly, Singh *et al*. (1997) found that alpine medicinal plants remain dormant in early spring, delaying flowering until May and June. The same effect was observed by Zaidi (1998) who reported that low temperature treatment delays flowering in *Althaea rosea*.

Analyses of yield data revealed that *Viola serpense* and *Valeriana jatamansi* have reasonable economic potential for supplementing the farmers' income. Economically, these two species appeared comparable with cereal crops in this area, although as a cash crop, tobacco clearly remains a more attractive proposition for farmers, given its relatively high price. Although, it seems unlikely that medicinal plants can replace any of the established crops in upper Swat at the moment, it is possible that the short growing period of these medicinal plant species coupled with their potentially high market value in relation to cereal or cash crops could be an added advantage in their commercial production. For example, Zaidi (1998) reported that cultivation of *Althaea officinales* has good potential for supplementing the farmers' income. Similar results were also reported by Khan (1998) who stated that Valerian root cultivation might earn foreign exchange and supplement the cash income of farmers. Likewise, Fuller (1991) described methods of cultivation of *Colchicum autumnale* to supplement cash income of the farmers in USA.

Conclusion

Our studies show that it is possible to cultivate some of these medicinal plants *ex-situ* in marginal conditions. However, the productive yield of *Polygonum amplexicaule*, *Viola serpense* and *Valeriana jatamansi* were not very encouraging. Worse still, *Dioscorea deltoidea*, *Paeonia emodi* and *Bergenia ciliata*, more or less failed to survive. Whatever, the specific causes, the results suggest that cultivating these species in Swat is likely to be marginal at best. But we acknowledge that this is a preliminary assessment and any plant cultivation is obviously site specific, thus it is difficult to make blanket statements. Moreover, the low survival of some species made species comparisons difficult. Nevertheless, our study used the type of marginal farmlands, typical conditions and resources available to rural communities in upper Swat, therefore, it would seem that unless better incentives are offered, these medicinal plants are unlikely to provide attractive alternatives to farmers at this time. Although economically comparable to cereal crops, medicinal plants seem unlikely to be able to replace these to any great extent, given the fact that farmers are familiar with cereals and may be dependent upon them for self-consumption. Similarly, tobacco is still regarded as the best cash crop in most of these communities. With increasing scarcity and increasing prices, it is possible that *Viola serpense* and *Valeriana jatamansi* may become commercially viable in the future. For the present, however, it seems that propagation of these medicinal plants at the margins of the farmlands and their *in-situ* protection, management and conservation of their natural habitat could be more fruitful.

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