

Full Length Research Paper

Cultivation and domestication study of high value medicinal plant species (its economic potential and linkages with commercialization)

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Accepted 30 August, 2010

This paper describes the domestication and economic potential of the cultivation of some therapeutically important medicinal plants. Pakistan is home to precious wide range of globally threatened species of plant resources with a number of progenitors of economically useful crops and a multitude of medicinal plants having applications for the development of pharmaceutical industries and possesses agro-industrial potentialities. In this context a study on the *ex-situ* cultivation of medicinal plants was conducted to evaluate the growth performance of six medicinal species (*Asparagus recemosus*, *Carum carvi*, *Rauwolfia serpentina*, *Atropa accuminata*, *Valeriana jatamonsii* and *Linum ustatissimum*) from Swat, Pakistan. The studies were conducted during 2007 - 2008 at four different locations in Swat, Pakistan at altitudes ranging from 1400 to 2200 m.a.s.l. The objectives were: (1) to study the domestication and cultivation of six medicinal plants in farm lands and (2) to analyze their economic potential under farm land condition. A highest mean survival of 85.5% across all locations was observed for *Linum ustatissimum* followed by 77.6% for *C. carvi*. The remaining four species showed poor survival rates. The productive yield and economic potential of *L. ustatissimum* was certainly not reduced, but rather slightly enhanced in the higher altitude sites. The results revealed that the cultivation of *C. carvi* and *L. ustatissimum* was successful and showed high economic potential under farmland conditions.

Key words: Domestication, medicinal plants, altitude, economic potential, farm lands.

INTRODUCTION

The geographical location of Pakistan has provided an ideal environment for the growth and nourishment of different medicinal plant species. The country is gifted with diverse vegetation types occurring in the tropical, sub-tropical desert, semi-desert, temperate, sub-alpine and alpine ecosystems. Medicinal plant species is one of the most important elements of biodiversity that usually grows in all kind of ecosystems and posses high pharmaceutical, economic and ecological values.

Different parts of medicinal plants are sold in large quantities both in national and international markets, indicating its importance as a source of income for the inhabitants of Pakistan. Due indiscriminate and over harvesting of MAP species have made them rare and sparse in many parts of the country. Such un-controlled collection of medicinal plants made it a candidate species to be monitored as a part of meeting the international obligations under the Bio-diversity convention. Its sustainable harvest and management; and protection against existing threats seems to be vital. The present study was therefore, designed to promote the cultivation of medicinal plants in order to make it a sustainable source of income for the people living in the mountainous

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ecosystems of the country. Based on the fact that the parent stock of medicinal plants is available in the country which ensure a possible chances for it to be produced from within its natural habitats. The medicinal plants are economically important as they provide the basic raw material for pharmaceutical, perfumery, flavor, soaps and cosmetic industries throughout the world. Since, most of the crops are new and uncommon; the farmers often lack knowledge in their scientific cultivation. The information on the cultivation of medicinal plant is also scanty, scattered and mostly beyond the reach of farmers community. 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 ha 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 cultivation, which are processed into powders, ointments and other plant extracts (Lang, 1998).

One of the largest markets for medicinal plants is Asia; Shan and Sheng (1998) reported that, at present, more than 250 species of medicinal plants are commercially cultivated on about 380,000 ha 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. 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.

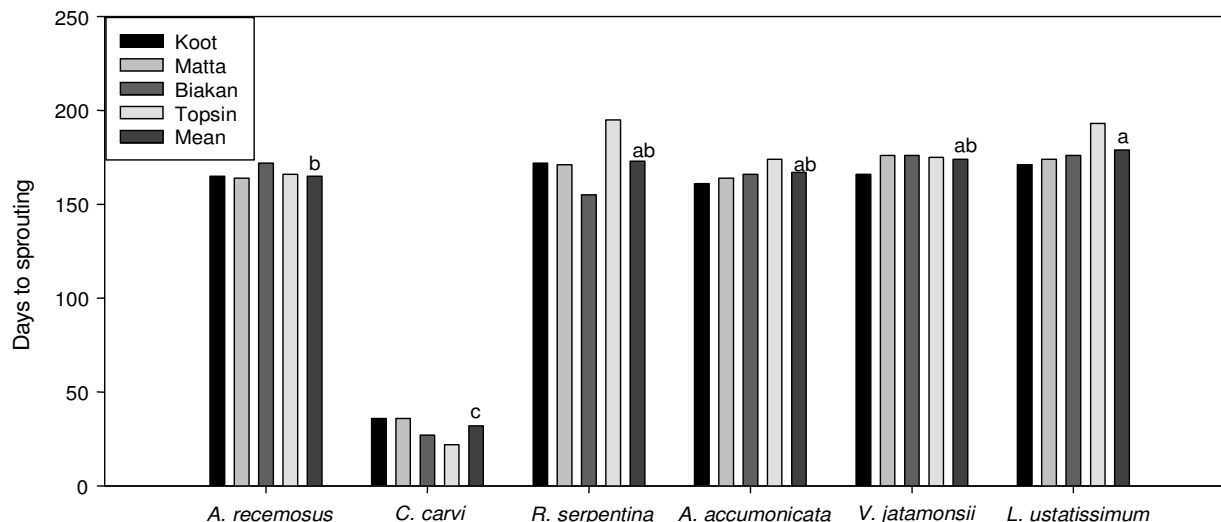
Demand for a wide variety of wild species is increasing with growth in human needs, numbers and commercial trade. With the increased realization that some wild species are being over-exploited, a number of agencies are recommending that wild species be brought into cultivation systems (Lambert et al., 1997; Schippmann et al., 2002). Cultivation can also have conservation impacts, however, and these need to be better understood. Medicinal plant production through cultivation, for example, can reduce the extent to which wild populations are harvested, but it also may lead to environmental degradation and loss of genetic diversity as well as loss of incentives to conserve wild populations (Anon, 2002b).

The relationship between *in-situ* and *ex-situ* conservation of species is an interesting topic with implications for local communities, public and private land owners and managers, entire industries and, of course, wild species. Identifying the conservation benefits and costs of the different production systems for medicinal plants should help guide policies as to whether species conservation should take place in nature or the nursery, or both (Bodeker et al., 1997; Schippmann et al., 2002). Looking into the demand for a continuous and uniform supply of medicinal plants and the accelerating depletion of forest resources, increasing the number of medicinal plants species in cultivation would appear to be an important strategy for meeting a growing demand. In this context the present endeavour on the cultivation of six medicinal plant species; *Asparagus recemosus*, *C. carvi*, *Rauvolfia serpentina*, *Atropa accumonicata*, *Valeriana jatamonsii* and *Linum ustatissimum*. These plants all occur naturally in the Swat district and are used as a basis for modern pharmaceuticals and, therefore, are commonly exploited commercially. However, domestication of the resource through farming is not always technically possible. Many species are difficult to cultivate because of certain biological features or ecological requirements (slow growth rate, special soil requirements, low germination rates, susceptibility to pests, etc.). Economical feasibility is the main rationale for a decision to bring a species in cultivation but it also is a substantial limitation as long as sufficient volumes of material can still be obtained at a lower price from wild harvest. Cultivated material will be competing with material harvested from the wild that is supplied onto the market by commercial gatherers who have incurred no input costs for cultivation. Low prices, whether for local use or the international pharmaceutical trade, ensure that few species can be marketed at a high enough price to make cultivation profitable (Cunningham, 1994; Schippmann et al., 2002). Domestication of a previously wild collected species does not only require substantial investment of capital (up to 200 000 US\$; Plescher *in litt.*) but also requires several years of investigations (e.g. 12 years for *Alchemilla alpina*; Schneider et al. (1999). 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 and domestication prospects of the aforementioned important medicinal plant species and (2) to assess the economic feasibility of commercially cultivating such medicinal plant species under farming conditions.

MATERIALS AND METHODS

Site

The domestication and cultivation of six economically and pharmaceutically important medicinal plant species was conducted in four different locations on farmers' fields in Swat Pakistan during 2007 - 2008. These locations included the villages of Koot, Matta,



Figures 1. Days to sprouting for six medicinal species evaluated in four different locations under farmland conditions at Swat during 2007 - 2008. Values with the same letter superscripts are not significantly different ($P < 0.05$).

Biakan and Topsis at altitudes of 1400, 1600, 1800 and 2200 m above sea level (m.a.s.l), respectively.

Study procedure

In September, 2007, rhizomes of *A. accumonicata*, *A. recemosus*, *V. jatamonsii*, *C. carvi* and *R. serpentina* were collected from the Shinko alpine pasture of Madyan area, and *L. ustatissimum* rhizomes were collected from their natural habitat at Topsis 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 5 X 5 m at each location. Planting was done during mid-September, 2007 on a well-prepared soil using farm yard manure to improve soil fertility (Table 1). The optimum plant to plant distance was 15 cm; the row to row distance was approximately 35 cm in order to achieve the full coverage of the soil which minimizes the competition with weeds and assures best yields.

Nursery preparation

A fine nursery bed was prepared by adding well-matured leaf compost or FYM in September seed was sown thinly in lines 1.5 to 2 cm deep and 20 cm apart into moist soil. 10 - 20 g of seed are required for 10 sqm of nursery bed. Regular weeding and irrigation during dry periods must be assured to optimize the seed germination and the development of the seedlings.

Soil preparation and fertilization

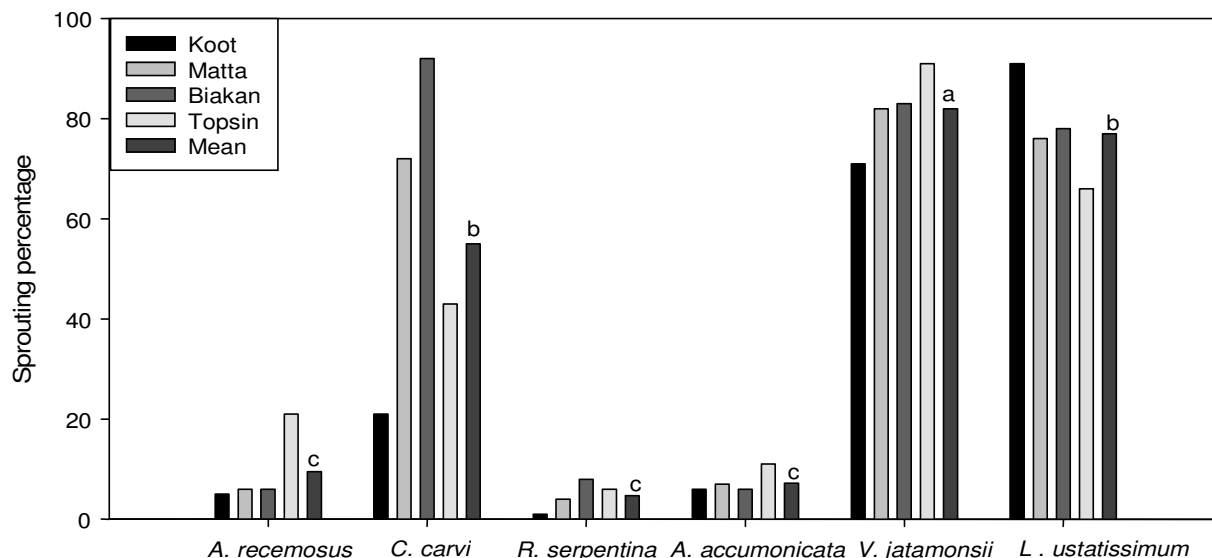
All the selected plants requires a very fine soil, therefore, the site was ploughing twice and remove weeds carefully. Weeds were controlled by hand weeding and hoeing in each location during December, 2007 and during April and May, 2008. Data were recorded for various parameters on each plot which included 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 *C. carvi* and *L. ustatissimum* was done during the months of April and May, 2008 while rhizomatous that is *A. accumonicata*, *A. recemosus*, *V. jatamonsii* and *R. serpentina* were harvested in September and October, 2007. 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).

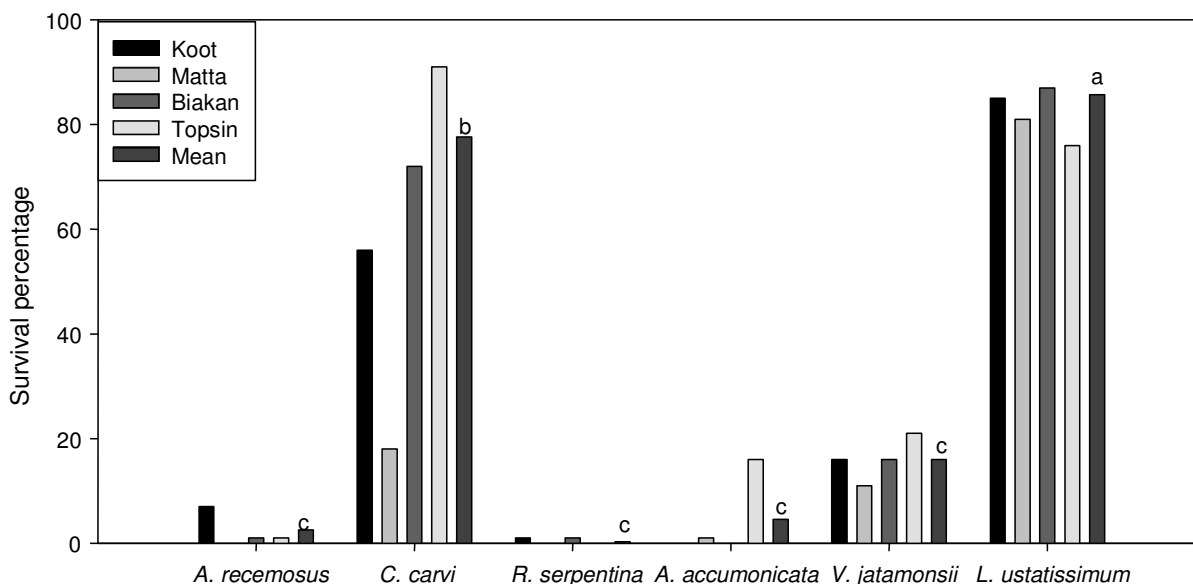
Economic analyses of yield data were carried out to determine the net income for each medicinal plant species, using prevailing market rates for land rent, costs of production and prices of useable plant parts relevant to the species. The most widely cultivated crops, wheat and maize among cereals and tobacco among cash crops, were included for comparison. The examples take into consideration that: (1) Mechanization is mostly lacking. Calculations are therefore made based on the assumption that soil preparation is carried out with oxen; (2) Cost of labour was high and (3) Yields were comparatively low. In this context of the economic assessment and feasibility of selected medicinal plant cultivation, take into consideration a substantial lack of information on yields in farmers' fields. We, therefore, propose the establishment of agreed and reliable methods to determine yields in farmer followed the method adopted by Krug (2008). Further, economic feasibility were based on assumptions which will change over time due to price fluctuations, variations in yields, increasing mechanization with a reduction in cost of production to name few of the influencing factors.

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 Figures 1 - 6. The relative responses of the species for sprouting duration and sprouting percentage were in most cases different both between and among



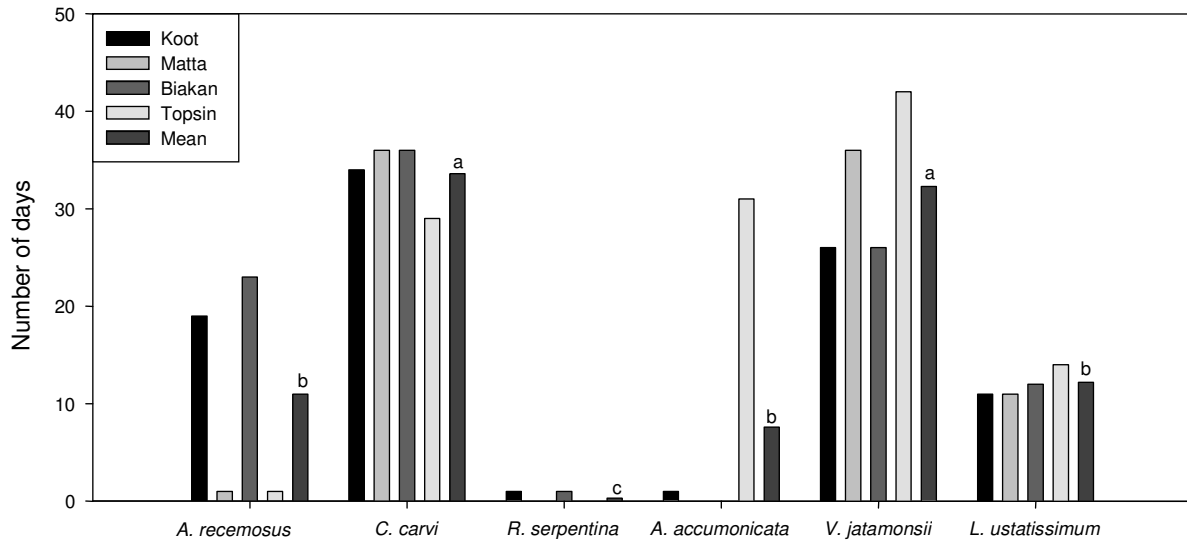
Figures 2. Sprouting percentage of six medicinal species evaluated in four different locations under farmland conditions at Swat during 2007 - 2008. Values with the same letter superscripts are not significantly different ($P < 0.05$).



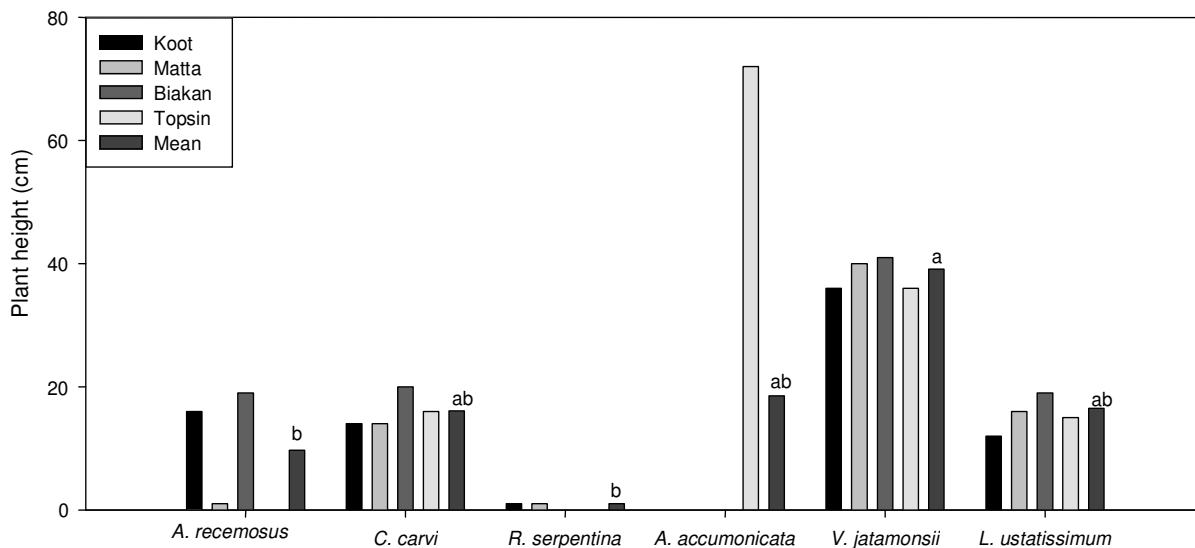
Figures 3. Survival percentage of six medicinal species evaluated in four different locations under farmland conditions at Swat during 2007 - 2008.

locations (Figures 2 and 3). Most species showed to take longer to sprout at higher altitudes, but this was not statistically significant (Figure 2). However, there was a tendency to increased sprouting at higher altitudes for all species, except for *L. ustatissimum*, which showed a decreased proclivity to sprout with increasing altitude (Figure 3). The study revealed that *C. carvi* took the minimum number of days to achieve 50% sprouting (mean of 32 days) – this was significantly less than the

other species in the test (Figure 2). The greatest degree of sprouting (82%) was observed for *V. jatamonsii*, followed by *L. ustatissimum* with 77% sprouting - these were significantly higher than all other species. *R. serpentina*, *A. accumonicata* and *A. recemosus* showed very poor sprouting with 4.7, 7.2 and 9.5%, respectively (Figure 3). The present study reported significant differences among species for survival after sprouting were observed (Figure 4). *L. ustatissimum* exhibited the



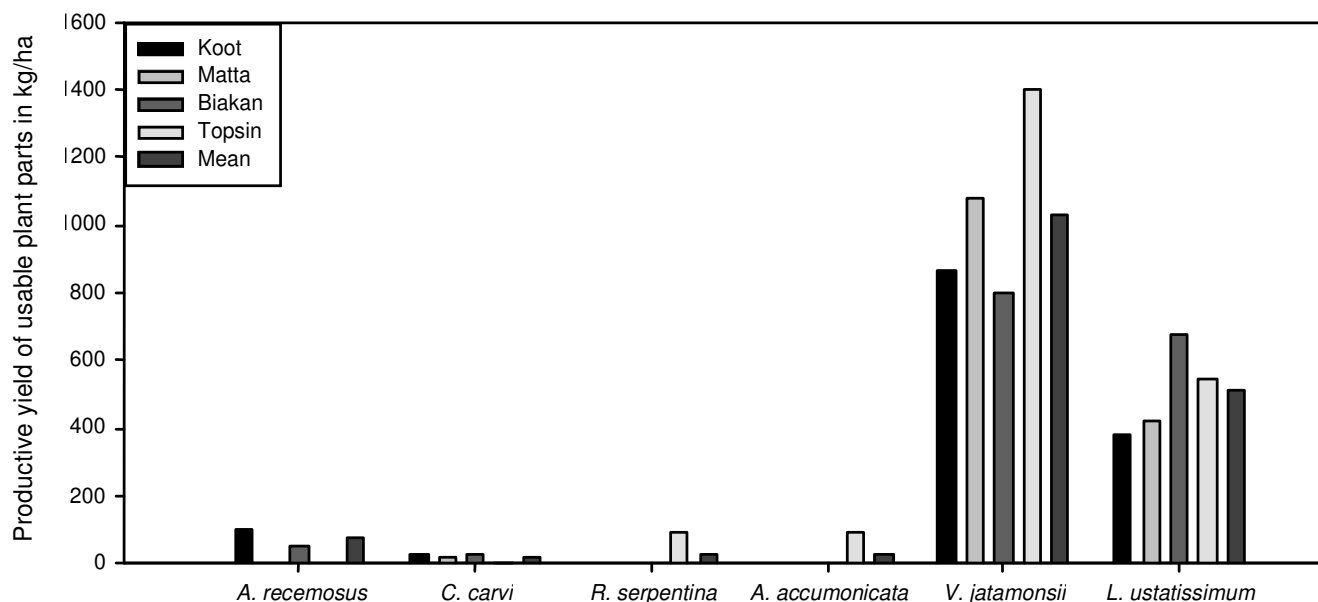
Figures 4. Number of days to flowering after sprouting of 6 medicinal species evaluated in four different locations under farmland conditions at Swat during 2007 - 2008. Values with the same letter superscripts are not significantly different ($P < 0.05$).



Figures 5. Plant height (cm) of six medicinal species evaluated in four different locations under farmland conditions at Swat during 2007-2008. Values with the same letter superscripts are not significantly different ($P < 0.05$).

highest survival (mean value of 85.5%) followed by *C. carvi* (mean value of 77.6%) - significantly greater than all other species. Survival rates were assessed 12 months after planting, by which time clear trends were apparent, however, it is worth noting that after showing quite good initial growth, many *V. jatamonsii* plants started to wilt and died 10 to 11 month after planting. Survival percentages of *R. serpentina*, *A. recemosus* and *A. accumonicata* were very poor under farmland conditions with mean values of 0.3, 2.55 and 7.2%, respectively, across locations (Figure 4). Significant differences among

species for days to flowering after sprouting (Figure 5) were observed. *C. carvi* and *V. jatamonsii* 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 *V. jatamonsii* and *L. ustatissimum*). Some variation among plant heights were also studied and showed significant variation among locations (Figure 5). *V. jatamonsii* had the highest mean value of 39.1 cm (though as mentioned earlier, this plant subsequently had late, high mortality rates). Generally, the greatest plant



Figures 6. Productive yield of usable plant parts in kg/ha of six medicinal species evaluated in four different locations under farmland conditions at Swat during 2007 - 2008.

Table 1. Physical and chemical properties of soils of four experimental locations at Swat during 2007-2008.

S/No.	Location	Altitude (M)	CaCO ₃ (%)	Organic matter (%)	pH	Textural classes	Water holding capacity (%)	N (%)	P (%)	K (%)
1	Koot	1400	0.23	4.10	7.1	Silt loam	23.13	5.6	4.3	5.4
2	Matta	1600	0.46	5.01	6.9	Sandy loam	22.34	7.0	7.0	7.2
3	Biakan	1800	0.83	2.56	7.45	Silt loam	22.04	4.1	4.10	4.5
4	Topsin	2200	0.34	5.12	7.2	Silt loam	20.01	5.9	6.88	7.8

heights were observed at Biakan across all species. However, it is difficult to ascribe any meaningful trend to this data as *A. accumonicata* only grew successfully at Topsin, where it grew to 72 cm.

Economic potential of medicinal plant cultivation

This study also described the economic potential of cultivation of six medicinal plants viz: *A. recemosus*, *C. carvi*, *R. serpentina*, *A. accumonicata*, *V. jatamonsii* and *L. ustatissimum* cultivated in four different sites of District Swat, Pakistan. These six species are chosen to demonstrate the influence of the present management practices on the economy potential of medicinal plant production. The finding of the present investigation revealed that the productive yield data (that is, rhizome, flower or leaf/shoot), for the six medicinal species in the four test locations is given in Figure 5. Due to poor sprouting and/or no survival, no rhizome yield for *R. serpentina* at any of four sites was obtained. Similarly

A. accumonicata failed to give any rhizome yield at three of four sites. While *A. recemosus* was found to have no rhizome yield at two locations. Rhizome yield of *A. recemosus* showed 98 kg/ha at Koot and 50 kg/ha at Biakan, while *V. jatamonsii* 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 *L. ustatissimum* 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 *C. carvi*. Results of economic analysis of the data indicated (Table 2) that only two of six medicinal species (*C. carvi* with income of Rs. 18,679 and *L. ustatissimum* with net income of Rs. 26,970) generated higher net incomes than cereal crops, maize and wheat (Rs. 18,669 and Rs. 17,000, respectively). However, the estimated net annual income of these two medicinal species was lower than that of tobacco (Rs. 26,970), due to their relatively high costs of production.

Table 2. 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 2007-2008.

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	<i>A. recemosus</i>	98	35	2678	32498	29767
2	<i>C. carvi</i>	20	3200	73890	54789	18679
3	<i>R. serpentina</i>	0	34	1	34570	33576
4	<i>A. accumonicata</i>	89	29	1760	32560	30770
5	<i>V. jatamonsii</i>	1276	30	25678	32560	4067
6	<i>L. ustatissimum</i>	645	1370	150	49678	26970
B. Cereal crops						
1	Maize	6850	10	54090	42546	18669
2	Wheat	5700	12	49000	35000	17000
C. Cash crop						
1	Tobacco	2574	45	67843	35123	34734

DISCUSSION

Given the demand for a continuous and uniform supply of medicinal plants and the accelerating depletion of forest resources, increasing the number of medicinal plants species in cultivation would appear to be an important strategy for meeting a growing demand (Uniyal et al., 2000). The present study observed that cultivated plants are sometimes qualitatively inferior when compared with wild gathered specimens. Our results are supported by Robbins (1998) who reported that wild ginseng roots are 5 - 10 times more valuable than roots produced by artificial propagation. The reason is primarily cultural, as the Chinese community, which is the largest consumer group of wild ginseng, believes that the similarity in appearance of gnarled wild roots to the human body symbolizes the vitality and potency of the root. Cultivated roots lack the characteristic shape of wild roots and are, therefore, not as highly coveted by consumers. While it can be presumed that cultivated plants are likely to be somewhat different in their properties from those gathered from their natural habitats it is also clear that certain values in plants can be deliberately enhanced under controlled conditions of cultivation (Palevitch 1991; Uniyal et al., 2000).

The majority of companies, the mass-market, over-the-counter pharmaceutical companies as well as the larger herb companies, prefer cultivated material, particularly since cultivated material can be certified biodynamic or organic (Laird and Pierce, 2002). However, our study also reported that domestication of the wild medicinal plants through farming is not always technically possible. Many species are difficult to cultivate because of certain biological features or ecological requirements (slow growth rate, special soil requirements, low germination

rates, susceptibility to pests, etc.). Economical feasibility is the main rationale for a decision to bring a species in cultivation but it also is a substantial limitation as long as sufficient volumes of material can still be obtained at a lower price from wild harvest. Cultivated material will be competing with material harvested from the wild that is supplied onto the market by commercial gatherers who have incurred no input costs for cultivation. In this context, the major aim of this study was to examine the viability of cultivating medicinal plants under farmland 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 Onwuerne (1973) that *R. serpentina* and *A. recemosus* 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, *D. deltoidea*, *C. luteum* and *A. recemosus* sprouted in early spring. We also found that *L. ustatissimum* showed greatest sprouting percentage in early spring (March/April). These findings agree with those of Khan (1989) and Uniyal (2000) who reported that seed germination/sprouting of several Umbellifers and *L. ustatissimum* 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 *A. accumonicata*, which only grew at one site) attained greatest heights in the sandier soil at Biakan. *C. carvi*, for example, grew tallest and sprouted most successfully at Biakan, supporting the contention of Khan (1998) that sandy soil and dry climate is more suitable for *Bunium* root cultivation. Overall, however, we observed very low sprouting percentage and survival of *R. serpentina*, *A. recemosus* and *A. accumonicata* in the farmland conditions. This starkly contrasts with Verlet and Leclereq (1997) who reported that farmland habitats are favorable for some medicinal plants like *V. officinale* and *R. serpentina*. 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 *C. luteum*, *R. serpentina* and *A. accumonicata* 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. (1998) found that alpine medicinal plants remain dormant in early spring, delaying flowering until May and June. The same effect was observed by Uniyal (2000) who reported that low temperature treatment delays flowering in many species of medicinal plants. Analyses of yield data revealed that *L. ustatissimum* and *C. carvi* 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. 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 *C. autumnale* to supplement cash income of the farmers in USA. Our results were also supported by Peter et al. (2005), who reported that consumption of herbal medicines is widespread and increasing. Harvesting from the wild, the main source of raw material, is causing loss of genetic diversity and habitat destruction. Domestic cultivation is a viable alternative and offers the opportunity to overcome the problems that are inherent in herbal extracts: misidentification, genetic and phenotypic variability, extract variability and instability, toxic components and contaminants.

The study concluded that small-scale cultivation, which requires low economic inputs, can be a response to declining local stocks, generating income and supplying regional markets. This can be a more secure income than from wild harvest which is notoriously inconsistent. For farmers that integrate medicinal plants into agro forestry or small-scale farming systems, these species can provide a diversified and additional source of income to the family. Home gardens are increasingly a focus of medicinal plant propagation and introduction programmes intended to encourage the use of traditional remedies for common ailments by making the plant sources more accessible.

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