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RESEARCH ARTICLE

Medicinal and aromatic plant cultivation in the Swat valley, north-western Pakistan, for economic development and biodiversity conservation

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Abstract Most people in the Swat valley of northwest Pakistan practice subsistence farming, supplementing their income by collecting and selling wild harvested plants for use in herbal medicine. Previous work showed that the collectors did not know the potential long-term impacts of collecting wild plants. We hypothesized that establishment of ex situ cultivation plots for these most valuable species would provide a sustainable alternative and lead to development of skills in agricultural production and marketing among participants. Swat valley farmers were helped to establish plots in four locations and taught to cultivate ten medicinal and aromatic plants (MAPs). In the first year, workshops were held on the financial benefits of growing MAPs for trade, criteria in selecting species, and strategies to improve MAP yield. In the second year, emphasis was placed on helping the farmers achieve a better price for their products by engaging them in discussions concerning criteria used in setting purchase prices. Seven of the ten cultivated MAPs yielded a better financial return than tomatoes (*Solanum lycopersicum* L.), the traditional cash crop in the area. Cultivating MAPs can yield a higher financial return than traditional cash crops, but a long-term assessment is necessary. Offering training in collection, preservation, and marketing can enhance the financial return and the long-term benefits of cultivation. Introduction of standardized production technology and appropriate post-harvest management has become a prime engine of growth for the economies of the subsistence farmers participating in our study, and is leading to better management and conservation practices for MAPs and the landscapes in which they grow.

Keywords Economic development · Mountain communities · MAPs cultivation · Pakistan · Subsistence farming

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Introduction

Plants have a long history of use in medicine, perfume, and cosmetics, but the monetary value of the trade in such plants has only recently been appreciated (Srivastava et al. 1996; Lambert et al. 1997; Lange 2002;

Schippmann et al. 2002). Medicinal and aromatic plants (MAPs) include the spices used in the food industry and the many species whose oils are extracted for use in herbal medicines, cosmetics and perfumes. Estimates of the value of global trade in MAPs vary widely but the numbers are large. Bodeker (1997) estimated the total value of imports by the largest importing countries to be over US$ 824 million in 1994. Later, the FAO (2008) estimated global export trade in medicinal plants to be in the order of US$ 1 billion in 2002, with the bulk of this material being obtained from wild populations.

Concerns for the conservation of medicinal plant resources were first expressed in 1984 (Lambert et al. 1997) and led to the Chiang Mai Declaration of 1988 that expresses “grave concern [with] the fact that many of the plants that provide traditional and modern drugs are threatened” (Akerele et al. 1991). In recent decades this concern has increased, particularly for developing countries (Kuipers 1997; Lange 2002) where wild-collection of MAPs is often an important means of generating cash income (Cunningham 1993; Schippmann et al. 2002).

Cultivation of MAPs as cash crops has been suggested as a possible mechanism for increasing incomes in rural communities while simultaneously reducing exploitation pressure on wild populations and associated conservation concerns (Farooquee and Saxena 1996; Shinwari 2010). From a market perspective, domestication and cultivation of MAPs has numerous advantages over wild-harvested species (Schippmann et al. 2006). However, many species are difficult to cultivate due to biological features or ecological requirements, e.g. slow growth rate, special soil requirements, interactions with pollinators and other species, low germination rates, and susceptibility to pests. Lack of secure, long-term land tenure is also a concern for farmers thinking of growing perennial species. These social and biological factors affect the economic viability of medicinal-plant cultivation, and need to be taken into account in MAP cultivation (Schippmann et al. 2006). Agricultural research and development programs in Pakistan have focused mainly on major crops, little attention being given to MAPs (PARC 2012), but previous work in the Swat valley has demonstrated that MAP cultivation can bring significant economic and socio-economic benefits to subsistence farmers (Sher 2013; Sher et al. 2014). Sher (2013) found that farmers in the Swat valley had no experience in cultivating MAPs and were unaware that MAPs can have greater economic value than their traditional agriculture crops.

This study follows up on positive outcomes from these pilot studies (Sher 2013; Sher et al. 2014), and aimed to establish cultivation plots for participatory training in MAP cultivation, harvesting and commercialization. The general objective was to help farmers in the Swat valley increase their income by cultivating and marketing high value MAPs on local and regional markets. Specific objectives were (1) to domesticate and evaluate growth characteristics under cultivation of 10 selected MAPs species; and (2) to compare the economic benefit of MAPs cultivation with cultivation of the cash crops traditionally grown in the area. Specific objective one was targeted by helping local farmers to: (a) cultivate MAP species traditionally wild collected in the area; (b) harvest and process plant materials for optimal quality and value following WHO guidelines on good agricultural practice (WHO 2003); and (c) providing technical and strategic advice and on obtaining better prices from commercial purchasers.

Materials and methods

Study area

The Swat valley lies in the north of Khyber-Pahktunkhwa Province, Pakistan (Fig. 1). The valley is part of the southern slope of the Hindu Kush Mountain Range, and is floristically rich, encompassing three different phytogeographic regions (Sino-Japanese, Irano-Turanian, and Sahara-Sindian) and having vegetation zones that vary from sub-tropical chir pine (*Pinus roxburghii* Sarg.) forests to alpine meadows. Several species of commercially important MAPs grow in the cooler vegetation zones. Most of them are slow growing perennial species that are or are becoming locally extirpated through logging, grazing, and collection (Sher et al. 2010).

In 1998, when the last census was taken, the population of Swat District was 1.3 million, its annual growth rate 3.4 %, and its population density 236 people/km^2 (CPPR 2010). This suggests its current population is close to 2 million and its population density about 374 people/km^2. In the northern and

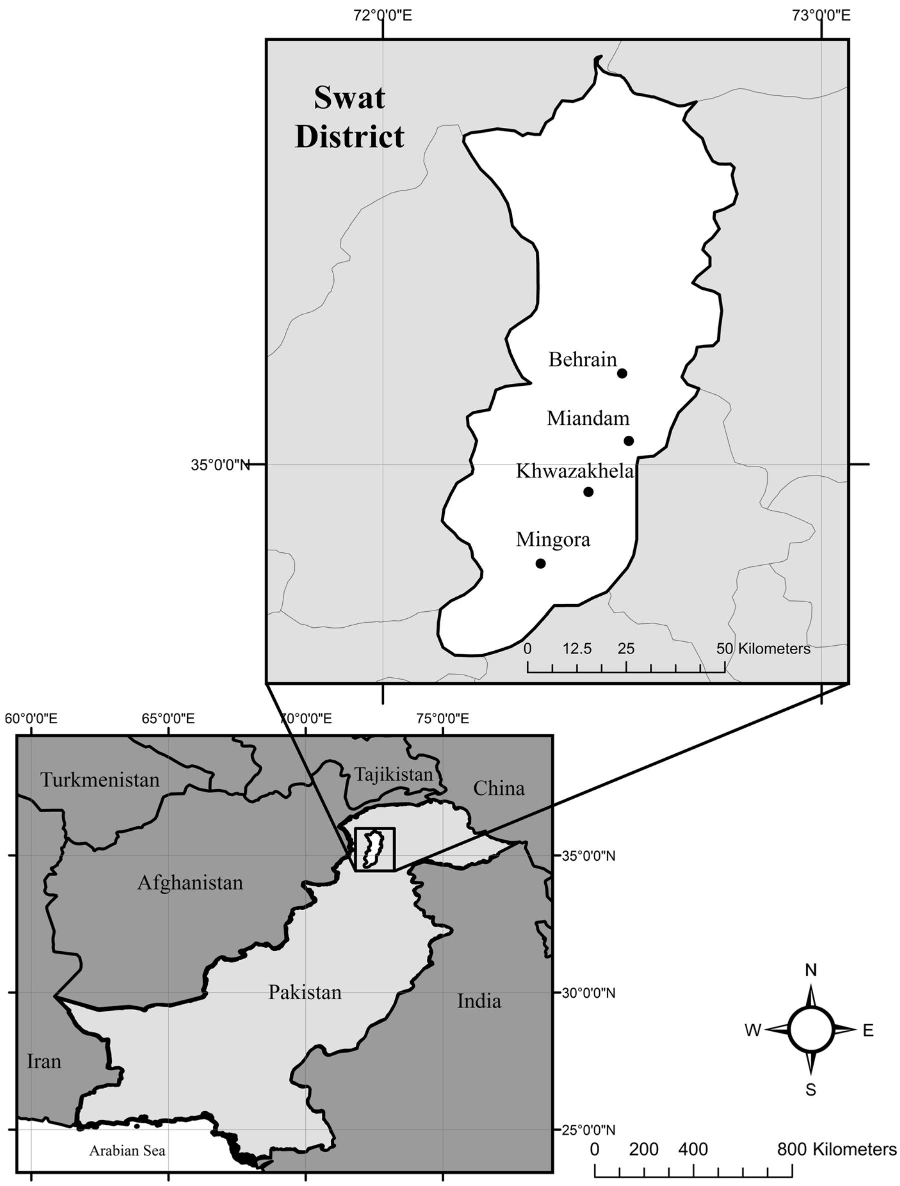

Fig. 1 Map of the study area indicating the villages where the four study plots are located: Behrein, Khwazakhela Miandam, and Mingora

most mountainous part of the district, most people make their livelihoods from a combination of small scale farming and raising of a few cattle. Many supplement their resources by selling plant material collected from wild populations to local traders but the money earned is minimal (Sher 2013).

Site selection and capacity building

The criteria used to select the four locations for the project were: (a) distance from the main road; (b) existence of a local organization of farmers; (c) interest shown by the farmers during introductory discussions; and d) suitable growing conditions as indicated by the area's native vegetation. The four sites chosen were located at Mingora (elev. 800 m), Khwazakhela (elev. 1100 m), Miandam (elev. 1500 m), and Behrain (elev. 2000 m) (Fig. 1).

At the start of the funding period, workshops were held at each location to discuss the project with 50 local farmers. The 200 participants included 175 males and 25 females. The workshops explained why MAPs cultivation was expected to be of economic value, and included open discussions on good agronomic, harvesting, and collecting practices. Agronomic aspects discussed included identifying potential sources of germplasm, appropriate cultivation practices, and the value of keeping records. The section on collecting practices emphasized the importance of collection of the appropriate parts, choice of collection time, and sustainability. These sessions were followed by a session on methods for preparing and storing collected material in a manner that would maximize its value.

Species selection

Species were chosen for study based on: (1) interest by the participants; (2) economic value; (3) market demand at local, national, and international levels; (4) time to maturity (shorter being better); (5) existence of known, simple cultivation techniques; and (6) availability of suitable cultivars for growth at high elevations. An initial selection by the participant farmers was reduced to 10 species: *Persicaria amplexicaulis* (D. Don) Ronse Decr., *Crocus sativus* L., *Curcuma longa* L., *Linum usitatissimum* L., *Nigella sativa* L., *Ocimum basilicum* L., *Saussurea costus* (Falc.) Lipsch., *Sesamum indicum* L., *Valeriana jatamansi* Jones, and *Viola pilosa* Blume. Germplasm for most species was obtained from the Pakistan Forest Institute. Rhizomes of *Valeriana jatamansi* and *Persicaria amplexicaulis* were obtained from forests near Miandam following recommended collecting procedures. Rhizomes for *Saussurea costus* had to be purchased from Azad Jammu and Kashmir because it had become locally extinct, a fact that is reflected in its inclusion in CITES Appendix 1. None of the other species are CITES listed but some countries have suspended export of wild-collected material of *Valeriana jatamansi* (CITES 2014).

Plot preparation and plant growth

At each location, 10 plots of 25 m^2 were rented for use in the project, one for each of the 10 species selected. All the plots had deep soil and were in locations where they would not dry out rapidly. The Agricultural Research Farm in Tarnab, Peshawar, determined soil characteristics, and these were similar for all four sites. The biggest difference was in calcium carbonate content, which was 0.65 % at Miandam, 0.47 % at Behrain, and 0.38 % at Mingora and Khwazakhela. Prior to planting, the plots were ploughed to create a fine textured soil after which both fresh and composted manure were added to improve their fertility and water-holding capacity. Planting took place in September 2012. Seeds were planted 5 cm apart in rows 10 cm apart. Those that failed to germinate were replaced with fresh seed. Rhizomes were cut into pieces 4–6 cm long, each with 2–3 active buds. These were planted 15 cm apart in rows 30 cm apart. The plots were first weeded and hoed 1 month after the plants had established and again after 2 months. After that, weeding and hoeing was carried out when needed.

For each individual in each plot, data were recorded on emergence time, flowering time, length to the tip of the plant, survival, weight of marketable biomass produced, and market price when sold. Observations on emergence and flowering were made daily until 50 % of the plants had emerged/flowered. Regular monitoring helped ensure that the crops were given the care they needed in addition to providing information for making planting decisions in subsequent years.

Economic data

Production costs were estimated to enable economic analysis of the benefits of cultivating the selected species. Estimated production costs included labour (based on local rates for day labourers), land rental, and consumables such as packing materials. The germplasm of all species was provided to the farmers at no cost but the project's purchase cost for *Saussurea costus* was included as a cost in the analyses. Labour costs included all aspects of raising and selling the harvested materials, as the participants conducted all work. The monetary return obtained from selling the crops was calculated using local market values. There was no formal estimate of the transaction costs associated with the project, as most where one-off investments to start the experiment, such as the cost of investigating which plants to grow, making contact with the farmers, costs associated with preparation and administration of the grant proposal, and the provision of training workshops.

Results

Plant growth

Growth data for the ten species at each of the four locations are summarized in Tables 1 and 2. Time to emergence generally increased with elevation, except that emergence times for several species at Behrain (2000 m) were the same as those for Miandam (1500 m). The order of emergence was the same at all locations except that *Valeriana jatamansi* was the last species to emerge at Mingora and Khwazakhela but the seventh at Miandam and fifth at Behrain.

Emergence percentages were less consistent. At all four locations, *Crocus sativus* and *Ocimum basilicum* had the lowest percentage emergence, followed by *Nigella sativa* and *Curcuma longa*. *Valeriana jatamansi* ranked fifth in emergence at Mingora, Miandam, and Behrain but sixth at Khwazakhela where *Persicaria amplexicaulis* ranked fifth. The most variable species with respect to emergence percentages were *Viola pilosa* (fifth at Mingora, fourth at Khwazakhela, third at Miandam and Behrain) and *Sesamum indicum* (second at Mingora, third at Khwazakhela, fourth at Miandam and Behrain).

Two species failed to flower in 2013, *Curcuma longa* and *Saussurea costus*. For the other species, flowering took an average of 4 days longer at the two higher locations than at the two lower locations (Table 1) but the order in which the species flowered was the same at all four locations (data not shown). The eight species that reached flowering maturity in 2013 also reached very similar heights at all four locations and their rank ordering was identical (data not shown). Survival rates varied among the species (Table 2), with those of *Ocimum basilicum* and *Nigella sativa* being particularly low (10 and 15 % respectively). The lowest (Mingora) and highest (Behrain) locations had slightly lower survival rates overall than the other two locations but the differences were slight.

In 2013, only the five annual species produced marketable biomass, but in 2014 all ten species did so (Table 2). The total marketable biomass produced at each location decreased with each increase in elevation in 2014. This was mainly attributable to *Curcuma longa*, which yielded 7000 kg/ha at Mingora, 6500 kg/ha at Khwazakhela, 5710 kg/ha at Miandam, and 5550 kg/ha at Behrain. The greatest difference in yield for the other nine species among the four sites was only 75 kg/ha.

Economic analysis

The yield and economic return data for the first 2 years are presented in Tables 3 and 4. Basic production costs for the annual MAPs increased in the second year because the rental rate for the land was increased, but increased yields and market prices compensated for the increased land cost. The ability of the farmers to sell their crops at a higher price in the second year was a result, in part, of the awareness they had developed in the first year of the benefits of providing clean, well-prepared products. For the perennial MAPs, production costs were lower in the second year despite the increased rental rates because no planting was needed. They were higher for *Curcuma longa* than for the other four perennial species because it required post-harvest processing before sale.

Table 1 Emergence and flowering characteristics of the MAP species in 2013

	Days for 50 % emergence				Days for 50 % flowering			
	Ming	Khaz	Mian	Behr	Ming	Khwa	Mian	Behr
Curcuma longa	15	15	20	20				
Valeriana jatamansi	35	35	25	20	35	35	40	40
Crocus sativus	10	10	15	15	15	15	15	14
Saussurea costus	20	20	30	30				
Persicaria amplexicaulis	15	15	20	20	20	20	25	25
Sesamum indicum	15	15	20	20	25	25	30	30
Ocimum basilicum	10	10	15	15	25	25	30	30
Nigella sativa	15	20	25	25	25	25	30	30
Linum usitatissimum	10	10	15	15	15	15	20	20
Viola pilosa	20	20	25	25	20	20	25	25
Average	16.5	17	21	20.5	23	23	27	27

Ming Mingora, *Khwa* Khwazakhela, *Mian* Miandam, *Behr* Behrein

Table 2 Survival rates in 2013 and biomass production in 2014 at each location

	Survival 2013 (%)				Yield 2014 (kg/ha)			
	Ming	Khwa	Mian	Bahr	Ming	Khwa	Mian	Bahr
Curcuma longa	60	65	70	70	7000	6500	5710	5550
Valeriana jatamansi	70	75	75	70	513	495	501	479
Crocus sativus	80	80	85	85	1	1	1	1
Saussurea costus	90	90	90	90	619	593	627	601
Persicaria amplexicaulis	95	95	90	90	713	719	743	737
Sesamum indicum	100	100	100	100	400	405	380	375
Ocimum basilicum	10	20	15	10	1560	1575	1576	1549
Nigella sativa	15	25	20	20	180	180	170	180
Linum usitatissimum	90	95	95	95	490	470	470	480
Viola pilosa	90	90	95	90	280	210	280	205
Average %, total kg/ha	70	74	74	72	11,756	11,148	10,458	10,157

Ming Mingora, *Khwa* Khwazakhela, *Mian* Miandam, *Behr* Behrein

Table 3 Comparison of the financial return from cultivating MAP species and *Solanum lycopersicum* (tomatoes) in 2013

2013	Yield (kg)	Market ($/kg)	Gross ($/ha)	Cost ($/ha)	Net ($/ha)
Curcuma longa	0	0.00	0	347.26	−347.26
Valeriana jatamansi	0	0.00	0	347.26	−347.26
Crocus sativus	0	0.00	0	347.26	−347.26
Saussurea costus	0	0.00	0	570.95	−570.95
Persicaria amplexicaulis	0	0.00	0	347.26	−347.26
Sesamum orientale	366	2.74	1004	347.26	657.04
Ocimum basilicum	1530	1.47	2249	347.26	1901.84
Nigella sativa	160	4.90	784	347.26	436.74
Linum usitatissimum	470	2.55	1198	347.26	850.30
Viola pilosa	200	9.80	1960	347.26	1612.74
Solanum lycopersicum	2100	0.59	1235	637.00	597.80
Net return from all MAPs					3500
Net return if all plots planted to *Solanum lycopersicum*					5980

See text for explanation of the costs associated with each species

In the first year, only the five annual species yielded marketable biomass but there were costs associated with all ten species. Consequently the net income from all ten species, $3499/ha, was less than $5978, the amount that would have been obtained had all ten plots been planted with tomatoes (*Solanum lycopersicum* L.).

In the second year, all ten MAPs yielded marketable biomass and the resulting net income rose to $25,775/ha, considerably more than would have been earned from planting tomatoes. The relative profitability of the ten species was the same at all four locations. *Curcuma longa* and *Saussurea costus* were by far the most profitable despite having to deduct 2 years of costs. The other three perennials all yielded a net profit in the second year but only one, *Valeriana jatamansi*, was more profitable than tomatoes. All five annual species were more profitable in the second year than the first. Their higher profitability reflected both increased yields and increased market prices. Overall, the five most profitable species for the 2 years combined were (1) *Curcuma longa*, (2) *Saussurea costus*, (3) *Viola pilosa*, (4) *Ocimum basilicum* and (5) *Linum usitatissimum*. Extrapolation to 2015, year 3 (data not shown), suggests that Valeriana jatamansi would replace Linum usitatissimum in fifth place in terms of return on investment because it will not need to be replanted.

Tomatoes are the traditional cash crop in Swat district but their production cost is high because they require cover, herbicides and insecticides to optimize production. The MAPs were grown without such interventions. Even so *Nigella sativa*, *Persicaria*

Table 4 Comparison of the financial return from cultivating MAP species and *Solanum lycopersicum* (tomatoes) in 2014 and the net return for both years. Calculations for *Solanum lycopersicum* reflect costs and prices in 2013

2014	Yield (kg)	Market ($/kg)	Gross ($/ha)	Cost ($/ha)	Net ($/ha)	Net ($/ha) 2013 and 2014
Curcuma longa	6190	1.76	10,919	411.60	10,508	10,508
Valeriana jatamansi	497	3.43	1705	196.00	1509	1509
Crocus sativus	1	637.00	764	196.00	569	568
Saussurea costus	610	12.74	7771	196.00	7575	7575
Persicaria amplexicaulis	728	0.88	642	196.00	446	446
Sesamum orientale	390	2.94	1147	392.00	755	1412
Ocimum basilicum	1565	1.67	2607	392.00	2215	2451
Nigella sativa	178	5.10	905	392.00	513	952
Linum usitatissimum	478	2.65	1263	392.00	871	1723
Viola pilosa	244	11.76	2866	392.00	2474	4090
Solanum lycopersicum					598	1196
Net return from MAPS					27,435	30,935
Net return if all plots planted *Solanum lycopersicum*					5980	11,960

See text for explanation of the costs associated with each species

amplexicaulis, and *Crocus sativa*, were less profitable than tomatoes over 2 years. The problem with *P. amplexicaulis* was its low market price, whereas for *Nigella sativa* and *Crocus sativa* it was low yields/ha.

The net earnings at the four locations differed because the amount of biomass produced by each species varied by location. In the second year, earnings decreased with an increase in elevation from $32,732/ha at Mingora to $28,913/ha at Behrain, a difference of $3819/ha but this reflects the strong association between elevation and yield of *Curcuma longa*. If it is excluded from the calculations, the difference in earnings between the most and least profitable locations was only $1352/ha. Returns were still highest at Mingora, followed by Miandam, Behrain and Khwazakhela.

Discussion

One of the goals of this project was to determine what subsistence farmers in Swat district could earn from cultivating MAPs on rented land compared to a control species, the standard cash crop tomatoes. It involved 50 farmers from four locations, which were provided with germplasm of 10 MAPs thought to be suited to the area, and instruction in cultivation and harvesting techniques. In the first year, the return from cultivating MAPs was less than would have been earned by planting the same area to tomatoes because, although there were costs associated with planting all ten species, only the annual species produced marketable biomass. In the second year, the return from cultivating MAPs was substantially greater than would have been obtained from tomatoes because all ten species produced marketable biomass and the cost of cultivating the perennial species was lower because they did not have to be planted. If continued for a third year, this “perennial effect” would increase because planting costs for the perennials would be amortized over 3 years rather than two; whereas annual species incur planting costs each year. The perennial effect was mainly attributable to the inclusion of two productive, high-valued species, *Curcuma longa* and *Saussurea costus*. A third species, *Valeriana jatamansi,* earned slightly more than tomatoes; the remaining two perennials, *Crocus sativus* and *Persicaria amplexicaulis*, earned less. The return on *Valeriana jatamansi* will increase in subsequent years because it will not need to be replanted but it will never be as valuable as *C. longa* and *S. costus.* The return on *Crocus sativa* should increase in the third year as the corms continue to multiply. Four of the five annual species earned more than tomatoes. The low return on *Nigella sativa* was a function of both its low survival rate and low productivity. Its continued cultivation cannot be justified on a financial basis but local communities rank its medicinal values and cultural significance very highly. For this reason, we recommend that efforts be made to develop strains better adapted to the mountainous regions of Pakistan.

The second goal of the project was to help the participants understand why cultivating MAPs might enable them to earn more and what they could do to maximize the benefits of MAP cultivation. The workshops were critical in achieving this goal. They directly impacted 200 individuals and indirectly an unknown number of others. One reflection of the impact was that the farmers agreed to continue the project for a second year even though the net return from all the plots was less than would have been obtained from growing tomatoes. This required some persuasion and, importantly, development of an element of trust between the farmers and the research team. Another consequence of the workshops was that farmers obtained higher prices for their crops in the second year, partly because they provided cleaner, better prepared materials that in the previous year and partly because they were more aware of the value of the plant material they were selling.

There were other positive impacts of the project: the farmers now have the knowledge and experience to make more informed decisions about the continued growth of the studied species and an approach for evaluating new MAP species; an additional 40 farmers have joined the initial group and are cultivating MAPs; the project has been able to obtain additional funding to develop direct connections between the farmers and commercial purchasers of MAPs. In addition, consideration is being given to re-establishing *Saussurea costus* in the local forests, using germplasm grown by the farmers. The success of such efforts will, however, depend on adoption of sustainable harvesting practices and establishment of effective monitoring.

The project built on previously established infrastructure. The farmers at the four locations had, with support and encouragement from various non-governmental organizations (NGOs), developed a local organization and learned to work together. The Village Development Councils of the respected villages owned the land used for this project, and provided the stability needed to support the relatively long term investment required to make planting perennial species financially rewarding. The locations were also chosen for their accessibility, without which it would have been impossible to monitor the project at the four locations and would probably lower the market value of the crops because of the increased transactions costs experienced by the purchasers for larger markets. The project highlighted the need for further infrastructure development.

Supplying MAPs commercially requires that the communities establish themselves as consistent providers of high quality materials and, increasingly and assurance that the plant material has been obtained and processed following WHO good manufacturing practices (WHO 2003). As mentioned in the introduction, cultivation of MAPs is often suggested as a means for improving the livelihood of subsistence farmers and reducing the harvesting of local populations of MAPs. This study showed that some species yield a higher net return than others and that, in the long term, perennial species may be more valuable than annual species. It also shows that subsistence farmers are interested in exploring the ability of new crops to improve the livelihoods of their families but that they need support in obtaining the knowledge required to grow, harvest, and evaluate such crops. It showed that cultivation could be used to generate germplasm for re-establishing species that have become locally extinct but did not directly address questions about the potential impact on local collecting practices.

Conclusions

Cultivation of MAP species on small plots can provide subsistence farmers in Swat district with an alternative source of income and a good financial return on investment. Initiating such cultivation requires local participation, careful education and financial support, but demonstrating the benefits of doing so catalysed wider adoption of MAP cultivation.

Cultivation of MAPs is designed to yield a cash return by satisfying external markets, involves few species, and in our study area is undertaken by men. It will not, in itself, result in alleviating harvesting pressure on wild plant populations because much of that collecting is done to meet local needs and carried out by actors that are not necessarily involved in cultivation such as women and children. This project benefited women and children indirectly by increasing family income but it did not directly increase their ability to contribute to that income.

Commercial supply of MAPs requires consistency in quality and volume, and this will take time to develop for local communities. In addition commercial ventures increasingly require assurance of adhere to WHO good manufacturing practice (WHO 2003) and national guidelines on pharmaceutical manufacturing. Enabling farmers in Swat district to meet these requirements will require far broader engagement than was possible for this study, but the current most critical need is for consistent and ongoing education and development of the appropriate infrastructure, e.g. developing post-harvesting processing facilities; providing instruction in reading, writing and arithmetic; sharing information about appropriate farming strategies with a focus on market value of different species; assistance in developing collaborative working and marketing arrangements and earning certification for sustainable production of MAPS; and legal advice on purchasing contracts.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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