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Conservation of *Picrorhiza kurrooa* through cultivation in Garhwal Himalaya: A review

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Abstract
The state of Uttarakhand, located in the foothills of Himalaya, is a home to various rare, threatened and endangered species of medicinal plants, *Picrorhiza kurrooa* being one of them. Drugs like Picroliv, Picroside-I, II, III, V and Kutkoside extracted from dried stolons and roots of *Picrorhiza kurrooa* are responsible for its vast medicinal properties. Due to large demand in national and international markets, exploitation of this species in wild is going on. In Western Himalaya (India), the conservation status of this species is either rare or threatened. The studies on genetic diversity and conservation of this species have become a priority in recent years. The main goal is to protect and maintain the evolutionary viability of this species and to maximize the chances of its survival and persistence in the changing environment. This paper gives an overview of the conservation of this species through cultivation in Garhwal Himalaya.

Keywords: Medicinal Plants, *Picrorhiza kurrooa,* Agro-techniques, Cultivation, Conservation, Livelihood.

1. Introduction
Garhwal Himalaya (Uttarakhand), situated between 29^0 26'-$31^0$28' N latitude and 77^0 49'-$80^0$06' E longitude, is a home to various vulnerable, threatened and endangered medicinal and aromatic plants [1]. Alpine zone of Garhwal Himalaya serves as special habitat for native and high value medicinal plants [2]. The plants of this zone synthesize secondary metabolites and therefore, offer greater possibilities of having novel bio-molecules and even larger quantity of active components [3].

Picrorhiza kurrooa Royle ex Benth. is an important medicinal herb belonging to family Scrophulariaceae. The species is native of India, Nepal, Bhutan, China, Tibet and Pakistan. In India, this species is naturally distributed from sub-alpine to alpine regions of North-Western Himalayan range from Kashmir to Sikkim between 3000-5300m asl [4]. Kaul and Kaul [5] have reported its distribution in three hill states of Western Himalaya *viz.,* Jammu and Kashmir, Himachal Pradesh and Uttarakhand. *P. kurrooa* grows in moist, rocky slopes as well as in organic soils. It prefers rocky crevices, sloppy and cliffy mountains. The generic name is derived from the bitter root, which is used in native medicine [6]. In Greek, "picros" means bitter, while "rhiza" means root. The vernacular name Kutki is derived from "Karu", the Punjabi name of the plant, which means bitter [7].

It is used either as an adulterant or as a substitute of Indian Gentian (*Gentiana kurroo*). Odour is slight and unpleasant. Taste is very bitter and long lasting. The medicinal properties of *P. kurrooa* are due to the iridoid glycosides like picrosides I, II, III, V, kutkosides [8] and other identified active constituents *viz.* Apocyanin, drosin and curcubitacins [9]. It is commonly used in both ISM (Indian system of medicine) as well as in modern pharmaceutical industries. In traditional medicine, it is considered to be a valuable tonic, blood purifier and has also been used to cure hepatitis, abdominal pain, stomach disorders, anaemia, jaundice, and for promoting bile secretion [10]. A wide range of biological activities have been attributed to iridoid contents of *P. kurrooa*, such as antihepatotoxic, choleretic, anti-inflammatory, antitumor, antiviral, antioxidant and leishmanicidal activities [11]. The antifungal potential of alcoholic extract of *P. kurrooa* was tested against the fungi, *Candida albicans*. The extract of Kutki and its major constituents exhibited significant activity against the fungi [12].

Since past couple of decades, exploitation of this species has suddenly become a flourishing business for illegal collectors. This uncontrolled exploitation along with several other factors like destruction of habitats, overgrazing and tourism interference are responsible for the dwindling status of this valuable species especially from higher altitudes.

Over 90% of the market demand for this species is met from the wild. To get one kg of dry weight of *P. kurrooa* plant, as many as 300 to 400 individual plants are uprooted [13]. Due to narrow distribution range, small population size, high use value and increasing demand, the species figured among the 37 identified as top priority species for conservation and cultivation in Western Himalaya. Indiscriminate, unscientific harvesting and lack of organized cultivation of the plant has threatened its status in wild and listed as endangered species by International Union for Conservation of Nature and Natural Resources [14]. The herb has been reported under depletion in Kumaun Himalaya [15] and Himachal Pradesh [16]. In a Conservation Assessment and Management Prioritization workshop for medicinal plants of Northwest Himalayan states of Jammu and Kashmir, Himachal Pradesh and Uttarakhand held at Shimla, in 2003, *P. kurrooa* was assigned endangered status in J&K and H.P. while its status in Uttarakhand was declared as critically endangered [17].

Collection of this species from its natural habitat provides extra source of income to local collectors, which compensate low agricultural production of crops. Due to high medicinal properties, the market demand of *P. kurrooa* has caused ruthless extraction from the natural habitat and illegal trade contributing to endangerment of the species. Over exploitation and consequent degradation of natural habitat are reported to be a major threat to this species in wild [13]. Cultivation of this species is the only option to reduce the pressure on its wild populations. High Altitude Plant Physiology Research Centre (HAPPRC) has developed the agro-techniques for the cultivation of this species and also established *P. kurrooa* cultivation cum demonstration nursery at Pothivasa (2200masl) in district Rudraprayag, Uttarakhand where variants of *P. kurrooa* collected from different microhabitats are cultivated in large scale. The interested farmers of this region are provided with healthy planting material for cultivation on large scale in their fields. Field training programmes are being organised for farmers from time to time.

2. Cultivation for sustainability

Cultivation of medicinal plants will certainly reduce the pressure on wild medicinal plants population, ensure regular supply of raw material to industries and uplift the economy of the local farmers [18, 19]. Garhwal Himalaya has suitable climatic conditions for cultivation of important high altitude medicinal plants and recently some industries have been established for promoting medicinal plant products and in this way farmers find it a curative option for livelihood enhancement as against the traditional farming [20].

3. Initiatives taken by Government of Uttarakhand for sustainable conservation

Motivated by the need to conserve biodiversity and increase farmer's income through agricultural diversification, the government of Uttarakhand has initiated policies to promote the cultivation of medicinal plants. These policies are being implemented through various government departments such as the Horticulture Department, Forest Department and the Department of Rural Development, as well as a number of research institutes. Herbal Research and Development Institute (HRDI), Gopeshwar (Chamoli) has been declared as nodal agency to promote cultivation activities to aware farmers with the potential of medicinal plants as cash crops; developing and disseminating cultivation technologies; setting up nurseries to propagate and supply planting material to farmers; training farmers; and providing loans and subsidies linked to the cultivation of medicinal plants. To promote the cultivation for sustainable development, Government of Uttarakhand launched the annual award scheme for outstanding cultivators or institutions for their contribution [21, 22, 23].

4. Work done by HAPPRC (High Altitude Plant Physiology Research Centre)

4.1 Morphological variants

In Garhwal Himalaya, two morphological variants of *P. kurrooa viz*., narrow leaf (NL) and broad leaf (BL) variants have been reported at the elevation of 2700-4500m asl (Figure 1). NL variant is generally found near springs on rock surfaces while BL variant is found under the shrub and scrub canopies [24, 25]. Broad leaf variant grows rapidly and shows better rate of multiplication through stolon cuttings instead of cultivation through seeds at both altitudes *viz*., Tungnath (3600 m asl) and Pothivasa (2200 m asl). On the basis of morphological parameters, such as leaf length, leaf width, number of leaves, number of flower, number of capsules per plant, number of seeds per capsule and total number of seeds per plant, the broad leaf variant showed superiority over narrow leaf variant [26]. Multiplication potential, growth, yield and active ingredients were found to be higher in BL variant under natural and cultivated conditions [26].

4.2 Biochemical composition analysis

Broad and narrow leaf variants showed variations on the basis of biochemical composition. Maximum concentration of biochemical constituents like carbohydrates, soluble proteins and free amino acids were found in broad leaf variant as compared to narrow leaf variant [26]. Same pattern of seed *Peroxidase* isoenzyme was observed in both broad and narrow leaf variants even though some population's showed different intensity of colour bands [25]. Concentration of picrotin and picrotoxin were found higher in broadleaf variant grown in polyhouse as compared to narrow leaf variant under both polyhouse and open field conditions [27].

Fig 1: A and B: BL and NL variants of *P. kurrooa* grown in Nature at Tungnath (3600 m asl); C and D: BL and NL variants of *P. kurrooa* grown in field nursery of HAPPRC at Tungnath; E and F: *P. kurrooa* grown in field nursery of HAPPRC at Pothivasa (2200m asl).

4.3 Development of Agro- techniques

Nautiyal and Nautiyal [28] developed the agro-techniques for successful cultivation and conservation of *P. kurrooa* in natural habitats at lower altitudes.

4.3.1. Means of propagation: The species propagated through seeds and stolons in Styrofoam trays and nursery beds.

4.3.2. Soil requirement: Sandy textured loamy soil, rich in organic carbon with a thick layer of humus or litter and high moisture content was found best for cultivation of *P. kurrooa*. Furthermore, partially shaded areas with canopy of small shrubs give maximum productivity [28].

4.3.3. Time of sowing the seeds and growth behaviour: Germination of seeds was found to be good when sown on the upper soil surface in Styrofoam seedling trays, and covered with a thin layer of dry moss powder. This condition increases seed germination from 52 to 58% at lower altitudes (2200m ASL) inside green house. Seeds are sown during November and December in greenhouses, during March and April in beds at lower altitude and during May in the alpine area. Seedlings raised from seeds at lower altitudes are transported to higher altitudes during March and April and transplanted in nursery beds. Thus, the harvesting period can be reduced by at least six months, by raising seedlings at lower altitudes in winter and transplanting them at higher altitudes during the spring [29].

4.3.4. Propagation through stolon cuttings: Propagation through stolon cuttings proved more successful for multiplication as well as for higher production within a short period of time than cultivation through seeds. Vegetative propagation of stolon segments can be successfully done through hormonal treatments as well as through convenient and simple methods *viz*., water dip treatment for 48 hours. Another technique used for rooting stolon cuttings is the use of trenches (approximately 2 x 1 x 1 ft. size for 1000 cuttings) to retain moisture in the soil. This method can be easily used for cultivation purposes by local growers and this method is generally used when planting material/cuttings are available during the off season or if beds are not ready for plantation. Top segments of stolons are found more suitable for multiplication. Through this method, nearly 90% rooting is observed in the top segments after two to three weeks [24].

4.3.5. Transplanting and optimum spacing: Approximately 44,000 plants are required at the time of transplantation for one acre of land and seedlings or stolon cuttings are planted 30 cm apart.

4.3.6. Intercropping system*:* Intercropping of *P. Kurrooa* with *Foeniculum vulgare*, *Solanum tuberosum* and *Digitalis purpurea* is quite successful, as these plants provide favourable microclimate for better growth, that is, they retain moisture for longer time and provide shade for the better growth of *P. kurrooa. F. vulgare* is found most suitable and with it production can be up to 320 kg/ ha harvested during the third year at 1800m elevation [24].

4.3.7. Nutrient requirement: Soil treated with a higher concentration of litter is found more suitable to achieve higher production. At lower altitudes, the survival of seedlings is found to be 40-60% and in higher altitude it is 50-75% under different manure and litter treatments. To achieve the best production within three years, 60 quintal (Q) manure per acre is required at lower altitudes and 40 Q at higher altitudes. Manuring is recommended during the winter months or before transplanting. Forest litter is found more suitable for better growth and yield.

4.3.8. Water management and weed control: To decrease the mortality rate at lower altitudes (1800m), during the early developmental stage, seedling as well as stolon cuttings need watering within every 24 hours. During the winter months, watering should be done after the gap of two days. Weeding and hoeing time varies from soil to soil. Weeding is generally done weekly during the first year of cultivation and at monthly intervals during second and third years of cultivation at both altitudes.

4.3.9. Disease and pest control: At lower altitudes, plants get infected by powdery mildew during early growth period (March–May), which can be controlled by spraying Topsin-M (thiophinate methyl 0.1%) about 15–20 days after initiation, followed by another spray after 15 days. At the time of flowering and seed formation, spraying of insecticide (ecalux, 0.5%) twice at 10-day interval prevents seed loss due to insects and aphids.

4.3.10. Crop maturity and best harvesting period: After completion of the reproductive phase, plant becomes mature for harvesting and contains a high percentage of active contents. Time of completion of reproductive phase depends on the altitude. Generally plants grown in alpine areas complete their reproductive phase during the months of September–October, while plants growing at lower altitudes complete their reproductive phase during the month of September.

4.3.11. Post-harvest management: After harvesting, the stolons and roots are washed to remove soil particles and then dried. Stolons and roots are dried in shade at room temperature (15-25 ^{0}C) which yields high content of picrotin and picrotoxin. Drying in direct sunlight or in oven, decrease the active contents rapidly. After proper drying, the stolons and roots should be packed in airtight polythene lined jute bags to ensure protection from moisture.

4.3.12. Yield and cost of cultivation: Maximum production after three years is about 450 kg/ha that is six or seven times more than that of first year and the maximum production is 612 kg/ha in forest litter treated beds. Cost benefit analysis of *P. kurrooa* cultivation at lower altitude is found suitable for cultivator. Benefit is quite high through cultivation by stolons as compared to seedlings [24].

Tripartite agreement of farmers, industry and HAPPRC

Ghaise is a remote village of Garhwal, situated in Deval block of district Chamoli. A farmer's organization is involved in a public–private partnership with an international firm and HAPPRC. The partnership was initiated by the HAPPRC, which is a well known research centre for alpine medicinal plants. The farmers of Ghaise village had worked earlier with HAPPRC on the cultivation of vegetables. As they had trust in the researchers from HAPPRC, the farmers agreed to start the cultivation of a number of medicinal plants, including *P. Kurrooa* (Kutki). HAPPRC provided planting material free of cost as well as technology and training to farmers. Following the marketing concerns of farmers, HAPPRC also located a company that could provide a guaranteed market for the produce. This resulted in a tripartite arrangement between the farmers group, HAPPRC and Dhawan International, a Delhi-based company (Fig 2).

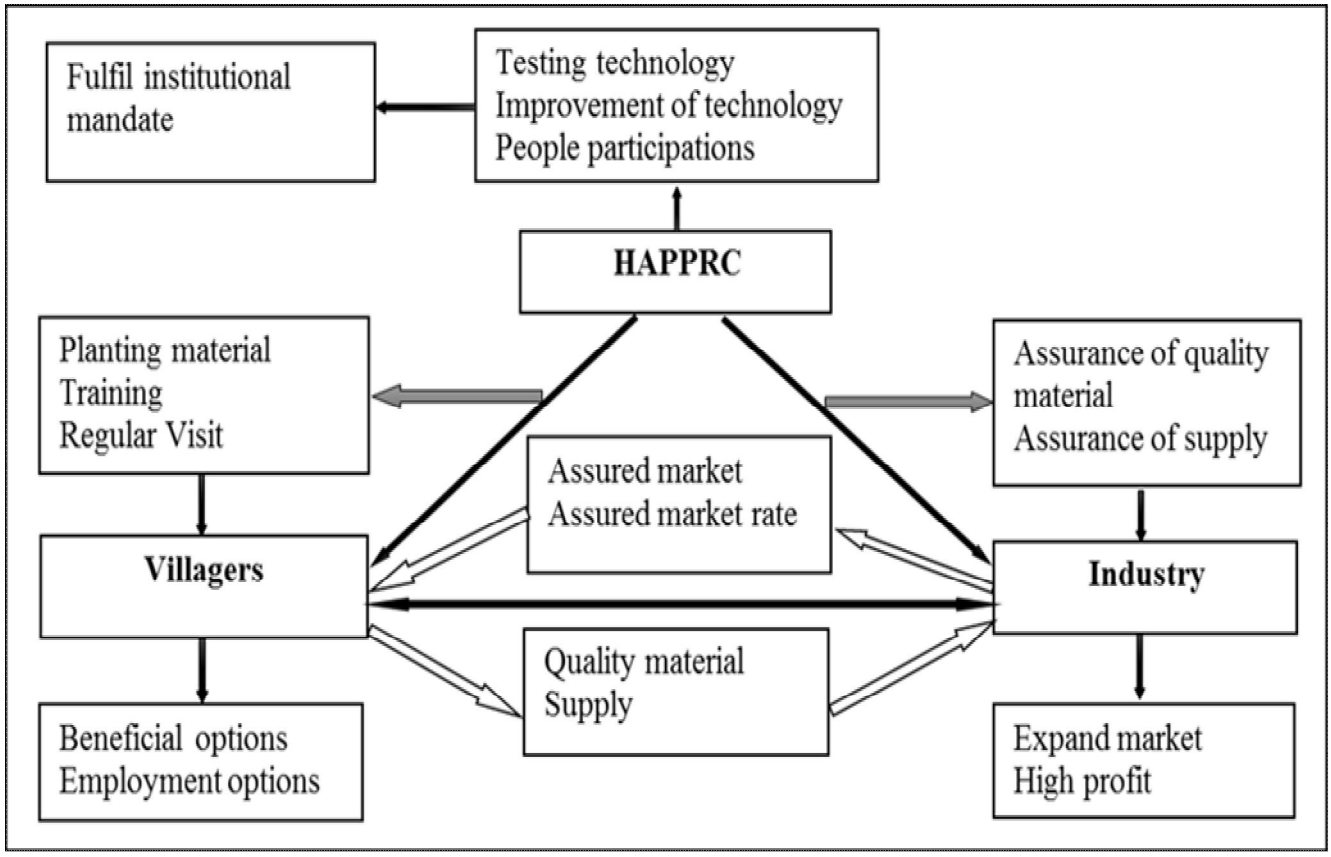

Fig 2: Collaboration features for public–private partnership in Ghaise village (Courtsey: Nautiyal and Nautiyal 2004).

The basic conditions of the agreement are as follows:

1. The farmers are required to sell their produce only to the company. Farmers can ask the company for an advanced loan.
2. The HAPPRC provides technological assistance to farmers to remove any cultivation-related problems and ensure high quality product.
3. The company has the exclusive rights to cultivation based on HAPPRC technology until cultivation covers a minimum area of 50 hectares.
4. HAPPRC is free to transfer the technology to other companies when cultivation extends to more than 50 hectares.

The tripartite agreement has succeeded in removing some of the bottlenecks in the cultivation of medicinal plants. It provided the farmers with an assured market at a pre-agreed price. This greatly reduced the risk faced by the farmers who were also ensured that they will receive planting material, technical support and training from HAPPRC.

6. Consolidation of the scheme launched by HAPPRC

At Ghaise village the average land holding of the farmers is far greater than in other villages. Experts of HAPPRC suggested the farmers that these plots would be the best for cultivation of medicinal plants especially Kutki. Initially 32 farmers signed the agreement, each indicating the area they would dedicate to Kutki cultivation. Out of the 32 farmers, 15 were selected for intensive training, organised by HAPPRC. The training was organised at HAPPRC field nursery at Pothivasa (2200 m asl) in district Rudraprayag, which has been developed as a demonstration cum planting material site, and at alpine field station, Tungnath (3600 m asl). Initially there was a limitation of planting material and hence only five farmers could start cultivation. Nevertheless, within the coming seasons, farmers achieved the desired target through cultivation. Staff of HAPPRC is regularly monitoring the cultivation practices of Kutki at Ghaise.

7. Main lessons from the Ghaise experiment

Ghaise experiment is the first kind of medicinal plant cultivation programme in Uttarakhand. HAPPRC has learnt a lesson from this experiment and encouraged farmers to cultivate Kutki in their fields. As the state government wishes to develop this state as an herbal state, such programmes can play a very crucial role in developing the medicinal plant cultivation sector. Once the farmers experience good returns from harvesting, such a model will easily be replicated as more and more farmers will become interested in cultivating medicinal plants. To continue the extensive work for the promotion of medicinal plants cultivation, HAPPRC gives training and demonstration to the farmers of other nearby villages who are willing to cultivate this species.

8. Role of NGOs in sustainable market supply chain of *Picrorhiza kurrooa*

After the successful experiment of HAPPRC, a number of Non-governmental organisations took the initiatives to promote cultivation of *P. kurrooa* in Garhwal Himalaya. Initially the seedlings of *P. kurrooa* were procured from HAPPRC. These NGOs have achieved the goal by making large scale cultivation possible and most of the farmers agree to continue with cultivation of medicinal plants. Villagers of Ramni at Ghat block in district Chamoli started the cultivation of *P. kurrooa* in 2006. These farmers produced 300 Kg of Kutki which was supplied to an Ayurvedic company "ANKUR" in 2008. Within five years, six other villages with 215 farmers started the cultivation of this species. These farmers produced 12 tons of Kutki annually from the year 2009. Framers obtain planting material and organic manure from "ANKUR" on a cost sharing basis [30].

9. Profit percentage of Kutki through different channels

Chauhan *et al.* [31]., while studying the trade of threatened medicinal and aromatic plants and their conservation issues in Garhwal Himalaya, revealed that volume of collected plants varied from site to site depending on the availability and concluded that the sale of *P. kurrooa* provided highest income of Rs. 34, 98,750 annually. Profit analysis of collectors, local traders and traders varied in different regions with the sale of *P. kurrooa* as shown in Table1 below:

Table 1: Profit percentage of different channels involved in trade of *P. kurrooa* in Garhwal Himalaya (Chauhan *et al*., 2013)

Sites	Categories	Profit Percentage
Dayara	Collector	36.84
	Local trader	-
	Trader	24.46
Har Ki- Doon	Collector	27.77
	Local trader	17.39
	Trader	19.72
Madmaheshwar	Collector	31.11
	Local trader	10.16
	Trader	24.46
Panwali Kantha	Collector	43.67
	Local trader	-
	Trader	29.60
Joshimath	Collector	37.5
	Local trader	36.0
	Trader	26.42
Drug Shop	Wholesaler	12.5
	Retailer	13.63

10. Discussion and conclusion

Medicinal plant species are depleting at a rapid pace due to large-scale, unsustainable collection from their natural habitats. Cultivation and conservation of medicinal plants is important for a number of reasons. Firstly, they are an important source of natural ingredients used by the manufacturers of homeopathy, traditional and modern pharmaceuticals [32]. Secondly, the collection and marketing of medicinal plants from forests is an important source of livelihood and employment for a large number of poor people who lived in or nearby forest areas [33]. Thirdly, medicinal plants are an essential component of biological diversity [33]. The cultivation and conservation of medicinal plants, therefore, is a vital component of efforts to conserve biodiversity [34]. Garhwal Himalaya is endowed with a rich variety of medicinal plants. Government of Uttarakhand has framed a number of policies to promote the cultivation and conservation of important medicinal plants. *P. kurrooa* is an important medicinal plant but it is endangered in Western Himalaya. In addition to a number of government institutions and NGOs, a large number of farmers are involved in the cultivation of Kutki in their fields in Garhwal Himalaya. But farmers face many difficulties related to planting material, irrigation facilities, transportation and trades. Farmers are highly motivated to cultivate Kutki in their fields from the tripartite experience of HAPPRC with farmers and an international company at Ghaise Village in district Chamoli (Garhwal Himalaya). A large number of farmers not only from Ghaise, but also from other villages of Garhwal Himalaya came in contact with HAPPRC and started cultivation of Kutki in their lands. Now-a-days, numbers of organizations are involved in the cultivation of Kutki. "ANKUR" is one of them and is involved in cultivation of Kutki with farmers on cast-sharing basis in Ghat block of Chamoli district. Now, farmers from these villages produce tons of Kutki every year and sell it to traders to fulfil their needs of livelihood. Farmers from these villages now earn lakhs of rupees every year through cultivation of Kutki. But due to this, illegal exploitation of kutki from wild is not stopped completely even though Government of Uttarakhand has made strong laws and acts. The illegal collection and trade of *P. kurrooa* from wild needs to be stopped. If the cultivation sector is improved, agricultural supporting agencies would come forward to strengthen the medicinal plants sector and research institutions would help the plant cultivators by improving their basic knowledge about cultivation practices. Awareness and interest of farmers, supportive government policies, assured markets, profitable price levels, access to simple and appropriate agro-techniques and availability of trained manpower is essential for the successful sustainable cultivation of Kutki for future use.

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