Assessment of germinability, productivity and cost benefit analysis of *Picrorhiza kurrooa* cultivated at lower altitudes

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Cultivation of *Picrorhiza kurrooa* Royle ex Benth, a small creeping, highly medicinal and endangered species of alpine region was observed at comparatively lower altitude than its natural habitat. Germination was observed better inside polyhouse at 15–20°C temperature in sandy soil with litter treatment and high-moisture content. Vegetative propagation was done successfully through stolon segments by using hormonal as well as convenient and simple methods, viz. water-dip treatment and use of high-moisture trenches for rooting in cuttings, which can be easily used for cultivation purpose by local growers. Top segments were found more suitable for multiplication. Yield measured in different landforms, i.e. raised and levelled grounds indicated that the latter was more suitable for better survival, growth and production. Similarly, intercropping with other economically beneficial plants was successfully observed and *Foeniculum vulgare* and *Solanum tuberosum* were recommended for intercropping. Forest litter was observed better for higher production by using broad-leaf variety and maximum production was estimated at Pothivasa (1092 kg/ha). For cultivation of *P. kurrooa*, broad-leaf variety, forest litter treatment, levelled ground and intercropping with plants able to retain moisture in the soil for growing plants, and altitude of 2200 m were endorsed as best for higher production. Cost benefit analysis after third year of cultivation indicated benefits of Rs 87,600/ha based on maximum production. Thus the cultivation of *P. kurrooa* can provide not only an alternate income-generating resource, but can also provide the opportunity for self-employment.

CONSIDERING the increasing demand for herbal drugs in general and Himalayan medicinal plants in particular and consequent depletion of several species, it is imperative to initiate urgent steps for conservation[1]. Indian Himalaya is represented by more than 1748 plant species, of which several are economically very important. In India, 814 plant species have been identified as threatened and of these, over 113 taxa occur in Indian Himalaya[2,3].

The list includes *Picrorhiza kurrooa* Royle ex Benth (Kutki in Hindi), which is considered endangered[2]. Root and stolon of *P. kurrooa* constitute an important drug, out of 2000 drug items derived from vegetable sources[4,5]. Over exploitation and consequent degradation of natural habitat are reported to be a major threat to this plant. Due to narrow distribution range, small population size and high use value, the species figure among the 37 identified as top priority species for conservation and cultivation in Western Himalaya. Beside these facts, the existing information of the species is inadequate, especially with regard to (i) germination under nursery conditions, (ii) survival and production using traditional methods of cultivation and (iii) cost benefit analysis, especially at lower altitudes near the vicinity of villages.

P. kurrooa Royle ex Benth of family Scrophulariaceae is a small, creeping, herbaceous, alpine species represented by two morphological variants in Garhwal Himalaya, viz. narrow leaf and broad-leaf, scarcely occurring between 2800 and 4500 m asl. The former variant is generally found in open pastures and near springs, while the latter is found generally under the shrub and scrub canopy. Information on taxonomy[6–8], ecophysiology and seed germination[9,10] of *P. kurrooa* is available. Medicinal and phytochemical properties are also well-mentioned in the literature[11–14].

P. kurrooa furnishes the drug, picrorhiza, obtained from dried stolons and roots. It is considered to be a valuable bitter tonic, antiperiodic, chalagouge, stomatic, laxative in small doses and cathartic in large doses[11,14]. The plant is used in fever and stomach ache by local inhabitants and its medicinal properties are well-described in the Indian system of medicine.

Keeping in view the increasing demand for *P. kurrooa* as a herbal drug, its assessment as an endangered species in nature, and consequently the need for its cultivation to raise the economy of poor, especially in the Himalayan region, it becomes obligatory to initiate steps for cultivation of this species at lower altitudes, near the vicinity of villages. By doing so, local people will get an option of income generation to improve their livelihood and an opportunity for self-employment. This will allow the plant to grow naturally without any disturbances and ultimately fulfil the conservation goal through cultivation. The present communication attempts to assess the production and cost benefit analysis of *P. kurrooa* cultivation at lower altitudes, multiplication methods and suitable sites for its cultivation.

Keeping in view the availability and accessibility of land near the vicinity of villages, cultivation of *P. kurrooa* was carried out at two locations, viz. Tala (1800 m asl) between 30°31′N lat. and 79°07′E long. and Pothivasa (2200 m asl; Figure 1) between 30°28′N lat. and 79°16′E long. in Rudraprayag district of Garhwal Himalaya, India. The region has submontane climate, with annual maximum temperature reaching up to 35°C (May–June) and minimum temperature below 0°C during winter months, with occasional snowfall. Annual precipitation is between

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345 and 459.5 cm and most of the rainfall was observed during the monsoon period (August–September). The soil of Tala is slightly acidic (pH 5.76–6.73), brownish-black in colour, sandy textured and poor in moisture. Soil organic carbon percentage is very low. Soil of Pothivasa is acidic (pH 4.67–5.01), black and sandy loam in texture with rich organic carbon (1.04–1.23%) and soil moisture. Nitrogen, phosphorous and potassium contents are also higher than those of Tala (Table 1).

These two sites are near the natural habitat of *P. kurrooa* from where the germplasm was brought initially for multiplication. After land preparation through digging or ploughing, manure of livestock i.e. buffalo manure (BM), sheep manure (SM) and forest litter (FL) were added into beds before plantation. Three concentrations viz. 20, 40, 60 kg, described in the text as BM1, BM2, BM3; SM1, SM2, SM3 and FL1, FL2 and FL3 (1, 2, 3 indicate 20, 40 and 60 kg respectively) were placed into $2 \times 2\ m^{-2}$ area plots represented by three replicates of each treatment. Twenty-four seedlings or stolon cuttings were transplanted into each bed represented by aforesaid treatments. Each treatment was examined for survival of plants after rooting, initiation of new leaf and yield after completion of the growth period for three years. Yield was estimated

Figure 1. Cultivation of *Picrorhiza kurrooa* in levelled ground at Pothivasa (2200 m).

on per hectare basis. Cost benefit analysis was calculated on the basis of total output in the form of cash and total investment estimated for one hectare land for site development, fencing, land preparation, labour charges and manure cost for three years.

Seed germinability was tested in different soil compositions and litter treatments. Soil texture classes were determined with soil sieves having meshes of known diameter, corresponding to sand, silt and clay (as proposed by the US Bureau of Soil). Different soil compositions were prepared, viz. sandy soil, sandy loam and silty loam. Further, sandy loam soil was mixed with litter in different ratios (Table 2) to provide additional nutrition for the germinating seeds. To retain moisture for long and avoid water-splash of seeds, trays were covered with a thin layer of moss. For germination study, three replicates each of 24 seeds were sown in styrofoam seedling trays having different soil types as described earlier and kept in polyhouses at Tala and Pothivasa. During the study period, temperatures inside the polyhouse were recorded as 10–26°C at Pothivasa and 15–33°C at Tala, while air temperature for the open environment ranged between 5–15°C in Pothivasa and 5–20°C at Tala. Further, seeds of each species, in three replicates of 24 seeds each, were directly sown in open nursery beds, three of which were covered with moss. Watering was done after every 24-h interval.

For vegetative propagation, stolons brought from nature were divided into top and basal segments of approximately 5 cm size. Three replicates of 24 cuttings of each segment were placed into 100 and 200 ppm solutions of IAA, IBA, NAA and GA_3 for 48 h and transplanted into beds. In another experiment, 24 cuttings of each segment were placed and completely dipped into a pot containing water for 48 h before the plantation. Further, one lot each of top and basal segments was kept under the trenches beneath the soil surface with sufficient moisture (75–85%) for root development. These cuttings were regularly observed for rooting and survival.

Earthing-up experiments were carried out in levelled beds, vertical (bunds along beds) and horizontal (bunds across beds) ground to observe survival and comparative

Table 1. Soil characteristics of both the experimental sites

Site/soil depth	Soil pH	Per cent moisture content	Per cent carbon	Per cent nitrogen	Per cent potassium	Per cent phosphorous
Tala (1800 m)						
0–10 cm	5.76	20.60	0.3198	0.0330	0.0027	0.0176
10–20 cm	6.33	25.48	0.6916	0.0865	0.0035	0.0178
20–30 cm	6.33	24.48	0.0036	0.1730	0.0036	0.0223
Pothivasa (2200 m)						
0–10 cm	4.69	37.44	1.0421	0.0800	0.0024	0.0200
10–20 cm	5.01	32.12	1.0029	0.2315	0.0033	0.0680
20–30 cm	4.67	34.20	1.2383	0.0415	0.0024	0.0073

production at both sites. For intercropping, *Solanum tuberosum* (potato) and *Foeniculum vulgare* (saunf) were selected. Intercropping with potato was done by using raised beds for the crop of potato and *P. kurrooa* seedlings were planted between vertical bunds at 10 cm distance. Saunf was planted at 2 feet distance and *P. kurrooa* was planted between saunf plants.

Since the species is endangered in status, availability of multiplication material from nature is an arduous task. Germination study of seeds of *P. kurrooa* was undertaken at Tala and Pothivasa inside the polyhouse, to provide favourable temperature and moisture regime and also in open beds, to raise sufficient seedlings for cultivation. Sandy loam, textured soil was found to be the best for germination and maximum germinability was recorded up to 48% and 54% respectively, at Tala and Pothivasa, after the addition of forest litter. Since the sandy soil is loose-textured, it has less perturbance pressure on germinating seeds, particularly in case of small and delicate seeds like that of *P. kurrooa*. Further, to retain moisture and to avoid water-splash of the seeds sown, a thin layer of moss was placed at the surface, which enhanced the seed germinability up to 52% and 58% at these two sites inside the polyhouse. Germination started within 8–9 days and was completed after 16–18 days. Earlier, Nautiyal[10] observed germination within 3–10 days in laboratory conditions by using hormonal, light and dark treatments. True leaf initiated after 12 days of germination. However, seed germination was very low in open beds at both sites and germination as well as first leaf initiation were also delayed, but moss cover slightly increased the percentage of germination (Table 2). Low germinability in open beds may be either due to water-splash or low temperature.

Stolon segments were observed to be most successful for multiplication as well as for higher production within a short period, than cultivation through seeds (Figure 2). Top segments of stolon showed better response, i.e. rooting and survival of new plantlets. When treated with growth hormones, unlike other plants, rooting was observed to be very poor in all segments treated with IBA. GA_3- and IAA-treated top segments showed more than 90% rooting. Water-dip treatment for 48 h also showed more than 90% rooting in top segments of the stolon, though rooting was delayed by 2–3 days. All these observations were made in open beds at Tala and Pothivasa (Table 3). Similarly, when cuttings were kept under soil in trenches or covered with moss with high-moisture content, 90% rooting was observed in top segments after 2 weeks. Basal segments which have less potential for rooting, can be harvested and sold in the market.

Table 2. Germination studies of *P. kurrooa* in polyhouse and open nursery bed

Condition/Treatment	Per cent germination	Days required for onset of germination	Days required for completion of germination	Days required for initiation of true leaf
Tala (1800 m)				
Polyhouse				
Sandy soil	23.00 ± 6.15	8	16	8 ± 2.15
Sandy loam soil	25.00 ± 4.25	8	16	9 ± 3.00
Sand: silt: clay				
1 : 1 : 1	15.00 ± 4.33	9	17	8 ± 2.00
Sandy loam: litter				
1 : 1	45.00 ± 6.13	8	17	7 ± 1.00
1 : 2	48.00 ± 3.33	8	16	9 ± 3.00
Sandy loam soil (moss covered)	52.00 ± 3.15	9	17	9 ± 3.33
Nursery bed				
Open beds	5.00 ± 2.33	15	20	12 ± 4.33
Open beds (moss covered)	20.00 ± 5.52	14	20	12 ± 5.00
Pothivasa (2200 m)				
Polyhouse				
Sandy soil	25.00 ± 3.23	9	17	8 ± 2.00
Sandy loam soil	29.00 ± 3.15	8	16	9 ± 1.00
Sand: silt: clay				
1 : 1 : 1	12.00 ± 2.25	7	17	7 ± 0.93
Sandy loam: litter				
1 : 1	45.00 ± 6.15	7	17	9 ± 3.00
1 : 2	54.00 ± 6.15	9	18	12 ± 4.15
Sandy loam soil (moss covered)	58.00 ± 3.46	8	17	12 ± 4.15
Nursery bed				
Open beds	5.00 ± 2.15	16	22	13 ± 50
Open beds (moss covered)	29.00 ± 3.13	15	20	12 ± 5.0

(± Standard deviation).

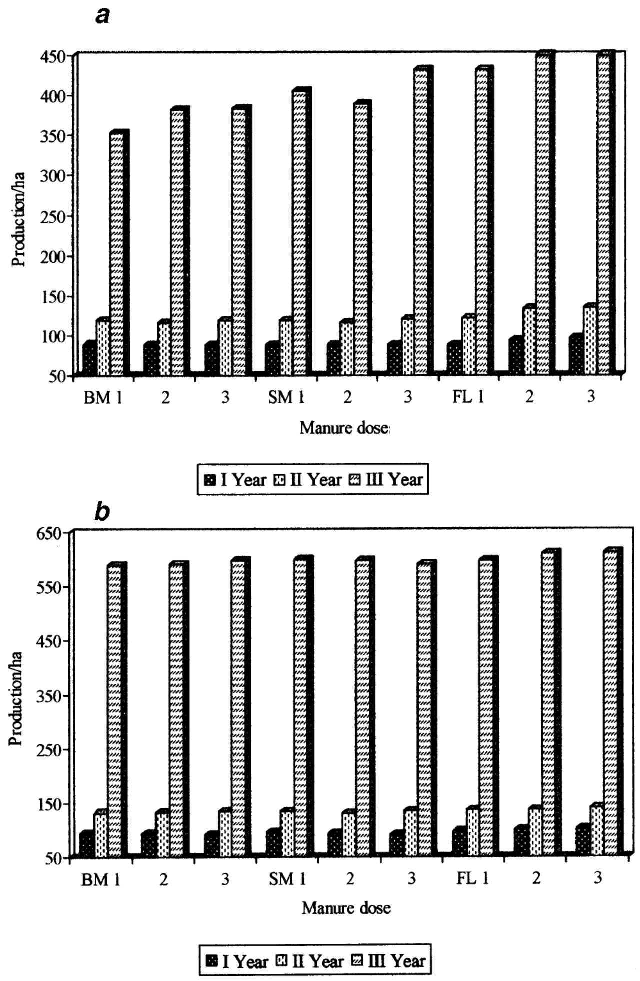

Figure 2. Production/ha of *P. kurrooa* raised from seedlings after treatment with farmyard manure and forest litter at Tala (***a***) and Pothivasa (***b***) during three years of growth. 1, 2 and 3 stand for 20, 40 and 60 kg treatments of BM–buffalo manure, SM–sheep manure and FL–forest litter.

Earthing-up experiments were carried out for transplanted seedlings at both sites for three years (Table 4). Levelled ground and horizontal bunds gave maximum production. However, mortality rate of seedlings was higher in the latter than in the former. Unlike natural conditions (Nautiyal[9]), vertical bunds were not found suitable for *P. kurrooa* cultivation, particularly at lower elevation (Tala) where soil texture was dominated by sand. During rainy season or at the time of watering, the soil was splashed from raised beds and hence increased the mortality rate of plants. Further, levelled ground gave more production (315.33 kg/ha) at lower altitudes and maximum production was obtained at Pothivasa in levelled ground. Cultivation in levelled ground at Pothivasa is shown in Figure 3. These experiments were carried out to examine the effect of raised beds on plant survival and production without any manure treatment.

Potato is generally grown in the area as a cash crop and cropping with *F. vulgare* may provide a potent source of extra income-generation. Keeping this in view, intercropping of *P. kurrooa* with potato and saunf was carried out at Tala (Table 4). Although growth of transplanted seedlings of *P. kurrooa* was fast with both species, mortality rate was higher with potato, specially at the time of potato harvesting and hence decreased the production. Contrary to this, intercropping with saunf had better production, which provides suitable microclimate to growing plants of *P. kurrooa* by providing moisture for a long time under its canopy. Production with *F. vulgare* was obtained up to 320 kg/ha harvested during the third year. Further, addition of manure and litter increased the production in this experiment as described next in this article.

Survival and production were observed under different manure and forest litter treatments separately for seedlings (Figure 2) and through vegetative propagation by stolon cuttings (Figures 2–3). To estimate the production for three years, broad-leaf and narrow-leaf variants were observed separately for comparative production at both sites. Survival of seedlings transplanted was found to be 40–60% at Tala and 50–75% at Pothivasa, in general, under different manure and litter treatments (BM1–FL3). However, mortality rate was high and production was low in beds treated with SM and BM during the first year. These beds needed excessive watering/irrigation to decrease the mortality rate. Powdery mildew also appeared in plants grown in these beds during early spring. Production by seedlings during the first year was highest from the fields treated with high FL doses. Total production on dry weight basis for root and stolon was estimated between 88.8 and 97.20 kg/ha at Tala and 91.20 and 102.24 kg/ha at Pothivasa. High production values corresponded to higher litter dose-treated beds (Figures 2–4). During the second year, a similar trend was observed for all treatments with less than 40% increase in total production and production exhibited significant increase, especially in FL3-treated beds ($r = 98$, $P > 0.01$) at Tala and ($r = 69$, $P > 0.01$) with 48% variation in production of the first year at Pothivasa. Further, on the basis of ANOVA, variation in production was found significant within the same treatment (i.e. BM, SM or FL) with different doses ($F = 3.36$ at Tala and $F = 12.31$ at Pothivasa) and also with similar doses of BM, SM and FL with $F = 8$ and 0.25 (F critical value = 161.44) at these two sites. During the third year, plants began to produce new plantlets/stolon at the rate of approximately 1.5/seedling at Tala and 2/seedling at Pothivasa. During this period, production was observed to be 3–5 times greater than that during the first year under the aforesaid treatments. At Tala, maximum production of 450 kg/ha was obtained and at Pothivasa, production was 6–7 times greater than that for the first year and a maximum of 612 kg/ha production was estimated from high doses of litter (FL3)-treated beds. However, productivity increased significantly ($r = 99$, $P > 0.01$, $r^2 = 99\%$) at Pothivasa from first to third year in all FL-treated beds (FL1, FL 2 and FL3).

Production on yearly basis, of crop raised from vegetative propagation through stolon cuttings of broad and narrow variants, was seen to be economically beneficial within three years. Production of narrow leaf *P. kurrooa* ranged from 792 to 864 kg/ha at Tala and 940.80 to 1008 kg/ha at Pothivasa during the third year, where maximum production again corresponded to beds treated with forest litter (FL1, FL2 and FL3). The increment was strongly significant in these treatments ($r = 1$, $P > 0.01$) from first to second year ($r = 98$, $P > 0.01$) and with 96% variation during the third year than during the first and second years. The rate of increment of production during the second and third years was higher than the production obtained from seedlings. More than 50% increment was observed during the second year, which further increased up to more than 3.5 times during the third year. During the second and third years, approximately 1.5 to 3 new plants were produced from the old ones at Tala. The rate of new plant emergence/formation of new stolon from previous year's plant was approximately 2 during the second year and 3.5 during the third year, which further increased the total yield. Emergence of new plants from previous year's transplanted cuttings was similar to that of narrow-leaf variety at both sites during the second and third years. The production from broad-leaf variety ranged from 900 to 932.4 kg/ha at Tala. Maximum production in all treatments and at both sites was estimated to be 1092 kg/ha (FL3, $r = 99$, $r^2 = 99$, $P > 0.01$) at Pothivasa. In general, high production was noted in all treat-

Table 3. Response of growth hormone, water treatment and moisture regime under soil on rooting and survival of stolon cuttings

		Top segment		Basal segment	
Treatment	No. of cuttings	Per cent survival	Days required for rooting	Per cent survival	Days required for rooting
Control	24	40.25 ± 2.3	12	39.07 ± 1.6	12
IAA					
100 ppm	24	95.8 ± 2.5	9	12.5 ± 0.55	10
200ppm		90.2 ± 4.4	9	2.7 ± 0.52	10
IBA					
100 ppm	24	40.2 ± 3.7	8	0.0	–
200 ppm	24	36.1 ± 2.5	10	9.7 ± 0.75	11
NAA					
100 ppm	24	84.7 ± 2.0	10	27.7 ± 1.0	11
200 ppm	24	75.0 ± 1.9	10	0.0	–
GA3					
100 ppm	24	95.0 ± 3.1	10	29.0 ± 4.0	11
200 ppm	24	90.0 ± 3.3	9	10.0 ± 3.3	12
Water dipped (48 h)	24	90.0 ± 5.0	10	30.1 ± 1.3	12
Under soil trenches	24	90.0 ± 2.0	12	25.5 ± 3.3	15

Table 4. Survival and production under different earthing-up and intercropping patterns (on the basis of production obtained from 3-year-old seedlings)

	Tala (1800 m)		Pothivasa (2200 m)	
Cropping pattern/site	Per cent survival	Production (kg/ha)	Per cent survival	Production (kg/ha)
Earthing-up				
Levelled ground	60	315.33 ± 55.33	70	398.15 ± 28.13
Vertical bunds (across the beds)	45	295.23 ± 63.12	55	345.33 ± 56.00
Horizontal bunds (along the beds)	55	302.12 ± 68.33	60	389.60 ± 39.33
Intercropping				
With *Solanum tuberosum*	50	296.85 ± 96.00	–	–
With *Foeneculum vulgare*	65	320.00 ± 48.45	–	–

ments at Tala and Pothivasa in the third year, from broad-leaf variety. Comparatively, highest production was noted from the fields treated with FL3 at Pothivasa.

Production of *P. kurrooa* has been worked out as discussed earlier through seedling and vegetative methods at two altitudes (Tala and Pothivasa). Total investment, including land preparation, fencing, labour and manure charges and post-harvesting cost was calculated. Cultivation cost was slightly higher for Tala since at this elevation, plants of *P. kurrooa* need more irrigation and care. Total cost for fencing and land preparation, including irrigation facilities was estimated as Rs 30,000, manure cost as Rs 900 for each year and post-harvesting cost, including harvesting and packing as Rs 2120. Labour charges (@ Rs 60 per day) were estimated on the basis of 6,5 and 3 days/month for Tala and 5,4 and 3 days/month for Pothivasa during the first, second and third year respectively. These values are the cost of cultivation carried out in one hectare land. Total benefit was analysed on the basis of total investment during cultivation and present market cost (Rs 120/kg) for maximum production observed from both sites (Table 5). Benefit was quite low during the third year, when cultivation was done by seedlings at Tala (Rs 9100). Production through seedlings at Pothivasa was higher than that at Tala and total benefit was Rs 30,060 during the third year. Cost benefit was nearly Rs 20,000 when narrow-leaf variety was grown at Pothivasa, in comparison to Tala. Maximum benefit was estimated Rs 87,660 in the third year, with maximum production from broad-leaf variety in FL3-treated fields at Pothivasa. Total benefit and maximum production at Pothivasa were similar to those from a previous analysis[10] in natural conditions. In general, cultivation of *P. korrooa* at 1800–2200 m altitude was found economically beneficial from seedlings as well as from narrow- and broad-leaf varieties, though benefits were different in different treatments at the two sites and also depended on methods of multiplication.

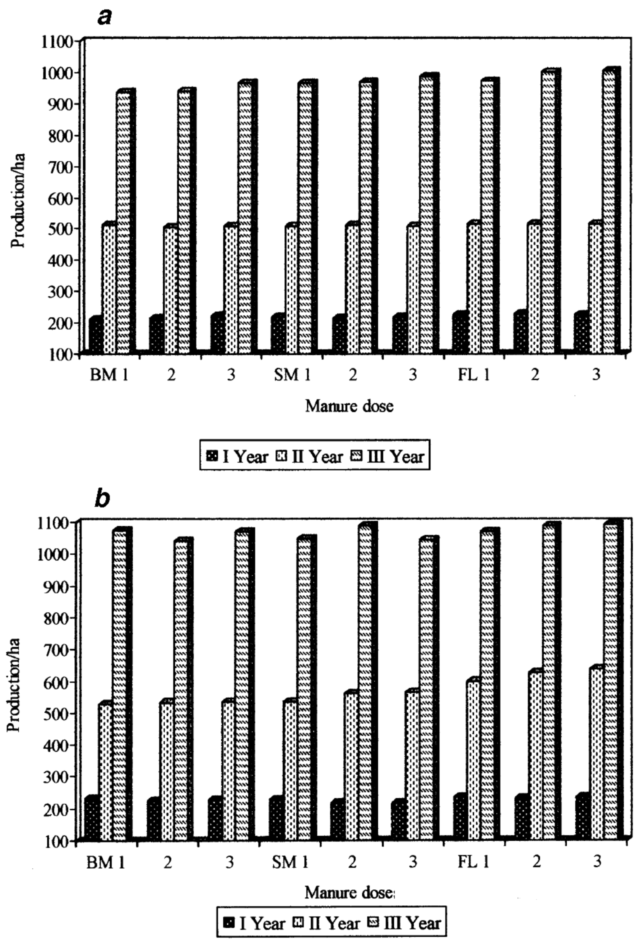

Figure 3. Production/ha of two varieties of *P. kurrooa*; ***a***, narrow leaf; ***b***, broad leaf, using different doses of farmyard manure and forest litter at Pothivasa during three years of growth using vegetative propagation. 1, 2 and 3 stand for 20, 40 and 60 kg treatments of BM – buffalo manure, SM – sheep manure and FL – forest litter.

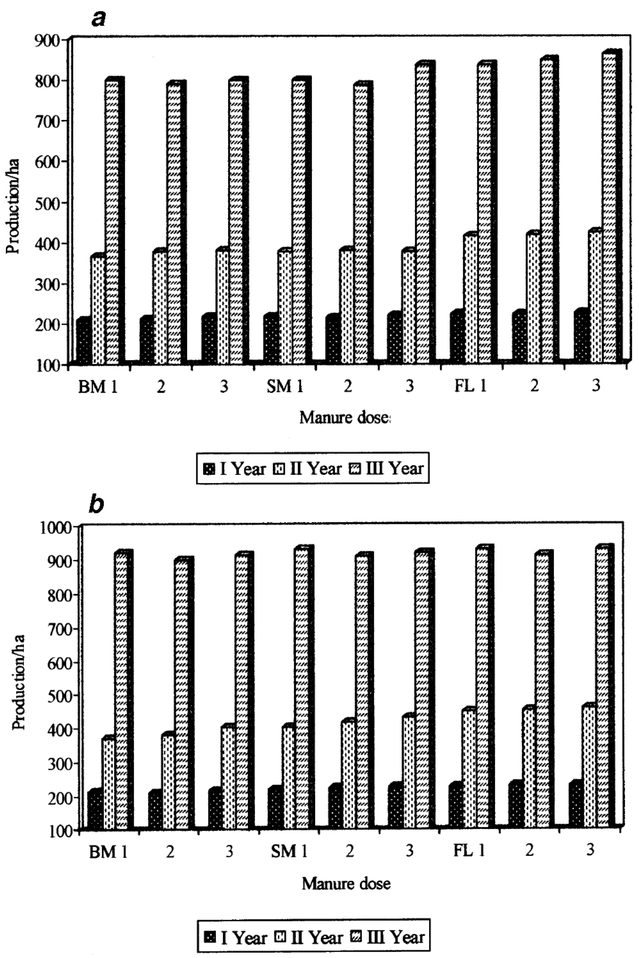

Figure 4. Production/ha of two varieties of *P. kurrooa*; ***a***, narrow leaf; ***b***, broad leaf, using different doses of farmyard manure and forest litter at Tala during three years of growth using vegetative propagation. 1, 2 and 3 stand for 20, 40 and 60 kg treatments of BM – buffalo manure, SM – sheep manure and FL – forest litter.

Table 5. Cost benefit analysis of *P. kurrooa* cultivated at two sites after 3 years of growth

Location	Cropping pattern	Total investment (Rs)	Total production (kg/ha)	Total income (@ Rs 120/kg)	Benefits (in Rs)
Tala	From seedling	44,900	450.00	54,000	9,100
	From stolon cuttings				
	Narrow leaf	44,900	864.00	1,03680	58,780
	Broad leaf	44,900	932.40	1,11880	66,980
Pothivasa	From seedling	43,380	612.00	73,440	30,060
	From stolon cuttings				
	Narrow leaf	43,380	1008.00	1,20960	77,580
	Broad leaf	43,380	1092.00	1,31040	87,660

On the basis of the above observations, the following facts are endorsed for cultivation of *P. kurrooa*. (1) To raise maximum seedlings, polyhouse conditions, sandy loam soil covered with moss layer with higher moisture and 15–20°C temperature are optimum conditions. Germination is fast and the first leaf emerges within 15 days without any hormonal treatment and can be adopted easily by local growers and farmers. (2) For vegetative propagation, top segments of stolon are suitable. Besides GA_3 and IAA treatments, water-dip treatment for 48 h was found suitable for survival and rooting (more than 90%) of stolon segments. Maximum rooting can be obtained by keeping cuttings into trenches covered with soil or moss having high-moisture content, although rooting is delayed by 2 weeks in this method; but it is very simple and convenient to growers. (3) Levelled beds with proper drainage system are suitable for cultivation of *P. kurrooa* at lower altitudes in sandy soil. (4) Intercropping with saunf was found suitable for growth and production. By adding forest litter or farmyard manure, productivity can be increased. Further, several species which retain moisture under their canopy for a long time, e.g. *Digitalis purpurea*, which is biannual and can provide alternate source of income within short periods, can be intercropped with *P. kurrooa*.

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