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Standardization of Cultivation Practices of Kod (Kutaki, *Picrorhiza kurroa* Royle ex Benth.): An Endangered Medicinal Plant Species of Kashmir Himalaya, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Picrorhiza kurroa Royle ex Benth (Scrophulariaceae) is a small creeping herbaceous alpine species commonly known as Kod or Kutaki, used by local and tribal people for curing fever, asthma, jaundice, stomach ache, indigestion, common fever and bronchial asthma. This has resulted in the loss of biodiversity of the species. Roots of *P. kurroa* have been used in traditional medicine for years for treating various kinds of diseases. The species has been ruthlessly harvested from the wild source and has become endangered. In the present investigation, an attempt was made to standardize the cultivation practices using organic manures and inorganic fertilizers in *P. kurroa*. The experiment comprised of 28 treatments **{**$M_1P_0N_0$, $M_1P_0N_1$, $M_1P_0N_2$, $M_1P_1N_0$, $M_1P_1N_1$, $M_1P_1N_2$, $M_1P_2N_0$, $M_1P_2N_1$, $M_1P_2N_2$, $M_2P_0N_0$, $M_2P_0N_1$, $M_2P_0N_2$, $M_2P_1N_0$, $M_2P_1N_1$, $M_2P_1N_2$, $M_2P_2N_0$, $M_2P_2N_1$, $M_2P_2N_2$, $M_3P_0N_0$, $M_3P_0N_1$, $M_3P_0N_2$, $M_3P_1N_0$, $M_3P_1N_1$, $M_3P_1N_2$, $M_3P_2N_0$, $M_3P_2N_1$, $M_3P_2N_2$ and $M_0P_0N_0$} with three replications each, including one control treatment. The dry root weight recorded by the application of poultry (20 tonnes ha^{-1}), sheep (25 tonnes ha^{-1}) and farm yard manure (25 tonnes ha^{-1}), was 533.60, 509.60 and 476.70 kg ha^{-1}, respectively. Dry root yield increased significantly with increasing levels of phosphorus (453.6 to 550.4 kg ha^{-1}), and nitrogen (444.8 to 565.6 kg ha^{-1}) as well. Application of organic manure and higher levels of inorganic fertilizers resulted in increase in the root weight with maximum dry root biomass of 640.00 kg ha^{-1} was observed in treatment M_1 P_2 N_2 (20 tonnes of PM, 100 kg P and 150 Kg N ha^{-1}) compared to the lowest dry yield of 328.0 kg ha^{-1} as observed in control treatment $M_0P_0N_0$ (zero tonnes of FYM, 0 kg P and 0 kg N ha^{-1}), although the effect of their interaction was non-significant. It is concluded that highest dry weight of root (692.80 kg ha^{-1}) in *P. kurroa* was obtained by the application of phosphorus @ 100 kg ha^{-1} as compared to various organic manures or/different levels of nitrogen used and among the organic manures used *viz.* poultry, sheep and farmyard manure, the highest root biomass of 533.60 kg ha^{-1} was recorded by the application of poultry manure. Since the species in Kashmir Himalayan region is endangered but has high commercial demand, hence immediate conservation measures are needed to protect the species from extinction.

Keywords: Morphological parameters; nitrogen; organic manure; phosphorus; root weight.

1. INTRODUCTION

"Medicinal plants are the most important source of life saving drugs for the majority of the world's population" [1]. They enjoy an inherent and prominent role in general health services of the people. Of the 1814 threatened plant species in India, over 113 taxa occur in Indian Himalaya and the list includes *P. kurroa* as an endangered species [2,3]*. P. kurroa* Royle ex Benth is a small creeping herbaceous alpine herb. The species is represented by two morphological variants *viz.* narrow leaf and broad leaf varieties [2] scarcely occurring between 2,800 to 4,500 meter above mean sea level (amsl). In India, the crude drug, Kutaki, is being used to treat dyspepsia, respiratory disorders, and diseases of the liver and spleen, including jaundice, cirrhosis, anaemia, hemorrhoids, dermatoses, and helminthiasis. Its root shows aantifungal activity by inhibition of the dermatophytic fungi [4-13]. A new iridoid, picuroside was isolated from roots of *P. kurroa* [14]. Picroside-I is a major active constituent of picroliv, a hepatoprotective agent [15,16]. The picroliv has significan effect in prevention of liver injury associated with aflatoxin [17,18]. An alcoholic extract of *P. kurroa* possesses anti-oxidant and anticancer and activity [19-21]. Being a hepatoprotective plant [3] *P. kurroa* has been subjected to heavy collection from the wild due to its ever-increasing demand. Further Anthropogenic activities have impact on physico-chemical properties of plant, water as well as on sediment [22-24]. The rate of exploitation of this medicinally important plant species exceeds the rate of regeneration under natural habitat conditions. This implies that immediate measures be adopted for its biodiversity conservation. So, the present study on cultivation practices of the species were carried out at lower altitude using different types of organic manures and inorganic fertilizers in order to investigate their effect on the root biomass and other morphological attributes of the plant.

2. MATERIALS AND METHODS

The trial was laid at the farmer's field during 2018-2019 under the supervision of Principal author, Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir, Shalimar, Jammu and Kashmir, India Figs. 1 and 2. "The crop was planted in split-split plot design with three replications each on an area of 400 m^2 which includes main and sub irrigation channels and path in between beds. Organic manures viz. poultry manure (M_1, 20 tonnes ha^{-1}), sheep manure (M2, 25 tonnes ha^{-1}) and farmyard manure (M3, 52 tonnes ha^{-1}) were used as the main factors. Three levels each of phosphorus (P_0 = 0, P_1 = 50 and P_2 = 100 kg ha^{-1}) and nitrogen (N0 = 0, N1 = 100 and N2 = 150 kg ha-1) were used as sub and sub-sub factors, respectively. Potassium was applied with a constant level of 50 kg ha^{-1}. Stolon cuttings were planted in the month of April. Half of the recommended dose of urea (nitrogen source) and the whole dose of di-ammonium phosphate (phosphorus and nitrogen source) and Murat of potash (potassium source) were applied at the time of planting. Out of remaining dose of nitrogen, one-fourth dose was applied (in the form of urea) at the time of the first hoeing {(30 days after transplanting (DAT)} and the remaining one-fourth was applied at the time of the 2nd hoeing (64 DAT). Standard package and practices were adopted for raising the healthy crop" [10]. Various pre-harvest {(plant height (cm), plant spread (sq. cm), petiole length (cm), number of leaves, leaf area (squared centimeter), number of inflorescences $plant^{-1,}$ length of the inflorescence (cm) and number of branches/shoots $plant^{-1}$} and post-harvest {root length $plant^{-1}$ (cm), number of roots plant-1, diameter of root plant-1 (cm) and root weight (dry weight of the root) plant-1} observations were recorded in two year old crop during growing season.

Statistical analysis: The data on various observations collected was subjected to statistical analysis of variance as detailed by Cochran and Cox (1960) for split-split plot design. The significance of the treatment effects was estimated with the help of F-test at 5 and 1% level of significance.

3. RESULTS AND DISCUSSION

3.1 Effect of Organic Manure on Various Yield Determining Characters of *P. kurroa*

The soil of the experimental field was of clay-loam type (Table 5). Nutrient content of FYM, sheep and poultry manure was also estimated before laying of trial (Table 6). Application of organic manure had significantly a positive ($p <$ 0.05) influence on plant height, petiole length, number of leaves, length of inflorescences, dry weight of root and root length $plant^{-1}$ (Table 1). Tallest plants (22.74 cm) and maximum number of leaves (108.07), dry weight of root and root length (10.18 cm) $plant^{-1}$ were observed in treatment M_1 as compared to smaller sized plants (19.03 cm), least number of leaves (84.07), dry weight of root (5.97 g) and root length $plant^{-1}plant^{-1}$ in control treatment (M_3). However, maximum length of inflorescences (6.97 cm $plant^{-1}$) was obtained in treatment M_3 compared to the least length of inflorescences (6.42 cm $plant^{-1}$) observed in treatment M_1. With respect to plant height, Treatments M_1 and M_2 were at par with each other but treatment M_1 was statistically different from M_3 which in turn was at par with treatment M_2. All the treatments M_1, M_2 and M_3 were at par with each with respect to petiole length. However, with respect to number of leaves, length of inflorescences, and root length $plant^{-1}$ treatment M_1 was statistically different from treatments M_2 and M_3, while as the latter two treatments were at par with each other. In case of dry root weight all the treatments M_1, M_2 and M_3 were statistically different from each other.

Application of organic manure was not having positive influence on plant spread, leaf area, number of inflorescences, number of shoots, and number of roots and diameter of root $plant^{-1}$ However, maximum plant spread (407.96 sq.cm $plant^{-1}$) was observed in treatment M_2 and least (399.77 sq. cm $plant^{-1}$) in treatment M_1, maximum leaf area $plant^{-1}$ (426.77 sq. cm) was obtained in the treatment M_1 and the least (411.11 sq. cm) in control. The data on number of inflorescences $plant^{-1}$ remained by and large same in all the three treatments *viz.* M_1, M_2 and M_3. Highest of number of shoots (12.33) and roots (36.81) $plant^{-1}$ were observed in treatment M_3 and the least number of these parameters (12.11) and (31.77) in treatment M_1. However, maximum diameter of 1.14 cm of root $plant^{-1}$ was recorded in treatment M_1 and the least of 1.00 cm in control (Table 1). Jahan et al. [8] also showed that consuming 30 tonnes/ha manure can increase sub- branches of chamomile (*Matricaria chamomilla* L). The difference in dry weight of root $plant^{-1}$ between M_1 and M_3 treatments was 0.70 g and between M_1 and M_2 treatments it was only 0.30 g. It seems that the poultry manure had an obvious impact on increasing the dry weight of root $plant^{-1}$ compared to sheep or FYM. As there were only minor differences in diameter of root $plant^{-1}$ among various treatments. This is

Table 1. Effect of organic manure, phosphorus and nitrogen on various morphological characters of *Picrorhiza kurroa*

Character	Main treatment (M)				Sub treatment (P)				Sub-sub treatment (N)			
	M_1	M_2	M_3	LSD (5%)	P_0	P_1	P_2	LSD (5%)	N_0	N_1	N_2	LSD (5%)
Plant height (cm)	22.74	20.62	19.03	2.50*	18.18	20.81	23.40	1.43**	17.14	21.00	24.25	1.64**
Plant spread (sq. cm)	399.77	407.96	401.88	NS	356.77	420.59	432.25	27.17**	344.44	441.40	423.77	49.11**
Petiole length leaf $^{-1}$ (cm)	1.07	0.97	1.11	0.06**	0.92	1.12	1.11	0.10**	0.96	1.04	1.15	0.06**
No. of leaves plant^{-1}	108.07	87.00	84.07	14.72**	72.37	96.85	109.92	14.23**	74.33	88.96	115.85	14.50**
Leaf area plant^{-1} (sq. cm)	426.77	420.33	411.11	NS	361.88	445.00	451.33	39.54**	313.33	433.44	511.44	25.35**
No.of inflore-scence plant^{-1}	9.66	10.11	10.22	NS	8.6666	10.66	10.66	1.17**	9.44	10.33	10.22	NS
Length of inflorescence (cm)	6.42	6.96	6.97	0.02**	4.99	6.51	8.85	0.08**	5.97	6.79	7.58	0.07**
No. of shoots plant^{-1}	12.11	12.25	12.33	NS	10.81	13.00	12.88	1.24**	11.66	12.37	12.66	NS
roorBiomass/Dry weight of root plant^{-1} (g)	6.67	6.37	5.97	0.27**	5.67	6.46	6.88	0.55**	5.56	6.38	7.07	0.66**
Root length plant-1 (cm)	10.18	8.37	8.29	1.50*	9.92	8.29	8.62	NS	9.44	9.07	8.33	NS
No. of roots plant^{-1}	36.81	34.55	31.77	NS	27.22	34.66	41.25	3.12**	28.33	35.00	39.81	4.21**
Diameter of root plant^{-1} (cm)	1.14	1.00	1.01	NS	0.91	1.07	1.16	0.17*	0.90	1.07	1.17	0.15**

*{Poultry manure (M1) (20 tonnes ha^{-1}), sheep manure (M2) (25 tonnes ha-1) and farmyard manure (M3) (25 tonnes ha-1): Phosphorus (P0=0, P1= 50 and P2= 100 kg ha-1) and Nitrogen (N0 = 0, N1 = 100 and N2 = 150 kg ha-1): LSD = Least significant difference, Non-significant (ns), *Significant at 5% level, **Significant at 1% level*

because organic matter uptake can increase soil nutrition content and its absorbing capacity and at the same time, it enhances nitrogen equilibrium and phosphorous absorption efficiency [25]. However, the effect was non-significant for plant height, petiole length, number of leaves, inflorescences and number of roots.

3.1.1 Effect of organic manure on root biomass or dry root yield (kg ha^{-1})

The organic manure comprised of three different manures *viz.* poultry, sheep and farmyard manure. The dry weight of root was significantly affected by the application of poultry sheep and farmyard manure. All the treatments were statistically different from each other. The dry weight of root recorded by the application of poultry, sheep and farm yard manure was 533.60, 509.60 and 476.70 kg ha^{-1}, respectively. Application of poultry manure produced 24.00 and 56.90 kg ha^{-1} more yield over the sheep and farm yard manure (Table 3). The increase in root yield was the cumulative effect of the yield attributes (leaf area, number of branches, diameter of root and root length). The high response of *P. kurroa* in terms of root yield may be attributed to additional nutrients supplied through poultry manure. As the use of organic manure improves the water-holding capacity in the soil and the production of plant growth regulators and leads to improved crop growth and yield. Similar results have also been observed by Nautiyal et al*.* [5] while working with *P. kurroa* wherein they got more yield of root in forest litter treated beds compared to buffalo and sheep manure treated ones.

3.2 Effect of Inorganic Fertilizers on Various Yield Determining Characters of *P. kurroa*

3.2.1 Effect of phosphorus on various yield determining characters of *P. kurroa*

Phosphorus had a highly significant ($p < 0.01$) effect on all morphological features except root length plant^{-1} (Table 1). Maximum plant height (23.40 cm), plant spread (432.25 sq. cm), number of leaves (109.92), leaf area (451.33 sq. cm) and all other morphological traits except root length plant^{-1} were obtained in treatment P_2 as compared to the least height (18.18 cm), spread (432.25 sq. cm), number of leaves (72.37), leaves, leaf area (361.88 sq. cm) and all other morphological traits in control treatment. (Table 1). However, the highest root length plant^{-1} (9.92cm) was observed in control treatment (P_0) and the least (8.62 cm) in treatment P_2 (Table 1). With respect to plant height, length of inflorescences and number of roots plant^{-1} all the treatments were statistically different from each other. With respect to plant spread, petiole length, number of leaves, leaf area, number of inflorescences, number of shoots and root biomass and diameter of root plant^{-1},treatments P_1 and P_2 were at par with each other but were statistically different from control treatment (Table 1).

3.2.2 Effect of phosphorus on root biomass (kg ha^{-1})

The dry weight of root increased significantly with every successive level of phosphorus i.e. from 50 to 100 kg ha^{-1}. The increase in yield of root due to 50 and 100 kg phosphorus ha^{-1} was in the order of 63.20 and 239.20 kg ha^{-1}, respectively over 0.0 kg of phosphorus level (control) (Table 3). The root yield obtained at 50 and 100 kg of phosphorus was statistically different from the yield obtained at 0.0 kg phosphorus ha^{-1}. The increase in root yield may be due to the positive influence of phosphorus on various yield determining characters (Table 1). As phosphorus is an important part of proteins and phospholipids and might be playing an important role in enhancing the metabolic activities of the plant. "Increase in root yield seems to be a reflection of favourable influence of phosphorus on important yield attributes like plant height, plant spread, leaf area, root length and root diameter. Proper nutrition of plants is an important factor in determining their performance. Phosphorus being a macronutrient plays a vital role in plant growth and development" [25]. "Thus higher phosphorus levels seem to have helped in increasing the crop growth by the improvement of yield attributes. Similar results were obtained by other workers while working with *Salvia miltiorrhiza* and *Rheum austrae"* [25, 26]. In a similar way, Ombodi and Saigusa (2000) reported that "fertilizer treatments improve the nutritional quality of rhubarb. They also reported that the improved nutritional quality in the polyofelin-coated diammonium phosphate (POC-DAP) treatment was a cause of ammonium nutrition rather than a cause of less amount of released nitrogen".

3.2.3 Effect of nitrogen on various yield determining characters of *P. kurroa*

Height of the plants showed a significant ($p < 0.01$) linear increase with increasing levels of nitrogen. Similar was the case with plant spread, petiole length, number of leaves, leaf area, length of inflorescences, dry weight of root, number of roots and diameter of root plant^{-1}. However, the effect of different doses of nitrogen was non- significant on number of inflorescences, number of shoots and root length plant^{-1} (Table 1). Maximum plant height (24.25 cm), petiole length (1.15cm leaf^{-1}), number of leaves (115.85), leaf area (511.44 sq. cm), length of inflorescences (5.97 cm), number of shoots (12.66), dry weight of root (7.07g), number of roots (39.81) and diameter of root(1.17 cm) plant^{-1} was observed in treatment N_2 and least values of all these parameters were recorded in control treatment N_0 (Table 1). However, maximum value of plant spread (441.40 sq. cm) and number of inflorescences (10.33) plant^{-1} were observed in treatment N_1 and their least values were recorded in control treatment N_0. Further maximum root length of 9.44 cm plant^{-1} was observed in treatment N_0 and the least of 8.33 cm in treatment N_2 (Table 1). With respect to plant height, number of leaves, leaf area, length of inflorescences and number of roots plant^{-1}, all the treatments were statistically different from each other. However, treatments N_1 and N_2 were at par with each other but were statistically different from a control treatment N_0 with respect to plant spread and diameter of root plant^{-1}. All the treatments were statistically different from each other with respect to petiole length plant^{-1}.With respect to plant dry weight of roots, Treatments N_1 and N_2 were statistically different from each other but the former treatment N_1 was at par with treatment N_0. (Table 1). El-Sayed et al. [27] also found that the highest level of nitrogen (300 kg/fed.) on *Echinacea parudoxa* L. significantly improved plant height, fresh and dry weight of herb, fresh and dry weight of whole plant.

3.2.4 Effect of nitrogen on root biomass (kg ha^{-1}) of *P. kurroa*

The dry weight of root increased significantly with every successive level of nitrogen i.e. from 100 to 150 kg ha^{-1}. The increase in yield of root due to 100 and 150 kg nitrogen ha^{-1} was in the order of 65.60 and 120.80 kg ha^{-1}, respectively over 0.0 kg of nitrogen level (control) (Table 3). The root yield obtained at 50 kg was statistically different from the yield obtained at 100 and 150 kg ha^{-1}. Nitrogen, in general, increases the vegetative growth of the plant and thus the plant produces more photosynthates that are deposited in the ultimate sink i.e. roots. The results obtained agreed with Shaheen et al. [28] who showed that, "treating *Cynara scolymus* with 100 to 120 kg N/fed as ammonium sulphate gained the best values of fresh and dry weight yield. Increase in the yield is attributable to the vigorous growth of plants with respect to plant height, plant spread and other morphological features at higher level of nitrogen (150 kg ha-1) (Table 1); resulting in accumulation of more photosynthates, which are responsible for increasing root yield. Nitrogen being a major constituent of proteins and phospholipids plays a vital role in plant growth and development. Thus higher nitrogen levels have helped in increasing the crop growth and improvement of yield attributes". Similar findings were reported by Rishi et al. [29] in *Dioscorea deltoidea*.

Table 2. Effect of interaction of organic manure, phosphorus and nitrogen on various morphological characters of *Picrorhiza kurroa*

S. No.	Treatment	Plant height(cm)	Plant spread (sq.cm)	Petiole length leaf^{-1}(cm)	No. of leaves plant^{-1}	Leaf area plant^{-1} (sq. cm)	No. of Inf. plant^{-1}
1.	$M_1P_0N_0$	18.33	229.66	0.96	63.00	100.00	6.000
2.	P_0N_1	18.00	408.00	0.80	83.33	418.00	8.000
3.	P_0N_2	21.33	354.33	1.20	110.0	524.00	10.00
4.	P_1N_0	20.33	404.00	1.10	92.00	380.00	11.00
5.	P_1N_1	24.33	439.66	0.90	98.00	490.00	10.00
6.	P_1N_2	27.00	380.00	1.40	135.0	540.00	9.000
7.	P_2N_0	21.33	396.00	1.20	102.0	400.00	9.000
8.	P_2N_1	26.00	468.00	1.10	143.3	505.00	12.00
9.	P_2N_2	28.00	518.33	1.00	146.0	484.00	12.00
10.	$M_2P_0N_0$	14.66	243.00	0.60	50.00	270.00	9.000
11.	P_0N_1	17.33	430.66	080	65.00	360.00	8.000
12.	P_0N_2	22.66	419.66	0.89	90.00	490.00	11.00
13.	P_1N_0	14.00	395.00	1.10	80.00	360.00	12.00
14.	P_1N_1	21.33	466.00	0.80	90.00	450.00	11.00
15.	P_1N_2	25.33	447.00	1.20	115.0	510.00	10.00

16.	P_2N_0	19.00	406.33	1.10	68.00	350.00	9.000
17.	P_2N_1	24.00	429.66	1.30	100.0	453.00	12.00
18.	P_2N_2	27.33	434.33	1.00	125.0	540.00	9.000
19.	$M_3P_0N_0$	16.66	204.66	0.70	55.00	280.00	7.000
20.	P_0N_1	16.00	481.00	1.10	60.00	345.00	10.00
21.	P_0N_2	18.66	440.00	1.30	75.00	470.00	9.000
22.	P_1N_0	12.00	420.66	1.00	65.00	320.00	11.00
23.	P_1N_1	20.00	435.33	1.40	70.00	430.00	10.00
24.	P_1N_2	23.00	397.66	1.20	126.6	525.00	12.00
25.	P_2N_0	18.00	400.66	0.90	94.00	360.00	11.00
26.	P_2N_1	22.00	414.33	1.20	91.00	450.00	12.00
27.	P_2N_2	25.00	422.66	1.20	120.0	520.00	10.00
28.	$M_0P_0N_0$	12.10	205.00	0.63	50.00	150.00	7.00
	LSD (5%)	NS	NS	0.19**	NS	76.05**	NS

Inf. =Inflorescence

Table 2. Continued…

S. No.	Treatment	Length of Inf. plant^{-1}	No. of shoots plant^{-1}	Root biomass plant^{-1} (g)	Root length plant^{-1} (cm)	No. of roots plant^{-1}	Diameter of root plant^{-1} (cm)
1.	$M_1P_0N_0$	4.20	09.10	5.0	13.33	0.80	0.80
2.	P_0N_1	4.80	10.00	6.0	13.00	1.00	1.00
3.	P_0N_2	5.30	14.00	7.0	11.00	1.30	1.30
4.	P_1N_0	5.00	14.00	6.1	7.330	0.99	0.99
5.	P_1N_1	6.80	13.00	7.0	10.66	1.10	1.10
6.	P_1N_2	6.60	11.00	7.4	08.33	1.30	1.30
7.	P_2N_0	7.19	10.00	6.4	08.00	1.20	1.20
8.	P_2N_1	8.09	15.00	7.2	12.00	1.20	1.20
9.	P_2N_2	9.80	14.00	8.0	8.000	1.40	1.40
10.	$M_2P_0N_0$	5.10	11.00	4.8	11.66	0.70	0.70
11.	P_0N_1	4.90	10.33	5.7	7.000	0.90	0.90
12.	P_0N_2	4.93	12.00	6.8	8.000	1.00	1.00
13.	P_1N_0	5.60	14.00	5.9	9.000	0.89	0.89
14.	P_1N_1	6.40	13.00	6.5	8.330	1.00	1.00
15.	P_1N_2	8.20	13.00	7.1	7.660	1.10	1.10
16.	P_2N_0	8.10	12.00	6.1	7.000	0.90	0.90
17.	P_2N_1	9.40	14.00	7.0	8.660	1.20	1.20
18.	P_2N_2	10.0	11.00	7.5	8.000	1.30	1.30
19.	$M_3P_0N_0$	5.50	09.00	4.3	10.33	0.60	0.60
20.	P_0N_1	5.03	12.00	5.2	6.660	0.90	0.90
21.	P_0N_2	5.20	11.00	6.3	8.330	1.00	1.00
22.	P_1N_0	5.30	13.00	5.5	9.000	1.10	1.10
23.	P_1N_1	6.90	11.00	6.2	7.000	1.20	1.20
24.	P_1N_2	7.80	15.00	6.5	7.330	1.00	1.00
25.	P_2N_0	7.80	14.00	6.0	9.330	0.90	0.90
26.	P_2N_1	8.79	13.00	6.7	8.330	1.20	1.20
27.	P_2N_2	10.4	13.00	7.1	8.330	1.20	1.20
28.	$M_0P_0N_0$	4.00	09.00	4.1	8.23	0.48	0.48
	LSD (5%)	0.20**	NS	NS	NS	NS	NS

*{Poultry manure (M1) (20 tonnes ha-1), sheep manure (M2) (25 tonnes ha-1) and farmyard manure (M3) (25 tonnes ha-1), phosphorus (P0=0, P1= 50 and P2= 100 kg ha-1) and nitrogen (N0 = 0, N1 = 100 and N2 = 150 kg ha-1): LSD = Least significant difference, non-significant (ns), *Significant at 5% level, **Significant at 1% level.}*

3.2.5 Effect of interaction of organic manure, phosphorus and nitrogen on various yield determining characters of *P. kurroa*

The effect of interaction of organic manure, phosphorus and nitrogen was significant ($p < 0.01$) with respect to petiole length, leaf area and length of inflorescence plant^{-1},but was non-significant with respect to all other morphological parameters. (Table 2). The maximum plant height (28.00 cm) plant^{-1} and least height (12.00 cm) was observed in treatment $M_3P_1N_0$. The maximum values of plant spread (518.33 sq.

cm), dry yield 98.00 g), number of roots (55.33) and diameter of root (1.40 cm) plant^{-1} was observed in treatment $M_1P_2N_2$ compared to their the least values {(204.66 sq. cm), (4.50 g), (23.00) and (0.48 cm)} in treatment $M_3P_0N_0$ (Table 2). The maximum number of 12.00 inflorescences plant^{-1} was observed in six treatments *viz.* $M_1P_2N_1$, M_1P_2 N_2, M_2P_1 N_0, $M_2P_2N_1$, $M_3P_1N_2$ and $M_3P_2N_1$ compared to the least number of 6.00 inflorescences plant^{-1} in the treatment $M_1P_0N_0$. In case of petiole length, treatments $M_1P_1N_1$, $M_3P_1N_1$, $M_2P_2N_1$ and $M_3P_0N_2$ were at par with each other. The data taken on leaf area plant $^{-1}$ showed that treatments $M_1P_1N_2$, $M_2P_2N_2$, $M_1P_0N_2$, $M_1P_1N_1$, $M_1P_2N_1$, $M_1P_2N_2$, $M_2P_0N_2$, $M_2P_1N_2$, $M_3P_0N_2$, $M_3P_1N_2$ and $M_3P_2N_2$ were at par with each other but were statistically different from the rest of other treatments. The length of inflorescence plant^{-1} had increased significantly and treatment $M_3P_2N_2$ was statistically different from all other treatments. Treatments $M_1P_2N_2$ and $M_1P_2N_2$, receiving different organic manures i.e. poultry manure and sheep manure but same quantity of phosphorus and nitrogen were at par with each other [30,31].

Highest length 10.40 cm of inflorescence plant^{-1} was observed in treatment $M_3P_2N_2$ compared to the least length of 4.00 cm of inflorescence plant^{-1} as observed in treatment M_0P_0 N_0 (Table 2). Examination of the data on number of shoots plant^{-1} revealed that the number of shoots plant^{-1} had got increased in all the treatments with respect to treatment $M_3P_0N_0$ (Table 2). The highest number of 15.00 shoots plant^{-1} were observed in two treatment *viz*. $M_1P_2N_1$ and $M_3P_1N_2$ as compared to the least number of 9.00 shoots obtained in control treatment $M_0P_0N_0$ (Table 2). Though the maximum dry yield of 8.00 g of root plant^{-1} was observed in treatment $M_1P_2N_2$ compared to the minimum dry yield of 4.10 g of root plant^{-1} in control treatment $M_0P_0N_0$ (Table 2). Poultry, sheep or farm yard manure in combination with higher levels of phosphorus and nitrogen resulted in increased dry yield of root plant^{-1}; however poultry manure in combination with higher level of phosphorus and nitrogen showed the highest dry yield of root plant^{-1} in contrast to sheep and farm yard manure receiving the same combination of inorganic fertilizers. (Table 2). The highest root length of 13.33 cm plant^{-1} was observed in treatment $M_1P_0N_0$ and the least root length of 6.66 cm plant^{-1} was observed treatments $M_3P_0N_1$ (Table 2). It is evident from the Table 2 that poultry manure alone or in combination with lower or higher levels of phosphorus (50 or 100 kg ha^{-1}) and nitrogen (100 or 150 kg ha^{-1}) or either with only lower or higher levels of phosphorus (50 or 100 kg ha^{-1}) or nitrogen (100 or 150 kg ha^{-1}) produced a greater length of roots. This is in contrast to sheep manure (25 tonnes ha^{-1}) or farm yard manure (25 tonnes ha^{-1}) receiving the same combination of inorganic fertilizers. Maximum number of 55.33 roots plant^{-1} was recorded in treatment $M_1P_2N_2$ compared to the least number of 23.00 roots plant^{-1} in treatment $M_3P_0N_0$ (Table 2).

3.2.6 Effect of interaction of organic manure, phosphorus and nitrogen on root yield or root weight (kg ha-1) of *P. kurroa*

The highest dry yield of 640.00 kg ha^{-1} was observed in treatment $M_1P_2N_2$ compared to the lowest dry yield of 344.00 kg ha^{-1} as observed in treatment $M_3P_0N_0$ (Table 4). However, the effect of interaction of organic manure, phosphorus and nitrogen was non-significant as depicted from analysis of variance (Table 1). Poultry, sheep or

Table 3. Yield of economic part as affected by organic manure phosphorus and nitrogen in *P. kurroa*

S/N	Treatment	Root weight m-^{2} (g)	Root weight (kg ha-^{1})
1	M^1	53.36	533.6
2	M^2	50.96	509.6
3	M3	47.76	477.6
4	P0	45.36	453.6
5	P1	51.68	516.8
6	P2	55.04	550.4
7	N0	44.48	444.8
8	N1	51.04	510.4
9	N2	56.56	565.6

Poultry manure (M1) (20 tonnes ha-1), sheep manure (M2) (25 tonnes ha-1) and farmyard manure (M3) (25 tonnes ha-1) phosphorus (P0=0, P1= 50 and P2= 100 kg ha-1) and nitrogen (N0= 0, N1= 100 and N2= 150 kg ha-1).

Table 4. Yield of economic part as affected by interaction of organic manure, phosphorus and nitrogen in *Picrorhiza kurroa*

S/N	Treatment	Root weight m-^{2} (g)	Root weight (kg ha-^{1})
1.	$M_1P_0N_0$	40.0	400.0
2.	P_0N_1	48.0	480.0
3.	P_0N_2	56.0	560.0
4.	P_1N_0	48.8	488.0
5.	P_1N_1	56.0	560.0
6.	P_1N_2	59.2	592.0
7.	P_2N_0	51.2	512.0
8.	P_2N_1	57.6	576.0
9.	P_2N_2	64.0	640.0
10.	$M_2P_0N_0$	38.4	384.0
11.	P_0N_1	45.6	456.0
12.	P_0N_2	54.4	544.0
13.	P_1N_0	47.2	472.0
14.	P_1N_1	52.0	520.0
15.	P_1N_2	56.8	568.0
16.	P_2N_0	48.8	488.0
17.	P_2N_1	56.0	560.0
18.	P_2N_2	60.0	600.0
19.	$M_3P_0N_0$	34.4	344.0
20.	P_0N_1	41.6	416.0
21.	P_0N_2	50.4	504.0
22.	P_1N_0	44.0	440.0
23.	P_1N_1	49.6	496.0
24.	P_1N_2	52.0	520.0
25.	P_2N_0	48.0	480.0
26.	P_2N_1	53.6	536.0
27.	P_2N_2	56.8	568.0
28.	$M_0P_0N_0$	32.8	328.0

Poultry manure (M1) (20 tonnes ha-1), sheep manure (M2) (25 tonnes ha-1) and farmyard manure (M3) (25 tonnes ha-1) phosphorus (P0=0, P1 = 50 and P2 = 100 kg ha-1) and nitrogen (N0 = 0, N1 = 100 and N2 = 150 kg ha-1)

Table 5. Soil fertility status of the experimental field [10]

Parameters	Value
pH (1:2.5)	7.02
E.C(1:2.5) dsm^{-1}	0.22
Organic matter	2.4%
Available N (kg ha^{-1})	213.0
Available P(kg ha^{-1})	71.0
Available K(kg ha^{-1})	263.0
Available S (kg ha^{-1})	40.0
Calcium (Meq)	11.0
Magnesium (Meq)	2.0

farm yard manure when in combination with higher levels of phosphorus (100 kg ha^{-1}) and nitrogen (150 kg ha^{-1}) had resulted in increased dry yield of root plant^{-1}, however poultry manure in combination with higher level of phosphorus and nitrogen showed the highest dry yield of root plant^{-1} in contrast to sheep and farm yard manure receiving the same combination of inorganic fertilizers. “Further a trend was seen that when poultry manure was used in combination with lower or higher levels of phosphorus (50 or 100 kg ha^{-1}) and/or nitrogen (100 or 150 kg ha^{-1}) produced a greater dry yield of root plant^{-1} in contrast to sheep manure or farm yard manure receiving the same combination of inorganic fertilizers (Table 4). Increase in root yield seems to be a reflection of favourable influence of organic manure and inorganic fertilizers on important yield attributes like plant height, plant spread and leaf area” [25].

Table 6. Nutrient content of FYM, sheep and poultry manure [10]

Parameter	Farm yard manure	Sheep manure	Poultry manure
pH (1:2.5)	7.19	7.0	6.5
Moisture content%	71.0	63.0	48.26
Organic matter%	35.25	39.63	40.11
N %	1.35	1.48	2.29
P_2O%	0.18	0.36	1.70
K_2o%	0.13	0.19	1.11
S %	0.03	0.04	0.6
Calcium oxide%	0.10	0.42	2.37
Magnesium oxide%	0.13	0.12	0.67

Fig. 1. Experimental field

Fig. 2. *Picrorhiza kurroa*

4. CONCLUSION

Cultivation of economically important plant revealed that the highest dry weight of root (692.80 kg ha^{-1}) in *P. kurroa* was obtained by the application of phosphorus @ 100 kg ha^{-1} as compared to various organic manures or/different levels of nitrogen used. Among the organic manures used *viz.* poultry, sheep and farmyard manure, the highest root biomass of 533.60 kg ha^{-1} was recorded by the application of poultry manure. *P. kurroa* species in Kashmir Himalayan region is endangered because of various biotic and abiotic stresses. Further, the species is a high value crop and has high commercial demand. Hence it's over exploitation by man continues at an alarming rate. This necessitates its immediate conservation measures to protect the species from extinction.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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