Effect of organic-inorganic fertilization on yield and yield determining parameters of *Picrorhizakurroa*Royle ex Benth.: an endangered medicinal plant species of Kashmir Himalaya.

Abstract

Picrorhizakurroa Royle ex Benth (Scrophulariaceae) is a small creeping herbaceous alpine species, 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. Consequently, preventing the species from getting extinct and increasing the yield of *P.kurroa* has become a major concern. 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, with three replications each, including one control treatment. The dry root weight recorded by the application of poultry, sheep and farm yard manure was 533.60, 509.60 and 476.70 kg ha^{-1}, respectively. Dry root yield increased significantly with increasing levels of phosphorus and nitrogen as well. Application of organic manure and higher levels of inorganic fertilizers resulted in increase in the root weightwith maximum dry root biomass of 640.00 kg ha^{-1} was observed in treatment M_1 P_2 N_2 (20 tones 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 $M_0P_0N_0$ (zeo tones of FYM, 0 kg P and 0 kg N ha^{-1}), although the effect of their interaction was non-significant.

Key words: *Picrorhizakurroa*, root weight, organic manure, inorganic fertilizer, yield related parameters

1. Introduction

Medicinal plants are the most important source of life saving drugs for the majority of the world's population [21]. 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 [9, and 24]. *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) [9] scarcely occurring between 2,800 to 4,500 meter above mean sea level (amsl). *P. kurroa* yields the drug, picrorhiza, obtained from stolons and roots. It is considered to be a viable bitter tonic, anti-periodic, cholagogue, stomachic, laxative in small doses and cathartic in large doses [9]. In India, the crude drug, Kutaki (*P. kurroa* roots), is being used to treat dyspepsia, respiratory disorders, and diseases of the liver and spleen, including jaundice, cirrhosis, anaemia, hemorrhoids, dermatoses, helminthiasis [2, 13, 14, 17, 26 and 31]. *P. kurroa* is a successful recommendation for restoring various liver-related issues, including anorexia, nausea, jaundice, dyspepsia, viral hepatitis, and periodic fevers. Its root shows aantifungal activity byinhibition of the dermatophytic fungi [8, 32, 33 and 34].

A new iridoid, picuroside was isolated from roots of *P. kurroa* (collected from India), together with 3 known iridoids *viz.*picroside-I, picroside-II and 6-feruloyl catalpol [10]. Picroside-I is a major active constituent of picroliv, a hepatoprotective agent [3 and 15]. The effect of picroliv when administered to rats significantly prevented the biochemical changes indicative of liver injury that were associated with aflatoxin B1 toxication [11 and 30]. An alcoholic extract of *P. kurroa* possesses anti-oxidant [6] and anti-diabetic activity [6]. Picrorhiza has also shown to reduce formation of liver cancer due to chemical exposures in animal studies [5]. Picroliv, picroside-I and kutkoside possess the properties of anti-oxidants [25]. Being a hepatoprotective plant [24] *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 [27, 28 and 29].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 experiment was carried out at the Experimental Field of Division of Floriculture, landscape and Architecture, Sher-e-Kashmir University of Agricultural Sciences and Technology Kashmir, Shalimar, Jammu and Kashmir, India. The Soil fertility test of the experimental field was done before the planting of the crop (Table 5)[1]. The soil of the experimental field was of clay-loam type. 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 (M1, 20 tones ha^{-1}), sheep manure (M2, 25 tones ha^{-1}) and farmyard manure (M3, 52 tones ha-1) were used as the main factors. Nutrient content of each of the manure used was also determined (Table 6). 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. 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.

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*

Application of organic manure had significantly a positive ($p < 0.05$) influence on plant height (Table 1) .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. Tallest plants (22.74 cm) were produced in treatment M_1 as compared to smaller sized plants (19.03 cm) in control. 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; but the effect was non-significant. An examination of the data revealed that petiole length was significantly ($p < 0.01$) decreased in treatment M_1 and M_2 with respect to a control. Significantly ($p < 0.05$) higher number of leaves plant^{-1} was observed in almost all the treatments with respect to control. 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. Maximum number of (108.07) leaves plant^{-1} was observed in treatment M_1 and the least (84.07 leaves plant^{-1}) in control. Obviously, poultry manure had a greater influence on increasing the number of leaves compared to sheep and farm yard manure. The data with regard to leaf area plant^{-1} showed that the 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. However, differences between treatments were non-significant. The data revealed that application of poultry, sheep or farm yard manure did not have any positive effect on increasing the number of inflorescences plant^{-1} but instead it remained by and large same in all the three treatments *via.* M_1, M_2 and M_3 (Table 1). Length of inflorescences was significantly ($p<0.01$) influenced by the application of organic manure. Treatment M_1 was statistically different from treatment M_2 and M_3 which were at par with each other. 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. Data pertaining to effect of organic manure on number of shoots plant^{-1} revealed that organic manure had no effect on number of shoots plant $^{-1}$ as it had remained by and large same for all the three treatments M_1, M_2 and M_3 used. Highest of number of 12.33 shoots plant^{-1} was observed in treatment M_3 and the least of 12.11 in treatment M_1 (Table 1). Jahan *et al.*[17] also showed that consuming 30 ton/ha manure can increase sub- branches of chamomile (*Matricaria chamomilla* L). The effect of organic manure on dry weight of root was highly significant ($p<0.01$). All the treatments M_1, M_2 and M_3 were statistically different from each other. Highest dry weight of root plant^{-1} (6.67 g) was obtained in treatment M_1 as compared to the least dry weight of root plant^{-1} (5.97 g) observed in control. 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. Maximum root length of 10.18 cm plant^{-1} was recorded when poultry manure was incorporated in the soil as compared to sheep manure or FYM. It was observed that organic manure had a highly significant ($p<0.01$) effect on root length plant^{-1}. Treatment M_1 was statistically different from treatments M_2 and M_3 which were at par with each other. The highest number of 36.81 roots plant^{-1} was recorded in treatment M_3 as compared to the least number of 31.77 roots obtained in treatment M_1. These differences were, however, non-significant. As there were only minor differences in diameter of root plant^{-1} among various treatments. 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).This is 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 [1]. 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 2). 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. Similar results have also been observed by Nautiyal *et al.* [8] 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 phosphorus on various yield determining characters of *P. kurroa*

Phosphorus had a highly significant ($p < 0.01$) effect on plant height. All the treatments were statistically different from each other. Maximum plant height was obtained in treatment P_2 (23.40 cm) compared to the least (18.18 cm) height in control treatment (Table 1).Application of phosphorus @ 50 or 100 Kg ha^{-1} showed a highly significant ($p < 0.01$) effect on plant spread. Treatments P_1 and P_2 were at par with each other but were statistically different from control. Highest plant spread (432.25 sq. cm) plant^{-1} was observed in treatment P_2 and minimum (356.77 sq. cm) in control. Phosphorus had highly significant ($p < 0.01$) influence on petiole length. Maximum petiole length (1.12 cm leaf^{-1}) was recorded for treatment P_1 and the least (0.92 cm) in control. Treatments P_1 and P_2 were at par with each other but were statistically different from control. Perusal of data presented in Table 1, showed that increase in phosphorus had significantly ($p<0.01$) resulted in an increase in number of leaves plant^{-1}. Treatments P_1 and P_2 were at par with each other but were statistically different from control. Maximum number of 109.92 leaves plant^{-1} was observed in treatment P_2 and the least of 72.37 in control .It was observed that phosphorus had a highly significant ($p<0.01$) effect on leaf area plant^{-1}. Treatments P_1 and P_2 were at par with each other but were statistically different from control. Maximum leaf area of 451.33 sq. cm plant^{-1} was observed in treatment P_2 and minimum leaf area of 361.88 sq. cm plant^{-1} in control. Significantly ($p< 0.01$)

higher number of inflorescences plant^{-1} was observed in almost all the treatments with respect to control. Treatments P_1 and P_2 were at par with each other but were statistically different from a control treatment. Highest number of 10.22 inflorescences plant^{-1} was observed in treatment P_2 and the least number of 9.66 inflorescences plant^{--1} in control. So it is obvious that lower level of phosphorus is the best optimal level to increase the number inflorescences plant^{-1} in the said crop.Highest length of inflorescence of 8.85 cm plant^{-1} was observed in treatment P_2 and the least of 4.99 cm in control. Significant increase ($p<0.01$) in length of inflorescences was observed in all the treatments compared to control. All the treatments P_0, P_1 and P_2 were statistically different from each other. A positive increase ($p < 0.05$) in number of shoots plant^{-1} was registered with the application of phosphorus. Maximum number of shoots (12.88 plant^{-1}) was observed in treatment P_2 and minimum number (10.81 plant^{-1}) in control. Treatments P_1 and P_2 were at par with each other but were statistically different from the control.Application of phosphorus had a significant positive ($p<0.01$) influence on the biomass of roots. Treatments P_1 and P_2 were at par with each other but were statistically different from a control treatment P_0. The highest dry weight of root (103.20 g plant^{-1}) was therefore, observed in treatment P_2 and the least (62.85 g plant^{-1}) in control. Highest biomassof 6.88g of root plant^{-1} was observed in treatment P_2 and least of 5.67g in control (P_0) .Again reflecting the positive effect of phosphorus on root biomass plant^{-1}.The highest root lengthplant^{-1} (9.92cm) was observed in control treatment (P_0)and the least (8.62 cm) in treatment P_2 .These differences were, however, non-significant .The number of roots produced by the plant varied significantly ($p < 0.01$) from 27.22 (in P_0) to 41.25 (in P_2). All the treatments P_0, P_1 and P_2 were statistically different from each other and treatment P_2 was superior to all.Significantly ($p<0.01$) remarkable increase in diameter plant^{-1} was observed in all the treatments as compared to control. Treatment P_2 was at par with treatment P_1, which was at par with treatment P_0. However, treatment P_0 was statistically different from other treatment $P_{0.}$ The highest diameter of root plant^{-1} (1.16 cm) was observed in treatment P_2 and the least (0.91 cm) in control (Table 1).

3.2.1 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 [1]. 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* [18] and *Rheum austrae*[1]. 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.

3.3 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. All the treatments were statistically different from each other. The highest plant height of 24.25 cm was obtained in treatment N_2 as compared to the least plant height of 17.14 cm in treatment N_0.There was a significant ($p <0.05$) increase in plant spread with the increasing levels of nitrogen @100 and 150 kg ha^{-1}. Treatment N_1 and N_2 were at par with each other but were statistically different from a control treatment P_0. However, the highest plant spread of 441.40 sq. cm was obtained in treatment N_1 as compared to the least plant spread of 344.44 sq. cm in control (N_0).The effect of nitrogen was highly significant ($p<0.01$). All the treatments N_0, N_1 and N_2 were at par with each other. However, highest petiole length of 1.15cm $leaf^{-1}$ was observed in treatment N_2 and least of 0.96cm in treatment N_0 (Table 1). Various levels of nitrogen had a highly significant ($p<0.01$) effect on increasing thenumber of leaves $plant^{-1}$. All the treatments were statistically different from each other. Highest number of 115.85 leaves $plant^{-1}$ was observed in treatment N_2 and the least of 74.33 leaves $plant^{-1}$ in treatment N_0.Increase in nitrogen resulted in a concomitant increase ($p< 0.01$) in the leaf area $plant^{-1}$ (Tables 1). All the treatments were statistically different from each other. Maximum leaf area 511.44 sq .cm $plant^{-1}$ was observed in treatment N_2 and minimum leaf area of 313.33 sq .cm $plant^{-1}$ in treatment N_0. An examination of data recorded indicated that nitrogen @ 100 or 150 Kg ha^{-1} does not show any positive effect on number ofinflorescences $plant^{-1}$ compared to the control. Highest number of 10.33 inflorescences $plant^{-1}$ was observed in treatment N_1 and the least number of 9.44 inflorescences $plant^{-1}$ in treatment N_0. Significant increase ($p<0.01$) in length of inflorescences $plant^{-1}$ has been observed in all the treatments compared to control. All the treatments were statistically different from each other. Highest length of inflorescences (6.79 cm) $plant^{-1}$was observed in treatment N_2 and least (5.97 cm) in control treatment N_0. The data showed a linear increase in number of shoots plant^{-1} with increasing levels of nitrogen @ of 100 and 150 Kg ha^{-1}.However, the non-significant effect on number of branches plant^{-1} was evident from analysis of variance. Maximum number of 12.66 shoots plant^{-1} had been observed in treatment N_2 and minimum number of 11.66 shoots in control.Application of nitrogen had a significant positive ($p<0.01$) influence on the biomass 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. Highest biomassof 7.07g of root plant^{-1} was observed in treatment N_2 and the least of 5.56 g in treatment N_0. So increase in the root biomass plant^{-1} was the reflection of favorable effect of nitrogen on **r**oot biomass plant^{-1}.Nitrogen @ 100 and 150 Kg ha^{-1} did not show any positive effect on increasing the root length plant^{-1}compared to the control. However, maximum root lengthof 9.44 cm plant^{-1} was observed in treatment N_0 and the least of 8.33 cm in treatment N_2 .The effect of nitrogen on number of roots plant^{-1} was highly significant ($p<0.01$). All the treatments N_0, N_1 and N_2 were statistically different from each other. Maximum number of 39.81 root plant^{-1} was observed in N_2 treatment and the least number of 28.33 root plant^{-1} in N_0 treatment. Examination of the data showed that diameter of root plant^{-1} had markedly increased ($p<0.01$) with the increase in nitrogen fertilization. Treatments N_1 and N_2 were at par with each other but were statistically different from a control treatment P_0. Highest diameter of root plant^{-1} (1.17 cm) was observed in treatment N_2 and least (0.90 cm) in control treatment N_0 (Table 1). El-Sayed et al. [19] 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.

3.3.1 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.*[12] 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. [4] in *Dioscoreadeltoidea*.

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

Data on the **e**ffect of interaction of organic manure, phosphorus and nitrogen on plant height revealed that the maximum plant height of 28.00 cm was observed in treatment $M_1P_2N_2$ compared to the least plant height of 12.00 cm in treatment $M_3P_1N_0$ (Table 2). However, the effect of interaction was non-significant (Table 1). Highest plant spreadof 518.33 sq. cm was observed in treatment $M_1P_2N_2$compared to the least plant spread of 204.66 sq. cm in control treatment $M0_3P_0N_0$ (Table 2).But the effect of interaction of organic manure, phosphorus and nitrogen was non-significant (Table 1).

The effect of interaction of organic manure, phosphorus and nitrogen was highly significant ($p < 0.01$) (Table 1). Treatments $M_1P_1N_1$, $M_3P_1N_1$, $M_2P_2N_1$ and $M_3P_0N_2$ were at par with each other. But the former two treatments were statistically different from the rest of the twenty three treatments. Highest petiole length of 1.40 cm was observed in two treatments *viz.* $M_1P_1N_2$ and $M_3P_1N_1$ and the least petiole length of 0.60 cm in treatment $M_2P_0N_0$ (Table 2).Data indicate that different organic manures and various levels of phosphorus and nitrogen applied did not influence the number of leaves significantly (Tables 1,2), though maximum number of 143.30 leaves plant^{-1} were recorded for $M_1P_2N_1$ and the least number of 50.00 for control treatment (Table 2).The data taken on leaf area plant $^{\mathbf{-1}}$ showed that leaf area plant $^{\mathbf{-1}}$ had increased significantly ($p < 0.01$) with the application of organic manure, phosphorus and nitrogen (Tables 1,2). 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 sixteen other treatments. The highest leaf area of 540.00 sq. cm was observed in two treatments i.e. $M_1P_1N_2$ and $M_2P_2N_2$ compared to the least leaf area of 100.00 sq. cm in treatment $M_1P_0N_0$ (Table 1).Although, the maximum number of 12.00 inflorescencesplant^{-1} was observed in six treatments *viz.* $M_1P_2N_1$, $M_1P_2N_2$,$M_2P_1N_0$, $M_2P_2N_1$, $M_3P_1N_2$ and $M_3P_2N_1$ compared to the least number of 6.00 inflorescences plant^{-1} in the treatment $M_1P_0N_0$ (Table 2), but effect of interaction was non-significant (Table 1).The length of inflorescence plant^{-1} had increased significantly ($p < 0.01$) in maximum number of treatments with respect to control treatment ($M_0P_0N_0$) (Tables 1,2). 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. 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 control treatment $M_3P_0N_0$ (Table 2).But the effect of interaction was non-significant (Table 1). 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). However, the effect of interaction was non-significant (Table 1). 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 effect of interaction on root length plant^{-1} was non-significant (Table 1) still 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 tones ha^{-1}) or farm yard manure (25 tones 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). Number of roots was increased in all treatments with respect to control treatment ($M_3P_0N_0$). However, differences among treatments were non-significant (Table 1).Diameter of root plant^{-1} had got increased in all treatments with respect to control (Table 2). Though, the effect of interaction of organic manure, phosphorus and nitrogen was non-significant (Table 1). Moreover, the highest diameter of 1.40 cm of root plant^{-1} was obtained in treatment $M_1P_2N_2$ compared to the least diameter of 0.48 cm of root plant^{-1} as observed in treatment $M_0P_0N_0$.

3.3.1 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 control 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 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 [1].

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 33.60 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.

Conflicts of Interests

The authors have not declared any conflict of interests

Table -1: Effect of organic manure, phosphorus and nitrogen on various morphological characters of *Picrorhizakurroa*

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.ofinflore-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 tones ha^{-1}), sheep manure (M2) (25 tones ha-1) and farmyard manure (M3) (25 tones 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.

Table 2: Effect of interaction of organic manure, phosphorus and nitrogen on various morphological characters of *Picrorhizakurroa*

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 30: Contd….

Table 2: Contd…

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 tones ha-1), sheep manure (M2) (25 tones ha-1) and farmyard manure (M3) (25 tones 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.}

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 tones ha-1), sheep manure (M2) (25 tones ha-1) and farmyard manure (M3) (25 tones 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 *Picrorhizakurroa*.

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 tones ha-1), sheep manure (M2) (25 tones ha-1) and farmyard manure (M3) (25 tones 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

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

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

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

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