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RESEARCH ARTICLE

Effects of root pruning on seedling growth and other parameters in *Juniperus polycarpos* under nursery conditions

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ABSTRACT

A nursery trial was conducted to study the effects of root pruning on the seedling growth and other parameters of *Juniperus polycarpos*. Roots of two-year-old seedlings of *J. polycarpos* were pruned at different levels and transplanted in polybags of size 9” × 5” filled with potting media comprising soil, sand, and farm yard manure (2:1:1). Maximum growth of various seedling parameters, *viz*., shoot length (42.90 cm), root length (38.40 cm), collar diameter (6.16 mm), number of roots (45.93) and biomass, *viz*., fresh shoot biomass (24.03 g), fresh root biomass (6.35 g), total fresh biomass (30.38 g), dry shoot biomass (10.21 g), dry root biomass (2.48 g), total dry biomass (12.69 g), weight of secondary + tertiary roots (0.61 g) were recorded in seedlings in which 5 cm roots were retained after pruning, whereas, minimum growth of seedling parameters and biomass was recorded in seedlings in which no root pruning was done. The maximum value of seedling quality parameters, *viz*., volume index (1627.86), Quality index (1.14), and ratio of secondary + tertiary roots to total root biomass (0.08) was also observed in seedlings in which 5 cm roots were retained after pruning. The study suggests that roots of *J. polycarpos* may be pruned up to 5 cm in length for production of quality nursery stock.

INTRODUCTION

Juniperus polycarpos C.Koch commonly called Himalayan Pencil Cedar is an indigenous conifer found in dry temperate and cold desert regions of the North-Western Himalayas. The natural distribution of this conifer extends from Nepal westwards to Uttarakhand, Himachal Pradesh, Jammu & Kashmir, Ladakh, Pakistan, and Afghanistan at altitudes of 2100-4500 m above msl (Anon, 1959). It has immense ecological, socio-cultural, and religious significance in the dry temperate and cold desert region of the North-West Himalayas. The wood of this conifer is used as fuel wood by the native communities, twigs and dried needles are used as incense in houses, temples, and monasteries for performing various religious rites in Kinnaur and Lahaul & Spiti districts of Himachal Pradesh and Leh & Kargil districts of Union Territory of Ladakh. The foliage especially needles, small twigs, and berries are also used to treat rheumatic pains (Aswal & Goel, 1989).

It is an excellent species for afforestation of dry temperate and cold desert areas of the Trans-Himalayan region. The success of afforestation activities in cold desert areas is quite low due to low survival of planted seedlings in these harsh areas. These areas possess xeric conditions due to low moisture availability and possess skeletal soil which is subjected to high intensity light. The seedlings of *J. polycarpos* are raised in nurseries from seeds for production of the planting stock for carrying out afforestation in dry temperate and cold desert areas of North-Western Himalayas (Negi & Sharma, 2017). The use of healthy and quality planting stock raised in the nurseries not only ensures better survival of seedlings but also favours vigorous growth of seedlings after outplanting in the field. The seedling quality parameters play a significant role in the production of healthy nursery stock which is eventually required for carrying out successful plantation in the field. If the seedlings produced in the nurseries are of poor quality, the mortality of seedlings and the chances of failure of the plantation programs are also maximum.

Hence, in order to produce robust and quality seedlings in nurseries, nursery managers often employ various cultural practices to promote the growth of planting stock in nursery. The root pruning operations are generally carried out by the

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nursery managers in order to promote the growth of secondary and adventitious roots. The plants which produce more adventitious roots not only help in better absorption of water and minerals from the soil but also ensure the production of quality planting stock in nursery. The use of quality nursery stock in plantation program will subsequently ensure better survival and growth of seedlings in plantation area.

The root growth potential is a very important parameter for assessing the health of the seedling and is considered to be the seedling's potential to grow new roots in an optimum environment (Ritchie & Tanaka, 1990). The seedlings with high root growth potential tends to establish quickly and produce new roots having better access to soil nutrients (Duryea, 1985). As water absorption is required for photosynthesis, the immediate establishment of roots when planted or when environmental conditions are optimal will contribute to their better survival in the field (Burdett, 1987). The pruning of roots not only increases root fibrosity but root carbohydrate status also tends to increase (Ritchie & Dunlap, 1980). Root pruning also increases long-term growth of plants (Watson & Sydnor, 1987), increase yields for both crops and trees in agro-forestry, and reduce below-ground competition (Woodall & Ward, 2002).

The morphological features alone are not sufficient to predict the performance of seedlings, instead, seedlings with better physiological traits perform well in the field (Ritchie & Dunlap, 1980). Root growth potential could fulfil this role because it is not only used for assessing the morphological part of the seedling but can also indicate the physiological status of the seedling (Davis & Jacobs, 2005). The effect of root pruning on the growth performance of various forestry species has been carried out by many researchers (Gilman & Yeager, 1987; Watson & Sydnor, 1987; Benson, Morgenroth & Koeser, 2019; Burcer et al., 2021), however, there is no information available on the seedling growth behaviour of *J. polycarpos* in response to root pruning. In view of the above, study was conducted to evaluate the effect of root pruning on seedling growth and quality parameters for the production of quality planting stock in the nursery.

MATERIALS AND METHODS

The experiment on the effect of root pruning on seedling growth performance and quality parameters of *J. polycarpos* was carried out at Model Nursery, Baragaon of Himalayan Forest Research Institute, Shimla from 2016 to 2020. The experimental site is situated at N 31º04'14.3" and E 77º10'15.7" at 1800 m above msl. The roots of two-year-old seedlings were pruned at different levels and transplanted in polybags of size 9"x 5" filled with potting media comprising soil, sand, and farm yard manure. A total of 50 seedlings per treatment (10 seedlings x 5 replications) were transplanted in polybags in nursery. The experimental trial was conducted in nursery with five treatments and five replications in a randomized block design (RBD).

T_1: Control (No Pruning)

T_2: Seedlings with 5 cm roots retained after pruning

T_3: Seedlings with 10 cm roots retained after pruning

T_4: Seedlings with 15 cm roots retained after pruning

T_5: Seedlings with 20 cm roots retained after pruning

The root-pruned seedlings planted in polybags were irrigated as and when required. The weeding and hoeing operations in polybags were also carried out periodically to keep the seedlings free from weeds. The seedlings were further maintained in the nursery for four years for observing their growth behaviour. At the end of experiment, three seedlings from all replications of each treatment were randomly extracted from polybags in December, 2020 to record the growth and plant biomass data. The root system containing potting media was thoroughly cleaned with water till all the particles of potting media were washed away from the root system. The various seedling growth parameters such as shoot length, root length, collar diameter, number of lateral roots, fresh shoot biomass, fresh root biomass, and total fresh biomass were recorded. After that, the shoot and root were separated with secateur and placed in the oven at 80ºC till constant weight was recorded and thereafter, dry weight of the shoot, root, total biomass and weight of secondary + tertiary roots were recorded.

The seedling quality parameters, *viz*., sturdiness quotient, volume index, quality index, root shoot ratio, and the ratio of secondary + tertiary roots to total root biomass were calculated as:

1. **Sturdiness Quotient** (Ritchie, 1984)

$$S.Q. = \frac{\text{Height(cm)}}{\text{Diameter(mm)}}$$

2. **Volume Index** (Hatchell, 1985)

$$V.I. = \text{Diameter (mm)}^2 \times \text{Height (cm)}$$

3. **Quality Index** (Dickson, Leaf & Hosner, 1960)

$$Q.I. = \frac{\text{Seedling Dry Weight (g)}}{\frac{\text{Height(cm)}}{\text{Diameter (mm)}} + (\text{Shoot dry Weight(g)}/\text{Root Dry Weight(g)})}$$

4. **Root Shoot Ratio** $= \frac{\text{Root Dry Weight(g)}}{\text{Shoot Dry Weight (g)}}$

5. **Ratio of Sec. + Ter. Roots to Total Root Biomass** $\frac{\text{Weight of Sec.+Ter.Roots (g)}}{\text{Total Root Biomass(g)}}$

The data of various growth parameters, shoot, root, the total biomass of the seedlings, and weight of secondary + tertiary roots were subjected to analysis of variance (ANOVA) to establish the significance of differences between treatments. The critical difference (CD) was calculated for the variables studied using the computer program "SPSS"- a statistical package for social sciences.

RESULTS

The mean value of various growth parameters, *viz*., shoot length, root length, collar diameter, number of roots, plant biomass production, *viz*., fresh shoot biomass, fresh root biomass, total fresh biomass, dry shoot biomass, dry root

Table 1. Seedling growth parameters of *Juniperus polycarpos* as affected by different levels of root pruning under nursery condition

Treatment	Shoot Length (cm)	Root Length (cm)	Collar Diameter (mm)	Number of Roots
T_1: Control	37.44	35.21	5.32	34.46
T_2: Seedlings with 5 cm roots retained after pruning	42.90	38.40	6.16	45.93
T_3: Seedlings with 10 cm roots retained after pruning	40.78	36.76	5.81	43.06
T_4: Seedlings with 15 cm roots retained after pruning	38.20	35.54	5.58	39.04
T_5: Seedlings with 20 cm roots retained after pruning	37.76	35.41	5.51	37.33
S. Em±	**1.30**	**2.67**	**0.30**	**1.64**
C.D.	**2.77**	**5.66**	**0.64**	**3.49**

Table 2. Shoot, root and total biomass of *Juniperus polycarpos* seedlings as affected by different levels of root pruning under nursery condition

Treatment	Fresh Shoot Weight (g)	Fresh Root Weight (g)	Total Fresh Biomass (g/plant)	Dry Shoot Weight (g)	Dry Root Weight (g)	Total Dry Biomass (g/plant)	Weight of Sec. +Ter. Roots (g/plant)
T_1	17.51	4.74	22.26	7.66	1.93	9.59	0.61
T_2	24.03	6.35	30.38	10.21	2.48	12.69	1.04
T_3	19.34	5.53	24.87	8.78	2.25	11.03	0.93
T_4	18.12	5.31	23.44	7.99	2.06	10.06	0.75
T_5	17.65	5.05	22.71	7.74	1.94	9.68	0.69
S. Em±	**2.61**	**0.78**	**3.22**	**1.22**	**0.36**	**1.53**	**0.19**
C.D.	**5.54**	**1.67**	**6.03**	**2.58**	**0.77**	**3.26**	**0.40**

Table 3. Seedling quality parameters of *Juniperus polycarpos* as affected by different levels of root pruning under nursery condition

Treatment	Root Shoot Ratio	Sturdiness Quotient	Volume Index	Quality Index	Ratio of Sec. + Ter. Roots to Total Root Biomass
T_1	0.25	7.03	1059.64	0.87	0.06
T_2	0.24	6.96	1627.86	1.14	0.08
T_3	0.26	7.01	1376.57	1.01	0.08
T_4	0.26	6.84	1189.41	0.93	0.07
T_5	0.25	6.85	1146.39	0.89	0.07

biomass, total dry biomass and weight of secondary + tertiary roots of *J. polycarpos* as affected by different level of root pruning in the nursery are given in Table 1 and Table 2, and seedling quality parameters, *viz*., root shoot ratio, sturdiness quotient, volume index, quality index and the ratio of secondary + tertiary roots to total root biomass are given in Table 3 respectively. A perusal of data from the tables reveal that root pruning intensity significantly influenced seedling growth parameters, biomass production, and seedling quality parameters of *J. polycarpos* in nursery.

The maximum shoot length of 42.90 cm was recorded in treatment T_2, i.e., seedlings in which 5 cm roots were retained after pruning followed by 40.78 cm in treatment T_3, i.e., seedlings in which 10 cm roots were retained after pruning and are statistically at par with each other but significantly better than 38.20 cm in treatment T_4, i.e., seedlings in which 15 cm roots were retained after pruning and 37.76 cm in treatment T_5, i.e., seedlings in which 20 cm roots were retained after pruning, whereas, the minimum shoot length of 37.44 cm was recorded in treatment T_1, i.e., seedlings where no root pruning was done. The maximum root length growth of 38.40 cm was recorded in treatment T_2 followed by T_3 (36.76 cm), T_4 (35.54 cm), and T_5 (35.41 cm) and are statistically at par with each other and the minimum root length growth of 35.21 cm was recorded in treatment T_1. The maximum collar diameter of 6.16 mm was also recorded in treatment T_2 followed by T_3 (5.81 mm), T_4 (5.58 mm) and are statistically at par with each other and the minimum collar diameter of 5.32 mm was recorded in treatment T_1. The maximum number of roots 45.93 was recorded in treatment T_2 followed by treatment T_3 (43.06) and are statistically at par with each other, but better than T_4 (39.04), T_5 (37.33), and the minimum number of roots 34.46 was recorded in T_1.

The maximum fresh shoot biomass of 24.03 g seedling^{-1} was also recorded in treatment T_2 followed by treatment T_3 (19.34 g seedling^{-1}) and are at par with each other but statistically significant than T_4 (18.12 g seedling^{-1}) and T_5 (17.65 g seedling^{-1}), whereas, minimum fresh shoot biomass of 17.51 g seedling^{-1} was recorded in treatment T_1. Similarly, maximum fresh root biomass of 6.35 g seedling^{-1} was also recorded in treatment T_2 followed by treatment T_3 (5.53 g seedling^{-1}), T_4 (5.31g seedling^{-1}), and T_5 (5.05 g seedling^{-1}), whereas, minimum fresh root biomass of 4.74 g seedling^{-1} was recorded in treatment T_1. The maximum total fresh biomass of 30.38 g seedling^{-1} was also recorded in treatment T_2 followed by treatment T_3 (24.87 g seedling^{-1}) and are at par with each other but significantly better than T_4 (23.44 g seedling^{-1}), T_5 (22.71 g seedling^{-1}) and minimum total fresh biomass of 22.26 g seedling^{-1} recorded in Treatment T_1.

The maximum dry shoot biomass of 10.21 g seedling^{-1} was also recorded in treatment T_2 followed by treatment T_3 (8.78 g seedling^{-1}), T_4 (7.99 g seedling^{-1}), and T_5 (7.74 g seedling^{-1})

and minimum dry shoot biomass of 7.66 g seedling^{-1} was recorded in treatment T_1. Similarly, maximum dry root biomass of 2.48 g seedling^{-1} was also recorded in treatment T_2 followed by treatments T_3 (2.25 g seedling^{-1}), T_4 (2.06 g seedling^{-1}), and T_5 (1.94 g seedling^{-1}) and minimum dry root biomass of 1.93 g seedling^{-1} was recorded in Treatment T_1. The maximum total dry biomass of 12.69 g seedling^{-1} was recorded in treatment T_2 followed by treatment T_3 (11.03 g seedling^{-1}), T_4 (10.06 g seedling^{-1}), and T_5 (9.68 seedling^{-1}), whereas, the minimum total dry biomass of 9.59 seedling^{-1} was recorded in treatment T_1. The maximum weight of secondary + tertiary roots (1.04 g seedling^{-1}) was recorded in treatment T_2 followed by treatment T_3 (0.93 g seedling^{-1}), T_4 (0.75 g seedling^{-1}) and T_5 (0.69 g seedling^{-1}), whereas, the minimum weight of secondary + tertiary roots (0.61 g seedling^{-1}) was recorded in T_1.

The seedling quality parameters calculated on the basis of various growth and biomass parameters are presented in Table 3. A perusal of data from Table 3 reveals that the maximum value of root shoot ratio (0.26) was observed in treatments T_3 and T_4 followed by treatments T_1 & T_5 (0.25) and T_2 (0.24) in decreasing order. It is observed that plant species possessing a high root-to-shoot ratio have a greater ability to penetrate hard soil layers and thereby, result in better absorption of minerals and water from the soil. Thus, a higher root-shoot ratio contributes significantly to a better establishment and survival of planting stock in the field and subsequently promotes better shoot growth after outplanting in the field (Chauhan & Sharma, 1997).

The least value of sturdiness quotient (6.84) was observed in treatment T_4 followed by treatment T_5 (6.85), T_2 (6.96), T_3 (7.01), and T_1 (7.03) in increasing order. The low sturdiness value helps in promoting vigorous growth in plantations (Chauhan & Sharma, 1997), and the seedlings showing high sturdiness value perform poorly in the plantations.

The maximum volume index of 1627.86 was observed in treatment T_2 followed by 1376.57 (T_3), 1189.41 (T_4), and 1146.39 (T_5) in decreasing order. The minimum volume index of 1059.64 was observed for the treatment T_1. The higher value of the volume index contributes significantly to better establishment, and survival and subsequently promotes better growth of seedlings after outplanting in the field (Chauhan & Sharma, 1997).

The highest value of the Dickson quality index (1.14) was recorded in treatment T_2 followed by the treatments T_3 (1.01), T_4 (0.93), and T_5 (0.89). The lowest value of the quality index (0.87) was recorded in T_1. The Dickson quality index usually indicates the overall quality of seedlings, therefore, it is evident from the above values of the quality index that seedlings in which 5 cm roots were retained after pruning, exhibited highest value of the quality index. The maximum value of the ratio of secondary + tertiary roots to total root biomass (0.08) was observed in treatments T_2 and T_3 followed by the treatments T_4 and T_5 (0.07) in decreasing order. The minimum value of ratio of secondary + tertiary roots to the total root biomass (0.06) was observed for the treatment T_1.

DISCUSSION

The results of the study indicated that among different levels of pruning done in roots of *Juniperus polycarpos* seedlings in the nursery, the maximum seedling growth and biomass of nursery stock were produced in seedlings where 5 cm roots were retained after pruning in the nursery. Secondly, seedlings in which 5 cm roots were retained after pruning also produced the highest values of volume index, quality index, and the ratio of secondary + tertiary roots to total root biomass. Thus, root pruning of seedlings not only resulted in maximum growth of various seedling growth parameters and plant biomass but it also produced the highest value of various seedling quality parameters compared to those seedlings where no root pruning was done. This study is also in conformity with results of Burcer et al. (2021) who suggested pruning of taproots to induce elongation of the primary roots and the initiation of lateral roots and further recommended root pruning as a treatment to induce root development. Similarly, Gilman and Yeager (1987) also reported a six-fold increase in the root density of *Quercus virginiana* root-pruned seedlings as compared to unpruned trees and Watson and Sydnor (1987) also reported a four-fold increase in the root density of *Picea pungens* as compared to unpruned trees. Gilman, Harchick and Wiese (2009), Gilman, Harchick and Paz (2010) and Gilman and Masters (2010) also observed the enhancement of seedling quality parameters of *Quercus Virginiana* in response to root pruning. Grossnickle (2012) also reported that seedlings possessing quality attributes ensure better survival, increases the speed with which plants overcome stress, and ensure successful seedling establishment after outplanting in the field. It is evident from the basis of above results that *Juniperus polycarpos* seedlings in which 5 cm roots are retained after pruning, result in better growth of various seedling parameters as well as biomass production along with good seedling quality attributes in the nursery.

CONCLUSION

The findings of the present investigation reveal that *Juniperus polycarpos* seedlings in which 5 cm roots retained after pruning in nursery, produced maximum growth of various seedling growth parameters and plant biomass along with good values of seedling quality attributes. Hence, it is concluded that its roots should be pruned up to 5 cm before transplanting in polybags for the production of robust and quality nursery stock.

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