

EVALUATION OF DIFFERENT ROOTING MEDIA AND ROOT TRAINER SIZES FOR CLONAL PROPAGATION OF *Casuarina* spp.

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ABSTRACT

The present study comprised experiments on the evaluation of different rooting media and root trainers for cuttings sprouting and rooting and plant growth performance in the interspecific hybrid of *Casuarina equisetifolia* x *Casuarina junghuhniana* (IFGTB-CH-2). The experiments were conducted under controlled mist chamber conditions in the Research Farm of the Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana during the year 2023-24. In the first experiment, thirteen rooting media (vermiculite, cocopeat, sand and mushroom compost in the ratio of 25, 50, 75, and 100%) were tried. Vermiculite (50%) + cocopeat (50%) showed the maximum rooting (88.33%), survival (85.00%) and shoot length (25.78 cm) followed by other combinations (75:25% and 25:75%). Plants can also be produced in sand, a locally available cheap material, though the rooting (70.00%), survival (60.00%), and shoot and root growth were not at par with the other media used. In the second experiment, root trainers of four different sizes (90, 150, 250 and 300 cc) were tried. The larger-sized root trainers (250 and 300 cc) promoted more root growth and shoot and root biomass than the smaller-sized ones (90 and 150 cc). However, non-significant differences were observed among root trainers for rooting (81.67-83.33%), survival (80.00-83.33%), shoot length (25.56-26.89 cm), and collar diameter (1.55-1.61 mm). Since larger containers required more rooting media and longer time for root plug formation and accommodated only 12 cuttings per tray, smaller-sized root trainers accommodate 40 cuttings per tray, require less rooting media, take less time to form root plugs and may be used for transplanting.

Keywords: *Casuarina*, Clonal propagation, Rooting media, Root trainer, Vegetative propagation

Casuarina is an exotic, fast-growing and evergreen tree species belonging to the family Casuarinaceae. It is commonly known as *Jor-tor* in India. It is known as Australian pine, beefwood, she-oak, ironwood, etc. Mainly, it is native to Australia, Southeast Asia, the Indian subcontinent, and the Islands of the Pacific Ocean; and is also found in the Andaman and Nicobar Islands. *Casuarina* species are commonly cultivated in the tropical and subtropical regions because of their various economic and ecological benefits (Turnbull, 1990). It is preferred for the afforestation in the coastal regions, the inland areas, swamps and areas around ponds and rivers for the prevention of soil degradation and erosion due to its deep-rooted system and enhances the soil fertility due to its atmospheric nitrogen-fixing capability (Parrotta and Baker, 1994). Moreover, its ability to tolerate salts makes it well-suited for cultivation in problematic soils, including nutrient-deficient, alkaline, saline and sandy soils (Turnbull, 1990; Moezal *et al.*, 1989). Commercially, it is grown for its best wood quality for papermaking and timber production. Moreover, it possesses excellent fuelwood/firewood, having a high calorific value of 5000 kcal/kg and is used for charcoal production (Orwa *et al.*, 2009).

It has already been integrated as a tree component for shelterbelts, windbreaks and agroforestry systems by farming communities in the southern states of India covering more than 500,000 hectares (Pinyopusarerk and Williams, 2000; Viswanath *et al.*, 2001; Nicodemus, 2009; Saravanan *et al.*, 2012).

In Punjab, screening and selection trials have been undertaken to identify genetically improved hybrid clones of *Casuarina* with superior adaptability and growth potential (Garg *et al.*, 2022). To incorporate these promising clones into afforestation programmes, their quality planting stock must be mass-multiplied through efficient vegetative propagation methods. The success of such propagation largely depends on optimizing nursery techniques, particularly the choice of suitable and readily available rooting media and root trainer sizes. Selecting the right media and container size is crucial for enhancing root formation, ensuring adequate nutrient and moisture availability and improving seedling survival. Therefore, the present study was carried out to evaluate different rooting media ingredients, their combinations in various proportions and root trainer sizes for producing quality planting stock of *Casuarina* in a cost-effective, easily accessible and time-efficient manner.

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MATERIALS AND METHODS

Description of experimental unit and site

The study was carried out during 2023-2024 under controlled environmental conditions of temperature ranging from 30 to 35°C and a relative humidity between 80 and 85% in the mist chamber unit of the Department of Forestry and Natural Resources, Punjab Agricultural University, Ludhiana. The experimental site is located at 247 m above sea level and lies at 30°50" N latitude and 75°52" E longitude. The climate at experimental site is subtropical, characterized by a prolonged dry season i.e. hot and dry summer from April to June, followed by a humid monsoon i.e. a wet season from July to September and a winter season i.e. cold months from November to January. The controlled conditions of temperature and humidity within experimental unit were regulated by an automated misting system installed on the roof of the chamber, which simultaneously supplied irrigation to the cuttings at a set frequency of 15-minute intervals with a misting duration of 15 seconds during daytime hours (4 mistings per hour).

Collection, preparation and planting of cuttings

In both studies, the clonal material (shoots) was obtained from a single clone (IFGTB CH-2) of an interspecific hybrid of *Casuarina equisetifolia* x *Casuarina junghuhniana*. The cuttings were prepared from the apical portion of shoots and standardized to a length of 8-10 cm. The excess leaves were trimmed to prevent transpiration losses in unrooted cuttings, while the lower 2-3 cm portion of each cutting was defoliated to facilitate rooting hormone application. Before planting, the cuttings were treated with a fungicide (0.1% Bavistin) for 2-3 minutes to

prevent fungal infections. After the fungicide treatment, the lower 1-2 cm section of each cutting was treated with rooting hormone IBA (Indole-3-Butyric Acid) 3000 ppm. Following the treatment, the cuttings were immediately planted into root trainers filled with rooting media and placed in the mist chamber.

Experimental design and layout

Both experiments were laid out in a Completely Randomized Design (CRD) with three replications, each consisting of 20 cuttings. Treatments were placed randomly in the mist chamber to minimize experimental error and ensure unbiased allocation in each experiment. In the first experiment, thirteen different rooting media were evaluated using 90 cc root trainers. The description of rooting media combinations and composition is listed in Table 1. In the second experiment, four different rooting trainers were tested. Descriptions of the root trainers used in the present study are given in Table 2. In this study, vermiculite (standard rooting media) was used as the rooting medium for all treatments to ensure that the effect of root trainer size alone was evaluated.

Observations recorded and statistical analysis

The data on morphological parameters included the number of days taken for initiation of sprouting, recorded from the day of establishment of all treatments in both experiments. The observations for sprouting percentage, survival percentage and rooting percentage were noted at the termination of the experiments. The data pertaining to other parameters viz. sprouting percentage, survival percentage, rooting percentage, shoot length (cm), collar diameter (mm), number of roots per cutting, root length (cm), shoot and root biomass (fresh/dry) (g) were recorded from 10

Table 1. Description of rooting media and their different combinations

Sr. No.	Rooting media	Composition
1	Vermiculite (V)	Vermiculite (100)
2	Mushroom (M)	Mushroom compost (100%)
3	Cocopeat (C)	Cocopeat (100%)
4	Sand (S)	Sand (100%)
5	V+C (75:25)	Vermiculite (75%) + Cocopeat (25%)
6	V+C (50:50)	Vermiculite (50%) + Cocopeat (50%)
7	V+C (25:75)	Vermiculite (25%) + Cocopeat (75%)
8	C+M (75:25)	Cocopeat (75%) + Mushroom compost (25%)
9	C+M (50:50)	Cocopeat (50%) + Mushroom compost (50%)
10	C+M (25:75)	Cocopeat (25%) + Mushroom compost (75%)
11	V+M (75:25)	Vermiculite (75%) + Mushroom compost (25%)
12	V+M (50:50)	Vermiculite (50%) + Mushroom compost (50%)
13	V+M (25:75)	Vermiculite (25%) + Mushroom compost (75%)

Table 2. Description of root trainers used in present study

Container	Volume (cc)	Length (cm)	Top diameter (cm)	Number of cuttings per tray
1	90	9	4	40
2	150	10	5	25
3	250	10	6.8	12
4	300	14	6.8	12

randomly selected rooted cuttings in each treatment and replication (at 45 days of planting). The analysis of the recorded data through standard statistical procedures was undertaken according to the guidelines defined for completely randomized design. The analysis of variance and critical difference (CD) were computed for the presentation and interpretation of the results of this investigation (Panse and Sukhatme, 1989).

RESULTS AND DISCUSSION

Effect of rooting media

The evaluation of different rooting media and their combinations in various proportions for clonal propagation of *Casuarina* resulted in significant differences (CD $p \leq 0.05$) in morphological traits i.e. days taken for initiation of sprouting, per cent sprouting,

per cent rooting, per cent survival, number of roots per cutting and root length (cm) (Table 3). The cuttings planted in vermiculite (V), cocopeat (C) and their combinations (V+C) sprouted the earliest (3.33-3.67 days) followed by those planted in mixtures of cocopeat with mushroom compost (C+M) and vermiculite with mushroom compost (C+M) resulted, 4-5 days. However, sand (100%) and mushroom compost (100%) took approximately 6 days to initiate sprouting. Maximum sprouting percentage (98.00-98.33%) was obtained in vermiculite (V), cocopeat (C) and V+C mixtures, followed by mushroom compost (M) in combinations with maximum proportions of vermiculite and cocopeat. Cuttings planted in sand resulted in 88.33% sprouting, whereas mushroom compost reported the least (81.67%). Vermiculite (100 %) and cocopeat (100 %) showed faster initiation of sprouting and maximum

Table 3. Effect of different rooting media on days taken for initiation of sprouting, sprouting (%), rooting (%), survival (%), no. of roots per cutting, root length (cm) of *Casuarina*

Rooting media	Days taken for initiation of sprouting	Sprouting (%)	Rooting (%)	Survival (%)	No. of roots per cutting	Root length (cm)
Vermiculite (V)	3.33±0.33 ^e	98.33±1.67 ^a	87.33±1.20 ^{ab}	83.33±1.67 ^a	4.33±0.19 ^a	8.40±0.31 ^a
Mushroom (M)	6.67±0.88 ^a	81.67±1.67 ^e	41.67±4.41 ^e	37.33±4.33 ^c	2.10±0.11 ^d	4.89±1.56 ^d
Cocopeat (C)	3.33±0.33 ^e	98.33±1.67 ^a	84.67±2.60 ^{ab}	80.00±2.89 ^a	4.44±0.11 ^a	8.38±0.35 ^d
Sand (S)	6.00±0.58 ^{ab}	88.33±1.67 ^{cde}	70.00±2.89 ^{cd}	60.00±2.89 ^b	3.00±0.19 ^c	5.22±0.40 ^{bcd}
V+C (75:25)	3.67±0.33 ^{de}	98.33±0.83 ^a	86.67±1.67 ^{ab}	83.33±1.67 ^a	4.33±0.19 ^a	8.22±0.55 ^a
V+C (50:50)	3.33±0.33 ^e	98.00±1.53 ^a	88.33±1.67 ^a	85.00±2.89 ^a	4.44±0.11 ^a	8.78±0.11 ^a
V+C (25:75)	3.67±0.33 ^{de}	98.00±1.16 ^a	85.00±2.89 ^{ab}	81.67±1.67 ^a	4.55±0.22 ^a	8.44±0.68 ^a
C+M (75:25)	3.67±0.33 ^{de}	96.67±1.67 ^{ab}	85.00±1.16 ^{ab}	80.67±2.19 ^a	4.22±0.11 ^a	8.83±0.10 ^a
C+M (50:50)	4.00±0.58 ^{cde}	93.00±1.53 ^{abc}	77.33±3.93 ^{abc}	75.67±3.48 ^a	4.11±0.22 ^{ab}	8.33±0.38 ^a
C+M (25:75)	4.67±0.33 ^{bode}	86.00±3.51 ^{de}	65.00±5.77 ^d	63.33±4.41 ^b	4.00±0.33 ^{ab}	8.00±0.77 ^a
V+M (75:25)	4.67±0.33 ^{bode}	94.33±2.33 ^{abc}	80.00±2.89 ^{abc}	78.00±1.53 ^a	3.56±0.11 ^{bc}	7.00±0.39 ^{abc}
V+M (50:50)	5.00±0.58 ^{bcd}	90.33±3.18 ^{bcd}	76.67±4.41 ^{bc}	75.00±2.89 ^a	3.44±0.11 ^c	7.00±0.19 ^{ab}
V+M (25:75)	5.33±0.33 ^{abc}	85.00±2.89 ^{de}	61.67±4.41 ^d	58.33±6.01 ^b	3.33±0.19 ^c	7.89±0.11 ^a
CD ($p \leq 0.05$)	1.35	6.08	9.78	9.38	0.53	1.71
SE(m)	0.46	2.09	3.37	3.23	0.18	0.59
SE(d)	0.65	2.96	4.76	4.56	0.26	0.83
CV (%)	18.15	3.90	7.66	7.71	8.24	13.36
F cal	5.560	8.016	16.121	18.603	15.395	4.723
F tab	0.00013	0.00001	0.000	0.000	0.000	0.001

Within a column means followed by different alphabets differ significantly

sprouting percentage among other treatments, due to better water retention and aeration properties which promote early root development. Similarly, Patel *et al.* (2020) worked on *Casuarina* and reported, minimum days to initiation of sprouting 6.67 days and 50% sprouting was achieved within 9.67 days when planted in vermiculite. Mushroom compost when used in pure composition (100 %) took the longer days to initiate sprouting and sprouting percentage possibly due to its dense structure, which may slow down root aeration. Similarly, Kendra (2013) reported that cocopeat have good water holding and nutrient retention capacity which promotes the sprouting.

Among all rooting media treatments, the maximum rooting (85-88.33%) was recorded in vermiculite (V), cocopeat (C) and V+C mixtures. While cuttings planted in sand (100%) exhibited 70.00% rooting, those raised in media mixtures containing 75% mushroom compost showed a moderate response (60-65.00%), whereas pure mushroom compost resulted in the lowest rooting (41.67%). The variation in rooting response of *Casuarina* cuttings under different growing media is visually presented in Plate 1. The highest survival (81.67-85.00%) was recorded in vermiculite (V), cocopeat (C) and their combinations (V+C) with each other or with mushroom compost (V+M, C+M) in lower proportions. Moderate survival (60-78%) was obtained in sand, V+M (75:25, 50:50), and C+M (50:50), while the lowest survival (37.33%) was observed in pure mushroom compost and its higher proportion combinations indicating the adverse effect of mushroom compost on cutting survival. The achievement of maximum rooting and survival percentage in vermiculite, cocopeat and their combinations might create favourable conditions for long-term growth by balancing moisture and aeration for root development (Wojtusik *et al.*, 1994;

Mehmood *et al.*, 2013). Furthermore, cutting planted in the mushroom compost (100%) resulted lowest rooting and survival rate. It might show poor results due to its compactness leading to waterlogging and less aeration in media for root development as reported by Wojtusik *et al.* (1994) in *Prosopis juliflora*. In general, it is very important to maintain the porosity of the growing media for proper root development reported by Srivastava *et al.* (1998). The present investigation supports earlier work done by other workers. Nazir *et al.* (2021) analyzed the impact of growing media on the rooting of *Ulmus villosa* and *Ulmus wallichiana* hardwood stem cuttings. They concluded that cocopeat + vermiculite + perlite (1:1:1) media showed the highest rooting (96.75 %) as compared to control (soil). Likewise, a similar finding was reported by David (2017), who observed that a cocopeat (50%) resulted in the highest survival (95 %), followed by cocopeat (80 %) and cocopeat (100 %) resulted in the survival (70 %). Similarly, Nazir *et al.* (2021) concluded that cocopeat + vermiculite + perlite (2:1:1) showed the highest survival (95.65 %) in *Ulmus* species. Tchoundjeu *et al.* (2002) worked on *Prunus africana* and resulted in 72% survival in sand.

The maximum number of roots per cutting (4.00-4.55) was obtained in vermiculite (V), cocopeat (C) and their mixtures with mushroom compost (V+M, C+M), whereas V+M combinations and sand showed moderate values (3.00-3.56) for roots per cutting. The minimum count was recorded in mushroom compost alone (2.10). Among all rooting media, the longest root length (8.00-8.82 cm) was recorded in vermiculite, cocopeat and mixtures of cocopeat with mushroom compost followed by combinations of vermiculite and mushroom compost which recorded moderate root lengths (7.00-7.89 cm). In contrast, sand and mushroom compost in 100% composition recorded the shortest root lengths of 5.22 cm and 4.89 cm, respectively. Nazir *et al.* (2021) examined the impact of growing media on the rooting of *Ulmus villosa* and *Ulmus wallichiana* hardwood stems cuttings. They reported that the highest shoot length and root length was recorded in cocopeat + vermiculite + perlite (2:1:1). Similarly, Singh and Kaur (2021) concluded that cocopeat + soil (1:1) gave better results concerning root length in per cuttings. Wojtusik *et al.* (1994) also observed shorter roots in coarse-washed sand as compared to perlite/vermiculite mixtures.

Table 4 delineates significant differences (CD $p \leq 0.05$) among different rooting media for shoot length (cm), collar diameter (mm), fresh/dry shoot biomass (g) and fresh/dry root biomass (g). The data depicted that shoot length did not vary significantly among most media (24.89-26.89 cm), with the maximum shoot length in media consisting of the maximum proportion of mushroom compost i.e. C+M (25:75, 26.89 cm) and V+M (25:75, 26.56 cm), while sand recorded the



A B C D E F G H I J K L M
Plate 1. Comparison of rooting of *Casuarina* cuttings planted in different growing media as A) vermiculite, B) Mushroom compost, C) Cocopeat, D) Sand, E) V+C (75:25), (F) V+C (50:50), G) V+C (25:75), H) C+M (75:25), I) C+M (50:50), J) C+M (25:75), K) V+M (75:25), L) V+M (50:50), M) V+M (25:75)

minimum (20.78 cm). Collar diameter was recorded maximum in mushroom compost (1.77 mm) and V+M (25:75, 1.78 mm) followed by C+M and V+M mixtures (1.67-1.71 mm) while the minimum was recorded in sand (1.42 mm) and cocopeat (1.50 mm). Our findings are similar to David (2017) who concluded that 50 % cocopeat showed the highest shoot length followed by 100 % cocopeat shoot length. Nazir *et al.* (2021) examined the impact of growing media on the rooting of *Ulmus villosa* and *Ulmus wallichiana* hardwood stems cuttings. They reported that the highest shoot length was recorded in cocopeat + vermiculite + perlite (2:1:1).

Among most of the rooting media, including vermiculite, cocopeat and their mixtures recorded higher and statistically similar fresh shoot biomass (2.34-2.57 g), whereas sand recorded 2.48 g of fresh shoot biomass. However, mushroom compost (100%) recorded the lowest fresh root biomass (1.96 g). Dry shoot biomass followed a similar trend, with the maximum (1.18 g) in V+C (75:50) and V+C (50:50) followed by moderate dry shoot biomass (1.10-1.16 g) in mixtures of vermiculite (V), cocopeat (C), and mushroom compost (M) in different proportions. Although the sand recorded 1.09 g of dry shoot biomass, mushroom compost (100%) recorded the lowest (0.99 g). Fresh root biomass was highest in cocopeat and

its mixtures with vermiculite in various proportions (0.83-0.85 g), while intermediate fresh root biomass (0.70-0.77 g) occurred in vermiculite, cocopeat and mushroom compost mixtures. Cuttings planted in sand recorded 0.57 g of fresh root biomass and the lowest was recorded in mushroom compost (0.29 g). A similar trend was recorded for dry root biomass with the highest in cocopeat and vermiculite in various proportions (0.30-0.32 g) followed by vermiculite, cocopeat in 100% proportions, and cocopeat and mushroom (25:65) (0.19-0.21 g). While intermediate fresh root biomass (0.14-0.17 g) occurred in sand, vermiculite, cocopeat and mushroom compost mixtures, the cuttings planted in mushroom compost (100%) recorded the lowest dry root biomass (0.10 g). Manila *et al.* (2017) reported the effect of different rooting media on fresh and dry root biomass of *Punica granatum*. The maximum fresh root biomass (0.20 g) and dry root biomass (0.08 g) were reported in vermiculite. Shrestha *et al.* (2023) examined different media for the vegetative propagation of *Bougainvillea glabra*. They reported that the maximum shoot fresh weight (10.04 g) and shoot dry weight (2.09 g) was observed in sand and cocopeat. Similar observations were also reported by Gopale and Zunjoroo (2011) that the type of growing media significantly affected the biomass of *Jatropha curcas*

Table 4. Effect of different rooting media on shoot length (cm), collar diameter (mm), fresh shoot biomass (g), dry shoot biomass (g), fresh root biomass (g) and dry root biomass (g) of *Casuarina*

Rooting media	Shoot length (cm)	Collar diameter (mm)	Fresh shoot biomass (g)	Dry shoot biomass (g)	Fresh root biomass (g)	Dry root biomass (g)
Vermiculite (V)	25.56±0.73 ^a	1.53±0.06 ^{bcd}	2.48±0.13 ^a	1.10±0.02 ^{ab}	0.77± 0.01 ^b	0.19±0.00 ^b
Mushroom (M)	25.22±0.97 ^a	1.77±0.08 ^a	1.96±0.13 ^b	0.99±0.01 ^c	0.29±0.02 ^g	0.10±0.00 ^e
Cocopeat (C)	24.89±1.50 ^a	1.50±0.05 ^{cd}	2.54±0.03 ^a	1.16±0.02 ^{ab}	0.84±0.00 ^a	0.21±0.00 ^b
Sand (S)	20.78±1.87 ^b	1.42±0.04 ^d	2.48±0.07 ^a	1.09±0.02 ^b	0.57±0.02 ^f	0.17±0.02 ^c
V+C (75:25)	24.89±1.16 ^a	1.55±0.07 ^{bcd}	2.57±0.02 ^a	1.18±0.04 ^a	0.83±0.01 ^a	0.30±0.00 ^a
V+C (50:50)	25.78±0.49 ^a	1.53±0.06 ^{bcd}	2.54±0.03 ^a	1.18±0.02 ^a	0.85±0.00 ^a	0.32±0.01 ^a
V+C (25:75)	25.56±0.48 ^a	1.51±0.05 ^{bcd}	2.52±0.04 ^a	1.15±0.03 ^{ab}	0.83±0.02 ^a	0.30±0.01 ^a
C+M (75:25)	25.78±0.49 ^a	1.67±0.07 ^{abc}	2.40±0.04 ^a	1.15±0.03 ^{ab}	0.77±0.02 ^{bc}	0.19±0.00 ^b
C+M (50:50)	25.89±0.11 ^a	1.69±0.04 ^{abc}	2.37±0.04 ^a	1.11±0.03 ^{ab}	0.75±0.01 ^{bcd}	0.17±0.01 ^c
C+M (25:75)	26.89±0.29 ^a	1.70±0.08 ^{abc}	2.34±0.04 ^a	1.10±0.02 ^{ab}	0.74±0.02 ^{bcd}	0.17±0.00 ^c
V+M (75:25)	25.56±0.04 ^a	1.69±0.03 ^{abc}	2.51±0.08 ^a	1.12±0.01 ^{ab}	0.72±0.00 ^{cde}	0.16±0.01 ^c
V+M (50:50)	26.22±0.22 ^a	1.71±0.06 ^{ab}	2.48±0.14 ^a	1.11±0.03 ^{ab}	0.71±0.01 ^{de}	0.14±0.00 ^d
V+M (25:75)	26.56±0.89 ^a	1.78±0.09 ^a	2.45±0.03 ^a	1.11±0.03 ^{ab}	0.70±0.01 ^e	0.14±0.00 ^d
CD ($p \leq 0.05$)	2.49	0.18	0.22	0.07	0.04	0.02
SE(m)	0.86	0.06	0.08	0.03	0.01	0.01
SE(d)	1.21	0.09	0.11	0.04	0.02	0.01
CV (%)	5.85	6.63	5.36	3.91	3.40	5.11
F cal	3.042	3.528	4.358	3.675	119.910	99.479
F tab	0.009	0.003	0.001	0.003	0.000	0.000

Table 5. Effect of different sizes of root trainer on days taken for initiation of sprouting, sprouting (%), rooting (%), survival (%), shoot length (cm) and collar diameter (mm) of *Casuarina*

Volume (cc)	Days taken for initiation of sprouting	Sprouting (%)	Rooting (%)	Survival (%)	Shoot length (cm)	Collar diameter (mm)
90	3.33±0.33 ^a	96.67±1.67 ^a	81.67±4.41 ^a	80.00±2.89 ^a	25.56±0.73 ^a	1.55±0.04 ^a
150	3.47±0.29 ^a	97.25±1.47 ^a	82.50±2.50 ^a	80.84±2.21 ^a	26.11±0.29 ^a	1.58±0.02 ^a
250	3.67±0.17 ^a	97.50±1.44 ^a	83.33±1.67 ^a	83.33±3.33 ^a	26.33±0.38 ^a	1.60±0.02 ^a
300	3.72±0.14 ^a	97.67±1.45 ^a	83.33±3.33 ^a	83.33±1.67 ^a	26.89±0.11 ^a	1.61±0.02 ^a
CD ($p \leq 0.05$)	NS	NS	NS	NS	NS	NS
SE(m)	0.25	1.51	3.15	2.60	0.44	0.02
SE(d)	0.35	2.14	4.45	3.68	0.623	0.03
CV (%)	12.04	2.69	6.59	5.51	2.909	2.57
F cal	0.529	0.084	0.064	0.436	1.569	1.005
F tab	0.675	0.967	0.977	0.733	0.271	0.439

stem cuttings. The combinations of sand:soil: cocopeat (1:2:1) and sand:soil: FYM (1:2:1) were found to yield favourable results for seedling growth.

In the present study, despite slower sprouting, lower rooting and survival rate in mushroom compost in pure composition due its compactness, which restricted aeration and root proliferation. However, its high organic matter content and readily available nutrients may have supported better shoot growth and collar diameter development during the initial stages. Moreover, vermiculite and cocopeat in various combinations along with mushroom compost in lower proportions provided more consistent growth across the parameters suggesting a more balanced and healthy development of both root and shoot systems. Sand, being coarse-textured and well-drained, improved aeration but had poor water and nutrient-holding capacity (Tchoundjeu *et al.*, 2002). As a result, it supported moderate overall growth and survival rate, followed by vermiculite, cocopeat and their mixtures.

Effect of root trainer size

The investigation indicates that the root trainer size (90, 150, 250 and 300 cc) exerts non-significant differences in morphological parameters i.e. days taken for initiation of sprouting, per cent sprouting, per cent rooting, per cent survival, shoot length (cm) and collar diameter (mm) (Table 5). On average, cuttings sprouted within 3-4 days, with sprouting, rooting and survival percentages ranging between 96-98%, 81-83% and 80-83%, respectively. The mean shoot length varied from 25.56 to 26.89 cm, while collar diameter ranged between 1.55 and 1.61 mm. The effect of root trainer size on rooting of *Casuarina* cuttings is shown in Plate 2. Furthermore, the data (Table 6) depicted that the growth of cuttings (number of roots per cutting,

root length, shoot biomass and root biomass) had significant differences and increased with an increase in root trainer size (volume) from 90 cc to 300 cc. The highest values were recorded in 300 cc, which produced approximately 6.00 roots per cutting, the maximum root length (14.38 cm), fresh shoot biomass (3.06 g), dry shoot biomass (1.53 g), fresh root biomass (1.08 g) and dry root biomass (0.45 g). However, these values were statistically at par with 250 cc root trainers, which also showed superior performance across all parameters. The 150 cc root trainers showed intermediate results, while 90 cc root trainers consistently recorded the lowest values for all traits, including number of roots (4.55), root length (11.22 cm) and dry shoot biomass (1.18 g).

The maximum growth in cuttings was associated with larger root trainer volumes (250 and 300 cc) as they provided more space and retain more rooting media as compared to root trainers (90 and 150 cc). That is because larger root trainers promote better fibrous root

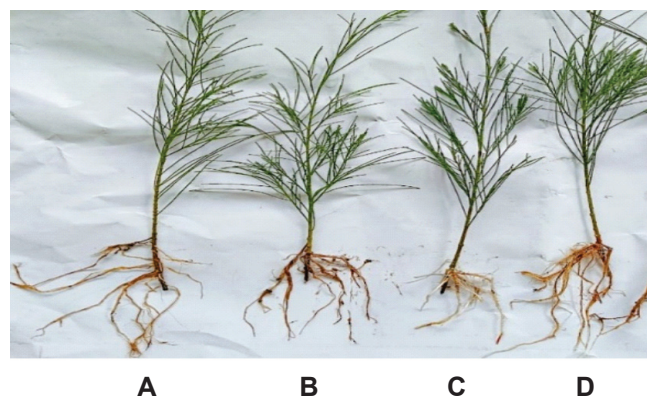


Plate 2. Comparison of rooting of *Casuarina* cuttings planted in different sizes of root trainers as A) 90 cc, B) 150 cc, C) 250 cc, D) 300 cc

Table 6. Effect of different sizes of root trainer on number of roots, root length (cm), fresh shoot biomass (g), dry shoot biomass (g), fresh root biomass (g) and dry root biomass (g) of *Casuarina*

Volume (cc)	Number of roots	Root length (cm)	Fresh shoot biomass (g)	Dry shoot biomass (g)	Fresh root biomass (g)	Dry root biomass (g)
90	4.55±0.22 ^b	11.22±0.22 ^c	2.48±0.19 ^b	1.18±0.02 ^c	0.88±0.02 ^b	0.33±0.02 ^b
150	5.11±0.24 ^b	12.39±0.23 ^b	2.65±0.04 ^b	1.39±0.01 ^b	0.91±0.02 ^b	0.36±0.02 ^b
250	6.00±0.19 ^a	14.17±0.26 ^a	3.00±0.01 ^a	1.49±0.03 ^a	1.00±0.01 ^a	0.44±0.03 ^a
300	6.00±0.00 ^a	14.38±0.36 ^a	3.06±0.03 ^a	1.53±0.01 ^a	1.08±0.02 ^a	0.45±0.02 ^a
CD ($p \leq 0.05$)	0.63	0.90	0.32	0.07	0.06	0.06
SE(m)	0.19	0.27	0.10	0.02	0.02	0.02
SE(d)	0.27	0.38	0.14	0.03	0.02	0.03
CV (%)	6.08	3.61	6.02	2.52	3.14	8.23
F cal	14.017	30.739	8.222	60.599	15.611	9.729
F tab	0.001	0.001	0.008	0.001	0.001	0.005

development, leading to improved overall growth and development of cuttings. Similar observations were reported by Rathore *et al.* (2004) on the production of high-quality *Casuarina equisetifolia* planting stock, Negi and Shamet (2020) on the quality stock production of *Emblica officinalis* Gaertn. Similarly, studies on *Acacia catechu*, *Azadirachta indica*, *Albizia lebbek* and *Pinus roxburghii* significantly enhanced collar diameter, plant height and other growth parameters with large-volume containers (Gera *et al.*, 2003). Similar results were observed in plant production of white spruce, lodgepole pine and Douglas fir for higher growth and biomass production (Hocking and Mitchell, 1975). This improved growth performance can be attributed to the larger root trainer size, which facilitated greater root proliferation and enhanced nutrient, moisture, and aeration availability in these systems. Furthermore, these findings align with the research on Chir pine and *Pinus gerardiana* seedlings, which demonstrated the effect of container size on growth and rooting performance under nursery conditions (Bhardwaj *et al.*, 1986; Malik and Shamet, 2009). Similar observations were reported by Singh *et al.* (2024) in the *Melia composita* for growth and maximum root/shoot dry weight under different growing conditions, Rasool *et al.* (2018) in *Jatropha carcus*. George *et al.* (2019) reported similar results for the comparative performance of stump and root trainer-raised teak plants and concluded that sturdiness and seedling quality have a direct and positive relationship with root-trainer size.

In clonal propagation methods, root trainers are the basic requirements for raising the nursery of various tree species. The requirement of ideal root trainer size is determined by factors such as the plant species, growing density, type of rooting media, duration of the growing season and the desired seedling size for planting (Jinks, 1994). Moreover, the size of root

trainers plays a crucial role in determining the capacity of the rooting media, which directly affects the root structure, growth and development of propagules during the nursery stage. Selection of container for mass production should be such that the container will produce an acceptable seedling without compromising certain diameter, root shoot ratio and sturdiness *etc.* in the shortest gestation period. However, the major constraint of large-volume root trainers is the reduced number of seedlings produced as compared to smaller sizes, along with the more requirement for rooting media and longer durations for root plug formation, which ultimately increase both the time and cost of seedling production (Sharma, 1996).

CONCLUSION

It is concluded from the present study that rooting media and the size of root trainers have a significant effect on vegetative propagation of *Casuarina*. Commercially, vermiculite is used as a standard rooting media for vegetative propagation of tree species on a mass scale. However, the use of vermiculite and cocopeat, both alone and in combinations at ratios of 75:25, 50:50, and 25:75, resulted in maximum survival and shoot/root growth. This was followed by mushroom compost combinations with these rooting media in lower proportions, specifically C+M (50:50, 75:25) and V+M (50:50, 75:25). Moreover, sand also reported moderate growth and plant production. Its poor nutrient and water retention limited overall growth, making it better suited in combination with organic media. Although larger-sized root trainers (250 and 300 cc) promoted greater shoot and root growth, all root trainer sizes showed no difference in survival percentage. Since larger trainers required more rooting media and longer time for root plug formation, smaller sizes (90 and 150 cc) are more efficient, potentially may produce transplantable

seedlings in less time and at lower usage of rooting media. Moreover, as small root trainer size trays accommodate more cuttings than larger ones, they allow production of a higher number of propagules per tray.

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