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Interaction effect of different sized root trainers, growing media and pre-sowing seed treatments on growth & development of *Myrica esculenta* buch. Ham. Seedlings under nursery condition

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Abstract
Myrica esculenta Buch. -Ham. ex D. Don is a multipurpose, economically important plant belongs to family Myricaceae. The hard seed coat creating the physical dormancy along with slow root growth in traditional polybag under nursery condition are the major concern in the growth and development of seedlings of this species. The combined performance of pre-sowing seed treatments, growing media and root trainers of different size in the production of seedlings of *Myrica esculenta* by soaking the seeds in beejamrita for varying periods (2 and 3 weeks) followed by sowing in different sized root trainers containing different media, have a profound effect on growth, biomass and quality parameters of the seedlings. The best result in germination, growth, biomass & quality parameters was recorded in seeds treated with beejamrita solution for 3 weeks and subsequently sown in root trainer of 250 cc containing growing media consisting soil + sand + vermicompost in ratio 1:1:1. Among various treatment combinations, seedlings raised under above treatment combination resulted maximum value for every growth parameter including shoot length (9.92 cm), collar diameter (1.56 mm), number of leaves (15), leaf area (9.70 cm^2), root length (20.38 cm), number of secondary roots (20) and root thickness (2.07).

Keywords: Pre-sowing treatments, Growing media, Beejamrita, vermicompost, Root trainers

Introduction
Containerised seedling production has been widely used since the early sixties. The practice improved seedling survival and management as compared to bare-root seedling production (Xuo and Gao 1984) [24]. The primary function of any container is to hold a discrete supply of growing medium, which in turn supplies water, air, mineral nutrients and physical support to the seedling. Apart from these functions, the containers must inhibit root spiralling and root coiling and encourage root pruning at the base of the cell, which favours a more fibrous root system (Jinks 1994) [12]. Improvement of the planting stock production system, especially the introduction of root trainers and establishment of permanent nursery facilities in the forestry sector was initiated under a World Bank aided forestry programme. Forest nurseries with facilities for raising and maintaining many seedlings, clonal multiplication facilities, composting and growing media development units are the major wings of forestry research to meet the need of annuals planting programmes.
The genus *Myrica* belongs to family Myricaceae and comprised of about 35 species. These are extensively distributed in the world's temperate as well as sub-tropical regions except Australia. They are mostly small trees/ large shrub. In India there is a species recognized as *Myrica esculenta* Buch. Ham. (syn *M. nagi* Hook. F.) commonly known as Boxberry, Kaiphal and Kathphala (Shood *et al.*, 2017) [21]. It is widely distributed in foot-hills to mid hills of the Himalayan region from east of the river Ravi to Assam including Jammu & Kashmir, Himachal Pradesh, Uttrakhand, Sikkim, Arunachal Pradesh, Manipur, Khasi and Jaintia, Naga and Lushai Hills of Meghalaya between 1000 and 2300 m elevations. *M esculenta* is a commercial slow growing multipurpose tree species that grows up to 3-9 m height and over 80 cm Diameter at Breast Height (DBH). Best development of kaphal found on sandy loam, porous and well-drained soil. *Myrica* plants grow well in nitrogen-depleted soils, mixed forests, agricultural and marginal lands where rainfall annually varies from 1000 mm to 3000

mm, temperature ranges from 15 °C to 20 °C. It is a shade bearer, moderately frost hardy and require good quantity of moisture for growth and development (Chauhan, 1999) [4]. *M. esculenta* is a dioecious plant, with red colored flowers. Inflorescence is in the form of spikes, which are developed in axillary clusters (Prashar *et al*. 2018) [17]. Flowering starts in the month of August and continues till December. Fruiting starts from April and continues till May. Fruit is a drupe, reddish in color, with around 1.5 cm diameter. There are about 5,500 seeds in one kilogram of a seed lot (Barola *et al*. 2017) [2].

The bark of *Myrica* boiled in water has various health benefits such as curing diarrhea, dysentery, and chronic bronchitis. Powdered bark boiled in mustard oil is effective in getting relief from rheumatic pain (Singh, Gautam, & Tewari, 2011) [23]. The roots of *Myrica* plant have great pharmacological importance in Ayurveda and are used in numerous Ayurvedic formulations. The bark has antiseptic properties and contains proanthocyanins, tannins (32.1%), glycosides, gallic acid, and essential oils (n-pentadecanol (7.7%), eudesmol acetate (21.9%), hexadecanol (25.2%), cis-β-caryophyllene (8.7%), and n-octadecanol (7.6%)) having antimicrobial activity (Kabra *et al*.,2019[a]) [13]. The leaves contain flavonoid glycosides with anti-inflammatory properties. Fruits contain antioxidants, phenolics, and flavonoids, which are helpful in oxidative stress. The varying contents of phenolic and flavonoid compounds of the fruit determining the morphological and biochemical features can be observed in various populations of plants. These characteristics can act as a key feature in identifying the most favorable sources for large-scale cultivation through the applications of horticulture and forestry methods (Gusain *et al*., 2016) [8]. Chewing the bark of a tree helps to get relief from toothache and makes lotion for washing putrid sores. The leaves are rich with wax, and fruits are used to make various products such as jellies, beverage and they can also be used to make pickles (Jeeva *et al*., 2011) [11]. There are many other uses for this plant such as the treatment of anemia, sprain, mental illness, cholera, cardiac edema, earache, body ache, headache, ulcer, asthma, bronchitis, and lung infections (Kabra *et al*.,2019[b]) [13]. The multipurpose ability of this plant makes it a valuable plant.

In addition to such tremendous medicinal benefits, Fruits of *M esculenta* are also sweet to taste & a rich source of Vitamin-C and can be utilized in food processing and bio-prospecting industries. It is one of non-leguminous Nitrogen fixing (By Frankia) tree and considered as a major tree component in fruit tree-based agroforestry system in hilly area. Being actinorhizal, *M. esculenta* is also useful in augmentation of nitrogen in depleted soils. Tress of *Myrica* spp. can survive in nitrogen-deficient soil and is often found to grow alongside pine and oak trees (Yanthan & Misra, 2013) [25], which make it suitable tree species for restoring land degradation and soil conservation in Hilly terrain of The Himalaya. Along with that, local tribes utilize tree as timber, fuel, fodder, wood as well as used for tanning and obtaining yellow coloured dye.

Even though being a multipurpose tree, the cultivation of the plant is very limited. Excessive exploitation of the species for fruit and fodder, the species is under imminent danger of extinction from wild sources. Due to increase in urbanization, anthropogenic activity, over harvesting, negligence of sustainable utilization and over exploitation of forests and waste lands for commercial uses, the natural habitat of the species is gradually vanishing. The result of such unscientific management of such valuable species making it endangered in Himalayan region by severely affecting its natural regeneration in forest area. Along with that, under nursery condition the seedling growth & development of the species is very poor and slow due to the absence of healthy root system in traditional polythene containers.

Traditional nursery practice entails raising seedlings in polythene bags (polybags) using soil, sand, and farmyard manure (FYM) as a potting medium. Such mixtures may produce seedlings with good shoot development but poor root systems (Miller and Jones 1995) [14]. Problems commonly associated with this conventional practice are the bulk, poor nutritional status, and poor aeration of the medium, limited root fibrositis and root coiling. A consequence is poor survival in the nursery and field. These problems can be addressed using a balanced potting mixture, by using an optimum type and size of container.

So, the current research work is focusing on the production of qualitative and quantitative seedlings of *M. esculenta* under nursery condition. Here the researcher has tried to establish the interaction effect of different pre-sowing seed treatments, growing media and root trainers on the growth and development of the seedlings with an objective of healthy planting stock production.

Materials and Methods

The mature seeds of *Myrica esculenta* were collected from vigorous, middle-aged trees during the months of April and May 2019. The collection of seed was carried out from Dudhar, Manighat and Maluti areas of Sirmour district (30° 33' 46.2456" N and 77° 28' 12.7092" E). The research work was conducted during the year 2019-20, at the nursery area of Department of Silviculture and Agroforestry, Dr Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, India.

The mature/ripe fruits (reddish in colour) of *M. esculenta* were collected from the randomly selected good fruit bearing middle aged trees of 6-9 m height. After removing all the foreign matter, the seeds were de-pulped and kept at room temperature for 30 days to get dried prior to pre-sowing treatments. Around one-kilogram mature fruits (5500 number) were collected and after de-pulping & careful inspection, 4500 number seeds from the seed lot selected for the experiment.

The seeds were subjected to different pre-sowing treatments such as T_1: Control (Without any treatment), T_2: Immersion of seeds in cow urine for 2 weeks, T_3: Immersion of seeds in cow urine for 3 weeks, T_4: Immersion of seeds in beejamrita for 2 weeks, T_5: Immersion of seeds in beejamrita for 3 weeks, T_6: Scarification of seeds in sulphuric acid for 15 minutes followed by washing in running tap water. After treating with different pre-treatments, seeds were subsequently sown in root trainers of different sizes such as C_1: Root trainers of 100 cc capacity, C_2: Root trainers of 150 cc capacity, C_3: Root trainers of 250 cc capacity having different growing media consisting of soil, sand, FYM and vermicompost in different proportion. The different ratio in growing media can be enlisted as M_1: Soil: FYM (1:1), M_2: Soil: Sand: FYM (1:1:1), M_3: Soil: Vermicompost (1:1), M_4: Soil: Sand: Vermicompost (1:1:1).

All growth, biomass & quality parameters were estimated in seedlings of six-month year old from date of sowing. After that, data were subjected to statistical analysis using experimental design factorial complete randomized Design (FCRD). Each treatment combination has 3 replications in it and under each replication 20 number of seeds were sown for the experiment.

For the growth parameters studies, five seedlings per replication were randomly selected and carefully uprooted without breaking the roots at the end of growing season. The attributes, such as, shoot length (cm), collar diameter (mm), number of leaves per seedling, leaf area (cm^2), root length (cm), number of secondary roots and root thickness (mm) were measured for each seedling separately and mean data of five seedlings was calculated for statistical analysis. The same five sample seedlings were also used for seedling biomass parameters (Shoot dry weight, root dry weight, total dry weight and per cent fibrous roots) and seedling quality studies (root and shoot ratio (dry weight basis), seedling vigour index, Dickson quality index and volume index). For biomass and quality studies the seedlings were uprooted and washed in running tap water and cut at collar region to separate root and shoot portion so that the biomass parameters were recorded separately for each seedling and mean data of five seedlings in each replication was attributed for statistical analysis.

Results

The results achieved while investigating "Interaction effect of different sized root trainers, growing media and pre-sowing seed treatments on growth & development of *Myrica esculenta* Buch. Ham. Seedlings under nursery condition." have been described after subjecting the data to statistical analysis under the following sub-headings.

Interaction effect of different sized root trainers, growing media and pre-sowing seed treatments (C×M×T) on seedling growth parameters of *Myrica esculenta* under nursery condition

Shoot length (cm)

Among different treatment combinations of container types, growing media and pre-sowing treatments (Table III), $C_3 \times M_4 \times T_5$ (root trainers of size 250 cc × soil +sand+ vermicompost in ratio 1:1:1× immersion in beejamrita for 3 weeks) recorded significantly highest shoot length of 9.92 cm. While the lowest value (2.06 cm) was noticed in $C_1 \times M_1 \times T_1$ (root trainers of size 100 cc × soil + FYM in ratio of 1:1 × control) (Table I) treatment combination which was statistically at par with $C_1 \times M_1 \times T_2$ and $C_1 \times M_1 \times T_6$.

Collar diameter (mm)

Among different treatment combinations of container types, growing media and pre-sowing seed treatments in Table III, the seeds raised in $C_3 \times M_4 \times T_5$ (root trainers of size 250 cc × soil +sand+ vermicompost in ratio 1:1:1 × immersion in beejamrita for 3 weeks) documented the highest collar diameter of 1.77 mm. While the lowest value for collar diameter (0.20 mm) was noticed in $C_1 \times M_1 \times T_1$ (root trainers of size 100 cc × soil + FYM in ratio of 1:1 × control) (Table I) treatment combination which was statistically at par with $C_1 \times M_2 \times T_1$, $C_1 \times M_1 \times T_2$ and $C_1 \times M_1 \times T_6$.

Number of leaves per seedling

Data in Table III show that combining effects of container types, growing media and pre-sowing seed treatments exerted significant effect on number of leaves. Seedlings raised in $C_3 \times M_4 \times T_5$ (root trainers of size 250 cc × soil +sand+ vermicompost in ratio 1:1:1 × soaking in beejamrita for 3 weeks) recorded significantly highest number of leaves (14.67). While the lowest number (2.00) of leaves was however, noticed in $C_1 \times M_2 \times T_1$ and $C_1 \times M_1 \times T_6$ treatment combinations (Table I) which was statistically at par with $C_1 \times M_1 \times T_1$, $C_1 \times M_2 \times T_2$, $C_1 \times M_3 \times T_1$, $C_1 \times M_1 \times T_3$, $C_1 \times M_2 \times T_6$ and $C_1 \times M_3 \times T_6$.

Leaf area (cm^2)

Among different treatment combinations presented in Table III, seedlings raised in $C_3 \times M_4 \times T_5$ (root trainers of size 250cc × soil + sand + vermicompost in ratio 1:1:1× immersion in beejamrita for 3 weeks) displayed significantly highest leaf area of 9.70 cm^2 and the least value (1.87 cm^2) was noticed in $C_1 \times M_1 \times T_1$ treatment combination (Table I), which was statistically at par with $C_1 \times M_2 \times T_5$ and $C_1 \times M_2 \times T_5$.

Root length (cm)

Among different treatment combinations of container types, growing media and pre-sowing seed treatments (Table III), seedlings raised in $C_3 \times M_4 \times T_5$ (root trainers of size 250 cc × soil+ sand + vermicompost in ratio 1:1:1× soaking in beejamrita for 3 weeks) resulted significantly highest root length of 20.38 cm. While the least value (3.59 cm) was noticed in C1×M2×T1 treatment combination (Table I) which was statistically at par with $C_1 \times M_1 \times T_1$, $C_1 \times M_3 \times T_1$, $C_1 \times M_4 \times T_1$, $C_1 \times M_1 \times T_6$, $C_1 \times M_2 \times T_6$, $C_1 \times M_3 \times T_6$, $C_1 \times M_4 \times T_6$, $C_1 \times M_3 \times T_2$ $C_1 \times M_4 \times T_2$, $C_1 \times M_2 \times T_3$ and $C_1 \times M_2 \times T_4$.

Number of secondary roots

Among different treatment combinations of pre-sowing treatments, container types and growing media (Table III), the seedlings raised in $C_3 \times M_4 \times T_5$ (250 cc root trainers × soil+ sand + vermicompost in ratio 1:1:1 × immersion in beejamrita for 3 weeks) inscribed significantly highest number of secondary roots (19.67). While the lowest numbers of secondary roots (1.67) were noticed in $C_1 \times M_1 \times T_1$ (100 cc root trainers × soil+ FYM in ratio 1:1 × control) treatment combination (Table I) which was statistically at par with $C_1 \times M_2 \times T_1$, $C_1 \times M_3 \times T_1$, $C_1 \times M_4 \times T_1$, $C_1 \times M_2 \times T_2$, $C_1 \times M_1 \times T_3$, $C_1 \times M_2 \times T_4$, $C_1 \times M_1 \times T_6$, $C_1 \times M_2 \times T_6$ and $C_1 \times M_3 \times T_6$.

Root thickness (mm)

The perusal of data presented in Table III divulges that *Myrica esculenta* seeds soaked in beejamrita for 3 weeks (T_5) subsequently raised in root trainers of size 250 cc (C_3) filled with growing medium consisting of soil + sand + vermicompost in ratio 1:1:1 (M_4) *i.e.*, $C_3 \times M_4 \times T_5$ resulted the highest root thickness of 2.07 mm and least value of 0.10 mm was found for $C_1 \times M_2 \times T_1$ treatment combination (Table I) which was statistically at par with $C_1 \times M_1 \times T_1$, $C_1 \times M_3 \times T_1$, $C_1 \times M_1 \times T_6$ and $C_1 \times M_2 \times T_6$.

Interaction effect of different sized root trainers, growing media and pre-sowing seed treatments (C×M×T) on seedling biomass parameters of *Myrica esculenta* under nursery condition

Dry shoot weight (g)

The result reveals that *Myrica esculenta* seedlings raised in $C_3 \times M_4 \times T_5$ (root trainers of size 250 cc × soil+ sand + vermicompost in ratio 1:1:1 × immersion in beejamrita for 3 weeks) (Table III) showed the highest shoot dry weight of 0.54 g. While the least value of 0.11 g was obtained for $C_1 \times M_2 \times T_1$ and $C_1 \times M_3 \times T_1$ treatment combination (Table I).

Dry root weight (g)

The Table III illustrates that *Myrica esculenta* seedlings raised in $C_3 \times M_4 \times T_5$ (root trainers of size 250 cc × soil+ sand + vermicompost in ratio 1:1:1 × immersion in beejamrita for 3 weeks) resulted the highest root dry weight of 0.99 g. While the minimum value of 0.10 g was obtained for $C_1 \times M_3 \times T_1$ (root trainer of size 100 cc × soil + vermicompost in ratio 1:1

$\times$ no pre-sowing treatment) (Table I) which was statistically at par with $C_1\times M_2\times T_1$, $C_1\times M_4\times T_1$, $C_1\times M_1\times T_1$, $C_1\times M_2\times T_2$, $C_1\times M_3\times T_6$, $C_1\times M_3\times T_2$, $C_1\times M_4\times T_6$, $C_1\times M_1\times T_6$, $C_1\times M_2\times T_6$, $C_2\times M_4\times T_6$, $C_2\times M_2\times T_6$, $C_2\times M_3\times T_1$, $C_2\times M_2\times T_1$, $C_2\times M_1\times T_1$, $C_3\times M_4\times T_1$, $C_3\times M_3\times T_1$, $C_3\times M_2\times T_1$ and $C_3\times M_1\times T_1$.

Total dry weight (g)

The result in Table III demonstrates that *Myrica esculenta* seeds raised under $C_3\times M_4\times T_5$ (root trainers of size 250 cc × soil+ sand + vermicompost in ratio 1:1:1× immersion in beejamrita for 3 weeks) resulted the maximum total dry weight of 1.57 g. However the least value of 0.22 g was obtained for $C_1\times M_3\times T_1$ (Table I) which was statistically at par with $C_1\times M_1\times T_1$, $C_1\times M_2\times T_1$, $C_1\times M_4\times T_1$, $C_1\times M_2\times T_2$, $C_1\times M_3\times T_2$, $C_1\times M_4\times T_6$, $C_1\times M_3\times T_6$, $C_1\times M_2\times T_6$, $C_1\times M_1\times T_6$, $C_2\times M_1\times T_6$, $C_2\times M_1\times T_1$, $C_2\times M_2\times T_1$, $C_2\times M_3\times T_1$, $C_2\times M_4\times T_1$, $C_3\times M_4\times T_1$, $C_3\times M_3\times T_1$ and $C_3\times M_1\times T_1$.

Per cent fibrous roots

Among different treatment combinations of Table III, $C_3\times M_4\times T_5$ (250 cc root trainers × soil+ sand + vermicompost in ratio 1:1:1 × immersion in beejamrita for 3 weeks) raised seedlings recorded significantly highest per cent of fibrous roots (60.32%), which was statistically at par with $C_3\times M_4\times T_4$ (55.84%). The significantly lowest per cent of fibrous roots (10.76%) was noticed in $C_1\times M_2\times T_1$ treatment combination (Table I) which was statistically at par with $C_1\times M_1\times T_1$, $C_1\times M_2\times T_6$, $C_1\times M_1\times T_6$ and $C_2\times M_3\times T_1$.

Interaction effect of different sized root trainers, growing media and pre-sowing seed treatments (C×M×T) on seedling quality parameters of *Myrica esculenta* under nursery condition

Root and Shoot ratio (dry weight basis)

Table II shows that the maximum root shoot ratio (1.63) was achieved in seedlings from $C_2\times M_4\times T_5$ (150 cc root trainers × soil+ sand + vermicompost in ratio 1:1:1 × immersion in beejamrita for 3 weeks) treatment interaction which was statistically at par with $C_3\times M_4\times T_5$ and $C_2\times M_4\times T_4$. While minimum value of root shoot ratio (0.13) was recorded in seedlings from $C_1\times M_1\times T_1$ (100 cc root trainers × soil+ FYM in ratio 1:1 × control) treatment interaction (Table I) which was at par with $C_1\times M_2\times T_1$, $C_1\times M_3\times T_1$, $C_1\times M_4\times T_1$ and $C_2\times M_1\times T_1$.

Seedling vigour index

The perusal of data in Table III depicts that *Myrica esculenta* seedlings raised in $C_3\times M_4\times T_5$ (root trainers of size 250 cc × soil+ sand + vermicompost in ratio 1:1:1× soaking of seeds in beejamrita for 3 weeks) reported the highest vigour index of 1344. The significantly least value (57) was obtained for $C_1\times M_1\times T_1$ treatment combination (Table I) which was statistically at par with $C_1\times M_1\times T_6$, $C_1\times M_2\times T_1$, $C_2\times M_3\times T_1$, $C_1\times M_1\times T_2$, $C_1\times M_2\times T_6$, $C_2\times M_1\times T_1$ and $C_1\times M_4\times T_1$.

Dickson Quality index

The data in Table III express that *Myrica esculenta seedlings* grown under $C_3\times M_4\times T_5$ (root trainers of size 250 cc × soil+ sand + vermicompost in ratio 1:1:1 × immersion in beejamrita for 3 weeks) ascribed the highest (0.40) quality index. While the least value of quality index (0.02) was obtained in treatment combination of $C_1\times M_1\times T_1$, $C_1\times M_2\times T_1$, $C_1\times M_3\times T_1$ and $C_1\times M_4\times T_1$ (Table I) which was statistically at par with $C_1\times M_4\times T_6$, $C_1\times M_3\times T_6$, $C_1\times M_2\times T_6$, $C_1\times M_1\times T_6$, $C_1\times M_1\times T_2$, $C_1\times M_2\times T_2$, $C_1\times M_3\times T_2$, $C_1\times M_4\times T_2$, $C_1\times M_1\times T_3$, $C_1\times M_3\times T_3$, $C_1\times M_1\times T_4$, $C_1\times M_1\times T_5$ and $C_2\times M_1\times T_1$.

Volume Index

The perusal of result in Table III reveals that *Myrica esculenta* seedlings raised in $C_3\times M_4\times T_5$ (root trainers of size 250 cc × soil+ sand + vermicompost in ratio 1:1:1 × immersion in beejamrita for 3 weeks) emerged the highest (23.56) volume index. While the least value (0.02) was obtained in treatment combination of $C_1\times M_1\times T_1$ (Table I) which was statistically at par with $C_1\times M_4\times T_6$, $C_1\times M_3\times T_6$, $C_1\times M_2\times T_6$, $C_1\times M_1\times T_6$, $C_1\times M_1\times T_2$, $C_1\times M_2\times T_2$, $C_1\times M_3\times T_2$, $C_1\times M_4\times T_2$, $C_1\times M_1\times T_3$, $C_1\times M_2\times T_3$, $C_1\times M_3\times T_3$, $C_1\times M_1\times T_4$, $C_1\times M_2\times T_4$, $C_1\times M_3\times T_4$, $C_1\times M_1\times T_5$, $C_1\times M_2\times T_5$, $C_1\times M_2\times T_1$, $C_1\times M_3\times T_5$, $C_1\times M_4\times T_5$ and $C_2\times M_1\times T_1$.

Discussion

The present investigation reveals that all seedling growth parameters were significantly influenced by the combining effect of different sized root trainers, growing media and pre-sowing seed treatments. Among various treatment combinations, seedlings raised under $C_3\times M_4\times T_5$ (root trainers of size 250 cc × soil + sand + vermicompost in ratio 1:1:1 × treatment with beejamrita for 3 weeks) resulted maximum value for every growth parameter including shoot length (9.92 cm), collar diameter (1.56 mm), number of leaves (15), leaf area (9.70 cm^2), root length (20.38 cm), number of secondary roots (20) and root thickness (2.07).

Damtew *et al.*, (2019) [5] also purported similar results where maximum growth were observed in seedlings raised in soil, sand and vermicompost based potting mixture for *Olea europaea*. It may due to the addition of appropriate amount of vermicompost (30% of potting mixture) to growing media which can stimulate the growth of seedlings due to the presence of major and other essential nutrients like P and K in more available forms to plant because vermicompost can progressively lower C: N ratio in the growing media. The results agree with the findings of Rasid *et al.*, (2018) [19] for *Jatropha curcas* where all growth parameters were found significantly higher in large size containers *viz.* root trainers of size 250 cc. It might due to the larger size of containers which provide more area for seedling to grow without any root restriction resulting a healthy and vigorous seedling.

The present investigation reveals that all seedling biomass parameters except dry shoot weight were significantly influenced by the combined effect of different sized root trainers, growing media and pre-sowing seed treatments. Among various treatment combinations, seedlings raised under $C_1\times M_4\times T_5$ (root trainers of size 250 cc × soil +sand +vermicompost in ratio 1:1:1 × treatment with beejamrita for 3 weeks) resulted maximum value for biomass parameters including dry root weight (0.99 g), total dry weight (1.57 g) and per cent fibrous roots (60.32%).

The results agree with the findings of Qaisar (2001) [18] in *Dalbergia sissoo* and Hassanein (2010) [9] in *Bauhinia variegata*. It might due to the addition of appropriate quantity of vermicompost to potting mixture which contains most nutrients in plant-available forms such as nitrates, phosphates, exchangeable calcium, soluble potassium (NPK), micro nutrients and growth regulators. These might play a vital role in early root and shoot development having more dry weight content. In the present investigation the lowest total dry weight was found in seedling raised in growing media having soil and vermicompost (50% of the total weight of potting mixture). In-spite of being in higher amount of vermicompost, growth of seedling has declined. It might be due to the higher concentration of vermicompost in potting medium which exert the high electrical conductivity and the excessively high number of certain ions cause phytotoxicity as contended by García-Gómez *et al.*, (2002) [7] as a consequence reduction in seedling fresh and dry weight.

Table 1: Interaction effect of different sized root trainers, growing media and pre-sowing seed treatments (C×M×T) on seedling growth, biomass & quality parameters of *Myrica esculenta* under nursery condition (CD=Critical Difference, S.E.d= Standard Error of Difference)

Treatment Combinations			Seedling Growth Parameters								Seedling Biomass Parameters				Seedling Quality Parameters		
			Shoot Length (Cm)	Collar Diameter (Mm)	Number Of Leaves	Leaf Area (Cm^2)	Root Length (Cm)	Number Of Secondary Roots	Root Thickness (Mm)	Dry Shoot Weight (G)	Dry Root Weight (G)	Total Dry Weight (G)	Per Cent Fibrous Roots	Root Shoot Ratio	Seedling Vigour Index	Dickson Quality Index	Volume Index
C_1	M_1	T_1	2.06	0.20	2.67	1.87	3.96	1.67	0.11	0.12	0.13	0.25	11.42	0.13	57	0.02	0.08
		T_2	2.34	0.27	2.33	2.78	5.87	3.00	0.26	0.16	0.17	0.32	18.00	0.46	94	0.03	0.18
		T_3	3.02	0.32	2.33	3.28	6.28	2.67	0.30	0.17	0.18	0.35	16.70	0.64	136	0.04	0.31
		T_4	3.31	0.36	2.67	3.57	5.75	3.00	0.32	0.17	0.20	0.37	19.27	0.79	130	0.04	0.44
		T_5	3.45	0.46	3.67	3.82	6.82	4.00	0.33	0.19	0.22	0.41	20.11	0.89	165	0.04	0.72
		T_6	2.11	0.29	2.00	2.58	4.42	2.67	0.22	0.15	0.15	0.31	13.22	0.31	72	0.03	0.18
	M_2	T_1	2.68	0.29	2.00	2.15	3.59	2.00	0.10	0.11	0.11	0.23	10.76	0.25	78	0.02	0.22
		T_2	3.18	0.41	2.67	3.39	4.81	2.67	0.29	0.15	0.13	0.28	17.01	0.60	136	0.03	0.56
		T_3	3.30	0.45	3.33	3.67	4.85	3.00	0.37	0.19	0.17	0.36	22.62	0.82	153	0.06	0.67
		T_4	3.50	0.56	3.33	4.15	5.21	2.67	0.40	0.15	0.20	0.35	20.82	0.96	173	0.05	1.10
		T_5	3.62	0.64	4.00	4.92	5.86	3.33	0.45	0.19	0.22	0.41	19.96	1.08	191	0.06	1.47
		T_6	3.05	0.34	2.33	3.01	4.48	2.00	0.17	0.13	0.15	0.28	11.28	0.49	98	0.03	0.35
	M_3	T_1	2.60	0.36	2.33	2.23	3.96	2.33	0.20	0.11	0.10	0.22	19.49	0.25	92	0.02	0.34
		T_2	3.42	0.52	3.00	3.01	5.30	3.33	0.45	0.15	0.14	0.30	26.56	0.76	135	0.04	0.92
		T_3	3.68	0.56	3.67	3.87	5.52	4.33	0.47	0.20	0.17	0.37	30.02	0.95	149	0.04	1.19
		T_4	4.00	0.64	3.67	4.89	5.88	3.67	0.45	0.23	0.20	0.42	35.97	1.08	187	0.05	1.66
		T_5	4.64	0.84	4.00	5.73	6.13	4.00	0.50	0.22	0.23	0.45	39.33	1.14	255	0.07	3.26
		T_6	3.07	0.41	2.33	2.70	4.73	2.67	0.36	0.16	0.13	0.29	25.27	0.63	134	0.03	0.52
	M_4	T_1	3.07	0.47	2.67	3.33	4.02	2.67	0.30	0.12	0.11	0.23	19.34	0.16	117	0.02	0.69
		T_2	3.44	0.65	4.00	4.12	5.28	4.00	0.42	0.17	0.17	0.34	30.32	0.92	175	0.04	1.43
		T_3	4.41	0.74	4.33	5.06	5.64	3.67	0.45	0.23	0.17	0.40	35.10	1.04	210	0.06	2.41
		T_4	4.94	0.85	4.00	5.69	6.03	4.00	0.53	0.24	0.21	0.45	36.83	1.13	244	0.09	3.55
		T_5	5.60	0.90	5.67	6.58	7.10	9.33	0.57	0.29	0.37	0.56	38.99	1.21	319	0.16	4.61
		T_6	3.67	0.46	3.67	3.81	4.49	3.00	0.33	0.13	0.14	0.27	28.27	0.62	144	0.03	0.78
$CD_{0.05}$			0.65	0.09	1.00	0.39	1.80	1.08	0.13	N/A	0.05	0.10	5.86	0.13	64.34	0.03	1.72
S.E.d±			0.33	0.05	0.51	0.20	0.91	0.54	0.07	0.04	0.03	0.05	2.97	0.06	32.55	0.01	0.87

Table 2: Interaction effect of different sized root trainers, growing media and pre-sowing seed treatments (C×M×T) on seedling growth, biomass & quality parameters of *Myrica esculenta* under nursery condition (CD=Critical Difference, S.E.d= Standard Error of Difference)

Treatment Combinations			Seedling Growth Parameters							Seedling Biomass Parameters				Seedling Quality Parameters			
			Shoot Length (Cm)	**Collar Diameter (Mm)**	**Number Of Leaves**	**Leaf Area (Cm^2)**	**Root Length (Cm)**	**Number Of Secondary Roots**	**Root Thickness (Mm)**	**Dry Shoot Weight (G)**	**Dry Root Weight (G)**	**Total Dry Weight (G)**	**Per Cent Fibrous Roots**	**Root Shoot Ratio**	**Seedling Vigour Index**	**Dickson Quality Index**	**Volume Index**
C_2	M_1	T_1	3.07	0.66	3.33	2.87	6.33	4.33	3.07	0.14	0.11	0.25	20.71	0.20	107	0.04	1.38
		T_2	3.36	0.91	4.67	3.30	7.39	6.33	3.36	0.16	0.18	0.34	30.92	0.66	134	0.06	2.87
		T_3	3.76	1.06	4.67	3.74	7.76	7.33	3.76	0.19	0.18	0.37	32.45	0.73	169	0.08	4.23
		T_4	4.15	1.03	5.33	4.50	8.71	8.00	4.15	0.17	0.23	0.40	35.59	0.80	202	0.08	4.37
		T_5	4.31	1.12	5.67	4.85	9.88	9.00	4.31	0.26	0.25	0.51	39.70	1.14	246	0.10	5.37
		T_6	3.78	0.85	3.67	3.32	8.06	5.67	3.78	0.14	0.17	0.32	24.39	0.52	152	0.05	2.80
	M_2	T_1	3.32	1.00	4.00	2.92	6.80	4.33	3.32	0.14	0.13	0.27	17.85	0.26	148	0.06	3.30
		T_2	3.82	1.08	4.67	3.30	9.10	7.33	3.82	0.21	0.23	0.44	26.55	0.66	234	0.09	4.45
		T_3	4.30	1.16	5.33	3.89	8.76	8.67	4.30	0.25	0.21	0.46	28.74	0.78	240	0.09	5.80
		T_4	4.52	1.19	5.00	4.84	8.44	9.33	4.52	0.20	0.24	0.44	37.90	1.00	246	0.09	6.41
		T_5	5.02	1.25	6.00	5.95	10.44	10.00	5.02	0.30	0.28	0.57	43.46	1.37	312	0.11	7.79
		T_6	3.60	1.15	4.33	3.14	7.89	6.33	3.60	0.20	0.15	0.35	20.61	0.60	198	0.07	4.71
	M_3	T_1	3.07	1.06	4.67	3.44	7.32	5.33	3.07	0.12	0.13	0.24	15.83	0.37	156	0.06	3.45
		T_2	4.30	1.13	5.33	4.47	9.87	7.33	4.30	0.22	0.24	0.46	27.40	0.82	242	0.09	5.76
		T_3	4.98	1.29	6.00	4.56	11.42	8.33	4.98	0.25	0.25	0.51	27.43	0.94	281	0.10	8.29
		T_4	5.49	1.34	6.00	5.97	13.99	9.67	5.49	0.30	0.24	0.54	35.02	1.10	379	0.09	9.85
		T_5	5.93	1.39	6.00	6.98	15.65	11.00	5.93	0.30	0.30	0.60	44.98	1.46	454	0.11	11.41
		T_6	3.97	1.19	4.67	4.25	8.64	7.00	3.97	0.18	0.16	0.34	17.67	0.65	219	0.07	5.65
	M_4	T_1	3.60	1.14	5.67	3.71	8.95	5.67	3.60	0.14	0.16	0.30	25.70	0.33	215	0.06	4.69
		T_2	5.34	1.31	6.33	4.49	13.64	8.33	5.34	0.20	0.28	0.46	35.58	1.01	344	0.10	9.08
		T_3	5.44	1.34	6.00	5.59	15.17	9.33	5.44	0.23	0.47	0.56	36.51	1.30	366	0.09	9.80
		T_4	5.83	1.38	7.00	6.91	15.79	10.33	5.83	0.27	0.54	0.72	48.16	1.52	580	0.17	11.15
		T_5	7.44	1.46	11.33	7.48	16.77	13.00	7.44	0.37	0.69	0.83	53.23	1.63	665	0.26	13.40
		T_6	4.50	1.20	6.00	4.31	11.19	6.67	4.50	0.17	0.11	0.27	24.90	0.74	287	0.05	6.52
$CD_{0.05}$			0.65	0.09	1.00	0.39	1.80	1.08	0.13	N/A	0.05	0.10	5.86	0.13	64.34	0.03	1.72
S.E.d±			0.33	0.05	0.51	0.20	0.91	0.54	0.07	0.04	0.03	0.05	2.97	0.06	32.55	0.01	0.87

Table 3: Interaction effect of different sized root trainers, growing media and pre-sowing seed treatments (C×M×T) on seedling growth, biomass & quality parameters of *Myrica esculenta* under nursery condition (CD=Critical Difference, S.E.d= Standard Error of Difference)

Treatment Combinations			Seedling Growth Parameters							Seedling Biomass Parameters				Seedling Quality Parameters			
			Shoot Length (Cm)	**Collar Diameter (Mm)**	**Number Of Leaves**	**Leaf Area (Cm^2)**	**Root Length (Cm)**	**Number Of Secondary Roots**	**Root Thickness (Mm)**	**Dry Shoot Weight (G)**	**Dry Root Weight (G)**	**Total Dry Weight (G)**	**Per Cent Fibrous Roots**	**Root Shoot Ratio**	**Seedling Vigour Index**	**Dickson Quality Index**	**Volume Index**
C_3	M_1	T_1	3.28	1.06	5.00	3.15	9.73	5.33	0.43	0.12	0.12	0.24	24.90	0.41	192	0.06	3.72
		T_2	3.80	1.30	6.67	4.33	11.42	6.33	1.07	0.21	0.19	0.40	33.28	0.75	283	0.09	6.37
		T_3	3.84	1.23	7.00	4.73	12.56	8.33	1.28	0.21	0.20	0.41	41.92	0.83	347	0.10	5.83
		T_4	4.45	1.27	9.33	4.92	12.08	9.33	1.41	0.19	0.22	0.40	43.47	1.17	415	0.09	7.26
		T_5	4.91	1.36	9.67	5.64	14.32	10.00	1.50	0.39	0.25	0.64	52.12	1.31	524	0.12	9.11
		T_6	3.81	1.12	6.33	3.54	10.99	5.00	0.74	0.19	0.16	0.35	34.08	0.66	221	0.07	4.79
	M_2	T_1	3.73	1.17	5.33	3.80	9.90	6.33	0.49	0.19	0.14	0.33	26.19	0.58	183	0.07	5.10
		T_2	4.52	1.33	6.33	4.22	13.92	6.67	1.42	0.23	0.21	0.44	33.81	0.93	430	0.09	8.01
		T_3	5.47	1.42	7.00	4.98	13.25	7.33	1.51	0.20	0.21	0.41	35.36	1.12	491	0.08	10.70
		T_4	6.02	1.43	7.33	5.79	13.76	9.67	1.67	0.24	0.27	0.51	36.05	1.30	589	0.10	12.29
		T_5	5.40	1.46	10.00	6.67	13.67	12.00	1.73	0.28	0.28	0.56	43.08	1.45	578	0.12	11.59
		T_6	4.29	1.25	6.00	4.04	12.02	5.67	0.83	0.15	0.17	0.32	26.79	0.81	312	0.07	6.68
	M_3	T_1	4.80	1.24	5.67	3.03	9.31	7.33	0.46	0.18	0.13	0.31	38.61	0.55	217	0.05	7.61
		T_2	5.72	1.40	6.33	4.44	13.82	9.33	0.84	0.21	0.28	0.49	43.67	0.86	438	0.10	11.17
		T_3	6.65	1.43	6.67	5.59	15.15	10.67	1.20	0.29	0.25	0.54	42.11	0.92	627	0.13	13.64
		T_4	6.19	1.56	8.00	6.85	14.15	11.67	1.37	0.33	0.28	0.61	44.14	1.08	643	0.13	15.09
		T_5	6.12	1.65	10.00	8.01	16.19	15.00	1.73	0.40	0.39	0.78	50.13	1.45	785	0.16	16.73
		T_6	4.59	1.33	6.00	3.80	11.51	6.67	0.70	0.18	0.20	0.37	24.03	0.74	351	0.08	8.19
	M_4	T_1	4.31	1.28	6.67	4.27	9.98	7.67	0.50	0.17	0.14	0.31	26.72	0.55	278	0.10	7.06
		T_2	5.62	1.43	9.00	6.16	13.92	8.67	1.29	0.24	0.41	0.57	44.12	0.88	554	0.12	11.49
		T_3	6.18	1.58	9.67	6.56	16.10	10.67	1.34	0.33	0.62	0.65	46.86	1.06	735	0.15	15.38
		T_4	6.62	1.64	10.67	7.84	17.89	15.00	1.84	0.41	0.77	0.82	55.84	1.24	902	0.28	17.97
		T_5	9.92	1.77	14.67	9.70	20.38	19.67	2.07	0.54	0.99	1.57	60.32	1.57	1344	0.40	23.56
		T_6	4.67	1.36	7.33	5.15	9.05	9.33	0.83	0.21	0.23	0.44	32.81	0.74	288	0.09	8.63
$CD_{0.05}$			0.65	0.09	1.00	0.39	1.80	1.08	0.13	N/A	0.05	0.10	5.86	0.13	64.34	0.03	1.72
S.E.d±			0.33	0.05	0.51	0.20	0.91	0.54	0.07	0.04	0.03	0.05	2.97	0.06	32.55	0.01	0.87

Biran and Eliassaf (1980) [3] construed that the large volume of containers positively affects the size of seedling raised. Poorter *et al*., (2012) [16] further explicated the effect of containers on different plant biology which showed that doubling of the pot size increased biomass production by 43% and the reduced growth in smaller pots was caused mainly by a reduction in photosynthesis per unit leaf area, rather than by changes in leaf morphology or biomass allocation. Mugloo *et al.*, (2015) [15] also contented an experiment to optimize the root trainer sizes for producing quality nursery stock of *Picea smithiana* (Indian spruce) and prescribed that all biomass related parameters were maximum in large sized root trainers.

The present investigation suggests that all seedling quality parameters were remarkably influenced by different sized root trainers, growing media and pre-sowing seed treatments. Among various treatment combinations, seedlings raised under $C_3 \times M_4 \times T_5$ (root trainers of size 250 cc × soil + sand + vermicompost in ratio 1:1:1 × treatment with beejamrita for 3 weeks) resulted highest value for quality parameters including seedling vigour index (1344), Dickson quality index (0.40) and volume index (23.56) while maximum root and shoot ratio (1.63) was observed in seedling raised under $C_2 \times M_4 \times T_5$ being statistically at par with $C_3 \times M_4 \times T_5$ and $C_2 \times M_4 \times T_4$.

Maximum value for seedling quality index was recorded in the seedling raised in potting mixture consisting soil, sand and vermicompost as contented by Jain *et al.,* (2018) [10] in *Moringa oleifera* L. seedlings. From the study, they observed that seeds sown in growing media consisting soil, sand and vermicompost (25% of total growing media/pot) showed the maximum quality index.

This might due to the suitable quantity of vermicompost, which enhanced the water holding capacity and released available nutrients to the growing zone of the plants intensifying the production of auxin, gibberellins, cytokinin and hence inoculated root elongation resulting in increased length and number of root hairs with well grown shoot system. Along with that presence of sand with them provided a good aeration inside growing media. Significant accumulation of N, P, K, Ca and Mg in root and shoot system with the application of humic acids derived from vermicompost was correlated to uptake of nutrients by plants. Hence, absorption of the nutrients from the soil had produced vigorous seedlings.

Farhana *et al.,* (2010) [6] explicated that maximum value of quality parameters were obtained from seedlings raised in big containers for *Albizia procera.* The plausible reason for the enhanced quality parameters may be the size of containers which provided the larger area to seedling for growth without any root restriction. Likewise, Sajana *et al*., (2018) [20] also stated that the seedlings of marking nut (*Semecarpus anacardium*) had showed the maximum quality parameters value when grown in potting mixture consisiting vermicompost + sand + pond soil (1:1:1) with reduced no of seedling mortality and produced maximum healthy seedlings. Result of present investigation corroborates the finding of Singh *et al.,* (2018) [22] in Allepo pine and Annapurna *et al*., (2003) [1] in Indian sandalwood (*Santalum album)* where more qualitative seedlings were obtained from the largest sized containers.

Conclusion

From this study, it could be concluded that among various treatment combinations, seedlings raised under $C_3 \times M_4 \times T_5$ (root trainers of size 250cc × soil + sand + vermicompost in ratio 1:1:1 × treatment with beejamrita for 3 weeks) has shown maximum values regarding all growth and quality parameters. Along with that, we can prescribe that the seedlings grown in above treatment combination (root trainers of size 250cc × soil + sand + vermicompost in ratio 1:1:1 × treatment with beejamrita for 3 weeks) has shown the maximum morphological growth. So, it can be suggested that the above treatment combination can be helpful in enhancing the growth performance of *Myrica esculenta* seedlings under nursery condition. Instead of using traditional polythene containers, we can enhance the use of root trainers, which has a very positive effect on the root development process of the seedlings by reducing root coiling. Root trainers are not only environment friendly but also cost effective to farmers as these are reuseable as compared to polybags. The species having germination problem due to the induced dormancy like hard seed coat can be overcome by the beejamrita pre-treatment. Regarding growing media, the equivalent proportion of soil, sand and vermicompost come-out as the best for the non-leguminous N-fixing plant nursery production. From the current investigation it can be concluded that seed treated with organic pre-sowing treatments and subsequently shown in root trainers of size 250cc containing vermin-compost based growing media have performed excellent manner than other treatment combination. The interaction effect of these three factors including pre-sowing seed treatments, growing medium and the root trainers has a significantly beneficial approach towards the production of quality planting stock of *Myrica esculenta* under nursery condition.

Statements and Declarations

I, Jyotiraditya Das hereby declare that all the research work conducted and mentioned above are purely original.

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