EFFECT OF PRE-SOWING SEED TREATMENTS AND GROWING MEDIA ON GERMINATION AND GROWTH PERFORMANCE OF BAHERA (*Terminalia bellirica* Roxb.)

Thesis

by

SHILPA
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CERTIFICATE-I

This is to certify that the thesis titled **"Effect of pre-sowing seed treatments and growing media on germination and growth performance of Bahera (*Terminalia bellirica* Roxb.)"** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE (FORESTY) SILVICULTURE** to Dr Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP)-173230 is a bonafide research work carried out by **Ms Shilpa (F-2018-50-M)** daughter of Shri Kameshwar Tanwar under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation has been fully acknowledged.

Place: Nauni-Solan
Dated:

(Dr Vimal Chauhan)
Major Advisor

CERTIFICATE-II

This is to certify that the thesis titled, **"Effect of pre-sowing seed treatments and growing media on germination and growth performance of Bahera (*Terminalia bellirica* Roxb.)"** submitted by **Ms Shilpa (F-2018-50-M)** daughter of Sh Kameshwar Tanwar to the Dr. Yashwant Singh Parmar University of Horticulture and Forestry, (Nauni) Solan (HP)-173 230 India in partial fulfillment of the requirements for the award of degree of **Master of Science (Forestry)** in the discipline of **Silviculture** has been approved by the Advisory Committee after an oral examination of the student in collaboration with the Internal Examiner.

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Needless to say Errors and Omissions are mine

Place: Nauni, Solan
Dated : __/__/ 2020 **(Shilpa)**

CONTENTS

LIST OF ABBREVIATIONS USED

Abbreviations		Meaning
%	:	Per cent
&	:	And
×	:	Multiplication
/	:	Per
+	:	Plus
°C	:	Degree Celsius
ANOVA	:	Analysis of variance
cc	:	Cubic centimeter
CD	:	Critical difference
cm	:	Centimeter
CRD	:	Complete Randomised design
df	:	Degree of freedom
et al.	:	Co-worker et alia (and others)
etc.	:	et cetera (and rest)
FYM	:	Farm Yard Manure
GA_3	:	Gibberelic acid
gm/ g	:	Gram
H P	:	Himachal Pradesh
H_2SO_4	:	Sulphuric acid
i.e.	:	id est (that is)
IAA	:	Indole Acetic Acid
K	:	Potassium
KNO_3	:	Potassium nitrate
mm	:	Millimeter
MSS	:	Mean Sum of Squares
N	:	Nitrogen
P	:	Phosphorus
ppm	:	Parts per million
$SE_{m\pm}$	:	Standard Error of means
viz.	:	Videlicet (namely)

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Chapter-1

INTRODUCTION

Forests play an imperative role in the conservation of natural resources. Forests bequeath significantly towards environmental upkeep, climate balance and are mainly instrumental for the rainfall patterns. Forests are the traditional source of multitude products particularly with regard to fuel wood, fodder, medicines, small and constructional timber, minor forest products and have sustained the large masses of population since ages. Increasing population and rapid decrease in the forest cover, poor increment, low sustainable yield and increasing demand led to shortage of timber and fuel wood in the country. Demand for different land uses and continual deforestation are responsible for decreasing natural forest land. As a result, continuous supply of wood from natural forests is becoming very difficult for different purposes (Asif *et al*., 2017). Plants propagation from the seeds ensures that the genetic diversity is maintained by different genetic recombinations which occur through sexual reproduction. The survival and natural evolution of the species in today's environmental changing conditions also makes possible due to this genetic diversity. Some species can only be raised from the seeds and seeds of many species can also be stored for longer period so the propagation of plants through seeds is the best method to produce more numbers of such plant species. Moreover, the plants produced from seed propagation generally carries a lower risk of transferring diseases from the parent plant. On the contrary, the vegetative propagation results to make plants true to type but makes them difficult to meet the challenges arising from diseases, insect attacks etc. (Bonner, 1990).

Bahera (*Terminalia bellirica* Roxb.) a member of family Combretaceae is tall, deciduous, multipurpose tree, found throughout the large parts of India, except in arid regions. It occurs throughout the Sub Himalayan tract up to 1200 to 1300 m above mean sea level in Sal (*Shorea robusta*) and miscellaneous forest of the subtropical zone (Osmaston, 1978). It also occurs in Nepal, Sri Lanka, Southeast Asia, and Malaysia. In Himachal Pradesh, it is found growing in the district of Bilaspur, Hamripur, Kangra (Nurpur), Sirmaur (Nahan, Rajgarh) and Solan (Kunihar) upto an elevation of 1500 m above mean sea level as reported by Bhardwaj and Seth (2017). The tree has thick brownish grey bark with shallow longitudinal fissures, attaining 40-50 m height and girth growth ranging from 3-4 m. Leaves

are petiolate, broadly elliptical, alternate and clustered towards the end of branches. Flowers are small, greenish yellow with a strong offensive smell, found in axillary spikes.

Medicinal trees play an important role in health care and they are the major raw material for both traditional and conventiontal medicine preparations. These trees are being used by Unani and Ayurvedic practitioners as well as by the common people to heal ailments at home. The fruit of this tree is one of the three ingredients of "Triphala", which is a popular Ayurvedic formulation extensively used to recover from fever, cough, diarrhoea, skin diseases, oral thrush, hypertension, known to reduce cardiac depression and the risk factors associated with the heart (Kumar *et al*., 2014, Chaudhary *et al*., 2012). In addition, fruit rind (pericarp) of *T. bellirica* constitutes the ayurvedic drug 'Bibhitaki' which has been used for curing diseases such as cardio vascular disorders, skin allergies and diabetes. Leaves are sometimes used as fodder for cattle and are fed to tasar silkworm (Bhatia *et al.*, 1977). Poles are used for making the beams of houses, handles of agricultural implements and furniture.

Natural regeneration of bahera through seeds is poor due to hard seed coat which results in low germination. Besides, the seeds of this tree are damaged by insects, rodents and cattles. The seeds of Bahera remain viable for one year (Luna, 2005) and poor germination due to hard seed coat and thick fleshy pulp of the fruits (Negi *et al*., 1995). Owing to high demand for its seedlings in forestry plantation work (Luna, 2006), there is urgent need to produce quality seedlings in the nursery.

Seed germination is reduced by the presence of impermeable seed coats that restricts the availability of water, which can penetrate into seeds at their optimum concentration and the seed dormancy are the reasons which results in insufficient production of seedling for forest plantations. The germination of seeds of many tree species is very slow and inadequate which result in unavailability of healthy and good quality seedlings and ultimately affect the large scale plantation of the species.

The success of any plantation programmes largely depends on quality nursery and fast growth rate of seedlings in the nursery. The nursery technique should be efficient enough to produce adequate number of quality seedlings with in a reasonable period of time. To overcome the problem of seed germination and to break the seed dormancy, pre-sowing seed

treatment is necessary to ensure rapid and uniform germination of seed. Raising quality seedlings requires careful planning for all the major components such as selection of quality seed, improving seed germination, appropriate growing media, containers and nursery management practices. The nurseries are usually raised as bare root or in the containers. Bare root seedlings are not produced in large quantity due to transpiration stress, packaging problems, which often result in high mortality rates when planted in the field. The containerized production system varies from simple tar paper pots to wide variety of rigid-walled containers which are in common use these days. Most common containers used in India are the polybags, but main problem with these, is root coiling as bottom is closed, which hamper quality stock production (Gera *et al*., 1998).

Modern container systems have been designed to overcome factors affecting seedling growth that reflect the special requirements of plantation programmes that are related to economic and management considerations both at nursery and on the outplanting site. These containers (root trainers) lack sharp horizontal corners, utilize vertical ribs inside to increase root growth downward and avoid root coiling. Beside container type, the growing medium is also of great significance as it composed of fertile soil which is well drained and aerated. The seedling biomass of any crop is the result of available nutrients during the seedling growth period and these nutrients can be provided either by chemical fertilizers, organic manures or some other means.

The application of pre-sowing seed treatments like Beejamrutha, cow urine and organic manures as a soil supplement may improve the performance of seed germination of number of tree species. In current forest nursery practices, expenditure on nursery alone takes a major portion of plantation cost so the cost can be reduced by evolving cheap, readily available local material and desirable methods for good germination and raising desired quantity of seedlings. In order to get maximum germination and mass production of seedlings, different pre-sowing seed treatments, growing media and the container size of proper dimensional features are of great significance for the production of quality nursery.

Since, the different parts of *Terminalia bellirica* are collected for medicinal purposes and the tree is lopped for fodder, this adversely affects its natural regeneration. In these situation, it is of utmost importance to standardize its nursery raising techniques in order to obtain quality planting stock for artificial regeneration by applying different pre-sowing seed

treatments using different growing media and containers. Therefore, the present study entitled "**Effect of pre-sowing seed treatments and growing media on germination and growth performance of Bahera (*Terminalia bellirica* Roxb.)"** was proposed to study the following objectives :-

i) To study the effect of different pre-sowing seed treatments and growing media on germination, growth and vigour of seedlings.

ii) To study the effect of different types of root containers on germination, growth and vigour of seedlings.

Chapter-2

REVIEW OF LITERATURE

The relevant information related to the present study has been reviewed under the following headings:

2.1 Effect of different pre-sowing seed treatments
2.2 Effect of different growing media
2.3 Effect of different types of root containers

2.1 EFFECT OF DIFFERENT PRE-SOWING SEED TREATMENTS

Shinde and Malshe (2009) studied the effect of cow urine and cow dung slurry on germination and growth of *Manilkara hexandra* (Khirni) and reported significant effect of soaking seed in cow urine and cow dung slurry in comparison to untreated seeds (control). Significantly early (15-24 days) and higher germination (66.11%) were recorded in seeds soaked in cow urine + cow dung slurry for 12 hours. The seedling height (33.19 cm), number of leaves (17.23 per seedling), length of primary roots (15.71 cm) and number of tertiary roots (41 per seedling) were also found significantly higher in comparison to untreated seeds (Control).

Patel *et al.* (2016) observed the effect of pre-sowing seed treatments on germination and growth of *Mangifera indica* (Mango) seedlings and reported that the maximum germination of 66.33 percent were observed in GA_3 (100 ppm) treated seeds, followed by GA_3 (200 ppm) with 63.67 percent and 55.67 percent in (3%) beejamrutha.

Bajaniya *et al.* (2018) studied the effect of pre-soaking seed treatments on seedling growth of *Manilkara hexandra* Roxb. (Khirni) and reported that the effect of GA_3 200 ppm showed maximum plant height (12.08 cm), total dry weight (1.44 gm), followed by GA_3 150 ppm for plant height (11.93 cm), total dry weight (1.41 gm) and cow dung slurry for plant height (11.12 cm) and total dry weight (1.10 gm).

Anand *et al.* (2012) reported that seeds of *Melia dubia* (Malabar neem) treated with cow dung slurry for 7 days (T_4 treatment) showed highest germination percent (34.3%), germination value (2.2), germination energy (25), followed by gibberellic acid treatment

for 24 hours (T_7). Similarly shoot length, root length, collar diameter followed the similar trend of higher value when treated with T_4 and T_7 treatments respectively.

Gunaga *et al*. (2011) observed that mechanical scarification of seed by beating, results in 86.4 percent germination, while the alternate wetting and drying of seeds in cow dung slurry for six days (every alternate day soaking and drying) gave germination of 79.4 percent in *Calophyllum inophyllum* (Borneo-mahogany).

Murugesh (2011) reported that soaking the seeds of *Grevillea robusta* (Silver oak) in cow urine for overnight recorded germination percentage of (23.30 %) as compared to control (21.97 %).

Hossain *et al.* (2005) studied the effect of pre-sowing seed treatments on germination and seedling growth of *Terminalia chebula* Retz. (Harad) in the nursery. The study revealed that depulping the fruits and soaking in water for various periods significantly enhanced seed germination and seedling growth. The highest germination percentage (66.7%) were observed in the depulped fruit (seeds) and soaked in cold water for 48 hours, followed by the germinaton of 60 percent in depulped seeds soaked in cold water for 24 hours. The lowest germination percentage (48.9 %) were obtained in untreated seeds.

Hossain *et al.* (2014) reported the effects of depulping of the fruits and soaking the seeds of *Terminalia bellerica* (Bahera) in water for different time period. Fruits of *T. bellerica* were depulped by rotting the fleshy pulp in water. Considering the imbibition period, germination percentage, growth performance including vigor index and total biomass produced per seedling, depulping the fruits and soaking the dry seeds in cold water for 48 hours were recommended for obtaining maximum seed germination and seedling growth in *T. bellerica.* The growth were maximum in the seedlings, developed through DT_3 (Depulped fruits soaked in cold water for 24 hours) and the vigor index were maximum in DT_2 (Depulped fruits soaked in cold water for 12 hours).

Vijayalakshmi and Renganayaki (2017) studied the effect of cow dung slurry and termite mount as a seed treatment on germination and seedling growth of *Pterocarpus santalinus* (Red Sanders). The results revealed that cow dung slurry for 24 hours showed maximum germination of (51%), followed by cow dung slurry for 48 hours (44%) as compared to control (33%).

Sutheesh *et al.* (2017) conducted an experiment to study the effect of organic and inorganic pre-sowing seed treatments for germination and seedling vigour in *Santalum album* (Sandal wood) and reported that the maximum germination energy (44.67%) were recorded in seeds soaked in GA_3 1000 ppm for 24 hours, followed by GA_3 500 ppm (42.67%) for 24 hours and soaking in cow dung slurry for 24 hours (38%).

Sujatha and Manjappa (2015) observed the effect of pre-sowing seed treatments on germination of *Melia azedarach* (Chinaberry tree) and reported that the KNO_3 solution (200 milli moles/liter for 24 hours) recorded highest germination of (84.0%), followed by biogas slurry applied for 6 days (70.7%) and cow dung slurry applied for 6 days (70.0%) as compared to control (53.3%).

Attri *et al.* (2014) conducted an experiment to study the effect of seed size and pre-sowing seed treatments on growth parameters and biomass of *Sapindus mukorossi* Gaertn. (Reetha) seedlings. Results indicated that the large sized seeds showed significantly higher germination percent (76.13%). The pre-sowing seed treatments such as immersion in H_2SO_4 for 20 minutes revealed maximum germination (66.22%) as compared to minimum germination (59.44 %) when seeds were immersed in hot water at 80 °c followed by soaking in tap water for 24 hours.

Garaniya and Bapodra (2015) studied the potential of cow urine to remove dormancy of *Abrus precatorious* (Jequirity bean). The ideal time period of soaking the seeds in cow urine were 8 hours for obtaining the highest germination percentage.

Das (2015) found that seed dormancy can be removed in the seeds of *Aquilaria agallocha* (Agarwood) by soaking the seeds in hot water for 3 minutes and then kept in normal water for 24 hours.

Kumar (2016) observed that the germination parameters of *Terminalia bellirica* (Bahera) seeds were significantly influenced by pre-sowing seed treatments. The highest germination percent (47.50 %), mean daily germination (0.84), peak value of germination (1.63) and germination value (0.52) were observed in the seeds soaked in water for 24 hours with removed pulp, followed by the seeds soaked in water for 48 hours.

Rana *et al.* (2017) studied that different pre sowing treatments and the growing media had a significant effect on *Parkia roxburghii* (Sapota) seedling growth parameters under

nursery conditions. The seeds treated with boiling water and soaked in normal tap water for 24 hours produced significantly highest root length (16.77 cm), shoot length (18.19 cm), seedling length (34.96 cm) and collar diameter (4.62 mm) and seeds sown in potting mixture consisting of soil, sand and FYM in ratio 1:2:4 (M_4) registered significantly higher seedling growth parameters.

Billah *et al*. (2015) conducted an experiment to study the effect of pre-sowing seed treatments on seed germinations of *Tectona grandis* (Teak). Seeds of selected species were subjected to six different pre-sowing treatments. Results revealed that the highest germination percentage of 86.67 percent were observed in Pith method (T_4), followed by 73.33 percent in (T_2) seeds soaked in normal water (72 hours) and 45 percent in (T_1) seeds soaked in normal water (24 hours). The highest germination value were found in (T_4) pith method (21.82), followed by (T_3) soaked in hot water for 5 minutes (13.52) and 8.37 % in (T_5) immersion in 80% concentrated H_2SO_4 for 20 minutes.

Alamgir and Kamal (2005) studied the effect of five pre-sowing treatments of *Albizia procera* (White siris) seeds on germination and initial seedling growth in the nursery. Results revealed that seeds treated with 24 hours cold water immersion indicated the highest (78%) seed germination, followed by the (77%) in seeds treated with boiled water and the lowest germination (33%) were obtained in the control (untreated seeds).

Pamei *et al*. (2017) observed the effect of various pre-sowing seed treatments on germination of *Tectona grandis* (Teak) in the nursery conditions. The highest seed germination percentage (43.3 %) were observed in T_3 (Alternate wet and drying, when seeds soaked in water for 12 hours and dried for 12 hours), followed by T_5 (Cow dung slurry 40 %) and T_{11} (H_2SO_4 20 min 33.3 %). The effect of pre-sowing treatments T_3 (alternate wet and drying) and T_5 (cow dung slurry) were observed more effective in germination and production of quality seedling of *Tectona grandis* (Teak) in the nursery.

Azad *et al.* (2011) while studying the impact of pre-sowing seed treatment on the seeds of *Acacia auriculiformis* (Northern black wattle), reported highest germination percentage of 83 percent in hot water treatment, followed by 78 percent in scarification with sand paper and 75 percent with immersion in sulphuric acid.

Azad *et al*. (2010) studied the effect of pre-sowing seed treatments on germination of *Melia azedarach* (Chinaberry tree) in Bangladesh and reported that the germination rates of pre-sowing treated seeds were significantly higher as compared to control. The highest germination (80%) were found in scarification with sand paper, followed by hot water treatment and immersion in H_2SO_4 (69%).

Panwar (2009) studied the effect of pre-sowing seed treatments on *Jatropha curcas* (Jatropha) and reported that cold water treatment for 24 hours coupled with sowing at 30 mm depth were the best treatment for higher germination. The growth of seedlings were however maximum (16.50 cm) when seeds were kept in cold water for 12 hours and sown at 20 mm depth.

Saini *et al*. (1999) investigated the effect of pre-sowing treatment on germination behavior of *Tectona grandis* (Teak) seed in sand beds and reported that maximum germination percentage (60.5) and germination value (0.75) were recorded when seeds were dipped for 6 minutes in hot water at 50 ^{0}C + 10 minutes air cooling + 6 minutes hot water + 10 minutes air cooling + 6 minutes hot water alternatively before sowing.

Thakur (2016) evaluated the effect of pre-sowing seed treatment, growing media on growth parameters and seedling biomass of *Vitex nigundo* (Nirgundi). The seeds treated with cow urine showed maximum germination (8.00%), germination energy (6.33%) and peak value (0.18). The seed sown in potting mixure consisting of soil, sand and FYM in 1:1:1 ratio showed higher seedling growth and biomass production parameters.

2.2 EFFECT OF DIFFERENT GROWING MEDIA

Sekepe *et al.* (2013) conducted pot experiment to investigate the effects of growing media on growth of *Cassia abbreviate* (Sjambok Pod) with four treatments comprising of top garden soil, top forest soil, commercial compost and a mixture of top garden soil, top forest soil, commercial compost in 1:1:1 ratio. It was concluded that top garden soil significantly increased the seedling height. No significant effects were observed for leaf number, leaf area and collar girth, green and dry weight as influenced by growth media. The results showed that top garden soil were found the best growing medium for the seedlings growth of this species.

Bhardwaj (2014) studied the effect of growing media on seed germination and seedling growth of *Carica papaya* (Papaya) during two successive seasons in the month of July-August. The results showed that the growing media consisting of vermicompost, sand and pond soil in 1:1:1 ratio showed highest germination percentage (95.27% and 90.15 %) in two successive season respectively.

Bali *et al.* (2013) conducted an experiment to determine the optimum conditions for germination and seedling growth of *Terminalia bellirica* (Bahera) by using four different manures mixed with soil *viz.* Celrich (bio-organic soil enricher), Farmyard manure (FYM), Goat and Poultry manures. The seeds were sown in three types of nursery beds such as sunken, flat, raised and three types of plastic pots were used as containers (having different volumes). Maximum seed germination percentage were recorded when FYM were used as manure and minimum in poultry manure. The best combination for optimum germination and growth in nursery for *T. bellirica* were recorded in soil mixed with FYM grown in sunken beds.

Venkatesh *et al*. (2009) studied the effect of growing media on germination and seedling growth of *Pterocarpus marsupium* (Malabar kino). They found that highest shoot and root length were recorded in treatment where vermicompost were added with soil as compared to the treatment without vermicompost.

Biradar *et al.* (2001) studied the effect of adding vermicompost and FYM in various proportion of potting mixture on germination and seedling growth of *Azadirachta indica* (Neem). It was found that the application of vermicompost alone recorded higher germination percentage (80.7%) as compared to other potting mixtures. Further, the higher shoot growth and higher leaf area were recorded in vermicompost treatment.

Vishnoi *et al.* (2010) determined the suitability of soil conditions for the growth of *Terminalia arjuna* (Arjun) for shoot length, stem biomass and root biomass. The seeds were sown in two types of growing media composed of sand and soil ratios (80 sand : 20 normal soil), (40 sand : 60 normal soil) and the control (normal soil). The results showed that root biomass in control condition were higher (2.74 gm per seedling) but stem biomass in soil ratio of 40:60 were higher (2.87 gm per seedling) than other two soil ratios.

Tiwari and Saxena (2003) studied the effect of different potting mixtures of soil, sand and farm yard manure (FYM) on growth and quality index of *Dalbergia sissoo* (Shisham) in nursery. It was observed that seeding growth increased with increasing FYM component in all the combination of potting mixture, while increase of sand beyond 1:2:2 ratio of soil, sand and FYM was not beneficial for the growth of seedlings.

Khaple *et al*. (2012) evaluated the effect of organic nutrients through highest concentrations of goat manure, vermicompost and pig manure and reported maximum increase in plant height of about (307 per cent) in *Grevillea robusta* (Silver oak) seedlings treated with highest concentration of goat manure. Collar diameter were found to increase upto 161 per cent at 90 days in response to highest dose of pig manure.

Trivedi and Joshi (2014) conducted a study to determine suitable planting substrates and an effective pre-sowing seed treatment for maximum germination of seeds of *Stereospermum suaveolens* (Padhal). Seeds were soaked overnight in water and then grown in various substrates like coco peat, soil, sand, coco peat and sand (1:1), coco peat and soil (1:1), filter paper, Murashige and Skoog's medium (MS) and Woody Plant Medium. The results revealed that the optimum seed germination (68%) were recorded in coco peat substrate followed by MS medium (66%) and the lowest in soil (6%).

Handa *et al.* (2005) reported that 1:2:2 ratio of sand, soil and FYM significantly enhanced seed germination of *Albizia amara* (Krishna siris) but the seedlings raised under 1:2:1 and 1:1:2 ratio of sand, soil and FYM recorded higher shoot length, root length and number of leaves.

Abirami *et al.* (2010) studied the effect of twenty one different combinations of growing media on seed germination, seedling growth and vigour of *Myristica fragrans* (Nutmeg) and found that the medium containing soil + coir dust + sand + vermicompost (1:1:1:1) produced best result in terms of early germination (42.10 days), germination percent (86.67%), seedling height (29.84 cm), shoot length (30.14 cm), root length (18.15 cm) and plant biomass of the seedlings.

Bala and Laura (2015) conducted an experiment to evaluate the effect of different soil medium and its various ratios on seed germination efficiency and seedling growth of *Simmondsia chinensis* (Jojoba). The highest germination of 94 percent were recorded for

seeds sown in medium containing desert soil : FYM (2:1) followed by 90 percent in medium having desert soil, clay, FYM (1:1:2) and 76 percent germination in medium having soil: clay: FYM (2:1:1).

Kumar *et al*. (2018) reported that the soil + sand + vermicompost (1:1:1) growing media resulted in maximum values of shoot length (23.82 cm), root length (21.14 cm), collar diameter (3.59 mm) and seedling quality index (0.350) in *Albizia lebbeck* (Black siris) seedlings whereas, the minimum shoot length (18.08 cm) and collar diameter (2.88 cm) were reported in media having only soil.

Ugese (2010) studied the effect of four growing media on emergence and growth of *Tamarindus indica* (Tamarind) seedlings in the nursery. The nursery media comprised of two rice hull based media (RHB) and two saw dust based media (SDB) formulated on volume basis in the following ratios: 1:2:3 (rice hull : poultry manure : river sand), 2:3:1 (rice hull: poultry manure: river sand), 1:4:3 (saw dust : poultry manure : river sand) and 1:2:3 (saw dust: poultry manure: river sand). It was concluded that saw dust based media gave superior performance in most seedling growth characters, including dry matter attributes.

Qaisar *et al.* (2001) studied the effect of five different growing media consisting of Peat moss + Vermiculite (1:1), Dalweed + Sand (1:1), Cupressus leaf litter + Sand (1:1), Peat moss + Sand (1:1) and Soil + Sand + FYM (1:1:1) on *Acacia catechu* and the result revealed that the growing media composed of Peat moss + Vermiculite in the ratio of 1:1 recorded maximum seedling height and collar diameter.

Hongal *et al*. (2018) studied the effect of different potting media components and biofertilizers on the seed germination and growth of *Emblica officinalis* (Aonla) seedlings. The results revealed that the highest seed germination per cent (86.11%), seedling vigour (264.35 g), seedling height (24.13 cm), root length (16.33 cm), seedling girth (0.63 cm), number of leaves (18.86), fresh weight (26.9 g) and dry weight (3.07 g) were recorded with the combination of potting mixture (Red earth, FYM, Sand in 2:1:1 ratio) along with cocopeat and Vesicular Arbuscular Mycorrhiza (20 g per polybag).

Rathore *et al.* (2004) conducted experiment to determine best potting mixture and size of root trainer for production of quality planting stock in *Casuarina equisetifolia* (Whistling Pine Tree). The best seedling growth in terms of height, collar diameter, total dry weight,

shoot dry weight, root dry weight and quality index at five months age were observed in potting mixture comprising of sand, soil, compost , burnt rice husk and charcoal in 30:10:50:5:5 ratio.

Menaie *et al*. (2010) in his experiment investigated the effect of three different soil mixtures using sand : peat moss : potting soil (humus) in the ratios of 1:1:1, 2:1:1 and 3:1:1 on the growth of *Cassia nodosa* (Pink cassia) and *Cassia fistula* (Amaltas) seedlings and revealed that both species of *cassia* showed better growth and development in the soil mixtures containing sand: peat moss: potting soil in equal proportion (1:1:1).

Munde *et al*. (2018) evaluated the effect of growing media on seed germination and seedling growth of *Semecarpus anacardium* (Marking nut). The results showed that the medium of vermicompost + sand + pond soil (1:1:1) with 2 cm cocopeat in top of the polybags gave maximum germination percentage (73.50), early germination (22.06 days) and highest germination vigour (0.58). The medium were also found to be the best for the growth of Marking Nut seedlings as it gave the highest parameters in terms of seedling height (18.72 cm), number of leaves (13.03) , stem girth (1.40 cm) , leaf area (22.28 cm^2), number of primary roots (30.50) and the number of secondary roots (55.60).

Rai *et al.* (2016) studied the effect of organic manures on seed germination and seedling growth of *Manikara hexandra* (Khirni) and reported that the maximum germination percent (74.80%), number of leaves (7.31), root length (14.90 cm), seedling length (26.90 cm) and seedling vigour index (2012.12) were recorded in media having soil, sand and FYM in 1:1:1 ratio.

Parasana *et al*. (2013) studied the effect of different growing media on germination and growth of *Mangifera indica* L. (Mango) seedlings and revealed that the maximum germination percent (77.33%) and seedling growth parameters such as number of leaves per plant (17.67), shoot length (52.30 cm), stem girth (4.53 cm) and maximum survival percent (82.67%) were observed in growing media composed of soil + sand + Farm yard manure in 2:1:1 ratio.

2.3 EFFECT OF DIFFERENT TYPES OF ROOT CONTAINERS

Gera *et al.* (1996) studied that the seedling height and the diameter have been found to increase with the increase in container size or volume. Seedlings of *Dalbergia sisso*

(Shisham) were raised in polybags of 3 different size (23 cm × 11 cm, 14 cm × 9 cm and 11 cm × 6 cm) in which height and diameter were significantly and positively influenced by polybag size.

Nanhorya *et al*. (1999) compared the growth of *Gmelina arborea* (Gamhar) seedlings raised in root trainers of 150 cc volume and polytubes (12 cm × 8 cm) with inserted six vertical ridges 12 cm long, 2 mm wide and 3 mm deep. On the basis of comparison in terms of height, collar girth of the seedlings and cost of the root trainers, they reported that polytubes can serve as a low cost, economical and cost effective alternative way as compared to root trainers for raising quality seedlings in a nursery.

Durai (2012) conducted an experiment to study the effect of root trainer size on quality seedling production in *Gmelina arborea* (Gamhar). Four different size of root-trainers T_1 (150 cc), T_2 (250 cc), T_3 (350 cc) and T_4 (500 cc) were tried. At the end of three months, significant effect for all the growth parameters like seedling height, collar diameter, shoot biomass, root biomass, root length and number of lateral roots were observed maximum in 500 cc and minimum in 150 cc root trainer.

Howell and Harrington (2004) reported the significant differences in stem diameter and height when *Quercus pagoda* (Cherrybark oak) seedlings were planted in different container size. The seedlings raised in different container sizes (170, 650 or 1250 cm^3) recorded increased growth of 104, 56 and 31 percent with the increase in container size.

Chadhar *et al*. (1996) grew the seedlings of *Dalbergia sissoo* (Shisham) and *Albizia procera* (White siris) in greenhouse for 4-5 months in root trainers and polybag. The growth of root trainers grown seedlings of both the species were better than polybag seedling.

Jabbar *et al.* (2010) studied the comparative growth of *Albizia procera* (White siris) seedlings grown in different sized polybags and root trainers. Seed germination and seedling growth were assessed for shoot length, root length, collar diameter, fresh weight, dry matter production, leaf number and number of nodules of the seedlings. Seedlings raised in polybags of 23 cm × 15 cm size revealed best performance with respect to germination and other growth parameters.

Nure *et al*. (2010) studied the growth of *Leucaena leucocephala* (Subabul) seedlings grown in polybag, nursery bed and root trainer with an aim to select suitable container for quality seedlings for large scale plantation programmes. Seedlings raised in polybags of 23 x 15 cm size revealed best performance in respect of germination and other growth parameters, while root-shoot ratio were higher in root trainers in *Leucaena leucocephala* (Subabul).

Mugloo *et al.* (2015) conducted an experiment to optimize the root trainer sizes and for producing quality nursery stock of *Picea smithiana* (Indian spruce). Three different volumes (150 cc, 250 cc and 300 cc) of root trainers were tested for suitability of container size. The best seedling growth at seven month age in terms of height (5.53 cm), collar diameter (1.57 mm), fresh shoot weight (0.34 g), dry shoot weight (0.10 g), fresh root weight (0.27 g), dry root weight (0.03 g), root-shoot ratio (2:52) and total fresh biomass (0.61 g) were observed in large sized root trainers (300 cc).

Varghese *et al*. (2005) studied the effect of size and type of polybags on *Hevea brasiliensis* (Rubber tree) seedlings. It was concluded that direct sowing in polybags significantly increased the length, girth and dry weight of tap roots. Polybagged plants raised by direct sowing method revealed better growth and ultimately which helped in better survival of the seedlings.

Salisu *et al.* (2018) conducted an experiment to evaluate the impact of various container size on the growth of seedlings of *Hevea brasiliensis* (Rubber tree) by raising the seeds in different sizes of polybags having volumes 600 ml, 710 ml, and 900 ml. Results indicated that large sized container like 900 ml had better and vigorous growth of seedlings of *Hevea brasiliensis.*

Ginwal *et al.* (2001) investigated the effect of container size (root trainers 90 cc, 150 cc, 300 cc, book type 200 cc, and single cell bullet type 290 cc) on growth performance of *Acacia nilotica* (Kikar) seedlings under nursery conditions and in the field for two consecutive years. The performance of seedling were observed to be the best in root trainer of size 300 cc under nursery and field conditions.

Malik and Shamet (2009) conducted an experiment on container type and potting medium in *Pinus gerardiana* (Chilgoza pine) and reported that the maximum plant height, collar diameter, dry shoot weight, vigour index, total biomass and stock quality index resulted

when seedlings were raised in bottom hole polybags of 23 × 10 cm size filled with Chilgoza forest soil + sand + moss + FYM (1:1:1:1) as compared to other containers and potting medium.

Annapurna *et al*. (2003) carried out an experiment to determine the effects of container type on the growth and quality of seedlings of *Santalum album* (Indian sandal wood). Three types of containers viz. root trainers (150, 270, 300, 450 and 600 ml), polythene bags (600, 1000 and 1500 ml) and plastic containers (1000 ml) were used with a potting medium that consisted of sand, soil, compost, burnt rice husk and charcoal in the ratio of 5:3:10:1:1. They found that the survival and overall growth of six month old sandal wood seedlings in terms of height, collar diameter, seedling biomass and root-shoot ratio were the best in root trainers, followed by the plastic containers. Among the root trainers, 600 ml size were found to be the superior for most of the parameters of seedling quality followed by the 270 ml and 300 ml root trainers.

Raj *et al*. (2010) conducted a study for seedling production of *Tectona grandis* (Teak) and *Dalbergia sissoo* (Shisham) and reported that the maximum seedling growth were recorded for seedlings raised in 600 cc root trainer.

Venkatesh *et al*. (2002) reported that *Acacia nilotica* (Kikar) seedlings raised in containers size of 300 cc (15 × 20 cm) registered superiority with respect to the seedlings grown in the nursery bed for root length, shoot length, collar diameter, number of leaves, root and shoot dry weight and dry matter production over 150 cc (10 × 15 cm) size polybags.

Geply *et al.* (2011) investigated the effect of different pot sizes and growing medium on performance of *Jatropha curcas* (Jatropha). The relative comparison in plant agronomic parameters showed that the big pot sizes were excellent with respect to the highest values of height, girth and number of leaves in the seedlings as compared to the smaller pot size.

Rahman *et al.* (2019) studied the effect of containers and potting media on raising quality seedlings of *Acacia auriculiformis* (Northern black wattle) and reported that the seedlings dry biomass production and quality index were highest in 20 cm × 15 cm size polybags whereas, the highest root length and root-shoot ratio were observed in 15 cm × 10 cm and 15 cm × 13 cm sized polybags respectively.

Chapter-3

MATERIALS AND METHODS

The present investigation entitled **"Effect of pre-sowing seed treatments and growing media on germination and growth performance of Bahera (*Terminalia bellirica* Roxb.)"** was conducted at the Majhgaon experimental farm, Department of Silviculture and Agroforestry, Dr Y.S Parmar University of Horticulture and Forestry, Nauni, Solan (Himachal Pradesh) during 2019-2020. The details about the experiment, materials used and methodologies employed are presented in this chapter as under :

3.1 EXPERIMENTAL SITE

3.1.1 Location

The experimental site of Majhgaon experimental farm, Department of Silviculture and Agroforestry, Dr Y.S Parmar University of Horticulture and Forestry, falls in the mid hill, sub-tropical zone of Himachal Pradesh and is located at $30^{o}55'$N latitude and $76^{o}11'$E longitude. The place lies at an altitude of 1250 m above mean sea level on the eastern direction of Solan town on Solan-Rajgarh road.

3.1.2 Climate

The experimental site is characterized by sub-tropical to sub-temperate climate which experiences an annual rainfall of 800-900 mm, the major part of which is received during July and August (monsoon period). Winter showers though common, are usually mild and frost occurs recurrently from December to February. In general, May and June are the hottest months and December and January are the coldest months. The meteorological data pertaining to the experimental site for the year May 2019 to Jan 2020 are presented in Appendix -I.

3.2 EXPERIMENTAL METHODOLOGY

3.2.1 Experiment: To study the effect of pre-sowing seed treatments (T), root containers (C) and growing media (M) on germination and growth performance of Bahera (*Terminalia bellirica* Roxb.)

The following pre-sowing seed treatments, root containers and growing media were applied for undertaking the present investigation.

A) Pre-sowing seed treatments (T) :

Seeds were treated with different pre-sowing treatments for different time period. Beejamrutha and cow urine were applied as a pre-sowing seed treatments in 100 per cent concentration form. Beejamrutha solutions were prepared by using locally available ingredients and method of preparation was followed as mentioned by Palekar, 2006. Beejamrutha is a traditional organic preparation especially used for seed treatments which enhances the seed germination and protects the seedlings from phytopathogenic infections.

T_1 **:** Control
T_2 **:** Seeds soaked in Beejamrutha for 3 weeks
T_3 **:** Seeds soaked in Beejamrutha for 4 weeks
T_4 **:** Seeds soaked in Beejamrutha for 5 weeks
T_5 **:** Seeds soaked in Beejamrutha for 6 weeks
T_6 **:** Seeds soaked in cow urine for 1 weeks
T_7 **:** Seeds soaked in cow urine for 2 weeks

B) Root containers (C) :

The following root containers were used for sowing of seeds and filled with different growing media after gentle taping on the ground.

C_1 : Side perforated polythene bags (18 × 12 cm)
C_2 : Root trainers (150 cc)

C) Growing media (M) :

The growing media were prepared by thoroughly mixing of soil, sand, FYM and vermicompost in different proportions as given under :

M_1 **:** Only Soil
M_2 **:** Soil : Sand (1:1)
M_3 **:** Soil : Sand : FYM (1:1:1)
M_4 **:** Soil : Sand : Vermicompost (1:1:1)

Number of treatments **:** 56
Replication **:** 3
Experimental design **:** CRD (factorial)
Sowing date **:** 1st May, 2019

(a)

(b)

Plate 1: (a) Seeds of Bahera (b) Soaking of seeds in Beejamrutha

3.3 OBSERVATIONS RECORDED

In order to assess the effect of different pre-sowing seed treatments, growing media and root containers on the seed germination and growth performance of *Terminalia bellirica* seedlings, the following observations were recorded.

3.3.1 Germination parameters

Following germination parameters were recorded in the field condition.

3.3.1.1 Germination Percent (%)

Germination percent was calculated as the total number of seeds germinated at the end of experiment out of total seeds sown in each treatment (as per ISTA rules).

$$\text{Germination percent (\%)} = \frac{\text{Total number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

3.3.1.2 Germination period

Germination period was calculated as the number of days from sowing to completion of germination.

3.3.1.3 Germination value

It is an index combining speed and completeness of seed germination. Daily germination counts were recorded and GV were calculated as per Czabator (1962).

$$GV = PV \times MDG$$

Where, PV = Peak value

MDG = Mean daily germination

3.3.1.4 Germination energy (%)

Germination energy (GE) were calculated on the basis of the percentage of the total number of seeds that had germinated when the germination reached its peak generally taken as the highest number of germination in 24 hours period (Czabator, 1962).

$$\text{Germination energy (GE)} = \frac{\sum ni}{N} \times 100$$

Where, GE = Germination Energy

ni = number of newly germination seed on i^{th} day

(taken up to the peak germination)

N = Total number of seeds sown

3.3.2 Seedling growth parameters

Five seedlings per replication were up-rotted and washed in running tap water. Seedlings were cut at collar region to separate root and shoot portion and following biomass parameters were recorded separately for each seedling and mean data of five seedlings in each replication were calculated for statistical analysis.

3.3.2.1 Seedling height (cm)

Seedling height were measured from collar region (ground level) up to the apex of leading shoot with the help of scale and expressed in centimeters (cm).

3.3.2.2 Collar diameter (mm)

Seedlings collar diameter were measured at the time of height measurement with the help of a digital vernier caliper and expressed in millimeters (mm).

3.3.2.3 Number of leaves

Total number of leaves per seedling were counted and expressed in numbers.

3.3.2.4 Leaf area (cm^2)

Leaf area of the seedlings were measured in square centimeter by using leaf area meter.

3.3.2.5 Vigour Index

It was calculated according to Abdulbaki and Anderson (1973) as germination percent × seedling total height (Total shoot + Root length).

3.3.2.6 Root length (cm)

Seedlings were uprooted carefully from the root containers and washed gently in running tap water. Then length of main root from collar region to the last point of root were measured with the help of scale and expressed in centimeters.

3.3.2.7 Root thickness (mm)

After uprooting the seedlings and gently washing of roots, the root thickness of the seedlings were measured with the help of digital vernier caliper and expressed in millimeters (mm).

3.3.2.8 Number of secondary roots

The uprooted seedlings were washed with gentle flow of water to expose the roots. The number of roots which were originated from the tap root (main root) of the plant were calculated and expressed in numbers.

3.3.3 Seedling biomass parameters

Five seedlings per replication were uprooted and washed in running tap water. Seedlings were cut at collar region to separate root and shoot portion and following biomass parameters were recorded separately for each seedling and mean data of five seedlings in each replication were calculated for statistical analysis.

3.3.3.1 Dry shoot weight (gm)

Fresh shoots were packed in paper bags and oven dried at 65 $^{\circ}$C for 72 hours. Then dry shoot weight were recorded by using electronic top pan balance and expressed in gram.

3.3.3.2 Dry root weight (gm)

Fresh roots were packed in paper bags and oven dried at 65 $^{\circ}$C for 72 hours. Then dry root weight were recorded by using electronic top pan balance and expressed in gram.

3.3.3.3 Root and Shoot ratio (dry weight basis)

The ratio were calculated on the basis of root and shoot dry weight as per the following formula.

$$\text{R-S Ratio} = \frac{\text{Root dry weight (gram)}}{\text{Shoot dry weight (gram)}}$$

3.3.3.4 Total dry biomass of seedling (gm)

Seedlings total dry weight were calculated by adding both dry shoot weight and dry root weight and expressed in gram.

3.3.3.5 Seedling Quality index (SQI)

Seedling Quality Index assessment were done by using the formula developed by Dickson *et al.* (1960) and also known as Dickson Quality Index.

$$SQI = \frac{TSDW}{H/D + SDW/RDW}$$

Where,

SDW	=	Shoot dry weight (gm)
TSDW	=	Total seedling dry weight (gm)
RDW	=	Root dry weight (gm)
H	=	Seedling height (cm)
D	=	Collar diameter (mm)

3.4. STATISTICAL ANALYSIS

The recorded data generated from the present investigation were subjected to analysis of variance (ANOVA) and analyzed in accordance with the procedure outlined by Gomez and Gomez (1984).

Chapter-4

RESULTS AND DISCUSSION

The results obtained during the course of present investigation are presented in this chapter. The recorded data have been analysed statistically, discussed and supported with relevant references under the following main headings :

4.1 Effect of different pre-sowing seed treatments, root containers and growing media on seed germination parameters.

4.2 Effect of different pre-sowing seed treatments, root containers and growing media on seedling vigour and growth parameters.

4.3 Effect of different pre-sowing seed treatments, root containers and growing media on seedling biomass parameters.

The effect of different pre sowing seed treatments, root containers, growing media and their interactions on seed germination parameters (germination per cent, germination period, germination value, germination energy), seedling vigour and growth parameters (seedling height, collar diameter, number of leaves, leaf area, vigour index, root length, root thickness and number of secondary roots) and also on biomass parameters (dry shoot weight, dry root weight, root-shoot ratio, total dry biomass of seedling and quality index) are presented in Tables (1-17).

4.1 EFFECT OF DIFFERENT PRE-SOWING SEED TREATMENTS, ROOT CONTAINERS AND GROWING MEDIA ON SEED GERMINATION PARAMETERS

4.1.1 Germination percent (%)

4.1.1.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

It is evident from the data (Table 1) that pre sowing seed treatments, root containers and growing media exercised significant effect on seed germination. Significantly, the maximum germination (56.92%) was recorded in T_3 treatment (seeds soaked in beejamrutha for 4 weeks), where as the lowest value of germination (35.71%) was recorded in T_1 treatment (control).

Table 1: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on germination percent (%) of Bahera (*Terminalia bellirica* Roxb.) seeds

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	31.67 (34.24)	28.00 (31.94)	**29.84 (32.98)**	35.33 (36.46)	34.00 (35.65)	**34.67 (36.05)**	44.00 (41.54)	37.33 (37.64)	**40.67 (39.59)**	39.33 (38.82)	36.00 (36.86)	**37.67 (37.84)**	37.58 (37.79)	33.84 (35.63)	**35.71 (36.69)**
T_2	40.00 (39.22)	36.67 (37.25)	**38.33 (38.23)**	50.00 (44.98)	46.67 (43.07)	**48.33 (44.03)**	62.67 (52.32)	58.00 (49.58)	**60.33 (50.95)**	60.67 (51.14)	56.67 (48.81)	**58.67 (49.98)**	53.33 (46.92)	49.50 (44.68)	**51.42 (45.80)**
T_3	46.67 (43.07)	38.67 (38.43)	**42.67 (40.75)**	56.67 (48.81)	52.67 (46.51)	**54.67 (47.66)**	70.67 (57.20)	64.00 (53.11)	**67.33 (55.15)**	66.67 (54.72)	59.33 (50.36)	**63.00 (52.54)**	60.17 (50.95)	53.67 (47.10)	**56.92 (49.03)**
T_4	38.00 (38.04)	35.33 (36.46)	**36.67 (37.25)**	47.33 (43.45)	44.67 (41.92)	**46.00 (42.69)**	62.00 (51.93)	53.33 (46.89)	**57.67 (49.41)**	59.33 (50.37)	52.00 (46.13)	**55.67 (48.25)**	51.67 (45.95)	46.33 (42.85)	**49.00 (44.40)**
T_5	37.33 (37.64)	34.67 (36.05)	**36.00 (36.85)**	43.33 (41.15)	40.67 (39.60)	**42.00 (40.38)**	58.67 (49.97)	51.33 (45.75)	**55.00 (47.86)**	56.00 (48.43)	49.33 (44.60)	**52.67 (46.51)**	48.83 (44.30)	44.00 (41.50)	**46.42 (42.90)**
T_6	34.67 (36.05)	32.00 (34.43)	**33.33 (35.24)**	41.33 (39.99)	38.67 (38.43)	**40.00 (39.21)**	52.67 (46.51)	46.67 (43.07)	**49.67 (44.79)**	49.33 (44.60)	42.67 (40.76)	**46.00 (42.68)**	44.50 (41.79)	40.00 (39.17)	**42.25 (40.48)**
T_7	33.33 (35.24)	31.67 (34.24)	**32.50 (34.72)**	38.00 (38.04)	36.00 (36.86)	**37.00 (37.45)**	48.67 (44.22)	42.67 (40.76)	**45.67 (42.49)**	44.00 (41.54)	41.33 (39.99)	**42.67 (40.76)**	41.00 (39.76)	37.91 (37.99)	**39.46 (38.90)**
Mean	**37.38 (37.68)**	**33.86 (35.57)**	**35.62 (36.63)**	**44.57 (41.84)**	**41.91 (40.29)**	**43.24 (41.07)**	**57.05 (49.10)**	**50.48 (45.26)**	**53.76 (47.18)**	**53.62 (47.09)**	**48.19 (43.93)**	**50.91 (45.51)**	**48.15 (43.92)**	**43.61 41.31)**	

The values in parenthesis are transformed value (angular transformation)

Factors	T	C	M	T ò M	T ò C	C ò M	Tò C ò M
$SE_{m\pm}$	0.502	0.268	0.379	1.004	0.710	0.537	1.42
$CD_{0.05}$	0.995	0.532	0.752	1.989	1.407	1.063	2.814

In case of root containers, significantly the highest germination (48.15%) was recorded in polybags (C_1), however the root trainer (C_2) recorded germination of 43.61 percent. The growing media (M_3) composed of soil + sand + FYM (1:1:1) recorded significantly maximum germination of 53.76 percent where as, the minimum germination of 35.62 percent was obtained in M_1 growing media (only soil).

4.1.1.2 Effect of pre-sowing seed treatments and growing media (TòM) interaction

The data in Table 1 shows that the significantly, maximum germination (67.33%) was recorded when seeds were treated with T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and sown in M_3 growing media composed of soil + sand + FYM (1:1:1) i.e. T_3M_3. However, the minimum germination (29.84%) was observed when seeds were sown in M_1 growing media (only soil) with T_1 treatment (control) i.e. T_1M_1.

4.1.1.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

It is apparent from the data in Table 1 that the significantly, maximum germination (60.17%) of seeds were recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and sown in polybags (C_1) i.e. T_3C_1 where as, the minimum germination (33.84) of seeds were resulted in (T_1) control treatment and sown in root trainer (C_2) i.e. T_1C_2.

4.1.1.4 Effect of root containers and growing media (CòM) interaction

The data presented in Table 1 reflects that interaction of root containers and growing media were significant. The maximum germination (57.05 %) was obtained when seeds were sown in polybags (C_1) filled with (M_3) growing media composed of soil + sand + FYM (1:1:1) i.e. C_1M_3 where as, the minimum germination (33.86 %) was observed when seeds were sown in root trainer (C_2) filled with M_1 growing media (only soil) i.e. T_1M_1.

4.1.1.5 Effect of pre-sowing seed treatments, root containers and growing media (TòCòM) interaction.

An appraisal of data in Table 1 shows that combined effect of T×C×M revealed significantly maximum germination (70.67%) of seeds in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and sown in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. $T_3C_1M_3$. However, the minimum value of germination (28.00%) of seeds were resulted in T_1 (control) treatment and sown in root trainer (C_2) filled with growing media composed of soil only i.e. $T_1C_2M_1$.

4.1.2 Germination period

4.1.2.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

The data presented in Table 2 reflects that pre sowing seed treatments showed significant effect on seed germination period. Significantly, the minimum germination days (38.17) were recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) where as. the maximum germination days (52.25) were recorded in T_1 treatment (control).

In case of root containers significantly, the minimum germination period of 43.76 days were recorded in polybags (C_1). However, the root trainer (C_2) recorded germination period of 46.11 days. As regards to the effect of, the growing media (M_3) composed of soil + sand + FYM (1:1:1) recorded minimum germination period of 41.43 days where as, the maximum germination period of 48.52 days were observed in growing media (M_1) composed of soil only.

4.1.2.2 Effect of pre-sowing seed treatments and growing media (T×M) interaction

From the data presented in Table 2, it is clear that the pre sowing seed treatments and growing media caused significant effect on germination period. The minimum germination days (33.67) were observed in T_3M_3 treatment combination i.e. T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seeds sown in (M_3) growing media composed of soil + sand + FYM (1:1:1). However, the maximum germination days (54.34) were recorded in T_1 treatment (control) when seeds sown in M_1 growing media (only soil) i.e. T_1M_1 treatment combination.

4.1.2.3 Effect of pre-sowing seed treatments and root containers (T×C) interaction

The combined effect of pre-sowing seed treatments and root containers revealed that the minimum (37.08) germination days were recorded in the seeds soaked in Beejamrutha for 4 weeks (T_3 treatment) which were sown in polybags (C_1) i.e. T_3C_1 where as, the maximum (53.50) germination days were recorded in control treatment (T_1) when seeds were sown in root trainer (C_2) i.e. T_1C_2.

Plate 2: Indicating best growth performance of Bahera seedlings in $T_3C_1M_3$ treatment combination as comparison to all other treatment combinations

Plate 3: Indicating low germination and poor growth performance under control treatment in polybags and growing media composed of only soil.

Table 2: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on germination period of Bahera (*Terminalia bellirica* Roxb.) seeds.

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	52.67	56.00	**54.34**	53.00	54.33	**53.67**	48.33	51.00	**49.67**	50.00	52.67	**51.34**	51.00	53.50	**52.25**
T_2	43.00	46.33	**44.67**	41.67	44.67	**43.17**	36.00	38.00	**37.00**	37.67	39.33	**38.50**	39.59	42.08	**40.83**
T_3	42.33	43.33	**42.83**	39.00	41.33	**40.17**	32.33	35.00	**33.67**	34.67	37.33	**36.00**	37.08	39.25	**38.17**
T_4	46.67	48.00	**47.34**	43.67	45.67	**44.67**	39.00	40.33	**39.67**	40.33	42.67	**41.50**	42.42	44.17	**43.29**
T_5	47.33	50.00	**48.67**	44.67	47.00	**45.84**	40.33	42.67	**41.50**	43.33	45.00	**44.17**	43.92	46.17	**45.04**
T_6	48.67	52.33	**50.50**	47.33	48.33	**47.83**	42.00	44.00	**43.00**	45.00	47.00	**46.00**	45.75	47.92	**46.83**
T_7	50.00	52.67	**51.34**	47.00	51.33	**49.17**	43.67	47.33	**45.50**	45.67	47.33	**46.50**	46.59	49.67	**48.13**
Mean	**47.24**	**49.81**	**48.52**	**45.19**	**47.52**	**46.36**	**40.24**	**42.62**	**41.43**	**42.38**	**44.48**	**43.43**	**43.76**	**46.11**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.16	0.085	0.121	0.320	0.226	0.171	0.452
$CD_{0.05}$	0.448	0.239	0.339	0.896	0.633	0.479	1.267

4.1.2.4 Effect of root containers and growing media (C×M) interaction

An overview of data in Table 2 revealed that the minimum germination period of 40.24 days were reported when the seeds were sown in polybags (C_1) filled with M_3 growing media (soil + sand + FYM) in equal proportion i.e. C_1M_3. However the maximum germination period of 49.81 days were observed in root trainer filled with soil only i.e. C_2M_1.

4.1.2.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

From Table 2, it is inferred that combined effect of T×C×M indicated significantly minimum germination days (32.33) in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seeds sown in polybags (C_1) filled with M_3 growing media (soil + sand + FYM) in equal proportion i.e. $T_3C_1M_3$, where as the highest germination days (56.00) were observed in T_1 (control) treatment when seeds were sown in root trainer (C_2) filled with M_1 growing media (only soil) i.e. $T_1C_2M_1$.

4.1.3 Germination value

4.1.3.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

It is apparent from the data presented in Table 3 that pre-sowing seed treatments exerted significant effect on germination value. The significantly maximum germination value (2.12) of seeds were recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks. The minimum germination value (0.42) were observed in control treatment (T_1).

The significantly highest germination value (1.26) of seeds were recorded in polybags (C_1), however the root trainer (C_2) recorded germination value of 0.88. In case of growing media, highest germination value (1.64) of seeds were observed in growing media (M_3) composed of soil + sand + FYM (1:1:1). The lowest germination value (0.54) of seeds were recorded in M_1 growing media (only soil).

4.1.3.2 Effect of pre-sowing seed treatments and growing media (T×M) interaction

The scrutiny of data presented in Table 3 revealed that the combined effect of growing media and pre-sowing seed treatments showed significantly the maximum germination value of 3.53 in T_3M_3 treatment combination i.e. T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) when seeds were sown in (M_3) growing media composed of soil + sand + FYM (1:1:1) i.e. T_3M_3. However, the lowest germination value (0.28) were observed in T_1 (control) treatment when seeds were sown in M_1 growing media composed of soil only i.e. T_1M_1.

Table 3: Effect of pre sowing seed treatments (T), root containers (C), growing media (M) and their interactions on germination value of Bahera (*Terminalia bellirica* Roxb.) seeds

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	0.31	0.25	**0.28**	0.39	0.32	**0.35**	0.67	0.46	**0.57**	0.51	0.41	**0.46**	0.47	0.36	**0.42**
T_2	0.79	0.60	**0.69**	1.16	0.97	**1.06**	2.90	1.83	**2.36**	2.11	1.58	**1.85**	1.74	1.24	**1.49**
T_3	1.07	0.76	**0.92**	1.59	1.22	**1.41**	4.55	2.51	**3.53**	3.28	2.00	**2.64**	2.62	1.62	**2.12**
T_4	0.64	0.53	**0.58**	0.96	0.81	**0.89**	2.13	1.46	**1.79**	1.73	1.25	**1.49**	1.36	1.01	**1.19**
T_5	0.55	0.44	**0.50**	0.79	0.65	**0.72**	1.64	1.16	**1.40**	1.33	0.95	**1.14**	1.08	0.80	**0.94**
T_6	0.51	0.36	**0.44**	0.67	0.57	**0.62**	1.21	0.87	**1.04**	1.00	0.72	**0.86**	0.85	0.63	**0.74**
T_7	0.42	0.31	**0.37**	0.54	0.44	**0.49**	0.97	0.69	**0.83**	0.80	0.64	**0.72**	0.68	0.52	**0.60**
Mean	**0.61**	**0.46**	**0.54**	**0.87**	**0.71**	**0.79**	**2.01**	**1.28**	**1.64**	**1.54**	**1.08**	**1.31**	**1.26**	**0.88**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.018	0.009	0.013	0.036	0.025	0.019	0.050
$CD_{0.05}$	0.050	0.027	0.038	0.100	0.070	0.053	0.141

4.1.3.3 Effect of pre-sowing seed treatments and growing media (T×C) interaction

The data pertaining to germination value in Table 3 reflects that the significantly highest germination value (2.62) were recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and polybags (C_1) where as, the lowest germination value (0.36) were found in T_1 treatment (control) and root trainer (C_2).

4.1.3.4 Effect of pre-sowing seed treatments and growing media (C×M) interaction

The data (Table 3) revealed that the significantly maximum germination value (2.01) were observed in polybags (C_1) filled with M_3 growing media composed of soil + sand + FYM (1:1:1) sown seeds i.e. C_1M_3 where as, the minimum germination value (0.46) were recorded in root trainer (C_2) filled with M_1 growing media (only soil) sown seeds i.e. C_2M_1.

4.1.3.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

An overview of data presented in Table 3 showed that the interaction effect of T×C×M resulted significantly maximum germination value of 4.55 in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) when seeds were sown in polybags (C_1) filled with growing media (M_3) of soil + sand + FYM in 1:1:1 ratio i.e. $T_3C_1M_3$ where as, the lowest germination value (0.25) were observed in T_1 treatment (Control) when seeds were sown in root trainer (C_2) filled with M_1 growing media (only soil) i.e. $T_1C_2M_1$ which were found statistically at par with $T_1C_1M_1$ (0.31).

4.1.4 Germination energy (%)

4.1.4.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

An appraisal of data in Table 4 reflects that the pre-sowing seed treatments exerted significant effect on germination energy. Germination energy as found to be significantly highest (42.83%) in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) Where as, the lowest germination energy (26.00 %) was observed in control treatment (T_1).

In case of root containers significantly highest germination energy (35.91%) was recorded in polybags (C_1), however the root trainer (C_2) indicated germination energy of 32.43 percent.

Plate 4: Indicating effect of $T_3C_2M_3$ treatment combination on germination and growth performance of Bahera seedlings

Plate 5: Indicating low germination and poor growth performance under control treatment in root trainer and media composed of soil only

Table 4: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on germination energy (%) of Bahera (*Terminalia bellirica* Roxb.) seeds

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	24.00 (29.32)	22.67 (28.40)	**23.33 (28.86)**	25.33 (30.19)	22.67 (28.40)	**24.00 (29.30)**	30.67 (33.60)	28.00 (31.94)	**29.33 (32.77)**	28.00 (31.94)	26.67 (31.06)	**27.33 (31.50)**	27.00 (31.26)	25.00 (29.95)	**26.00 (30.61)**
T_2	36.00 (36.86)	32.00 (34.44)	**34.00 (35.65)**	36.00 (36.86)	34.67 (36.05)	**35.33 (36.45)**	48.00 (43.84)	41.33 (39.99)	**44.67 (41.91)**	42.67 (40.76)	38.67 (38.43)	**40.67 (39.60)**	40.67 (39.58)	36.67 (37.23)	**38.67 (38.40)**
T_3	37.33 (37.64)	34.67 (36.05)	**36.00 (36.85)**	40.00 (39.22)	36.00 (36.86)	**38.00 (38.04)**	56.00 (48.43)	44.00 (41.54)	**50.00 (44.98)**	52.00 (46.13)	42.67 (40.76)	**47.33 (43.45)**	46.33 (42.85)	39.33 (38.80)	**42.83 (40.83)**
T_4	32.00 (34.44)	30.67 (33.60)	**31.33 (34.02)**	34.67 (36.05)	33.33 (35.24)	**34.00 (35.65)**	44.00 (41.54)	38.67 (38.43)	**41.33 (39.98)**	40.00 (39.22)	37.33 (37.64)	**38.67 (38.43)**	37.67 (37.81)	35.00 (36.23)	**36.33 (37.02)**
T_5	30.67 (33.58)	28.00 (31.94)	**29.33 (32.76)**	32.67 (34.84)	30.67 (33.60)	**31.67 (34.22)**	40.00 (39.22	36.00 (36.86)	**38.00 (38.04)**	37.33 (37.64)	33.33 (35.24)	**35.33 (36.44)**	35.17 (36.32)	32.00 (34.41)	**33.58 (35.36)**
T_6	30.67 (33.58)	26.67 (31.06)	**28.67 (32.32)**	31.33 (34.01)	30.67 (33.60)	**31.00 (33.81)**	36.00 (36.86	33.33 (35.24)	**34.67 (36.05)**	34.67 (36.05)	32.00 (34.44)	**33.33 (35.24)**	33.17 (35.12)	30.67 (33.59)	**31.92 (34.35)**
T_7	28.00 (31.94)	25.33 (30.19)	**26.67 (31.06)**	29.33 (32.78)	26.67 (31.06)	**28.00 (31.92)**	34.67 (36.05)	30.67 (33.60)	**32.67 (34.83)**	33.33 (35.24)	30.67 (33.60)	**32.00 (34.42)**	31.33 (34.00)	28.33 (32.12)	**29.83 (33.06)**
Mean	**31.24 (33.91)**	**28.57 (32.24)**	**29.91 (33.07)**	**32.76 (34.85)**	**30.67 (33.55)**	**31.71 (34.20)**	**41.33 (39.93)**	**36.00 (36.80)**	**38.67 (38.37)**	**38.29 (38.14**	**34.48 (35.88)**	**36.38 (37.01)**	**35.91 (36.71)**	**32.43 (34.62)**	

The values in parenthesis are transformed value (angular transformation)

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.40	0.21	0.30	0.80	0.57	0.43	1.13
$CD_{0.05}$	1.12	0.60	0.85	2.24	1.58	1.20	N.S

The growing media (M_3) gave significantly maximum germination energy (38.67 %) where as, the lowest germination energy (29.91%) were recorded in M_1 growing media (only soil).

4.1.4.2 Effect of pre-sowing seed treatments and growing media (TòM) interaction

The perusal of data presented in Table 4 showed that the effect of growing media and pre-sowing seed treatments gave significantly maximum germination energy (50.00 %) in T_3M_3 treatment combination i.e. T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and M_3 growing media composed of soil + sand + FYM (1:1:1) where as, the minimum germination energy (23.33 %) was recorded in T_1M_1 treatment combination i.e. control treatment (T_1) and M_1 growing media composed of soil only.

4.1.4.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

The data from the Table 4 shows that the interaction effect of pre sowing seed treatments and root containers indicated significantly the maximum germination energy of 46.33 percent in T_3C_1 treatment combination. However, the minimum germination energy of 25.00 percent was observed in T_1C_2 treatment combination.

4.1.4.4 Effect of root containers and growing media (CòM) interaction

The combined effect of root containers and growing media (Table 4) gave significantly, the maximum value of germination energy (41.33 %) in polybags (C_1) filled with M_3 growing media i.e. C_1M_3 where as, the minimum value of germination energy (28.57) was obtained in root trainer (C_2) filled with M_1 growing media which composed of soil only i.e. C_2M_1.

4.1.4.5 Effect of pre-sowing seed treatments, root containers and growing media (TòCòM) interaction

An overview of data in Table 4 reveals that the combined effect of T×C×M produced significantly, the maximum germination energy of 56.00 percent when seeds were soaked in Beejamrutha for 4 weeks (T_3), sown in polybags (C_1) and filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. $T_3C_1M_3$ where as, the minimum germination energy (22.67 %) was recorded in control treatment (T_1), sown in root trainer (C_2) composed of M_1 growing media (only soil) i.e., $T_1C_2M_1$. However, the interaction was found statistically non-significant.

Among all the interactions of different pre-sowing seed treatments, growing media and containers (T×M, T×C, C×M and T×C×M) on seed germination parameters were found significant except the interaction of T×C×M only in case of germination energy (Tables 1-4).

The highest values of seed germination parameters revealed in $T_3C_1M_3$ treatment combination that might be attributed to the ideal characteristics of Beejamrutha constituents like cow dung, cow urine, water, lime and soil which consists of free living nitrogen fixers, phosphate solubilizers, beneficial nutrients, essential amino acids, which are capable of enhancing germination processes. It is also rich in beneficial microbes that enhanced the mobilization of essential nutrients and might have provided the plant growth promoters like IAA and GA_3 that causes initiation of germination process. All these creates the favorable condition for seed germination which might be resulted in early swelling of embryo that promoted the emergence of radicle and triggers the germination process by breaking seed dormancy (Sreenivasa *et al*., 2009 and Devakumar *et al*., 2014).

Similarly, T_3 treatment showed the significant effect on germination energy and germination value (peak value and mean daily germination) of seeds. However, it is clear from the Tables (1-4) that the other pre-sowing seed treatments were also based upon Beejamrutha for different time period yielding different results, which may vary due to its duration and effect of its constituents on seeds during that time period, thereby affecting the germination of seeds variably.

The results are in agreement with the findings of Anand *et al*. (2012) and Navale *et al*. (2017), who reported maximum value of all the germination parameters for *Melia dubia* (Malabar neem) and *Hydnocarpus pentandra* (Kadu kawath) seeds treated with cow dung slurry.

The significant result of M_3 growing media (soil + sand + FYM) in 1:1:1 ratio and polybags (C_2) were obtained from the present investigation might be due to large size of polybags which hold larger amount of growing media, good water holding capacity and provide more nutrients. FYM is non toxic in nature, good source of nutrients, favourable pH, having good water holding capacity which provide moisture to promote germination and softens the hard seed coat.

These results are in conformity with the findings of Bali *et al*. (2013) who found maximum value of *Terminalia bellirica* (Bahera) seeds germination in large sized containers filled with growing media composed of FYM. Similarly, Rai *et al*. (2016) and Jabbar *et al*. (2010) reported maximum value of *Manikara hexandara* (Khirni) and *Albizia procera* (White siris) seeds germination parameters in FYM and bigger sized polybags.

4.2 EFFECT OF DIFFERENT PRE-SOWING SEED TREATMENTS, ROOT CONTAINERS AND GROWING MEDIA ON SEEDLING VIGOUR AND GROWTH PARAMETERS

4.2.1 Seedling Height (cm)

4.2.1.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

The data pertaining to seedling height in Table 5 reveals that the significantly maximum seedling height (22.57 cm) was observed in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) where as, the minimum seedling height (12.14 cm) was obtained in T_1 treatment (control).

As regards to the effect of root containers, significantly maximum seedling height (18.13 cm) was obtained in polybags (C_1) and the root trainer (C_2) grown seedlings recorded seedling height of 16.04 cm.

In case of growing media, significantly the maximum seedling height (21.96 cm) was observed in growing media (M_3) composed of soil + sand + FYM (1:1:1). However the minimum seedling height (12.30 cm) was obtained in media composed of soil only (M_1).

4.2.1.2 Effect of pre-sowing seed treatments and growing media (T×M) interaction

It is evident from the data (Table 5) that pre sowing seed treatments and growing media exerted significant influence on seedling height. The maximum seedling height of 31.00 cm was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. T_3M_3 raised seedlings where as, the minimum seedling height of 9.45 cm was observed in T_1 treatment (control) and M_1 growing media (only soil) i.e. T_1M_1 raised seedlings.

Table 5: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on seedling height (cm) of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	10.00	8.91	**9.45**	11.10	9.53	**10.32**	15.93	13.83	**14.88**	14.50	13.33	**13.92**	12.88	11.40	**12.14**
T_2	14.77	13.37	**14.07**	15.90	14.07	**14.98**	31.00	26.00	**28.50**	27.33	23.40	**25.37**	21.79	19.21	**20.50**
T_3	16.17	14.33	**15.25**	17.17	14.73	**15.95**	34.00	28.00	**31.00**	29.50	25.70	**27.60**	24.50	20.65	**22.57**
T_4	13.40	12.73	**13.07**	14.60	13.10	**13.85**	25.53	22.50	**24.02**	23.83	21.73	**22.78**	19.34	17.52	**18.43**
T_5	13.03	12.43	**12.73**	14.23	12.57	**13.40**	22.83	20.83	**21.83**	22.63	20.87	**21.75**	18.18	16.68	**17.43**
T_6	11.40	10.80	**11.10**	14.03	11.87	**12.95**	19.17	16.77	**17.97**	17.93	15.77	**16.85**	15.63	13.80	**14.72**
T_7	10.63	10.20	**10.42**	13.27	11.60	**12.43**	17.50	15.37	**16.43**	16.83	14.97	**15.90**	14.56	13.03	**13.80**
Mean	**12.77**	**11.83**	**12.30**	**14.33**	**12.50**	**13.41**	**23.45**	**20.47**	**21.96**	**21.96**	**19.37**	**20.67**	**18.13**	**16.04**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.116	0.088	0.062	0.164	0.232	0.124	0.329
$C.D_{0.05}$	0.326	0.246	0.174	0.461	0.651	0.348	0.921

4.2.1.3 Effect of pre-sowing seed treatments and root containers (T×C) interaction

A scrutiny of data presented in Table 5 reflects that significantly, the maximum value of seedling height (24.50 cm) was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seedlings raised in polybags (C_1) i.e. T_3C_1 where as, the minimum seedling height (11.40 cm) was observed in T_1 treatment (control) and seedlings raised in root trainer (C_2) i.e. T_1C_2.

4.2.1.4 Effect of root containers and growing media (C×M) interaction

The data presented in Table 5 reveals that the significantly maximum seedling height of 23.45 cm was recorded in seedlings raised in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. C_1M_3. However, the minimum seedling height of 11.83 cm was observed in root trainer (C_2) filled with M_1 growing media composed of soil only i.e. C_2M_1.

4.2.1.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

The perusal of data in Table 5 reflects that the significantly maximum height (34.00 cm) of seedling was observed in $T_3C_1M_3$ treatment combination i.e. seeds soaked in Beejamrutha for 4 weeks (T_3) and raised in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) where as, the minimum height of seedling (8.91 cm) was recorded in root trainer (C_2) filled with M_1 growing media (only soil) when seeds were sown without any pre sowing seed treatment T_1 (control) i.e. $T_1C_2M_1$ treatment combination.

4.2.2 Collar diameter (mm)

4.2.2.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

The data pertaining to collar diameter in Table 6 indicated significantly the maximum value of collar diameter (5.83 mm) in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks). However, the minimum value of collar diameter (3.61 mm) was observed in T_1 (control) treatment. In case of root containers, significantly the maximum collar diameter (5.08 mm) of seedlings was observed in C_1 (polybags) and the seedling grown in root trainer (C_2) recorded collar diameter of 4.64 mm.

Table 6: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on collar diameter (mm) of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4					
	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**	C_1	C_2	**Mean**
T_1	2.49	2.16	**2.33**	3.07	2.93	**3.00**	5.03	4.33	**4.68**	4.82	4.03	**4.43**	3.85	3.36	**3.61**
T_2	3.69	3.14	**3.42**	4.81	4.46	**4.64**	7.42	6.86	**7.14**	7.07	6.48	**6.78**	5.75	5.24	**5.49**
T_3	3.92	3.38	**3.65**	5.13	4.84	**4.98**	8.03	7.09	**7.56**	7.38	6.92	**7.15**	6.11	5.55	**5.83**
T_4	3.41	2.99	**3.20**	4.49	4.15	**4.32**	7.06	6.79	**6.92**	6.90	6.03	**6.47**	5.47	4.99	**5.23**
T_5	3.06	2.73	**2.90**	4.41	4.09	**4.25**	6.75	6.55	**6.65**	6.38	5.72	**6.05**	5.15	4.78	**4.96**
T_6	2.92	2.68	**2.80**	4.14	3.69	**3.92**	6.05	5.86	**5.95**	5.88	5.63	**5.76**	4.75	4.46	**4.61**
T_7	2.85	2.41	**2.63**	3.92	3.37	**3.65**	5.71	5.40	**5.55**	5.51	5.20	**5.35**	4.50	4.09	**4.30**
Mean	**3.19**	**2.78**	**2.99**	**4.28**	**3.93**	**4.11**	**6.58**	**6.13**	**6.35**	**6.28**	**5.71**	**6.00**	**5.08**	**4.64**	

Factors	**T**	**C**	**M**	**T ò M**	**T ò C**	**C ò M**	**T ò C ò M**
$SE_{m\pm}$	0.03	0.016	0.022	0.059	0.042	0.032	0.084
$CD_{0.05}$	0.083	0.044	0.063	0.166	0.117	0.089	0.235

As regards to the effect of growing media, the growing media M_3 composed of soil + sand + FYM (1:1:1) raised seedlings recorded significantly the maximum collar diameter of 6.35 mm where as, the minimum value of collar diameter (2.99 mm) was reported in M_1 growing media (only soil) raised seedlings.

4.2.2.2 Effect of pre-sowing seed treatments and growing media (T×M) interaction

It is clear from the data presented in Table 6 that the interaction between pre sowing seed treatments and growing media showed significant effect on collar diameter of seedlings. The treatment combination T_3M_3 recorded significantly the maximum collar diameter of 7.56 mm and the minimum value of collar diameter (2.33 mm) was obtained in T_1 (control) treatment and M_1 growing media i.e. T_1M_1 raised seedlings.

4.2.2.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

The combined effect of pre sowing seed treatments and root containers (Table 6) indicated significantly the maximum collar diameter of 7.56 mm was obtained in T_3 treatment and polybags (C_1) raised seedlings i.e. T_3C_1 treatment combination. However, the minimum collar diameter (2.33 mm) was obtained in T_1 (control) and root trainer (C_2) raised seedlings i.e. T_1C_2 treatment combination.

4.2.2.4 Effect of root containers and growing media (CòM) interaction

Among different combinations of root containers and growing media (Table 6) the C_1M_3 treatment combination recorded significantly the highest value of collar diameter (6.11 mm) where as, the minimum value of collar diameter 3.36 mm was observed in C_2M_1 treatment combination grown seedlings.

4.2.2.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

An overview of data (Table 6) shows that the significantly maximum value of collar diameter (8.03 mm) was observed in $T_3C_1M_3$ treatment combination i.e. seeds soaked in Beejamrutha for 4 weeks (T_3) and seedlings raised in polybags (C_1) filled with (M_3) growing media composed of soil + sand + FYM (1:1:1) where as, the minimum value of collar diameter (2.16 mm) was found in $T_1C_2M_1$ treatment combination i.e., T_1 (control) treatment and seedlings raised in root trainer (C_2) filled with M_1 growing media (only soil).

In case of seedlings height and collar diameter (Table 5 and 6), the combined effect of (T_3) pre sowing seed treatment (seeds soaked in Beejamrutha for 4 weeks), polybags (C_1) and growing media (M_3) recorded significantly maximum value that might be attributed to the rich source of nutrients (N, P, K), enzymes and beneficial microbes present in cow dung and cow urine, which also helped in production of growth hormones like auxins and gibberellins (Prajapati *et al*., 2014).

The application of growing media (M_3) composed of soil + sand + FYM (1:1:1) resulted in highest value pertaining to germination and growth parameters of seedlings might be due to FYM, which may have improved the soil physical and chemical properties, increased the water holding capacity of soil, conversion of unavailable nutrients to available forms through microbial activity, low bulk density of soil which could have provided favourable environment for better seedlings growth and development. The nutrients availability enhanced the meristematic cells function and photosynthetic activity which indicated good results in terms of seedling height and collar diameter as suggested by Khan *et al*. (2010) and Ramteke *et al*. (2016), support the present findings.

As regard to the effect of containers, good results obtained along with media and pre-sowing seed treatments might be due to the large size of polybags. The large sized polybags (C_1) were able to hold more amount of growing media and due to specific area it had low plant density that enhanced availability of required nutrients, moisture and proper space to establish roots and better growth of seedlings. The results are in agreement with the findings of Thanuja *et al*. (2019) who reported maximum value of *Pterocarpus santalinus* (Red sanders) seedling growth parameters in cow dung slurry as a pre sowing seed treatment and FYM growing media. Juvekar (2019) and Qaisar *et al.* (2008) also reported maximum value of height and collar diameter of *Garcinia indica* (Kokum) and *Cedrus deodara* (Deodar) seedlings raised in media composed of FYM and in large sized polybags, which support these findings.

4.2.3 Number of leaves

4.2.3.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

The perusal of data presented in Table 7 shows that the significantly highest number of leaves (13.29) were observed in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) where as, the lowest number of leaves (7.88) were recorded in T_1 treatment (control).

It is apparent from the data (Table 7) that significantly the maximum number of leaves (11.00) were recorded in polybags (C_1), however the root trainer (C_2) grown seedlings recorded 9.69 number of leaves. The growing media (M_3) composed of soil + sand + FYM (1:1:1) recorded the highest number of leaves (12.90). However, the lowest number of leaves (8.19) were observed in M_1 growing media (only soil).

4.2.3.2 Effect of pre-sowing seed treatments and growing media (T×M) interaction

An overview of data in Table 7 indicated that the combined effect of growing media and pre sowing seed treatments exerted significant influence on number of leaves. Significantly, the maximum number of leaves (16.34) were obtained in T_3M_3 i.e. T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seedlings raised in M_3 growing media composed of soil + sand + FYM (1:1:1) where as, the minimum number of leaves (6.67) were observed in T_1 (control) treatment and in M_1 growing media composed of only soil i.e. T_1M_1.

4.2.3.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

The combined effect of pre sowing seed treatments and root containers (Table 7) revealed that the maximum number of leaves (14.34) were observed in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and polybags (C_1) i.e. T_3C_1 raised seedlings where as, the minimum number of leaves (7.34) were obtained in T_1 treatment (control) and growing media (M_1) composed of soil only i.e. T_1C_2.

4.2.3.4 Effect of root containers and growing media (CòM) interaction

It is apparent from the Table 7 that the significantly maximum number of leaves (13.81) were observed in large sized polybags (C_1) and M_3 growing media composed of soil + sand + FYM (1:1:1) i.e. C_1M_3 raised seedlings. However, the minimum number of leaves (7.71) were obtained in M_1 growing media (only soil) and root trainer (C_2) raised seedlings i.e. C_2M_1.

Table 7: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on number of leaves of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	7.00	6.00	**6.67**	7.33	6.67	**7.00**	10.00	8.67	**9.34**	9.33	8.00	**8.67**	8.42	7.34	**7.88**
T_2	9.67	8.67	**9.17**	10.00	9.67	**9.83**	16.67	14.33	**15.50**	14.00	12.67	**13.34**	12.59	11.34	**11.96**
T_3	11.67	9.33	**10.50**	12.67	11.00	**11.67**	17.67	15.00	**16.34**	15.33	13.67	**14.50**	14.34	12.25	**13.29**
T_4	9.00	8.00	**8.00**	9.67	8.67	**9.17**	14.33	12.33	**13.33**	13.33	10.67	**12.00**	11.58	9.92	**10.75**
T_5	8.00	7.67	**7.67**	8.67	8.33	**8.50**	13.67	12.00	**12.84**	12.33	10.33	**11.33**	10.67	9.58	**10.13**
T_6	7.67	7.33	**7.50**	8.33	7.67	**8.00**	12.33	11.33	**11.83**	11.67	9.67	**10.67**	10.00	9.00	**9.50**
T_7	7.67	7.00	**7.33**	7.67	7.33	**7.50**	12.00	10.33	**11.17**	10.33	9.00	**9.67**	9.42	8.42	**8.92**
Mean	**8.67**	**7.71**	**8.19**	**9.14**	**8.48**	**8.81**	**13.81**	**12.00**	**12.90**	**12.33**	**10.57**	**11.45**	**11.00**	**9.69**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.111	0.06	0.084	0.223	0.157	0.119	0.315
$CD_{0.05}$	0.312	0.167	0.236	0.624	0.441	0.334	0.883

4.2.3.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

The data presented in Table 7 indicates that the interaction of T×C×M resulted in significantly the maximum number of leaves (17.67) in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seedlings raised in polybags (C_1) filled with growing media (M_3) soil + sand + FYM (1:1:1) i.e. $T_3C_1M_3$ where as, the lowest number of leaves (6.00) were recorded in $T_1C_2M_1$ i.e. T_1 treatment (control) and seedlings raised in root trainer (C_2) filled with (M_1) growing media (only soil).

The interaction of pre-sowing seed treatments (T_3), polybags (C_1) and growing media (M_3) in Table 7 revealed the highest number of leaves which might be due to favourable effect of FYM on soil physical properties like soil porosity, water holding capacity and low bulk density. The availability of organic content and adequate nutrients N, P, K in growing media (soil + sand + FYM) accelerated the metabolic activities which might be attributed to encourage the vegetative growth of seedlings and formation of more number of functional leaves per seedling.

In case of polybags, the best results were obtained in larger size which might be due to its large size as it has good water holding capacity, nutrients availability because of low plant density and optimum growing space which might have resulted in better growth of seedlings. The significant effect of pre-sowing seed treatments might be attributed to the microbial biomass, supply of macro and micro nutrients and growth promoters which support the earlier seed germination that also might be helpful in earlier vegetative growth of seedlings and resulted in production of more number of leaves than other treatments.

These results are in harmony with the findings of Parasana *et al*. (2013) and Srivastava and Behl (2002) who reported maximum number of leaves in *Mangifera indica* (Mango) and *Terminalia arjuna* (Arjuna) seedlings raised in growing media composed of soil, sand and FYM. Besides, Kanth *et al.* (2020) and Sharma *et al*. (2018) reported the highest number of leaves *Anacardium occidentale* (Cashew) and *Salvia officinalis* (Garden sage) seedlings when cow dung slurry were used as a pre sowing seed treatment.

Chand (2008) also reported that growing media and large sized containers interacted positively and performed better in respect of growth and biomass of *Terminalia bellirica*

(Bahera), *Terminalia chebula* (Harad) and *Emblica officinalis* (Aonla) seedlings, which support the present findings.

4.2.4 Leaf Area (cm^2)

4.2.4.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

An appraisal of data (Table 8) reveals that the significantly maximum leaf area of seedling (29.77 cm^2) was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks). However, the minimum leaf area (15.79 cm^2) of seedling was obtained in T_1 treatment (control).

As regards to the effect of root containers, significantly the highest value of leaf area (26.23cm^2) was recorded in polybags grown seedlings, followed by root trainers (C_2) having value of (18.74 cm^2). The seedlings raised in growing media (M_3) composed of soil + sand + FYM (1:1:1) recorded significantly maximum leaf area (29.31 cm^2) where as, the minimum leaf area (14.12 cm^2) of seedling was observed in M_1 growing media (only soil).

4.2.4.2 Effect of pre-sowing seed treatments and growing media (TòM) interaction

From the data (Table 8), it is clear that interaction of pre-sowing seed treatments and growing media exercised significant effect on leaf area of seedlings. Significantly the maximum leaf area of seedling (39.83 cm^2) was observed in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seedlings raised in M_3 growing media composed of soil + sand + FYM (1:1:1) i.e T_3M_3 treatment combination. However, the lowest value of leaf area (9.95 cm^2) was recorded in seedling raised with no pre sowing seed treatment and media consisting of only soil i.e., T_1M_1 treatment combination.

4.2.4.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

The data pertaining to leaf area in Table 8 reflects that the T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seedlings raised in large sized polybags (C_1) i.e., (T_3C_1) treatment combination recorded maximum leaf area (34.20 cm^2). However, in T_1 treatment (control) and seedlings raised in root trainer (C_2) i.e. T_1C_2 recorded the minimum value of leaf area (13.96 cm^2).

Table 8: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on Leaf area (cm^2) of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	10.65	9.25	**9.95**	14.78	12.17	**13.48**	23.42	17.28	**20.35**	21.65	17.14	**19.39**	17.63	13.96	**15.79**
T_2	19.08	13.17	**16.13**	22.48	20.33	**21.41**	42.00	28.35	**35.18**	42.00	26.50	**34.25**	31.39	22.09	**26.75**
T_3	20.38	15.33	**17.86**	24.50	21.62	**23.06**	46.58	33.08	**39.83**	45.33	31.30	**38.31**	34.20	25.33	**29.77**
T_4	17.83	12.72	**15.28**	21.88	18.77	**20.33**	38.32	22.98	**30.65**	37.13	22.05	**29.59**	28.79	19.13	**23.96**
T_5	16.40	11.92	**14.16**	19.50	18.23	**18.87**	37.27	21.50	**29.38**	33.98	19.57	**26.78**	26.79	17.80	**22.30**
T_6	15.25	11.32	**13.28**	17.50	15.97	**16.73**	30.75	20.53	**25.64**	29.77	19.58	**24.68**	23.32	16.85	**20.08**
T_7	13.65	10.78	**12.22**	17.10	14.67	**15.88**	28.47	19.80	**24.13**	26.70	18.75	**22.73**	21.48	16.00	**18.74**
Mean	**16.18**	**12.07**	**14.12**	**19.68**	**17.39**	**18.54**	**35.26**	**23.36**	**29.31**	**33.76**	**22.13**	**27.94**	**26.23**	**18.74**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.159	0.085	0.120	0.317	0.224	0.170	0.449
$C.D_{0.05}$	0.445	0.238	0.336	0.890	0.629	0.475	1.258

4.2.4.4 Effect of pre-sowing seed treatments and growing media (CòM) interaction

The scrutiny of data (Table 8) reveals that the M_3 growing media composed of soil + sand + FYM (1:1:1) and polybags ($C_{1)}$ i.e C_1M_3 raised seedlings recorded maximum leaf area of 35.26 cm^2. However, the minimum leaf area (12.07 cm^2) was observed in root trainer (C_2) filled with M_1 growing media (only soil).

4.2.4.5 Effect of pre-sowing seed treatments, root containers and growing media (TòCòM) interaction

The perusal of data in Table 8 shows that the seedlings raised in large sized polybags filled with M_3 growing media comprising of soil + sand + FYM (1:1:1) and seeds soaked in Beejamrutha for 4 weeks (T_3) resulted in significantly highest leaf area of 46.58 cm^2 i.e. $T_3C_1M_3$ statistically at par with $T_3C_1M_4$ composed of soil + sand + vermicompost (1:1:1) having leaf area of 45.33 cm^2 where as, the minimum leaf area 9.25 cm^2 was observed in T_1 treatment (control) and root trainer (C_2) filled with M_1 growing media (only soil) raised seedlings i.e. $T_1C_2M_1$ treatment combination.

The maximum value of seedlings leaf area obtained in $T_3C_1M_3$ treatment combination. The pre-sowing seed treatment (T_3) recorded earlier and highest germination which resulted in earlier and fast growth rate of seedlings as compared to other treatments. As regards to the effect of growing media, it might be due to the FYM application which changed the physical and chemical properties of soil.

The nutrients, specially the nitrogen, is a major constituent of proteins and the presence of abundant protein tends to increase the size of the leaves and ultimately increase the carbohydrate synthesis which might have enhanced cell division, elongation as well as greater chlorophyll content that enhanced the vegetative growth and more division of cells as reported by Bungard *et al*. (2000) and Srivastva and Behl (2002).

In polybags (C_1) better results were recorded might be due to the large size of polybags that maintained high chlorophyll content, proper moisture content, low plant density, which eliminated the root restrictions and allowed the seedlings to grow vigorously (Salisu *et al*., 2018), which support our findings.

These results are in consonance with the findings of Swain and Malik (2018) who reported maximum leaf area of *Rauvolfia serpentina* (Sarpagandha) seedlings raised in growing media composed of soil, sand and FYM.

Table 9 : Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on vigour index of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	708	568	**638**	923	787	**855**	1474	1111	**1292**	1219	1042	**1130**	1081	877	**979**
T_2	1397	1194	**1296**	1962	1644	**1803**	3975	3072	**3524**	3508	2764	**3136**	2711	2168	**2439**
T_3	1796	1333	**1565**	2353	1961	**2157**	5350	3851	**4601**	4507	3126	**3816**	3501	2568	**3035**
T_4	1238	1092	**1165**	1725	1480	**1603**	3337	2560	**2949**	2988	2375	**2681**	2322	1877	**2099**
T_5	1194	1046	**1120**	1476	1264	**1370**	2813	2298	**2556**	2635	2138	**2387**	2030	1687	**1858**
T_6	1015	856	**935**	1336	1125	**1231**	2195	1752	**1973**	1954	1539	**1746**	1625	1318	**1471**
T_7	853	743	**798**	1144	990	**1067**	1841	1453	**1647**	1584	1370	**1477**	1356	1139	**1247**
Mean	**1172**	**976**	**1074**	**1560**	**1322**	**1441**	**2998**	**2300**	**2649**	**2628**	**2050**	**2339**	**2089**	**1662**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_m\pm$	16.188	8.653	12.237	32.376	22.893	17.305	45.786
$C.D_{0.05}$	45.366	24.249	34.293	90.731	64.157	48.498	128.313

Similarly, Anand *et al*. (2012) obtained significant growth of seedlings by applying cow dung slurry for pre sowing seed treatment when raised in growing media composed of FYM. Ginwal *et al*. (2001) obtained significant growth of *Acacia nilotica* (Kikar) seedlings raised in large sized containers.

4.2.5 Vigour index

4.2.5.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

The data presented in Table 9 shows that significantly highest value of seedling vigour index (3035) was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) where as, the minimum value of vigour index (979) was observed in T_1 treatment (control).

Among the root containers, significantly maximum seedling vigour index (2089) was observed in polybags (C_1), however the minimum vigour index of 1662 was found in root trainer (C_2).

In case of growing media, (Table 9) significantly highest value of seedling vigour index (2649) was obtained in growing media (M_3) composed of soil + sand + FYM (1:1:1) (M_3) raised seedlings. However, the lowest value of vigour index (1074) was recorded in M_1 growing media (only soil) raised seedlings.

4.2.5.2 Effect of pre-sowing seed treatments and growing media (TòM) interaction

An overview of data (Table 9) shows that the combined effect of growing media and pre-sowing seed treatments exercised significant effect on seedling vigour. Significantly, the maximum seedling vigour index (4601) was obtained in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. T_3M_3 raised seedlings. The minimum value of vigour index (638) was observed in T_1 (control) treatment and seedlings raised in M_1 growing media composed of soil only i.e. T_1M_1.

4.2.5.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

The data in Table 9 reveals that the significantly maximum vigour index (3501) was observed in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seedlings raised in

polybags (C_1) i.e. T_3C_1 and the minimum vigour index (877) of seedling was recorded in T_1 (control) treatment raised in root trainer (C_2) i.e. T_1C_2.

4.2.5.4 Effect of root containers and growing media (CòM) interaction

The data in Table 9 reflects that the significantly maximum vigour index (2998) was observed in large sized polybags (C_1) filled with M_3 growing media composed of soil + sand + FYM (1:1:1) i.e. C_1M_3 raised seedlings where as, the minimum vigour index (976) was obtained in root trainer (C_2) filled with M_1 growing media (only soil) i.e. C_2M_1 raised seedlings.

4.2.5.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

The perusal of data in Table 9 indicates that the combined effect of T×C×M exercised significant influence on seedling vigour index. The maximum value of vigour index (5350) was reported in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seedlings raised in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. $T_3C_1M_3$. However, the lowest value of vigour index (568) was observed in T_1 (Control) treatment and seedlings raised in root trainer (C_2) filled with growing media M_1 (only soil) i.e. $T_1C_2M_1$.

The maximum value of seedling vigour index revealed in T_3 treatment combination may be due to highest and earlier germination of seeds because of presence of beneficial bacteria, growth promoters and nutrients, which promoted the earlier growth of seedlings. The seedling vigour index is directly linked to germination of seeds and seedlings total height (shoot and root length). In growing media (M_3) composed of soil + sand + FYM (1:1:1) which might have provided aeration, nutrients, increased the soil porosity, good moisture content, which ultimately enhanced the rate of photosynthesis, root growth and other metabolic activity that promotes the vegetative growth.

Growth rate of shoots and roots are interdependent. Roots rely upon plant aerial portions for photosynthesis and various hormones, while seedlings aerial portion rely on the roots for water, nutrients availability by application of manures and growth promoters that make it available to the seedlings through roots for better availability of these factors, which resulted in healthy and better growth of seedlings (Sharma *et al*., 2018). These findings support our investigation.

The polybags (C_1) grown seedlings showed the highest value of seedling vigour index, which might be due to larger in its size making it available the more surface area for root development, hold good amount of growing media, form balance between roots and shoots and ensuring the more availability of nutrients for longer period (Rashid *et al*., 2018).

The results are in conformity with the findings of Vijayalaxmi and Renganayaki (2017) who reported maximum vigour index of *Pterocarpus santalinus* (Red sanders) seedlings grown in cow dung slurry. Besides, Bahuguna and Pyare lal (1990) reported significantly the maximum germination and growth of *Acacia nilotica* (Kikar) in terms of shoot length in large sized polybags filled with soil, sand and FYM. Similarly, Malik and Shamet (2009) reported highest vigour index of *Pinus gerardiana* (Chilgoza pine) seedlings raised in large sized containers filled with growing media composed of FYM.

4.2.6 Root length (cm)

4.2.6.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

The data in Table 10 reflects that the significantly maximum root length (28.44 cm) was recorded in seedlings germinated from the seeds soaked in Beejamrutha for 4 weeks (T_3 treatment). However, the minimum root length (14.78 cm) was observed in T_1 treatment (control). In case of root containers, the result reveals that significantly the highest root length of 22.56 cm was observed in polybags (C_1) raised seedlings where as, root trainer (C_2) raised seedlings recorded root length of 20.10 cm.

As regards to the effect of growing media, the highest root length (25.28 cm) was observed in growing media (M_3) composed of soil + sand + FYM (1:1:1) raised seedlings where as, the seedlings raised in M_1 growing media (only soil) recorded the minimum root length of 17.38 cm.

4.2.6.2 Effect of pre-sowing seed treatments and growing media (T×M) interaction

The interaction between pre sowing seed treatments and growing media (Table 10) presents that the T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) combined with growing media (M_3) composed of soil + sand + FYM (1:1:1) recorded significantly maximum root length of 37.02 cm. However, significantly the lowest values in root length (12.02 cm) was observed in M_1 growing media (only soil) raised seedlings combined with T_1 treatment (control).

Table 10 : Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on root length (cm) of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M3			M4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	13.10	10.93	**12.02**	15.00	13.62	**14.31**	17.57	15.93	**16.75**	16.50	15.60	**16.05**	15.54	14.02	**14.78**
T_2	20.17	19.20	**19.68**	23.33	21.17	**22.25**	34.27	26.97	**30.62**	30.50	25.37	**27.93**	27.07	23.18	**25.12**
T_3	22.33	20.17	**21.25**	24.33	22.50	**23.42**	41.70	32.33	**37.02**	36.97	27.17	**32.07**	31.33	25.54	**28.44**
T_4	19.17	18.17	**18.67**	21.83	20.03	**20.93**	28.33	25.50	**26.92**	26.57	23.93	**25.25**	23.98	21.91	**22.94**
T_5	18.97	17.73	**18.35**	19.83	18.53	**19.18**	25.10	23.93	**24.52**	24.43	22.50	**23.46**	22.08	20.68	**21.38**
T_6	17.87	15.93	**16.90**	18.30	17.23	**17.77**	22.50	20.77	**21.63**	21.67	20.30	**20.98**	20.08	18.56	**19.32**
T_7	15.00	14.57	**14.78**	16.83	15.90	**16.37**	20.33	18.67	**19.50**	19.17	18.17	**18.67**	17.83	16.83	**17.33**
Mean	**18.09**	**16.67**	**17.38**	**19.92**	**18.43**	**19.18**	**27.11**	**23.44**	**25.28**	**25.11**	**21.86**	**23.49**	**22.56**	**20.10**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.116	0.062	0.088	0.232	0.164	0.124	0.328
$CD_{0.05}$	0.325	0.174	0.246	0.650	0.460	0.347	0.919

4.2.6.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

An overview of data in Table 10 reflects that the seeds treated with T_3 treatment and seedlings raised in large sized polybags (C_1) recorded significantly the highest value (31.33 cm) in root length i.e. T_3C_1 treatment combination where as, the seedlings raised in root trainer (C_2) involving T_1 treatment (control) recorded the lowest value (14.02 cm) in root length i.e. T_1C_2.

4.2.6.4 Effect of root containers and growing media (CòM) interaction

The data (Table 10) indicated that significantly the highest value of root length (27.11 cm) was obtained in large sized polybags (C_2) raised seedlings in M_3 growing media composed of soil + sand + FYM (1:1:1) i.e. C_1M_3. However, the lowest value of root length (16.67 cm) was recorded in seedling raised in root trainer (C_2) filled with M_1 growing media comprised of only soil i.e. C_2M_1.

4.2.6.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

The scrutiny of data in Table 10 reveals that the pre-sowing seed treatments, growing media and root containers exerted significant influence on root length of seedlings. The maximum root length (41.70 cm) was observed in $T_3C_1M_3$ treatment combination i.e. seeds soaked in Beejamrutha for 4 weeks (T_3) and raised in polybags (C_1) filled with M_3 growing media composed of soil + sand + FYM (1:1:1) where as, the minimum value of root length (10.93 cm) was found in $T_1C_2M_1$ treatment combination i.e. T_1 (control) treatment and seedlings raised in root trainer (C_2) filled with M_1 growing media (only soil).

4.2.7 Root thickness (mm)

4.2.7.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

An appraisal of data in Table 11 shows that significantly the maximum root thickness (6.22 mm) of seedlings were recorded when seeds was soaked in Beejamrutha for 4 weeks (T_3) and the minimum root thickness (3.39 mm) was recorded in T_1 treatment (control).

As regards to the effect of containers, the seedlings raised in polybags (C_1) significantly gave the maximum root thickness of 4.91 mm and the root trainer (C_2) recorded the minimum root thickness of 4.44 mm.

Table 11: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on root thickness (mm) of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	2.53	1.37	**1.95**	2.52	2.28	**2.40**	3.82	5.02	**4.42**	4.88	4.73	**4.81**	3.44	3.35	**3.39**
T_2	3.73	2.92	**3.33**	4.35	3.86	**4.11**	8.17	7.10	**7.64**	7.25	6.17	**6.71**	5.88	5.01	**5.44**
T_3	4.20	3.67	**3.94**	4.70	4.27	**4.48**	9.50	7.77	**8.63**	8.37	7.30	**7.83**	6.69	5.75	**6.22**
T_4	3.30	2.77	**3.03**	4.06	3.60	**3.83**	7.40	6.73	**7.07**	7.03	5.88	**6.46**	5.45	4.75	**5.10**
T_5	2.67	2.53	**2.60**	3.80	3.14	**3.47**	6.10	6.00	**6.05**	6.13	5.43	**5.78**	4.68	4.28	**4.48**
T_6	2.97	2.63	**2.80**	3.60	3.00	**3.30**	5.33	5.72	**5.53**	5.38	5.15	**5.27**	4.32	4.13	**4.22**
T_7	2.87	2.23	**2.55**	3.03	2.93	**2.98**	4.68	5.28	**4.98**	5.15	4.95	**5.05**	3.93	3.85	**3.89**
Mean	**3.18**	**2.59**	**2.89**	**3.72**	**3.30**	**3.51**	**6.43**	**6.23**	**6.33**	**6.31**	**5.66**	**5.99**	**4.91**	**4.44**	

	T	C	M	T ò M	TòC	C ò M	T ò C ò M
$SE_{m\pm}$	0.042	0.023	0.032	0.085	0.060	0.045	0.120
$CD_{0.05}$	0.119	0.063	0.090	0.238	0.168	0.127`	0.336

In case of growing media significantly the highest root thickness of 6.33 mm was observed in M_3 growing media composed of soil + sand + FYM (1:1:1) raised seedlings and the lowest root thickness of 2.89 mm was recorded in M_1 growing media (only soil) raised seedlings.

4.2.7.2 Effect of pre-sowing seed treatments and growing media (TòM) interaction

The data (Table 11) reflects that the maximum value of root thickness (8.63 mm) was recorded in T_3M_3 treatment combination i.e. seeds soaked in Beejamrutha for 4 weeks (T_3 treatment) and M_3 growing media composed of soil + sand + FYM (1:1:1) raised seedlings where as, the minimum value of root thickness (1.95 mm) was resulted in T_1M_1 treatment combination i.e. T_1 treatment (control) and M_1 growing media (only soil) raised seedlings.

4.2.7.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

It is evident from the data (Table 11) that root containers and pre sowing seed treatments showed significant effect on thickness of roots. Significantly, the highest value of root thickness (6.69 mm) was observed in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and polybags (C_1) raised seedlings i.e. T_3C_1. However, the lowest value of root thickness (3.35 mm) was obtained in T_1 treatment (control) and root trainer (C_2) raised seedlings i.e. T_1C_2.

4.2.7.4 Effect of root containers and growing media (CòM) interaction

The data in Table 11 presents that significantly the maximum root thickness of 6.43 mm was obtained in large sized polybags (C_1) and growing media (M_3) composed of soil + sand + FYM (1:1:1) raised seedlings i.e. C_1M_3. However, the minimum root thickness of 2.59 mm was resulted in root trainer (C_2) and M_1 growing media (only soil) raised seedlings i.e. C_2M_1.

4.2.7.5 Effect of pre-sowing seed treatments, root containers and growing media (TòCòM) interaction

From the data (Table 11) it is clear that significantly the maximum root thickness (9.50 mm) was obtained in $T_3C_1M_3$ treatment combination i.e. seeds soaked in Beejamrutha for 4 weeks (T_3 treatment) and seedlings raised in large sized polybags (C_1) filled with M_3 growing media composed of soil + sand + FYM (1:1:1) where as, the minimum root

thickness 1.37 mm was found in $T_1C_2M_1$ treatment combination i.e. T_1 treatment (control) and seedlings raised in root trainer (C_2) filled with M_1 growing media (only soil)

From the data presented in Table 10 and 11 it is inferred that significantly the maximum values in root length and root thickness were exhibited in T_3 treatment, polybags (C_1) and growing media (M_3) composed of soil + sand + FYM (1:1:1), might be due to the fact that the composition of M_3 growing media especially FYM improved the physical and chemical properties of soil, provided aeration to the roots, increased the water holding capacity, reduce bulk density of soil, easily availability of nutrients by conversion of immobilised nutrients to available form and ultimately the better decomposition rate which led to narrower C:N ratio (Husain *et al*., 2018).

All these favourable factors enhanced the length of roots which resulted in more nutrients absorption and cells differentiation that supported the vigorous growth of roots and increased the root thickness. As explained earlier the effect of pre sowing seed treatment (T_3) caused earlier seed germination due to Beejamrutha beneficial constituents which helped in earlier growth and proper establishment of roots, ultimately resulting in better root length and thickness. The large sized polybags (C_1) added the favourable condition, moisture and nutrients for longer period that gave better results in terms of root growth as compared to small sized root trainer.

The results of the present investigation are in conformity with the findings of Prajapati *et al*. (2014) and Swamy *et al*. (1999) who reported the highest value of root length and root thickness in *Manikara hexandara* (Khirni) and *Szygium cumini* (Jamun) seedlings by applying cow dung slurry as a pre-sowing seed treatment. Besides, Venkatesh *et al*. (2002) and Nure *et al*. (2010) found maximum root growth of *Acacia nilotica* (Kikar) and *Leucaena leucocephala* (Subabul) seedlings raised in large sized containers. Komala *et al*. (2017) and Thakur *et al.* (2016) recorded maximum root growth in *Simarouba glauca* and *Vitex nigundo* seedlings raised in media composed of FYM.

4.2.8 Number of secondary roots

4.2.8.1 Effect of pre sowing seed treatments (T), root containers (C) and growing media (M)

It is apparent from the data (Table 12) that the significantly highest number of secondary roots (24.63) were recorded in T_3 treatment (seeds soaked in beejamrutha for 4 weeks), where as, the lowest number of secondary roots (11.33) were recorded in T_1 treatment (control).

Table 12: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on number of secondary roots of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	7.33	**6.00**	**6.67**	10.67	8.33	**9.50**	17.00	10.00	**13.50**	18.67	12.67	**15.67**	13.42	9.25	**11.33**
T_2	12.67	9.33	**11.00**	21.00	18.33	**19.67**	32.00	22.33	**27.17**	35.67	25.33	**30.50**	25.33	18.83	**22.08**
T_3	14.33	11.00	**12.67**	24.33	20.33	**22.33**	37.33	24.67	**31.00**	38.00	26.67	**32.33**	28.50	20.75	**24.63**
T_4	11.00	8.67	**9.83**	20.33	16.00	**18.17**	28.67	19.67	**24.17**	31.33	21.67	**26.50**	22.83	16.50	**19.67**
T_5	10.00	7.67	**8.83**	19.33	12.33	**15.83**	26.33	18.33	**22.33**	30.00	19.00	**24.50**	21.42	14.33	**17.88**
T_6	9.00	7.67	**8.33**	15.00	10.00	**12.50**	23.33	15.67	**19.50**	26.33	16.33	**21.33**	18.42	12.42	**15.42**
T_7	8.00	7.33	**7.67**	13.33	9.33	**11.33**	22.00	15.00	**18.50**	22.67	15.67	**19.17**	16.50	11.75	**14.13**
Mean	**10.33**	**8.24**	**9.29**	**17.71**	**13.52**	**15.62**	**26.67**	**17.95**	**22.31**	**28.95**	**19.62**	**24.29**	**20.92**	**14.83**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_m\pm$	0.163	0.087	0.123	0.326	0.230	0.174	0.461
$C.D_{0.05}$	0.457	0.244	0.345	0.913	0.646	0.488	1.291

As regards to the effect of root containers, the seedlings raised in large sized polybags (C_1) showed significantly the maximum number of secondary roots (20.92). However, the seedlings raised in root trainer (C_2) recorded 14.83 number of secondary roots. In case of growing media, significantly the highest number of secondary roots (24.29) were observed in growing media (M_4) composed of soil + sand + vermicompost (1:1:1) where as, the lowest number of secondary roots (9.29) were recorded in M_1 media composed of soil only.

4.2.8.2 Effect of pre-sowing seed treatments and growing media (TòM) interaction

An overview of data (Table 12) presents that the significantly highest number of secondary roots (32.33) were recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and growing media (M_4) composed of soil + sand + vermicompost (1:1:1) raised seedlings i.e. T_3M_4 raised seedlings. However, the T_1 treatment (control) and M_1 growing media (only soil) raised seedlings i.e. T_1M_1 recorded the lowest number of secondary roots (6.67).

4.2.8.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

An appraisal of data (Table 12) reveals that the significantly higher number of secondary roots (28.50) were recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and polybags (C_1) raised seedlings i.e. T_3C_1. However, the lower number of secondary roots (9.25) were found in T_1 treatment (control) and root trainers (C_2) raised seedlings i.e. T_1C_2.

4.2.8.4 Effect of root containers and growing media (CòM) interaction

The data in Table 12 reflects that significantly highest number of secondary roots (28.95) were observed in polybags (C_1) filled with (M_4) growing media composed of soil + sand + vermicompost (1:1:1) raised seedlings i.e. C_1M_4 where as, the lowest number of secondary roots (8.24) were recorded in root trainers (C_2) filled with M_1 growing media (only soil) raised seedlings i.e. C_2M_1.

4.2.8.5 Effect of pre-sowing seed treatments, root containers and growing media (TòCòM) interaction

A perusal of the data (Table 12) shows that the different pre sowing seed treatments, root containers and growing media reflected significant effect on number of secondary roots. Significantly, the highest number of secondary roots (38.00) were observed in $T_3C_1M_4$

treatment combination i.e. seeds soaked in Beejamrutha for 4 weeks (T_3) and seedlings raised in large sized polybags (C_1) filled with growing media (M_4) composed of soil + sand + vermicompost (1:1:1) raised seedlings, indicating non-significant differences with $T_3M_3C_1$ (37.33). However, the lowest number of secondary roots (6.00) were obtained in T_1 treatment (control) and in root trainer (C_2) filled with M_1 growing media (only soil) raised seedlings i.e. $T_1C_2M_1$.

In $T_3C_1M_4$ treatment combination, the highest number of secondary roots were observed and the fact is attributed to the vermicompost and sand present in M_4 growing media which improved the physical and chemical properties of soil. The vermicompost and sand composed growing media increased the soil aeration, porosity, moisture content and also the supply of essential nutrients which are considered beneficial for roots initiation and better development of roots (Abirami *et al*., 2010).

Significantly, the highest number of secondary roots were obtained in large sized polybags (C_1) might be due to its larger size which increased the availability of nutrients and water holding capacity for longer period that favors the better root development. In addition, the root containers had specific area for roots establishment which resulted in low seedling density that enhanced the vigourous growth of roots as compared to the small sized root trainers.

The results are corroborated with the findings of Shinde and Malshe (2009) who found maximum number of secondary roots of *Manikara hexandara* (Khirni) seedlings when pre-sowing seed treatment were applied with cow dung + cow urine. Munde *et al*. (2018) and Verma *et al*. (2018) observed maximum number of secondary roots in *Semecarpus anacardium* (Marking nut) and *Prosopis cineraria* (Khejri) raised in large sized polybags filled with vermicompost.

4.3 EFFECT OF DIFFERENT PRE-SOWING SEED TREATMENTS, ROOT CONTAINERS AND GROWING MEDIA ON SEEDLING BIOMASS PARAMETERS

4.3.1 Dry shoot weight (gm)

4.3.1.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

The data (Table 13) suggests that dry shoot weight was found to be significantly highest (3.19 gm) in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks). However, the minimum dry shoot weight (2.09 gm) was observed under T_1 treatment (control).

As regards to the effect of root containers significantly the maximum dry shoot weight (2.83 gm) was obtained in large sized polybags (C_1) raised seedlings and the root trainer (C_2) raised seedlings recorded the dry shoot weight of 2.48 gm. The growing media (M_3) composed of soil + sand + FYM (1:1:1) raised seedlings recorded significantly maximum dry shoot weight of 3.14 gm where as, the minimum dry shoot weight of 1.99 gm was observed in growing media (M_1) composed of soil only.

4.3.1.2 Effect of pre-sowing seed treatments and growing media (T×M) interaction

The data presented (Table 13) reveals that the pre-sowing seed treatments and growing media exerted significant influence on dry weight of shoots. Significantly, the maximum dry shoot weight (3.78 gm) was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seedlings raised in growing media composed of soil + sand + FYM (1:1:1) i.e. T_3M_3 where as, the minimum dry shoot weight (1.69 gm) was obtained in T_1 treatment (control) and seedlings raised in M_1 growing media (only soil) i.e. T_1M_1.

4.3.1.3 Effect of pre-sowing seed treatments and root containers (TòC) interaction

The data in Table 13 reflects that significantly the highest value of dry shoot weight (3.45 gm) was recorded in T_3 treatment (seeds soaked in beejamrutha for 4 weeks) and seedlings raised in polybags (C_1) i.e. T_3C_1. However, the lowest value of dry shoot weight (1.98 gm) was recorded in root trainer (C_2) and T_1 treatment (control) i.e. T_1C_2.

4.3.1.4 Effect of root containers (C) and growing media (C×M) interaction

The inquisition of data presented (Table 13) reveals that the significantly maximum dry shoot weight of 3.43 gm was recorded in the seedlings grown in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. C_1M_3. However, the minimum dry shoot weight of 1.87 gm was recorded in root trainer (C_2) and M_1 growing media (only soil) raised seedlings i.e. C_2M_1.

4.3.1.5 Effect of pre-sowing treatment, root containers and growing media (T×C×M) interaction

A scrutiny of data (Table 13) reflects that the T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and the seedlings raised in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. $T_3C_1M_3$ recorded significantly the highest dry shoot weight (4.08 gm). However, the minimum dry shoot weight (1.53 gm) was obtained in T_1 treatment (control) and root trainer (C_1) filled with soil only raised seedlings i.e. $T_1C_2M_1$.

Table 13: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on dry shoot weight (gm) of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	1.86	1.53	**1.69**	2.13	1.98	**2.06**	2.44	2.25	**2.35**	2.37	2.15	**2.26**	2.20	1.98	**2.09**
T_2	2.25	2.04	**2.15**	2.94	2.74	**2.84**	3.92	3.23	**3.57**	3.60	2.96	**3.28**	3.17	2.74	**2.96**
T_3	2.54	2.10	**2.32**	3.20	2.94	**3.07**	4.08	3.47	**3.78**	3.70	3.13	**3.42**	3.45	2.93	**3.19**
T_4	2.16	1.94	**2.05**	2.79	2.59	**2.69**	3.80	2.94	**3.37**	3.20	2.82	**3.01**	2.99	2.57	**2.78**
T_5	2.14	1.92	**2.03**	2.62	2.47	**2.55**	3.65	2.80	**3.23**	2.95	2.72	**2.84**	2.84	2.48	**2.66**
T_6	2.05	1.84	**1.94**	2.57	2.42	**2.50**	3.22	2.69	**2.95**	2.84	2.60	**2.72**	2.67	2.39	**2.53**
T_7	1.85	1.73	**1.79**	2.43	2.28	**2.36**	2.88	2.63	**2.76**	2.72	2.51	**2.62**	2.47	2.25	**2.36**
Mean	**2.12**	**1.87**	**1.99**	**2.67**	**2.49**	**2.58**	**3.43**	**2.86**	**3.14**	**3.05**	**2.69**	**2.88**	**2.83**	**2.48**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.015	0.008	0.011	0.029	0.021	0.016	0.042
$C.D_{0.05}$	0.041	0.022	0.031	0.083	0.058	0.044	0.117

Table 14: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on dry root weight (gm) of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	0.93	0.65	**0.79**	1.20	1.08	**1.14**	1.63	1.34	**1.48**	1.47	1.34	**1.41**	1.31	1.10	**1.21**
T_2	1.38	1.16	**1.27**	2.11	1.88	**2.00**	3.47	2.57	**3.05**	3.02	2.26	**2.64**	2.48	1.97	**2.23**
T_3	1.62	1.32	**1.47**	2.35	2.12	**2.23**	3.91	2.85	**3.38**	3.42	2.43	**2.92**	2.83	2.18	**2.50**
T_4	1.33	1.04	**1.19**	1.97	1.74	**1.86**	3.14	2.23	**2.68**	2.68	2.07	**2.38**	2.28	1.77	**2.03**
T_5	1.14	1.01	**1.08**	1.81	1.64	**1.73**	2.81	2.06	**2.43**	2.37	1.94	**2.15**	2.03	1.66	**1.85**
T_6	1.07	0.90	**0.99**	1.71	1.57	**1.64**	2.43	1.87	**2.14**	2.12	1.79	**1.96**	1.83	1.53	**1.68**
T_7	0.98	0.77	**0.88**	1.57	1.33	**1.45**	2.17	1.70	**1.94**	1.97	1.68	**1.83**	1.67	1.37	**1.52**
Mean	1.21	0.98	**1.09**	1.82	1.62	**1.72**	2.79	2.09	**2.44**	2.44	1.93	**2.18**	**2.06**	**1.66**	

Factors	**T**	**C**	**M**	**T ò M**	**T ò C**	**C ò M**	**T ò C ò M**
$SE_{m\pm}$	0.014	0.007	0.01	0.027	0.019	0.015	0.039
$C.D_{0.05}$	0.038	0.02	0.029	0.077	0.054	0.041	0.108

4.3.2 Dry root weight (gm)

4.3.2.1 Effect of pre sowing seed treatments (T), root containers (C) and growing media (M)

The data presented in Table 14 recorded significantly highest dry root weight (2.50 gm) in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and the lowest dry root weight (1.21 gm) in T_1 treatment (control).

In case of root containers, the polybags (C_1) grown seedlings revealed significantly the maximum dry root weight of 2.06 gm and the root trainer (C_2) recorded minimum dry root weight of 1.66 gm.

The growing media (M_3) composed of soil + sand + FYM (1:1:1) gave significantly the maximum dry root weight of 2.44 gm and the minimum dry root weight of 1.09 gm in M_1 growing media (only soil) raised seedlings.

4.3.2.2 Effect of pre-sowing seed treatments and growing media (T×M) interaction

The data presented in Table14 reflects that the maximum dry root weight (3.38 gm) was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and growing media (M_3) comprising of soil + sand + FYM (1:1:1) raised seedlings i.e. (T_3M_3) where as, the lowest dry root weight (0.79 gm) was recorded in M_1 growing media (only soil) raised seedlings without any pre-sowing seed treatment (control).

4.3.2.3 Effect of pre-sowing seed treatments and growing media (T×C) interaction

The perusal of data (Table 14) reveals that the significantly highest dry root weight of 2.83 gm was obtained under T_3 treatment and large sized polybags (C_1) raised seedlings where as, the lowest dry root weight of 1.10 gm was obtained in root trainers (C_2) and T_1 treatment (control) raised seedlings.

4.3.2.4 Effect of pre-sowing seed treatments and growing media (C×M) interaction

An appraisal of data presented (Table 14) showed that significantly, the highest dry root weight of 2.79 gm was obtained in polybags (C_2) filled with M_3 growing media composed of soil + sand + FYM (1:1:1) raised seedlings i.e. C_1M_3 where as, the root trainer (C_2) filled with M_1 growing media (only soil) raised seedlings gave lowest dry root weight of 0.98 gm i.e. C_2M_1.

4.3.2.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

The perusal of data (Table 14) reveals that the seedlings raised in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) and seeds soaked in Beejamrutha for 4 weeks (T_3) i.e. $T_3C_1M_3$ treatment combination resulted significantly the maximum value of dry root weight (3.91 gm). However, the minimum value of dry root weight (0.65 gm) was recorded in T_1 treatment and small sized root trainer (C_2) filled with soil only (M_1) raised seedlings i.e. $T_1C_2M_1$ treatment combination.

4.3.3 Root-shoot ratio

4.3.3.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

The data presented in Table 15 reveals that the T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) indicated significantly, the maximum root-shoot ratio of 0.77. However, the minimum root-shoot ratio of 0.57 was recorded in T_1 treatment (control). In case of root containers, significantly the seedlings raised in polybags (C_1) recorded highest root-shoot ratio of 0.71 and the root trainer (C_2) indicated the lowest root-shoot ratio of 0.65.

As regards to the effect of growing media**,** significantly the maximum root shoot ratio 0.76 was observed in growing media (M_3) composed of soil + sand + FYM (1:1:1) where as, the minimum root-shoot ratio (0.54) was found in growing media M_1 (only soil) raised seedlings.

4.3.3.2 Effect of pre sowing seed treatments and growing media (T×M) interaction

The data (Table 15) reveals that significantly the maximum root-shoot ratio of 0.89 was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and in growing media (M_3) comprising of soil + sand + FYM (1:1:1) i.e. T_3M_3 raised seedlings. However, the minimum root-shoot ratio of 0.47 were observed in T_1 treatment (control) and M_1 growing media (only soil) i.e. T_1M_1 raised seedlings.

4.3.3.3 Effect of pre sowing seed treatments and root containers (T×C) interaction

An appraisal of data presented (Table 15) shows that significantly the T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and polybags (C_1) raised seedlings recorded maximum root-shoot ratio of 0.80 i.e., T_3C_1. However, the minimum root-shoot ratio (0.55) was obtained in T_1 treatment (control) and root trainers (C_2) i.e. T_1C_2 raised seedlings.

Table 15: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on Root-shoot ratio of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	0.50	0.43	**0.47**	0.57	0.55	**0.56**	0.67	0.59	**0.63**	0.62	0.63	**0.62**	0.59	0.55	**0.57**
T_2	0.61	0.57	**0.59**	0.72	0.68	**0.70**	0.88	0.79	**0.84**	0.84	0.76	**0.80**	0.76	0.70	**0.73**
T_3	0.64	0.60	**0.62**	0.74	0.72	**0.73**	0.96	0.82	**0.89**	0.86	0.78	**0.81**	0.80	0.73	**0.77**
T_4	0.61	0.54	**0.58**	0.71	0.67	**0.69**	0.84	0.76	**0.80**	0.82	0.73	**0.78**	0.75	0.68	**0.71**
T_5	0.53	0.53	**0.53**	0.69	0.66	**0.68**	0.77	0.73	**0.75**	0.80	0.70	**0.75**	0.70	0.66	**0.68**
T_6	0.52	0.49	**0.51**	0.67	0.64	**0.66**	0.76	0.70	**0.73**	0.75	0.69	**0.72**	0.67	0.63	**0.65**
T_7	0.54	0.48	**0.51**	0.65	0.58	**0.62**	0.75	0.65	**0.70**	0.72	0.67	**0.69**	0.67	0.60	**0.63**
Mean	0.57	0.52	**0.54**	0.68	0.64	**0.66**	0.80	0.72	**0.76**	0.77	0.71	**0.74**	**0.71**	**0.65**	

Factors	**T**	**C**	**M**	**C ò M**	**T ò M**	**T ò C**	**T ò C ò M**
$SE_{m\pm}$	0.005	0.002	0.004	0.005	0.009	0.007	0.013
$C.D_{0.05}$	0.013	0.007	0.010	0.014	0.026	0.018	0.037

4.3.3.4 Effect of root containers and growing media (C×M) interaction

The perusal of data (Table 15) reveals that significantly the maximum root-shoot ratio (0.80) was recorded in growing media (M_3) composed of soil + sand + FYM (1:1:1) and polybags (C_1) i.e. C_1M_3 raised seedlings where as, the root trainer (C_2) filled with growing media M_1 (only soil) i.e. C_2M_1 raised seedlings gave the minimum root-shoot ratio of 0.52.

4.3.3.5 Effect of pre sowing seed treatments, root containers and growing media (T×C×M) interaction

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An appraisal of data presented in Table 15 reveals that the T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) raised seedlings i.e. $T_3C_1M_3$ treatment combination resulted in significantly the maximum root-shoot ratio of 0.96 where as, the minimum root- shoot ratio of 0.43 seedlings was recorded in $T_1C_2M_1$ treatment combination where seedlings were raised in root trainer (C_2) filled with M_1 growing media (only soil) and seeds were sown without any pre sowing seed treatment (control).

4.3.4 Total dry biomass of seedling (gm)

4.3.4.1 Effect of pre sowing seed treatment (T), root containers (C) and growing media (M)

It is evident from the data (Table 16) that the significantly maximum dry biomass of seedling (5.69 gm) was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks). However, the minimum (3.30 gm) dry biomass of seedling was obtained in T_1 treatment (control).

As regards to the effect of root containers, significantly the highest value (4.89 g) of dry biomass of seedlings was observed in polybags (C_1) and the root trainer (C_2) recorded lowest (4.13 gm) dry biomass of seedling.

The growing media M_3 composed of soil + sand+ FYM (1:1:1) revealed significantly the highest (5.58 g) dry biomass of seedling where as, the lowest (3.08 g) dry biomass of seedling was recorded in M_1 growing media (only soil).

4.3.4.2 Effect of pre sowing treatment and growing media (T×M) interaction

An appraisal of data (Table 16) revealed that the pre sowing seed treatments and growing media exercised significant influence on total dry biomass of seedlings.

Table 16: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on total dry biomass of seedling (gm) of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	2.79	2.18	**2.49**	3.33	3.07	**3.20**	4.07	3.59	**3.83**	3.84	3.49	**3.67**	3.51	3.08	**3.30**
T_2	3.63	3.20	**3.41**	5.06	4.61	**4.84**	7.36	5.80	**6.58**	6.62	5.22	**5.92**	5.66	4.71	**5.18**
T_3	4.16	3.51	**3.83**	5.55	5.06	**5.30**	7.99	6.32	**7.15**	7.32	5.54	**6.43**	6.28	5.11	**5.69**
T_4	3.48	2.97	**3.23**	4.76	4.33	**4.55**	6.96	5.17	**6.06**	5.88	4.89	**5.39**	5.27	4.34	**4.81**
T_5	3.28	2.93	**3.10**	4.43	4.11	**4.27**	6.45	4.86	**5.66**	5.32	4.64	**4.98**	4.87	4.14	**4.50**
T_6	3.11	2.74	**2.93**	4.29	3.99	**4.14**	5.65	4.56	**5.10**	4.96	4.42	**4.69**	4.50	3.92	**4.21**
T_7	2.83	2.37	**2.60**	4.00	3.61	**3.81**	5.05	4.33	**4.69**	4.69	4.20	**4.45**	4.14	3.63	**3.89**
Mean	**3.33**	**2.84**	**3.08**	**4.49**	**4.11**	**4.30**	**6.21**	**4.95**	**5.58**	**5.53**	**4.63**	**5.08**	**4.89**	**4.13**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.025	0.013	0.019	0.050	0.035	0.026	0.07
$C.D_{0.05}$	0.069	0.037	0.052	0.139	0.098	0.074	0.196

Significantly, the maximum dry biomass of seedling (7.15 gm) was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and growing media (M_3) comprising of soil + sand + FYM (1:1:1) raised seedling i.e. T_3M_3 where as, the minimum dry biomass of seedling (2.49 gm) was observed in T_1 treatment (control) and M_1 growing media (only soil) raised seedlings i.e. T_1M_1.

4.3.4.3 Effect of pre-sowing seed treatments and root containers (T×C) interaction

The data (Table 16) showed that the seedling raised in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and in polybags (C_2) recorded significantly the highest (6.28 gm) dry biomass of seedling i.e. T_3C_1 where as, the seedlings raised in T_1 treatment (control) and in root trainer (C_2) indicated the lowest (3.08 gm) dry biomass of seedling i.e. T_1C_2.

4.3.4.4 Effect of root containers and growing media (C×M) interaction

An appraisal of data (Table 16) showed that the maximum (6.21 gm) dry biomass of seedling was found in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. C_1M_3 raised seedlings where as, the minimum (2.84 gm) dry biomass of seedling was obtained in root trainer (C_2) filled with M_1 growing media (only soil) raised seedlings i.e. C_2M_1.

4.3.4.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

The scrutiny of data (Table 16) reflected that the maximum dry biomass of seedling (7.99 gm) was observed in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and seedlings raised in large sized polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. $T_3C_1M_3$. However, the minimum dry biomass of seedling (2.18 gm) was recorded in control treatment (T_1) and seedlings raised in small sized root trainer (C_2) filled with M_1 growing media (only soil) i.e. $T_1C_2M_1$.

As explained earlier, $T_3C_1M_3$ interaction effect of these treatments recorded the highest values of seedling growth parameters, similarly the seedling biomass parameters such as shoot dry weight, root dry weight, root-shoot ratio and total dry biomass of seedling. The T_3 treatment combination promoted the seed germination due to microbial biomass and the readily available nutrients in it. The highest seedling biomass production were observed in M_3 growing media and the fact is attributed to the FYM application which improved the

physical and chemical properties of soil, increased the porosity, organic content, good water holding capacity, low bulk density, availability of macro and micro nutrients which resulted in better root development. In addition, the adequate water supply and the availability of essential nutrients through M_3 growing media might be the reason for maximum growth parameters observed under $T_3C_1M_3$. Besides, this enhanced metabolic activities along with activated meristematic cells might have caused the better and healthy growth of seedlings.

The significant effect of polybags (C_1) on seedling biomass might be due to its larger in size, low seedling density, good carrying capacity of growing media that provided the conditions favorable for long duration like moisture retention, nutrients supply, as these are the basic factor for seedlings establishment and faster growth of roots ultimately leading to more vegetative growth and roots development in combination with growing media and pre-sowing seed treatment.

These results are in conformity with the findings of Sofi *et al*. (2014) who reported the maximum dry biomass of *Acer negundo* (Boxelder) seedlings in FYM growing media. Similarly, Mugloo *et al*. (2015) reported maximum values of *Picea smithiana* (Indian spruce) seedling biomass parameters when raised in large sized containers filled growing media composed of FYM. Besides, Kanth *et al*. (2020) and Thanuja *et al*. (2019) recorded maximum dry weight of *Anacardium occidentale* (Cashew) and *Pterocarpus santalinus* (Red sanders) seedlings when cow dung slurry were used as a pre-sowing seed treatment, also support the present investigation.

4.3.5 Seedling quality index

4.3.5.1 Effect of pre-sowing seed treatments (T), root containers (C) and growing media (M)

An appraisal of the data presented in Table 17 shows that the T_3 treatment (seeds soaked in beejamrutha for 4 weeks) recorded significantly the highest value of seedling quality index (1.12) where as, the lowest value of quality index (0.65) was observed in T_1 treatment (Control).

In case of root containers, the seedlings raised in large sized polybags (C_1) recorded significantly the highest quality index of 0.99, while the root trainer (C_2) yielded quality index of 0.84.

The growing media (M_3) composed of soil + sand + FYM (1:1:1) raised seedlings indicated significantly the maximum value of quality index (1.17). However, the growing media M_1 (only soil) raised seedlings showed the lowest value of quality index (0.52).

4.3.5.2 Effect of pre-sowing seed treatments and growing media (T×M) interaction

The interaction effect between pre-sowing seed treatments and growing media involving T_3M_3 treatment combination raised seedlings recorded significantly the maximum value of quality index (1.37) where as, the minimum value of quality index (0.40) was obtained in T_1 treatment (control) and M_1 growing media (only soil) i.e. T_1M_1 treatment combination raised seedlings (Table 17).

4.3.5.3 Effect of pre-sowing seed treatments and root containers (T ò C) interaction

The data (Table 17) reflects that the significantly maximum value of quality index (1.21) was recorded in T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and polybags (C_1) i.e. T_3C_1 raised seedlings and the minimum value of quality index (0.60) was indicated by T_1 treatment (control) and root trainer (C_2) i.e. T_1C_2 raised seedlings.

4.3.5.4 Effect of root containers and growing media (C ò M) interaction

The scrutiny of data (Table 17) reveals that significantly the highest value (1.29) of quality index was recorded in polybags (C_1) filled with M_3 growing media composed of soil + sand + FYM (1:1:1) raised seedlings i.e. C_1M_3 where as, the lowest value (0.46) of quality index was recorded in root trainers (C_2) filled with M_1 growing media (only soil) raised seedlings i.e. C_2M_1.

4.3.5.5 Effect of pre-sowing seed treatments, root containers and growing media (T×C×M) interaction

The combined effect of pre-sowing seed treatments, root containers and growing media (Table 17) showed significant influence on quality index of seedlings. Significantly, the maximum value of quality index (1.52) was observed in $T_3C_1M_3$ treatment combination i.e. seeds soaked in Beejamrutha for 4 weeks (T_3 treatment) and seedlings raised in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1). However, the minimum value of quality index (0.34) was obtained in T_1 (control) treatment and root trainer (C_2) filled with M_1 growing media (only soil) raised seedlings i.e. $T_1C_2M_1$ treatment combination.

Table 17: Effect of pre-sowing seed treatments (T), root containers (C), growing media (M) and their interactions on seedling quality index of Bahera (*Terminalia bellirica* Roxb.) seedlings

	M_1			M_2			M_3			M_4			C_1	C_2	Mean
	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean	C_1	C_2	Mean			
T_1	0.47	0.34	**0.40**	0.62	0.60	**0.61**	0.87	0.74	**0.80**	0.83	0.71	**0.77**	0.70	0.60	**0.65**
T_2	0.64	0.53	**0.59**	1.08	1.00	**1.04**	1.45	1.15	**1.30**	1.31	1.06	**1.18**	1.12	0.94	**1.03**
T_3	0.73	0.59	**0.66**	1.18	1.14	**1.16**	1.52	1.23	**1.37**	1.40	1.12	**1.26**	1.21	1.02	**1.12**
T_4	0.63	0.49	**0.56**	1.02	0.93	**0.98**	1.44	1.12	**1.28**	1.27	0.99	**1.13**	1.09	0.88	**0.98**
T_5	0.53	0.46	**0.49**	0.95	0.90	**0.92**	1.38	1.07	**1.23**	1.11	0.92	**1.01**	0.99	0.84	**0.91**
T_6	0.53	0.45	**0.49**	0.88	0.84	**0.86**	1.26	1.06	**1.16**	1.13	1.03	**1.08**	0.95	0.85	**0.90**
T_7	0.50	0.38	**0.44**	0.81	0.70	**0.76**	1.15	0.99	**1.07**	1.06	0.96	**1.01**	0.88	0.76	**0.82**
Mean	**0.58**	**0.46**	**0.52**	**0.93**	**0.87**	**0.90**	**1.29**	**1.05**	**1.17**	**1.16**	**0.97**	**1.06**	**0.99**	**0.84**	

Factors	T	C	M	T ò M	T ò C	C ò M	T ò C ò M
$SE_{m\pm}$	0.009	0.005	0.007	0.018	0.013	0.010	0.025
$CD_{0.05}$	0.025	0.013	0.019	0.050	0.036	0.027	0.071

Seedling quality index incorporates seedling dry biomass, root-shoot ratio, seedling height and collar diameter. It provides an estimate of resistance of seedlings, useful indicator of seedlings quality and is often used during seedling selection. The larger value of quality index indicates the better phenotype, robustness and the balanced distribution of biomass in the seedling (Liun *et al*., 2019)

The highest values of quality index parameters were observed maximum in $T_3C_1M_3$ treatment combination might be due to ideal characteristics of growing media for seedling growth and the favourable effect of pre-sowing seed treatments on germination. Large sized polybags may have enhanced the growth promoting processes by providing suiTable resources for growth and development of shoots and roots along with growing media applied with pre-sowing seed treatments.

The results are in harmony with the findings of Kumar (2016) who reported the maximum value of quality index and dry biomass of *Terminalia bellirica* (Bahera) seedlings when cow dung slurry were used as a pre-sowing seed treatment and seedlings raised in FYM comprising growing media. Similarly, Tiwari and Saxena (2003) reported significant effect of growing media composed of FYM on seedling quality index of *Dalbergia sisoo* (Shisham). Rahman *et al*. (2019) observed that the large sized containers raised seedlings indicated maximum quality index of *Acacia auriculiformis* seedlings, which support the present investigation.

Chapter-5

SUMMARY AND CONCLUSION

The present investigation entitled "**Effect of pre-sowing seed treatments and growing media on germination and growth performance of Bahera (*Terminalia bellirica* Roxb.)"** was carried out at the Majhgaon experimental farm of Department of Silviculture and Agroforestry, Dr Y.S Parmar University of Horticulture and Forestry, Nauni-Solan (Himachal Pradesh) during 2019-2020. The experiment was laid out in complete randomized design (factorial) with three replications comprised of seven pre-sowing seed treatments and the pretreated seeds were sown in two types of root containers which composed of four growing media. The seeds were sown in the month of May 2019 and the observations related to germination parameters were recorded daily and the data pertaining to seedling vigour, growth and biomass parameters were recorded during the month of January 2020. The results obtained from the present investigation are summarized as below:

5.1 EFFECT OF DIFFERENT PRE-SOWING SEED TREATMENTS (T), ROOT CONTAINERS (C), GROWING MEDIA (M) AND THEIR INTERACTIONS ON THE SEED GERMINATION, SEEDLING VIGOUR, GROWTH AND BIOMASS RELATED PARAMETERS.

5.1.1 Effect of different pre-sowing seed treatments (T)

The effect of pre-sowing seed treatments applied with T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) surpassed the effect of all other applied treatments and significantly revealed the maximum germination percent (56.92%), germination value (2.12), germination energy (42.83%) and the minimum germination period of 38.17 days.

The seedlings raised from the seeds subjected to T_3 treatment recorded significantly the highest values of seedling vigour and growth parameters i.e. seedling height (22.57 cm), collar diameter (5.83 mm), number of leaves (13.29), leaf area (29.77 cm^2), vigour index (3035), root length (28.44 cm), root thickness (6.22 mm) and also the maximum number of secondary roots (24.63).

Similarly, the maximum value of dry shoot weight (3.19 gm), dry root weight (2.50 gm), root-shoot ratio (0.77), total dry biomass of seedling (5.69 gm) and seedling quality index (1.12) were observed for the seedlings raised from the seeds treated with T_3 treatment.

5.1.2 Effect of different root containers (C)

The seeds sown in polybags (C_1) revealed significantly the maximum germination percent (48.15%), germination value (1.26), germination energy (35.91%) and the minimum germination period of 43.76 days.

The seedlings raised in polybags (C_1) significantly recorded the maximum seedling height (18.13 cm), collar diameter (5.08 mm), number of leaves (11.00), leaf area (26.23 cm^2), vigour index (2089), root length (22.56 cm), root thickness (4.91 mm) and the highest number of secondary roots (20.92) also.

Similarly, the maximum values pertaining to the seedlings biomass parameters such as dry shoot weight (2.83 gm), dry root weight (2.06 gm), root-shoot ratio (0.71), total dry biomass of seedling (4.89 gm) and also the maximum value of seedling quality index (0.99) were observed in polybags (C_1) raised seedlings.

5.1.3 Effect of different growing media (M)

In case of growing media, significantly the maximum value of germination percent (53.76%), germination value (1.64), germination energy (38.67%) and the minimum germination period of 41.43 days were recorded when the seeds were sown in growing media (M_3) composed of soil + sand + FYM (1:1:1).

The seedlings raised in M_3 growing media recorded significantly the maximum values of seedling vigour and growth parameters *viz*. seedling height (21.96 cm), collar diameter (6.35 mm), number of leaves (12.90), leaf area (29.31 cm^2), vigour index (2649), root length (25.28 cm) and the root thickness (6.33 mm) also. However, the maximum number of secondary roots (24.29) were observed in growing media (M_4) composed of soil + sand + vermicompost (1:1:1) raised seedlings.

In case of seedling biomass parameters, significantly the maximum value of dry shoot weight (3.14 gm), dry root weight (2.44 gm), root-shoot ratio (0.76), total dry biomass of seedling (5.58 gm) and seedling quality index (1.17) were recorded in the seedlings grown in M_3 growing media.

5.1.4 Effect of different pre-sowing seed treatments and growing media (TòM) interaction

The seeds treated with T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and sown in growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. T_3M_3 treatment combination recorded significantly the highest value of germination percent (67.33%), germination value (3.53), germination energy (50.00 %) and minimum germination period of 33.67 days.

In case of seedling vigour and growth parameters, the interaction effect of T_3M_3 treatment combination out performed as compared to other treatment combinations and significantly reflected the highest value in seedling height (31.00 cm), collar diameter (7.56 mm), number of leaves (16.34), leaf area (39.83 cm^2), vigour index (4601), root length (37.02 cm) and root thickness (8.63 mm). However, the highest number of secondary roots (32.33) were obtained in T_3 treatment and growing media (M_4) comprised of soil + sand + vermicompost (1:1:1) raised seedlings i.e. T_3M_4 treatment combination.

Similarly, the seedlings raised in T_3M_3 treatment combination significantly revealed the maximum values of seedling dry shoot weight (3.78 gm), dry root weight (3.38 gm), root-shoot ratio (0.89), total dry biomass of seedling (7.15 gm) and also the seedling quality index (1.37).

5.1.5 Effect of different pre-sowing seed treatments and root containers (TòC) interaction

The seeds sown in polybags (C_1) after being treated with T_3 treatment i.e. T_3C_1 treatment combination recorded significantly the maximum germination percent (60.17%), germination value (2.62), germination energy (46.33%) and minimum germination period of 37.08 days.

The interaction effect of T_3C_1 treatment combination rised above the effect of other treatment combinations in terms of seedling vigour and growth parameters which significantly resulted in maximum value of seedling height (24.50 cm), collar diameter (6.11mm), number of leaves (14.34), leaf area (34.20 cm^2), vigour index (3501), root length (31.33 cm) and root thickness (6.69 mm) and the highest number of secondary roots (28.50) also.

Similarly, in case of seedling biomass parameters the T_3C_1 treatment combination raised seedlings significantly revealed the maximum value of dry shoot weight (3.45 gm), dry root weight (2.83 gm), root-shoot ratio (0.80), total dry biomass of seedling (6.28 gm) and also the seedling quality index of 1.21.

5.1.6 Effect of different root containers and growing media (CòM) interaction

In case of root containers (C) and growing media (M) interaction, the seeds sown in polybags (C_1) composed of M_3 growing media i.e. C_1M_3 treatment combination revealed significantly the maximum value of germination percent (57.05%), germination value (2.01), germination energy (41.33%) and the minimum germination period of 40.24 days.

As regards to the seedling vigour and growth parameters, the seedlings raised in polybags (C_1) composed of M_3 growing media i.e. C_1M_3 treatment combination significantly reflected the maximum value of seedling height (23.45 cm), collar diameter (6.58 mm), number of leaves (13.81), leaf area (35.26 cm^2), vigour index (2998), root length (27.11 cm) and root thickness (6.43 mm). However, the maximum number of secondary roots (28.95) were obtained the seedlings grown in C_1M_4 treatment combination.

The C_1M_3 treatment combination exhibited significant effect on seedling biomass parameters and revealed the maximum value of dry shoot weight (3.43 gm), dry root weight (2.79 gm), root-shoot ratio (0.80), total dry biomass of seedling (6.21 gm) and the seedling quality index of 1.29.

5.1.7 Effect of different pre-sowing seed treatments, root containers and growing media (TòCòM) interaction

The combined effect of different pre-sowing seed treatments, root containers and growing media (T×C×M) interaction were found significant in case of all germination parameters except germination energy. The maximum value of seed germination percent (70.67%), germination energy (56.00%), germination value (4.55) and the minimum germination period of 32.33 days were recorded when the seeds were treated with T_3 treatment (seeds soaked in Beejamrutha for 4 weeks) and sown in polybags (C_1) filled with growing media (M_3) composed of soil + sand + FYM (1:1:1) i.e. $T_3C_1M_3$ treatment combination.

The $T_3C_1M_3$ treatment combination performed best in terms of seedling vigour and growth as compared to other treatment combinations. Therefore, the seedlings raised in $T_3C_1M_3$ treatment combination, significantly recorded the maximum value of growth parameters like seedling height (34.00 cm), collar diameter (8.03 mm), number of leaves (17.67), leaf area (46.58 cm^2), vigour index (5350), root length (41.70 cm) and the root thickness (9.50 mm). However, the maximum number of secondary roots (38.00) were found in the seedlings grown in $T_3C_1M_4$ treatment combination.

Similarly, the highest values of seedling biomass parameters were significantly observed in $T_3C_1M_3$ treatment combination and reflected the highest value of dry shoot weight (4.08 gm), dry root weight (3.91 gm), root-shoot ratio (0.96), total dry biomass of seedling (7.99 gm) and the seedling quality index of 1.52.

CONCLUSION

From the present investigation, it is concluded that as a way to enhance the seed germination along with better seedling growth and vigour, the seeds were soaked in Beejamrutha for 4 weeks and subsequently sown in polybags of size 18×12 cm filled with growing media comprised of soil + sand + FYM in equal ratio.

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APPENDIX- I

Meteorological data of Nursery of Dr Y.S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) on monthly basis during the period of study (May, 2019 to Jan, 2020)

Months	Temperature (îC)		Relative Humidity (%)	Rainfall (mm)
	Max	Min		
May	30.48	14.73	44	21.30
June	33.68	17.79	48	98.51
July	27.73	19.90	79	218.10
August	28.77	20.09	79	225.80
September	28.33	18.62	77	151.42
October	25.63	11.30	65	5.60
November	22.80	8.20	62	32.20
December	18.10	1.60	51	47.72
January	15.70	2.50	53	74.80

Source: Meteorological Observatory, Department of Environmental Science, College of Forestry, Dr Y.S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) 173 230

APPENDIX- II

ANALYSIS OF VARIANCE FOR GERMINATION PARAMETERS AS INFLUENCED BY PRE-SOWING SEED TREATMENTS (T), ROOT CONTAINERS (C) AND GROWING MEDIA (M) UNDER POLYHOUSE CONDITION

ANOVA 1: Germination percent (%)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	7,774.143	1,295.690	428.496
Root containers (C)	**1**	868.595	868.595	287.252
Growing media (M)	**3**	8,508.643	2,836.214	937.961
T ò M	**18**	628.524	34.918	11.548
T ò C	**6**	45.571	7.595	2.512
C ò M	**3**	99.310	33.103	10.948
T ò C ò M	**18**	48.524	2.696	0.892
Error	**112**	338.667		
Total	**167**	18,311.976		

ANOVA 2: Germination period

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	3,253.810	542.302	884.531
Root containers (C)	**1**	190.720	190.720	311.078
Growing media (M)	**3**	1,055.637	351.879	573.939
T ò M	**18**	132.238	7.347	11.983
T ò C	**6**	8.071	1.345	2.194
C ò M	**3**	14.923	4.974	8.113
T ò C ò M	**18**	19.786	1.099	1.793
Error	**112**	68.667	0.613	
Total	**167**	4,743.851		

ANOVA 3: Germination value

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	49.801	8.300	1,095.243
Root containers (C)	**1**	5.859	5.859	773.150
Growing media (M)	**3**	31.390	10.463	1,380.692
T ò M	**18**	14.884	0.827	109.113
T ò C	**6**	3.332	0.555	73.289
C ò M	**3**	2.371	0.790	104.299
T ò C ò M	**18**	2.024	0.112	14.839
Error	**112**	0.849	0.008	
Total	**167**	110.511		

ANOVA 4: Germination energy (%)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	4,649.571	774.929	161.925
Root containers (C)	**1**	579.429	579.429	121.075
Growing media (M)	**3**	1,439.619	479.873	100.272
T ò M	**18**	287.381	15.966	3.336
T ò C	**6**	70.905	11.817	2.469
C ò M	**3**	40.762	13.587	2.839
T ò C ò M	**18**	56.905	3.161	0.661
Error	**112**	536.000	4.786	
Total	**167**	7,660.571		

APPENDIX-III

ANALYSIS OF VARIANCE FOR SEEDLING VIGOUR AND GROWTH PARAMETERS AS INFLUENCED BY PRE-SOWING SEED TREATMENTS (T), ROOT CONTAINERS (C) AND GROWING MEDIA (M) UNDER POLYHOUSE CONDITION

ANOVA 5: Seedling height (cm)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	2,024.526	337.421	1,040.686
Root containers (C)	**1**	183.891	183.891	567.164
Growing media (M)	**3**	3,061.001	1,020.334	3,146.951
T ò M	**18**	519.810	28.878	89.068
T ò C	**6**	27.931	4.655	14.358
C ò M	**3**	25.746	8.582	26.468
T ò C ò M	**18**	12.878	0.715	2.207
Error	**112**	36.314	0.324	
Total	**167**	5,892.096		

ANOVA 6: Collar diameter (mm)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	82.680	13.780	655.575
Root containers (C)	**1**	8.269	8.269	393.382
Growing media (M)	**3**	318.820	106.273	5,055.891
T ò M	**18**	7.612	0.423	20.120
T ò C	**6**	0.320	0.053	2.535
C ò M	**3**	0.267	0.089	4.234
T ò C ò M	**18**	1.209	0.067	3.194
Error	**112**	2.354	0.021	
Total	**167**	421.531		

ANOVA 7: Number of leaves

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	447.143	74.524	255.510
Root containers (C)	**1**	84.292	84.292	289.000
Growing media (M)	**3**	636.732	212.244	727.694
T ò M	**18**	41.143	2.286	7.837
T ò C	**6**	7.167	1.194	4.095
C ò M	**3**	14.875	4.958	17.000
T ò C ò M	**18**	7.500	0.417	1.429
Error	**112**	32.667	0.292	
Total	**167**	1,271.518		

ANOVA 8: Leaf area (cm^2)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	3,299.420	549.903	909.724
Root containers (C)	**1**	2,350.496	2,350.496	3,888.507
Growing media (M)	**3**	6,798.636	2,266.212	3,749.073
T ò M	**18**	518.560	28.809	47.660
T ò C	**6**	190.037	31.673	52.397
C ò M	**3**	788.295	262.765	434.701
T ò C ò M	**18**	112.236	6.235	10.315
Error	**112**	67.701	0.604	
Total	**167**	14,125.382		

ANOVA 9: Vigour index

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	73,771,014.825	12,295,169.138	1,955.013
Root containers (C)	**1**	7,673,576.205	7,673,576.205	1,220.149
Growing media (M)	**3**	69,078,275.375	23,026,091.792	3,661.301
T ò M	**18**	17,741,360.804	985,631.156	156.722
T ò C	**6**	2,313,510.734	385,585.122	61.311
C ò M	**3**	1,948,249.902	649,416.634	103.262
T ò C ò M	**18**	886,342.770	49,241.265	7.830
Error	**112**	704,373.266	6,289.047	
Total	**167**	174,116,703.882		

ANOVA 10: Root length (cm)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	3,129.984	521.664	1,615.900
Root containers (C)	**1**	253.897	253.897	786.467
Growing media (M)	**3**	1,701.174	567.058	1,756.512
T ò M	**18**	427.846	23.769	73.627
T ò C	**6**	109.667	18.278	56.617
C ò M	**3**	43.197	14.399	44.603
T ò C ò M	**18**	87.123	4.840	14.993
Error	**112**	36.157	0.323	
Total	**167**	5,789.045		

ANOVA 11: Root thickness (mm)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	135.883	22.647	525.272
Root containers (C)	**1**	9.192	9.192	213.203
Growing media (M)	**3**	378.859	126.286	2,929.056
T ò M	**18**	20.643	1.147	26.599
T ò C	**6**	4.829	0.805	18.666
C ò M	**3**	1.321	0.440	10.210
T ò C ò M	**18**	7.804	0.434	10.056
Error	**112**	4.829	0.043	
Total	**167**	563.360		

ANOVA 12: Number of secondary roots

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	3,105.167	517.528	812.567
Root containers (C)	**1**	1,554.292	1,554.292	2,440.383
Growing media (M)	**3**	5,864.351	1,954.784	3,069.193
T ò M	**18**	378.690	21.038	33.032
T òC	**6**	56.833	9.472	14.872
C ò M	**3**	388.208	129.403	203.174
T ò C ò M	**18**	45.500	2.528	3.969
Error	**112**	71.333	0.637	
Total	**167**	11,464.375		

APPENDIX- IV

ANALYSIS OF VARIANCE FOR SEEDLING BIOMASS PARAMETERS AS INFLUENCED BY PRE-SOWING SEED TREATMENTS (T), ROOT CONTAINERS (C) AND GROWING MEDIA (M) UNDER POLYHOUSE CONDITION

ANOVA 13: Dry Shoot weight (gm)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	19.575	3.262	625.379
Root containers (C)	**1**	5.159	5.159	988.925
Growing media (M)	**3**	31.231	10.410	1,995.545
T ò M	**18**	1.732	0.096	18.441
T òC	**6**	0.475	0.079	15.170
C ò M	**3**	0.910	0.303	58.124
T ò C ò M	**18**	0.792	0.044	8.432
Error	**112**	0.584	0.005	
Total	**167**	60.456		

ANOVA 14: Dry root weight (gm)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	27.524	4.587	1,024.129
Root containers (C)	**1**	6.958	6.958	1,553.476
Growing media (M)	**3**	43.873	14.624	3,264.985
T ò M	**18**	3.653	0.203	45.307
T òC	**6**	0.875	0.146	32.549
C ò M	**3**	1.810	0.603	134.729
T ò C ò M	**18**	0.668	0.037	
Error	**112**	0.502	0.004	
Total	**167**	85.863		

ANOVA 15: Root-Shoot ratio

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	0.634	0.106	202.932
Root containers (C)	**1**	0.134	0.134	256.770
Growing media (M)	**3**	1.249	0.416	799.612
T ò M	**18**	0.038	0.002	4.103
T òC	**6**	0.007	0.001	2.229
C ò M	**3**	0.015	0.005	9.541
T ò C ò M	**18**	0.023	0.001	2.477
Error	**112**	0.058	0.001	
Total	**167**	2.159		

ANOVA 16: Total dry biomass of seedling (gm)

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	93.480	15.580	1,057.984
Root containers (C)	**1**	24.099	24.099	1,636.505
Growing media (M)	**3**	148.987	49.662	3,372.399
T ò M	**18**	10.051	0.558	37.918
T òC	**6**	2.599	0.433	29.412
C ò M	**3**	5.250	1.750	118.841
T ò C ò M	**18**	2.616	0.145	9.870
Error	**112**	1.649	0.015	
Total	**167**	288.731		

ANOVA 17: Seedling Quality Index

Source of Variation	DF	Sum of Squares	MSS	F-Calculated
Pre-sowing seed treatment (T)	**6**	3.303	0.550	284.603
Root containers (C)	**1**	0.969	0.969	501.116
Growing media (M)	**3**	10.280	3.427	1,771.780
T ò M	**18**	0.351	0.020	10.091
T òC	**6**	0.067	0.011	5.756
C ò M	**3**	0.206	0.069	35.468
T ò C ò M	**18**	0.065	0.004	1.877
Error	**112**	0.217	0.002	
Total	**167**	15.458		

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Title of Thesis	:	**"Effect of pre-sowing seed treatments and growing media on germination and growth performance of Bahera (*Terminalia bellirica* Roxb.) "**
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Admission Number	:	F-2018-50-M
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Minor Field(s)	:	Silviculture
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ABSTRACT

The present investigation entitled **"Effect of pre-sowing seed treatments and growing media on germination and growth performance of Bahera (*Terminalia bellirica* Roxb.)"** was carried out at the Experimental Farm, Department of Silvilculture and Agroforestry, Dr Y.S Parmar University of Horticulture and Forestry, Nauni, Solan (HP) during 2019-2020. The experiment was laid under polyhouse condition in complete randomized design (CRD factorial) with three replications. Bahera (*Terminalia bellirica* Roxb.) belongs to the family combretaceae and its different parts have been used for various purposes but due to the presence of thick fleshy pulp of fruits, hard seed coat and inappropriate use of forest products due to population pressure results in poor natural regeneration and low availability of bahera quality seeds. Therefore, the objectives of present study were to determine the most suitable pre-sowing seed treatment, root container and growing media for better seed germination, seedling vigour, growth and also for the production of better seedling biomass of bahera. The seeds were subjected to seven pre-sowing seed treatments (T) and the pre-treated seeds were sown in two types of root containers (C) filled with four growing media (M) composed of soil, sand, FYM and vermicompost. From the present study it is evident that the significantly maximum germination percent (70.67 %), germination value (4.55), germination energy (56.00 %) and the minimum germination period of 32.33 days were obtained when the seeds were treated with T_3 treatment (seeds soaked in beejamrutha for 4 weeks) and sown in C_1 (polybags) filled with M_3 growing media composed of soil + sand + FYM (1:1:1) i.e. $T_3C_1M_3$ treatment combination. Similarly, maximum seedling height (34.00 cm), collar diameter (8.03 mm), number of leaves (17.67), leaf area (46.58 cm^2), vigour index (5350), root length (41.70 cm) and root thickness (9.50 mm) were obtained when seedlings were grown in $T_3C_1M_3$ treatment combination where as, the maximum number of secondary roots (38.00) were observed when the seedlings were grown from the pre- treated seeds with T_3 treatment and grown in C_1 (polybags) filled with M_4 growing media composed of soil + sand + vermicompost (1:1:1) i.e. $T_3C_1M_4$ treatment combination. However, maximum value of dry shoot weight (4.08 gm), dry root weight (3.91 gm), root-shoot ratio (0.96), total dry biomass of seedling (7.99 gm) and the maximum value of quality index (1.52) were obtained for the seedlings grown in $T_3C_1M_3$ treatment combination.

Signature of the Major Advisor **Signature of the Student**

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(Shilpa)