STUDY OF CONTAINERS AND ROOTING MEDIA FOR GROWTH AND FIELD ESTABLISHMENT OF COFFEE SEEDLINGS

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STUDY OF CONTAINERS AND ROOTING MEDIA FOR GROWTH AND FIELD ESTABLISHMENT OF COFFEE SEEDLINGS

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C E R T I F I C A T E

This is to certify that the thesis entitled "**STUDY OF CONTAINERS AND ROOTING MEDIA FOR GROWTH AND FIELD ESTABLISHMENT OF COFFEE SEEDLINGS**" *submitted by* **Ms. SRIGANDHA D. D. (UHS15PGM612)** *for the degree of* **MASTER OF SCIENCE (HORTICULTURE)** *in* **PLANTATION, SPICES, MEDICINAL AND AROMATIC CROPS** *to the University of Horticultural Sciences, Bagalkot is a record of research work carried out by her during the period of her study in this university, under my guidance and supervision, and the thesis has not previously formed the basis of the award of any degree, diploma, associate ship, fellowship or other similar titles.*

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Affectionately dedicated to
My Beloved Parents
Shri. D. R. Duggappa Gowda
Smt. Sridevi,
Sister Srinanda D. Gowda and
My Loving Husband
Mr. Shivakashi

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1. INTRODUCTION

Coffee (*Coffea* sp.) belongs to the family Rubiaceae. Most of the *Coffea* species are native to Africa. *Coffea arabica* is native to tropical rain forest of Ethiopia, while *Coffea canephora* is a native of Central Africa. Coffee is the second important commodity in international trade, next to petroleum products in trade volume and value. It is also the second important beverage for its aroma and mild stimulant action. Coffee of commerce is the beans which are roasted, ground and brewed to make a refreshing beverage. Use of coffee has evolved from original chewing of leaves and beans of the plant to relieve pain, hunger and fatigue to the present more sophisticated uses, like espresso and decaffeinated coffees.

Coffee is consumed as a beverage for its pleasant aroma and stimulating effect. It stimulates the heart, brain, nervous system and kidneys. It has several positive effects on nutritional status of the consumer, it comprises nicotinic acid, chlorogenic acid, proteins and amino acids, minerals (K, Mg and Mn) and alkaloids. Chlorogenic acid is the most abundant polyphenol in coffee, which represents a substantial part of coffee anti-oxidants. Coffee is associated with reduced incidence of gallstones, liver cirrhosis and type 2 diabetes and protective in model cancer studies (Dam and Hu, 2005).

Nearly 75 per cent of world's coffee is produced from *Coffea arabica*, 24 per cent from *Coffea canephora* and 1 per cent from *Coffea liberica*. Arabica coffee is known for its aroma and low caffeine content. Robusta coffee characterized by high caffeine content, is preferred for the manufacture of instant coffee. Liberica coffee with a bitter taste is used as filler with other coffees. Area under coffee plantation is 397.147 thousand hectares in India of which Karnataka accounts for 54.95 per cent (2,35,438 ha.). India is producing 3,48,000 MT of coffee (2015-16 data) of which Robusta variety account for 2,44,500 MT of production (70.3%), while Arabica accounted for 1,03,500 MT (29.7%). The Karnataka leads in production (2,51,520 MT) next top producer states are Kerala and Tamilnadu. India exports 70-80 per cent of its produce. Italy, Russia and Germany are the top 3 buyers of Indian coffee. With 4 per cent share in world output, India is ranked 6^{th} in the world (Anon., 2017).

Coffee (*Coffea arabica*) is a tropical plant introduced to India during 1600 AD from Yemen and planted in the high hills in Chikmagaluru district of Karnataka. It can grow up to the height of 10 to 15 m at maturity, the elliptical leaves of the coffee tree are shiny, dark green, waxy and up to 15-24 cm long. The white to pinkish flowers are very fragrant and arranged in glomerules of 3 to 16, which, in turn, are grouped together in the axils of the leaves or above the leaf scars. The flowers wither a few hours after they have bloomed. The roots of the coffee tree can extend 2.0 to 2.5 m in total length. The coffee fruit is oval, similar in size and shape to a small olive and turns red from green during ripening. The fruit is a fleshy berry, in which two seeds are embedded.

It is a tetraploid (2n=44) grown in a tropical climate with medium shade, higher elevation of 1000-1500 m MSL. It thrives well in an annual rainfall of 1600-2500 mm, ideal temperature of 15-25^{0}C with relative humidity of 70-80%. It is grown well in deep friable, porous, rich in organic matter, moisture retentive slightly acidic pH of 6-6.5 and gentle to moderate slope is ideal. Coffee cultivation is mainly confined to the hilly tracts of western and Eastern Ghats. A well distributed rainfall with dry months from December to February, blossom showers during March, April and backing showers from April to May are required for successful crop.

In Arabica coffee several selections/varieties were released for cultivation. The recent variety Chandragiri, is the selfed F_1 progeny developed from the cross between Villa Sarchi and Hibrido de Timor, and released for cultivation in India during 2007. Plants are large with broad leaves, elongated fruits formed in loose clusters. Terminal leaves are light green in colour. This variety shows high resistance to leaf rust. This is the best variety for cultivation for higher elevation with uniform development of berries and ripening. The average yield is 1156 - 1875 kg/ha from the plants of 5-8 year old (Jayarama, 2007).

Coffee plantations are perennial in nature. Some of the coffee plantations survive and produce fruits for about 100 years. Coffee is mainly propagated through seeds especially in Arabica plants which are self fertile and produce uniformity in character for which nursery units are necessary. A good quality seedling production is very essential for getting higher yield and quality produce. Coffee seedling production is a specialized activity and planters buy seedlings from these nurseries. The

traditional method of raising coffee seedlings is first raising in raised beds, at topee stage transferring into polybags (23×15 cm) of 150 gauge thickness containing 6 part of soil, 2 part of FYM and 1 part of sand mixture and allow to grow for 8-12 months. Coffee seedling production system has changed in recent years in the intensive coffee growing areas. Seedling production has come up as a specialized enterprise in these areas.

There are various factors that influence the initial development of coffee grown in the field, such as the seedlings production process and, specially, the container and substrate used (Vallone *et al.*, 2009). Amongst the containers used in conventional coffee seedling production in Brazil, one can first list black polyethylene bags (Carla and Edison, 2015). This container presents disadvantages, such as hardening of media, root coiling and the contamination of the environment by the plastic bags when they are not properly discarded.

In recent days the practice of new plastic container known as root trainer is a new aid to raise young plants and trees in nursery. There is a drainage hole at the bottom and the main tap root tends to grow towards this. This encourages the roots to grow denser. When polythene bags are used instead, roots tend to go through the bag into the ground and are then broken off when the tree is moved for planting. The root trainer is mounted on a stand above ground, so that, when the tap root emerges, it is dried by air. This air pruning causes the root inside the pot to thicken with stored carbohydrates which will support vigorous root growth when the plant is put into the ground and avoids nipping of tap root while planting in main field (Sunil, 2014).

Regarding the substrate, the most common mixture in the production of coffee seedlings using conventional polyethylene bags was formed by soil (70%) and cattle manure (30%), enriched with chemical fertilizers (Dias *et al*., 2009). Cunha *et al.* (2006) state that the substrate used must contain biological, physical, and chemical characteristics that fulfill the plant needs. Besides, the individual cost of the seedling must be considered in relation to its final cost (Dias *et al*., 2009).

Growing of coffee seedlings in root trainer using different media is the latest technology, where Brazil is already using since many years but this is a new concept in Indian coffee. Since it is perennial crop seedling selection is very important during

field planting. Therefore, cost effective, good and healthy seedling production is very much necessary.

Since the study on influence of different containers and rooting media in coffee seedling production has not been attempted in the coffee nurseries located in this region, hence an effort is being made in the present investigation to know the suitable container and rooting media to grow quality coffee seedlings for large scale plantation programme with following objectives.

1. To evaluate the different seedling containers for better rooting and growth of coffee seedlings.
2. To find out the most suitable media for better rooting and growth of coffee seedlings.
3. To study the field establishment of seedlings developed in different containers and media.
4. To work out benefit: cost ratio for different containers and media used.

2. REVIEW OF LITERATURE

Scientific propagation for raising seedlings and its usage is the pre requisite for the expansion of area under perennial crops. Propagation is one of the important operations in horticulture. A viable and successful plantation in coffee mainly depends on raising of vigorous and disease free seedlings in nursery.

The recommended nursery mixture for coffee in India consists of Jungle soil, FYM and sand in 6:2:1 proportion (Prasad *et al*., 2014). Nutrition rich media plays an important role for producing seedlings with better vigour and healthy.

Conventional coffee seedling production in Brazil, one can first list black polyethylene bags and black hard plastic tubes (Carla and Edison, 2015). A root pruning container is an aid to the cultivation of young plants and trees in nursery.

Scientific literature available on recent methods of propagation of coffee is very meager. Hence, available information pertaining to coffee as well as other related crops are collected and presented under following headings.

2.1 Effect of different containers on seedling production in nursery

2.1.1 Effect of different containers on seedling production of plantation and beverage crops

Small polybag sizes (12.5 cm × 25 cm, 12.5 cm × 20 cm, and 12.5 cm × 15 cm) could be used to raise cocoa seedlings and transplanted early to 3 months after sowing instead of the recommended practice of nursing in 17.5 cm × 25 cm polybags and transplanting at 5 to 6 months after sowing (Oppong *et al.,* 2008).

Berko *et al.* (2011) concluded that optimum performance of cashew seedlings can be obtained in bag size of 5.5 x 7 inch.

The highest growth restriction of cocoa seedling was in the tubete, where container substrate volume is only 1 kg compared with the bag (3 kg) and the bucket (5 kg). The development of seedlings grown in tubete (0.4 L) was normal until 60 days compared with the bag (1.6 L) and the bucket (3.0 L). Abnormal plant growth occurred in the bucket at 120 days and the bag at 90 days (Mauricio *et al*., 2011)

Soman *et al*. (2011) revealed that, budding success, scion establishment, number of whorls, number of leaves was high in seedlings raised in polybag where as plant height was highest recorded in green budding on stocks raised in polybag and number of lateral roots in green budding on stocks raised in root trainer in *Hevea*.

Conilon coffee seedling grows better in plastic bags than in polyethylene tubes at 50% and 75% level of shading. The shaded seedlings showed better quality and growth than the ones kept in full sun (Dardengo *et al*., 2013).

Biradar *et al.* (2014), showed that when the seedlings are ready for field planting, all the three varieties (*viz*., Chandragiri, Selection 5b and C × R) recorded significantly higher growth in big size poly bags (5"×12") when compared to normally recommended standard size poly bags (6"×9") irrespective of whether the tap root is nipped or not at the time of transplanting. .

Carla and Edison (2015) conducted research on quality levels of organic arabica coffee seedlings in black and white non-woven fabric containers of various size. Seedlings produced in 1200 ml black containers presented the best results in most of the evaluated parameters. Seedlings produced in 410 ml containers presented Dickson Quality Index of 0.2, which is the index described by other authors as the adequate standard of quality for seedlings.

In an experiment conducted by Ibrahim *et al.* (2015) reported that, the 11× 23 cm size pot give the highest (41.35) SVI-4 index, plant height (22.59 cm), internodal length and leaf area index (2.16), leaf dry weight, stem dry weight, root volume (5.06 cm^3) and total dry weight (3.56 g) in coffee.

Patricia *et al.* (2015) recommended that polybag sizes 14.0 cm x 17.8 cm and 12.7 cm x 17.8 cm should be used to raise cashew seedlings and transplanted at 6-weeks old to achieve higher establishment success.

In the experiment conducted by Sumesh *et al*. (2015) root trainer rubber plants had only 55 per cent less biomass than polybag plants at single whorled stage and total chlorophyll content and chlorophyll *a/b* ratio were higher in polybag plants than root trainer plants of both clones (RRII 105 and RRII 430). Polybag plants showed higher light saturation point when gas exchange was measured at different

photosynthetic photon flux densities. Though there was no variation in effective quantum yield (F PSII), the root trainer plants of RRII 105 showed more excess electrons (J*) at higher light intensities. Photosystem II activity and photosynthetic carbon assimilation rates were less in root trainer plants under open and shaded conditions.

2.1.2 Effect of different containers on seedling production of forest crops

The trial scale teak seedlings raised in root trainers has given better development of biologically desirable lateral roots. The root trainer plants are sturdier, healthier and they are putting up better collar girth in comparison to stump origin plants (Khedkar and Subramanian, 1997).

Venkatesh *et al.* (2002) recommended that the *Acacia nilotica* subsp. *indica* should be grown in 15×20 cm sized container in order to obtain vigorous seedlings capable of surviving under out planted condition.

Annapurna *et al.* (2004) found that, root trainers are the best containers, with compost as the major ingredient of the potting medium, for the production of good quality seedlings of *Santalum album.* For overall growth of seedlings, the 600 ml root trainers were best, followed by the 300 ml and 270 ml sizes.

Tsakaldimi *et al.* (2005) reported that, *Quercus ilex* seedlings raised in paper-pot had significantly greater height, diameter, shoot and root biomass and root volume than those raised in the other two container types. Similarly, *Quercus coccifera* seedlings raised in paper-pot had significantly greater above-and below-ground growth than those raised in the other two container types. 2 years after out planting, the paper-pot seedlings of the two oak species showed better field performance.

The study conducted by Mohit *et al.* (2007) has shown that good quality bamboo seedlings (*Dendrocalamus strictus* and *Bambusa bambos)* can be raised in root trainers on large scale. The limited space available to the plant in root trainers had no adverse effect on rhizome development. The system also facilitates mass propagation of bamboo stock through macro proliferation.

Little leaf linden and field elm grown in Air-Cell^{TM} and Quadro fondo rete container had less deformed root percentage, chlorophyll in leaves and root biomass compared to commercially used smooth sided container (Amoroso *et al.*, 2010).

Anthony *et al*. (2010) revealed that, maximum seedling height (35 cm), collar diameter (3.85 mm), tap root length (9.6 cm), number of lateral roots, number of leaves, above ground biomass, total seeding biomass, root to shoot ratio, sturdiness and quality index were recorded for seedlings raised in 600 cc root trainer, respectively for *Tectona grandis* and *Dalbergia sissoo.*

Ferdousee *et al*. (2010) concluded from an experiment that root-shoot ratio was higher in root trainer in comparison to other treatments. Polybag size of 23x15 cm was found suitable in the nursery for quality seedling production of *Leucaena leucocephala*.

Jabbar *et al*. (2010) conducted an experiment on comparative growth of *Albizia procera* seedlings grown in polybag, nursery bed and root trainers. Germination percentage was found better in nursery bed. Seedling raised in polybags of 23 x 15 cm size revealed best performance in respect to germination and other growth parameters. However, root-shoot ratio was higher in root trainer in comparison to other treatments. Polybag size of 23 x 15 cm was found suitable in the nursery for quality seedling production of *Albizia procera*.

John *et al*. (2011) revealed that heat sensitive plants like *Acer rubrum* benefit from being grown in white containers or painting outer surfaces of green and black containers white. In heat-tolerant *Cercis canadensis*, the effects of container color on whole-plant growth were less evident.

20 cavities/tray (400 ml container) is optimal for *Liriodendron tulipifera*, *Fraxinus mandshurica*, and *Ulmus parvifolia*, 20 or 24 cavities/tray (320 ml container) for *Fraxinus rhynchophylla*, 24 or 35 cavities/tray (240 ml container) for Zelkova *serrata*, and 35 cavities/tray for *Betula costata*, respectively for seedling production (Cho *et al*., 2012).

Twenty cavities/tray are optimal for container seedling production of *Chamaecyparis obtusa*. Usage of optimal container will make us get better quality seedlings and reduction of production costs in the container nursery as well as good field performances with higher survival rate in plantation (Cho *et al*., 2014).

For high quality timber production plantations, the optimal seedling morphology resulted from production using the bigger Plastecnic, the two larger Air-pot and the Tubex for *Quercu robur* (Barbara *et al*., 2015).

Chavan and Tembhurne (2015) recommended that *Simarouba gluaca* seedlings hypothetical to be grown in 25x18 cm size containers, in order to obtain vigorous seedlings. But, recently Government is discouraging the use of polybags for raising seedlings because of non degradable and act as hazards to edaphic factors. Hence, root trainers are becoming popular as they can be reused for several years and very light to transport.

2.2 Effect of different rooting media on seedling production in nursery

2.2.1 Effect of different media on seedlings production of plantation and beverage crops

Aliyu (2007) revealed that top soil combined with either sawdust or river sand in the ratio 1:?1 (v/v) gave the best rooting and sprouting, thus suggesting its use as an effective rooting medium for cashew layering.

The recommended dosage of slow-releasing fertilizer for coffee seedlings production was 10 kg/m^3. The seedlings that grew in slow-releasing fertilizer (10kg/m^3) fertilized Plantmax® presented: plant height/stem diameter ratio equal 4:0; Dickson quality index 2.10, and the shoot dry mass/ root dry mass ratio, equal 4.7 (Marana *et al*., 2008).

Oil-tea camellia seedling height, leaf number recorded high in the seedlings grown in peat soil followed by red loamy soil where as ground diameter was high in the seedlings grown in red loamy soil followed by peat soil (Peng *et al*., 2009).

Abirami *et al.* (2010) revealed that, early germination, germination percentage, germination index and earliness index was maximum in the treatment containing soil: coir dust: sand: vermicompost in 1:1:1:1: as the media followed by soil: coir dust: sand: FYM 1:1:1:1. Similarly the seedling height, girth, number of leaves, shoots length, root length and plant biomass was highest in the treatment

media of soil: coir dust: sand: vermicompost 1:1:1:1 which reflected on higher vigour index in the same treatment in *Myristica fragrans*.

Ugese (2010) found that saw dust based media 1:4:3 and 1:2:3 (Saw dust: Poultry manure: River sand) exhibited superior performance in terms of tamarind seedling growth and should be used especially in environments with an abundance of saw dust and poultry manure.

Osaigbovo *et al*. (2012) revealed that potting medium with sole pig dung significantly produced the best seedling attributes in terms of plant height (11.46 cm), stem girth (1.01 cm), canopy diameter (9.58 cm) while, leaf number (11.16), dry weight of shoots (0.51 g) and roots (0.19 g) were best with sole rice husk and rice husk plus pig dung (1:1) respectively in pepper fruit.

In Coffee, seedling emergence was highest in seedlings grown in forest soil: Effective micro organisms compost 75:25 and forest soil combined with a 4.5 hr soaking the coffee seeds in EM solution resulted in largest seedling height (75 cm), number of primary branches (12.17) and total dry matter (54.6 g) (Ali *et al*., 2013).

Silva *et al*. (2013) conducted experiment on coffee in different substrates and protected environments seedlings. The substrates containing 50% cattle manure associated with vermiculite or the commercial substrate may be indicated for production of coffee seedlings.

Jafer (2016) concluded that soil media and watering frequency improved both biomass production and distribution patterns of korarima seedlings. Hence mixed top and compost soil media in 3:1 ratio as soil media and considering water availability and environment to irrigate every two or three days interval recommended for nursery korarima (a perennial aromatic spice) seedlings.

Paulo *et al.* (2014) Sugarcane agro-industrial residues (sugarcane bagasse and filter cake) are promising materials for use as substrates in *Anacardium othonianum* Rizz. Seedlings grown on a substrate of sugarcane bagasse and filter cake had the highest leaf macronutrient levels, followed by those grown on a substrate of Mecplant® with carbonized rice husk and on a substrate of Bioplant®.

Standard nursery soil (3:2:1, topsoil: poultry: river sand) seemed to be the appropriate growth media for the nursery of tree crops such as *Monodora myristica* (African nutmeg) (Peter *et al*., 2014).

Cocoa seedlings can be raised in polybags filled with a mixture of river sand and topsoil (1:1) for a period of six months provided, foliar fertilizer is applied at the rate of 10 ml NPK (10:10:10) in 15 litres of water at bi-weekly intervals (Sampson *et al*., 2014).

Beatrice *et al*. (2015) revealed that, Coffee husk improved physico-chemical properties of soil, improved the nutrient in the nursery soil medium and actively supported the morphological development of the cashew seedling. The appropriation of this organic material in agricultural system of nursery seedling production will profitably claim the waste (*i.e.*, coffee husk) and ultimately supply nutrient to growing seedlings without adverse impact on soil.

Weathered sawdust and sawdust plus poultry manure can be used as suitable alternatives to topsoil for raising *Moringa oleifera* seedlings with short nursery life span (Ede *et al*., 2015).

Garcinia cola seedlings grown in the standard perforated nursery polybags (27 cm x 25 cm: 1 mm thick) containing ground charcoal as media performed well and more than standard nursery soil (3:2:1, topsoil, poultry droppings and river sand) in almost all the plant growth parameters and developments evaluated in the nursery (Peter-Onoh *et al*., 2015).

Earthworm casting added to the artificial substrate in proportion of 80% or by itself (100%) increases the leaf area of coffee seedlings and, as a consequence it provides a higher accumulation of dry matter in the shoot (Ricardo *et al*., 2009).

Media containing vermiculite, perlite, coconut husk, compost, peat moss, burnt rice husk, rock phosphate and urea is recommended for use in rubber nursery plantation especially in the tropics where some of the soils are certified to be acidic and negatively impact plant growth (Monsuru *et al.*, 2016).

2.2.2 Effect of different media on seedlings production of forest crops

The selection of proper potting mixture for eucalyptus hybrid seedlings grown in root trainer was carried out with various combinations of compost, soil, sand, coal pebbles, Teak seed husk, rice husk and saw dust. Seedlings height and root collar development were observed. The best results were obtained for potting mixture of compost, sand and soil in ratio 2:1:2 (Shrivastava *et al*., 1998).

Media prepared with peat and cowdung in 3:1 ratio can be used for production of *Leocaena leococephala* seedlings (Alam *et al*., 2004).

Fraxinus pennsylvanica and *Quercus rubra* seedling responses to nursery soil amendments vary with different forms and amounts of organic matter. Benefits to seedling growth through application of appropriate materials like chicken manure and composted leaf, tree, and lawn trimmings in the proper balance can improve seedling morphological quality and positively influence soil chemical properties (Davis *et al*., 2006).

Seedlings grown in the media containing peat: straw powder: organic fertilizer: vermiculite (1:1:1:1) was the most economic and practical substrate for container-grown-seedling breeding of *Platycladus orientalis* (Bing *et al*., 2011).

The substrates made with sewage sludge, carbonized rice hull and coffee straw provided better results of growth of *Chamaecrista desvauxii* seedlings. Moreover, the treatment with 60% sewage sludge + 20% carbonized rice hull + 20% coffee straw provided the best development of the morphological characteristics evaluated, and it was recommended for the production (Marcos *et al*., 2013).

Getachew (2014) revealed that the growth performance of the seedlings was increased when the higher amount/part of compost was used in the nursery soil substrate. Hence, it is recommended to use 5 part forest soil: 4 part compost: 1 part sand as a potting mixture for *Cordia africana* and *Albizia gummifera* tree species.

Peter and Uzokwe (2014) by their study revealed that optimum growth performance of *Pterocarpus osun* can be obtained in top soil followed by river sand and saw dust as potting media.

Afzelia africana, a woody tree can be propagated by sowing the seeds in and growing the seedlings in 2:1:1 top forest soil + saw dust + poultry manure medium (Nzekwe *et al*., 2016).

2.2.3 Effect of different media on seedlings production of fruit crops

Mumtaz *et al*. (2006) concluded that, sand + peat (1:1) is a superior potting medium followed by sand + peat + spent compost of Button mushroom (1:1:1) for growth of rough lemon (*Citrus jambhiri*) nursery stock.

The use of peat + perlite and perlite led to increased plant growth and quality of fig nursery trees grown in high-tunnel (Ugur *et al*., 2010).

Parasana *et al*. (2012), recorded minimum days (24.33) to germinate as well as maximum germination percentage of mango stone (81.00 %) in combination of M_3V_3 (Soil + sand + farm yard manure (2:1:1) + LSM-12-Master royal) at 60 DAS. Significantly maximum number of leaves per plant (17.67), length of shoot (52.30 cm), stem girth (4.53 mm), fresh weight of seedling (33.23 g), dry weight of seedling (23.23 g) and maximum survival (82.67 %) were noted in combination of M_3V_3 (Soil + sand + farm yard manure (2:1:1) + LSM-12 Master-royal) at 180 DAS, respectively.

Amrendra *et al.* (2014) from studies, potting media containing riverbed soil + vermi-compost (2:1) + NPK (5 g/sapling) or riverbed soil + vermicompost (2:1) + vermiculite (50 g/sapling) was found most suitable alternate potting media mixtures for mass propagation of litchi in black polyethylene bags under net house.

Bhardwaj (2014) suggest by his study that, vermicompost, pond soil and sand with cocopeat should be used as growing media for higher germination percentage (95.27%) in papaya cv Red lady.

Surakshitha and Sharath (2015) concluded that, the growth medium containing red earth: sand: vermicompost (2:1:1) and the bio-inoculant *Glomus fasciculatum* helped to reduce the gestation period by increasing the growth of jamun seedlings individually. The combined effect of growing medium red earth: sand: vermicompost (2:1:1) supplemented with the bio-inoculant *Glomus fasciculatum* showed the increased growth of jamun seedlings. The use of growth medium and bio-inoculants

are very helpful to nursery activities for faster multiplication of propagating materials either by budding and grafting in required quantities and in time by reducing the gestation period of seedlings.

2.3 Effect of bio fertilizers on seedling production in nursery

2.3.1 Effect of bio fertilizers on seedling production of plantation and beverage crops

Biradar *et al*. (2006) studied on role of biofertilizers and PGPR on growth and development of coffee seedlings. Result revealed that the combined inoculation of Azospirillum + VAM + PSB + N-PGPR increased the plant height (30.2 cm), tap root length (31.1 cm), stem girth (4.5 mm) and dry matter weight (17.4 g) of seedlings significantly at field planting stage (150 Days after transplanting) as compared to un inoculated control and other treatments.

Mya *et al.* (2008) revealed that the total dry weight, K and Ca uptake (mg plant-1) were significantly increased in all mycorrhizal coffee varieties sown in red soil compared to black soil. Significantly higher total dry weight was observed in Catimor in comparison with those of San Ramon in red soil and three varieties: Caturra (red) and Caturra (yellow) and San Ramon in black soil. K and Ca uptake mg plant-1 of Catimor and S-795 were significantly increased when compared with those of other three varieties at both soil types.

Prasad *et al.* (2014) indicated that the recommended standard package of practice with jungle soil, Farm Yard Manure (FYM) and sand in the 6:2:1 proportion is a best suited potting mixture to raise the coffee nursery. But in absence of the fertile jungle soil, the marginal soils also can be utilized as an ingredient of potting mixture with due care to incorporate adequate quantity of farm yard manure and the microbial consortia (*Azosprillum*, *Pseudomonas fluorescens*, PSB and VAM) is not a substitute for FYM in the potting mixture.

The inoculation of *Claroideoglomus etunicatum* and *Dentisculata heterogama* in Arabica seedlings increases the competitive power against the *Bidens pilosa* weed interference and also increases the growth, dry matter accumulation and leaf contents of P, K, Ca, Cu, Fe and Zn in coffee seedlings (Andre *et al*., 2016).

Bhattacharya and Bagyaraj (2002) suggest that the simple method of inoculating nursery beds or poly bags with *Gigaspora margarita* or *Acaulospora laevis* can be taken as a routine nursery technology by growers to produce healthy and vigorously growing coffee seedlings.

2.3.2 Effect of bio fertilizers on seedling production of forest crops

The inoculation of olive seedlings with both AMF tested, *Glomus intraradies* BEG72 and *Glomus mosseae* BEG116, was effective in promoting early development of plants. Olive trees pre-inoculated with selected AMF before transplanting showed long lasting improvement in growth and crop yield (Victoria *et al*., 2003).

Verma *et al*. (2008) revealed that, seed germination was maximum in *Azospirillum* treatment followed by its combination with AM and PSB after 2 months. Maximum height of teak seedlings was recorded in AM + *Azospirillum*, AM + PSB and AM + PSB + *Azospirillum* combination after 5 months. Diameter of seedlings at collar region was maximum in AM, AM + *Azospirillum* and AM + *Azospirillum* + PSB combination.

Growth and nutrient uptake were found significantly higher in the *Tectona grandis* seedlings treated with AM+ *Azotobacter* combination (3.91 times higher bio mass) than other (Seema and Rakhi, 2009).

Meenakshisundaram *et al.* (2011) inferred that under appropriate management, the use of more efficient biofertilizers lead to an increased growth and biomass of *Delonix regia* and the combined application of bioinoculants *Azospirillum* + *Azotobacter* + AM fungi might play a significant role in improving the growth response and nutrient uptake of *D.regia* seedlings there by producing good quality planting stock.

Potting mixture for Silver oak has to be provided with bioinoculants *viz., Trichoderma,* P-solubilizers and if necessary the Nitrogen fixers based on the nutrient status of the potting mixture and the plant requirement (Umashankar *et al*., 2012).

2.3.3 Effect of bio fertilizers on seedling production of fruit crops

Aseri *et al.* (2008) study represents the positive response of biofertilizers in nursery seedlings followed by their transplantation in harsh field conditions of Indian Thar Desert. In both nursery and field experiments the combined treatment of *Azotobacter chroococcum* and *Glomus mosseae* was found to be the most effective. Besides enhancing the rhizosphere microbial activity and concentration of various metabolites and nutrients, these bioinoculants helped in better establishment of pomegranate plants under field conditions. A significant improvement in the plant height, plant canopy, pruned material and fruit yield was evident in 5-year-old pomegranate plants in field conditions.

2.4 Effect of containers and media on seedling production

2.4.1 Effect of containers and media on seedling production of plantation and beverage crops

Janaina *et al.* (2010) revealed that, the sugar-cane bagasse and filter cake compound was adequate for producing *Coffea canephora* transplants. The compound, compound/controlled-release fertilizer and soil/manure/ controlled-release fertilizer substrates are the best options for producing *Coffea canephora* transplants where as the commercial substrate was inadequate for production of *C.canephora* regardless of the container. Pressed block, polyethelyne bags and large size tubette (120 mL) are the most adequate containers for producing *Coffea canephora* transplants.

Silva *et al.* (2010) revealed that, type of container and substrate significantly influence the development of coffee tree seedlings; and the container of larger volume (polyethylene bags and 120mL tubettes) filled with alternative and commercial substrates provide seedlings with improved growth rate.

Compost and vermicompost can be used as an alternative growing medium replacing top soil and small polybags as a container of growing medium can be replaced by a bamboo strips in pre nursery. Whilst, compost, vermicompost and cow manure can be used as an alternative growing medium replacing top soil on the main nursery in oil palm (Toto *et al.*, 2015).

2.4.2 Effect of containers and media on seedling production of forest crops

Sugar maple seedlings grown for 20 weeks in 9.0-liter plastic containers filled with a peat perlite- sand medium were larger than those grown in any of eight other container-medium combinations used (Ward *et al*., 1981).

When pot length increased, the seedling quality improved in Juniper. The seedlings with the best quality in terms of the seedling height, root collar diameter, shoot and root fresh and dry weights and shoot/root ratios can be grown in 11 cm x 30 cm pots. With respect to the growing media, 70% forest soil + 15% humus + 15% pumice or creek sand should be used (Gulcu *et al.*, 2010).

The combination of root trainer (300 cc) and growing medium (Soil: Sand: FYM: Dalweed) in the ratio of 2:1:2:1 by volume proved best among all the tested combination to have the quality nursery stock of *Melia azedarach* seedling *(*Mugloo *et al*., 2010).

The best combination for optimum germination and growth in nursery for *Terminalia bellirica* was silt loam soil + FYM + sunken beds or 4000 ml-plastic pots. Collar diameter was higher in seedlings raised in goat manure, sunken bed, and silt loam soil and root trainer. Survival percent under field conditions was higher in seedlings raised in FYM and Celrich (bio-organic soil enricher) compared to other treatments (goat and poultry manures), whereas maximum height and collar diameter were recorded in seedlings raised in plastic pots (Bali *et al*., 2013).

To improve the production of high quality seedlings of tropical pioneer trees and avoid growth depression in nurseries, one must consider the combination of higher volume pots or tubes, pure or diluted (up to 50% with subsoil) manure compost, and AMF inoculation (Waldemar *et al*., 2015).

Mauricio *et al*. (2016) recommended by his study that, for early development of *Schizolobium amazonicum* seedlings, the use of 280 ml plastic tubes and Tropstrato® commercial substrate is the best.

2.4.3 Effect of containers and media on seedling production of fruit crops

Maximum height of papaya seedlings at 15 days after sowing (5.26 cm) was noted in media containing soil + cocopeat + vermicompost + sand (1: 1: 1: 1). Height of seedling (5.27, 7.06 and 15.23 cm) at 15, 30 and 45 DAS respectively, stem diameter (1.70 mm), number of leaves per seedling (6.30) at 30 DAS and diameter of primary root (3.92 mm) recorded significantly highest in papaya seedlings raised in polythene bags. Earthen pots grown papaya seedlings showed significantly maximum leaf area (37.09 cm^2), fresh weight of seedling (6.73 g), dry weight of seedling (0.597 g) and length of primary root (10.05 cm) as compared to rest of the media (Arvind *et al*., 2015).

Mohd *et al*. (2015) showed that the budded kinnow plants planted in black poly bag of size 22x10x8 cm filled with propagation media soil: sand: vermicompost in the ratio of 1:1:1 recorded highest out planting performance (survival percentage of 93.33%) with maximum leaf area (15.21 cm^2), number of primary roots (12.00) and secondary roots (99.67) as compared to other treatments.

2.5 Field establishment of seedlings developed in different containers and media

2.5.1 Field establishment of plantation crop seedlings developed in different containers and media

Vallone *et al.* (2009) evaluated the behavior of coffee seedlings (*Coffea arabica* L.) produced in different containers and substrates when transplanted in the field without supplemental irrigation. In the field, 20 months after transplanting, the coffee trees from seedlings produced in a polyethylene bag and in a 120 mL tube using a standard substrate are superior to those obtained from seedlings produced in 50 mL tubes.

Post transplanting effect of pot size and nursery period on the growth performance of cashew seedlings was studied by Adeyemi (2013) and he revealed that cashew seedlings can be successfully raised in small sized nursery pots such as 30× 6.25 and 15×12.50 cm polythene pots and also be transplanted to the field at tender ages of 4 and 8 weeks in the nursery.

Danielle *et al*. (2013) revealed that it is possible to increase productivity in the first harvest of coffee by utilizing pruned trees (with two steams) and a stay of 18 months in nursery bags 16x25cm, with ripening of the fruit similar to that of conventional seedlings without the occurrence of hollow grains.

George *et al*. (2013) observed field performance of Hevea grown in different containers and revealed that, three- whorled polybag plants were significantly superior in girth of the plant compared to polybag one-whorl, two-whorl and root trainer one-whorl, two-whorl and three-whorl plants. Considering the practical convenience and cost involved, root trainer one- whorl plants appeared to be the ideal planting material for commercial planting of Hevea.

Segun (2015) showed that *Arbuscular mycorrhizae* fungi inoculated cocoa seedlings at level of 50 g and 100 g exhibited better transplant performance due to its higher plant height (34.24 and 37.89 cm), higher leaf number (11.70 and 12.67), higher stem girth (0.67 mm and 0.75 mm), higher leaf area (51.38 cm^2 and 59.45 cm^2), higher shoot fresh weight (7.42 g and 9.98 g), higher root fresh weight (6.48 g and 6.77 g), higher shoot dry weight (3.17 g and 3.88 g), higher root dry weight (1.17 g and 1.21 g) and higher fresh root/shoot ratio (0.87 and 0.69). While application of mycorrhizae at 50 g level, recorded the highest level of *Glomus mossae* colonization (81.4%).

2.5.2 Field establishment of forest crop seedlings developed in different containers and media

Philip (1991) revealed that, container seedlings of Ponderosa pine were significantly taller than bareroot seedlings at ages 4 and 10 yr and container seedlings of ponderosa pine and Douglas-fir were significantly larger in breast-height, diameter than bareroot seedlings at age 10 year. Survival of container seedlings was significantly higher than bareroot seedlings for both pine species at all ages tested.

At the time of planting, size and quality of the open-grown container stock were equal to or better than bareroot material of *Pinus taeda* seedlings. When outplanting conditions were ideal, field plantings in March, April, and May of 2 successive years indicated equal performance of the 2 stock types. When conditions

were more stressfu1, container stock survived and grew better than bareroot seedlings (Barnett and Gilvray, 1993).

Cordia alliodora (Boraginaceae) grew better in plastic bags of soil with NPK fertilizer and compost than in unamended soil, despite large treatment differences at planting, there were no significant differences in plant size after one year in the field between book containers and plastic bags. Stump plants that were shorter and had higher mortality. *Hyeronima alchorneoides* (Euphorbiaceae) grew better in compost than in soil with or without fertilizer. Plants produced in compost were also bigger after one year's field growth. Plants produced with soil or in paper pots had higher mortality. *Calophyllum brasiliense* (Clusiaceae), grew less in compost compared to soil in the field, seedling produced in soil had higher survival rate (Kevyn *et al.*, 2001).

Sambeek *et al.* (2016) study demonstrated that swamp white oak, when established from repeatedly air-root-pruned container planting stock on less than ideal oak sites (droughty or poorly drained with frequent flooding), has the capacity for faster height, diameter, and biomass growth than trees from bare root planting stock.

2.6 Benefit cost ratio

Polytube grown seedlings are more or less similar in performance and the capital investment in polytube nursery is much less than that of a root trainer nursery. The establishment of a root - trainer nursery is 6.25 times more costly than a polytube nursery (Nanhorya *et al.*, 1999).

Verma *et al.* (2008) recorded that based on the profit index application of AM fungi along with *Azospirillum* produced the maximum profit besides AM fungi has also got other beneficial effects on plant growth.

Bashir *et al.* (2009) revealed that *Pinus wallichiana* seedlings raised in 100 cm^3 and 150 cm^3 root trainers (*i.e.*, 1.56 and 1.611) were found to be the most cost effective when compared with seedlings grown in 300 cm^3 root trainers.

3. MATERIAL AND METHODS

The present investigation was carried out at the College of Horticulture, Mudigere, Chikkamagaluru district, Karnataka during the period from April 2016 to January 2017, to evaluate the, "Containers and rooting media for growth and field establishment of coffee seedlings". The detail of the materials used and methods adopted during the course of investigations are presented under this chapter.

3.1 Experimental location

The college of Horticulture, Mudigere is situated in hilly zone of Karnataka state at 13^0 25^1 North Latitude, 75^0 25^1 East longitudes and is at an altitude of 976 m above Mean Sea Level. Mudigere is considered to be mild tropical rainy region. It receives an annual rainfall of 2500 mm which is fairly distributed throughout the year. The mean maximum temperature ranges between 26^0 C to 34^0 C while mean minimum temperature ranges between 10^0 C to 13^0 C with the mean maximum relative humidity of 98 percent during June to August and the minimum of 60 per cent during April-May.

During the year 2016 the total rainfall of 1469.65 mm was received in 119 rainy days from January 2016 to December 2016. The mean maximum temperature was 28.89°C and the mean minimum temperature was 20.49°C. The mean maximum relative humidity was 83.24% wherein, the mean minimum relative humidity was 76.10%. The total rainfall of 1469.65 mm was received in 119 rainy days from January 2016 to December 2016.

During the experimental period the mean maximum temperature was 28.11°C.Whereas, the mean minimum temperature was 20.32°C. The mean maximum relative humidity during the period of experimentation was 83.28% whereas, the mean minimum relative humidity was 77.48 per cent. The total rainfall of 1465.65 mm was received in 118 rainy days during seedlings growth period from April 2016 to January 2017. The details of meteorological data for the period of experiment is presented in appendix-I.

3.2 Experimental details

The details of the experiment are given below.

3.2.1 Treatment details

3.2.1.1 Primary nursery

Factor I: Containers

Treatment	Containers
C_1	Raised bed
C_2	Protrays (2" × 2")

Factor II: Media

Treatment	Media
M_1	Red soil + sand + FYM (3:1:1) (Control)
M_2	Red soil + cocopeat + FYM (3:1:1)
M_3	Red soil + sand + vermicompost (3:1:1)
M_4	Red soil + sand + pressmud (3:1:1)
M_5	M_1 + *Pseudomonas fluorescens* (5 g/ kg FYM)
M_6	M_5 + VAM - *Gigaspora gigantea* (10 g/kg FYM)
M_7	M_5 + PSB - *Bacillus megaterium* (10 g/kg FYM) + Nitrifying Bacteria- *Azospirillum* (10 g/kg FYM)

3.2.1.2 Secondary nursery

Factor I: Containers

Treatment	Containers
C_1	Black polythene bag (6" × 9") [Control]
C_2	Transparent polythene bag (6" × 9")
C_3	Protray raised seedlings in black polythene bag (6"× 9")
C_4	Root trainers (160 cc)
C_5	Raising in beds (till transplanting to main field)

Factor II: Media

Treatment	Media
M_1	Red soil + sand + FYM (3:1:1) (Control)
M_2	Red soil + cocopeat + FYM (3:1:1)
M_3	Red soil + sand + vermicompost (3:1:1)
M_4	Red soil + sand + pressmud (3:1:1)
M_5	M_1 + *Pseudomonas fluorescens* (5 g/ kg FYM)
M_6	M_5 + VAM - *Gigaspora gigantea* (10 g/kg FYM)
M_7	M_5 + PSB - *Bacillus megaterium* (10 g/kg FYM) + Nitrifying Bacteria - *Azospirillum* (10 g/kg FYM)

3.2.2 Plant material, design and layout of the experiment

The experiment was carried out in Arabica cultivar Chandragiri adapting factorial randomized block design consisting of 2 factors *i.e.*, Container (Factor I) and Media (Factor II). Factor I consists of 2 treatments and Factor II with 7 treatments making 2×7 factorial RBD design in primary nursery. Whereas in secondary nursery and main field, Factor I consists of 5 treatments and factor II with 7 treatments making 5×7 factorial RBD. Each treatment consists of 20 seedlings replicated twice.

3.3 Operational detail

Nursery raising

3.3.1 Source of seeds and bio-inoculants

Seeds of *Coffea arabica* cv. Chandragiri variety were procured from Central Coffee Research Institute, Balehonnur, Chikkamagaluru District. Bio-inoculants such as *Pseudomonas fluorescens* (CFU 1×10^8), *Azospirillum*, *Bacillus megaterium* were procured from bio-control laboratory, UHS, Bagalkot.

3.3.2 Preparation of primary nursery bed

The land selected for preparation of nursery bed was dugged 2-3 times, clods were crushed and brought to a fine tilt and 7 raised beds of 1×1 m^2 and 15 cm height from the ground level were prepared. Each bed was provided with different

proportions of rooting media consisting of red soil, sand, FYM, cocopeat, vermicompost, pressmud and bio-inoculants such as VAM (*Gigaspora gigantea*), PSB (*Bacillus megaterium*), nitrifying bacteria (*Azospirillum*), *Pseudomonas fluorescens* (CFU 1×10^8) for preparation in accordance with the treatments. The germination beds were spaced 30 cm apart.

3.3.3 Preparation of protrays

Seven protrays of 2" × 2" size containing 98 wells per portray were taken and each portray was filled with 7 different media consisting of red soil, sand, FYM, coco peat, vermicompost, pressmud and bio-inoculants such as VAM (*Gigaspora gigantea*), PSB (*Bacillus megaterium*), nitrifying bacteria (*Azospirillum*), *P. fluorescens* (CFU 1×10^8) as per the treatment.

3.3.4 Sowing of seeds

Seeds were sown with their flat side facing the soil at a distance of 2 cm between seeds and 10 cm between rows in beds and in portrays, 2 seeds per well was sown in the similar way at the centre of the well. Later they were covered with thin layer of finely sieved soil. After sowing, beds and portrays were mulched with a layer of paddy straw which ensures optimal temperature for seed germination and protect the seeds from dessication.

3.3.5 Preparation of different media for containers and secondary nursery bed

In this experiment, 7 different media were used. M_1 was prepared by mixing red soil, sand, FYM in the ratio 3:1:1, M_2 by mixing red soil, cocopeat and FYM in the ratio 3:1:1, M_3 was prepared by thorough mixing of red soil, sand and vermicompost in the ratio 3:1:1, M_4 by mixing red soil, sand and pressmud in the ratio 3:1:1, M_5 was prepared by mixing red soil, sand, FYM in the ratio 3:1:1, to this *P. flouresence* was added at 5 g/kg of FYM, M_6 was prepared by adding VAM - *Gigaspora gigantea* (10 g/kg FYM) and *Pseudomonas fluorescence* (5 g/kg of FYM) to the mixture of red soil, sand and FYM (3:1:1) and M_7 was prepared by adding *P. fluorescens* (5 g/kg FYM), PSB - *Bacillus megaterium* (10 g/kg FYM) and nitrifying

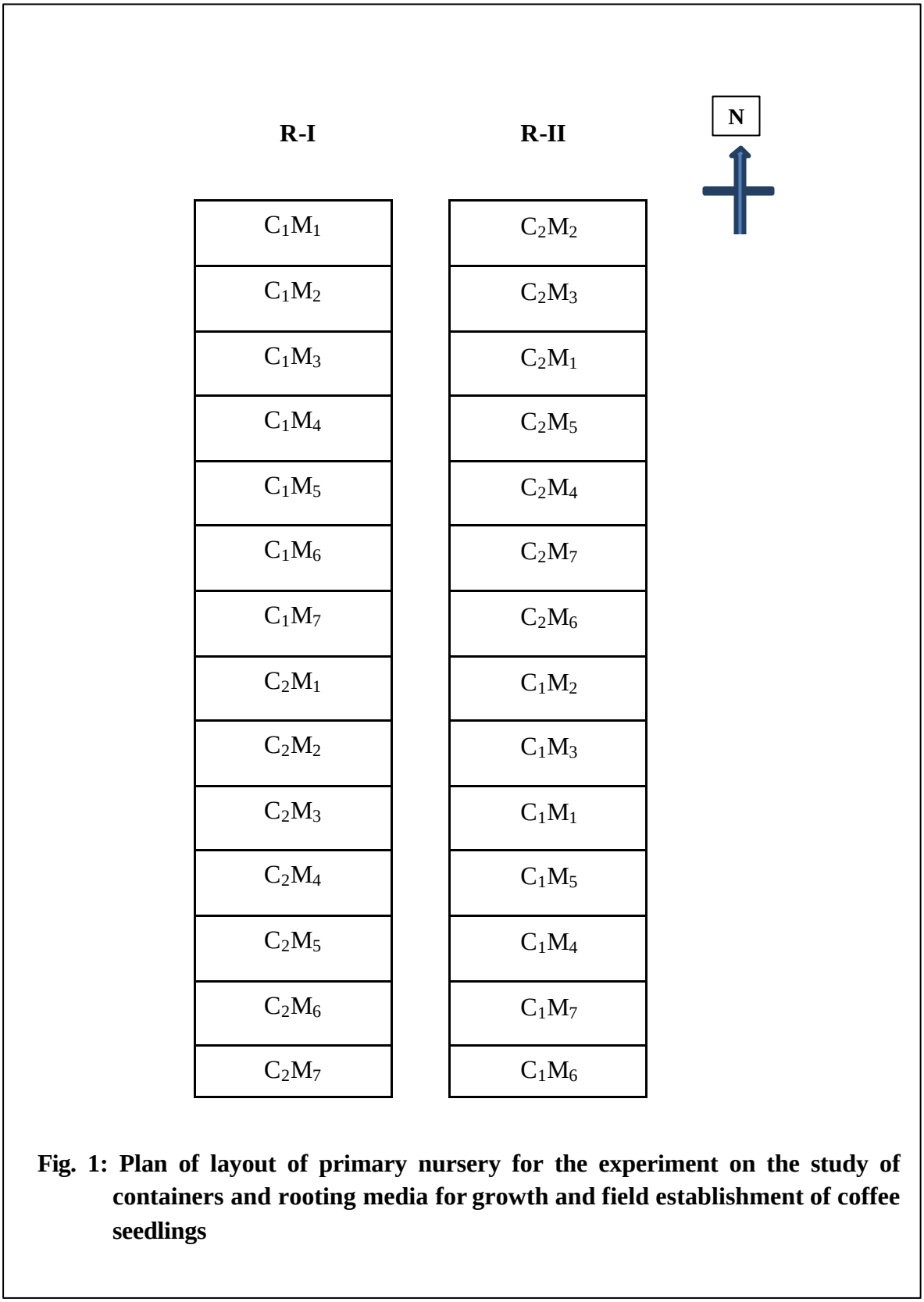

Fig. 1: Plan of layout of primary nursery for the experiment on the study of containers and rooting media for growth and field establishment of coffee seedlings

R-I	R-II
C_1M_1	C_2M_2
C_1M_2	C_2M_3
C_1M_3	C_2M_1
C_1M_4	C_2M_5
C_1M_5	C_2M_4
C_1M_6	C_2M_7
C_1M_7	C_2M_6
C_2M_1	C_1M_2
C_2M_2	C_1M_3
C_2M_3	C_1M_1
C_2M_4	C_1M_5
C_2M_5	C_1M_4
C_2M_6	C_1M_7
C_2M_7	C_1M_6
C_3M_1	C_4M_2
C_3M_2	C_4M_3
C_3M_3	C_4M_1
C_3M_4	C_4M_5
C_3M_5	C_4M_4
C_3M_6	C_4M_7
C_3M_7	C_4M_6
C_4M_1	C_5M_2
C_4M_2	C_5M_3
C_4M_3	C_5M_1
C_4M_4	C_5M_5
C_4M_5	C_5M_4
C_4M_6	C_5M_7
C_4M_7	C_5M_6
C_5M_1	C_3M_2
C_5M_2	C_3M_3
C_5M_3	C_3M_1
C_5M_4	C_3M_5
C_5M_5	C_3M_4
C_5M_6	C_3M_7
C_5M_7	C_3M_6

Fig. 2: Plan of layout of secondary nursery and main field for the experiment on the study of containers and rooting media for growth and field establishment of coffee seedlings

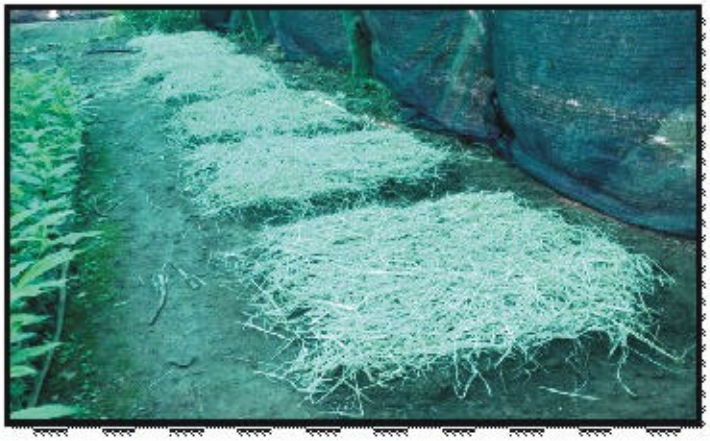

Plate 1: Preparation of primary nursery

bacteria - *Azospirillum* (10 g/kgFYM) to the media mixture red soil, sand, FYM (3:1:1). Later these prepared media were filled into 3 different containers *i.e.*, Black polythene bag (C_1 and C_3), transparent polythene bag (C_2) and root trainer (C_3) and also used to prepare secondary nursery bed (C_5).

3.3.6 Preparation of secondary nursery bed

Seven raised beds of size 1×1 m^2 of 15 cm height were prepared using seven different media combinations which were prepared earlier as per the treatment. 1m wide and 1m length was measured and dug it well to a depth of 0.3-0.45 m. Stones and roots lying underneath are dug out and thrown outside the nursery. The soil was then mixed with different media component as per the treatment and beds were prepared (C_5).

3.3.7 Transplanting of coffee seedlings into secondary nursery bed

Coffee seedlings of 45 days (topee stage) old raised in bed were transplanted to secondary nursery bed (C_5). In raised bed spacing of 30×30 cm^2 was maintained.

3.3.8 Transplanting of seedlings into different containers in secondary nursery

Coffee seedlings of 45 days (topee stage) old raised in bed were transplanted to secondary nursery into different containers such as black polythene bag (C_1), transparent polythene bag (C_2), root trainer (C_4) as per the treatment. Seedlings raised in portrays were transplanted to black polythene bag (C_3).

3.3.9 After care

3.3.9.1 Mulching

Immediately after sowing, the beds were mulched with a layer of paddy straw

3.3.9.2 Watering

Immediately after sowing light irrigation was given using rose can and later on watering was done everyday depending on the moisture content.

Plate 2: Preparation of secondary nursery

Plate 3: Over all view of secondary nursery at 180 days after sowing

3.3.9.3 Weeding

Weeding was done at monthly interval manually and nursery was kept clean and free from weeds, fallen leaves etc.

3.3.9.4 Plant protection

In nursery, drenching as well as spraying of bavestin 0.2% was taken up at monthly interval to protect from damping off (*Pythium* sp) and cercospora leaf spot diseases.

3.4 Observations recorded

Observations on germination, shoot parameters (Plant height, number of leaves, leaf area, collar girth) and root parameters (length of taproot, number of primary and secondary roots, fresh and dry weight of roots) were recorded from five randomly selected coffee seedlings in each treatment. Different observations recorded are as follows.

3.4.1 Shoot parameters

3.4.1.1 Days taken for 50 and 100 per cent germination

Days taken for 50 per cent germination was recorded at 30 days after sowing. Similarly 100 per cent germination was registered at 45 days after sowing, The number of seeds germinated was counted and expressed in percentage. The following formula was used to compute the germination percentage,

$$\text{Germination percentage} = \frac{\text{Number of seedlings germinated}}{\text{Number of seeds sown}} \times 100$$

3.4.1.2 Plant height (cm)

Plant height of 5 different coffee seedlings in each treatment were measured from the soil surface to the apical tip by using centimeter scale at 60, 90, 120 and 180 days after sowing and average of these 5 seedlings were taken for statistical analysis and expressed in centimeter (cm).

3.4.1.3 Number of leaves

Fully opened leaves of 5 coffee seedlings per treatment at 60, 90, 120 and 180 days after sowing was counted and their mean was used to record this parameter and expressed in numbers per plant.

3.4.1.4 Collar girth (mm)

Girth of the seedlings was measured at the collar region using digital vernier caliper scale at 90 and 180 days after sowing of 5 different seedlings per treatment. Later the mean of 5 seedlings collar girth was used to analyze the data. Collar girth was expressed in millimeter (mm).

3.4.1.5 Leaf area (cm^2)

Graphical method was adapted to measure the leaf area of fully developed matured leaf of coffee seedlings at 60, 90, 120 and 180 days after sowing. Leaf area was expressed in cm^2.

3.4.2 Root parameters

3.4.2.1 Length of tap root (cm)

This parameter was recorded at 45, 90 and 180 days after sowing by removing the seedlings from the media without damaging the roots and dipping in fresh water to remove the adhering soil and length was measured using scale and expressed in centimeter (cm).

3.4.2.2 Number of primary roots

Seedlings were uprooted and after removing the adhering soil by washing with fresh water, number of primary roots of 5 seedlings per treatment was counted at 45, 90 and 180 days after sowing and expressed in numbers per seedling.

3.4.2.3 Number of secondary roots

Number of secondary roots were counted similar to the counting of primary roots at 45, 90 and 180 days after sowing and expressed in number of secondary roots per seedlings.

3.4.2.4 Fresh weight of roots (g)

The roots were separated from the sampled seedlings. After measuring length of taproot and counting of primary and secondary roots, the fresh weight of roots was recorded using an electronic balance and the mean was calculated and expressed in gram (g) per seedling.

3.4.2.5 Dry weight of root (g)

After recording the fresh weight, the same roots were dried in hot air oven at 70° C for 48 hr till constant weight was noted (Ibrahim *et al.*, 2015). The mean dry weight was expressed in gram (g) per seedling.

3.4.2.6 Economics (Benefit cost ratio)

The economics of cost of production of transplantable coffee seedlings using different containers/raised bed starting from the preparation of bed, seeds procurement, sowing, containers, media cost and maintenance cost calculated using present price of each item and wages. The cost of inputs is given in appendix II. Benefit cost ratio of each treatment combination was calculated by using the formula

$$\text{B:C ratio} = \frac{\text{Gross income}}{\text{Total cost of production}}$$

3.5 Field establishment

3.5.1 Transplanting to the main field

Seedlings of 180 days old were transplanted to the main field containing *Grevillea robusta* as shade tree (planted at a spacing of 9×9 feet) by adapting Square system of planting at the spacing of 2×2 m to study the survivability and growth of coffee seedlings raised in different containers and media. Pits of 45×45 cm were dug 15-20 days before planting. In case of polybag seedlings, the polythene bag was cut at the bottom and seedlings were planted. In the case of ball plants, the tap root and lateral roots were spread out in proper position before packing with soil. In case of root trainer, cup was placed upside down and slight hit was given by hand at the bottom, whole ball of earth comes to the hand and was planted.

3.5.2 After care

3.5.2.1 Hutting

In main field, immediately after transplanting the seedlings were provided with artificial shade with branchlets of *Caryota mitis*.

3.5.2.2 Mulching

Soil around the seedlings were mulched using waste litter and grass.

3.5.2.3 Irrigation

Immediately after transplanting irrigation was done. Later on seedlings were irrigated at 15 days interval.

3.5.2.4 Digging

To control weeds, especially grasses, cover digging was done 1 month after transplanting.

3.5.2.5 Mannuring

Seedlings were sprayed with NPK mixture (Urea 250 g + Superphosphate 250 g + MOP 187.5 g in 100 lt of water) at 45 days interval after 1 month of transplanting.

3.5.3 Observations recorded

Survival percentage, days taken for first flush, number of leaves, plant height (cm) were recorded at monthly interval for 3 months and number of primary shoot was recorded at 3 months after transplanting.

3.5.3.1 Shoot parameters

3.5.3.1.1 Survivability (%)

Survivability at 1 month after transplanting of coffee seedlings was recorded by using the following formula,

$$\text{Survivability (\%)} = \frac{\text{Number of seedlings survived}}{\text{Number of seedlings planted}} \times 100$$

3.5.3.1.2 Number of days taken for new flush emergence

The time taken by the seedlings to put forth a new growth (flush) was observed in each treatment and used to analyze the data.

3.5.3.1.3 Plant height (cm)

Plant height of 5 different coffee seedlings in each treatment were measured from the soil surface to the apical tip at 30, 60 and 90 days after transplanting and average of these 5 seedlings were taken for statistical analysis.

3.5.3.1.4 Number of leaves

Fully opened leaves of 5 coffee seedlings per treatment at 30, 60 and 90 days after transplanting was counted and their mean was used to record this parameter.

3.5.3.1.5 Number of primary shoots

The number of primary shoots was recorded at 3 months after transplanting to main field as until that no primary shoots were noticed. Primary branches of 5 plants per treatment was recorded and their mean was used to analyze the data.

3.6 Statistical analysis

The design adapted was factorial RBD (2×7 and 5×7) replicated twice. The data was subjected to statistical analysis as per the procedure outlined by Panse and Sukhatme (1985).

4. EXPERIMENTAL RESULTS

The results of the present investigation on the "Study of containers and rooting media for growth and field establishment of coffee seedlings" are presented in this chapter under the following headings.

4.1 Effect of containers, rooting media and their interaction on germination and root parameters of coffee seedlings in primary nursery

4.1.1 Germination percentage

The data pertaining to the germination percentage at 30 and 45 days after sowing as influenced by different containers and rooting media are depicted in Table 1. Germination percentage of coffee seeds varied significantly among the containers, media and with their interactions.

4.1.1.1 Germination percentage at 30 days after sowing

The mean germination percentage among the containers irrespective of media used ranged from 39.57% to 53.62%. Maximum germination percentage (53.62) was recorded in the seeds sown in raised bed and least (39.57%) in the seeds sown in protrays. Both the treatments were significantly different with each other.

The effect of media on germination percentage was found to be significant irrespective of container used. Maximum germination percentage (60.15%) was recorded in red soil + sand + vermicompost (M_3) and least (36.55%) in M_1. All the treatments were significantly different with each other.

The interaction between the container and media were found to be significantly different. The maximum germination percentage (61) was found in the seeds sown in raised bed prepared by using red soil + sand + vermicompost (C_1M_3) which was on par with C_1M_7 (59.8%) and the least (31.60%) was observed in C_2M_1. All other treatments were significantly different from the treatment C_1M_3 with respect to germination percentage.

Table 1. Effect of containers, rooting media and their interaction on germination percentage in primary nursery at 30 and 45 days after sowing

30 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	41.50	45.80	61.00	51.50	56.40	59.40	59.80	**53.62**
C_2	31.60	37.20	59.30	39.80	32.90	37.50	38.70	**39.57**
Mean	**36.55**	**41.5**	**60.15**	**45.65**	**44.65**	**48.45**	**49.25**	
CV (%) = 1.23	**S.Em±**				**CD at 5%**			
Container (C)	0.15				0.47			
Media (M)	0.28				0.88			
Interaction (C × M)	0.40				1.24			
45 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	65.60	70.90	87.80	75.40	81.40	82.80	83.40	**78.18**
C_2	62.50	65.80	78.10	70.00	63.10	64.50	65.60	**67.08**
Mean	**64.05**	**68.35**	**82.95**	**72.70**	**72.25**	**73.65**	**74.50**	
CV (%) = 1.13	**S.Em±**				**CD at 5%**			
Container (C)	0.21				0.67			
Media (M)	0.41				1.25			
Interaction (C × M)	0.58				1.77			

C: Container **C_1 :** Raising in bed
C_2 : Protray (2" ×2")

M: Media **M_1 :** Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2 : Red soil + cocopeat + FYM in 3:1:1 ratio
M_3 : Red soil + sand + vermicompost (3:1:1)
M_4 : Red soil + sand + pressmud (3:1:1)
M_5 : M_1 + *Pseudomonas fluorescens* (5 g/kg FYM)
M_6 : M_5 + VAM (10 g/kg FYM)
M_7 : M_5 + PSB + *Azospirillum* (10 g/kg FYM)

DAS : Days after sowing

4.1.1.2 Germination percentage at 45 days after sowing

The significant difference was manifested regarding different containers irrespective of media used with respect to germination percentage and ranged from 67.08 to 78.18% at 45 days after sowing. Significantly maximum germination percentage (78.18%) was recorded in the seeds sown in raised bed (C_1) and least percentage (67.08%) was found in the seeds sown in protrays (C_2). Both the treatments were significantly different with each other.

The effect of media on germination percentage was found to be significant irrespective of container used. The maximum germination percentage (82.95) was recorded in M_3 - Red soil + sand + vermicompost followed by M_7 (74.50%) and the least in M_1 (64.05%). All the treatments were significantly different with each other.

The interaction between the containers and media were found to be significantly different. The maximum germination percentage (87.80%) was found in seeds sown in raised bed prepared by using red soil + sand + vermicompost as media (C_1M_3) followed by C_1M_7 (83.40%) and C_1M_6 (82.80%) and least (62.50%) was recorded in C_2M_1. All other treatments were significantly different with respect to germination percentage of coffee seeds from the treatment C_1M_3.

4.1.2 Root parameters

4.1.2.1 Length of tap root (cm) at 45 days after sowing

The data with respect to length of tap root grown in different containers at 45 days after sowing is presented in Table 2. The significant differences were manifested regarding different containers, rooting media and with their interactions.

Among raised bed and protrays, the maximum taproot length (4.87 cm) was registered in the seedlings raised in raised bed and least taproot length (4.27 cm) was registered in protray grown seedlings.

The maximum tap root length (5.39 cm) was recorded in seedlings grown in the media red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (M_7) which was on par with M_5 (5.08 cm) and the least taproot length was recorded in M_1 (3.62 cm).

Table 2. Effect of containers, rooting media and their interaction on length of tap root (cm) of coffee seedlings at 45 days after sowing in primary nursery

45 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	3.83	4.89	5.14	4.71	5.29	4.51	5.69	**4.87**
C_2	3.42	3.93	4.38	3.81	4.88	4.41	5.10	**4.27**
Mean	**3.62**	**4.41**	**4.76**	**4.26**	**5.08**	**4.46**	**5.39**	
CV (%) = 6.20	**S.Em±**				**CD at 5%**			
Container (C)	0.07				0.22			
Media (M)	0.13				0.41			
Interaction (C × M)	0.19				0.58			

C: Container
C_1 : Raising in bed
C_2 : Protray (2" ×2")

M: Media
M_1 : Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2 : Red soil + cocopeat + FYM in 3:1:1 ratio
M_3 : Red soil + sand + vermicompost (3:1:1)
M_4 : Red soil + sand + pressmud (3:1:1)
M_5 : M_1 + *Pseudomonas fluorescens* (5 g/kg FYM)
M_6 : M_5 + VAM (10 g/kg FYM)
M_7 : M_5 + PSB + *Azospirillum* (10 g/kg FYM)

DAS : Days after sowing

The interaction effect of containers and media was found significant with respect to tap root length and ranged from 3.42 to 5.69 cm. The maximum taproot length (5.69 cm) was recorded in the seedlings raised in nursery bed prepared using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) which was on par with C_1M_5 (5.29 cm) and C_1M_3 (5.14 cm) whereas the least tap root length (3.42 cm) was recorded in C_2M_1.

4.1.2.2 Number of primary roots at 45 days after sowing

The data obtained on number of primary roots revealed that there were significant differences among the seedlings raised in different containers, media and interactions at 45 days after sowing (Table 3).

The maximum number of primary roots per seedling (25.38) was recorded in raised bed and least number of primary roots per seedling in protray grown seedlings (22.71).

The maximum number of primary roots per seedling (30.25) was recorded in the red soil + sand+ FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (M_7) followed by M_5 (23.70) and the least primary roots (20.8) count was registered in M_1.

The interaction between containers and media was found to be significant and ranged from 19.90 to 34.50. The maximum number of primary roots (34.50) was recorded in the seedlings raised in raised bed prepared using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) followed by C_1M_3 (27.10) and the least number of primary roots per seedling (19.90) was recorded in C_2M_4 .

4.1.2.3 Number of secondary roots at 45 days after sowing

The data pertaining to the number of secondary roots at 45 days after sowing as influenced by different container and rooting media are depicted in Table 4. The number of secondary roots of coffee seedlings varied significantly among the containers, media and with their interactions.

Table 3. Effect of containers, rooting media and their interaction on number of primary roots of coffee seedlings at 45 days after sowing in primary nursery

	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	21.10	23.40	27.10	23.30	26.20	22.10	34.50	**25.38**
C_2	20.50	23.00	25.10	19.90	21.20	23.30	26.00	**22.71**
Mean	**20.80**	**23.20**	**26.10**	**21.60**	**23.70**	**22.70**	**30.25**	
CV (%) = 6.43	**S.Em±**				**CD at 5%**			
Container (C)	0.41				1.26			
Media (M)	0.77				2.36			
Interaction (C × M)	1.09				3.34			

C: Container
C_1 : Raising in bed
C_2 : Protray (2" ×2")

M: Media
M_1 : Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2 : Red soil + cocopeat + FYM in 3:1:1 ratio
M_3 : Red soil + sand + vermicompost (3:1:1)
M_4 : Red soil + sand + pressmud (3:1:1)
M_5 : M_1 + *Pseudomonas fluorescens* (5 g/kg FYM)
M_6 : M_5 + VAM (10 g/kg FYM)
M_7 : M_5 + PSB + *Azospirillum* (10 g/kg FYM)

Table 4. Effect of containers, rooting media and their interaction on number of secondary roots of coffee seedlings at 45 days after sowing in primary nursery

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	Mean
C_1	1.80	2.80	2.10	3.80	3.40	4.00	5.70	**3.37**
C_2	1.20	1.40	2.90	2.00	2.10	2.00	3.20	**2.11**
Mean	**1.50**	**2.10**	**2.50**	**2.90**	**2.75**	**3.00**	**4.45**	
CV (%) = 19.39	**S.Em±**				**CD at 5%**			
Container (C)	0.14				0.43			
Media (M)	0.26				0.81			
Interaction (C × M)	0.37				1.14			

C: Container — **C_1 :** Raising in bed; **C_2 :** Protray (2" ×2")

M: Media — **M_1 :** Red soil + sand + FYM in 3:1:1 ratio (Control); **M_2 :** Red soil + cocopeat + FYM in 3:1:1 ratio; **M_3 :** Red soil + sand + vermicompost (3:1:1); **M_4 :** Red soil + sand + pressmud (3:1:1); **M_5 :** M_1 + *Pseudomonas fluorescens* (5 g/kg FYM); **M_6 :** M_5 + VAM (10 g/kg FYM); **M_7 :** M_5 + PSB + *Azospirillum* (10 g/kg FYM)

DAS : Days after sowing

The maximum number of secondary roots per seedling (3.37) was recorded in raised bed grown seedlings and the least in protray grown seedlings (2.11).

The maximum number of secondary roots (4.45) were recorded in the seedlings grown using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) followed by M_6 (3.00) and the least number of secondary roots (1.50) was observed in M_1.

The interaction effect between containers and media on secondary roots production was found to be significant and ranged from 1.20 to 5.70. The maximum number of secondary roots (5.70) were recorded in C_1M_7 followed by C_1M_6 (4.00) and the least (1.20) was recorded in C_2M_1.

4.1.2.4 Fresh weight of roots at 45 days after sowing

The data pertaining to the fresh weight of roots at 45 days after sowing as influenced by different containers and rooting media are depicted in Table 5. Fresh weight of coffee seedlings roots per plant varied significantly among the containers and media but not with their interactions.

The mean fresh weight of roots of coffee seedlings grown in raised bed and protrays varied significantly irrespective of media used. The maximum fresh weight of roots (0.116 g) was recorded in the seedlings grown in raised bed and least (0.105 g) in protray grown seedlings.

Fresh weight of roots as influenced by different media was found significant and ranged from 0.095 g to 0.125 g per seedling. The maximum fresh weight of roots (0.125 g) was recorded in seedlings raised using the media red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (M_7) and the least (0.095 g) was recorded in M_1 which was on par with M_4 (0.099 g), M_3 (0.109 g), M_2 (0.111 g).

The interaction effect between containers and media was found non-significant. However the maximum fresh weight of roots per seedling (0.130 g) was recorded in seedlings grown in raised bed using the media red soil + sand+ FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) followed by C_1M_6 (0.122 g). The least fresh weight of roots (0.089 g) was registered in C_2M_1.

Table 5. Effect of containers, rooting media and their interaction on fresh weight (g) of roots of coffee seedlings at 45 days after sowing in primary nursery

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	Mean
C_1	0.092	0.124	0.120	0.106	0.118	0.122	0.130	**0.116**
C_2	0.089	0.098	0.098	0.092	0.110	0.104	0.113	**0.105**
Mean	**0.095**	**0.111**	**0.109**	**0.099**	**0.114**	**0.113**	**0.125**	
CV (%) = 13.00	**S.Em±**				**CD at 5%**			
Container (C)	0.003				0.010			
Media (M)	0.004				0.020			
Interaction (C × M)	0.009				NS			

C: Container
C_1 : Raising in bed
C_2 : Protray (2" ×2")

M: Media
M_1 : Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2 : Red soil + cocopeat + FYM in 3:1:1 ratio
M_3 : Red soil + sand + vermicompost (3:1:1)
M_4 : Red soil + sand + pressmud (3:1:1)
M_5 : M_1 + *Pseudomonas fluorescens* (5 g/kg FYM)
M_6 : M_5 + VAM (10 g/kg FYM)
M_7 : M_5 + PSB + *Azospirillum* (10 g/kg FYM)

4.1.2.5 Dry weight of roots at 45 days after sowing

The data pertaining to the dry weight of roots per seedling at 45 days after sowing as influenced by different container and rooting media is depicted in Table 6. The dry weight of roots varied significantly among the containers and media but not with their interactions.

The dry weight of roots grown in raised bed and protray varied significantly irrespective of media used. The maximum dry weight of roots (0.036 g) was recorded in the seedlings grown in raised bed and least (0.025 g) in protray grown seedlings.

The dry weight of roots as influenced by media ranged from 0.025 g to 0.035 g. The maximum dry weight of roots (0.035 g) was recorded in seedlings raised using the media red soil + sand+ FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7), M_2 and M_3 which was on par with M_6 (0.034 g), M_5 (0.033 g) and the least dry weight of roots (0.025 g) was recorded in M_1.

The interaction effect between containers and media was found non-significant. However, the maximum dry weight of roots (0.040 g) of coffee seedlings were recorded in C_1M_7 and C_1M_6. The least weight (0.027 g) was recorded in C_2M_1.

4.2 Effect of containers, rooting media and their interaction on growth of coffee seedlings in secondary nursery

4.2.1 Plant height (cm)

The data with respect to plant height of different treatments from 60 days after sowing to 180 days after sowing are presented in Table 7 and 8. The significant differences were manifested regarding different containers, rooting media and with their interactions.

4.2.1.1 Plant height at 60 DAS

The plant height of coffee seedlings in different containers irrespective of media used ranged from 3.68 to 4.29 cm. The maximum plant height (4.29 cm) was recorded in the seedlings grown in black polythene bag (C_1) which was on par with C_4 (4.23 cm) and the least in C_2 (3.68 cm) which was on par with C_5 (3.75 cm) and C_3 (3.82 cm).

Table 6. Effect of containers, rooting media and their interaction on dry weight (g) of roots of coffee seedlings at 45 days after sowing in primary nursery

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	Mean
C_1	0.032	0.037	0.035	0.034	0.034	0.040	0.040	**0.036**
C_2	0.027	0.028	0.028	0.029	0.032	0.028	0.035	**0.025**
Mean	**0.025**	**0.035**	**0.035**	**0.035**	**0.033**	**0.034**	**0.035**	
CV (%) = 12.71	**S.Em±**				**CD at 5%**			
Container (C)	0.001				0.004			
Media (M)	0.001				0.004			
Interaction (C × M)	0.009				NS			

C: Container — **C_1 :** Raising in bed; **C_2 :** Protray (2" ×2")

M: Media — **M_1 :** Red soil + sand + FYM in 3:1:1 ratio (Control); **M_2 :** Red soil + cocopeat + FYM in 3:1:1 ratio; **M_3 :** Red soil + sand + vermicompost (3:1:1); **M_4 :** Red soil + sand + pressmud (3:1:1); **M_5 :** M_1 + *Pseudomonas fluorescens* (5 g/kg FYM); **M_6 :** M_5 + VAM (10 g/kg FYM); **M_7 :** M_5 + PSB + *Azospirillum* (10 g/kg FYM)

DAS : Days after sowing

The mean plant height of coffee seedlings grown in different rooting media irrespective of containers used varied between 3.46 to 4.39 cm. Seedlings grown in media containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) recorded the maximum plant height (4.39 cm) which was on par with red soil + sand + FYM + *P. fluorescens* + VAM - M_6 (4.07 cm) and red soil + sand + vermicompost - M_3 (4.06 cm). While, the minimum plant height (3.46 cm) was recorded with control - red soil: sand: FYM.

The plant height of coffee seedlings was found significant between the interaction of containers and media. The maximum plant height (5.32 cm) was recorded with C_1M_7 - seedlings raised in black polythene bag containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media which was on par with the C_4M_7 (4.89 cm) and C_4M_3 (4.61 cm) and the minimum plant height (2.51 cm) was registered with C_5M_1.

4.2.1.2 Plant height at 90 DAS

The plant height of coffee seedlings grown in different containers irrespective of media used was found significantly at 90 days after sowing. The maximum plant height (6.26 cm) was registered in C_1 - black polythene bag followed by C_4 (5.92 cm) - root trainer and the minimum plant height (5.44 cm) was found in C_5. All the other treatments showed significant difference with respect to plant height.

Significant difference was found with respect to plant height of coffee seedlings grown in different media. Maximum plant height (6.44 cm) was recorded in the treatment M_7 - seedlings raised in media containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* which was on par with M_6 (6.10 cm) while the least plant height (5.23 cm) was recorded with M_1.

In interaction effect, the maximum plant height (7.45 cm) was recorded in the treatment combination of C_1M_7 - black polythene bag containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media followed by C_4M_7 (6.5 cm) - root trainer containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media and the least plant height (4 cm) was recorded in C_5M_1.

Table 7. Effect of containers, rooting media and their interaction on plant height (cm) of coffee seedlings at 60 and 90 days after sowing

60 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	3.85	4.03	4.23	4.39	4.02	4.24	**5.32**	**4.29**
C_2	3.56	3.67	3.85	3.38	3.55	3.78	4.00	**3.68**
C_3	3.31	3.7	3.51	4.42	3.69	4.22	3.89	**3.82**
C_4	4.07	3.74	4.61	4.17	4.03	4.12	4.89	**4.23**
C_5	2.51	3.46	4.12	3.78	4.51	4.02	3.89	**3.75**
Mean	**3.46**	**3.72**	**4.06**	**4.02**	**3.96**	**4.07**	**4.39**	
CV (%) = 10.43	**S.Em±**				**CD at 5%**			
Container (C)	0.11				0.31			
Media (M)	0.13				0.37			
Interaction (C × M)	0.29				0.83			
90 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	5.66	5.98	6.10	6.00	6.25	6.39	7.45	**6.26**
C_2	5.41	5.58	5.79	5.39	5.45	5.79	6.30	**5.67**
C_3	5.23	5.53	5.24	6.21	5.10	6.24	5.95	**5.64**
C_4	5.85	5.70	6.20	5.07	5.99	6.13	6.50	**5.92**
C_5	4.00	5.11	5.45	5.55	5.98	5.99	6.00	**5.44**
Mean	**5.23**	**5.58**	**5.75**	**5.64**	**5.756**	**6.10**	**6.44**	
CV (%) = 6.93	**SEm±**				**CD at 5%**			
Container (C)	0.10				0.30			
Media (M)	0.12				0.36			
Interaction (C × M)	0.28				0.8			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

4.2.1.3 Plant height at 120 DAS

The containers significantly influenced on plant height irrespective of media used and varied between 6.70 to 8.02 cm. The maximum plant height (8.02 cm) was recorded with black polythene bag (C_1) which was on par with root trainer - C_4 (7.79 cm) and the minimum (6.70 cm) was recorded with C_5.

Significant difference was observed with respect to plant height of coffee grown in different media. The maximum plant height (8.15 cm) was recorded in red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* media (M_7) which was on par with M_6 (8.00 cm), while the minimum plant height (6.48 cm) was recorded with M_1.

The interaction effect between container and media significantly influenced on the plant height of coffee seedlings. The maximum plant height (8.87 cm) was registered with black polythene bag containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media (C_1M_7) which was on par with C_4M_7 (8.80 cm) - root trainer containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media and C_4M_6 (8.80 cm) while minimum plant height (5.20 cm) was registered in C_5M_1.

4.2.1.4 Plant height at 180 DAS

The plant height of coffee seedlings raised in different containers differed significantly and ranged from 11.69 to 14.91 cm. The maximum plant height (14.91 cm) was recorded in black polythene bag (C_1) which was on par with root trainer - C_4 (14.35 cm) whereas, the lowest plant height (11.69 cm) was recorded in C_5.

Significant difference was observed with respect to plant height of coffee seedlings grown in different media. The maximum plant height (14.78 cm) was recorded in the media containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) which was significantly different from all other treatments and the lowest (11.69 cm) was recorded in control - M_1.

Table 8. Effect of containers, rooting media and their interaction on plant height (cm) of coffee seedlings at 120 and 180 days after sowing

120 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	6.75	7.65	8.00	7.93	8.68	8.25	8.87	**8.02**
C_2	6.83	7.58	7.53	7.42	7.52	7.83	7.90	**7.51**
C_3	6.95	7.60	7.35	7.98	7.83	7.98	7.88	**7.65**
C_4	6.70	7.55	7.73	6.98	8.00	8.80	8.80	**7.79**
C_5	5.20	6.54	6.39	7.44	6.95	7.13	7.30	**6.70**
Mean	**6.48**	**7.38**	**7.40**	**7.55**	**7.79**	**8.00**	**8.15**	
CV (%) = 4.87	**S.Em±**				**CD at 5%**			
Container (C)	0.09				0.28			
Media (M)	0.11				0.33			
Interaction (C × M)	0.25				0.74			
180 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	11.15	14.29	16.50	15.50	15.50	14.55	16.91	**14.91**
C_2	13.37	13.47	15.02	13.13	13.79	13.87	16.65	**14.18**
C_3	11.28	11.87	11.79	11.82	11.65	11.87	11.94	**11.74**
C_4	11.30	13.53	13.97	14.91	15.18	15.55	16.06	**14.35**
C_5	11.38	11.49	11.16	11.31	11.85	12.31	12.37	**11.69**
Mean	**11.69**	**12.93**	**13.68**	**13.33**	**13.59**	**13.63**	**14.78**	
CV (%) = 6.09	**S.Em±**				**CD at 5%**			
Container (C)	0.21				0.62			
Media (M)	0.25				0.74			
Interaction (C × M)	0.57				1.65			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

The interaction effect between container and media was significantly influenced on plant height of coffee seedlings. The maximum plant height (16.91 cm) was recorded in the seedlings raised in black polythene bag filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) which was on par with the C_2M_7 (16.65 cm), C_1M_3 (16.5 cm) and C_4M_7 (16.06 cm) where as the lowest plant height (11.15 cm) was registered in C_1M_1.

4.2.2 Number of leaves

The data regarding number of leaves produced per seedling in different treatments from 60 days after sowing to 180 days after sowing are presented in Table 9 and 10. At 60 days after sowing, significant difference was observed with respect to media and no significant difference was observed with respect to containers and interactions. At 90 and 120 days after sowing, the significant differences were manifested regarding different containers and rooting media but not with their interactions. At 180 days after sowing significant difference was manifested among different containers, media and with their interactions.

4.2.2.1 Number of leaves at 60 days after sowing

The number of leaves produced per seedling as influenced by containers was not significant. However the maximum number of leaves was recorded with C_1 (2.41) and C_4 (2.40) while, the minimum number of leaves was registered with C_3 (2.20).

The maximum number of leaves (2.7) were recorded in the seedlings grown with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media (M_7) while, the minimum number of leaves were found in M_1 (2.06).

The interaction effect of container and media was found non- significant. However, the maximum number of leaves (3.00) were found with C_5M_7 and C_5M_4 while, the least number of leaves (2.00) was registered with the treatment combination C_1M_1, C_3M_1, C_5M_1.

4.2.2.2 Number of leaves at 90 days after sowing

The number of leaves produced varied significantly among the seedlings grown in different containers. The maximum number of leaves (4.82) was found in

Table 9. Effect of containers, rooting media and their interaction on number of leaves in coffee seedlings at 60 and 90 days after sowing

60 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	2.00	2.20	2.20	2.40	2.60	2.80	2.70	**2.41**
C_2	2.10	2.20	2.40	2.40	2.40	2.20	2.50	**2.31**
C_3	2.00	2.00	2.30	2.10	2.40	2.00	2.60	**2.20**
C_4	2.20	2.20	2.40	2.20	2.50	2.60	2.70	**2.40**
C_5	2.00	2.20	2.00	3.00	2.20	2.00	3.00	**2.34**
Mean	**2.06**	**2.16**	**2.26**	**2.42**	**2.42**	**2.32**	**2.70**	
CV (%) = 12.79	**S.Em±**				**CD at 5%**			
Container (C)	0.07				NS			
Media (M)	0.09				0.27			
Interaction (C × M)	0.21				NS			
90 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	4.80	4.60	4.80	4.80	4.80	4.80	5.20	**4.82**
C_2	4.20	4.40	4.40	4.40	4.60	4.80	5.00	**4.54**
C_3	4.00	4.40	4.20	4.80	4.40	4.80	4.80	**4.48**
C_4	4.80	4.40	4.80	4.60	4.60	5.00	5.20	**4.77**
C_5	4.00	4.40	4.20	4.60	4.40	4.60	5.00	**4.45**
Mean	**4.36**	**4.44**	**4.48**	**4.64**	**4.56**	**4.80**	**5.04**	
CV (%) = 7.24	**S.Em±**				**CD at 5%**			
Container (C)	0.08				0.25			
Media (M)	0.10				0.30			
Interaction (C × M)	0.23				NS			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6"× 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing
NS: Non-significant

the seedlings grown in black polythene bag (C_1) which was on par with the root trainer - C_4 (4.77) while the minimum number of leaves (4.45) was registered with C_5.

The maximum number of leaves (5.04) were recorded in the seedlings grown in red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media (M_7) which was on par with the M_6 (4.8) whereas, the lowest count (4.36) was obtained with M_1 which was on par with M_2 (4.44), M_3 (4.48), M_5 (4.56) and M_4 (4.64).

Interaction effect between container and media was not significant, although maximum number of leaves (5.2) were recorded with C_1M_7 - black polythene bag filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* and C_4M_7 - root trainer filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* and the minimum count (4) was obtained in C_3M_1 and C_5M_1.

4.2.2.3 Number of leaves at 120 days after sowing

Significant difference was recorded with respect to number of leaves produced in the seedlings grown in different containers. The maximum number of leaves (6.11) was recorded in the seedlings grown in black polythene bag (C_1) and root trainer grown seedlings - C_4 (6.11) which was on par with C_2 (6.08). The least number of leaves (5.88) was registered in C_3.

The maximum number of leaves (6.32) were recorded in the seedlings grown in red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (M_7) whereas the minimum count (5.8) was obtained in M_1.

Interaction effect between container and media was not significant at 120 days after sowing. However, the maximum number of leaves (6.40) were recorded in treatment combinations C_1M_7 - black polythene bag + red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum*, C_4M_7 - root trainer + red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* and C_5M_7 - raised bed + red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* and the lowest number of leaves (5.40) was registered in C_3M_1.

4.2.2.4 Number of leaves at 180 days after sowing

The influence of different containers was found to be significant on number of leaves. The maximum number of leaves (7.71) were recorded in black polythene bag

Table 10. Effect of containers, rooting media and their interaction on number of leaves in coffee seedlings at 120 and 180 days after sowing

120 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	6.00	6.00	6.00	6.00	6.20	6.20	6.40	**6.11**
C_2	6.00	5.80	6.20	6.20	6.00	6.20	6.20	**6.08**
C_3	5.40	6.00	6.00	6.00	6.00	5.60	6.20	**5.88**
C_4	6.00	6.00	6.20	6.20	6.00	6.00	6.40	**6.11**
C_5	5.60	6.00	6.00	6.00	6.00	6.00	6.40	**6.00**
Mean	**5.80**	**5.96**	**6.08**	**6.08**	**6.04**	**6.00**	**6.32**	
CV (%) = 3.73	**S.Em±**				**CD at 5%**			
Container (C)	0.06				0.17			
Media (M)	0.07				0.20			
Interaction (C × M)	0.15				NS			
180 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	7.40	7.20	7.20	7.00	8.40	7.60	9.20	**7.71**
C_2	7.00	7.00	7.80	7.30	7.20	7.60	7.20	**7.30**
C_3	6.00	6.40	6.20	6.00	6.20	6.40	7.20	**6.34**
C_4	7.60	6.80	8.20	7.60	7.80	7.20	8.80	**7.71**
C_5	6.20	6.20	6.20	6.80	6.60	6.40	6.80	**6.45**
Mean	**6.84**	**6.72**	**7.12**	**6.94**	**7.24**	**7.04**	**7.84**	
CV (%) = 6.22	**S.Em±**				**CD at 5%**			
Container (C)	0.11				0.33			
Media (M)	0.13				0.40			
Interaction (C × M)	0.31				0.89			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing
NS: Non-significant

(C_1) and root trainer (C_4) and the lowest number of leaves (6.34) were encountered in the treatment C_3.

The maximum number of leaves (7.84) was registered in media containing red soil+ sand+ FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (M_7) while, the least number of leaves was recorded with M_2 (6.72).

The maximum number of leaves (9.2) were recorded in the seedlings grown in black polythene bag containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* as media (C_1M_7) which was on par with the C_4M_7 (8.8) whereas the least number of leaves (6.00) were recorded in the treatment combination C_3M_1 and C_3M_4.

4.2.3 Leaf area (cm^2)

The data on leaf area as influenced by containers and media is presented in Table 11 and 12. No significant difference was found regarding leaf area of coffee seedlings among containers and media and with their interactions at 60 days after sowing but during later period significant difference was observed.

4.2.3.1 Leaf area at 60 days after sowing

There was no significant difference in leaf area of coffee seedlings grown in different containers but the maximum leaf area (11.89 cm^2) was recorded with root trainer (C_4) and minimum leaf area (10.32 cm^2) was registered in the C_5.

The effect of media on leaf area of coffee seedlings was found to be non-significant. However, the maximum leaf area (12.32 cm^2) was recorded in M_7 and the minimum leaf area (10.40 cm^2) was found in M_3.

Interaction effect between the container and media with respect to leaf area was found to be non significant. However, the maximum leaf area (13 cm^2) was found in C_4M_7 and the least leaf area (8.50 cm^2) in C_5M_1.

4.2.3.2 Leaf area at 90 days after sowing

The leaf area of coffee seedlings grown in different containers irrespective of media used ranged from 1.85 to 3.71 cm^2. The maximum leaf area (3.71 cm^2) was recorded in root trainer (C_4) followed by C_2 (2.70 cm^2) and the least leaf area (1.85 cm^2) was recorded in C_5.

Table 11. Effect of containers, rooting media and their interaction on leaf area (cm^2) of coffee seedlings at 60 and 90 days after sowing

60 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	11.27	10.94	10.32	10.88	10.38	11.70	11.74	**11.03**
C_2	11.74	12.10	9.74	11.99	13.02	11.32	12.12	**11.72**
C_3	10.38	12.46	7.83	12.56	10.58	10.20	12.36	**10.91**
C_4	12.01	11.58	12.51	10.09	13.18	10.91	13.00	**11.89**
C_5	8.50	9.54	11.63	10.76	10.13	9.26	12.42	**10.32**
Mean	**10.78**	**11.32**	**10.40**	**11.25**	**11.46**	**10.68**	**12.32**	
CV (%) = 16.35	**S.Em±**				**CD at 5%**			
Container (C)	0.48				NS			
Media (M)	0.57				NS			
Interaction (C × M)	1.29				NS			
90 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	2.35	2.31	2.51	2.21	2.32	2.57	2.59	**2.41**
C_2	2.21	2.12	2.65	1.27	2.72	3.98	3.97	**2.70**
C_3	2.07	1.97	2.91	2.71	1.96	2.55	2.56	**2.39**
C_4	2.46	3.79	3.08	3.66	4.39	4.23	4.39	**3.71**
C_5	1.42	2.89	1.69	1.29	2.20	1.37	2.06	**1.85**
Mean	**2.10**	**2.62**	**2.57**	**2.23**	**2.72**	**2.94**	**3.11**	
CV (%) = 14.73	**S.Em±**				**CD at 5%**			
Container (C)	0.10				0.30			
Media (M)	0.12				0.35			
Interaction (C × M)	0.27				0.78			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing
NS: Non-significant

The maximum leaf area (3.11 cm^2) was found in red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) which was on par with the M_6 (2.94 cm^2). The least leaf area (2.10 cm^2) was found in M_1.

The interaction effect between container and media with respect to leaf area was found to be significant. The maximum leaf area (4.39 cm^2) was recorded in the treatment combination C_4M_7 - root trainer containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media and C_4M_5 - root trainer containing red soil + sand + FYM + *P. fluorescens* which was on par with C_4M_6 (4.23 cm^2) and the least leaf area (1.27 cm^2) was recorded in C_2M_4.

4.2.3.3 Leaf area at 120 days after sowing

The leaf area of coffee seedlings grown in different containers irrespective of media used ranged from 10.94 to 17.96 cm^2. The maximum leaf area (17.96 cm^2) was recorded in root trainer (C_4) which was on par with C_1 (16.96 cm^2) and the minimum leaf area (10.94 cm^2) was recorded in the C_5 which was on par with the C_3 (13.90 cm^2).

The maximum leaf area (21.66 cm^2) was recorded with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media (M_7) followed by M_6 (16.17 cm^2) and the minimum leaf area (12.18 cm^2) was registered in M_1.

The interaction between the containers and media was found significant. The maximum leaf area (36.05 cm^2) was recorded in root trainer containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media (C_4M_7) followed by C_1M_7 (22.67 cm^2) and the least (8.02 cm^2) was registered in C_5M_4 which was on par with the C_5M_1 (9.63 cm^2).

4.2.3.4 Leaf area at 180 days after sowing

The leaf area of coffee seedlings grown in different containers irrespective of media used ranged from 27.39 to 53.37 cm^2. The maximum leaf area (53.37 cm^2) was recorded with root trainer grown seedlings (C_4) followed by C_1 (52.55 cm^2) and the least (27.39 cm^2) was recorded in C_3.

The effect of media on leaf area was found to be significant. The maximum leaf area (52.87 cm^2) was recorded in the seedlings grown in the media containing red

Table 12. Effect of containers, rooting media and their interaction on leaf area (cm^2) of coffee seedlings at 120 and 180 days after sowing

120 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	14.86	14.02	15.86	16.85	16.58	17.91	22.67	**16.96**
C_2	11.97	14.87	13.64	12.19	13.57	16.50	17.97	**14.39**
C_3	10.84	11.44	14.64	11.14	15.99	15.17	18.12	**13.90**
C_4	13.60	13.65	14.00	14.46	15.53	18.42	36.05	**17.96**
C_5	9.63	11.26	10.59	8.02	10.72	12.86	13.51	**10.94**
Mean	**12.18**	**13.05**	**13.75**	**12.53**	**14.48**	**16.17**	**21.66**	
CV (%) = 19.87	**S.Em±**				**CD at 5%**			
Container (C)	0.78				2.26			
Media (M)	0.93				2.67			
Interaction (C × M)	2.08				5.99			
180 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	48.23	49.59	51.97	49.78	55.57	56.26	56.45	**52.55**
C_2	34.80	38.30	40.98	49.41	41.36	51.35	56.66	**44.69**
C_3	18.29	22.36	24.07	21.95	34.29	34.98	35.84	**27.39**
C_4	49.83	57.73	44.94	52.49	52.77	54.89	60.95	**53.37**
C_5	31.17	33.97	34.54	33.31	35.43	45.75	54.44	**38.37**
Mean	**36.46**	**40.39**	**39.30**	**41.38**	**43.88**	**48.64**	**52.87**	
CV (%) = 10.38	**S.Em±**				**CD at 5%**			
Container (C)	1.08				3.10			
Media (M)	1.27				3.67			
Interaction (C × M)	2.85				8.21			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermic ompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (M_7) followed by M_6 (48.64 cm^2). The least leaf area (36.46 cm^2) was recorded in M_1.

The interaction effect between container and media with respect to leaf area was found to be significant. The maximum leaf area (60.95 cm^2) was registered in the seedlings raised in root trainer filled with the media red soil + sand+ FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with C_2M_7 (56.66 cm^2), C_1M_7 (56.45 cm^2) and C_1M_6 (56.26 cm^2) and the least leaf area was recorded in C_3M_1 (18.29 cm^2).

4.2.4 Collar girth (mm)

The data pertaining to the collar girth at 90 and 180 days after sowing as influenced by different containers and rooting media are depicted in Table 13. Collar girth of coffee seedlings varied significantly among the containers, media and with their interactions.

4.2.4.1 Collar girth at 90 days after sowing

The collar girth among the containers irrespective of media used ranged from 2.4 to 2.63 mm. The maximum collar girth (2.63 mm) was recorded with root trainer (C_4) which was on par with C_1 (2.58 mm) and C_5 (2.55 mm) and the minimum collar girth (2.4 mm) was recorded in the C_3.

The effect of media on collar girth was found to be significant irrespective of container used. The maximum collar girth (2.91 mm) was recorded in the media red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (M_7) followed by M_3 (2.71 mm) and the least collar girth (2.37 mm) was registered in M_1.

The interaction between the containers and media was found significant. The maximum collar girth (3.13 mm) was found in root trainer filled with the media red soil + sand + *P. fluorescens* + FYM + PSB + *Azospirillum* (C_4M_7) which was on par with the C_5M_7 (3.04 mm) and C_1M_7 (2.91 mm) and the least collar girth (2 mm) was registered in C_3M_1.

Table 13. Effect of containers, rooting media and their interaction on collar girth (mm) of coffee seedlings at 90 and 180 days after sowing

90 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	2.37	2.57	2.71	2.59	2.47	2.48	2.91	**2.58**
C_2	2.30	2.48	2.72	2.20	2.40	2.46	2.46	**2.43**
C_3	2.00	2.29	2.42	2.33	2.46	2.59	2.68	**2.40**
C_4	2.33	2.55	2.53	2.66	2.52	2.67	3.13	**2.63**
C_5	2.30	2.42	2.40	2.25	2.48	2.94	3.04	**2.55**
Mean	**2.37**	**2.57**	**2.71**	**2.59**	**2.47**	**2.48**	**2.91**	
CV (%) = 6.36	**S.Em±**				**CD at 5%**			
Container (C)	0.04				0.12			
Media (M)	0.05				0.14			
Interaction (C × M)	0.11				0.32			
180 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	3.35	3.37	3.56	3.55	3.62	3.55	3.64	**3.52**
C_2	3.23	3.31	3.33	3.36	3.46	3.45	3.46	**3.37**
C_3	2.85	3.26	3.32	3.22	3.24	3.23	3.17	**3.18**
C_4	3.36	3.31	3.39	3.60	3.82	3.91	4.01	**3.63**
C_5	3.21	3.27	3.19	3.11	3.34	3.46	3.95	**3.36**
Mean	**3.20**	**3.31**	**3.36**	**3.37**	**3.49**	**3.52**	**3.65**	
CV (%) = 4.71	**S.Em±**				**CD at 5%**			
Container (C)	0.04				0.12			
Media (M)	0.05				0.14			
Interaction (C × M)	0.11				0.32			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

4.2.4.2 Collar girth at 180 days after sowing

The collar girth of coffee seedlings in different containers ranged from 3.18 to 3.63 mm. The maximum collar girth was recorded in root trainer - C_4 (3.63 mm) which was on par with C_1 (3.52 mm) and least in C_3 (3.18 mm).

The mean collar girth of coffee seedlings grown in different rooting media irrespective of container used varied between 3.20 to 3.65 mm. Seedlings grown in media containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* - M_7 recorded the maximum collar girth (3.65 mm) which was on par with red soil + sand + FYM + *P. fluorescens* + VAM - M_6 (3.52 mm). Whereas, the control (M_1) recorded the lowest collar girth (3.20 mm).

Significant difference was found between the container and media. The maximum collar girth (4.01 mm) was recorded in the seedlings grown in root trainer using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with the C_5M_7 (3.95 mm) and the least collar girth (2.85 mm) was registered in C_3M_1.

4.2.5 Length of tap root (cm)

The data with respect to length of tap root grown in different containers and media at 90 and 180 days after sowing is presented in Table 14. The significant differences were manifested regarding different containers, rooting media and with their interactions.

4.2.5.1 Length of tap root at 90 days after sowing

Irrespective of media used, the tap root length of coffee seedlings grown in different containers ranged from 6.38 to 8.98 cm. The maximum taproot length (8.98 cm) was recorded in the seedlings raised in root trainer (C_4) and the least taproot length was recorded in C_3 (6.38 cm) which was on par with C_1 (6.91 cm), C_5 (6.94 cm) and C_2 (6.97 cm) at 90 DAS.

The maximum tap root length of coffee seedlings grown in different media regardless of container recorded in M_7 - red soil + sand + FYM + *P. fluorescens* +

Table 14. Effect of containers, rooting media and their interaction on length of taproot (cm) of coffee seedlings at 90 and 180 days after sowing

90 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	5.98	6.02	6.04	6.84	6.99	7.42	9.09	**6.91**
C_2	6.85	6.77	6.56	6.47	6.23	7.96	8.00	**6.97**
C_3	6.09	6.00	6.06	6.39	6.53	6.65	6.98	**6.38**
C_4	7.37	7.75	7.71	6.87	9.62	10.93	12.63	**8.98**
C_5	6.05	6.12	6.51	6.05	6.14	7.04	10.68	**6.94**
Mean	**6.46**	**6.53**	**6.57**	**6.52**	**7.10**	**8.00**	**9.47**	
CV (%) = 12.39	**S.Em±**				**CD at 5%**			
Container (C)	0.23				0.68			
Media (M)	0.28				0.81			
Interaction (C × M)	0.63				1.82			
180 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	16.61	18.5	18.82	18.84	19.12	20.98	21.41	**19.18**
C_2	14.80	16.45	16.84	17.20	18.27	18.67	20.58	**17.54**
C_3	16.30	16.78	16.84	16.56	17.20	17.50	18.45	**17.09**
C_4	15.02	14.84	14.77	15.02	15.20	15.18	15.45	**15.06**
C_5	15.06	18.35	17.05	16.99	19.27	19.60	22.26	**18.36**
Mean	**15.55**	**16.98**	**16.86**	**16.92**	**17.81**	**18.38**	**19.63**	
CV (%) = 8.24	**S.Em±**				**CD at 5%**			
Container (C)	0.38				1.11			
Media (M)	0.45				1.31			
Interaction (C × M)	1.01				2.92			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

PSB + *Azospirillum* (9.47 cm) followed by M_6 (8 cm), while control (M_1) recorded the minimum tap root length (6.46 cm).

The interaction between container and media was found to be significantly different. The maximum tap root length (12.63 cm) was recorded in the treatment combination root trainer using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with the C_4M_6 (10.93 cm) and least (5.98 cm) was recorded in control - C_1M_1.

4.2.5.3 Length of tap root at 180 days after sowing

Among the different containers used, the maximum tap root length (19.18 cm) was recorded in seedlings grown in black polythene bag (C_1) which was on par with C_5 (18.36 cm) and the least length of taproot was recorded in the C_4 (15.06 cm).

Among the different media used irrespective of container, the maximum tap root length (19.63 cm) was recorded in M_7 - red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* which was on par with M_6 (18.38 cm) and the least (15.55 cm) was registered in control (M_1).

The interaction effect was found to be significant and the maximum taproot length (22.26 cm) was recorded in the treatment combination C_5M_7 - raised bed using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* which was on par with C_1M_7 (21.41 cm), C_1M_6 (20.98 cm). The least taproot length (14.77 cm) was recorded in C_4M_3 which was on par with C_2M_1 (14.80 cm) and C_4M_2 (14.84 cm).

4.2.6 Number of primary roots

The data obtained on number of primary roots revealed that there were significant differences among the seedlings grown in different containers, media and with their interactions at 90 and 180 days after sowing (Table 15).

4.2.6.1 Number of primary roots at 90 days after sowing

The number of primary roots produced per seedlings among the different containers used irrespective of media varied significantly. The maximum number of primary roots (50.20) were recorded in the seedlings raised in root trainer (C_4) and the

Table 15. Effect of containers, rooting media and their interaction on number of primary roots of coffee seedlings at 90 and 180 days after sowing

90 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	32.30	34.00	33.70	39.20	32.60	42.50	52.50	**38.11**
C_2	33.52	36.70	38.50	38.75	39.10	40.70	41.90	**38.45**
C_3	30.90	33.30	40.90	34.70	43.00	44.80	47.20	**39.25**
C_4	35.70	40.90	42.90	42.10	60.84	64.11	64.90	**50.20**
C_5	33.70	34.25	34.90	38.80	41.15	41.10	43.00	**38.12**
Mean	**33.22**	**35.83**	**38.18**	**38.71**	**43.33**	**46.64**	**49.90**	
CV (%) = 11.85	**S.Em±**				**CD at 5%**			
Container (C)	1.29				3.71			
Media (M)	1.53				4.40			
Interaction (C × M)	3.42				9.83			
180 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	104.2	116.4	133.4	133.0	136.6	163.5	166.7	**136.2**
C_2	115.1	116.4	120.3	132.4	159.2	163.3	166.9	**139.1**
C_3	110.9	124.8	161.5	162.00	135.1	131.0	207.5	**147.5**
C_4	137.2	146.6	153.8	120.8	201.9	206.1	238.6	**172.1**
C_5	117.0	141.3	133.5	134.7	139.7	149.7	152.0	**138.2**
Mean	**116.8**	**129.1**	**140.5**	**136.5**	**154.5**	**162.7**	**186.3**	
CV (%) = 15.30	**S.Em±**				**CD at 5%**			
Container (C)	4.0				11.5			
Media (M)	4.7				13.6			
Interaction (C × M)	10.6				30.6			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

minimum number of primary roots (38.11) per seedling was registered in the control (C_1) which was on par with all other treatments.

Among the different media used irrespective of container, the maximum number of primary roots per seedling (49.90) was recorded in red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) which was on par with M_6 (46.64) and least number of primary roots per seedling (33.22) was registered in control (M_1).

The interaction effect between containers and media on number of primary roots per seedling was found significant and ranged from 30.90 to 64.90. The maximum number of primary roots per seedling (64.90) was recorded in the seedlings raised in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with C_4M_6 (64.11) and C_4M_5 (60.84) and the least number of primary roots per seedling was recorded in the treatment combination C_3M_1 (30.90) which was on par with the C_1M_1 (32.3).

4.2.6.2 Number of primary roots at 180 days after sowing

The number of primary roots of seedlings grown in different containers irrespective of media used ranged from 136.27 to 172.14. The maximum number of primary roots (172.14) was recorded in the seedlings raised in root trainer (C_4) and the least primary roots production was recorded in C_1 (136.20).

The effect of media on number of primary roots production was found significant. The highest number of primary roots per seedling (186.35) was recorded in red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) followed by M_6 (162.72). The least number of primary roots was recorded in M_1 (116.88).

The interaction effect between container and media with respect to number of primary roots per seedling varied significantly. The maximum number of primary roots (238.6) was registered in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) and the least (104.2) was found in C_1M_1.

4.2.7 Number of secondary roots

The data pertaining to the number of secondary roots at 90 and 180 days after sowing as influenced by different container and rooting media are depicted in

Table 16. The number of secondary roots of coffee seedlings varied significantly among the containers and media and with their interactions.

4.2.7.1 Number of secondary roots at 90 days after sowing

The number of secondary roots production per seedling grown in different containers ranged from 31.90 to 54.12 irrespective of media used. The maximum count (54.12) was recorded in root trainer grown seedlings (C_4) followed by C_2 (44.17) and the least count (31.90) was registered in the (C_1).

Among different media used, M_7 - red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* recorded the maximum number of secondary roots (55.90) which was on par with M_6 (54.78). While, control (M_1) recorded the minimum number of secondary roots (27.26).

The interaction effect between container and media was found significant. The maximum number of secondary roots (65.60) was recorded in seedlings raised in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with the C_4M_5 (64.20) and C_4M_6 (64.00) and the least was recorded in C_2M_1 (20.15).

4.2.7.2 Number of secondary roots at 180 days after sowing

Among different containers used, the maximum number of secondary roots per seedling (428.1) was recorded in the root trainer (C_4) and the least number of secondary roots per seedling (320.6) was registered in C_1.

Among different media used, the maximum number of secondary roots per seedling (424.7) was recorded in the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) which was on par with M_6 (393.1) and the least (292.7) was recorded in the control (M_1).

The interaction effect between containers and media was found significant. The maximum number of secondary roots per seedling (557.8) was recorded in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB +

Table 16. Effect of containers, rooting media and their interaction on number of secondary roots of coffee seedlings at 90 and 180 days after sowing

90 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	21.15	24.75	29.37	26.90	39.10	40.90	41.15	**31.90**
C_2	20.15	31.00	37.20	35.40	61.50	61.20	62.75	**44.17**
C_3	21.20	22.40	21.70	25.30	53.08	53.80	55.65	**36.16**
C_4	41.40	42.45	48.06	53.10	64.25	64.00	65.60	**54.12**
C_5	32.40	35.80	39.90	38.31	54.30	54.00	54.35	**44.15**
Mean	**27.26**	**31.28**	**35.24**	**35.80**	**54.44**	**54.78**	**55.90**	
CV (%) = 17.30	**S.Em±**				**CD at 5%**			
Container (C)	1.29				3.72			
Media (M)	1.52				4.40			
Interaction (C × M)	3.41				9.82			
180 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	213.8	227.9	371.8	347.3	359.6	362.0	362.2	**320.6**
C_2	276.0	277.0	345.3	331.0	321.5	321.1	404.5	**325.2**
C_3	321.3	362.8	380.4	354.6	401.6	402.1	402.5	**375.0**
C_4	340.5	357.9	377.3	365.6	442.7	555.5	557.8	**428.1**
C_5	312.3	315.4	321.4	292.1	308.9	324.8	396.8	**324.5**
Mean	**292.7**	**308.2**	**359.2**	**338.1**	**366.8**	**393.1**	**424.7**	
CV (%) = 11.95	**S.Em±**				**CD at 5%**			
Container (C)	11.3				32.5			
Media (M)	13.4				38.5			
Interaction (C × M)	29.9				86.2			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

Azospirillum (C_4M_7) which was on par with the C_4M_6 (555.5) and the least was recorded in the control - C_1M_1 (213.8).

4.2.8 Fresh weight of roots (g)

The data pertaining to the fresh weight of roots at 90 and 180 days after sowing as influenced by different containers and rooting media are depicted in Table 17. Fresh weight of coffee seedlings roots per plant varied significantly among the containers, media and with their interactions.

4.2.8.1 Fresh weight of roots at 90 days after sowing

The significant difference was registered among different containers with respect to fresh weight of roots per seedling. The maximum fresh weight of roots per seedling (0.46 g) was recorded in root trainer (C_4) and the least fresh weight of roots (0.30 g) was recorded in the control (C_1).

Among different media used, the maximum fresh weight of roots per seedling (0.42 g) was recorded in the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) which was on par with M_6 (0.40 g) and the least fresh weight of roots (0.29 g) was registered in the control - M_1.

The interaction effect between container and media was found significant. The maximum fresh weight of roots was recorded in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* - C_4M_7 (0.65 g) which was on par with the C_4M_6 (0.61 g) and the least fresh weight of roots per seedling was recorded in C_1M_1 (0.27 g).

4.2.8.2 Fresh weight of roots at 180 days after sowing

The fresh weight of roots of coffee seedlings grown in different containers irrespective of media used found significant and ranged from 1.36 to 2.11 g. The maximum fresh weight of roots (2.11 g) was recorded in root trainer (C_4) and the lowest (1.36g) was recorded in the control (C_1).

Table 17. Effect of containers, rooting media and their interaction on fresh weight (g) of roots of coffee seedlings at 90 and 180 days after sowing

90 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	0.27	0.29	0.31	0.30	0.31	0.31	0.33	**0.30**
C_2	0.28	0.33	0.34	0.32	0.32	0.37	0.37	**0.33**
C_3	0.30	0.35	0.37	0.34	0.33	0.33	0.35	**0.34**
C_4	0.32	0.39	0.41	0.34	0.50	0.61	0.65	**0.46**
C_5	0.29	0.31	0.32	0.31	0.36	0.37	0.40	**0.34**
Mean	**0.29**	**0.33**	**0.35**	**0.32**	**0.37**	**0.40**	**0.42**	
CV (%) = 14.22	**S.Em±**				**CD at 5%**			
Container (C)	0.01				0.03			
Media (M)	0.01				0.04			
Interaction (C × M)	0.03				0.10			
180 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	1.22	1.23	1.29	1.31	1.45	1.51	1.54	**1.36**
C_2	1.31	1.33	1.36	1.44	1.62	1.73	1.75	**1.50**
C_3	1.26	1.31	1.47	1.46	1.58	1.63	1.65	**1.48**
C_4	1.41	1.45	1.62	1.60	2.79	2.93	2.96	**2.11**
C_5	1.24	1.39	1.56	2.02	2.09	2.15	2.18	**1.80**
Mean	**1.29**	**1.34**	**1.46**	**1.57**	**1.90**	**1.99**	**2.01**	
CV (%) = 15.90	**S.Em±**				**CD at 5%**			
Container (C)	0.07				0.20			
Media (M)	0.11				0.23			
Interaction (C × M)	0.18				0.53			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

The effect of media on fresh weight of roots varied significantly. The maximum fresh weight of roots (2.01 g) was recorded in the media red soil+ sand+ FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) which was on par with M_6 (1.99 g) and M_5 (1.90 g). The least fresh weight of roots (1.29 g) was recorded in (M_1).

The interaction effect between containers and media with respect to fresh weight of roots was found significant. The maximum fresh weight of roots (2.96 g) was recorded in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with C_4M_6 (2.93 g) and C_4M_5 (2.79 g) and least fresh weight of roots (1.22 g) was registered in C_1M_1.

4.2.9 Dry weight of roots (g)

The data pertaining to the dry weight of roots at 90 and 180 days after sowing as influenced by different container and rooting media are depicted in the Table 18. The dry weight of roots varied significantly among the containers and media and with their interactions.

4.2.9.1 Dry weight of roots at 90 days after sowing

Among different containers used, the seedlings grown in the root trainer (C_4) recorded maximum dry weight of roots (0.136 g) and the least dry weight of roots per seedling (0.069 g) was recorded in C_1.

Significant difference was registered with respect to dry weight of roots as influenced by different media irrespective of container used. The maximum dry weight (0.128 g) was recorded in red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (M_7) followed by M_6 (0.113 g) and the least dry weight of roots (0.058 g) was recorded in the control - M_1.

Significant difference was found between the containers and media with respect to dry weight of roots. The treatment combination C_4M_7 - root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* registered the maximum dry weight of roots (0.242 g) followed by C_4M_6 (0.201 g) whereas, the minimum dry weight of roots (0.049 g) was recorded in the control - C_1M_1.

Table 18. Effect of containers, rooting media and their interaction on dry weight (g) of coffee seedlings roots at 90 and 180 days after sowing

90 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	0.049	0.071	0.076	0.074	0.08	0.082	0.086	**0.069**
C_2	0.061	0.065	0.064	0.058	0.077	0.083	0.107	**0.073**
C_3	0.058	0.063	0.078	0.073	0.080	0.087	0.097	**0.076**
C_4	0.069	0.073	0.086	0.086	0.185	0.201	0.242	**0.136**
C_5	0.054	0.054	0.069	0.074	0.095	0.099	0.108	**0.079**
Mean	**0.058**	**0.061**	**0.072**	**0.073**	**0.103**	**0.113**	**0.128**	
CV (%) = 12.88	**S.Em±**				**CD at 5%**			
Container (C)	0.003				0.008			
Media (M)	0.003				0.010			
Interaction (C × M)	0.007				0.022			
180 DAS								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	0.400	0.430	0.478	0.425	0.493	0.515	0.524	**0.466**
C_2	0.400	0.414	0.427	0.478	0.506	0.525	0.591	**0.477**
C_3	0.403	0.419	0.489	0.404	0.502	0.525	0.541	**0.469**
C_4	0.490	0.496	0.449	0.524	0.850	0.959	1.098	**0.695**
C_5	0.485	0.486	0.475	0.512	0.615	0.785	0.800	**0.594**
Mean	**0.435**	**0.449**	**0.463**	**0.468**	**0.593**	**0.661**	**0.710**	
CV (%) = 12.88	**S.Em±**				**CD at 5%**			
Container (C)	0.022				0.070			
Media (M)	0.026				0.080			
Interaction (C × M)	0.060				0.173			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

4.2.9.2 Dry weight of roots at 180 days after sowing

The significant difference was recorded among different containers with respect to dry weight of roots. The maximum dry weight of roots (0.695 g) was registered in the root trainer (C_4) and the least dry weight of roots per seedling (0.466 g) was registered in C_1 which was on par with C_3 (0.469 g).

Among different media used, the maximum dry weight of roots (0.71 g) was recorded in red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) which was on par with M_6 (0.661 g) and the least (0.435 g) was registered with the control (M_1) which was on par with M_2 (0.449 g), M_3 (0.463 g) and M_4 (0.468 g).

The interaction effect between containers and media on dry weight of roots per seedling varied significantly. The maximum dry weight of roots per seedling (1.098 g) was recorded in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with the C_4M_6 (0.959 g) and the least dry weight of roots per seedling (0.400 g) was recorded in C_1M_1, C_2M_1 and C_3M_1.

4.3 Effect of containers, rooting media and their interaction on growth and field establishment of coffee seedlings in the main field

4.3.1 Survivability (%) of coffee seedlings after transplanting to the main field

There was significant difference in survivability of transplanted coffee seedlings planted in main field among the containers but media and interaction effect were found to be non-significant with respect to survivability of seedlings in the main field. The data with respect to survivability of different treatments is presented in Table 19.

The survivability of coffee seedlings grown in different containers irrespective of media used ranged from 75.71 to 100 per cent. The 100 per cent survivability was recorded in plants raised in black polythene bag, transparent polythene bag and root

Table 19. Effect of containers, rooting media and their interaction on survivability (%) of coffee seedlings in the main field

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	**Mean**
C_1	100	100	100	100	100	100	100	**100**
C_2	100	100	100	100	100	100	100	**100**
C_3	100	100	100	100	100	100	100	**100**
C_4	100	100	100	100	100	100	100	**100**
C_5	70	70	80	70	80	80	80	**75.71**
Mean	94	94	96	94	96	96	96	
CV (%) = 19.10	**S.Em±**				**CD at 5%**			
Container (C)	2.94				8.47			
Media (M)	3.48				NS			
Interaction (C × M)	7.80				NS			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing
NS: Non-significant

trainer (C_1, C_2, C_3 and C_4) whereas seedlings grown in raised bed (C_5) recorded least survival percentage (75.71).

The survivability of coffee seedlings grown in different rooting media irrespective of container used found to be non-significant. However the maximum survivability (96%) was recorded with M_3, M_5, M_6 and M_7 and minimum survivability (94%) was registered in M_1, M_2 and M_4.

There was no significant difference between the containers and media. However 100 per cent survivability was recorded in all treatment combinations except C_5M_1 (70%), C_5M_2 (70%), C_5M_3 (80%), C_5M_4 (70%), C_5M_5 (80%), C_5M_6 (80%) and C_5M_7 (80%).

4.3.2 Number of days taken for first flush of coffee seedlings after transplanting to the main field

The data pertaining to the number of days taken for new flush after transplanting to the main field as influenced by different containers, rooting media and their interactions in nursery is depicted in Table 20. The number of days taken for first flush of coffee seedlings varied significantly among the containers but not with the media and interaction between containers and media.

The mean number of days taken for first flush of coffee seedlings in different containers irrespective of media used ranged from 23.51 to 44.68 days. The least number of days taken for first flush formation (23.51 days) was registered by root trainer raised seedlings (C_4) which was on par with C_1 (24.04 days) and C_2 (27.22 days) and the treatment C_5 was taken more number of days (44.68 days) for first flush formation.

The influence of media on days taken for first flush was found to be non-significant. However minimum number of days (26.36 days) was recorded in M_7 - red soil + sand + FYM + PSB + *P. fluorescens* + *Azospirillum*. Whereas, the maximum number of days (32.98 days) was registered in M_1.

The interaction effect of container and media on number of days taken for new flush emergence was found non- significant. However the least number of days (21.70

Table 20. Effect of containers, rooting media and their interaction on number of days taken for new flush of coffee seedlings in main field

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	Mean
C_1	25.40	24.80	25.40	24.10	23.70	22.90	22.00	**24.04**
C_2	33.10	30.50	26.30	26.20	26.00	25.00	23.50	**27.22**
C_3	32.00	31.90	31.58	31.41	31.30	27.75	27.10	**30.43**
C_4	22.50	22.30	24.10	25.60	25.40	23.00	21.70	**23.51**
C_5	51.90	50.50	44.80	43.90	42.20	42.00	37.50	**44.68**
Mean	**32.98**	**32.00**	**30.43**	**30.24**	**29.72**	**28.13**	**26.36**	
CV (%) = 17.11	**S.Em±**				**CD at 5%**			
Container (C)	1.37				3.94			
Media (M)	1.62				NS			
Interaction (C × M)	3.62				NS			

C: Container
- **C_1:** Black polythene bag (6" × 9")
- **C_2:** Transparent polythene bag (6"× 9")
- **C_3:** Protray raised seedlings in black polythene bag (6" × 9")
- **C_4:** Root trainers
- **C_5:** Raising in beds

M: Media
- **M_1:** Red soil + sand + FYM (3:1:1)
- **M_2:** Red soil + cocopeat + FYM (3:1:1)
- **M_3:** Red soil + sand + vermicompost (3:1:1)
- **M_4:** Red soil + sand + pressmud (3:1:1)
- **M_5:** M_1 + *Pseudomonas fluorescens*
- **M_6:** M_5 + VAM
- **M_7:** M_5 + PSB + *Azospirillum*

DAS: Days after sowing
NS: Non-significant

days) was recorded with the treatment C_4M_7 and maximum number of days (51.90 days) was recorded in the treatment combination C_5M_1.

4.3.3 Plant height (cm)

The data with respect to plant height of different treatments from 30 to 90 days after transplanting to the main field are presented in Table 21. The significant differences were manifested regarding different containers, rooting media and with their interactions.

4.3.3.1 Plant height at 30 days after transplanting of coffee seedlings

The plant height in different containers irrespective of media used found significant. The maximum plant height (15.42 cm) was registered with C_1 - black polythene bag which was on par with C_4 (15 cm) and the minimum plant height (11.62 cm) was registered in C_5 which was on par with C_3 (11.90 cm).

Significant difference was observed with respect to plant height of coffee seedlings grown in different media. Maximum plant height (15.31 cm) was recorded with M_7 - red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* followed by M_6 (14.13 cm) and the least plant height (11.51 cm) was registered with M_1.

The interaction effect between the container and media was found significant. The maximum plant height (17.81 cm) was recorded in treatment combination of C_1M_7 – black polythene bag filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* which was on par with C_2M_7 (17.05 cm), C_4M_7 and C_4M_6 (16.53 cm) and the least plant height (11.16 cm) was recorded with C_5M_3 which was on par with C_3M_1 (11.29 cm), C_5M_4 (11.31 cm), C_5M_5 (11.35 cm) and C_5M_1 (11.38 cm).

4.3.3.2 Plant height at 60 days after transplanting of coffee seedlings

The plant height of coffee seedlings in different containers irrespective of media used found significant. Maximum plant height (16.66 cm) was recorded in the coffee seedlings raised in black polythene bag - C_1 which was on par with root trainer - C_4 (16.13 cm) and the lowest plant height was recorded with C_5 (12.09 cm).

Table 21. Effect of containers, rooting media and their interaction on plant height (cm) of coffee seedlings at 30, 60 and 90 days after transplanting to the main field

30 DAT								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	11.45	14.52	16.70	16.05	16.02	15.40	17.81	**15.42**
C_2	11.92	13.53	15.04	13.24	14.09	14.17	17.05	**14.15**
C_3	11.29	11.90	11.87	11.86	11.92	12.21	12.28	**11.90**
C_4	11.55	13.88	14.37	15.17	16.48	16.53	16.53	**15.00**
C_5	11.38	11.49	11.16	11.31	11.35	12.34	12.37	**11.62**
Mean	**11.51**	**13.06**	**13.83**	**13.52**	**13.97**	**14.13**	**15.31**	
CV (%) = 8.36	**S.Em±**				**CD at 5%**			
Container (C)	0.20				0.59			
Media (M)	0.24				0.70			
Interaction (C × M)	0.54				1.57			
60 DAT								
	M_1	**M2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	12.65	15.87	18.10	17.07	16.87	16.43	19.63	**16.66**
C_2	13.13	14.65	16.10	15.57	15.17	15.25	18.30	**15.45**
C_3	12.40	13.32	13.43	13.35	12.94	13.26	13.55	**13.18**
C_4	12.55	14.87	15.74	16.42	17.70	17.37	18.25	**16.13**
C_5	12.07	12.15	11.46	11.70	11.65	12.86	12.77	**12.09**
Mean	**12.56**	**14.17**	**14.96**	**14.82**	**14.86**	**15.03**	**16.50**	
CV (%) = 4.93	**S.Em±**				**CD at 5%**			
Container (C)	0.19				0.55			
Media (M)	0.22				0.66			
Interaction (C × M)	0.51				1.47			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

Contd……

90 DAT								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	14.84	17.60	20.19	18.95	19.15	19.65	21.50	**18.84**
C_2	15.10	15.85	17.83	17.10	17.47	18.40	20.40	**17.45**
C_3	13.60	14.96	14.65	14.25	14.20	14.45	14.93	**14.43**
C_4	15.22	17.00	17.98	18.58	20.35	21.12	22.30	**18.93**
C_5	13.00	13.15	13.30	13.75	13.25	13.95	14.15	**13.50**
Mean	**14.35**	**15.71**	**16.79**	**16.52**	**16.88**	**17.51**	**18.65**	
CV (%) = 4.38	**S.Em±**				**CD at 5%**			
Container (C)	0.19				0.56			
Media (M)	0.22				0.66			
Interaction (C × M)	0.51				1.47			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

Significant difference was observed with respect to plant height of coffee seedlings grown in different media. Maximum plant height (16.50 cm) was recorded in M_7 - red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* followed by M_6 (15.03 cm) and the least plant height was recorded in M_1 (12.56 cm).

The interaction between the container and media was found significant. The maximum plant height (19.63 cm) was registered in treatment combination of black polythene bag filled with the media red soil+ sand+ FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) which was on par with C_2M_7 (18.30 cm) and C_4M_7 (18.25 cm) and the least plant height (11.46 cm) was recorded in the treatment combination C_5M_3 which was on par with C_5M_5 (11.65 cm) and C_5M_4 (11.70 cm).

4.3.3.3 Plant height at 90 days after transplanting of coffee seedlings

The maximum plant height was found in the root trainer grown seedlings - C_4 (18.93 cm) which was on par with the C_1 (18.84 cm) whereas, the lowest plant height was registered with C_5 (13.50 cm).

Among the different media used, the maximum plant height (18.65 cm) was recorded in the media containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) followed by M_6 (17.51 cm) and the lowest (14.35 cm) was found in M_1.

The interaction effect between containers and media was found to be significant. The maximum plant height (22.30 cm) was registered in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with the C_1M_7 (21.50 cm) while, the least plant height (13 cm) was recorded in the treatment combination C_5M_1.

4.3.4 Number of leaves

The data regarding number of leaves of different treatments from 30 to 90 days after transplanting to the main field were presented in Table 22. The significant differences were manifested regarding different containers and rooting media but not with their interactions at 30 and 60 days after transplanting. Whereas, at 90 days after

transplanting, significant difference was observed among containers, media and with their interactions.

4.3.4.1 Number of leaves at 30 days after transplanting to the main field

The effect of different containers was found to be significant with respect to number of leaves. The maximum number of leaves (9.71) was recorded in the root trainer (C_4) which was on par with the C_1 (9.68) and the lowest number of leaves (6.58) was encountered in C_5.

Significant difference was observed regarding number of leaves of seedlings grown in different media. The maximum number of leaves (9.66) was recorded in seedlings raised in the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) whereas the least number of leaves (8.16) was registered in M_2 which was on par with M_1 (8.18), M_4 (8.55) and M_3 (8.56).

Interaction effect between container and media was not significant. Although, the maximum number of leaves was recorded in black polythene bag filled with the media red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* - C_1M_7 (11.20) whereas, the least number of leaves (6.20) were recorded in C_5M_2 and C_5M_3.

4.3.4.2 Number of leaves at 60 days after transplanting to the main field

The mean number of leaves of seedlings in different containers irrespective of media used ranged from 8.58 to 11.54. The maximum number of leaves (11.54) was noticed in the seedlings raised in root trainer (C_4) which was on par with the C_1 (11.48) and the minimum number of leaves (8.58) was recorded in C_5.

Significant difference was recorded with respect to number of leaves of coffee seedlings grown in different media. Maximum number of leaves (11.50) was recorded in M_7 - red soil+ sand+ FYM + *P. fluorescens* + PSB + *Azospirillum* and the least plant height (9.92) was recorded in M_2.

The interaction between the container and media was found to be non-significant. However, the maximum number of leaves (13.20) was recorded in treatment combination of C_1M_7 – black polythene bag filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* followed by C_4M_7 - root trainer

Table 22. Effect of containers, rooting media and their interaction on number of leaves in coffee seedlings at 30, 60 and 90 days after transplanting to the main field

30 DAT								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	9.00	9.20	9.20	9.40	9.60	10.20	11.20	**9.68**
C_2	8.00	8.60	9.20	8.60	9.20	9.80	10.20	**9.08**
C_3	8.00	8.00	8.00	8.00	8.20	8.40	9.20	**8.25**
C_4	9.60	8.80	10.20	9.60	9.80	9.20	10.80	**9.71**
C_5	6.33	6.20	6.20	7.16	6.73	6.50	6.93	**6.58**
Mean	**8.18**	**8.16**	**8.56**	**8.55**	**8.70**	**8.82**	**9.66**	
CV (%) = 6.04	**S.Em±**				**CD at 5%**			
Container (C)	0.13				0.40			
Media (M)	0.16				0.48			
Interaction (C × M)	0.37				NS			
60 DAT								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	11.20	11.00	11.00	10.60	11.80	11.60	13.20	**11.48**
C_2	10.60	10.00	11.20	10.60	11.60	11.20	12.20	**11.05**
C_3	9.60	9.80	10.40	10.00	10.20	10.40	11.00	**10.20**
C_4	11.60	10.60	11.80	11.60	11.80	11.20	12.20	**11.54**
C_5	8.33	8.20	8.20	9.16	8.73	8.50	8.93	**8.58**
Mean	**10.26**	**9.92**	**10.52**	**10.39**	**10.82**	**10.58**	**11.50**	
CV (%) = 5.25	**S.Em±**				**CD at 5%**			
Container (C)	0.14				0.42			
Media (M)	0.17				0.50			
Interaction (C × M)	0.39				NS			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing
NS: Non-significant

Contd……..

90 DAT								
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**	**Mean**
C_1	16.00	17.60	17.60	17.20	18.20	20.20	20.40	**18.17**
C_2	16.20	17.40	17.40	16.60	19.40	19.60	20.40	**18.14**
C_3	11.60	12.00	12.60	13.00	12.40	12.80	13.20	**12.51**
C_4	16.60	17.20	18.20	17.20	19.80	19.20	20.90	**18.44**
C_5	10.30	10.20	10.20	11.16	10.73	10.50	10.73	**10.55**
Mean	**14.14**	**14.88**	**15.20**	**15.03**	**16.10**	**16.46**	**17.12**	
CV (%) = 5.53	**S.Em±**				**CD at 5%**			
Container (C)	0.214				0.62			
Media (M)	0.253				0.73			
Interaction (C × M)	0.567				1.63			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

filled with the media red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (12.20) and the least number of leaves (8.20) was recorded in C_5M_2 and C_5M_3.

4.3.4.3 Number of leaves at 90 days after transplanting to the main field

The maximum number of leaves (18.44) was found in root trainer (C_4) which was on par with the C_1 (18.17) and C_2 (18.14) whereas, the lowest number of leaves (10.55) was recorded in C_5.

Among the different media used, the maximum number of leaves (17.12) was registered in M_7 - red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* which was on par with M_6 (16.46) and the lowest (14.14) found in M_1.

The interaction effect between containers and media was found to be significant. The maximum number of leaves (20.90) was recorded in the root trainer filled with the media red soil+ sand+ FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* - C_4M_7 which was on par with the C_2M_7 and C_1M_7 (20.40) whereas, the least plant height (10.20) was recorded in C_5M_2 and C_5M_3.

4.3.5 Number of primary branches at 90 days after transplanting

The data on number of primary branches as influenced by containers and media is presented in Table 23. The significant difference was recorded regarding number of primary branches among containers, media and with their interactions.

The maximum number of primary branches (1.54) was found in root trainer (C_4) which was on par with the C_2 (1.51) and C_1 (1.47) whereas in C_3 and C_5 no primary branches were registered until 3 months after transplanting.

Among the different media used, the maximum number of primary branches (1.16) was found in red soil + sand + FYM + *P. fluorescens* + VAM (M_6) which was on par with red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* - M_7 (1.14) and M_5 (1.04) and the lowest (0.64) was found in M_4.

The interaction effect between containers and media was found to be significant. The maximum number of primary branches (2) was registered in C_4M_7,

Table 23. Effect of containers, rooting media and their interaction on number of primary branches in coffee seedlings at 90 days after transplanting to main field

	M_1	M_2	M_3	M_4	M_5	M_6	M_7	Mean
C_1	1.10	1.50	1.30	1.00	1.50	2.00	1.90	**1.47**
C_2	1.50	1.20	1.20	1.20	1.90	1.80	1.80	**1.51**
C_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
C_4	1.40	1.20	1.40	1.00	1.80	2.00	2.00	**1.54**
C_5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**0.00**
Mean	**0.80**	**0.78**	**0.78**	**0.64**	**1.04**	**1.16**	**1.14**	
CV (%) = 15.96	**S.Em±**				**CD at 5%**			
Container (C)	0.03				0.11			
Media (M)	0.04				0.13			
Interaction (C × M)	0.10				0.29			

C: Container

C_1: Black polythene bag (6" × 9")
C_2: Transparent polythene bag (6"× 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M: Media

M_1: Red soil + sand + FYM (3:1:1)
M_2: Red soil + cocopeat + FYM (3:1:1)
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)
M_5: M_1 + *Pseudomonas fluorescens*
M_6: M_5 + VAM
M_7: M_5 + PSB + *Azospirillum*

DAS: Days after sowing

C_4M_6 and C_1M_6 which was on par with the C_1M_7 (1.9). Whereas, no primary branches were recorded in all the interactions of C_3 and C_5.

4.4 Effect of container and media on benefit–cost ratio of coffee cv. Chandragiri for nursery raising

The benefit cost ratio of different containers and media used in raising coffee seedlings is presented in the Table 24. The maximum benefit cost ratio (2.85) was recorded in C_4M_4 where, the root trainer filled with red soil + sand + press mud , which was followed by C_4M_1 where root trainer filled with red soil + sand + FYM (2.82) and C_4M_3 where seedlings were grown in root trainer using the media red soil + sand + vermicompost. Whereas, the minimum benefit cost ratio (0.98) was registered in raised bed prepared using red soil + coco peat + FYM (C_5M_2).

Table 24. Effect of containers and media on benefit–cost ratio of coffee cv. Chandragiri for nursery raising

Tr. No.	Treatment	(₹/seedling)			Benefit : Cost ratio
		Total cost	Gross income	Net return	
C_1M_1	Black polythene bag + red soil + sand + FYM in 3:1:1	4.61	7	2.39	1.51
C_1M_2	Black polythene bag + red soil + cocopeat + FYM in 3:1:1	5.61	7	1.39	1.24
C_1M_3	Black polythene bag + red soil + sand + vermicompost in 3:1:1	5.49	7	1.51	1.27
C_1M_4	Black polythene bag + red soil + sand + pressmud in 3:1:1	4.41	7	2.59	1.58
C_1M_5	Black polythene bag + M_1+ *Pseudomonas fluorescens* (5 g/ kg FYM)	4.79	7	2.21	1.46
C_1M_6	Black polythene bag + M_5 + VAM (10 g/kg FYM)	5.04	7	1.96	1.38
C_1M_7	Black polythene bag + M_5 + PSB (10 g/kg) + *Azospirillum* (10 g/kg FYM)	5.29	7	1.71	1.32
C_2M_1	Transparent polythene bag + red soil + sand + FYM in 3:1:1	4.10	7	2.90	1.7
C_2M_2	Transparent polythene bag + red soil + cocopeat + FYM in 3:1:1	5.10	7	1.90	1.37
C_2M_3	Transparent polythene bag + red soil + sand + vermicompost in 3:1:1	4.98	7	2.10	1.40
C_2M_4	Transparent polythene bag + red soil + sand + pressmud in 3:1:1	3.90	7	3.10	1.79
C_2M_5	Transparent polythene bag + M_1+ *Pseudomonas fluorescens* (5 g/ kg FYM)	4.28	7	2.72	1.63
C_2M_6	Transparent polythene bag + M_5 + VAM (10 g/kg)	4.53	7	2.47	1.54

Contd.…...

Tr. No.	Treatment	(₹/seedling)			Benefit : Cost ratio
		Total cost	Gross income	Net return	
C_2M_7	Transparent polythene bag + M_5 + PSB (10 g/kg FYM) + *Azospirillum* (10 g/kg FYM)	4.78	7	2.22	1.46
C_3M_1	Protray raised seedlings in black polythene bag + red soil + sand+ FYM in 3:1:1	4.21	7	2.79	1.66
C_3M_2	Protray raised seedlings in black polythene bag + red soil + cocopeat + FYM in 3:1:1	5.21	7	1.79	1.34
C_3M_3	Protray raised seedlings in black polythene bag + red soil + sand + vermicompost in 3:1:1	5.09	7	1.91	1.37
C_3M_4	Protray raised seedlings in black polythene bag + red soil + sand + press mud in 3:1:1	4.01	7	2.99	1.74
C_3M_5	Protray raised seedlings in black polythene bag + M_1+ *Pseudomonas fluorescens* (5 g/ kg FYM)	4.39	7	2.61	1.59
C_3M_6	Protray raised seedlings in black polythene bag + M_5 + VAM (10 g/kg FYM)	4.64	7	2.36	1.50
C_3M_7	Protray raised seedlings in black polythene bag + M_5 + PSB (10 g/kg FYM) + *Azospirillum* (10 g/kg FYM)	4.89	7	2.11	1.43
C_4M_1	Root trainers + red soil + sand + FYM in 3:1:1	2.47	7	4.52	**2.82**
C_4M_2	Root trainers + red soil + cocopeat + FYM in 3:1:1	2.59	7	4.41	2.70
C_4M_3	Root trainers + red soil + sand + vermicompost in 3:1:1	2.58	7	4.42	2.71

Contd.……..

Tr. No.	Treatment	(₹/seedling)			Benefit : Cost ratio
		Total cost	Gross income	Net return	
C_4M_4	Root trainers + red soil + sand + pressmud in 3:1:1	2.45	7	4.55	**2.85**
C_4M_5	Root trainers + M_1+ *Pseudomonas fluorescens* (5 g/ kg FYM)	2.54	7	4.46	2.75
C_4M_6	Root trainers + M_5 + VAM (10 g/kg FYM)	2.63	7	4.37	2.65
C_4M_7	Root trainers + M_5+ PSB (10 g/kg FYM) + *Azospirillum* (10 g/kg FYM)	2.72	7	4.28	2.57
C_5M_1	Raising in beds + red soil + sand+ FYM in 3:1:1	5.10	7	1.90	1.37
C_5M_2	Raising in beds + red soil + cocopeat + FYM in 3:1:1	7.10	7	0.10	**0.98**
C_5M_3	Raising in beds + red soil + sand + vermicompost in 3:1:1	6.85	7	0.15	1.02
C_5M_4	Raising in beds + red soil + sand + pressmud in 3:1:1	4.70	7	2.30	1.48
C_5M_5	Raising in beds + M_1+ *Pseudomonas fluorescens* (5 g/ kg FYM)	5.47	7	1.53	1.27
C_5M_6	Raising in beds + M_5 + VAM (10 g/kg FYM)	5.97	7	1.03	1.17
C_5M_7	Raising in beds + M_5 + PSB (10 g/kg FYM) + *Azospirillum* (10 g/kg FYM)	6.47	7	0.53	**1.08**

Note: *The detailed cost of cultivation and the cost of the different components of media during the experimentation period are enclosed in the appendix –III. Seedling sold at Rs.7.00Rs/ seedling.

Plate 4: General view of experimental plot

5. DISCUSSION

Conventionally coffee seeds are sown in raised bed and transplanted at topee stage into black polyethylene bag of size 6" × 9" using forest soil: sand: FYM (6:2:1) as media. This polyethylene container impose several disadvantages such as, hardening of media, root coiling and the contamination of the environment by the plastic bags when they are not properly discarded. The availability of forest soil becomes scarce due to the receding forest lands in traditional coffee growing areas. Similarly, used plastic bag disposal is also found difficult and non-eco-friendly.

In recent days the practice of new plastic container known as root trainer is a new aid to raise young nursery plants and trees. This container is tube shaped with drainage hole at the bottom which facilitates the growth of main tap root with denser root system including root hairs, while polythene bags are used for raising seedlings, the roots tend to go through the bag into the ground and bags are broken off when the seedlings are moved for planting. The root trainer is mounted on a stand above ground, so that, when the tap root emerges, it is dried by air. This air pruning causes the root inside the pot to thicken with stored carbohydrates which will support vigorous root growth when the plant is put into the ground and avoids nipping of tap root while planting in main field.

Hence, an investigation entitled “Study of containers and rooting media for growth and field establishment of coffee seedlings” was taken up and the results obtained from investigations are discussed under this chapter.

5.1 Effect of containers, rooting media and their interaction on germination and root parameters of coffee seedlings in primary nursery

The maximum germination percentage was recorded in raised bed at 30 (53.62%) and 45 (78.18%) days after sowing, while the minimum germination percentage was registered in the seeds sown in protrays at 30 (39.57%) and 45 (67.08%) days after sowing respectively (Table 1 and Fig. 3). This maximum germination could be attributed to ample surface area, better moisture availability and good aeration in raised bed which facilitated better germination of seeds in raised bed

compared to protrays wherein surface area is less and inadequate drainage. Similar finding was recorded by Jabbar *et al.* (2010) in *Albizia procera* which attained 95% germination within 14 days after sowing in traditional nursery bed.

The different media used for sowing of seeds was significantly influenced on germination percentage of coffee seeds (Table 1 and Fig. 3). The maximum percentage of germination (60.15 and 82.95) at 30 and 45 days after sowing respectively was registered in the media red soil + sand + vermicompost (M_3) while, the lowest germination percentage (36.55 and 64.05) was registered with the media red soil + sand + FYM (M_1). The maximum percentage of seed germination in M_3 media could be attributed to optimal moisture and drainage supported for better imbibing of water into the seed and availability of oxygen with better aeration helped in activation of embryo resulted in better germination of seeds. The results are in conformity with the findings of Bhardwaj (2014) in papaya cv. Red lady.

The interaction effect between containers and media was significantly influenced on germination percentage. The maximum germination percentage (61 and 87.80) was recorded in coffee seeds sown in raised bed prepared using red soil + sand + vermicompost (C_1M_3) at 30 and 45 days after sowing respectively (Table 1 and Fig. 3). This could be attributed to the fact that well decomposed vermicompost maintains optimum moisture and in addition sand provides good aeration and oxygen for better respiration and red soil supports better anchorage, this integrated condition favours for better germination of seeds. Bhardwaj (2014) recorded highest percentage of germination (95.27) in papaya cv. Red lady in similar media of vermicompost: sand: pond soil (1:1:1) with cocopeat.

The containers significantly influenced on length of taproot and the maximum length (4.87 cm) was found with the seedlings grown in raised bed (C_1) while, the least length of taproot (4.27 cm) was registered with the seedlings grown in protrays (Table 2 and Fig. 4). This could be attributed to minimum space and less availability of media in protrays compared to raised bed. Milks *et al.* (1989) reported that plants growing in small containers have the problem of poor aeration or low water holding capacity of the growing medium.

The length of tap root was significantly influenced by different media (Table 2 and Fig. 4). The maximum length of taproot (5.08 cm) was recorded in the seedlings

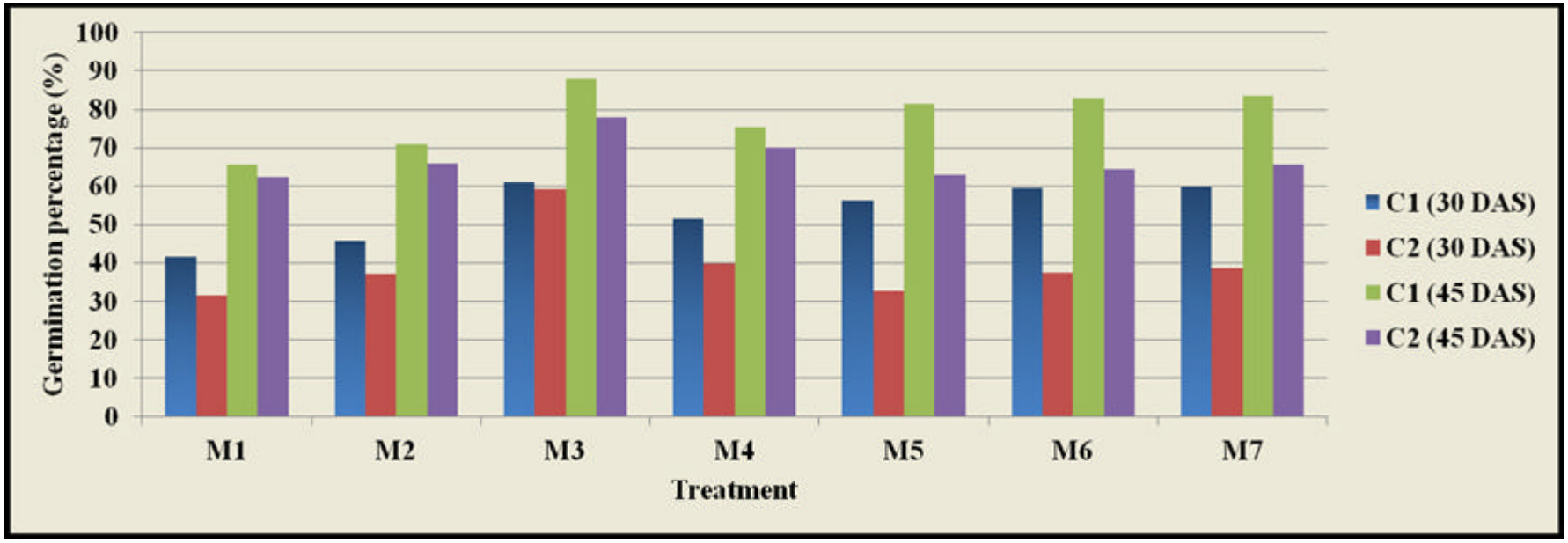

Fig. 3. Effect of containers, rooting media and their interaction on germination percentage in primary nursery at 30 and 45 days after sowing

C_1: Raising in bed

C_2: Protray (2" × 2")

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)

M_2: Red soil + cocopeat + FYM in 3:1:1 ratio

M_3: Red soil + sand + vermicompost (3:1:1)

M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)

M_6: M_5 +VAM (10g/kg FYM)

M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

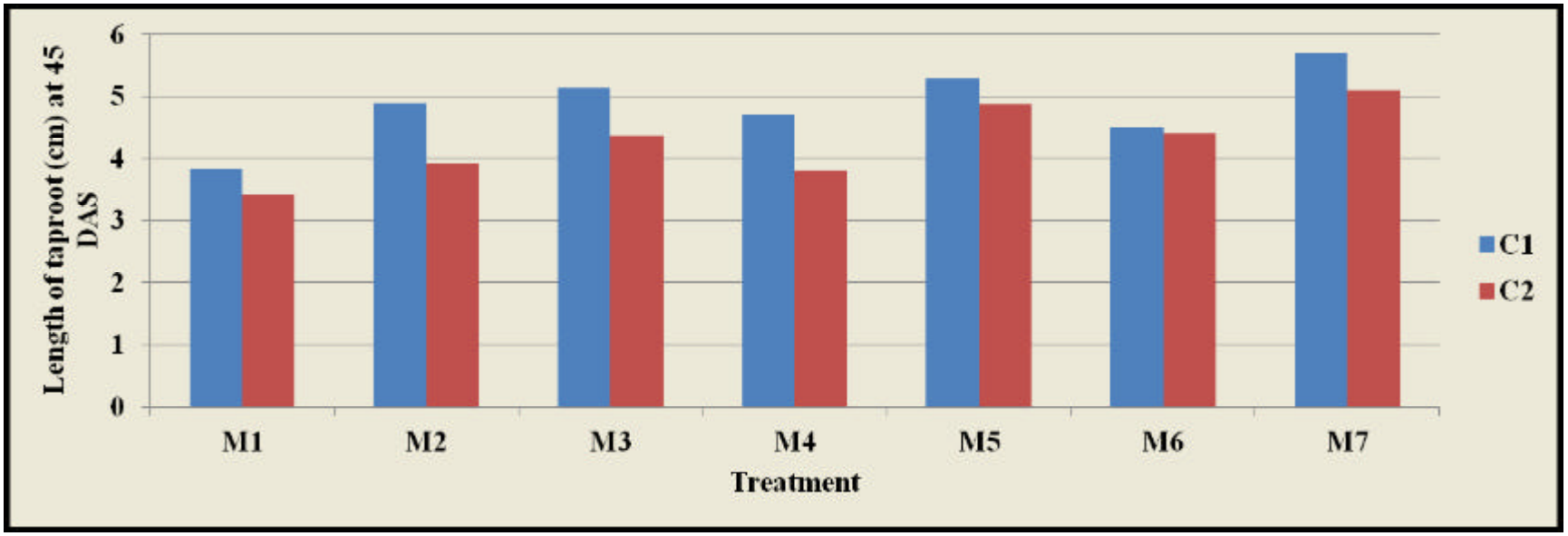

Fig. 4. Effect of containers, rooting media and their interaction on length of tap root (cm) at 45 days after sowing in primary nursery

C_1: Raising in bed

C_2: Protray (2" × 2")

M_1: Red soil + sand+ FYM in 3:1:1 ratio (Control)

M_2: Red soil + cocopeat+ FYM in 3:1:1 ratio

M_3: Red soil + sand+ vermicompost (3:1:1)

M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)

M_6: M_5 +VAM (10g/kg FYM)

M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

grown with red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (M_7) while, the lowest length of taproot (3.62 cm) was found in the media of red soil + sand + FYM - M_1. This could be related to favourable rhizospere created by microbes helps in better absorption of nutrients and also production of bio-active substances which are having similar effect as that of growth regulators helps in increase in growth of taproot. Similar findings was reported by Biradar *et al*. (2006) in coffee seedlings when endophytic fungi VAM (*Glomus fasciculatum*) were inoculated with other microbial cultures especially the *Azospirillum*, P – Solubilizer and N-PGPR.

The interaction between the containers and media significantly influenced on length of taproot (Table 2 and Fig. 4). The maximum length of taproot (5.69 cm) was recorded with raised bed prepared using red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) which was on par with C_1M_5 (5.29 cm) and C_1M_3 (5.14 cm) where as the least tap root length (3.42) was recorded in C_2M_1 which was on par with C_1M_1 (3.83 cm). Similar result was obtained by Prasad *et al.* (2014) wherein, at 100 days after sowing root length was maximum (19.1 cm) in seedlings grown in Jungle soil, farm yard manure and sand (6:2:1) + Consortia (*Azosprillum, Pseudomonas fluorescens,* PSB and VAM). Maximum taproot length in raised bed could be attributed to more free space and adequate media availability facilitates seedlings for its luxuriant growth.

Containers significantly influenced on number of primary roots, the maximum number of primary roots (25.38) was found with raised bed grown seedlings and least (22.71) in protray grown seedlings (Table 3 and Fig. 5). This could be attributed to adequate space, aeration, moisture and better uptake of nutrients. Plants growing in small containers have growth problems due to poor aeration or low water holding capacity of the growing medium which led to less number of primary roots in raised bed (Milks *et al*., 1989).

The maximum number of primary roots (30.25) were produced in the coffee seedlings grown with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) followed by M_5 (23.70) and the least (20.8) was observed in M_1 (Table 3 and Fig. 5). The maximum number of primary roots production with M_7 media treatment could be attributed to adequate nutrition, better uptake due to favourable condition

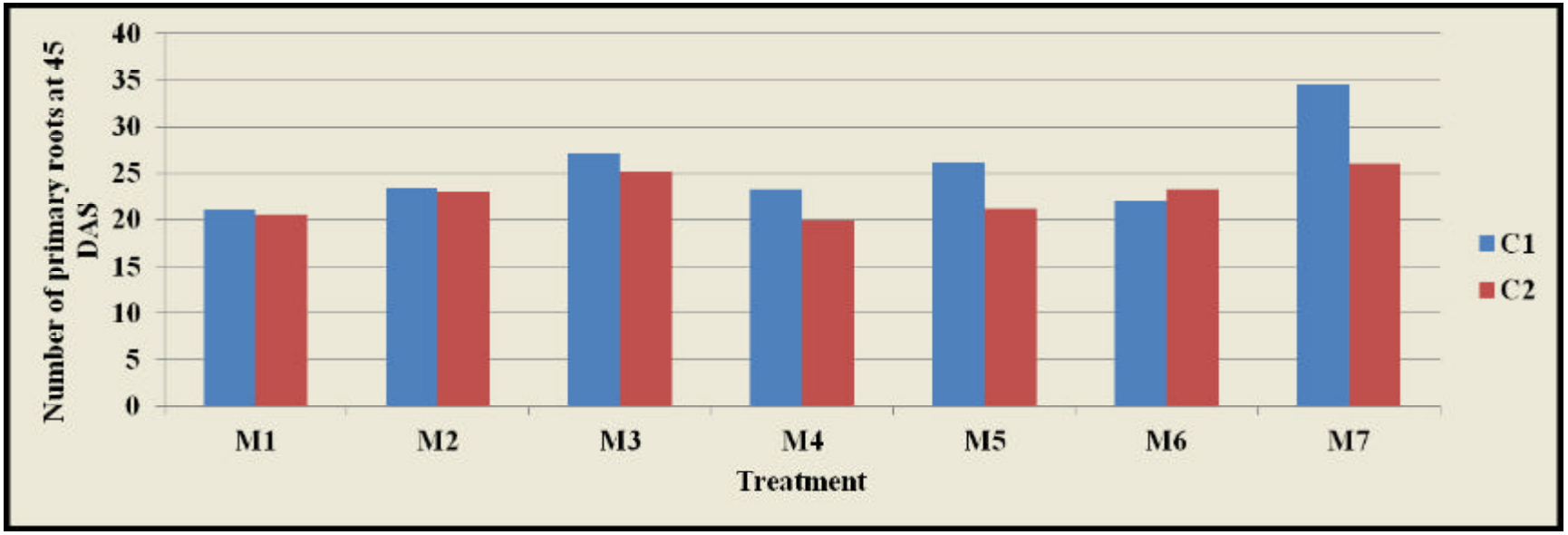

Fig. 5: Effect of containers, rooting media and their interaction on number of primary roots at 45 days after sowing in primary nursery

C_1: Raising in bed

C_2: Protray (2" × 2")

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)

M_2: Red soil + cocopeat+ FYM in 3:1:1 ratio

M_3: Red soil + sand + vermicompost (3:1:1)

M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)

M_6: M_5 +VAM (10g/kg FYM)

M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

around rhizosphere of roots and effective bio-active substances produced by the bio fertilizers. This result was in conformity with the findings of Meenakshisundaram *et al.* (2011) where the combined application of bio-inoculants *Azospirillum* + *Azotobacter* + AM fungi improved the growth response and nutrient uptake of *Delonix regia* seedlings thereby producing good quality planting stock.

The interaction between containers and rooting media found to be significantly influenced on production of primary roots (Table 3 and Fig. 5). The maximum number of primary roots (34.50) was found with the seedlings grown in the treatment C_1M_7 – raised bed prepared using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* followed by C_1M_3 (27.10) and the least (19.90) was recorded in C_2M_4 which was on par with the C_2M_1 (20.50) and C_1M_1 (21.10). This is due to availability of adequate space and balanced uptake of nutrients through FYM as well as bio-inoculants consortia in raised bed compared to protray where there was poor aeration and low water holding capacity (Milks *et al.*, 1989)

The maximum number of secondary roots (3.37) was produced with raised bed grown seedlings and the least number of secondary roots (2.11) was found with protray grown seedlings (Table 4 and Fig. 5). Milks *et al.* (1989) reported that plants growing in small containers have growth problems due to poor aeration, low water holding capacity and nutrition in growing medium. Adequate free space in raised bed compared to protray may led to better growth of lateral roots.

The maximum number of secondary roots (4.45) were produced in the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) followed by M_6 (3.00) and the least (1.50) was found with M_1 which was on par with M_2 (2.10). This could be attributed to better effect of media in combination with bio-fertilizers. This result is in line with the findings of Meenakshisundaram *et al*. (2011) wherein, the combined application of bio-inoculants *Azospirillum* + *Azotobacter* + AM fungi played a significant role in improving the growth response and nutrient uptake of *Delonix regia* seedlings thereby producing good quality planting stock (Table 4 and Fig. 6).

The interaction effect between containers and media was found to be significant and ranged from 1.20 to 5.70 (Table 4 and Fig. 6). The maximum number of secondary roots (5.70) were recorded with the treatment raised bed prepared using

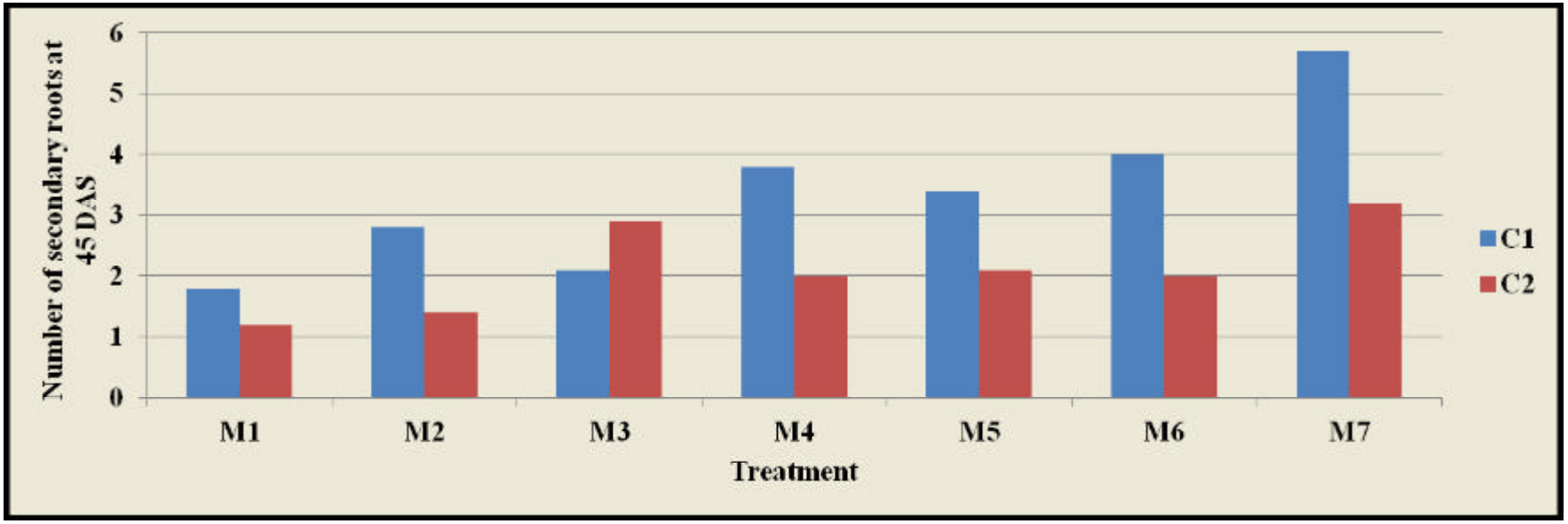

Fig. 6: Effect of containers, rooting media and their interaction on number of secondary roots at 45 days after sowing in primary nursery

C_1:	Raising in bed	**M_1:**	Red soil + sand + FYM in 3:1:1 ratio (Control)	**M_5:**	M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
C_2:	Protray (2" × 2")	**M_2:**	Red soil + cocopeat+ FYM in 3:1:1 ratio	**M_6:**	M_5 +VAM (10g/kg FYM)
		M_3:	Red soil + sand + vermicompost (3:1:1)	**M_7:**	M_5+ PSB + *Azospirillum* (10g/kg FYM)

the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) followed by C_1M_6 (4.00) and the least number of roots was found with C_2M_1 (1.20) which was on par with the C_2M_2 (1.40). This could be attributed to more space availability in raised bed for better production and spread of laterals, while the least number with portray was due to poor aeration and low water holding capacity (Milks *et al.,* 1989) and also due to availability, uptake of balanced and higher quantum of nutrients to seedlings through FYM as well as bio-inoculants consortia compared to control (Prasad *et al*., 2014).

The containers influenced significantly on fresh and dry weight of roots (Table 5, 6 and Fig. 7, 8), the maximum fresh (0.116 g) and dry weight (0.036 g) of roots were recorded in raised bed (C_1) and the least was with protray – C_2 (0.105 g and 0.025 g) respectively. This could be attributed maximum length of taproot, more number of primary and secondary roots and maximum fresh weight in turn resulted in maximum dry weight of roots. Milks *et al.* (1989) reported that plants growing in small containers have growth problems due to poor aeration and low water holding capacity of the growing medium. More space availability in raised bed compared to protrays led to better growth of lateral roots there by fresh and dry weight of roots.

The different rooting media significantly influenced on fresh and dry weight of roots (Table 5, 6 and Fig. 7, 8), the maximum fresh weight of roots (0.125 g) was recorded in M_7 and dry weight in M_7, M_4, M_2 and M_3 (0.035 g) while, the least fresh and dry weight were recorded in M_1 (0.095 g and 0.025 g) respectively. This could be attributed to better uptake of nutrients due to combined influence of media and bio-inoculants. Meenakshisundaram *et al.* (2011) shown that the combined application of bio-inoculants *Azospirillum* + *Azotobacter* + AM fungi might play a significant role in improving the growth response and nutrient uptake of *Delonix regia* seedlings thereby producing good quality planting stock.

The interaction between containers and rooting media was not significantly influenced on fresh and dry weight of roots (Table 5, 6 and Fig. 7, 8). The maximum fresh weight of roots (0.130 g) were recorded with seedlings raised in raised bed prepared using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) followed by C_1M_6 (0.122 g) whereas maximum dry weight of roots (0.040 g) was registered with C_1M_7 and C_1M_6. The least fresh (0.089 g) and dry weight (0.027 g) was recorded in C_2M_7.

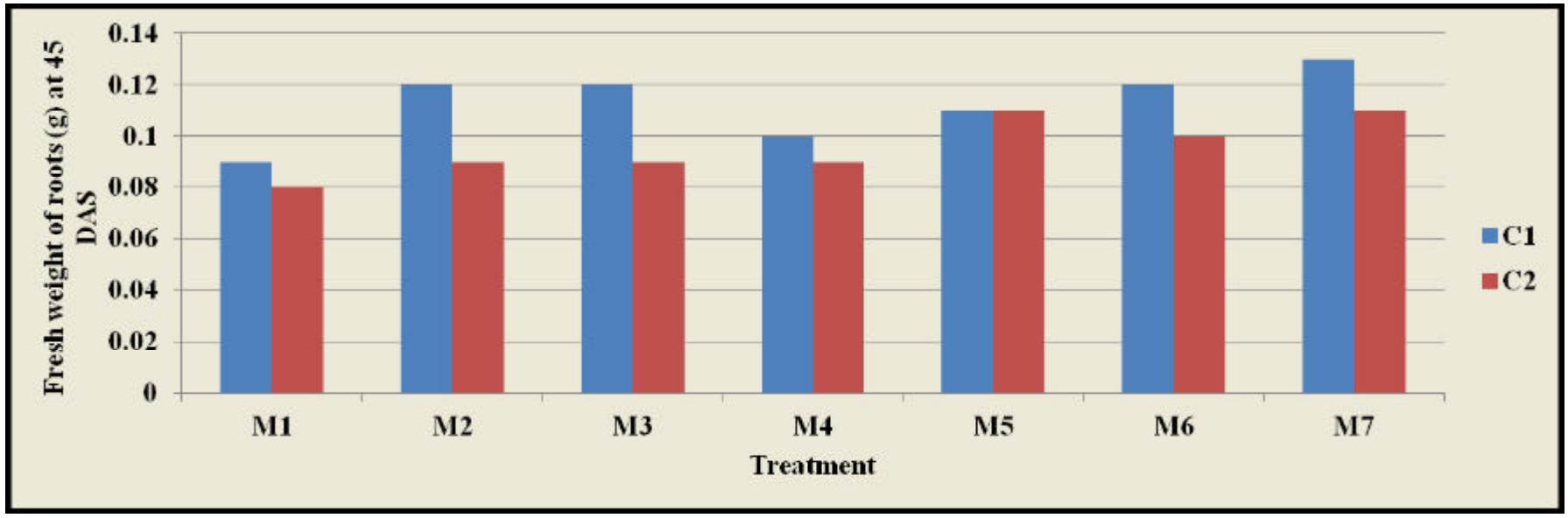

Fig. 7: Effect of containers, rooting media and their interaction on fresh weight of roots at 45 days after sowing in primary nursery

C_1: Raising in bed

C_2: Protray (2" × 2")

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)

M_2: Red soil + cocopeat+ FYM in 3:1:1 ratio

M_3: Red soil + sand + vemicompost (3:1:1)

M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)

M_6: M_5 +VAM (10g/kg FYM)

M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

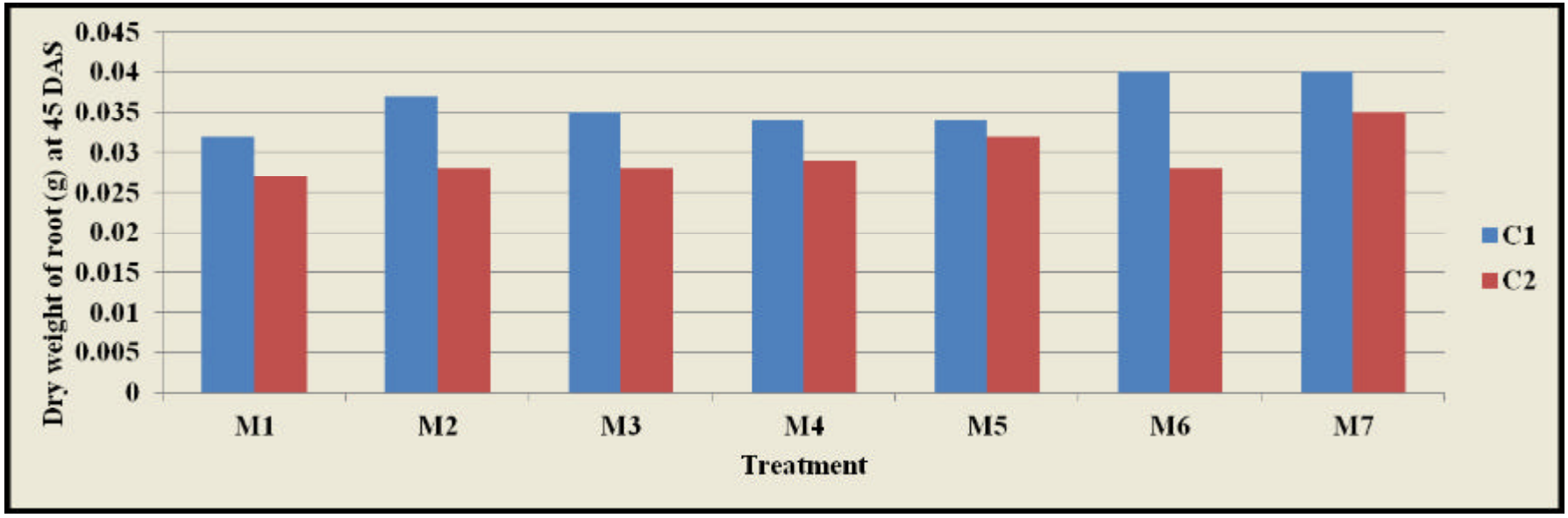

Fig. 8: Effect of containers, rooting media and their interaction on dry weight of roots at 45 days after sowing in primary nursery

C_1: Raising in bed

C_2: Protray (2" × 2")

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)

M_2: Red soil + cocopeat + FYM in 3:1:1 ratio

M_3: Red soil + sand + vermicompost (3:1:1)

M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)

M_6: M_5 +VAM (10g/kg FYM)

M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

C_1M_7 C_1M_6 C_1M_5 C_2M_1

C_1M_7 C_1M_6 C_1M_5 C_2M_1

C_1M_7: Raised bed + red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum*
C_1M_6 Raised bed + red soil + sand + FYM + *Pseudomonas fluorescens*

C_1M_5 Raised bed + red soil + sand + vermicompost (3:1:1)
C_2M_1 Protray + red soil + sand + FYM in (3:1:1) (Control)

Plate 5: Shoot and root growth of coffee seedlings at 45 days after sowing

5.2 Effect of containers, rooting media and their interaction on growth of coffee seedlings in secondary nursery

5.2.1 Plant height (cm)

The containers showed significant variation with respect to plant height (Table 7, 8 and Fig. 9). The maximum plant height (4.29 cm, 6.26 cm, 8.02 cm and 14.91 cm) was found with black polythene bag (C_1) at 60, 90, 120 and 180 days after sowing respectively which was on par with the C_4 (4.23 cm, 5.92 cm, 7.79 cm and 14.35 cm) whereas, the least plant height (3.68 cm) was recorded in C_2 which was on par with C_5 (3.75 cm) at 60 days after sowing. At 90 days after sowing least plant height (5.44 cm) was noticed in C_5 which was on par with C_3 (5.64 cm) and C_2 (5.67 cm). At 120 and 180 days after sowing least plant height (6.70 cm and 11.69 cm) was recorded in C_5 respectively. Similar results were obtained in rubber seedlings raised in polybag and root trainer (67.9 cm and 62.2 cm) respectively (Soman *et al*., 2011).

The different rooting media significantly influenced on the plant height at 60, 90, 120 and 180 days after sowing (Table 7, 8 and Fig. 9). The maximum plant height (4.39 cm, 6.44 cm, 8.15 cm and 14.78 cm) was recorded in red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) at 60, 90, 120 and 180 days after sowing respectively. Whereas, the lowest plant height (3.46 cm, 5.23 cm, 6.48 cm and 11.69 cm) was recorded in M_1 at 60, 90, 120 and 180 days after sowing respectively. This could be attributed to adequate nutrition, better uptake of nutrients, production of bio-active substances from bio-inoculants which was similar action of growth regulators facilitate better cell division and cell elongation results in better plant height. Similarly maximum plant height was recorded at the time of field planting in case of coffee seedlings treated with *Azospirillum* + VAM + PSB + N PGPR (Biradar *et al*., 2006). Marina Prem Kumari and Balasubramanian, (1993), reported that inoculation of two bio-fertilizers enhanced production and subsequent release of IAA, IBA, NAA, GA 1, 2, 3 phytohormones, vitamins, antibiotics and other PGPRs in growth media and *Azospirillum* and VAM fungi in combined inoculation boosted the growth, dry matter production of coffee seedlings at all the stages. Further, consortia of these microbes in increasing nutrients availability helped the seedlings to attain maximum growth as compared to individual inoculation.

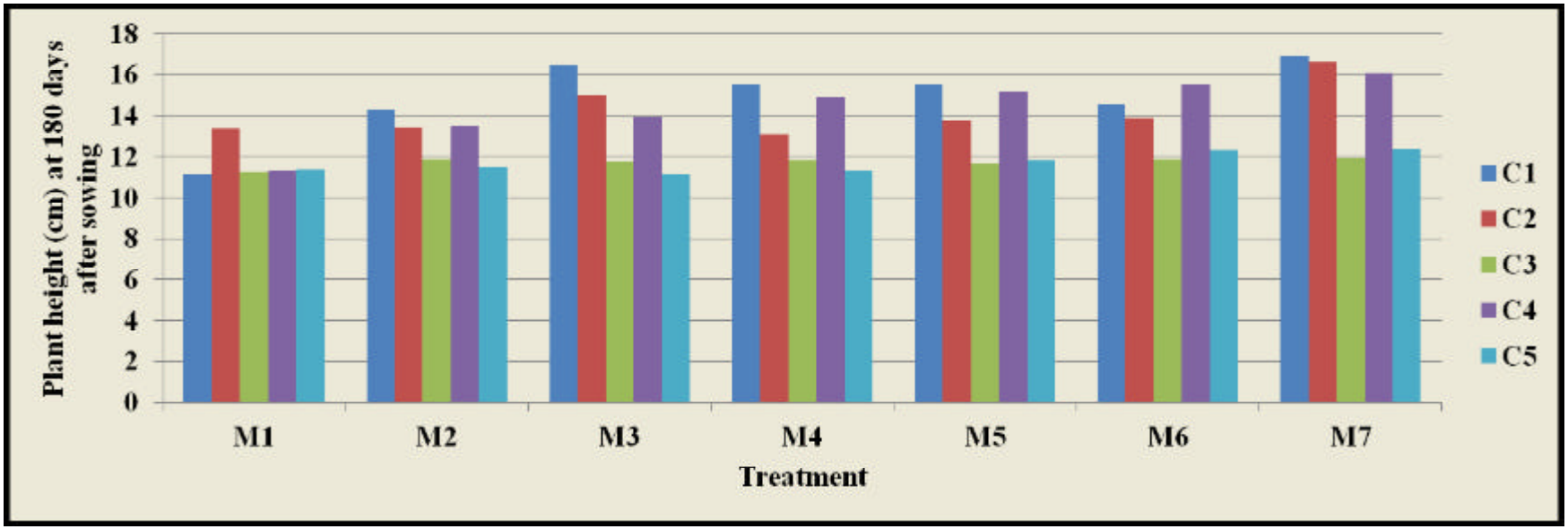

Fig. 9: Effect of containers, rooting media and their interaction on plant height (cm) of coffee seedlings at 180 days after sowing

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

The interaction effect between containers and rooting media were significantly influenced on plant height at 60, 90, 120 and 180 days after sowing (Table 7, 8 and Fig. 9). The maximum plant height (5.32 cm, 7.45 cm and 8.87 cm) was recorded in black polythene bag containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) which was on par with C_4M_7 (4.89 cm, 6.5 cm and 8.80 cm) whereas the lowest plant height (2.51 cm, 4 cm and 5.20 cm) was registered with C_5M_1 at 60, 90 and 120 days after sowing respectively. Similarly at 180 days after sowing maximum plant height (16.91 cm) was recorded in black polythene bag containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) which was on par with C_2M_7 (16.65 cm), C_1M_3 (16.5 cm) and C_4M_7 (16.06 cm) where as the lowest plant height (11.15 cm) was recorded in C_1M_1 which was on par with C_5M_3 (11.16 cm) and C_3M_1 (11.28 cm). This increased height in black polybag (6" × 9") containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* is due to availability of space, nutrients as well as growth media containing bio-inoculants which helped in vigorous growth of seedlings, further, bigger poly bags could able to retain more amount of moisture for longer time which resulted in better growth of seedlings (Biradar *et al*., 2014). The colour and thermal conductivity of container materials have a direct bearing on heat absorption by containers and thus the temperature of the growing medium and the interaction of type and colour of container and potting medium may produced differences in growth (Sharma, 1996).

5.2.2 Number of leaves

The influence of container did not differ significantly on number of leaves at 60 days after sowing. The observation made at 90 days after sowing, the maximum number of leaves (4.82) was registered with black polythene bag (C_1), which was on par with root trainer - C_4 (4.77) whereas the lowest number of leaves (4.45) was recorded in C_5. Similarly at 120 and 180 days after sowing, the maximum number of leaves were recorded in both C_1 and C_4 (6.11 and 7.71), while the least number of leaves was recorded in C_3 (5.88 and 6.34) respectively (Table 9, 10 and Fig. 10). Similar trend of results have also been reported by Soman *et al*. (2011) in *Hevea*.

The rooting media significantly influenced on number of leaves at 60, 90, 120 and 180 days after sowing (Table 9, 10 and Fig. 10). The maximum number of leaves (2.70, 5.04 and 6.32) was recorded in red soil + sand + FYM + *P. fluorescens* + PSB

+ *Azospirillum* (M_7) and the least (2.06, 4.36 and 5.80) in M_1 at 60, 90 and 120 days after sowing. Whereas at 180 days after sowing maximum number of leaves (7.84) was recorded in -red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) but the least number of leaves (6.72) was recorded in M_2 which was on par with the M_1 (6.84). Increased leaf production could be attributed to increased plant height, synthesis of more carbohydrates due to balanced nutrition. It was also related to production of bio-active substances and better absorption of nutrients due to bio-inoculants which favoured the production of more number of leaves. Similar trend of results have also been reported by Prasad *et al*. (2014) in coffee when grown using the rooting media Jungle soil, farm yard manure (FYM) and sand (6:2:1) + *Azosprillum*, *Pseudomonas fluorescens* , PSB and VAM (100 g).

The interaction effect between of containers and rooting media did not influenced significantly on number of leaves at 60, 90 and 120 days after sowing (Table 9, 10 and Fig. 10). Whereas at 180 days after sowing, there was significant difference between containers and rooting media. The maximum number of leaves (9.2) was recorded in black polythene bag filled with - red soil + sand + FYM + *P. flouresence* + PSB + *Azospirillum* (C_1M_7) which was on par with the C_4M_7 - red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (8.8) whereas the least number of leaves (6.00) were recorded in C_3M_1 and C_3M_4 which was on par with C_5M_2 (6.20) and C_5M_3 (6.20) at 180 days after sowing. This is due to availability and uptake of balanced and higher quantum of nutrients to seedlings through FYM as well as bio-inoculants consortia (Prasad *et al.*, 2014) which helped in production of more number of leaves. Further, bigger poly bags could able to retain more amount of moisture for longer time which resulted in better growth of seedlings (Biradar *et al*., 2014).

5.2.3 Leaf area (cm^2)

The container did not significantly influenced on leaf area at 60 days after sowing. Whereas at 90, 120 and 180 days after sowing significant difference was observed (Table 11, 12 and Fig. 11). The maximum leaf area (3.71 cm^2, 17.96 cm^2 and 53.37 cm^2) was registered with root trainer (C_4) at 90, 120 and 180 days after sowing respectively and the least leaf area (1.85 cm^2 and 10.94 cm^2) was registered with C_5 at 90 and 120 days after sowing and C_3 (27.39 cm^2) at 180 days after sowing respectively. Increased leaf area in the seedlings grown in root trainer is because, root

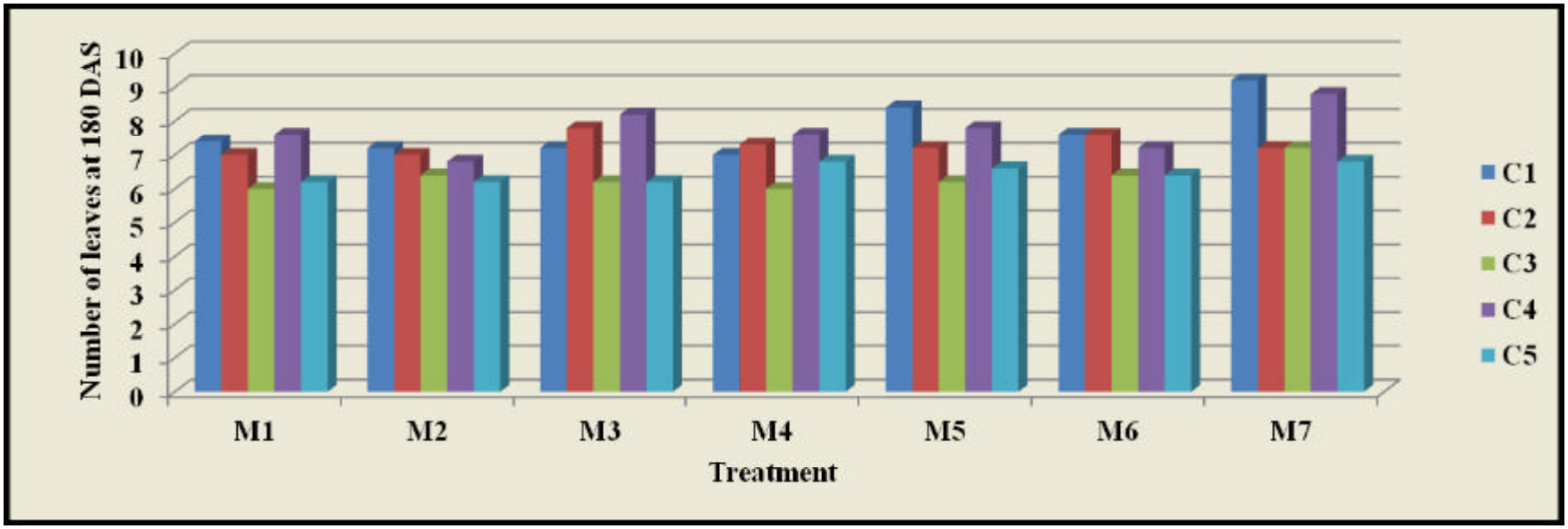

Fig. 10: Effect of containers, rooting media and their interaction on number of leaves in coffee seedlings at 180 days after sowing

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

trainers have better conditions *viz*., regulated supply of nutrients, moisture and better aeration due to container shape, opening at the bottom and drainage holes (Nandakumar, 1996).

The rooting media did not significantly differ with respect to leaf area at 60 days after sowing (Table 11, 12 and Fig. 11). Whereas, at 90,120 and 180 days after sowing significant difference was registered with respect to leaf area. The maximum leaf area (3.11 cm^2, 21.66 cm^2 and 52.87 cm^2) was recorded in red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) at 90, 120 and 180 days after sowing respectively. The lowest leaf area (2.10 cm^2, 12.18 cm^2 and 36.46 cm^2) was found with M_1 at 90, 120 and 180 days after sowing respectively. This could be attributed to adequate nutrition, better uptake of nutrients, production of bio-active substances from bio-inoculants which was similar action of growth regulators facilitate better cell division and cell elongation results in better leaf area. This results are in conformity with the findings of Prasad *et al*. (2014) in coffee seedlings where leaf area was higher in seedlings receiving treatment Jungle soil, farm yard manure (FYM) and sand (6:2:1)+ 100 g consortia (VAM + PSB + *Azosprillum* + *Pseudomonas fluorescens*).

The interaction effect between containers and rooting media was found to be significant from 90 days after sowing (Table 11, 12 and Fig. 11). At 60 days after sowing there was no significant difference between container and rooting media. The maximum leaf area (4.39 cm^2) was recorded in root trainer filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) and in root trainer filled with red soil + sand + FYM + *P. fluorescens* (C_4M_5) whereas the least leaf area was recorded in the treatment C_2M_4 (1.27 cm^2) at 90 days after sowing. At 120 days after sowing maximum leaf area (36.05 cm^2) was found in red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) and least (8.02 cm^2) was registered with C_5M_4. Similarly, at 180 days after sowing, the maximum leaf area (60.95 cm^2) was recorded in C_4M_7 and the least (18.29 cm^2) was recorded in C_3M_1 which was on par with C_3M_4 (21.95 cm^2). This superiority could be attributed better nutrition, moisture, aeration facilitates better enlargement and elongation of cell result in better growth of leaf. This was also related to organic-rich potting medium (red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum*) used in the study would have exhibited favourable physical and chemical properties (drainage, aeration, water holding

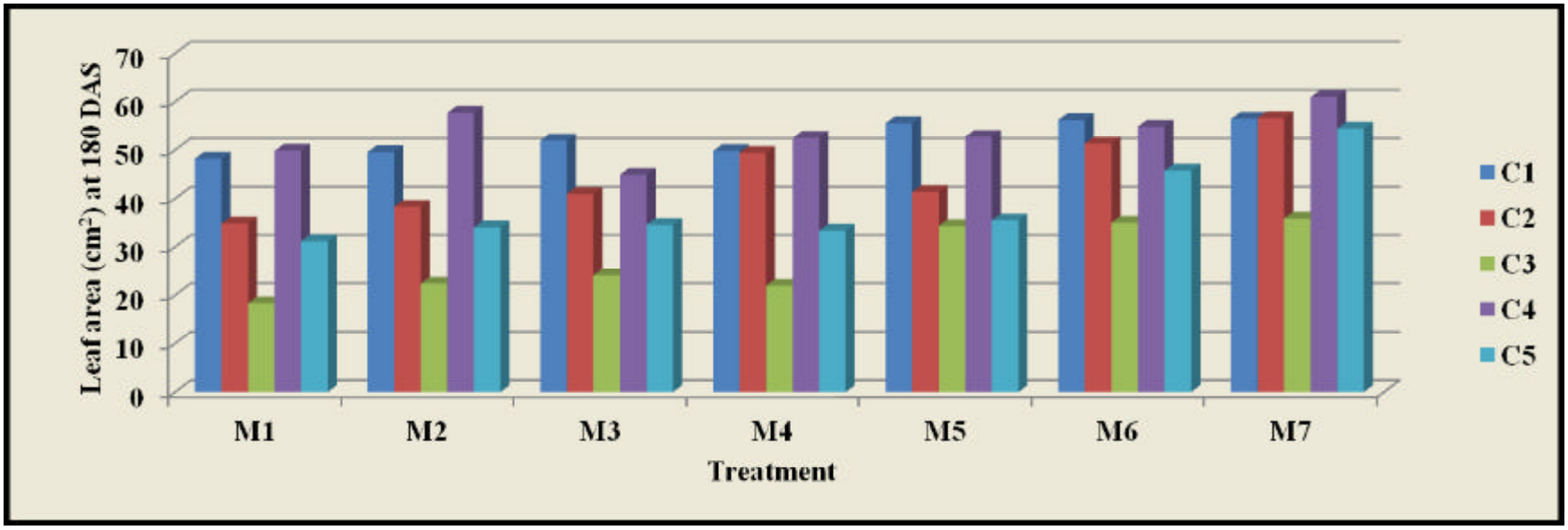

Fig. 11: Effect of containers, rooting media and their interaction on Leaf area (sq cm) of coffee seedlings at 180 days after sowing

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

capacity and nutrition) in root trainers. In polybags with inadequate drainage, however, the same medium may have hindered root growth and consequently shoot growth of seedlings (Annapurna *et al.,* 2004).

5.2.4 Collar girth (mm)

The containers significantly influenced on collar girth at 90 and 180 days after sowing (Table 13 and Fig. 12). The maximum collar girth (2.63 mm and 3.63 mm) was recorded with root trainer (C_4) and least was recorded in the treatment C_3 (2.4 mm and 3.18 mm) at 90 and 180 days after sowing respectively. This result is in accordance with the findings of Annapurna *et al*. (2004) where collar diameter at 6 month after sowing recorded maximum in root trainer grown sandal wood seedlings (3.3 mm).

The different rooting media significantly influenced on collar girth (Table 13 and Fig. 12). The maximum collar girth (2.91 mm and 3.65 mm) was recorded in the media red soil + sand + FYM + PSB + *Azospirillum* (M_7) and least (2.37 mm and 3.20 mm) in the treatment M_1 at 90 and 180 days after sowing respectively. This result is in line with the findings of Prasad *et al.* (2014) who found significant increase in collar girth of coffee seedlings when media containing Jungle soil, farm yard manure (FYM) and sand (6:2:1) + *Azosprillum* , *P. fluorescens*, Phosphate Solubilizing Bacteria and Vesicular Arbuscular Mycorrihiza (100 g) were used to raise coffee seedlings in nursery.

The interaction effect between the container and rooting media was significantly influenced on girth at the collar region (Table 13 and Fig. 12). The maximum collar girth (3.13 mm and 4.01 mm) was recorded in root trainer filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) and least (2 mm and 2.85 mm) was registered with the treatment C_3M_1 at 90 and 180 days after sowing respectively. This result was in conformity with the findings of Soman *et al.* (2011) where collar diameter of *Hevea* seedling recorded highest when grown in root trainer (8.66 mm) compared to polybag (7.93 mm) and in root trainer, the superior quality potting medium [red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum*) used also helps in efficient storage and release of nutrients (Nandakumar, 1996).

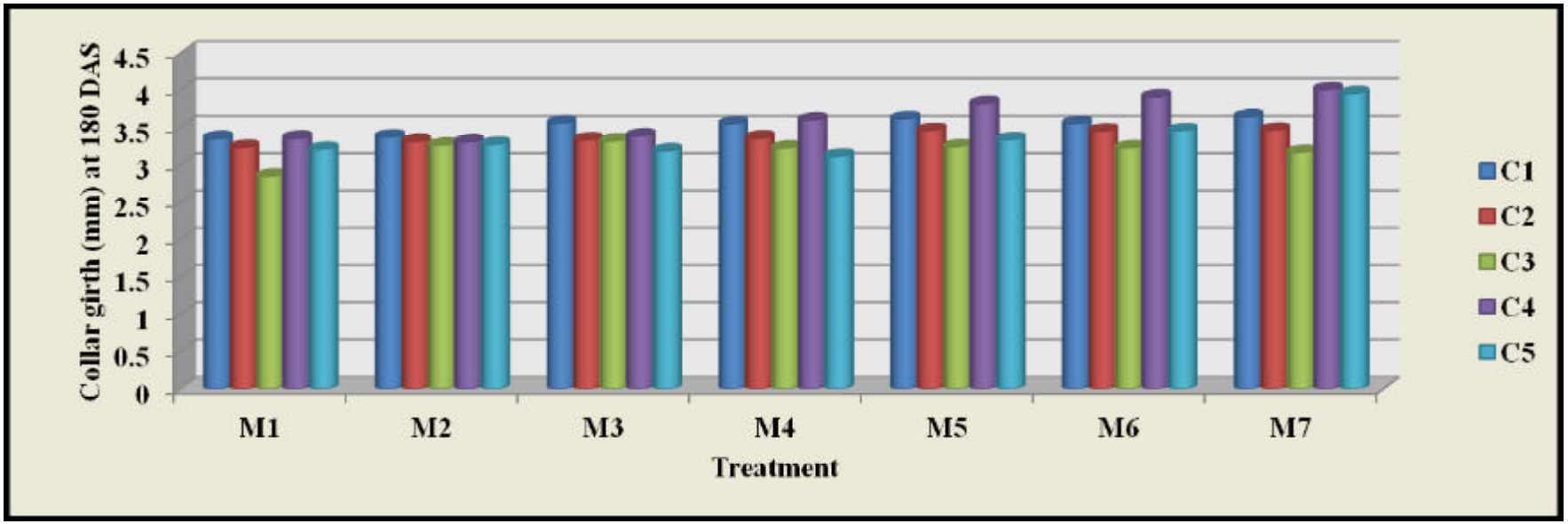

Fig. 12: Effect of containers, rooting media and their interaction on collar girth of coffee seedlings at 180 days after sowing

C_1: Black polythene bag (6" × 9") [Control]

C_2: Transparent polythene bag (6" × 9")

C_3: Protray raised seedlings in black polythene bag (6" × 9")

C_4: Root trainers

C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)

M_2: Red soil + cocopeat + FYM in 3:1:1 ratio

M_3: Red soil + sand + vermicompost (3:1:1)

M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)

M_6: M_5 +VAM (10g/kg FYM)

M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

5.2.5 Taproot length (cm)

The containers had significant influence on length of tap root (Table 14 and Fig. 13). At 90 days after sowing, the maximum length of taproot (8.98 cm) was registered with root trainer (C_4) and least (6.38 cm) in the treatment C_3. At 180 days after sowing, the maximum taproot length (19.18 cm) was recorded in black polythene bag (C_1) which was on par with C_5 (18.36 cm) and least (15.06 cm) in the C_4 which was on par with C_2 (17.54 cm) and C_3 (17.09 cm). This result is in line with the findings of Ferdousee *et al.* (2010) where poly bag of size 23 × 15 cm recorded highest root length in *Leucaena leucocephala* seedlings. The stop in taproot growth during later period in root trainer is because, containers (root trainer) have large bottom hole which promote good drainage and encourage air pruning. Roots stop growing when they reach an air layer under the container. Polybags generally produce seedlings with poorly formed root systems that spiral around the sides and the bottoms of the smooth-walled containers (Thomas *et al*., 1990).

The different media used significantly influenced on taproot length (Table 14 and Fig. 13). The maximum taproot length (9.47 cm and 19.63 cm) was recorded in red soil+ sand+ FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) and the least (6.46 cm and 15.55 cm) was recorded in M_1 at 90 and 180 days after sowing respectively. This could be related to favourable rhizospere created by microbes helps in better absorption of nutrients and also production of bio-active substances which are having similar effect as that of growth regulators helps in increase in growth of taproot. Similar results were recorded by Prasad *et al*., (2014) when coffee seedlings were raised using the media Jungle soil, farm yard manure and sand (6:2:1) + *Azospirillum, P. fluorescens*, Phosphate Solubilizing Bacteria and Vesicular Arbuscular Mycorrihiza (19.1 cm at 200 days after sowing) and Biradar *et al*., (2006) when coffee seedlings were treated with *Azospirillum* +VAM + P-Solubalizer + N-PGPR (31.1 cm at 150 days after sowing).

The interaction effect between the containers, rooting media and their interactions were found to be significant (Table 14 and Fig. 13) and at 90 days after sowing, the maximum taproot length (12.63 cm) was recorded in root trainer filled with the media red soil + sand + FYM + PSB + *Azospirillum* (C_4M_7) which was on par with the C_4M_6 (10.93 cm) and least (5.98 cm) was recorded in control (C_1M_1). At

180 days after sowing the interaction effect was found to be significant and the maximum (22.26 cm) was recorded in C_5M_7 which was on par with C_1M_7 (21.41 cm), C_1M_6 (20.98 cm). The least taproot length was recorded in C_4M_3 (14.77 cm) which was on par with C_2M_1 (14.80 cm) and C_4M_2 (14.84 cm). This result is in line with the findings of Ferdousee *et al.* (2010) where poly bag of size 23 × 15 cm recorded highest root length followed by nursery bed in *Leucaena leucocephala*. The stop in taproot growth during later period is because, containers (root trainer) have large bottom hole which promote good drainage and encourage "air pruning". Roots stop growing when they reach an air layer under the container (Thomas *et al*., 1990). According to Annapurna *et al.* (2004) in sandalwood, organic-rich potting medium used in the study had exhibited favourable physical and chemical properties (drainage, aeration, water holding capacity and nutrition) in root trainers, whereas in polybags with inadequate drainage, however, the same medium had hindered root growth and consequently shoot growth of seedlings.

5.2.6 Number of primary and secondary roots

The containers showed significant differences with respect to number of primary and secondary roots (Table 15, 16 and Fig. 14, 15). The maximum number of primary roots (50.20 and 172.14) was recorded in root trainer (C_4) and least (38.11 and 136.20) in the C_1 at 90 and 180 days after sowing respectively. Similarly the maximum number of secondary roots (54.10 and 428.1) was recorded in C_4 and least in the C_1 (31.90 and 320.6) at 90 and 180 days after sowing respectively. This result is in accordance with the findings of Soman *et al*. (2010) where average of 14.4 lateral roots were recorded in root trainer grown rubber plants as against 7.8 laterals in polybag plants of same age. In root trainer nursery lateral root formation is enhanced by providing a temporary stress during the hardening process (Soman et al. 2013).

The rooting media significantly influenced on number of primary and secondary roots (Table 15, 16 and Fig. 14, 15). The maximum number of primary roots (49.9 and 424.7) was recorded with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7), while M_1 recorded the minimum number of primary roots (33.22 and 116.88). This could be attributed to adequate nutrition, better uptake due to favourable condition around rhizosphere of roots and effect bio-active substances produced by the bio fertilizers. Similarly, the maximum number of secondary roots

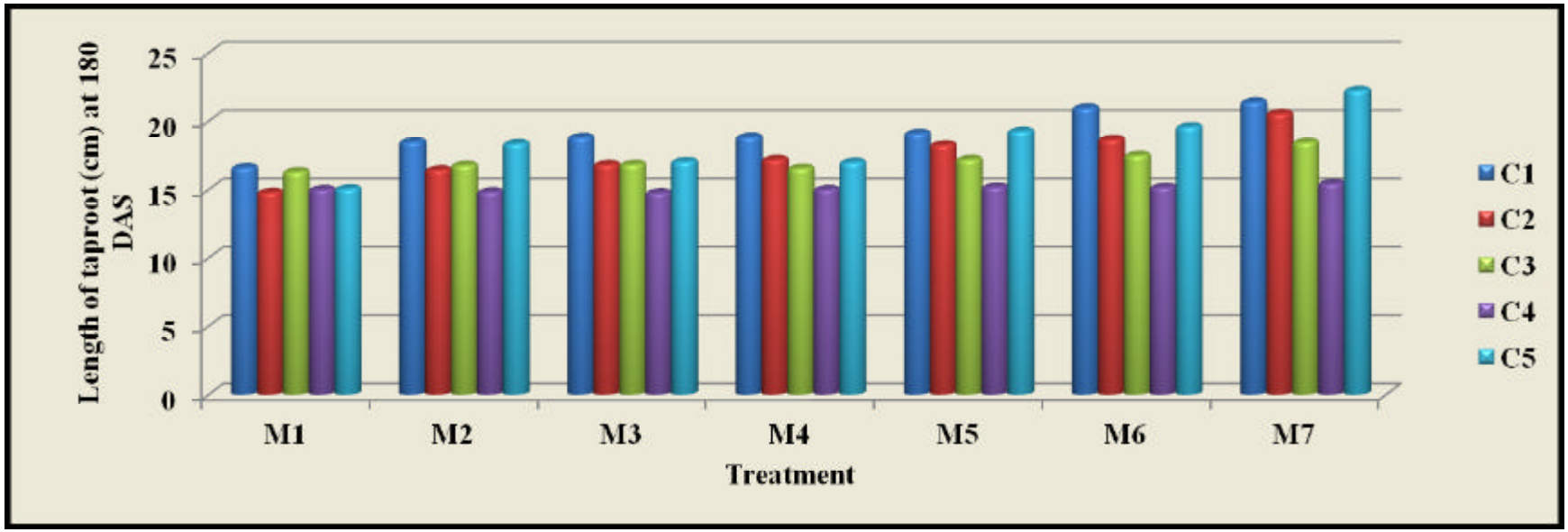

Fig. 13: Effect of containers, rooting media and their interaction on length of taproot of coffee seedlings at 180 days after sowing

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

(55.90 and 424.7) was recorded in M_7 and the least in M_1 (27.26 and 292.7). The similar results were reported by Anandaraj and Leema (2010) in green gram.

The interaction effect between containers and media was found to be significant with respect to number of primary and secondary roots (Table 15, 16 and Fig. 14, 15). The maximum number of primary roots (64.90 and 238.6) were recorded in the treatment root trainer filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) at 90 and 180 days after sowing and least (30.90) was recorded in C_3M_1 which was on par with C_1M_1 (32.3) at 90 days after sowing and at 180 days after sowing the least number of primary roots (104.2) were recorded in C_1M_1. Similarly the maximum number of secondary roots (65.60 and 557.8) were recorded in root trainer filled with red soil + sand + FYM + PSB + *P. fluorescens* + *Azospirillum* (C_4M_7) at 90 and 180 days after sowing respectively, whereas the least number of secondary roots (20.15) were recorded in C_2M_1 which was on par with C_1M_1 (21.15) at 90 days after sowing and C_1M_1 (213.8) at 180 days after sowing. This could be because of good media combination of FYM and bio-inoculants helps in development of a healthy and fibrous root system and this root trainer is used to produce seedlings with more fibrous root system. This container have open bottom and vertical ribs which avoid root coiling and allow for free flow of air resulting in proliferation of lateral roots (Saravanan *et al*., 2013). In teak planting stock improvement through VAM fungal manipulation using root trainer seedlings showed promising result and the root trainer technology offers quick assessment of mycorrhization of root system (Mohanan, 2002).

5.2.2.3 Effect of container, rooting media and their interactions on fresh and dry weight of roots (g) at 90 and 180 days after sowing

The containers influenced significantly on fresh and dry weight of roots (Table 17, 18 and Fig. 16, 17), the maximum fresh weight of roots (0.46 g and 2.11 g) were recorded in the container root trainer (C_4) and the least (0.30 g and 1.36 g) in C_1 at 90 and 180 days after sowing respectively. Similarly, the maximum dry weight of roots (0.136 g and 0.695 g) was recorded with the root trainer container (C_4) and the least (0.069 g and 0.466 g) in C_1 at 90 and 180 days after sowing respectively. Similar result was recorded by Annapurna *et al.* (2004) in Indian sandalwood.

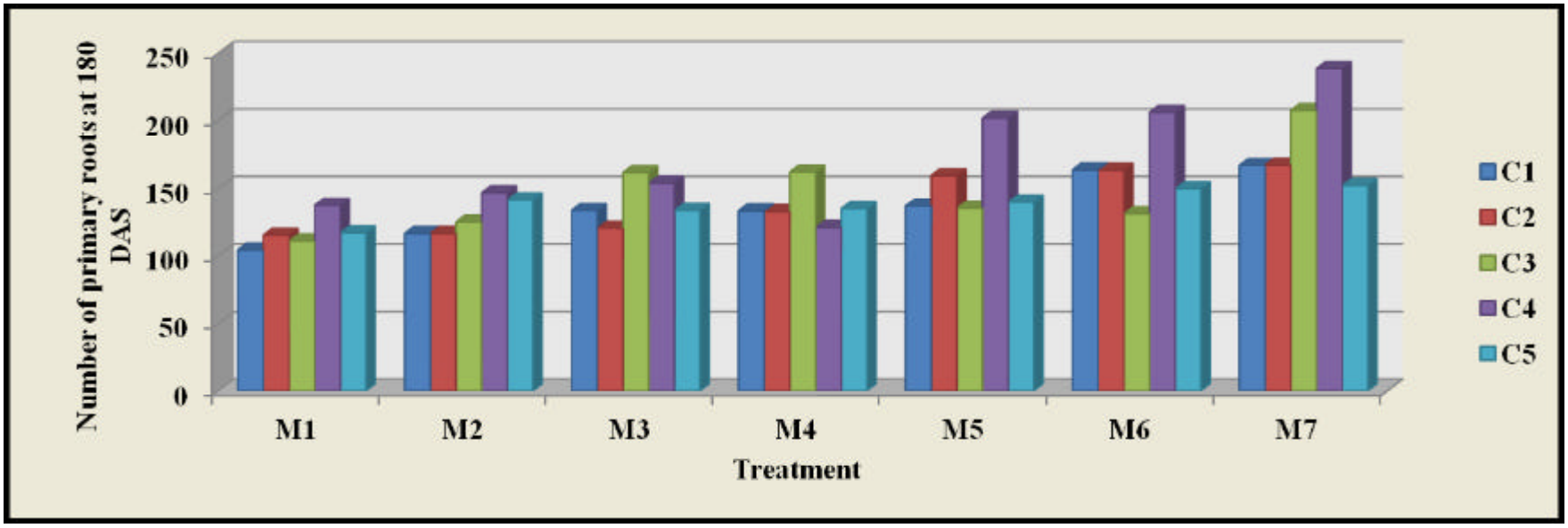

Fig. 14: Effect of containers, rooting media and their interaction on number of primary roots of coffee seedlings at 180 days after sowing

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

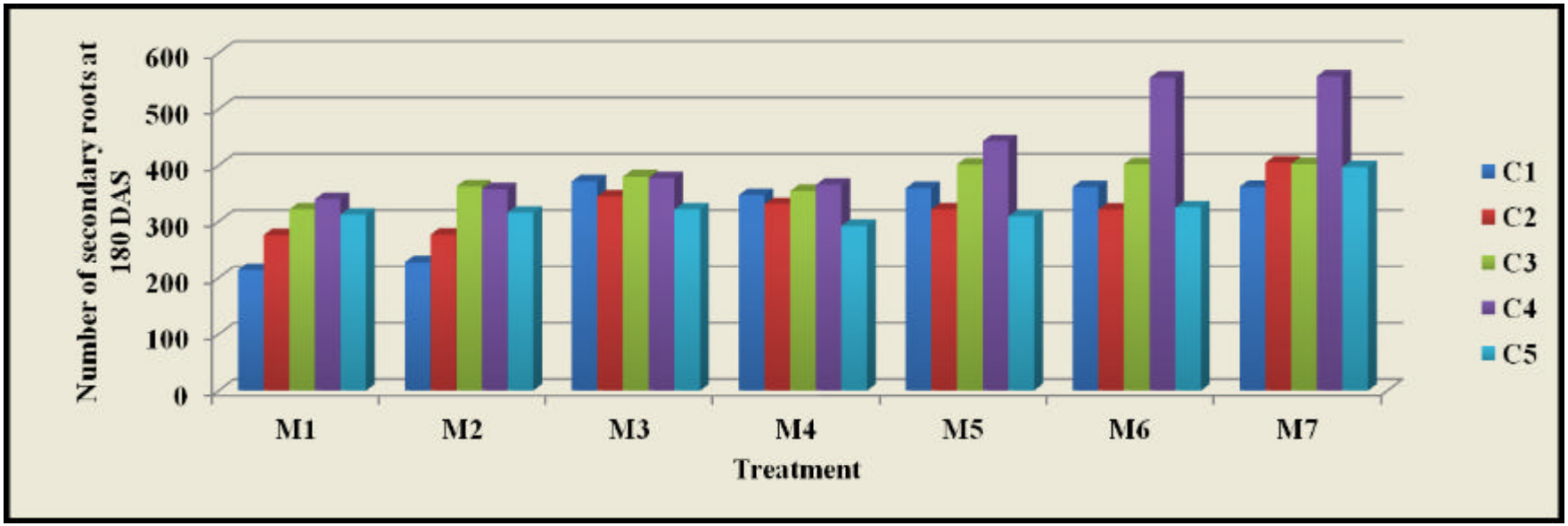

Fig. 15: Effect of containers, rooting media and their interaction on number of secondary roots of coffee seedlings at 180 days after sowing

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

The different rooting media significantly influenced on fresh and dry weight of roots (Table 17, 18 and Fig. 16, 17), the maximum fresh weight of roots (0.42 g and 2.01 g) were recorded in the seedlings grown in the media containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (M_7) and the least (0.29 g and 1.29 g) in M_1 at 90 and 180 days after sowing. Similarly, the maximum dry weight (0.128 g and 0.710 g) was recorded in the media red soil + sand + FYM + PSB + *Azospirillum* (M_7) and the least in M_1 (0.058 g and 0.435 g) at 90 and 180 days after sowing respectively. Similar result was obtained by Biradar *et al*., (2006) in coffee. Meenakshisundaram *et al*. (2011) shown that the combined application of bio-inoculants *Azospirillum* + *Azotobacter* + AM fungi might play a significant role in improving the growth response and nutrient uptake of *Delonix regia* seedlings thereby producing good quality planting stock.

The interaction between containers and rooting media significantly influenced on fresh and dry weight of roots (Table 17, 18 and Fig. 16, 17). The maximum fresh weight of roots (0.65 g and 2.96 g) was recorded in root trainer filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) and the least (0.27 g and 1.22 g) was recorded in C_1M_1 at 90 and 180 days after sowing respectively. Similarly, the dry weight of roots recorded maximum (0.242 g and 1.098 g) in root trainer filled with red soil + sand + FYM + PSB + *Azospirillum* (C_4M_7) and the least (0.049 g and 0.400 g) was recorded in C_1M_1 at 90 and 180 days after sowing respectively. Similar result was obtained by Biradar *et al*. (2006) when endophytic fungi VAM (*Glomus fasciculatum*) were inoculated with other microbial cultures especially the *Azospirillum*, P–Solubilizer and N-PGPR in coffee seedlings compared to individual inoculations. This container have open bottom and vertical ribs which avoid root coiling and allow for free flow of air resulting in proliferation of lateral roots (Saravanan *et al*., 2013) and there by higher fresh and dry weight of roots.

5.3 Effect of containers, rooting media and their interaction on growth and field establishment of coffee seedlings in the main field

5.3.1 Survivability (%)

Survival percentage in the main field was cent percent in all containers except C_5 (raised bed) where 75.1 per cent survivability was recorded (Table 19 and Fig. 18).

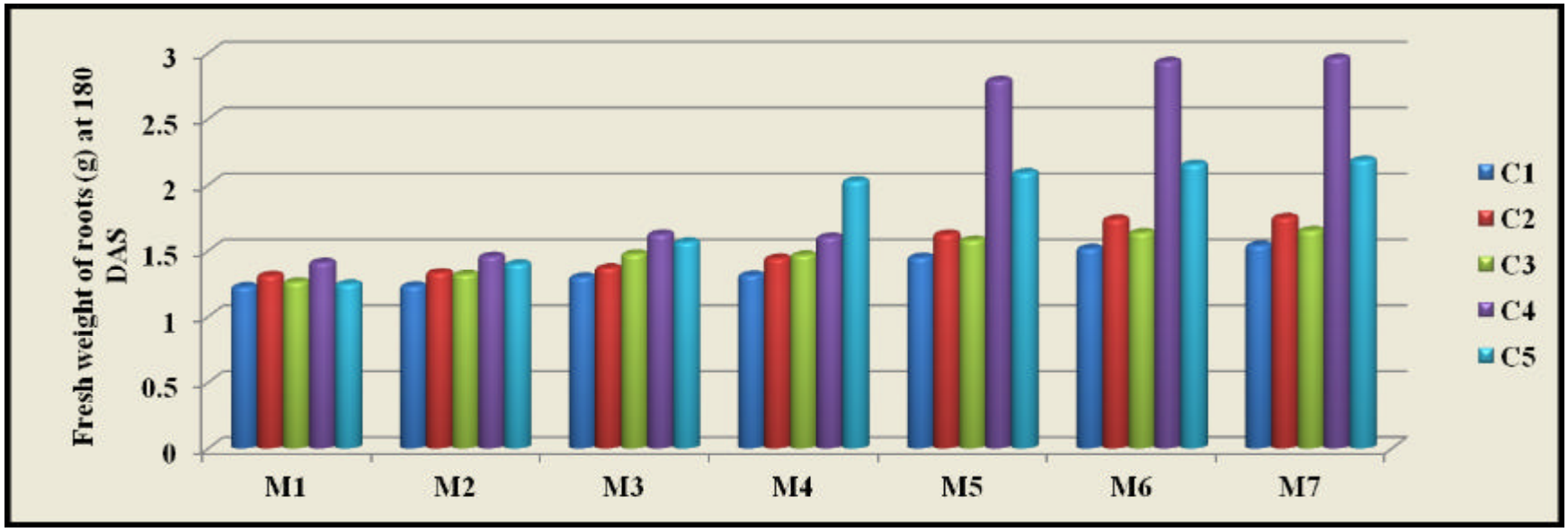

Fig. 16: Effect of containers, rooting media and their interaction on fresh weight of roots (g) of coffee seedlings at 180 days after sowing

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

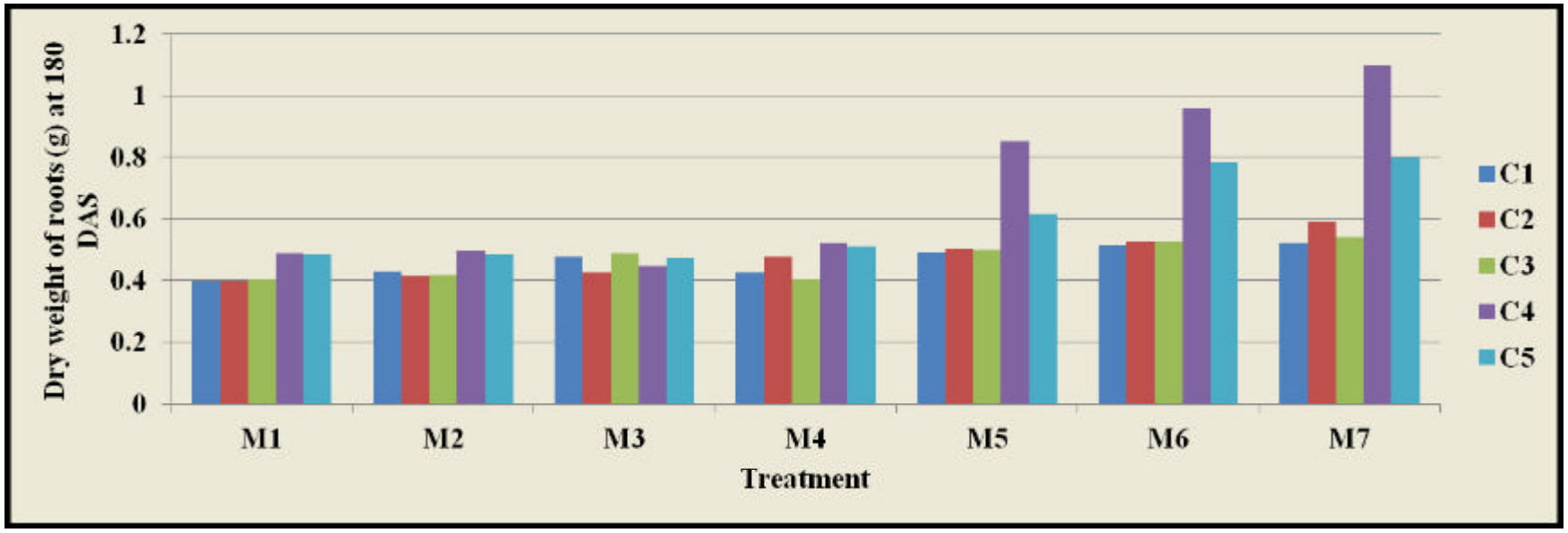

Fig. 17: Effect of containers, rooting media and their interaction on dry weight of roots (g) of coffee seedlings at 180 days

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 + VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

C_1M_7 C_4M_7 C_1M_1

C_1M_7 C_4M_7 C_1M_1

C_1M_7: Black polythene bag + red soil + sand + FYM + *Pseudomonas fluorecens* + PSB + *Azospirillum*
C_4M_7: Black polythene bag + red soil + sand + FYM + *Pseudomonas fluorecens* + PSB + *Azospirillum*

C_1M_1: Black polythene bag + red soil + sand + FYM in (3:1:1) (Control)

Plate 6: Shoot and root growth of coffee seedlings at 180 days after sowing

This could be attributed to damage caused to root system while uprooting of seedlings from bed. This result is in line with the findings of Philip (1991) in Ponderosa pine, Jeffrey pine, and Douglas-fir seedlings and Bali *et al.* (2013) in *Terminalia bellirica*.

5.3.2 New flush formation

The container grown seedlings showed significant difference with respect to the days taken for first flush (Table 20 and Fig. 19). Early flushing (23.51 days) was recorded in root trainer (C_4) and late flushing was recorded in C_5 (44.68 days) because, as the root system of root trainer grown stock is of high growth potential, the stock gets established in the planting site at a much faster rate with early subsequent growth (Nandakumar, 1990).

5.3.3 Plant height (cm)

The container influenced significantly on the plant height (Table 21 and Fig. 20). The maximum plant height (15.42 cm and 16.66) was registered in the seedlings raised in black polythene bag (C_1) which was on par with root trainer - C_4 (15 cm and 16.13 cm) and the least (11.62 cm and 12.09) was recorded in C_5 at 30 and 60 days after transplanting. Whereas, at 90 days after transplanting, the maximum plant height (18.93 cm) was registered with root trainer - C_4 and the least in C_5 (13.50 cm). This is because, the vertical ridges in the root trainer container wall ensures proper orientation of lateral roots and the natural air pruning in nursery which enhances their vigour of growth after transplanting to the main field (Soman *et al.*, 2013).

The rooting media significantly influenced on the plant height (Table 21 and Fig. 20). The maximum plant height (15.31 cm, 16.50 cm and 18.65 cm) was recorded in red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* M_7 and the least in M_1 (11.51 cm, 12.56 cm and 14.35 cm) at 30, 60 and 90 days after transplanting. Similarly, when *Arbuscular mycorrhizae* fungi was inoculated to cocoa seedlings at level of 50 g and 100 g exhibited better transplant performance (Segun, 2015).

The interaction effect was found be significant (Table 21 and Fig. 20) and the maximum plant height (17.81 cm and 19.63 cm) was recorded in the treatment combination of black polythene bag filled with red soil + sand+ FYM + *P. fluorescens*

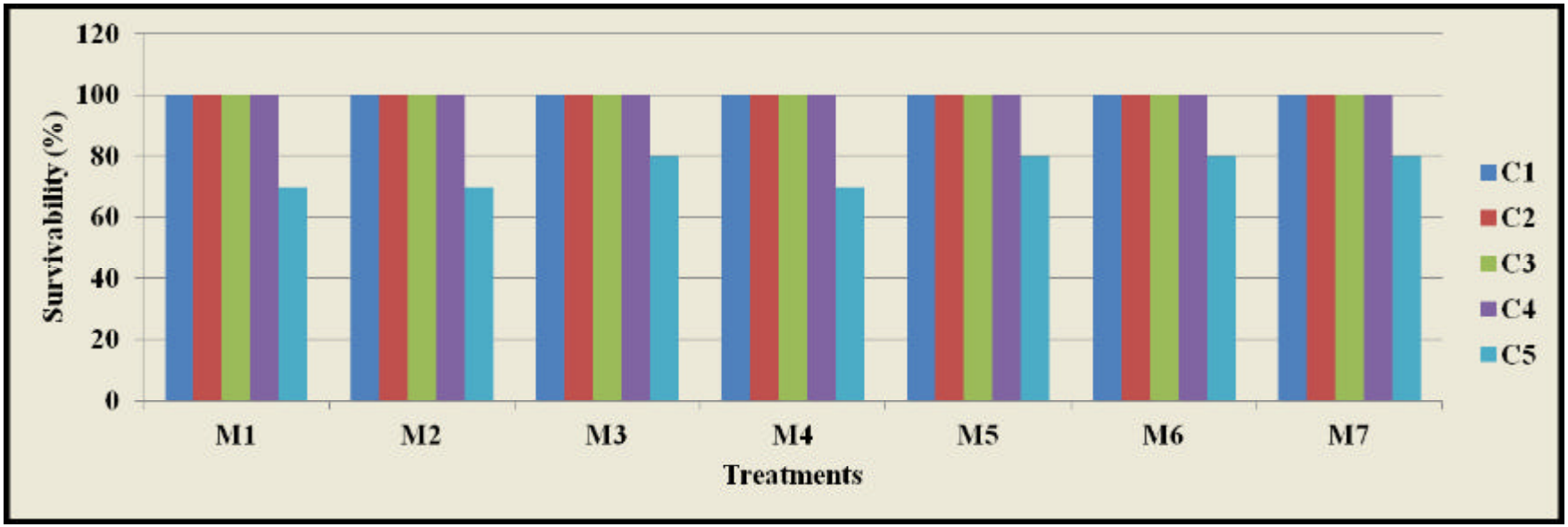

Fig. 18: Effect of containers, rooting media and their interaction on survivability (%) of coffee seedlings after transplanting to the main field

C_1: Black polythene bag (6" × 9") [Control]

C_2: Transparent polythene bag (6" × 9")

C_3: Protray raised seedlings in black polythene bag (6" × 9")

C_4: Root trainers

C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)

M_2: Red soil + cocopeat + FYM in 3:1:1 ratio

M_3: Red soil + sand + vermicompost (3:1:1)

M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)

M_6: M_5 +VAM (10g/kg FYM)

M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

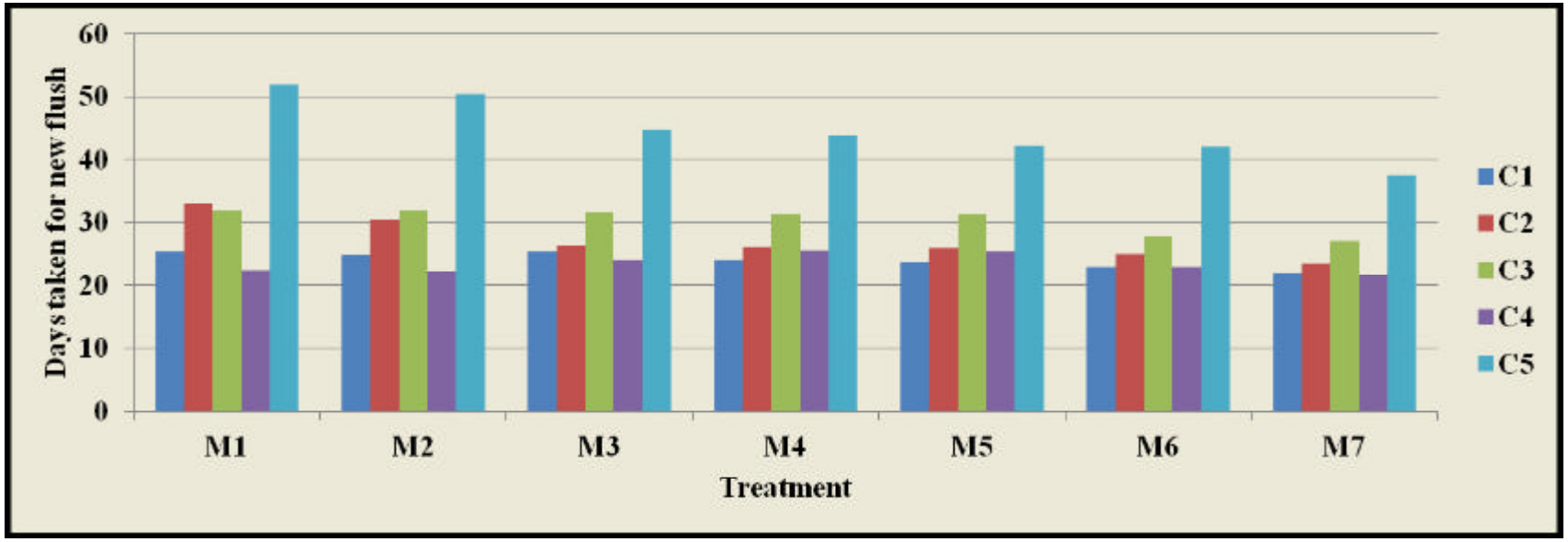

Fig. 19: Effect of containers, rooting media and their interaction on days taken for new flush of coffee seedlings in main field

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

+ PSB + *Azospirillum* (C_1M_7) which was on par with C_2M_7 (17.05 cm and 18.3 cm) and C_4M_7 (16.53 cm and 18.25 cm) and the least plant height (11.16 cm and 11.46) was recorded in C_5M_3 at 30 and 60 days after transplanting respectively. At 90 days after transplanting, the maximum plant height (18.93 cm) was recorded in root trainer filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with the C_1M_7 (21.50 cm) and the least was recorded in C_5M_1 (13 cm). Since root trainer technology envisages use of containers of smaller volume it is more exacting with regard to potting media (Nandakumar, 1996). Organic-rich potting medium used in the study had exhibited favourable physical and chemical properties (drainage, aeration, water holding capacity and nutrition) in root trainers in nursery (Annapurna *et al*., 2004) there by good growth in the nursery as well as in the main field.

5.3.4 Number of leaves

The container showed significant difference with respect to number of leaves (Table 22 and Fig. 21). The maximum number of leaves (9.71, 11.54 and 18.44) were recorded in root trainer (C_4) and the lowest number of leaves (6.58, 8.58 and 10.55) was encountered in C_5 at 30, 60 and 90 days after transplanting to the main field. This is because, the vertical ridges in the container wall ensures proper orientation of lateral roots and the natural air pruning enhances their vigour of growth after transplanting to the main field (Soman *et al*., 2013).

The rooting media had significantly influenced on number of leaves (Table 22 and Fig. 21). The maximum number of leaves (9.66 and 11.50) were recorded in red soil+ sand+ FYM + *P. fluorescens* + PSB + *Azospirillum* the (M_7) and the least (8.16 and 9.92) was recorded in M_2 which was on par with the M_1 (8.18 and 10.26) at 30 and 60 days after transplanting to the main field. Similarly at 90 days after transplanting maximum number of leaves (17.12) were recorded in M_7 whereas the minimum number of leaves (14.14) were registered in M_1. This result is in line with the findings of Segun (2015) when *Arbuscular mycorrhizae* fungi was inoculated to cocoa seedlings at level of 50 g and 100 g exhibited better transplant performance.

The interaction between container and media was found to be non-significant at 30 and 60 days after transplanting. At 90 days after transplanting significant difference was observed (Table 22 and Fig. 21) and the maximum number of leaves

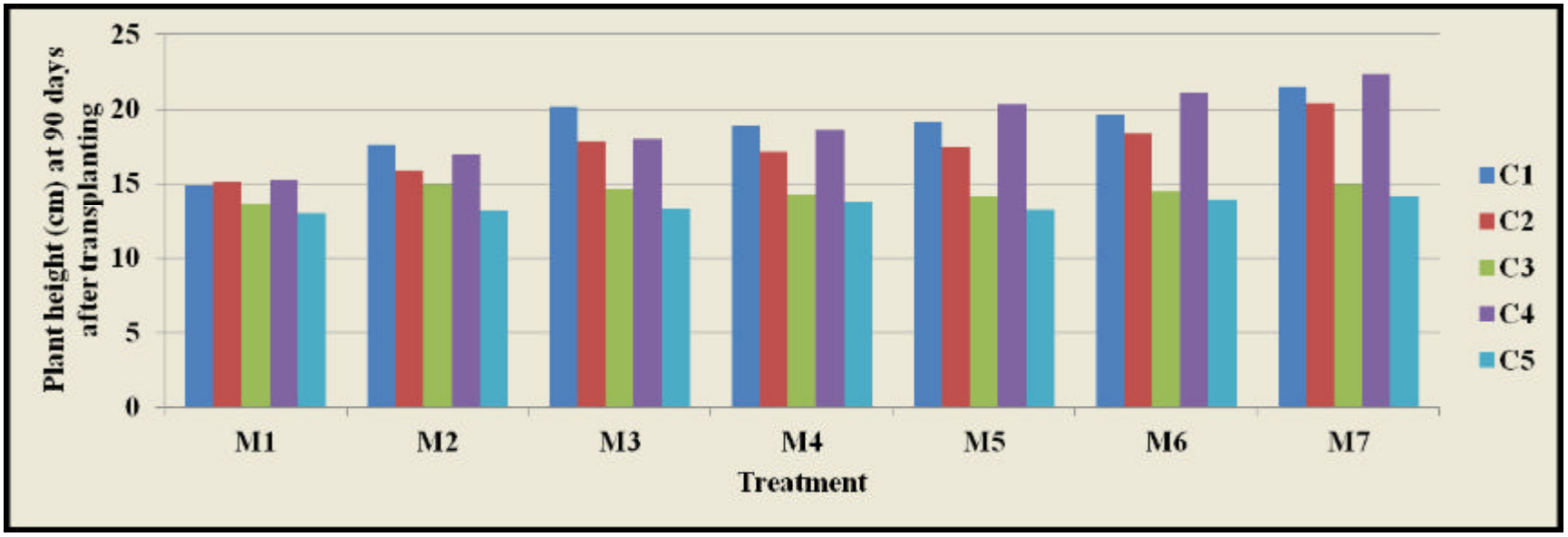

Fig. 20: Effect of containers, rooting media and their interaction on plant height (cm) of coffee seedlings at 90 days after transplanting

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9"
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

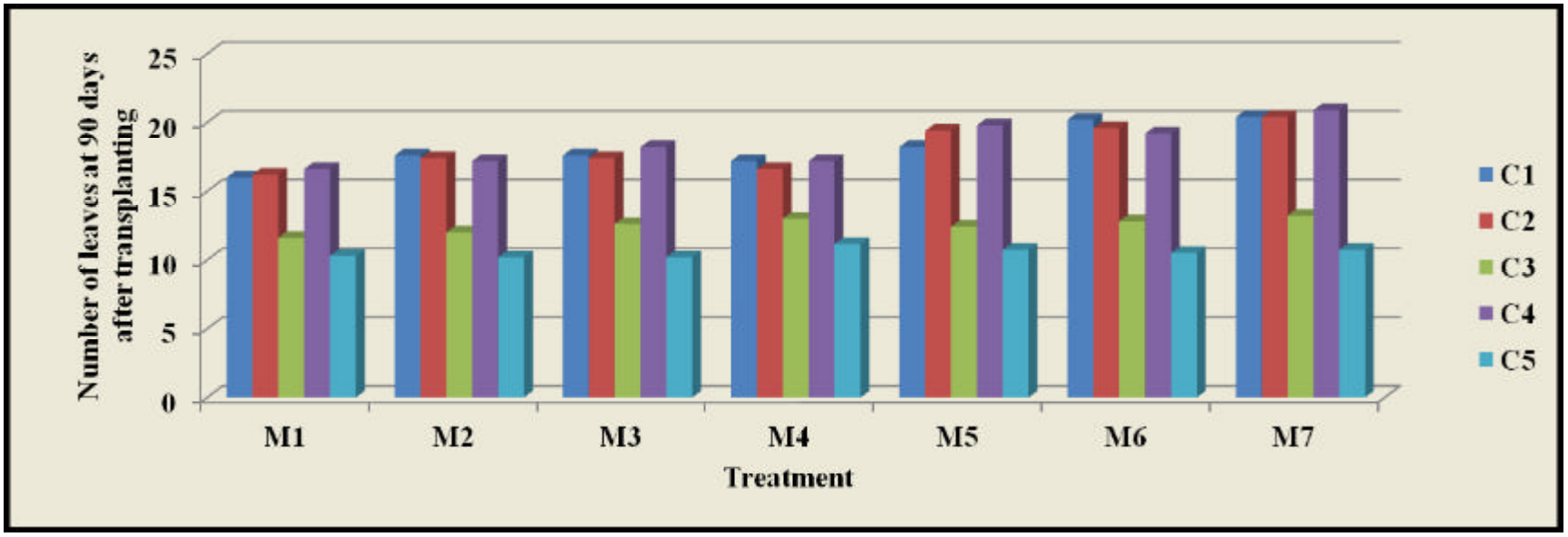

Fig. 21: Effect of containers, rooting media and their interaction on number of leaves in coffee seedlings at 90 days after transplanting

C_1: Black polythene bag ((6" × 9") [Control]

C_2: Transparent polythene bag (6" × 9")

C_3: Protray raised seedlings in black polythene bag (6" × 9")

C_4: Root trainers

C_5: Raising in beds

M_1: Red soil + sand+ FYM in 3:1:1 ratio (Control)

M_2: Red soil + cocopeat + FYM in 3:1:1 ratio

M_3: Red soil + sand + vermicompost (3:1:1)

M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)

M_6: M_5 +VAM (10g/kg FYM)

M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

(20.90) were recorded in root trainer filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) and the least (10.20) was recorded in C_5M_2 and C_5M_3 which was on par with C_5M_1 (10.20). Organic-rich potting medium used in the study had exhibited favourable physical and chemical properties (drainage, aeration, water holding capacity and nutrition) in root trainers in nursery (Annapurna *et al*., 2004) there by good growth in the nursery as well as in the main field.

5.3.5 Effect of containers, rooting media and their interaction on number of primary branches in coffee seedlings at 90 days after transplanting to the main field

The container significantly influenced the number of primary branches at 90 days after transplanting to the main field (Table 23 and Fig. 22). The maximum number of primary branches (1.54) were recorded in root trainer (C_4) whereas in C_3 and C_5 no primary branches were observed until 90 days after transplanting. This is because, the vertical ridges in the container wall ensures proper orientation of lateral roots and the natural air pruning enhances their vigour of growth after transplanting to the main field (Soman *et al*., 2013).

Among different media used, the maximum number of primary branches (1.16) was recorded in M_6 which was on par with M_7 (1.14) and the lowest (0.64) was found in M_4 which was on par with M_2 (0.78), M_3 (0.78) and M_1 (0.80). Similarly, when *Arbuscular mycorrhizae* fungi was inoculated to cocoa seedlings at level of 50 g and 100 g exhibited better transplant performance (Segun, 2015).

The interaction effect between container and media was found to be significant (Table 23 and Fig. 22). The maximum number of primary branches (2) were recorded in root trainer containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7), C_4M_6 and C_4M_6. Whereas, no primary branches were recorded in all the interactions of C_3 and C_5. Organic-rich potting medium used in the study had exhibited favorable physical and chemical properties (drainage, aeration, water holding capacity and nutrition) in root trainers in nursery (Annapurna *et al*., 2004) there by good growth in the nursery as well as in the main field.

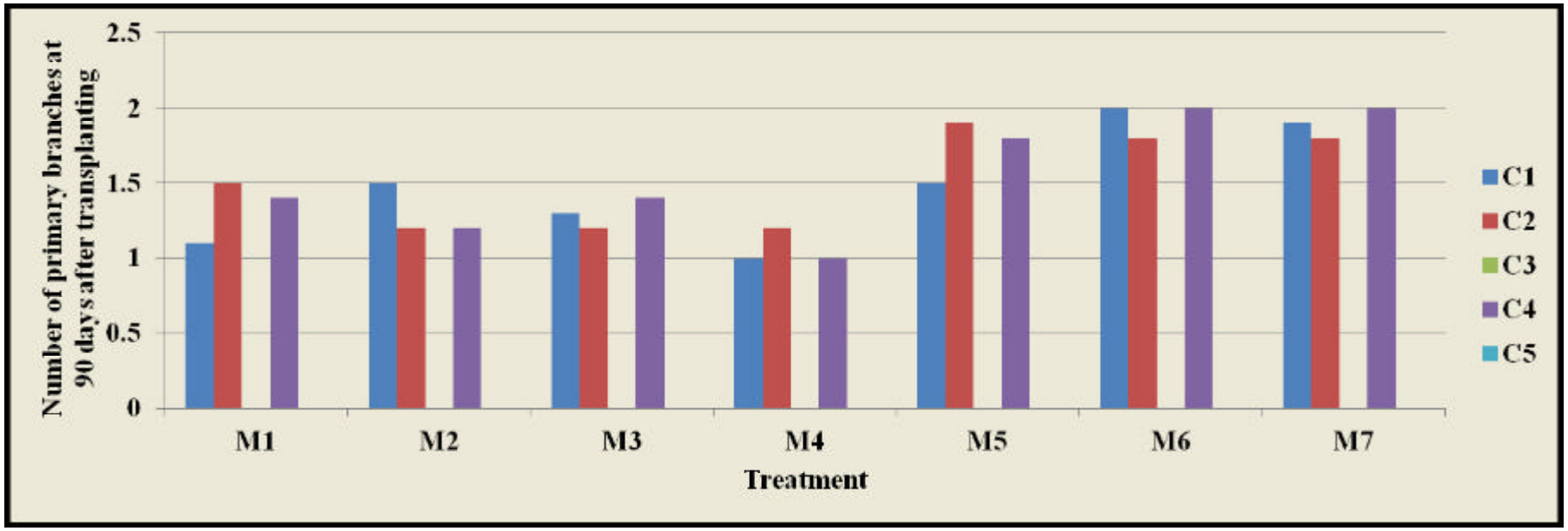

Fig. 22: Effect of containers, rooting media and their interaction on number of primary branches in coffee seedlings at 90 days after planting

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1:1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

C_2M_7: Root trainer + red soil+ sand+ FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum*

C_1M_7: Black polythene bag + red soil+ sand+ FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum*

C_2M_1: Protray raised seedlings in black polythene bag + red soil+ sand+ FYM

Plate 7: Coffee seedlings at 90 days after transplanting to the main field

5.4 Effect of containers and media on benefit–cost ratio of coffee cv. Chandragiri for nursery raising

It was found that, treatment root trainers filled with red soil + sand + press mud in 3:1:1 (C_4M_4) recorded maximum benefit cost ratio (2.85) which was followed by C_4M_1 where root trainer filled with red soil + sand + FYM in 3:1:1 (2.82) and C_4M_3 (2.71) where seedlings were grown in root trainer using the media red soil + sand + vermicompost in 3:1:1. Whereas, the minimum benefit cost ratio (0.98) was obtained in C_5M_2 (Raising in beds using red soil + coco peat + FYM in 3:1:1 (Table 24 and Fig 23). This is because root trainer cups once purchased can be used for 8-10 years. Cost of root trainer cup is ₹ 5, every year the cost involved is ₹ 50 paisa per root trainer which is cheaper compared to polybag and raised bed (Sunil, 2014).

Future line of work

- The study indicates the necessity of further research on automated coffee seedlings development with the components identified in the present study for larger area coverage and precision of producing healthy seedlings.
- Understanding the underlying mechanism associated with bio-inoculants used and also elaborating the mechanistic features of root trainer.
- Standardization of size of root trainers with optimum quantity of media for better performance of seedlings are need to be investigated.
- The effect of coating of inner surface of different containers with copper hydroxide or suitable chemical to restrict the growth of roots and to increase the lateral roots when it reaches the ground is need to be studied in coffee nursery.

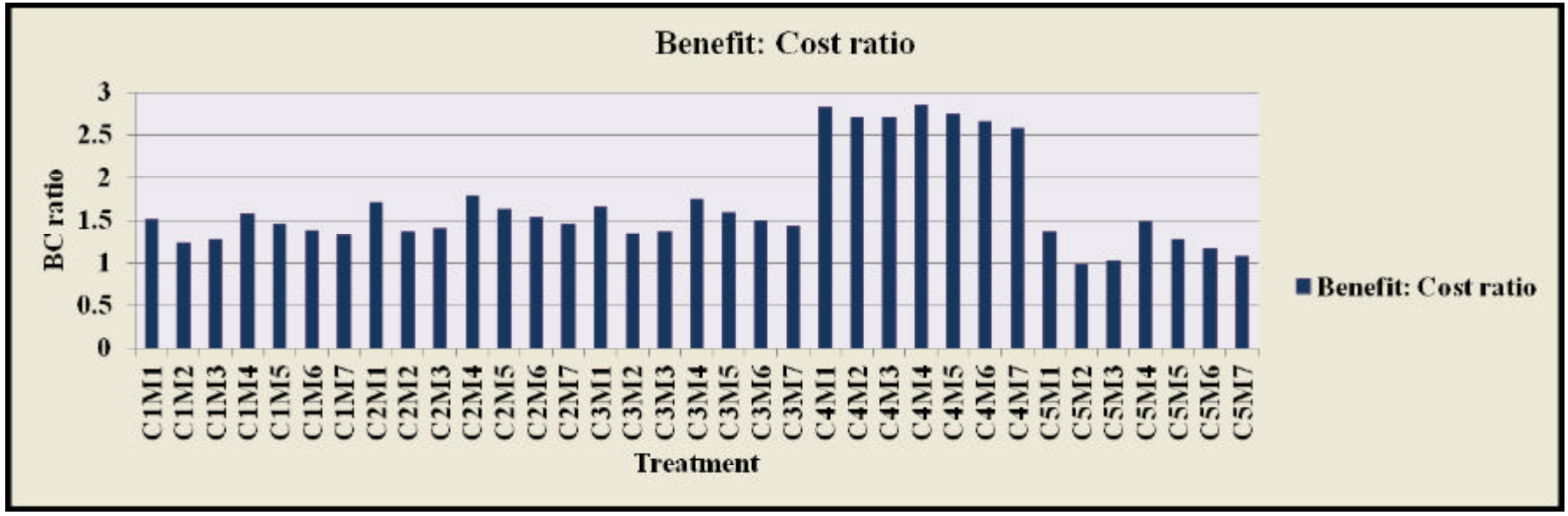

Fig. 23. Effect of containers and media on benefit–cost ratio of coffee cv. Chandragiri for nursery raising

C_1: Black polythene bag (6" × 9") [Control]
C_2: Transparent polythene bag (6" × 9")
C_3: Protray raised seedlings in black polythene bag (6" × 9")
C_4: Root trainers
C_5: Raising in beds

M_1: Red soil + sand + FYM in 3:1:1 ratio (Control)
M_2: Red soil + cocopeat + FYM in 3:1 :1 ratio
M_3: Red soil + sand + vermicompost (3:1:1)
M_4: Red soil + sand + pressmud (3:1:1)

M_5: M_1 + *Pseudomonas fluorescens* (5g/ kg FYM)
M_6: M_5 +VAM (10g/kg FYM)
M_7: M_5 + PSB + *Azospirillum* (10g/kg FYM)

(A) (B)

Plate 8. Root system of root trainer (A) and black polythene bag (B) grown seedlings at 180 days after sowing

Plate 9: Coffee seedlings raised in different containers at 180 days after sowing (A. black polythene bag; B. transparent polythene bag; C. protray raised seedlings in black polythene bag; D. root trainer and E. raised bed)

6. SUMMARY AND CONCLUSIONS

The present investigation on “Study of containers and rooting media for growth and field establishment of coffee seedlings” was carried out at the Department of Plantation, Spices, Medicinal and Aromatic crops, College of Horticulture, Mudigere during 2016-17 with the following objectives.

1. To evaluate different seedling containers for better rooting and growth of coffee seedling.

2. To find out the most suitable media for better rooting and growth of coffee seedling.

3. To study the field establishment of seedlings developed in different containers and media.

4. To work out cost: benefit ratio for different containers and media used.

6.1 Coffee seedlings in primary nursery

The treatment consist of protrays and raised bed using 7 different media *viz*., Red soil + sand + FYM **(**M_1 - Control); red soil + cocopeat + FYM (M_2); red soil + sand + vermicompost (M_3); red soil + sand + pressmud (M_4); M_1 + *Pseudomonas fluorescens* (M_5); M_5 + VAM (M_6); M_5 + PSB + *Azospirillum* (M_7) were studied and experimented by adapting factorial randomized block design with 2 replications.

- Maximum germination percentage (87.80) was recorded in the seeds sown in raised bed using the media, red soil + sand + vermicompost (C_1M_3) compared to rest of the treatments and the least germination percentage (62.50) was registered with seeds sown in protrays using the media red soil + sand + FYM – (C_2M_1) at 45 days after sowing.

- Seedlings in raised bed prepared using the media red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (C_1M_7) found maximum taproot length (5.69 cm) which was on par with C_1M_5 – raised bed + red soil + sand + FYM + *P. fluorescens* (5.29 cm) and C_1M_3 – raised bed + red soil + sand + vermicompost (5.14 cm) and the minimum taproot length (3.42 cm)

was found with the coffee seedlings raised in protray using the media red soil + sand + FYM (C_2M_1).

- Maximum number of primary roots per seedling (34.50) was recorded with the seedlings in raised bed prepared using the media red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (C_1M_7) followed by C_1M_3 – raised bed + red soil + sand + vermicompost (27.10) and the least number of primary roots per seedling (19.90) was registered in protray filled with red soil + sand + pressmud (C_2M_4) which was on par with the C_2M_1 - red soil + sand + FYM (20.50) at 45 days after sowing.

- The seedlings which are grown in raised bed using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) registered maximum production of secondary roots (5.70) followed by C_1M_6 - raised bed prepared using the media red soil + sand + FYM + *P. fluorescens* + VAM (3.80) and the least number of secondary roots (1.20) was recorded in protray filled with media red soil + sand + FYM (C_2M_1) at 45 days after sowing.

- Maximum fresh (0.13 g) and dry weight (0.04 g) of roots were registered in seedlings grown in raised bed prepared by using the media red soil + sand+ FYM + *P. fluorescens* + PSB + *Azospirillum* (C_1M_7) followed by C_1M_6 - red soil + sand+ FYM + *P. fluorescens* + VAM (0.12 g and 0.04 g) compared to seedlings raised in protray filled with red soil + sand + FYM where minimum fresh (0.08 g) and dry weight (0.02 g) of roots were recorded at 45 days after sowing.

6.2 Coffee seedlings in secondary nursery

In this, the effect of 5 different containers *viz*., Black polythene bag of 6" × 9" (C_1 - Control); transparent polythene bag of 6" × 9" (C_2); protray raised seedlings in black polythene bag of 6" × 9" (C_3); root trainers (C_4) and raising in beds (C_5) and 7 different media *viz*., Red soil + sand + FYM in 3:1:1 ratio (M_1 - Control), red soil + cocopeat + FYM in 3:1:1 ratio (M_2); red soil + sand + vermicompost in 3:1:1 ratio (M_3); red soil + sand + pressmud in 3:1:1 (M_4), M_1+ *P. fluorescens* (M_5); M_5 + VAM (M_6), M_5 + PSB (10 g/kg FYM) + *Azospirillum* (M_7) were studied and experimented by adapting factorial randomized block design with 2 replications.

- Maximum plant height (16.91 cm) was recorded from the seedlings raised in black polythene bag containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media (C_1M_7) which was on par with the C_2M_7 – transparent polythene bag containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* media (16.65 cm), whereas the minimum plant height (11.15 cm) was registered in black polythene bag containing red soil + sand + FYM (C_1M_1) at 180 days after sowing.

- As regards to number of leaves per seedling, maximum number (9.2) was recorded in seedlings raised in black polythene bag containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* as media (C_1M_7) which was on par with the C_4M_7 – root trainer containing red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* as media (8.8) whereas the least number of leaves (6.00) were recorded in protray raised seedlings in black polythene bag containing red soil + sand + FYM as media (C_3M_1) and protray raised seedlings in black polythene bag containing red soil + sand + pressmud (C_3M_4) at 180 days after sowing.

- Maximum leaf area (60.95 cm^2) of coffee seedlings was recorded with seedlings raised in root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) and the least leaf area (18.29 cm^2) was recorded in protray raised seedlings in black polythene bag containing red soil + sand + FYM as media (C_3M_1) at the time of transplanting to the main field.

- Maximum collar girth (4.01 mm) was recorded by the seedlings raised in root trainer using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) at 180 days after sowing which was on par with the C_5M_7 – raised bed using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (3.95 mm) and the least collar girth (2.85 mm)was registered in protray raised seedlings in black polythene bag containing red soil + sand + FYM as media (C_3M_1) at 180 days after sowing.

- Taproot length was maximum (22.26 cm) in seedlings grown in raised bed using the media red soil + sand + FYM + *P. fluorescens* + PSB +

Azospirillum (C_5M_7) and the least taproot length (14.77 cm) was recorded in root trainer containing red soil + sand + vermicompost (C_4M_3) at 180 days after sowing.

- Maximum production of primary (238.6) and secondary roots (557.8) per seedling at the time of transplanting were registered with seedlings raised in root trainer using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) and the least number of primary (104.2) and secondary roots (213.8) were recorded in black polythene bag using the media red soil + sand + FYM (C_1M_1) at the time of transplanting to the main field.

- Maximum fresh (2.96 g) and dry weight (1.098 g) of roots per seedling was recorded in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with C_4M_6 - root trainer filled with the media red soil + sand+ FYM + *P. fluorescens* + VAM (2.93 g and 0.959 g respectively) and least fresh (1.22 g) and dry weight (0.400 g) of roots was registered in black polythene bag filled with the media red soil + sand + FYM (C_1M_1) at the time of transplanting.

- The maximum benefit cost ratio (2.85:1) was recorded in seedlings raised in the root trainer filled with red soil + sand + press mud (C_4M_4) which was very close to the C_4M_7 where, the root trainer filled with red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* (2.57:1) while the minimum (0.98:1) was recorded in seedlings grown in raised bed using red soil + coco peat + FYM as media (C_5M_2).

6.3 Field establishment of coffee seedlings in main field

- The survival percentage of coffee seedlings was 100 per cent in all treatment combinations except C_5M_1 – raised bed filled with red soil + sand + FYM (70%), C_5M_2 – raised bed filled with red soil + cocopeat + FYM (70%), C_5M_3 – raised bed filled with red soil + sand + vermicompost (80%), C_5M_4 – raised bed filled with red soil + sand + pressmud (70%), C_5M_5 – raised bed filled with red soil + sand + FYM + *P. fluorescens* (80%), C_5M_6 – raised bed filled with red soil + sand + FYM + *P. fluorescens* + VAM (80%) and C_5M_7 – raised bed filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (80%).

- The least number of days taken for new flush emergence (21.70 days) was recorded with the treatment root trainer filled with red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) and maximum number of days (51.90 days) was recorded in the treatment combination raised bed filled with red soil + sand + FYM (C_5M_1).

- Maximum plant height (22.30 cm) was registered in the root trainer filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) which was on par with the C_1M_7 – black polythene bag filled with the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (21.50 cm) while, the least plant height (13 cm) was recorded in the treatment combination raised bed filled with the media red soil + sand + FYM (C_5M_1) at 90 days after transplanting to the main field.

- Seedlings raised in root trainer using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7) recorded the maximum number of leaves (20.90) in main field at 90 days after transplanting whereas, the least plant height (10.20) was recorded in raised bed prepared using the media red soil + cocopeat + FYM (C_5M_2) and in raised bed prepared using the media red soil + sand + vermicompost (C_5M_3) which was on par with the C_5M_1 - raised bed prepared using the media red soil + sand + FYM (10.30).

- Maximum number of primary branches (2) was registered in root trainer using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (C_4M_7), root trainer using the media red soil+ sand + FYM + *P. fluorescens* + VAM (C_4M_6) and black polythene bag using the media red soil+ sand + FYM + *P. fluorescens* + VAM (C_1M_6) which was on par with the C_1M_7 – black polythene bag using the media red soil + sand + FYM + *P. fluorescens* + PSB + *Azospirillum* (1.9). Whereas, no primary branches were recorded in all the interactions of C_3 (protray raised seedlings in black polythene bag) and C_5 (root trainer).

In general, the seedlings raised in root trainer containing red soil + sand + FYM + *Pseudomonas fluorescens* (5 g/kg FYM) + PSB (10 g/kg FYM) +

Azospirillum (10 g/kg FYM) – C_4M_7 as media excelled in most of all growth parameters (leaf area, collar girth, number of primary and secondary roots, fresh and dry weight of roots) with optimum plant height and number of leaves. In root trainer, maximum importance is given to root parameters and lesser importance to plant height (Soman and Saraswathyamma, 1999).

Conclusion

- From the study, it is evident that for obtaining healthy seedlings raised bed was found better for primary nursery and root trainer for secondary nursery.
- Red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* rooting media was found better for rooting and growth of coffee seedlings in nursery.
- The seedlings raised in root trainer containing red soil + sand + FYM + *Pseudomonas fluorescens* + PSB + *Azospirillum* as media have excelled in all growth parameters at field establishment.
- To obtain quality seedlings root trainer raised coffee seedlings were found economical.

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Appendix I: The monthly mean meteorological data for the experimental period recorded at ZAHRS, Mudigere

Month	Temperature (^{0} c)		Relative humidity (%)		Rainfall (mm)	No. of rainy days
	Minimum	Maximum	Maximum	Minimum		
April-16	23.23	33.76	83.23	75.10	20.8	5
May-16	19.90	31.54	76.20	84.58	148.4	7
June-16	20.66	25.36	85.43	79.63	363.6	22
July-16	20.32	25.35	85.87	79.93	557.75	29
Aug-16	20.4	25.5	85.2	80.3	201.3	28
Sept-16	20.13	24.56	85.16	79.6	75.7	15
Oct-16	20.06	29.03	85.19	78.03	38.40	4
Nov -16	20.06	29.70	84.40	73	49.1	3
Dec -16	20.03	28.70	80	71.19	10.6	4
Jan-17	18.50	27.65	82.20	73.50	0.00	0
Total	**-**	**-**	**-**	**-**	**1465.65**	**118**
Mean	**20.32**	**28.11**	**83.28**	**77.48**	**-**	**-**

Appendix-II: Cost of production of coffee seedlings during 2016-17

A. Black polythene bag (C_1)							
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**
I. Input	Rs./seedling						
Planting material	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Black polythene bag	1.19	1.19	1.19	1..19	1.19	1.19	1.19
Red soil (750 g at ₹0.7/kg)	0.50	0.50	0.50	0.50	0.50	0.50	0.50
FYM (250 g at ₹1.5/kg)	0.37	0.37	-	-	0.37	0.37	0.37
Sand (250 g at ₹2/kg)	0.50	-	0.50	0.50	0.50	0.50	0.50
Cocopeat (250 g at ₹6/kg)	-	1.50		-	-	-	-
Vermicompost (250 g at ₹5/kg)	-	-	1.25	-	-	-	-
Pressmud (250 g at ₹68/quintal)		-	-	0.17	-	-	-
P. fluorescens (1.25 g at ₹150/kg)	-	-	-	-	0.18	0.18	0.18
PSB (2.5 g at ₹100/kg)	-	-	-	-	-	-	0.25
VAM (2.5 g at ₹100/kg)	-	-	-	-	-	0.25	
Azospirillum (2.5 g at ₹100/kg)	-	-	-	-	-	-	0.25
Carbendazim	0.20	0.20	0.20	0.20	0.20	0.20	0.20
19:19:19	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Miscellaneous	0.20	0.20	0.20	0.20	0.20	0.20	0.20
II. Labour charge							
Bed preparation and sowing in primary nursery	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Filling of polybag (₹0.75/bag)	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total cost	**4.61**	**5.61**	**5.49**	**4.41**	**4.79**	**5.04**	**5.29**

Appendix-II Contd…

B. Transparent polythene bag (C_2)							
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**
I. Input	Rs./seedling						
Planting material	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Transparent polythene bag	0.68	0.68	0.68	0.68	0.68	0.68	0.68
Red soil (750 g at ₹0.7/kg)	0.50	0.50	0.50	0.50	0.50	0.50	0.50
FYM (250 g at ₹1.5/kg)	0.37	0.37	-	-	0.37	0.37	0.37
Sand (250 g at ₹2/kg)	0.50	-	0.50	0.50	0.50	0.50	0.50
Cocopeat (250 g at ₹6/kg)	-	1.50		-	-	-	-
Vermicompost (250 g at ₹5/kg)	-	-	1.25	-	-	-	-
Pressmud (250 g at ₹68/quintal)		-	-	0.17	-	-	-
P. fluorescens (1.25 g at ₹150/kg)	-	-	-	-	0.18	0.18	0.18
PSB (2.5 g at ₹100/kg)	-	-	-	-	-	-	0.25
VAM (2.5 g at ₹100/kg)	-	-	-	-	-	0.25	
Azospirillum (2.5 g at ₹100/kg)	-	-	-	-	-	-	0.25
Carbendazim	0.20	0.20	0.20	0.20	0.20	0.20	0.20
19:19:19	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Miscellaneous	0.20	0.20	0.20	0.20	0.20	0.20	0.20
II. Labour charge							
Bed preparation and sowing in primary nursery	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Filling of polybag (₹0.75/bag)	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total cost	**4.10**	**5.10**	**4.98**	**3.90**	**4.28**	**4.53**	**4.78**

Appendix-II Contd…

C. Protray raised seedlings in black polythene bag (C_3)							
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**
I. Input	Rs./seedling						
Planting material	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Black polythene bag	1.19	1.19	1.19	1.19	1.19	1.19	1.19
Protray	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Red soil (750 g at ₹0.7/kg)	0.50	0.50	0.50	0.50	0.50	0.50	0.50
FYM (250 g at ₹1.5/kg)	0.37	0.37	-	-	0.37	0.37	0.37
Sand (250 g at ₹2/kg)	0.50	-	0.50	0.50	0.50	0.50	0.50
Cocopeat (250 g at ₹6/kg)	-	1.50		-	-	-	-
Vermicompost (250 g at ₹5/kg)	-	-	1.25	-	-	-	-
Pressmud (250 g at ₹68/quintal)		-	-	0.17	-	-	-
P. fluorescens (1.25 g at ₹150/kg)	-	-	-	-	0.18	0.18	0.18
PSB (2.5 g at ₹100/kg)	-	-	-	-	-	-	0.25
VAM (2.5 g at ₹100/kg)	-	-	-	-	-	0.25	
Azospirillum (2.5 g at ₹100/kg)	-	-	-	-	-	-	0.25
Carbendazim	0.20	0.20	0.20	0.20	0.20	0.20	0.20
19:19:19	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Miscellaneous	0.20	0.20	0.20	0.20	0.20	0.20	0.20
II. Labour charge							
Filling of polybag (₹0.75/bag)	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Total cost	**4.21**	**5.21**	**5.09**	**4.01**	**4.39**	**4.64**	**4.89**

Appendix-II Contd…

D. Root trainer (C_4)							
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**
I. Input	Rs./seedling						
Planting material	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Root trainer	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Red soil (90 g at ₹0.7/kg)	0.07	0.07	0.07	0.07	0.07	0.07	0.07
FYM (30 g at ₹1.5/kg)	0.045	0.045	-	-	0.045	0.045	0.045
Sand (30 g at ₹2/kg)	0.50	-	0.50	0.50	0.50	0.50	0.50
Cocopeat (30 g at ₹6/kg)	-	0.18	-	-	-	-	-
Vermicompost (30 g at ₹5/kg)	-	-	0.15	-	-	-	-
Pressmud (30 g at ₹68/quintal)		-	-	0.02	-	-	-
P. fluorescens (0.45 g at ₹150/kg)	-	-	-	-	0.067	0.067	0.067
PSB (0.90 g at ₹100/kg)	-	-	-	-	-	-	0.09
VAM (0.90 g at ₹100/kg)	-	-	-	-	-	0.09	
Azospirillum (0.90 g at ₹100/kg)	-	-	-	-	-	-	0.09
Carbendazim	0.20	0.20	0.20	0.20	0.20	0.20	0.20
19:19:19	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Miscellaneous	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Bed preparation and sowing in primary nursery	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Filling of root trainer	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Total cost	**2.47**	**2.59**	**2.58**	**2.45**	**2.54**	**2.63**	**2.72**

Appendix-II Contd…

E. Raised bed (C_5)							
	M_1	**M_2**	**M_3**	**M_4**	**M_5**	**M_6**	**M_7**
I. Input	Rs./seedling						
Planting material	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Red soil (1.5 kg at ₹0.7/kg)	1.05	1.05	1.05	1.05	1.05	1.05	1.05
FYM (0.5 kg at ₹1.5/kg)	0.75	0.75	-	-	0.75	0.75	0.75
Sand (0.5 kg at ₹2/kg)	1.00	-	1.00	1.00	1.00	1.00	1.00
Cocopeat (250 g at ₹6/kg)	-	3.00	-	-	-	-	-
Vermicompost (250 g at ₹5/kg)	-	-	2.50	-	-	-	-
Pressmud (250 g at ₹68/quintal)		-	-	0.35	-	-	-
P. fluorescens (1.25 g at ₹150/kg)	-	-	-	-	0.37	0.37	0.37
PSB (2.5 g at ₹100/kg)	-	-	-	-	-	-	0.50
VAM (2.5 g at ₹100/kg)	-	-	-	-	-	0.50	
Azospirillum (2.5 g at ₹100/kg)	-	-	-	-	-	-	0.50
Carbendazim	0.20	0.20	0.20	0.20	0.20	0.20	0.20
19:19:19	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Miscellaneous	0.20	0.20	0.20	0.20	0.20	0.20	0.20
II. Labour charge							
Bed preparation and sowing in primary nursery	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Bed preparation and sowing in secondary nursery	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Total cost	**5.10**	**7.10**	**6.85**	**4.70**	**5.47**	**5.97**	**6.47**

STUDY OF CONTAINERS AND ROOTING MEDIA FOR GROWTH AND FIELD ESTABLISHMENT OF COFFEE SEEDLINGS

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ABSTRACT

The present investigation was carried out to study the different containers and rooting media for growth and field establishment of coffee seedlings at the College of Horticulture, Mudigere during 2016-17. The treatments comprised of 2 containers and 7 media under primary nursery; 5 containers and 7 media in secondary nursery. The experiment was laid out in factorial design with 2 replications.

In primary nursery, the maximum seed germination percentage (87.80) was recorded with raised bed using the media red soil + sand + vermicompost. Whereas, taproot length (5.69 cm), number of primary roots (34.50), secondary roots (5.770), fresh weight (0.13 g) and dry weight of roots (0.04 g) were recorded maximum in raised bed using the media red soil + sand + FYM + *Pseudomonas fluorescens* + *Bacillus megaterium* + *Azospirillum*.

In secondary nursery, the maximum plant height (16.91 cm) and number of leaves (9.20) were recorded in seedlings raised in black polythene bag using the media red soil + sand + FYM + *Pseudomonas fluorescens* + *Bacillus megaterium* + *Azospirillum.* Whereas, the maximum leaf area (60.69 cm^2), collar girth (4.01 mm), number of primary roots (238.6), number of secondary roots (557.8), fresh weight (2.96 g) and dry weight (1.098 g) of roots were recorded in root trainer using the media red soil + sand + FYM + *Pseudomonas fluorescens* + *Bacillus megaterium* + *Azospirillum*.

The coffee seedlings grown in different treatments were transplanted to the main field. The result at 90 days after transplanting revealed that, survival percentage was maximum in all treatment (100%) except raised bed grown seedlings. However the plants grown in root trainer containing red soil + sand + FYM + *Pseudomonas fluorescens* + *Bacillus megaterium* + *Azospirillum* recorded maximum plant height (22.30 cm), number of leaves (20.90), number of primary branches (2) and least days for new flush emergence (21.70 days).

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¸ÁgÁA±À

««z §UAiÄ zÁgPU¼Ä ºÁUÆ ¨ÃgÆj¸Äª ªiÁzÀªÄU¼º PÁ¦Ã ¸¹U¼ ¨¼ªtU ªÄvÄ PÃvæºÆAzÁtPAiÄ CzÀiÄ£ª£Äß vÆÃlUÁjPÁ ªÄºÁ «zÁå®AiÄ, ªÄÆrUgAiÄ° 2016-17 g Cª¢AiÄ° PÈUÆ¼¯Á¬ÄvÄ. ¥Áæ«ÄP £¸ðjAiÄ°, G¥ZÁgªÁV JgqÄ zÁgPU¼Ä ºÁUÆ K¼Ä ªiÁzÀªÄU¼£Äß ªÄvÄ ¢wÃAiÄ £¸ðjAiÄ°, LzÄ zÁgPU¼Ä ºÁUÆ K¼Ä ªiÁzÀªÄU¼£Äß G¥ZÁgU¼ÁV vUzÄPÆ¼¯Á¬ÄvÄ.

¥Áæ«ÄP £¸ðjAiÄ°, Ujµ ±ÃPqªÁgÄ ©Ãd ªÆ¼P MqAiÄÄ«PAiÄÄ (87.80%) PA¥ÄªÄtÄ + ªÄg¼Ä + Jgº¼ÄUÆ§g G¥AiÆÃV¹ vAiiÁj¹z KgÄ ªÄrU¼° PAqÄ§A¢z. Dzg Ujµ ¥Áæ«ÄP ¨ÃgÄU¼ (34.50), ªiÁzÀ«ÄP ¨ÃgÄU¼ ¸ASÀ (5.70), º¹ (0.13 UÁæ) ªÄvÄ Mt ¨ÃgÄU¼ vÆP (0.04 UÁæ) PA¥ÄªÄtÄ + ªÄg¼Ä + PÆnU UÆ§g + ¸*ÄqÆÃªÆÃ£Á¸ï ¥ÆÃgÆÃ¸£ï* + ¨¹®¸*ï ªÄUmÃjAiÄA* + *CghÆÃ¸öÉj®ªiï* §¼¹ vAiiÁgÄ ªiÁrz KgÄ ªÄrU¼° zÁR°¸¯ÁVz.

¢wÃAiÄ £¸ðjAiÄ°, Ujµ ¸¹ Jvg (16.91 ¸A.«ÄÃ.), J¯U¼ ¸ASÀAiÄÄ (9.20) P¥Ä ¥Á°wÃ£ï §ÄnAiÄ° PA¥ÄªÄtÄ + ªÄg¼Ä + PÆnU UÆ§g + ¸*ÄqÆÃªÆÃ£Á¸ï ¥ÆÃgÆÃ¸£ï* + ¨¹®¸*ï ªÄUmÃjAiÄA* + *CghÆÃ¸öÉj®ªiï* ªiÁzÀªiÁV G¥AiÆÃV¹ ¨¼z ¸¹U¼° PAqÄ§A¢gÄvz. Dzg Ujµ J¯ «¹Ãtð (60.69 Z.¸A.«ÄÃ.), PÁAqz ¸Äv¼v (4.01 «Ä.«ÄÃ), ¥Áæ«ÄP ¨ÃgÄU¼ ¸ASÀ (238.6), ªiÁzÀ«ÄP ¨ÃgÄU¼ ¸ASÀ (557.8), º¹ (2.96 UÁæ) ªÄvÄ Mt ¨ÃgÄU¼ vÆPªÀ (1.098 UÁæ) PA¥ÄªÄtÄ + ªÄg¼Ä + PÆnU UÆ§g + ¸*ÄqÆÃªÆÃ£Á¸ï ¥ÆÃgÆÃ¸£ï* + ¨¹®¸*ï ªÄUmÃjAiÄA* + *CghÆÃ¸öÉj®ªiï* ªiÁzÀªÄª£Äß ºÆA¢gÄª gÄmï mæ£g zÁgPz° ¨¼¹z ¸¹U¼° PAqÄ§A¢z.

««z §UAiÄ zÁgPU¼Ä ªÄvÄ ªiÁzÀªÄz° 6 wAU¼ªgU PÁ¦Ã ¸¹U¼£Äß ¨¼¹ vÆÃlz PÃvæ° £lÄ 3 wAU¼ Cª¢AiÄ £Avg zÁR¯Áz ¥°vÁA±z ¥Pæg PA¥ÄªÄtÄ + ªÄg¼Ä + PÆnU UÆ§g + ¸*ÄqÆÃªÆÃ£Á¸ï ¥ÆÃgÆÃ¸£ï* + ¨¹®¸*ï ªÄUmÃjAiÄA* + *CghÆÃ¸öÉj®ªiï* ªiÁzÀªÄ ºÆA¢gÄª gÄmï mæ£g zÁgPz° ¨¼¹z ¸¹U¼Ä ªÄÄRÀ ¨Æ«ÄU £Án ªiÁrz £Avg CwÃ ¨ÃU (21.70) ºÆ¸ aUÄgÄ PAqÄ §A¢z®zÃ Ujµ §zÄPÄ½AiÄÄ«P (100%), ¸¹ Jvg (22.30 ¸A.«ÄÃ.), J¯U¼ ¸ASÀ (20.90) ªÄvÄ ¥Áæ«ÄP mÆAUU¼Ä (2) PAqÄ§A¢z.