STANDARDISATION OF NURSERY MANAGEMENT PRACTICES IN PACHOTTI (*Symplocos cochinchinensis* (Lour.) S. Moore)

by

AJIL M. S.

(2016-12-019)

THESIS

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DECLARATION

I, hereby declare that this thesis, entitled **"STANDARDISATION OF NURSERY MANAGEMENT PRACTICES IN PACHOTTI (*Symplocos cochinchinensis* (Lour.) S. Moore)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
Date: 17-11-2018

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CERTIFICATE

Certified that this thesis, entitled **"STANDARDISATION OF NURSERY MANAGEMENT PRACTICES IN PACHOTTI (*Symplocos cochinchinensis* (Lour.) S. Moore"** is a record of bonafide research work done independently by **Mr. AJIL M. S. (2016-12-019)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

@	At the rate of
a.i.	Active ingredient
CD	Critical difference
cm	Centimetre
DAS	Days after sowing
dS m^{-1}	Deci Siemens per metre
et al.	And other co workers
Fig.	Figure
FYM	Farmyard manure
g	Gram
ha	Hectare
IAA	Indole acetic acid
IBA	Indole butyric acid
Kg	Kilogram
kg ha^{-1}	Kilogram per hectare
LAD	Leaf area duration
LAI	Leaf area index
m	Metre
mg g^{-1}	Milligram per gram
mg L^{-1}	Milligram per litre
MSL	Mean sea level
NAA	Naphthalene acetic acid
^{o}C	Degree Celsius
^{o}E	Degree East
^{o}N	Degree North
PG	Phloroglucinol
SA	Salicylic acid

cfu	Colony forming units
mm	Millimetre
viz.	Namely
N	Nitrogen
NS	Non significant
No.	Number
BSA	Bovine serum albumin
MS Medium	Murashig Skoog medium
%	Per cent
ha^{-1}	Per hectare
m^{-2}	Per square metre
P_2O_5	Phosphate
K_2O	Potash
K	Potassium
RH	Relative humidity
MAT	Month after transplanting
m^2	Square metre
MAP	Months after planting
SE	Standard error
i.e.	That is
t ha^{-1}	Tonnes per hectare
PGPR	Plant Growth Promoting Rhizobactria
AMF	Arbuscular Mycorrhizal Fungi
PSB	Phosphorus Solubilising Bacteria

INTRODUCTION

1. INTRODUCTION

Symplocos cochinchinensis (Lour.) S. Moore (locally called pachotti), is an evergreen tree that falls in the monogeneric family Symplocaceae. The genus *Symplocos* consists of ca. 3200 species, mostly distributed in the tropical and subtropical regions of Asia, America and Australia (Nooteboom, 2004). The tree acts as a source of medicine, dye, tannins, alkaloids, and wood (Matta *et al.*, 2017).

The tropical rainforests form the treasure chest of plant diversity in the Western Ghats, the biodiversity hotspot of India. The Shola forests form an endemic ecosystem near to the water bodies at high altitudes of the Western Ghats above 1500 m above Mean Sea Level (MSL). These forests have been succumbed to destruction due to anthropogenic activities. This has led to the loss of endemic biodiversity of this region. *Symplocos cochinchinensis*, endemic to Shola forests is enlisted as rare, endangered and threatened (RET) species (Mohandass *et al.*, 2008). Hence, restoration planting of this species may aid to restore its population in the region.

S. cochinchinensis is therapeutically very valuable and is designated as "Lodhra". It is being exploited in the Indian System of Medicine, *Ayurveda*, to treat diabetes mellitus (Nair, 2005; Bhanu and Kashyap, 2013). The bark extract has been proved to have antidiabetic activity in terms of alpha glucosidase inhibition and improved insulin sensitivity (Antu *et al.*, 2016). In addition to this, it has anti-inflammatory (Vadivu and Lakshmi, 2008), antioxidant (Sunil and Ignacimuthu, 2011) and hypolipidemic (Sunil *et al.*, 2012) activities. The bark is astringent, acrid, ophthalmic, expectorant, analgesic, haemostatic, aphrodisiac and stomachic. It is also used in the treatment of respiratory disorders, dropsy, arthritis, ulcers, leprosy, skin diseases, dyspepsia and gonorrhea. Leaf and bark extract of *S. cochinchinensis* has phytochemical compounds with antioxidant and antitumor properties (Kalpana and Dhamotharan, 2016).

The innumerable medicinal traits of the species have led to its huge industrial demand. According to Sasidharan and Muraleedharan (2009), the annual requirement of *S. cochinchinensis* in ayurvedic medicine manufacturing units of Kerala is about 110 t. It is also used in the preparation of cosmetic products. The Aromatic and Medicinal Plants Research Station (AMPRS), Odakkali has included this species in the list of cosmetic producing or anti-dermatic medicinal plants.

High pharmaceutical demand of the species makes collections from wild populations inevitable. Its population is declining due to unscrupulous harvest of the bark (a part with immense medicinal properties) that damages the plant. Appropriate nursery techniques have to be developed for promoting the cultivation of the plant and augment its conservation by restoration planting (Prakashkumar, 2016).

Lack of availability of quality planting material is one of the impediments to expand the area of cultivation of *S. cochinchinensis*. Quality seedling production is the main objective of tree nursery but the slow growth of seedlings limits the high quality seedling production. Standardisation of proper growing media is mandatory for ensuring and enhancing quality seedling production in nurseries. Several plant hormones, enzymes, bioagents etc. were found to induce germination and increase the growth rate of propagules in wide variety of plants (Gupta and Chakrabarty, 2013; Ananthi *et al.*, 2014).

In this context, the present study entitled "Standardisation of nursery management practices in pachotti (*Symplocos cochinchinensis* (Lour.) S. Moore)" has been undertaken with the following objectives.

- Evaluation of propagation efficiency of different propagules *viz.*, seeds, stem cuttings and root cuttings

- Standardisation of potting media for the establishment of nursery plants of pachotti (*Symplocos cochinchinensis* (Lour.) S. Moore)

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

S. cochinchinensis (family Symplocaceae) is an indigenous drug, cited in Ayurvedic classics as a remedy for varied human ailments. *Symplocos* species have been found to have many medicinally valuable attributes (Banu and Kashyap, 2013). According to Ved and Goraya (2007), *S. cochinchinensis* has been used in the treatment of diabetes mellitus. Sunil *et al.* (2011; 2012) have reported the presence of steroids, triterpinoids and phenolic compounds in the leaves and sitosterol in the bark of *S. cochinchinensis.* Sunil *et al.* (2012) and Antu *et al.* (2016) reported that the bark of the plant had antidiabetic and antilipidemic activities. It also has antimicrobial, anti-inflammatory, antioxidant (anticancer properties (Vadivu and Lakshmi, 2008; Sunil *et al.*, 2011; Abida *et al.*, 2016). It is also used in the treatment of ulcers (Dhaon *et al.*, 1989), malaria (Li *et al.*, 2003) uterine and eye disorders (Ali *et al.*, 1990) etc. *S. racemosa* is used to treat fever, spongy gums, skin disorders and mensural disorders (Raghunathan and Mithra, 2000; Chunekar, 2010). The leaf powder is used as a natural dye mordant (Cunningham *et al.,* 2017).

The plant is being exploited for its immense medicinal value in the pharmaceutical and cosmetic industries. As organised cultivation is lacking in this plant, the demand is being met from the wild, which may lead to the depletion of this valuable resource. Quality planting material is the prime requisite for promoting organised cultivation and restoration planting for the conservation of this species.

Literature on *S. cochinchinenesis*, especially, on its nursery management practices is very meagre. Hence, related works on other crops are also reviewed.

2.1 PROPAGATION SYSTEMS

Symplocos is reported to have two propagation systems *viz.*, clonal reproduction through the formation of ramets (Banu and Khasyap, 2013) and by

stem cuttings (Weerakon *et al.*, 2014) and sexual reproduction *via* seeds (Yunchun *et al.*, 2006).

2.1.1 Seed Propagation

Almeida (1990) reported that the flowering in *S. cochinchinenesis* takes place during September to December followed by fruiting. *Symplocos laurina* is a perennial cross pollinating plant with dissemination occurring primarily through seeds. Seed dispersal is endozoic by birds and bats (Meher-Homji, 1975). Long distance dispersal of seeds is mediated by wind (Banu *et al.*, 2010). Seed propagation was reported in *S. cochinchinensis* var. *laurina* by Yunchun *et al.* (2006). Everett (1982) and Nagaraj (2014) reported seed propagation in *S. paniculata and S. racemosoa.* Everett (1982) reported that ripened seeds when immediately sown, did not germinate until second spring after sowing, which indicated dormancy of the seed. Seed dormancy of *S. cochinchinensis* for more than 30 days was reported by Athugala *et al.* (2014). According to Shah *et al.* (2016), seeds of *S. racemosa* could retain viability for three months only. Maximum emergence of seedlings was observed in potting mixture, soil: paddy husk: farm yard manure (1:1:1) and urea (1 per cent). But weak seedlings were produced that resulted in ultimate death. Kalidass (2014) reported that natural regeneration is very low from root segments of *S. racemosa* and it produces fruits with non-viable seeds.

2.1.1.1 In vivo seed germination

Hutchison and Ashton (1979) reported induced germination of mature dodder seeds by mechanical scarification with sandpaper or by immersion in sulfuric acid. Either mechanical scarification or extracting the true seed from its fruit is necessary for the successful propagation of albaida (*Anthyllis cytisoides* L.) (Ibanez and Passera, 1997). The germination rates of *Medicago scutellata* and *Trifolium striatum* seeds were increased to 52.3 and 70.8 per cent, respectively by scarification with sand paper (Uzun and Aydin, 2004).

Sabongari and Aliero (2003) reported maximum germination per cent under 24 h soaking in tomato. Soaking enhanced growth and dry matter accumulation in tomato. Venudevan and Srimathi (2013) reported that 6 h hydro priming had positive influence on seedling vigour, germination per cent and dry matter production in bael (*Aegle marmelos*) but beyond 6 h, priming failed to improve germination.

Muhammed and Amusa (2003) confirmed the positive influence of sulphuric acid and hot water treatments on the germination of tamarind (*Tamarindus indica* L). Kher and Nataraj (2015) observed a successful germination of *Hyphaene dichotoma* seeds in soil and sand (1:1) mixture, when treated with 10 per cent sulphuric acid (H_2SO_4) for 24 h. The highest germination was obtained in seeds exposed to 50 per cent sulphuric acid for 1h. *Zanthoxylum armatum* seeds preteated with 50 per cent H_2SO_4 for 15 min recorded a maximum germination of 93.30 per cent along with mean germination time (MGT) of 149.5 days (Purohit *et al.*, 2015).

Roychowdhury *et al.* (2012) studied the effect of various concentrations of plant growth regulators, *viz.*, gibberellic acid (GA_3), kinetin and indole 3-acetic acid (IAA) on seed germination of *Dianthus caryophyllus.* Among these plant growth regulators, GA_3 recorded the highest seed germination of 87.46 per cent. Liopa-Tsakalidi *et al.* (2012) observed that seeds when pretreated with GA_3 200 ppm for 24 h recorded maximum germination in *Stevia.*

Rauvolfia serpentina seeds treated with H_2O_2 and GA_3 showed improved germination of 34.94 per cent and 48.65 per cent respectively, over the control, which gave a germination of 11.27 per cent only. *R. tetraphylla* seeds when pretreated with KNO_3 and GA_3 gave a germination of 52.70 and 56.66 per cent respectively, compared to untreated seeds which gave 31.26 per cent germination (Hussain and Jha, 2014).

Biopriming is the inoculation of the seeds or seedlings with microorganisms to promote plant growth, development and ultimately yield by modifying the

microbial population around the crop plants. Biopriming of seeds give better germination, seedling growth and establishment of plants (Sharafzadeh *et al.*, 2006). The positive influence of biopriming on germination and establishment of medicinal plants have been reported by Baser-Kouchebagh *et al.* (2013)

According to Kleifeld and Chet (1992), pepper seeds on biopriming with *Trichoderma harzianum* increased germination, emergence, seedling length and leaf area of seedlings.

Naseby *et al.* (2000) observed the increasing fresh shoot weight, root weight and root length in pea, when the seeds were treated with *Trichoderma* strains.

Raj *et al.* (2004) observed enhanced germination, seedling vigour, plant height, leaf area, seed weight and increased yield in pearl millet (22 per cent) on biopriming of seeds with *Pseudomonas fluorescens.*

The inoculation of *Azotobacter* and *Azospirillum* strains to canola seeds, increased the yield by 21.17 per cent, pod per plant by 16.05 per cent, number of branches by 11.78 per cent and weight of 1000 grain by 2.92 per cent (Yasari and Patwardhan, 2007)

Gholami *et al.* (2009) studied the effect of bacterial strains namely *Pseudomonas putida*, *Pseudomonas fluorescens*, *Azospirillum lipoferum* and *Azospirillum brasilense* on the seedling growth and vigour in maize. The study showed that all the bacterial strains significantly increased plant height, 100 seed weight, number of seeds per ear and leaf area in maize.

Biopriming of *Helianthus annus* L. seeds with *Pseudomonas fluorescens* promoted rapid and uniform seed germination with enhanced germination index, germination percentage, germination rate, vigour index and also seedling growth indices such as root length, shoot height, dry and wet weight of seedlings and numbers of lateral roots (Moeinzadeh *et al.*, 2010).

Ghorbanpour and Hatami (2014) investigated the response of seed priming with PGPRs (*Pseudomonas fluorescens* and *P. putida*) in *Salvia officinalis* and

observed its positive influence on seed germination percentage (GP), mean time germination, germination rate, root and shoot length and seedling vigour index (VI)

2.1.1.2. In vitro seed germination

The plant growth regulators, *viz.*, cytokinins, auxins and gibberellins are reported to have varied influence on *in vitro* seed germination in different plant species.

Cytokinin promoted *in vitro* seed germination of the Western European orchid species *Cypripedium calceolus* and *Epipactis helborine* whereas, it inhibited germination in *Lisiera ovata* and *Dactylorhiza maculata* (Waes and Debergh, 1986). Nikolic *et al.* (2006) studied the effects of cytokinins on *in vitro* germination in *Lotus corniculatus* L. They reported two fold increase in seed germination in optimum concentrations of cytokinins, thidiazuron and zeatin, followed by benzyl adenine.

Costa *et al.* (2002) used 1.0 mg L^{-1} GA_3 for *in vitro* sprouting of jenipapo (*Genipa americana*) which promoted growth to 15 mm. Use of Wood Plant Medium (WPM) supplemented with 25-32 mg L^{-1} GA_3 and MS with 26-30 mg L^{-1} GA_3 and 2 mg L^{-1} NAA promoted rooting and plant growth of *Annona cracciflora* (Ribeiro *et al.*, 2009).

Among the different combinations of growth regulators tested, embryos inoculated on the medium containing 1.0 mg L^{-1} Kn + 0.2 mg L^{-1} NAA resulted in 100 per cent germination of *Nothapodytes foetida* (Kaveri and Rao, 2015).

2.1.2 Vegetative Propagation

2.1.2.1 Stem cuttings

Among the various methods of vegetative propagation of forest tree species, shoot cuttings is the most preferred planting material (Bhatnagar, 1973). According to Mathew *et al.*, (2011), stem cuttings is the main method of propagation in

Ficus spp. The propagation by stem cuttings is the most popular among propagation methods, as it is simpler and cheaper. Hence, this is being used for large scale production of plants with irregular seed bearing habit, long flowering or fruiting intervals, slow seedling initiation and seed dormancy (Thakur *et al.*, 2018).

A significant shoot sprouting of 78.35 per cent was recorded in *Crataegus oxyacantha* cuttings, when treated with IBA 1000 mg L^{-1}. Also statistically significant shoot lengths (5.67 and 5.33 cm) were observed when treated with IAA 2000 mg L^{-1} and IBA 1000 mg L^{-1}, respectively (Gopichand and Meena, 2015). Khudhur and Omer (2015) reported that *Dalbergia* had the maximum percentage of rooted cuttings, shoot length, number of main branch, diameter of main branch, leaf area, number and length of root, fresh and dry weight of root and shoots and chlorophyll a, when the cuttings were pretreated with IAA and NAA 500 ppm. Nitrogen and protein content also increased on treatment with NAA 500 ppm. Gopichand and Meena (2015) found significantly higher rooting percentage (85.33 per cent) and root length, when *Ginkgo biloba* cuttings were pretreated with IBA 250 mg L^{-1}.

Purohit *et al.* (2009) reported that higher concentration of IBA 500 mM resulted in maximum rooting (50 per cent) in cuttings of *Ginkgo biloba*, whereas no rooting was recorded in cuttings kept as control.

Shekhawat and Manokari (2016) demonstrated significant shoot bud induction and growth when nodal cuttings of *Couroupita guinanensis* were pretreated with naphthalene acetic acid (NAA) 400 mg L^{-1}.

According to Swamy *et al.* (2001), cuttings when pretreated with NAA 500 mg L^{-1}, gave substantial rooting in *Robinia pseudoacacia.* The stem cuttings of *Embelia tsjeriam* and *Caesalpinia bondu,* when treated with NAA and IBA @ 1000 ppm respectively, recorded maximum percentage of sprouting and survival, irrespective of diameter and length of the cuttings (Tiwari and Das, 2010). Adekola and Akpan (2012) found that growth hormone application had no significant effect on survival and sprouting behaviour of *Jatropha curcas*. The untreated cuttings

(control) performed better than the hormone treated cuttings. However, the cuttings treated with IBA were found to root better than those of NAA.

The percentage of rooting was found higher in Poinsettia treated with salicylic acid, which revealed its positive influence on rooting (Sardoei and Shahdadneghad, 2015).

The semihardwood cuttings of *Azadirachta indica* treated with 500 ppm IBA and planted in vermiculite media showed maximum rooting with number of roots (32.38) with root length (5.77 cm), numbers of sprouts (3) and number of leaves (4.92) (Gehlot, 2017).

Swamy *et al.* (2001) studied the rooting ability of stem cuttings harvested from juvenile (2-year-old) and mature hardwood (15-year old) trees of *Robinia pseudoacacia* and *Grewia optiva*. It was found that the juvenile cuttings of both species rooted significantly better (42.9 per cent in *R. pseudoacacia* and 46.6 per cent in *G. optiva*) than mature hardwood cuttings (34.7 per cent in *R. pseudoacacia* and 41.4 per cent in *G. optiva*). In *R. pseudoacacia*, the highest rooting in juvenile (83.3 per cent) and mature (66.6 per cent) cuttings was observed with the treatment, NAA 500 mg L^{-1}. In *G. optiva*, IBA 250 mg L^{-1} gave the most effective response and recorded a maximum of 80 per cent and 70 per cent rooting in juvenile and mature cuttings, respectively.

Tiwari and Das (2010) reported that thin and medium stem cuttings at four nodal lengths were found to be the best for higher sprouting and survival of two ethno-medicinally important shrub species *Embelia tsjeriam* and *Caesalpinia bondu.*

Kesari *et al.* (2009) reported that all auxin treatments promoted sprouting and at lower concentrations triggered rooting of cuttings in *Pongamia pinnata.* In *Aesculus indica,* the cuttings treated with IBA @ 4000 ppm and IBA @ 2000 ppm had a sprouting rate of 75 and 50 per cent respectively, which was significantly higher than that of control. The highest rooting rate (50 per cent) was recorded in

the cuttings with the application of IBA @ 4000 ppm and 25 per cent in those treated with IBA @ 2000 ppm (Majeed *et al.*, 2009).

Shekhawat and Manokari (2016) reported that stem cuttings of *Courouptia guianensis* when pretreated with NAA 400 mg L^{-1} for 5 min, gave 100 per cent rooting and excellent shoot induction. The pretreatment with IBA 300 mg L^{-1} and IAA 400 mg L^{-1} for 5 min induced shoots in 79 and 75 per cent cuttings, respectively.

According to Sundharaiya *et al.* (2016), the terminal cuttings of vellerukku (*Calotropis procera*) treated with IBA 500 ppm registered the highest rooting percent (86.66 per cent and 90.00 per cent), number of roots (11.21), root length (23.75 cm and 24.98 cm), shoot length (29.40 cm and 30.64 cm) and survival percentage (68.13 per cent and 71.20 per cent) in the main field.

James and Thurbon (1981) observed that in apple rootstocks M.9, phloroglucinol 1000 µM combined with IBA promoted rooting. Jani *et al.* (2015) demonstrated the influence of phloroglucinol on shoot bud induction in *Tinospora cordifolia in vitro*. Basal MS + Kin 6.98 µM + PG 79.4 µM increased shoot bud induction from 52.20 to 84.80 per cent.

Chettri and Rai (2014) reported that the cuttings of *Aechynanthus sikkimensis* recorded maximum sprouting percentage (86.40 and 78.00 per cent), shoot length (4.50 and 4.40 cm), diameter (2.50 and 1.30 mm), number of leaves per shoot (4.0 and 4.50), when treated with IAA 1000 ppm and NAA 100 ppm, respectively.

The treatment of cuttings with acetyl salicylic acid in combination with IAA was found to be effective in woody plant propagation (Kling and Meyer, 1983). The exogenous application of salicylic acid (SA) is useful for the growth and development of plants (Sanaa *et al.*, 2002; Galal, 2012). Akbulut and Yigit (2014) observed the highest callus formation in semihardwood shoot cuttings of

Amygdalus sp., when applied with acetylsalicylic acid 50 mg L^{-1} in combination with IAA.

Weerakon *et al.* (2014) reported that softwood cuttings of *S. cochinchinensis* grown in sand medium showed the highest percentage survival (30 per cent) and average root biomass (0.004 g) in the semi glass house condition. The highest percentage survival (40 per cent) was shown by hardwood cuttings in the media containing forest soil + sand and that containing sole forest soil.

2.1.2.2 Root cuttings

In experiments with root cuttings of *Prumi savium* best results were obtained when cuttings were inserted with the proximal 2-3 cm exposed to the air (Ghani and Cahalan, 1991). Pandey and Mandal (2010) demonstrated the superiority of root cuttings (40-85 per cent) over stem cuttings (40-65 per cent) in terms of establishment in *Rauvolfia serpentina.* According to Ragone (2008) and Roberts-Nkrumah (2012), ideal planting material for commercial production of bread fruit is root cuttings, as they can be induced to produce adventitious shoots.

2.2 INFLUENCE OF POTTING MEDIA ON NURSERY PLANT ESTABLISHMENT

The selection and optimisation of potting media is very essential for the successful establishment of nursery plants. Growth substrate influences the photosynthetic efficiency, morphological and physiological parameters, that play an important role in growth and development processes in plants. The growth media encompasses sand, soil, cow dung, vermicompost, bio inoculants etc.

Vermicompost, produced as a result of bioconversion of organic waste materials by earthworms can be used as a component in potting media owing to its excellent nutrient status, physiochemical characters and cost effectiveness. The substantial improvement in plant growth and productivity on vermicompost supplementation in soil is due to its biological and physico-chemical properties (Gaur and Sadasivam, 1993, Pathma, and Sakthivel, 2012).Vermicompost adds

beneficial microbes to soil and thus contributes to the biological fertility. Vermicompost provide large surface area that act as microsites for microbial activity and for the strong retention of nutrients. Sinha *et al.* (2009) reported that the growth promotion of vermicompost could be attributed to their micro and macro elements, vitamins, enzymes and hormones. It also promotes higher uptake of nitrogen, phosphorus and potassium. According to Scheuerell *et al.* (2005) when vermicompost is added to soil, it improves soil structure, fertility, plant growth and also, suppresses diseases caused by soil-borne plant pathogens.

Cow dung is an important source of organic fertilizer, which enhances crop productivity in terms of improved soil health, nutrient status and enhanced microbial population. Mandal *et al.* (2013) reported higher yield (50-92 per cent) in *Aonla*, on combined application of inorganics, organics and biofertilizers. Cow dung, when applied to growing medium improves water infiltration and water holding capacity and exhibits increased cation exchange capacity (Raj *et al.*, 2014).

PGPR comprises of beneficial, free-living bacteria that stimulates plant growth and enhances yield in different crop plants including tree crops. The genera of PGPR includes *Azotobacter, Azospirillum, Pseudomonas, Bacillus, Paenibacillus*, etc. (Raj *et al.*, 2005). The rhizobacteria have the ability to produce phytohormones, organic acids, siderophores, antibiotics and promotes fixation of atmospheric nitrogen and phosphate solubilization (Glick, 1995). Youseff and Eissa (2014) reported that growth, yield and quality parameters of certain plants significantly increased with the application of biofertilizers containing bacterial nitrogen fixer, phosphate and potassium solubilizing bacteria. The PGPR Mix 1, (consortium of *Azospirillum lipoferum, Azotobacter chroococcum, Bacillus megaterium* and *Bacillus sporothermodurans,* each with 5×10^7 cfu) has been evaluated in the establishment of rooted cuttings of black pepper and it was observed that PGPR Mix 1 in combination with humic acid and fish amino acid would produce quality rooted cuttings for black pepper nurseries (Aswathy *et al.*, 2018).

Arbuscular mycorrhizal fungi (AMF) is an obligate symbiont that provides the host plant with mineral nutrients and water, in exchange for photosynthetic products (Smith and Read, 2008). Higher root colonization by AMF promotes host fungus interaction and exchange of nutrients for better growth (Mallesha and Bagyaraj, 1990). The thin fungal mycelium that emerges from the root system penetrates small pores and acquires nutrients from soil regimes that are inaccessible to roots (Smith *et al.*, 2000; Allen, 2011). The external application of mycorrhizal spores is done by adding AMF inoculum either to growing medium or into the planting hole at the time of transplanting. This would account for enhanced growth of seedlings in the nursery and better performance of mature plants following planting in the field (Giananazzi *et al.*, 2001). Rahman *et al.* (2014) found that mycorrhizal plants showed better performance in terms of vigour, yield, spore population in soil and root colonization than non-mycorrhizal plants.

Azospirillum are proteobacteria that stimulate the plant growth through nitrogen fixation, production of phytohormones and molecules with antimicrobial activity. *Azospirillum* in the media fixes atmospheric nitrogen and makes it available to the plant. The stimulated supply of nitrogen would enhance the synthesis of chlorophyll and amino acid, subsequently proteins and nucleic acids that would form a framework for chloroplast, there by improve the photosynthetic activity (Somers *et al.*, 2005). It also produces auxins that hastens the rooting process in cuttings (Bartolini *et al.*, 2017). Phosphorus solubilizing bacteria (PSB) increases P uptake by the plant and thereby increase the crop yield. PSB produces organic acids, and acid phosphatases that play a significant role in the mineralization of organic phosphorous in soil and make phosphorus available to the plant (Rodriguez and Fraga, 1999). Phosphorus is abundant in soils in both inorganic and organic forms. Its occurrence in insoluble mineral complexes, makes it unavailable for root uptake. The PSB solubilizes the insoluble P forms and make it available to the plant. The application of PSB to the soil substantially reduces the need for chemical application of P. The use of efficient PSB, sustains soil health and improves crop productivity (Sharma *et al.*, 2013).

2.2.1 Effect of potting media on morphological parameters

Thankamani *et al.* (1996) investigated the effect of different organic manures *i.e.*, vermicompost, farmyard manure, saw dust, forest leaf and coir dust compost on clove (*Syzygium aromaticum*) seedlings and black pepper cuttings under nursery conditions. In this study, vermicompost was identified as the better option than farmyard manure, as it improved physico-chemical properties of soil and growth of plants. This could be attributed to higher nutrient content of vermicompost compared to farm yard manure. However Arunkumar (2000) reported that both FYM and vermicompost maintained their superiority at all growth stages considering the plant height, number of leaves and number of branches of *Amaranthus,* among the various organic manures tried.

Ge *et al.* (2016) reported the positive effects of vermicompost on growth characteristics of *Asparagus officinalis* L. Shrimal and Khan (2017) found that the application of vermicompost in the soil, improved plant biomass in bengal gram. Alidadi *et al.* (2014) opined that vermicompost is a potential source of plant nutrients for sustainable tomato production.

Rekha *et al.* (2018) compared the effect of plant growth enhancers like GA, IAA, and vermicompost 50 per cent on growth of *Capsicum annum.* Vermicompost 50 per cent showed significant improvement in growth compared to the GA and IAA treated plants.

Sahoo and Gupta (2017) reported that vermicompost mixed soil recorded higher value in all the growth parameters *viz,* leaf number, branch number, shoot height, shoot fresh and dry weight, leaf area, leaf fresh and dry weight, root length, root fresh and dry weight, compared to control in *Piper longum.*

In a study, Ewulo *et al.* (2007) reported that cow dung could improve growth parameters such as numbers of leaves, branches, plant height, girth, fruit number and fruit weight in pepper.

Najafabadi *et al.* (2017) demonstrated that 55 per cent cow dung in soil could enhance, leaf growth, stem and root weight, root length, growth indices, leaf area ratio etc. substantially, in *Aloe vera.*

Baldi and Toselli (2013) investigated the application of compost and cow manure on root growth of nectarine (*Prunus persica* L.). According to them, cow manure enhanced new root production compared to compost. Compost produced root at a depth of 21–40 cm and cow manure at 61–80 cm. The root lifespan was longer in compost than in cow manure treated trees. No differences were observed in root length and diameter.

The PGPR would substantially enhance plant growth parameters. This could be attributed to the production of plant growth regulators such as auxins, gibberellins, cytokinins and ethylene by PGPR (Frankenberger and Arshad, 1995). Ramamoorthy and Samiyappan (2001) and Raj *et al.* (2005) demonstrated that treatment with PGPR would improve shoot growth and subsequently shoot biomass in various crop plants including plantation crops and tree species.

Chawla and Mehta (2015) reported that growth of transplanted litchi layers on orchard soil + FYM + PGPR @ 50g kg^{-1} growing media recorded early sprouting in 105 days compared to untreated soil (131.94 days). It also gave better response with respect to survival per cent (90), increase in plant height (10.65 cm), leaves per layer (32.30), total leaf area (823.45 cm^2), root length (14.27 m), fresh and dry weight of roots (8.17 and 3.08 g), fresh and dry weight of shoot (58.03 and 35.30g), root:shoot ratio on fresh and dry weight basis (0.141 and 0.087) and chlorophyll content (0.91 mg g^{-1}).

Damam *et al.* (2014) concluded that in field conditions, PGPR strains significantly increased plant growth parameters (shoot length, number of branches, number of tubers, diameter of tuber and total biomass) in *Coleus. Withania* plants inoculated with PGPR showed an increase in plant growth parameters and nutrient status compared to uninoculated plants (Anuroopa and Bagyaraj, 2017). Khosravi *et al.* (2017) reported the co-application of PGPR and rock phosphate in non-

vermicomposting treatments significantly increased shoot dry weight, shoot nitrogen, phosphorus, potassium, zinc and manganese uptake rates while co-application of PGPR and vermicompost significantly decreased dry weight of shoots.

Ashwagandha treated with different PGPR strains showed improved plant growth parameters *viz.* plant height, shoot and root weight, tuber length and number of branches (Mallesh, 2008). Yousefi *et al.* (2017) reported that PGPR application on hopbush (*Dodonaea viscosa* L.) seedlings improved plant growth parameters *viz.*, root length, stem length, root biomass and stem biomass.

Megala and Paranthaman (2017) studied the effect of PGPR on plant height in *Solanum nigrum*. They observed increase in plant height on PGPR inoculation and the maximum value was recorded in PGPR consortium (*Azospirillum lipoferum, Azotobacter chroococcum, Bacillus megaterium* and *Pseudomonas fluorescens*).

Mohan and Rajendran (2014) reported that substantial increase (more than 75 per cent) in shoot length, root length, collar diameter and biomass on combined inoculation of *Azospirillum* + AM fungi + *Pseudomonas* compared to control and this combination was observed to be beneficial for quality seedling production in *Feronia elephantum*. Ilangamudali and Senarathne (2016) reported higher root volume in coconut seedlings treated with AMF.

Wang *et al.* (2018) examined the effects of colonization with AM fungi, *Funneliformis mosseae* and *Diversispora versiformis*, alone and in combination, on the growth and nutrient uptake of the medicinal plant *Chrysanthemum morifolium* and found that root length, total biomass and root N concentration were higher in the mycorrhizal plants than in the non-mycorrhizal plants.

The effect of PGPRs and AMF on growth characters in *Stevia rebaudiana* were studied by Vafadar *et al.* (2014) and reported that the root and shoot biomass increased significantly by the inoculation.

The application of biofertilizers such as *Azospirillum* spp., phosphorus solubilizing bacteria (PSB) and *Pseudomonas flourescens* along with vesicular arbuscular mycorrhiza (VAM) significantly increased the shoot length, stem girth and number of leaves in cashew grafts under nursery conditions (Shankarappa *et al.*, 2017).

Raja and Kumari (2008) investigated the application of various combinations of *Azospirillum, Azotobacter,* phosphate solubilizing bacteria (PSB) and VAM fungi in *Jatropha* plant and observed that combined inoculation resulted in significant increase in morphological parameters, *viz.*, root length, shoot length, shoot biomass, root biomass and leaf area. Khoramdel *et al.* (2008) reported that the inoculation of biological fertilizers significantly increased plant height and dry matter accumulation over control in black cumin. The maximum plant height and dry matter accumulation was observed in *Azospirillum* – mycorrhiza combination.

Patel *et al.* (2016) revealed that the application of biofertilisers, *Azotobacter, Azospirillum*, phosphate solubilizing bacteria and their combination increased plant height, number of branches, number of leaves, length of root, fresh weight, dry weight and bioactive component (plumbagin) in *Plumbago rosea.*

2.3.2. Effect of potting media on physiological parameters

The influence of organic manures on leaf number and leaf area index (LAI) was found to be superior over inorganic fertilizer application in *Oryza sativa* (Sharma and Mitra, 1990). In turmeric, LAI was found to be the highest in plants raised in the media comprising of FYM and coirpith compost (Rakhee, 2002).

Azarmi *et al.* (2008) revealed that the application of vermicompost significantly increased the growth characteristics such as leaf number, leaf area, leaf area index, shoot dry weights and yield when compared to the control in *Lycopersicum esculentum*. Sandhya *et al.* (2013) studied the effect of biofertilizers, vesicular arbuscular mycorrhiza (VAM) and PSB individually and in combination on growth and physiological parameters of *Marsdenia volubilis* plant under nursery conditions

and observed that VAM- PSB combination enhanced number of leaves per plant and leaf area per plant.

Raja and Kumari (2008) reported that, among the various combinations of PGPR tried, *Azospirillum*, *Azotobacter*, phosphate solubilizing bacteria (PSB) and VAM fungi considerably enhanced the leaf area in *Jatropha* plants. Estrada-Luna and Devies (2003) reported that the AM fungi inoculated plantlets markedly increased the leaf area, leaf dry mass and leaf area ratio than the non-inoculated plantlets in ancho pepper.

Sanjutha *et al.* (2008) revealed that the application of farm yard manure at 15 t ha^{-1} significantly increased leaf area index in *Andrographis paniculata.* The application of biological fertilizers enhanced the leaf area index over control in black cumin (Khoramdel *et al.*, 2008).

Najafabadi *et al.* (2017) reported enhanced growth indices *viz.*, absolute growth rate (AGR), leaf area ratio (LAR), leaf weight ratio (LWR), and harvest index (HI) in *Aloe vera,* when 55 per cent cow dung was applied to soil.

2.3.3. Effect of potting media on phytochemical parameters

An increased tissue N, P and K concentrations were observed in transplanted seedlings of *Eucalyptus tereticornis* that were inoculated with AMF, *Glomus sp.* individually and in combinations with *Azospirillum* (Sugavanam *et al.*, 2000).

Raja and Kumari (2008) reported that treatments such as *Azospirillum* ,*Azotobacter*, phosphate solubilizing bacteria (PSB) and VAM fungi significantly increased chlorophyll a content, total protein content and total soluble sugars in *Jatropha* plants. Patil (2010) reported that the combination treatment of biofertilizers with chemical fertilizer increased protein, carbohydrate content and chlorophyll content compared to control in *Stevia rebaudiana.*

Vafadara *et al.* (2013) studied the effect of PGPRs and AMF on *Stevia rebaudiana* and reported that stevioside content, total chlorophyll and N, P, K content in plants were found to be higher in inoculated plants than the control. Sandhya *et al.* (2013) demonstrated enhanced chlorophyll content in *Marsdenia volubilis* plant under nursery conditions, when they were treated with VAM or PSB individually and in combination. Murugesan *et al.* (2016) demonstrated that the application of bioinoculants (PGPR, AMF) could appreciably improve the growth performance of nursery plants, as they supplement primary nutrients like protein, chlorophyll, Ca, N, P, Mg, K and organic carbon, and thus reducing the need for fertilizers in eucalyptus.

Chithra *et al.* (2015) reported high total chlorophyll and protein contents in PSB treated *Abelmoschus esculentus* compared to untreated ones. Significant increase in chlorophyll content was reported by Singh and Siddiqui (2015), when phosphorous solubilizer, *Pseudomonas fluorescens* was applied to tomato plants.

The total chlorophyll content and protein content in *Solanum nigrum* were significantly increased by the application of microbial consortium containing PGPR like *Azospirillum lipoferum, Azotobacter chroococcum, Bacillus megaterium* and *Pseudomonas fluorescens* over the control (Megala and Paranthaman, 2017).

Kinany *et al.* (2018) reported that date palm plantlets transplanted into compost inoculated with AMF showed increased chlorophyll and mineral nutrient contents than plantlets transplanted into non-inoculated compost, after twelve months of growth.

The application of *Azospirillum lipoferum* on *Myracroduon urundeuva* under drought condition significantly increased the chlorophyll a, b and total chlorophyll content (Oliveira *et al.*, 2018).

2.3.4 Effect of vermicompost, cow dung and microbial inoculants on physico-chemical properties of growing media

More (1994) reported that addition of farm waste and organic manures increased the status of organic carbon, available N, P and K of the soil. According to Lal *et al.* (2000), incorporation of organic waste significantly increased the soil pH and nutrient status of an acid soil.

Azarmi *et al.* (2008) reported that vermicompost application to soil increased soil EC and decreased soil pH compared to untreated plots. The soil treated with 15 t ha^{-1} vermicompost recorded a higher EC of 3.69 mS cm^{-1} and a lower pH of 7.33 compared to untreated soil (EC-1.30 mS cm^{-1}; pH – 8.00). Alidadi *et al.* (2014) observed that vermicompost treated soil recorded higher EC (1.48 mS cm^{-1}) and lower pH (7.49) compared to that of cow dung applied soil. Soil treated with cow dung recorded an EC 0.7 mS cm^{-1} and a pH of 7.66.

According to Ramalakshmi *et al.* (2008), soils from plot treated with biofertilisers exhibited enhanced soil biological activity in terms of higher microbial population. The incorporation of *Azospirillum* improved available nitrogen, and that of mycorrhiza and phosphobacteria increased the status of available soil phosphorus. The Azophos and mycorrhizal inoculation resulted in higher soil potassium. The biofertilizer inoculation resulted in variation in pH indicated by slight reduction in alkalinity. Illmer and Schinner (1994) proposed that acidification of rhizosphere could be through release of organic acids by the mechanism of proton extrusion.

Kaur *et al.* (2017) reported in a study on pea that soil electrical conductivity, available nitrogen and available potassium were found significantly higher in treatments having 50 per cent farm yard manure + 50 per cent recommended dose of nitrogen and phosphorus + consortium while soil organic carbon and available phosphorus were significantly higher in treatments having 100 per cent farm yard manure + consortium. The inoculation of biofertilizers in addition to organic and inorganic fertilizers resulted in higher residual soil nutrients.

The findings of Sharma *et al.* (2001) revealed that integrated use of biofertilizers with chemical fertilizers significantly improved the available N, P, K in the soil. Increase in available N, P and K contents in soil by the application of biofertilizers has also been reported by Yaduvanshi (2001).

Tolanur and Badanur (2003) reported that available N, P and K contents increased significantly with the application of biofertilisers in combination with chemical fertilizers over the chemical fertilizers alone. Kumar and Shivay (2010) revealed that integrated use of biofertilisers and chemical fertilizers significantly improved the available N, P and K contents compared to application of chemical fertilizers alone.

An effective potting media with adequate supplements, especially organic supplements is a prerequisite for the production of quality planting material under nursery conditions. The application of microbial inoculants to the growing media has profound influence on the establishment and growth performance of plants. The microbial inoculants also add to soil health by improving the soil biological activity (Ramalakshmi *et al.,* 2008; Soumya *et al.,* 2017).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study "Standardisation of nursery management practices in pachotti (*Symplocos cochinchinensis* (Lour.) S. Moore)" was carried out at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala during 2017-18. The study aimed at the evaluation of propagation efficiency of different propagules *viz.*, seeds, stem cuttings and root cuttings and standardization of the potting media for the nursery plants of pachotti.

The study was carried out in two phases:
Phase1: Evaluation of propagation efficiency of different propagules
Phase 2: Evaluation of potting media on nursery plant establishment

3.1 LOCATION

The field study was conducted at the Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram. The location is situated at 8° 30' North latitude and 76° 54' East longitude at an attitude of 28 m above MSL.

3.2 SOURCE OF PLANTING MATERIAL

The propagules *viz.*, seeds, stem cuttings and root cuttings for the study were sourced from Jawaharlal Nehru Tropical Botanical Gardens and Research Institute, Palode, Thiruvananthapuram and from Wayanad district.

3.3 PHASE 1: EVALUATION OF PROPAGATION EFFICIENCY OF DIFFERENT PROPAGULES

The different propagules viz., seeds, stem cuttings and root cuttings were subjected to different treatments to evaluate their propagation efficiency and to bring out the best planting material for nursery establishment.

3.3.1 Seeds

Seeds of *Symplocos cochinchinensis* were procured from Meppadi area and Padinjarethara of Wyanad district during October 2017 and April 2018. The fruit set during the two years were at different times of the year. The flowering and fruting in *S. cochinchinensis* is presented in Plate 1. The matured and ripened fruits were collected from the trees and washed thoroughly in tap water. The fruits were soaked overnight in water and the softened pulp covering the seeds were removed manually. The seeds were then towel dried. The seeds were subjected to *in-vivo* and *in-vitro* germination experiments. The experiments were conducted twice; first during October-December 2017 and second in April –June 2018. The experiments were laid out in Completely Randomised Design. Each treatment was replicated thrice and each replication consisted of 50 seeds.

3.3.1.1 In vivo seed germination

3.3.1.1.1 Physical treatments

The seeds were subjected to various physical treatments as described in Table 1 to study their effect on seed germination. Before the physical tretamnet *via* scarification (with sandpaper), the seeds were dissected out vertically to identify the position of the embryo. The embryo was found near to the protruded end opposite to

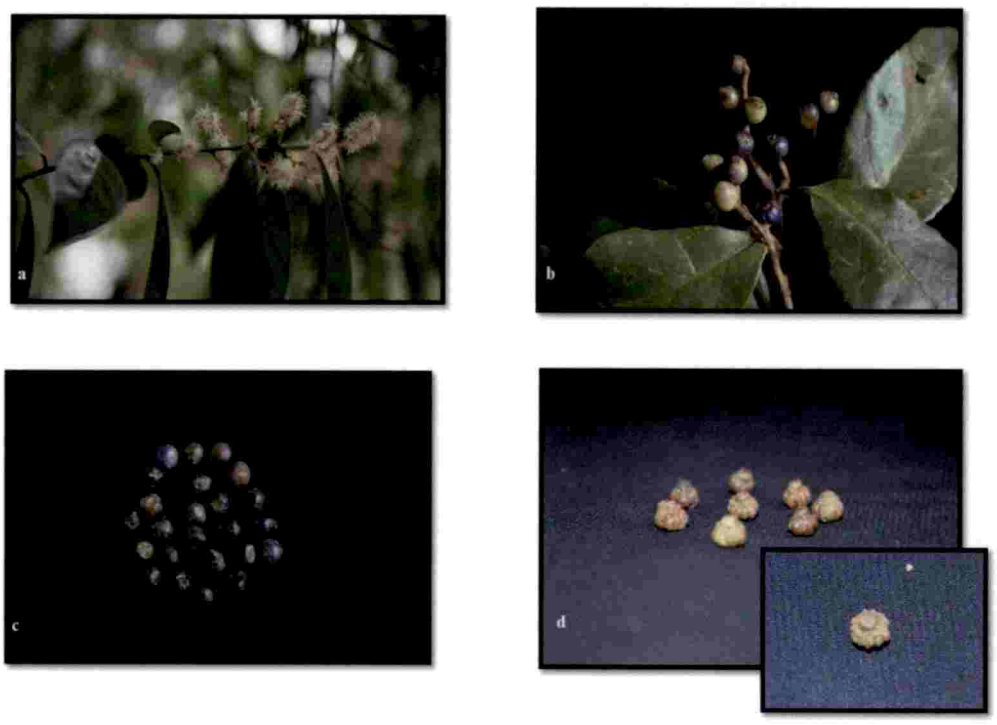

Plate 1. Flowering and fruiting in *S. cochinchinensis* a) Flowering b) Fruiting c) Ripe fruit or seed extraction d) Seed

Table 1: Physical pretreatments tried for seed germination

Treatment	Physical pretreatments
T_1	Scarification (using sand paper)
T_2	Watersoaking (overnight)
T_3	Hotwater treatment (65°C for 10 min)
T_4	Concentrated Sulphuric acid @ 98 per cent (1 min)
T_5	Control (no pretreatment)

Table 2: Chemical priming tried for seed germination

Treatments	Chemical pretreatments
T1	GA_3 @ 100 mg L^{-1}
T2	GA_3 @ 250 mg L^{-1}
T3	IAA @ 100 mg L^{-1}
T4	IAA @ 250 mg L^{-1}
T5	IBA @ 100 mg L^{-1}
T6	IBA @ 250 mg L^{-1}
T7	NAA @ 100 mg L^{-1}
T8	NAA @ 250 mg L^{-1}
T9	Salicylic acid @ 100 mg L^{-1}
T10	Salicylic acid @ 250 mg L^{-1}
T11	Potassium Nitrate @ 5%
T12	Potassium Nitrate @ 10%
T13	Control

the hilum. The scarification was done on the seed accordingly so that embryo did not get damaged. The seeds were initially placed on Whatmann No.42 filter paper in petri plates and given water spray as required, so that the seeds remain adequately wet. Seeds were also sown in protrays for germination comprising of soil, coirpith compost and vermicompost in the ratio of 1:1:1.

3.3.1.1.2 ***Chemical priming***

Seeds were pretreated with different concentration of various chemicals viz., GA3, IAA, IBA, NAA, Salicylic acid and Potassium nitrate for 24 hours to study their effect on seed germination. The treatments for chemical priming of seeds are presented in Table 2. The pretreated seeds were also sown in protrays comprising of soil, coirpith compost and vermicompost in the ratio of 1:1:1.

3.3.1.1.3 Biopriming

The 100 ml broth of the organisms *viz., Trichoderma viride* (10^7 cfu/ml), *Pseudomonas fluorescens* (10^8 cfu/ml), *Azospirillum lipoferum* (10^7 cfu/ml) and *Bacillus megatherium* (10^7 cfu/ml) were procured from the Department of Microbiology. The 50 seeds were immersed in 15 ml of each of these culture for 24 h. The bioprimed seeds were also sown in protrays comprising of soil, coirpith compost and vermicompost in the ratio of 1:1:1. The microbial cultures used for biopriming are presented in Table 3.

3.3.1.2 In vitro seed germination

Seeds were subjected to surface sterilization treatments using mercuric chloride 0.10 percent for 10 minutes followed by ethanol flaming. The seeds after surface

sterilization were given a scarification using sterilized blade to improve the imbibition. The seeds were then inoculated on to sterilized MS medium supplemented with different growth regulators to evaluate its germination efficiency. The growth regulators used for *in vitro* germination study are presented in Table 4.

3.3.1.3 Observations on seed germination

The observations recorded for seed studies were 100 seed weight and germination percentage.

a) **100 seed weight**

100 seeds were randomly taken from the seed lot and weighed and observations recorded

b) **Germination percentage**

Germination percentage is an estimate of viability of a population of seed. Seeds were extracted from the fruit, cleaned and kept for germination . The number of seeds germinated upto two months after the treatments were recorded. The germination percentage was calculated by the following equation

$$\text{Germination percent} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds kept for germination}} \times 100$$

3.3.2 Vegetative propagation

3.3.2.1 Stem cuttings

Three types of stem cuttings *viz.*, hardwood, semihardwood and softwood cuttings of *S. cochinchinensis* used for evaluating the propagation efficiency were subjected to different pretreatments and planted in protrys with potting media comprising

Table 3: Biopriming using microbial culture for seed germination

Treatment	Organisms for biopriming
T_1	*Trichoderma viride* (10^7cfu mL^{-1})
T_2	*Pseudomonas fluorescens* (10^8cfu mL^{-1})
T_3	*Azospirillum lipoferum* (10^7cfu mL^{-1})
T_4	*Bacillus megatherium* (10^7cfu mL^{-1})
T_5	Control (no pretreatment)

Table 4: Growth regulators supplemented in MS medium for *in vitro* seed germination

Treatment	Growth regulators supplemented in MS medium
T_1	GA_3 @ 0.5mg L^{-1}
T_2	GA_3 @, 1 mg L^{-1}
T_3	GA_3 @ 2 mg L^{-1}
T_4	BA @ 0.5 mg L^{-1}
T_5	BA @ 1 mg L^{-1}
T_6	BA @ 2 mg L^{-1}
T_7	Kn @ 0.5 mg L^{-1}
T_8	Kn @ 1 mg L^{-1}
T_9	Kn @, 2 mg L^{-1}
T_{10}	IAA @ 0.5 mg L^{-1}
T_{11}	IAA @ 1 mg L^{-1}
T_{12}	IAA @ 2 mg L^{-1}
T_{13}	NAA @ 0.5 mg L^{-1}
T_{14}	NAA @ 1 mg L^{-1}
T_{15}	NAA @ 2 mg L^{-1}
T_{16}	MS medium (without growth regulator)

of soil, coirpith compost and vermicompost in the ratio of 1:1:1.and were maintained in the polyhouse for three months. The cuttings of uniform size were used for the experiment.

Hardwood cuttings of length 12-15 cm, diameter of 1- 1.5 cm and having 3- 5 nodes (brown colour); semihardwood cutting of length 12-15 cm, diameter 0.5 -1 cm and having 3-5 nodes (brown colour); softwood cutting of length 12-15 cm and 0.5-0.8 cm diameter and having 3-5 nodes (brown with green tinge) were used for the study. The cuttings were given a basal slanting cut and 60 cuttings were tied together and were pretreated in chemical / hormone solution for 2 h, before planting in protrays. The protrays placed in the polyhouse were given misting every two hours for 3 minutes. The different pretreatments tried to evaluate the propagation efficiency of stem cuttings are presented in Table 5.

3.3.2.1.1 Observations on propagation efficiency of stem cuttings

The observations recorded were days to initial sprouting, survival per cent, number of leaves, shoot length and basal shoot girth. Treatments were replicated 3 times with 20 cuttings per replication.

a) Days to initial sprouting

Number of days taken to initiate sprouts on a stem cutting indicated by emergence of shoot from the preexisting buds were recorded.

b) Survival per cent

The survival per cent was recorded at monthly interval upto three months using the formula

$$\text{Survival per cent} = \frac{\text{Number of cuttings survived per treatment}}{\text{Total number of cuttings planted per treatment}} \times 100$$

Table 5: Pretreatments tried to evaluate the propagation efficiency of stem cuttings

Treatment	Pretreatments
C_1	IAA @ 250 mg L^{-1}
C_2	IAA @ 500 mg L^{-1}
C_3	IBA @ 250 mg L^{-1}
C_4	IBA @ 500 mg L^{-1}
C_5	NAA @ 250 mg L^{-1}
C_6	NAA @ 500 mg L^{-1}
C_7	Phloroglucinol @ 10mgL^{-1}
C_8	Phlorogucinol @ 20 mgL^{-1}
C_9	Salicylic acid @ 10 mg L^{-1}
C_{10}	Salicylic acid @ 20 mg L^{-1}
C_{11}	Control

c) Number of leaves

The total number of leaves were counted and mean value recorded. The observations were recorded upto three months at monthly interval.

d) Shoot length

Length of the shoot was measured by using a measuring scale, mean length was worked out and expressed in cm. The observations were recorded upto three months at monthly interval.

e) Basal shoot girth

Shoot girth of the stem cutting was taken by measuring the circumference of the basal collar region, mean value recorded and expressed in cm. The observations were recorded upto three months at monthly interval.

3.3.2.2 Root cuttings

Cuttings of 10-15 cm length and 0.5-1 cm diameter were excised from the roots of *S. cochinchinensis* after removing the soil covering the roots. The root cuttings were pretreated with hormones for two hours and planted in trays with potting media comprising of soil, coirpith compost and vermicompost in the ratio of 1:1:1. They were kept in poly house and subjected to misting at 2 h interval for 3 minutes. The pretreatments tried to evaluate the propagation efficiency of root cuttings are presented in Table 6.

3.3.2.2.1 Observations on propagation efficiency of root cuttings

The observations recorded were days to initial sprouting, survival per cent, number of leaves, shoot length and basal shoot girth. Treatments were replicated thrice with 5 cuttings per replication. The observations were recorded as detailed in 3.3.2.1.1.

Table 6: Pretreatments tried to evaluate the propagation efficiency of root cuttings

Treatment	Pretreatments
H_1	IAA @ 250 mg L^{-1}
H_2	IAA @ 500 mg L^{-1}
H_3	IBA @ 250 mg L^{-1}
H_4	IBA @ 500 mg L^{-1}
H_5	NAA @ 250 mg L^{-1}
H_6	NAA @ 500 mg L^{-1}
H_7	Control

3.3.3 Statistical Analysis

The experiments in the study were laid out in completely randomized design. The data generated from the experiments were subjected to analysis of variance (ANOVA). The data generated at three months after planting were subjected to statistical analysis to compare the effect of two factors, types of stem cuttings and pretreatments and its interaction using Factorial CRD.

3.4 PHASE 2: EVALUATION OF POTTING MEDIA ON PLANT ESTABLISHMENT

3.4.1 Nursery plant establishment in different potting media

The best propagule identified from the Phase 1 experiments were transplanted to polybags containing different potting media. The treatments consisted of the addition of various microbial supplements, PGPR (Plant Growth Promoting Rhizobacteria) Mix1 Azospirillum, PSB (Phosphorus solubilising Bacteria) and AMF (Arbuscular Mycorrhizal Fungi) at 5g per plant to two basal potting media, B1 and B2. B1 comprised of soil: coirpith compost: cowdung (1:1:1) and B2 comprised of soil : coirpith compost: vermicompost (1:1:1). The supplements were placed in the hole made in the centre of the growbags containing 1.25 kg of the potting media. The rooted cuttings were then planted in to these holes. The plants were maintained in these growbags for four months. The potting media with different microbial supplements evaluated for plant establishment in the nursery are presented in Table 7.

Table 7: Potting media evaluated for nursery plant establishment

Treatment	Potting media
T_1	Soil: Coirpith Compost : Cowdung (B1)
T_2	Soil: Coirpith Compost : Vermicompost (B2)
T_3	B_1+ PGPR Mix1
T_4	B1+Azospirillum
T_5	B1 + PSB
T_6	B1+AMF
T_7	B2+PGPR MIX 1
T_8	B2 + Azospirillum
T_9	B2 + PSB
T_{10}	B2+AMF

3.4.1.1. Observations on nursery plant establishment

The observations on morphological and physiological parameters of the nursery plants were recorded. Phytochemical and nutrient analysis of the nursery plants and physicochemical analysis of the media were also done. The treatments were replicated three times with four plants per replication.

3.4.1.1.1. Morphological parameters

The morphological parameters *viz.*, shoot length, number of branches, number of leaves and collar girth were recorded at monthly intervals upto four months after transplanting. The root length, root girth, fresh amd dry weight of shoot and root were recorded at fourth month after transplanting.

a) Shoot length

The length of the shoot was measured by using measuring scale and mean length was worked out and expressed in cm.

b) **Number of branches**

The total number of branches arising in the stem were counted and mean values recorded.

c) Number of leaves

The total number of leaves were counted and mean values recorded.

d) Collar girth

The girth of the collar region of the stem was taken by measuring the circumference of the collar region by using a thread and a scale. Mean girth was calculated and expressed in cm.

e) Root length

The length of the root was measured from the base of the plant to the growing tip of the root. The mean values were worked out and expressed in cm.

f) Root girth

The girth of root was taken by measuring the circumference of the root and mean girth was expressed in mm.

g) Fresh weight of shoot

The plants from the observational plot were uprooted and the fresh weight of the above ground portion was recorded and expressed as g plant^{-1}.

h) Dry weight of shoot

Above ground portion of the samples were collected after uprooting, packed and properly labelled. The samples were dried to a constant weight in a hot air oven at temperature of 70 ± 5°C. Total dry weight was expressed as g plant^{-1}.

i) Fresh weight of root

The weight of the roots after uprooting the plants, fourth month after transplanting was recorded and mean value workout and expressed in g plant^{-1}.

h) **Dry weight of root**

Fresh roots were dried in a hot air oven at 70 ± 5°C until constant weight was obtained. The mean dry weight of the roots was recorded and expressed as g plant^{-1}.

3.4.1.1.2. Physiological parameters

a) Leaf area index

Representative leaves were collected from observational plants and the leaf area were measured using a graph paper at the end of each month. The total leaf area was worked out using the leaf area of selected leaves and number of leaves under each group. Leaf Area Index (LAI) was calculated using the following formula (Williams, 1946)

$$LAI = \frac{\text{Total leaf area of the plant } (cm^2)}{\text{Area covered by the plant } (cm^2)}$$

b) Leaf area duration

Leaf area duration is a measurement that expresses the magnitude and persistence of leaf area during the period of crop growth and it is the duration and extent of photosynthetic tissue of the crop canopy. It is calculated using the formula given by Power *et al.*, (1967)

LAD is expressed in days

$$\mathbf{LAD = [(L_1 + L_2) / 2] \times t_2 - t_1}$$

L_1 – LAI at the first stage (t_1)

L_2 – LAI at the second stage (t_2)

$t_2 - t_1$ = Time interval in days

3.4.1.1.3. Phytochemical and nutrient analysis in nursery plants

a) Carbohydrate

Total carbohydrate content was estimated by Anthrone method (Hedge *et al.*, 1962). Fresh leaf samples of 100 mg was weighed out into a tube, with 5ml of 2.5 N hydrochloric acid (HCL) in a boiling water bath for three hours .The hydrolyzate was

neutralised with solid sodium carbonate until the effervescence ceased. The volume was made up to 100 ml and centrifuged at 5000 rpm for 15 minutes. From the supernatant, 0.5 ml aliquot was taken and made up to one ml by adding distilled water. 4 ml of anthrone reagent was added to this and heated for eight minutes in a boiling water bath. This was cooled rapidly and absorbance was measured at 630 nm in a spectrophotometer. Amount of carbohydrate present was calculated from standard graph prepared using glucose and expressed in terms of milligrams of glucose equivalent per gram of leaf tissue on fresh weight basis.

b) Chlorophyll

Chlorophyll content (chlorophyll a, b and total chlorophyll content) of leaf samples were estimated as per the procedure described by Arnon (1949). Leaf sample 100 mg was taken and chopped into pieces. DMSO (Dimethyl sulfoxide): Acetone (80%) (1:1) mixture 5ml was added to the sample and incubated overnight. The supernatant was collected and the absorbance was measured at 645 and 663 nm. The chlorophyll a, chlorophyll b and total chlorophyll contents were calculated using the formulae given below and expressed in mg g^{-1} of leaf fresh weight.

Chlorophyll a= {[12.7(OD at 663)-2.69(OD at 645)] ×V}/W/×1000)

Chlorophyll b= {[22.9(OD at 645)-4.68 (OD at 663)} ×V}/W×1000)

Total chlorophyll= {[20.2(OD at 645) +8.01(OD at 663)] × V}/ W×1000)

Where V=volume of the solution made up

W=fresh weight of leaves

3.4.1.1.4 Plant analysis

Plant samples were collected four month after transplanting for analysis. The samples were dried in a hot air oven at 70 ± 5°C until constant weight was obtained. The dried samples were ground for analysis. The required quantity of sample was then

weighed out in a electronic balance and the following nutrient analysis were carried out in each treatment.

a) **Plant nitrogen**

Nitrogen content in the plant sample was estimated by modified micro Kjeldhal method (Jackson, 1973) and was expressed in per cent.

b) **Plant Phosphorus**

Phosphorus content in the plant sample was estimated by vanado molybdo phosphoric yellow colour method using spectrophotometer (Jackson, 1973) and was expressed in per cent.

c) **Plant Potassium**

Potassium content in the plant sample were estimated using flame photo meter method (Jackson, 1973) and was expressed in per cent.

d) **Soluble protein**

Total soluble protein of leaf was estimated using simple protein dye binding assay (Sadasivam and Manickam, 1996) using bovine serum albumin (BSA) as the standard. Coommassie Brilliant Blue (CBB) 250 @ 100 mg was dissolved in 50 ml of 95 per cent ethanol. To this solution, 100 ml of 85 per cent (w/v) orthophosphoric acid was added. The resulting solution was diluted to final volume of 200 ml with distilled water. One gram of leaf material was ground to a thin paste and soluble protein was extracted with 10 ml of phosphate buffer (pH 7.8) containing 1 mM EDTA, 2 per cent (w/w) PVP. The extract was centrifuged in cold (40° C) at 10,000 rpm for 10 minutes. To 50 µl of the supernatant 4ml of Bradford reagent was added and mixed well. The absorbance of the solution was recorded using spectrophotometer at 595 nm. The

protein content was calculated using the BSA standard in the range of (10-100µg). The protein content was expressed as mg g^{-1}.

3.4.1.1.5 Physico chemical analysis of the media

The media samples were collected from the growbag containing the basal media before the experiment and were analysed for pH, electrical conductivity, available nitrogen, phosphorus and potassium. After the experiment, the air dried samples of the media supplemented with various microbial inoculants were analysed for same parameters.

a) pH

The pH meter with glass electrode (Jackson, 1973) was used to estimate the pH of the media tried after the experiment.

b) Electrical Conductivity

The electrical conductivity of the soil was estimated using conductivity meter (Jackson, 1973).

c) Nitrogen

The available nitrogen content in the soil was estimated by alkaline permanganate method (Subbiah and Asija, 1956) and expressed in mg per kg of potting media.

d) Phosphorus

The phosphorus content in the soil was estimated by Bray No 1 extraction and estimation method (Jackson, 1973) using spectrophotometer and expressed in mg per kg of potting media.

e) Potassium

The potassium content was estimated by neutral normal ammonium acetate extraction and estimation using the flame photometer (Pratt, 1965) and expressed in mg per kg of potting media.

3.4.1.1.6 Plant growth potential

The plant growth potential of the plants raised in the basal media supplemented with different microbial inoculants were estimated to find out the best potting media supplement for nursery management using the following equation (Jincy, 2010)

$$\text{Plant growth potential (PGP)} = \frac{\text{Total dry matter production}}{\text{SQ + Shoot : Root ratio}}$$

$$\text{SQ (sturdiness quotient)} = \frac{\text{Plant height}}{\text{Girth}}$$

$$\text{S:R Ratio} = \frac{\text{Shoot length}}{\text{Root length}}$$

3.4.2 Statistical Analysis

The experiments in the study were laid out in completely randomized design (Panse and Sukhatme, 1985). The data generated from the experiments were subjected to analysis of variance technique (ANOVA).

RESULTS

4. RESULTS

The study entitled "Standardisation of nursery management practices in pachotti (*Symplocos cochinchinensis* (Lour.) S. Moore)" was carried out during 2017-18 at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani. The field experiments were laid out in the polyhouse of the Instructional Farm, College of Agriculture, Vellayani. The data collected from the field experiment and laboratory analysis were statistically analysed and the results are presented in this chapter.

4.1 EVALUATION OF PROPAGATION EFFICIENCY OF DIFFERENT PROPAGULES OF *SYMPLOCOS COCHINCHINENSIS*

4.1.1 Seeds

The seeds extracted from the fruits, collected during October 2017 and April 2018 from Wayanad district, were subjected to *in vivo* and *in vitro* germination studies. The 100 seed weight and germination percentage were recorded. The extracted dried seeds recorded a 100 seed weight of 20.6 g. Among the various *in vivo* experiments conducted, the only one physical treatment i.e., scarification responded positively with a germination (indicated by the emergence of radicle from the seeds) of 22 per cent, in the Petri plate (Plate 2a). The radicle emergence from the seed occurred two months after the treatment. The seeds that were sown in protrays gave a lower germination of 2 per cent in two months after sowing. Among the 50 seeds placed, only one seed germinated with proper leaves and roots (Plate 2b). However, the plant did not survive more than two weeks.

In *in vitro* germination study, the surface sterilised seeds did not give germination even after four weeks of inoculation in any of the treatments tried.

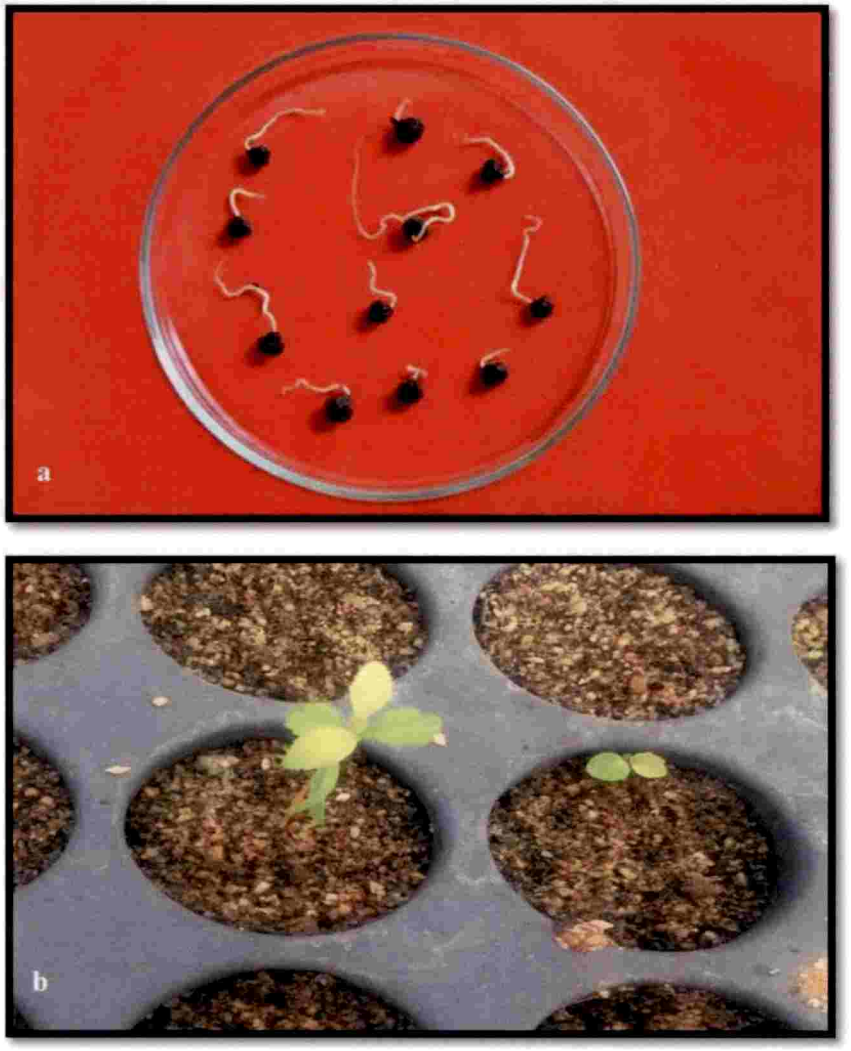

Plate 2. a) Germination of seed as indicated by emergence of radicle b) Seedlings of *S. cochinchinensis*

Hence, it may be concluded that the treatments envisaged in the study could not evoke effective germination of the seeds of *S. cochinchinensis.*

4.1.2 Vegetative propagation

4.1.2.1 Stem cuttings

The three types of stem cuttings, hardwood, semihardwood and softwood cuttings were used to study the propagation efficiency. The cuttings were pretreated with different concentrations of hormones *viz.,* IAA, IBA, NAA or chemicals *viz.,* phloroglucinol (PG), salicylic acid (SA) and control (without pretreatments). The observations were recorded on days to initial sprouting, survival per cent, shoot length, number of leaves and basal shoot girth.

4.1.2.1.1 Hardwood cuttings

4.1.2.1.1.1 Days to initial sprouting

The results of the effect of treatments on days to initial sprouting of hardwood cuttings are presented in Table 8. The data indicated that various treatments tried had no significant influence on initial sprouting in hardwood cuttings. However, C_{10} (SA @ 20 mg L^{-1}) recorded least number of days (11.58 days) to initial sprouting in hardwood cuttings. Initial sprouting was obtained in more than 75 per cent cuttings. Plate 3a and 3b represents sprouting in hardwood cuttings.

4.1.2.1.1.2 Survival per cent

The survival per cent was recorded for three months at monthly intervals. The pretreatments of the hardwood cuttings with hormones / chemicals had significant influence on survival per cent in all the three stages recorded. The results of

Table 8. Effect of pretreatments on days to initial sprouting in hardwood cuttings

Treatment	Pretreatment	Days to initial sprouting
C_1	IAA @ 250 mg L^{-1}	12.11±0.56
C_2	IAA @ 500 mg L^{-1}	12.32±0.52
C_3	IBA @ 250 mg L^{-1}	12.00±0.39
C_4	IBA @ 500 mg L^{-1}	12.06±0.34
C_5	NAA @ 250 mg L^{-1}	12.22±0.62
C_6	NAA @ 500 mg L^{-1}	12.89±0.97
C_7	PG @ 10mg L^{-1}	11.67±0.40
C_8	PG@ 20 mg L^{-1}	11.82±0.62
C_9	SA@ 10 mg L^{-1}	11.67±0.19
C_{10}	SA @ 20 mg L^{-1}	11.58±0.21
C_{11}	Control	13.77±0.44
SEm (±)		0.522
C.D (0.05)		NS

IAA-indole-3-acetic acid; IBA- indole-3-butyric acid; NAA-naphthalene acetic acid; PG-phloroglucinol; SA- salicylic acid

Plate 3. Effect of pretreatment in hard wood cutting a) Sprouting on 11-13 days b) Sprouting in one-month c) Three month after planting of hardwood cutting

pretreatment effects on survival per cent in hardwood cuttings are presented in Table 9.

Among the different treatments tried, C_{10} (SA @ 20 mg L^{-1}) recorded maximum survival of 33.33 per cent which was on par with C_9 (SA @ 10 mg L^{-1}), that recorded 31.67 per cent at one month after planting. The lowest (11.67 per cent) survival rate was observed in the control. This was on par with C_1 (IAA @ 250 mg L^{-1}) and C_5 & C_6 (NAA @ 250 and 500 mg L^{-1}, respectively).

At two months after planting, the treatment C_{10} recorded maximum survival of 31.67 per cent, which was on par with the treatments C_8 (PG @ 20 mg L^{-1}) and C_9. The lowest survival rate (11.67 per cent) was observed in control treatment and C_5 (NAA@ 250 mg L^{-1}) which was on par with the treatments C_1 (IAA@ 250 mg L^{-1}), C_2 (IAA@ 500 mg L^{-1}), C_3 (IBA@ 250 mg L^{-1}), C_4 (IBA@ 500 mg L^{-1}) and C_6.

At three months after planting, the treatment C_9 and C_{10} exhibited the highest survival of 30.00 per cent which was on par with the treatment C_8, while the control and C_5 recorded the lowest survival (10.00 per cent) which was on par with the treatments C_1, C_2, C_3, C_4 and C_6. The survival of hardwood cuttings three months after planting is presented in Plate 3c.

Though more than 75 per cent hardwood cuttings sprouted initially, only 33.33 per cent survived after one month of planting. The drying up of the sprouts in hardwood cuttings is presented in Plate 4. The maximum survival rate hence recorded for hardwood cuttings after three months of planting was 30.00 per cent. The survival rate was consistent with all the treatments after three months of planting.

Table 9. Effect of pretreatments on survival per cent in hardwood cuttings upto three months after planting

Treatment	Pretreatments	Survival per cent		
		1 MAP	2 MAP	3 MAP
C_1	IAA @ 250 mg L^{-1}	15.00±0.00	15.00±0.00	13.33±1.67
C_2	IAA @ 500 mg L^{-1}	18.33±1.67	16.67±1.67	15.00±0.00
C_3	IBA @ 250 mg L^{-1}	16.67±1.67	13.33±3.33	11.67±1.67
C_4	IBA @ 500 mg L^{-1}	16.67±1.67	15.00±2.89	15.00±2.87
C_5	NAA @ 250 mg L^{-1}	15.00±0.00	11.67±3.33	10.00±2.87
C_6	NAA @ 500 mg L^{-1}	15.00±0.00	15.00±0.00	15.00±0.00
C_7	PG @ 10 mg L^{-1}	23.33±1.67	23.33±1.67	21.67±1.67
C_8	PG@ 20 mg L^{-1}	28.33±1.67	26.67±3.33	25.00±2.87
C_9	SA@ 10 mg L^{-1}	31.67±1.67	30.00±0.00	30.00±0.00
C_{10}	SA @ 20 mg L^{-1}	33.33±1.67	31.67±1.67	30.00±0.00
C_{11}	Control	11.67±1.67	11.67±1.67	10.00±2.87
SEm (±)		1.421	2.190	1.946
C.D (0.05)		4.196	6.466	5.745

IAA-indole-3-acetic acid; IBA- indole-3-butyric acid; NAA-naphthalene aceticacid; PG-phloroglucinol; SA- salicylic acid

Plate 4: Drying up of new sprouts in hardwood cuttings

4.1.2.1.1.3 Shoot length

The effect of pretreatments on shoot length in hardwood cuttings are presented in Table 10. The treatments exhibited significant variation with respect to shoot length. The observations were recorded at monthly intervals up to three months.

In the first month after planting, the treatment C_{10} (SA @ 20 mg L^{-1}) exhibited higher shoot length (1.74 cm) among the various treatments. This was found to be on par with the treatment C_7 (PG @ 10 mg L^{-1}). The lowest shoot length (0.50 cm) was recorded in the control treatment, which was found to be on par with C_1, C_5 and C_6.

In the second month after planting, the highest shoot length (2.54 cm) was recorded in the treatment C_{10}, which was found to be on par with the treatments C6, C_8 and C_9. The lowest shoot length (1.03 cm) was recorded in control plant which was on par with C_1.

In the third month after planting, significantly higher shoot length (3.62 cm) was observed in the treatment C_{10}. This was found to be on par with C_4. The control treatment exhibited lowest shoot length (1.43 cm) which was observed to be on par with the treatments C_1 and C_3.

At all the stages of observation, it was found that the treatment C_{10} (SA @ 20 mg L^{-1}) gave maximum shoot length among all the treatments tried.

4.1.2.1.1.4 Number of leaves

Table 11 shows the effects of pretreatments on number of leaves in hardwood cuttings.

Table 10. Effect of pretreatments on shoot length of plants from hardwood cuttings upto three months after planting

Treatment	Pretreatment	Shoot length (cm)		
		1 MAP	2 MAP	3 MAP
C_1	IAA @ 250 mg L^{-1}	0.78±0.10	1.07±0.09	1.46±0.20
C_2	IAA @ 500 mg L^{-1}	0.90±0.05	1.63±0.10	2.14±0.13
C_3	IBA @ 250 mg L^{-1}	1.05±0.08	1.52±0.10	1.78±0.12
C_4	IBA @ 500 mg L^{-1}	0.98±0.03	1.73±0.14	3.13±0.20
C_5	NAA @ 250 mg L^{-1}	0.77±0.15	1.47±0.07	2.23±0.22
C_6	NAA @ 500 mg L^{-1}	0.76±0.14	1.70±0.25	2.05±0.31
C_7	PG @ 10 mg L^{-1}	1.61±0.16	2.16±0.05	2.77±0.09
C_8	PG@ 20 mg L^{-1}	1.12±0.08	2.00±0.21	2.45±0.24
C_9	SA@ 10 mg L^{-1}	1.31±0.21	2.20±0.18	2.99±0.20
C_{10}	SA @ 20 mg L^{-1}	1.74±0.07	2.54±0.05	3.62±0.14
C_{11}	Control	0.50±0.06	1.03±0.09	1.43±0.12
SEm (±)		0.115	0.136	0.188
C.D (0.05)		0.339	0.402	0.556

IAA - indole-3-acetic acid; IBA - indole-3-butyric acid; NAA - naphthalene acetic acid; PG-phloroglucinol; SA- salicylic acid

Table 11. Effect of pretreatments on number of leaves in plants from hardwood cuttings upto three months after planting

Treatment	Pretreatment	Number of leaves		
		1 MAP	2 MAP	3 MAP
C_1	IAA @ 250 mg L^{-1}	1.22±0.11	2.07±0.07	3.12±0.34
C_2	IAA @ 500 mg L^{-1}	1.39±0.06	2.58 ±0.22	3.80±0.28
C_3	IBA @ 250 mg L^{-1}	1.38 ±0.06	1.56 ±0.29	2.22±0.62
C_4	IBA @ 500 mg L^{-1}	1.37±0.04	1.83±0.09	3.61±0.20
C_5	NAA @ 250 mg L^{-1}	1.08±0.08	1.77±0.15	2.42±0.08
C_6	NAA @ 500 mg L^{-1}	1.17±0.17	1.78±0.11	2.56 ±0.29
C_7	PG @ 10 mg L^{-1}	1.29±0.20	2.00±0.23	2.98 ±0.21
C_8	PG@ 20 mg L^{-1}	1.47±0.12	2.03±0.26	2.87±0.13
C_9	SA@ 10 mg L^{-1}	1.51±0.08	2.22±0.15	4.15±0.38
C_{10}	SA @ 20 mg L^{-1}	1.87±0.13	3.77±0.26	4.87±0.98
C_{11}	Control	1.00±0.00	1.39 ±0.20	2.22±0.22
SEm (±)		0.111	0.199	0.419
C.D (0.05)		0.326	0.586	1.237

IAA - indole-3-acetic acid; IBA - indole-3-butyric acid; NAA - naphthalene acetic acid; PG-phloroglucinol; SA- salicylic acid

At the first month after planting, the number of leaves (1.87) was significantly higher in the treatment C_{10} followed by C_9 (1.51). The lowest value (1.00) was recorded in the control plant, which were on par with the treatments C_1, C_5, C_6 and C_7.

At second month after planting, the significantly higher number of leaves (3.77) was observed in the treatment C_{10}. The lowest value (1.39) was observed in control treatment which was found to be on par with the treatments C_3, C_4, C_5 and C_6.

At third month after planting, C_{10} recorded the highest number of leaves (4.87). This was found to be on par with C_2 and C_9. The lowest number of leaves (2.22) was recorded in the control and was found to be on par with C_1, C_3 and C_5.

The hardwood cuttings pretreated with SA @ 20 mg L^{-1} recorded the highest number of leaves and the control recorded the lowest number of leaves at all stages of observation.

4.1.2.1.1.5 Basal shoot girth

The results of pretreatment effects on basal shoot girth in hardwood cuttings are presented in Table 12. C_7 (PG @10 mg L^{-1}) recorded the highest shoot girth of 3.32, 3.42 and 3.51 cm respectively in first, second and third month after planting. The lowest shoot girth of 2.98, 3.10 and 3.12 cm was observed in C_5 (NAA @ 250 mg L^{-1}). The shoot girth recorded at monthly intervals, showed only a slight increase over the three months in all the pretreatments tried.

4.1.2.1.2 Semihardwood cuttings

4.1.2.1.2.1 Days to initial sprouting

The results of pretreatment effects on days to initial sprouting in semihardwood cuttings are presented in Table 13. The pretreatments had no significant effects on days to initial sprouting in semihardwood cuttings. The number of days to initial sprouting in semi hardwood cuttings varied between 11-12 days. As with hardwood cuttings, the

Table 12. Effect of pretreatments on basal shoot girth of plants from hardwood cuttings upto three months after planting

Treatment	Pretreatment	Basal shoot girth (cm)		
		1 MAP	2 MAP	3 MAP
C_1	IAA @ 250 mg L^{-1}	3.23± 0.09	3.36± 0.06	3.39 ± 0.09
C_2	IAA @ 500 mg L^{-1}	3.12 ±0.04	3.20± 0.06	3.30± 0.06
C_3	IBA @ 250 mg L^{-1}	3.20 ± 0.06	3.28 ± 0.08	3.37 ± 0.09
C_4	IBA @ 500 mg L^{-1}	3.07 ± 0.09	3.17± 0.04	3.27 ± 0.03
C_5	NAA @ 250 mg L^{-1}	2.98 ± 0.23	3.10 ± 0.12	3.12 ± 0.07
C_6	NAA @ 500 mg L^{-1}	3.18 ± 0.02	3.22 ± 0.06	3.32± 0.05
C_7	PG @ 10mgL^{-1}	3.32 ± 0.07	3.42 ± 0.05	3.51 ± 0.06
C_8	PG @ 20 mgL^{-1}	3.29 ± 0.06	3.39 ± 0.05	3.48 ± 0.03
C_9	SA @ 10 mg L^{-1}	3.20 ± 0.09	3.39 ± 0.10	3.42 ± 0.09
C_{10}	SA @ 20 mg L^{-1}	3.24 ± 0.05	3.28 ± 0.06	3.48± 0.07
C_{11}	Control	3.09 ± 0.11	3.12± 0.24	3.19 ± 0.14
SEm (±)		0.099	0.098	0.077
C.D (0.05)		NS	0.289	0.226

IAA - indole-3-acetic acid, IBA - indole-3-butyric acid,NAA - naphthalene acetic Acid, PG-phloroglucinol, SA- salicylic acid.

Table 13. Effect of pretreatments on days to initial sprouting in semihardwood cuttings

Treatment	Pretreatment	Days to initial sprouting
C_1	IAA @ 250 mg L^{-1}	12.63 ± 0.78
C_2	IAA @ 500 mg L^{-1}	12.20 ± 0.20
C_3	IBA @ 250 mg L^{-1}	12.33 ± 1.17
C_4	IBA @ 500 mg L^{-1}	12.42 ± 0.21
C_5	NAA @ 250 mg L^{-1}	12.43 ± 0.60
C_6	NAA @ 500 mg L^{-1}	12.66 ± 1.16
C_7	PG @ 10 mg L^{-1}	12.15 ± 0.43
C_8	PG @ 20 mgL^{-1}	11.55 ± 0.22
C_9	SA @ 10 mg L^{-1}	11.89 ± 0.48
C_{10}	SA @ 20 mg L^{-1}	11.00 ± 0.19
C_{11}	Control	13.11 ± 0.22
SEm (±)		0.625
C.D (0.05)		NS

IAA - indole-3-acetic acid; IBA - indole-3-butyric acid; NAA - naphthalene acetic acid; PG-phloroglucinol; SA- salicylic acid

least number of days (11 days) to sprouting in semihardwood cuttings was also obtained in the treatment C_{10} (SA @ 20 mg L^{-1}).

4.1.2.1.2.2 Survival per cent

The results of treatment effects on survival per cent in semihardwood cuttings are presented in Table 14 (Plate 5).

Significantly higher survival per cent was recorded in C_{10} (SA @ 20 mg L^{-1}) in semihardwood cuttings at all stages of observation. The value being 26.67, 25 and 23.33 per cent respectively at first, second and third month after planting. The lowest values (11.67 and 10.00 per cent) were observed in control treatment and C_4 (IBA @500 mg L^{-1}) in first and second month after planting, respectively. At third month after planting, the lowest value (8.33 per cent) was recorded in C_1 (IAA@ 250 mg L^{-1}).

4.1.2.1.2.3 Shoot length

The effects of different pretreatments on shoot length in semihardwood cuttings are presented in Table 15.

At first month after planting, shoot length had no significant variation among the various treatments tried. In the second and third month after planting this parameter showed significant variation among the treatments. The treatment C_{10} recorded the highest shoot length (2.24 cm) in the second month after planting and it was on par with all treatments except control (1.01 cm) and C2 (IAA @ 500 mg L^{-1}) (1.32 cm), which recorded the lower shoot lengths. In the third month, C_{10} recorded significantly higher shoot length (3.72 cm) and the lowest value (1.65 cm) was observed in control, which was on par with C_1 (2.10 cm).

4.1.2.1.2.4 Number of leaves

Table 16 shows the effects of different pretreatments on number of leaves in semihardwood cuttings.

Table 14. Effect of pretreatments on survival per cent in semihardwood cuttings upto three months after planting

Treatment	Pretreatment	Survival per cent		
		1 MAP	2 MAP	3 MAP
C_1	IAA @ 250 mg L^{-1}	13.33 ± 1.67	11.67 ± 1.67	8.33 ± 1.67
C_2	IAA @ 500 mg L^{-1}	16.67 ±1.67	16.67 ±1.67	13.33 ±3.33
C_3	IBA @ 250 mg L^{-1}	13.33 ±1.67	13.33 ±1.67	11.67 ±1.67
C_4	IBA @ 500 mg L^{-1}	11.67 ± 1.67	10.00 ±2.89	10.00 ±2.89
C_5	NAA @ 250 mg L^{-1}	15.00 ±0.00	13.33 ±1.67	11.67 ±1.67
C_6	NAA @ 500 mg L^{-1}	15.00 ±0.00	13.33 ±1.67	11.67 ±3.33
C_7	PG @ 10 mg L^{-1}	16.67 ±1.67	13.33 ±1.67	10.00 ±2.89
C_8	PG @ 20 mgL^{-1}	13.33 ±1.67	13.33 ±1.67	13.33 ±1.67
C_9	SA @ 10 mg L^{-1}	18.33 ±1.67	18.33 ±1.67	16.67 ±3.33
C_{10}	SA @ 20 mg L^{-1}	26.67 ±3.33	25.00 ±2.89	23.33 ±4.41
C_{11}	Control	11.67 ±1.67	10.00 ±2.89	10.00 ±2.89
SEm (±)		1.741	2.072	2.843
C.D (0.05)		5.138	6.116	NS

IAA - indole-3-acetic acid; IBA - indole-3-butyric acid; NAA - naphthalene acetic acid; PG-phloroglucinol; SA- salicylic acid

Plate 5: Plants raised from pre-treated (hormones/chemicals) in semi hardwood cuttings

Table 15. Effect of pretreatments on shoot length of plants from semihardwood cuttings upto three months after planting

Treatment	Pretreatment	Shoot length (cm)		
		1 MAP	2 MAP	3MAP
C_1	IAA @ 250 mg L^{-1}	1.43 ± 0.09	1.70 ± 0.17	2.10 ± 0.21
C_2	IAA @ 500 mg L^{-1}	0.77 ± 0.07	1.32 ±0.09	2.27 ± 0.41
C_3	IBA @ 250 mg L^{-1}	1.37 ± 0.14	1.93 ± 0.07	2.38 ± 0.04
C_4	IBA @ 500 mg L^{-1}	1.23 ± 0.17	1.71 ± 0.09	2.72 ± 0.06
C_5	NAA @ 250 mg L^{-1}	1.04 ± 0.03	2.08 ± 0.15	2.87 ± 0.03
C_6	NAA @ 500 mg L^{-1}	0.93 ± 0.03	1.70± 0.43	2.79 ± 0.06
C_7	PG @ 10mgL^{-1}	1.42 ± 0.39	2.11 ± 0.14	2.99 ± 0.18
C_8	PG@ 20 mgL^{-1}	1.19 ± 0.09	2.14± 0.01	2.60 ± 0.15
C_9	SA@ 10 mg L^{-1}	1.09 ± 0.41	2.23 ± 0.09	3.18± 0.17
C_{10}	SA @ 20 mg L^{-1}	1.12 ± 0.07	2.24 ± 0.26	3.72± 0.14
C_{11}	Control	0.63 ± 0.06	1.01 ± 0.11	1.65 ± 0.09
SEm (±)		0.192	0.185	0.173
C.D (0.05)		NS	0.545	0.512

IAA - indole-3-acetic acid; IBA - indole-3-butyric acid; NAA - naphthalene acetic acid; PG-phloroglucinol; SA- salicylic acid

Table 16. Effect of pretreatments on number of leaves in semihardwood cuttings upto three months after planting

Treatment	Pretreatment	Number of leaves		
		1 MAP	2 MAP	3 MAP
C_1	IAA @ 250 mg L^{-1}	1.50 ± 0.10	2.70 ± 0.15	2.78 ± 0.22
C_2	IAA @ 500 mg L^{-1}	1.57 ± 0.03	2.73 ± 0.13	3.67 ± 0.44
C_3	IBA @ 250 mg L^{-1}	1.45 ± 0.14	2.72 ± 0.15	4.45 ± 0.10
C_4	IBA @ 500 mg L^{-1}	1.50 ±0.29	2.14 ± 0.24	4.33 ± 0.22
C_5	NAA @ 250 mg L^{-1}	1.33 ± 0.19	2.22 ± 0.22	3.42 ± 0.10
C_6	NAA @ 500 mg L^{-1}	1.44 ± 0.11	2.66 ± 0.00	3.65 ± 0.09
C_7	PG @ 10 mg L^{-1}	1.44 ± 0.06	2.43 ± 0.05	3.70 ± 0.12
C_8	PG@ 20 mgL^{-1}	1.55 ± 0.05	3.40 ± 0.31	4.67 ± 0.33
C_9	SA@ 10 mg L^{-1}	1.72 ± 0.15	3.39 ± 0.20	4.80 ± 0.38
C_{10}	SA @ 20 mg L^{-1}	1.69 ± 0.10	3.82 ± 0.10	4.92 ± 0.51
C_{11}	Control	1.20 ± 0.10	2.01 ± 0.11	2.81 ± 0.20
SEm (±)		0.137	0.172	0.284
C.D (0.05)		NS	0.508	0.837

IAA - indole-3-acetic acid; IBA - indole-3-butyric acid; NAA - naphthalene acetic acid; PG-phloroglucinol; SA- salicylic acid; MAP - months after planting

In the semihardwood cuttings, as in the case of shoot length, the number of leaves also did not show any significant variation among the various treatments tried at first month after planting. But at second and third month, significant variation was observed in the treatments.

During second month after planting, C_{10} recorded the highest number (3.82) of leaves and was observed to be on par with C_8 (PG @ 20 mg L^{-1}) and C_9 (SA @ 10 mg L^{-1}). The lowest value (2.01) was recorded in control, which was on par with C_5 (NAA @ 250 mg L^{-1}) and C_7 (PG @10 mg L^{-1}).

During third month after planting, maximum number (4.92) of leaves were observed in C_{10}, which was on par with C3 (IBA @ 250 mg L^{-1}), C_4 (IBA @ 500 mg L^{-1}), C_8 and C_9. The lowest number (2.78) of leaves was recorded in C_1 (IAA @ 250 mg L^{-1}), which was on par with the control.

4.1.2.1.2.5 Basal shoot girth

The results of pretreatment effects on basal shoot girth in semihardwood cuttings were presented in Table 17.

Irrespective of the stage of observations, the semihardwood cuttings treated with C_{10} (salicylic acid @ 20 mgL^{-1}) recorded higher basal shoot girth (2.41 cm, 2.47cm and 2.62 cm) at first, second and third month after planting. The lowest values were recorded in control plants with a basal shoot girth of 2.12, 2.16 and 2.24 cm, respectively at first, second and third month after planting.

4.1.2.1.3 Soft wood cutting

The pretreatment effects on soft wood cuttings at three months after planting are presented in Table 18.

The effect of pretreatments on days to initial sprouting, survival per cent, shoot length, number of leaves and basal shoot girth was observed at first, second and third

Table 17. Effect of pretreatments on basal shoot girth of plants from semihardwood cuttings upto three months after planting

Treatment	Pretreatment	Basal shoot girth (cm)		
		1 MAP	2 MAP	3 MAP
C_1	IAA @ 250 mg L^{-1}	2.23±0.072	2.37±0.06	2.48±0.02
C_2	IAA @ 500 mg L^{-1}	2.33±0.03	2.41±0.097	2.50±0.09
C_3	IBA @ 250 mg L^{-1}	2.15±0.05	2.17±0.07	2.31±0.06
C_4	IBA @ 500 mg L^{-1}	2.22±0.08	2.34±0.03	2.39±0.05
C_5	NAA @ 250 mg L^{-1}	2.35±0.07	2.40±0.06	2.51±0.06
C_6	NAA @ 500 mg L^{-1}	2.34±0.04	2.38±0.04	2.49±0.04
C_7	PG @ 10 mg L^{-1}	2.36±0.07	2.40±0.06	2.53±0.06
C_8	PG@ 20 mg L^{-1}	2.37±0.03	2.45±0.03	2.55±0.06
C_9	SA@ 10 mg L^{-1}	2.33±0.04	2.42 ±0.04	2.53±0.05
C_{10}	SA @ 20 mg L^{-1}	2.41±0.02	2.47±0.04	2.62±0.02
C_{11}	Control	2.12±0.09	2.16±0.095	2.24±0.08
SEm (±)		0.062	0.060	0.056
C.D (0.05)		0.184	0.178	0.165

IAA - indole-3-acetic acid; IBA - indole-3-butyric acid; NAA - naphthalene acetic acid; PG-phloroglucinol; SA- salicylic acid; MAP - months after planting

months after planting. Among the various pretreatments tried, only four (C_7, C_8, C_9 and C_{10}) responded but with a very low survival per cent of 5 to 6.67 per cent. The C_7 (PG@10 mg L^{-1}) and C_{10} (SA@ 20 mg L^{-1}) recorded the higher survival of 6.67 per cent. Only those cuttings pretreated with salicylic acid and phloroglucinol responded. Statistical analysis could not be carried out due to very low survival per cent.

The days taken for initial sprouting in softwood cuttings in the responded treatments were between 10-12 days. The maximum shoot length (2.42 cm), number of leaves (3.50) and basal shoot girth (1.34 cm) was recorded in C_{10} (SA @ 20 mg L^{-1}).

4.1.2.1.4 Effect of stem cuttings and pretreatments on days to initial sprouting, survival per cent and morphological parameters of the nursery plants

The effect of stem cuttings (hardwood and semi hardwood) and pretreatments (10 pretreatments and control) on days to initial sprouting, survival per cent and morphological parameters are presented in Table 19.

The type of stem cuttings have significant influence on survival per cent, shoot length and basal shoot girth. S_1 (Hardwood cutting) has significantly higher survival of 17.88 per cent compared to semihardwood cutting (12.73 percent). While S_2 (semi hardwood cuttings) exhibited a higher value with respect to morphological parameters such as shoot length (2.66 cm) and number of leaves (3.92), compared to hardwood cuttings with 2.37 cm shoot length and 3.17 number of leaves. The days to initial sprouting and percentage increase in shoot girth over the three months did not vary significantly between the two types of cuttings.

Among the various pretreatments tried, C_{10} recorded the highest value in terms of survival per cent (26.67) and morphological parameters (Shoot length-3.67 cm; number of leaves-4.89). This was found to be on par with C_9. Pretreatments with salicylic acid @ 10 mg L^{-1} and 20 mg L^{-1} were found to be effective in the initial establishment (primary nursery) of *S. cochinchinensis.*

Table 18. Effect of pretreatments on days to initial sprouting, survival per cent and morphological parameters of plants from softwood cuttings at three months after planting

Treatment	Pretreatment	Days to initial sprouting	Survival per cent	Number of leaves	Shoot length (cm)	Basal shoot girth (cm)
C_7	PG @ 10 mg L^{-1}	12.33	6.67	2.17	2.37	1.30
C_8	PG@ 20 mg L^{-1}	10.00	5.00	2.00	1.80	1.28
C_9	SA@ 10 mg L^{-1}	10.00	5.00	3.00	2.35	1.34
C_{10}	SA @ 20 mg L^{-1}	11.67	6.67	3.50	2.42	1.34

PG-phloroglucinol; SA- salicylic acid

Table 19. Effect of type of stem cuttings and pretreatments on days to initial sprouting, survival per cent and morphological parameters of nursery plants at three months after planting

Treatments	Days to initial sprouting	Survival per cent	No. of leaves	Shoot length (cm)	Basal shoot girth (cm)
Type of stem cuttings					
S_1	12.19	17.88	3.17	2.37	3.40
S_2	12.22	12.73	3.93	2.66	2.47
SEm (±)	0.174	0.734	0.108	0.055	0.022
CD (0.05)	N/A	2.100	0.309	0.156	0.064

Contd....

Treatments	Days to initial sprouting	Survival per cent	No. of leaves	Shoot length (cm)	Basal shoot girth (cm)
Pretreatments					
C1	12.37	10.83	3.27	1.78	2.94
C2	12.26	14.17	3.73	1.90	2.95
C3	12.17	11.67	3.34	2.08	2.79
C_4	12.24	12.50	3.97	2.93	2.88
C_5	12.33	10.83	2.50	2.55	2.90
C_6	12.78	13.33	3.11	2.42	2.99
C_7	11.91	15.83	3.34	2.88	3.02
C_8	11.69	19.17	3.77	2.53	3.00
C_9	11.78	23.33	4.48	3.09	3.03
C_{10}	11.29	26.67	4.89	3.67	3.05
C_{11}	13.44	10.00	2.61	1.85	2.73
SEm (±)	0.407	1.723	0.253	0.128	0.053
CD (0.05)	NS	4.926	0.724	0.366	0.120

Contd....

Treatments	Days to initial sprouting	Survival per cent	No. of leaves	Shoot length (cm)	Basal shoot girth (cm)
Interaction effects					
S_1C_1	12.11	13.33	3.12	1.46	3.39
S_1C_2	12.32	15.00	3.80	2.14	3.40
S_1C_3	12.00	11.67	2.22	1.78	3.27
S_1C_4	12.06	15.00	3.61	3.13	3.37
S_1C_5	12.22	10.00	2.22	2.23	3.28
S_1C_6	12.89	15.00	2.56	2.05	3.49
S_1C_7	11.67	21.67	2.98	2.77	3.51
S_1C_8	11.82	25.00	2.87	2.45	3.48
S_1C_9	11.67	30.00	4.15	2.99	3.52
S_1C_{10}	11.58	30.00	4.87	3.62	3.48
S_1C_{11}	13.77	10.00	2.42	1.43	3.21
S_2C_1	12.63	8.33	3.42	2.10	2.48
S_2C_2	12.20	13.33	3.67	1.65	2.50
S_2C_3	12.33	11.67	4.45	2.38	2.31
S_2C_4	12.42	10.00	4.33	2.72	2.39
S_2C_5	12.43	11.67	2.78	2.87	2.51
S_2C_6	12.66	11.67	3.65	2.79	2.49
S_2C_7	12.15	10.00	3.70	2.99	2.53
S_2C_8	11.55	13.33	4.67	2.60	2.53
S_2C_9	11.89	16.67	4.80	3.18	2.55
S_2C_{10}	11.00	23.33	4.92	3.72	2.62
S_2C_{11}	13.11	10.00	2.81	2.27	2.24
SEm (±)	0.576	2.44	0.358	0.181	0.074
C.D (0.05)	NS	6.966	NS	0.518	NS

S_1- Hardwood cutting; S_2- Semihardwood cutting; C_1- pretreatment with (p.w.) IAA @ 250 mg L^{-1}; C_2- p.w. IAA @ 500 mg L^{-1}; C_3-p.w.IBA @ 250 mg L^{-1}; C_4-p.w. IBA @ 500 mg L^{-1}; C_5- p.w. NAA @ 250 mg L^{-1}; C_6- p.w. NAA @ 500 mg L^{-1}; C_7- p.w. PG @ 10 mg L^{-1}; C_8- p.w. PG @ 20 mg L^{-1}; C_9-p.w. SA @ 10 mg L^{-1}; C_{10}-p.w. SA @ 20 mg L^{-1}

The interaction effect of the type of stem cuttings and pretreatments indicated that there is no significant variation among treatments with respect to days to initial sprouting. However, significant variation was observed with respect to survival per cent (fig.1) and shoot length (fig. 2). During third month after planting, S_1C_{10} (hardwood cuttings pretreated with SA @ 20 mg L^{-1}) gave significantly the higher survival of 30 per cent. The highest shoot length (3.72 cm) was recorded in S_2C_{10} (semihardwood cuttings pretreated with SA @ 20 mg L^{-1}) which was on par with S_1C_{10}. The number of leaves and basal shoot girth did not show any significant variation among the treatments tried.

4.1.2.2 Root cuttings

The effect of hormonal (auxin) pretreatments on days to initial sprouting, survival per cent, shoot length, number of leaves and basal shoot girth in root cuttings were studied at monthly intervals up to three months. The control (without any pretreatments) did not give any sprouting response.

4.1.2.2.1 Days to initial sprouting

The results of treatment effects on days to initial sprouting in root cuttings are presented in Table 20.

The treatments tried significantly influenced the days to initial sprouting in the root cuttings. The lowest number of days (13.33 days) to initial sprouting was observed in H_4 (root cuttings pretreated with IBA @ 500 mg L^{-1}) which was on par with the treatments H_2 (IAA @ 500 mg L^{-1}) (14.33 days) and H3 (IBA @ 250 mg L^{-1}) (15 days). The highest number of days (19 days) to initial sprouting was recorded in H_5 (NAA @ 250 mg L^{-1}), which was on par with H_6 (NAA @ 500 mg L^{-1}).

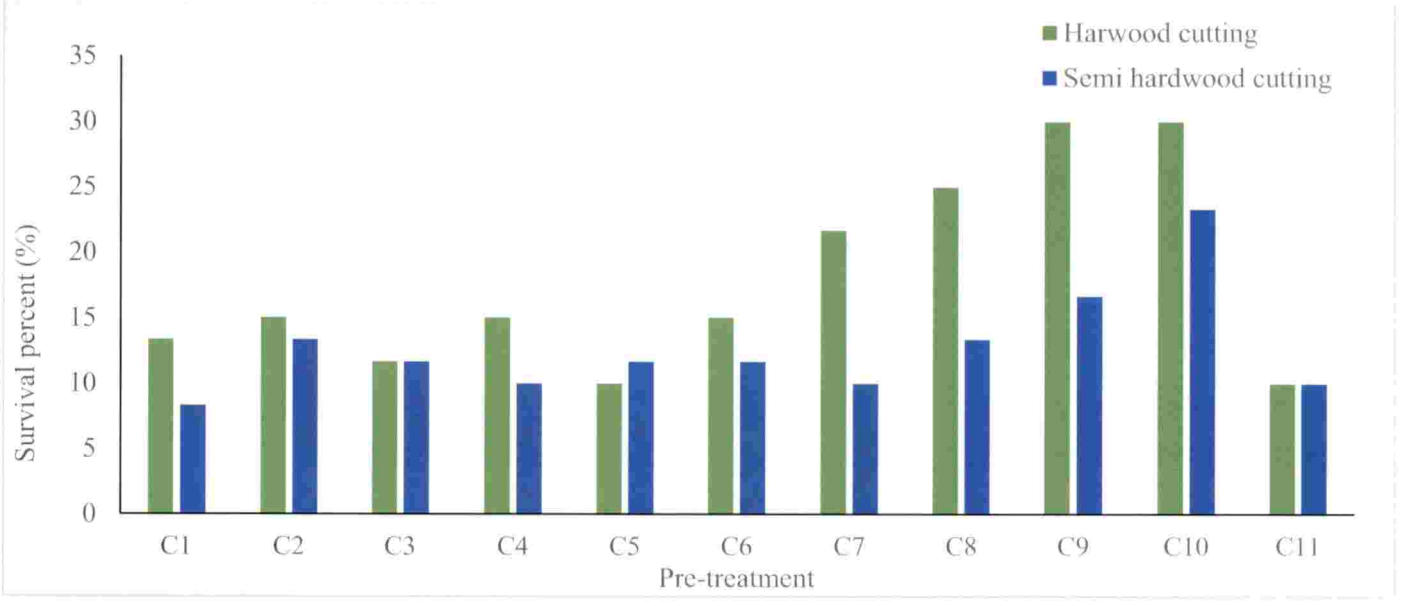

Fig 1. Effect of pretreatments on survival percent in hardwood cutting and semi hardwood cuttings of *S.cochinchinensis*

C_1) IAA @ 250 mg L^{-1}, C_2) IAA @ 500 mg L^{-1}, C_3) IBA @ 250 mg L^{-1} ; C_4) IBA @ 500 mg L^{-1}, C_5) NAA @ 250 mg L^{-1}, C_6) NAA @ 500 mg L^{-1}, C7) Phloroglucinol @ 10mgL^{-1}, C_8) Phlorogucinol @ 20 mgL^{-1}, C_9) Salicylic acid @ 10 mg L^{-1} ,C_{10}) Salicylic acid @ 20 mg L^{-1}, C_{11}) Control.

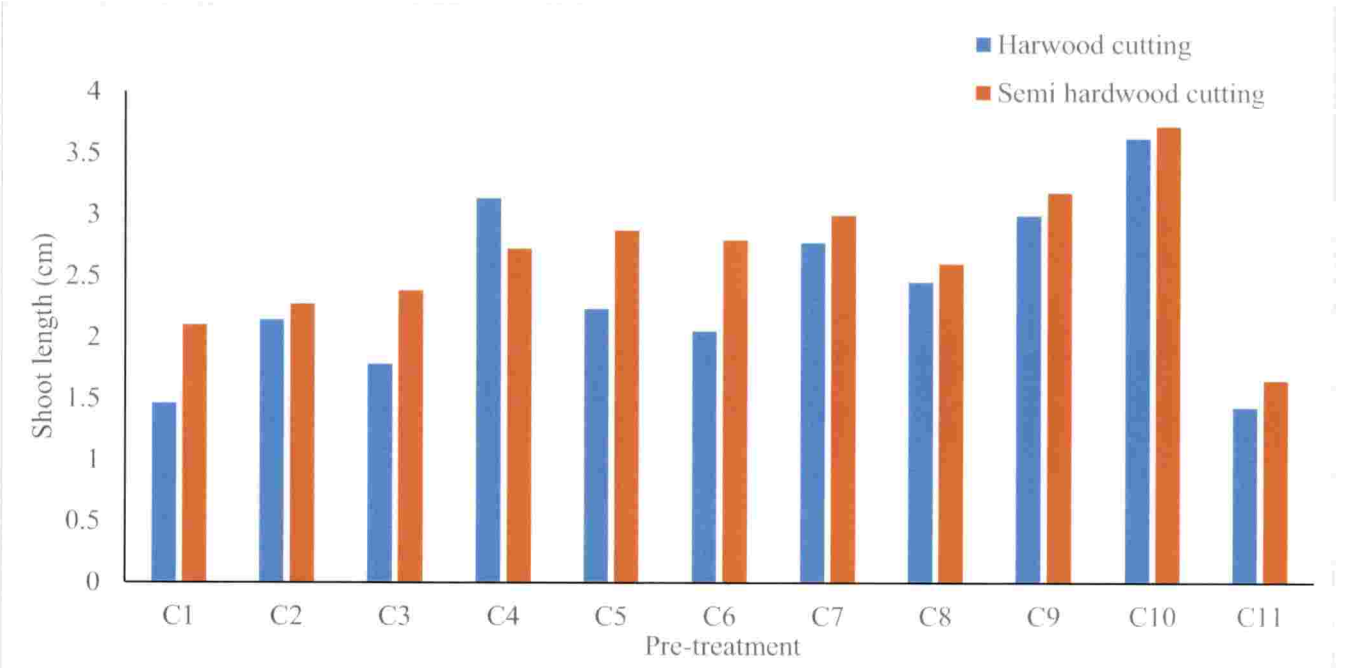

Fig 2. Effect of pre-treatments on shoot length in hardwood cutting and semi hardwood cuttings of *S. cochinchinensis*

C_1) IAA @ 250 mg L^{-1}, C_2) IAA @ 500 mg L^{-1}, C_3) IBA @ 250 mg L^{-1} ; C_4) IBA @ 500 mg L^{-1}, C_5) NAA @ 250 mg L^{-1}, C_6) NAA @ 500 mg L^{-1}, C7) Phloroglucinol @ 10mgL^{-1}, C_8) Phlorogucinol @ 20 mgL^{-1}, C_9) Salicylic acid @ 10 mg L^{-1} ,C_{10}) Salicylic acid @ 20 mg L^{-1}, C_{11}) Control.

Table 20. Effect of pretreatments on days to initial sprouting in root cuttings

Treatment	Pretreatment	Days to initial sprouting
H_1	IAA @ 250 mg L^{-1}	15.67 ± 0.33
H_2	IAA @ 500 mg L^{-1}	14.33 ± 0.33
H_3	IBA @ 250 mg L^{-1}	15.00 ± 0.58
H_4	IBA @ 500 mg L^{-1}	13.33 ± 1.20
H_5	NAA @ 250 mg L^{-1}	19.00 ± 1.00
H_6	NAA @ 500 mg L^{-1}	18.00 ± 0.00
SEm (±)		0.707
C.D (0.05)		2.203

Table 21. Effect of pretreatments on survival per cent of plants from root cuttings upto three months after planting

Treatment	Pretreatment	Survival per cent		
		1 MAP	2 MAP	3 MAP
H_1	IAA @ 250 mg L^{-1}	33.33 ± 6.67	33.33 ± 6.67	33.33 ± 6.67
H_2	IAA @ 500 mg L^{-1}	20.00 ± 0.00	20.00 ± 0.00	20.00 ± 0.00
H_3	IBA @ 250 mg L^{-1}	20.00 ± 0.00	20.00 ± 0.00	20.00 ± 0.00
H_4	IBA @ 500 mg L^{-1}	20.00 ± 0.00	20.00 ± 0.00	20.00 ± 0.00
H_5	NAA @ 250 mg L^{-}	20.00 ± 0.00	13.33 ± 6.67	13.33 ± 6.67
H_6	NAA @ 500 mg L^{-}	20.00 ± 13.33	13.33 ± 13.33	13.33 ± 13.33
SEm (±)		1.36	4.08	4.08
C.D (0.05)		4.24	12.72	12.72

4.1.2.2.2 Survival per cent

The results of treatment effects on survival per cent in root cuttings are presented in Table 21 and Fig 3. The effects of hormonal pretreatments had significant influence on survival percentage in root cuttings. The highest survival of 33.33 per cent was recorded by H_1 (IAA @250 mg L^{-1}) at all stages of observation. H_5 and H_6 recorded the lowest survival per cent (20, 13.33 and 13.33 per cent, respectively) at first month, second and third month after planting. Plate 6 represents pretreatment of root cutting with IAA @250 mg L^{-1}.

4.1.2.2.3 Shoot length

The shoot length of nursery plants from root cuttings had significant variation among the pretreatments. The results are presented in Table 22 and fig 4.

The pretreatments did not show any significant variation in the first month after planting. However, significant effect was exhibited in the second and third months after planting. H_1 (IAA at 250 mg L^{-1}) recorded the longest shoot lengths (3.41 cm at second and 5.73 cm at third months after planting). These were found to be on par with H_2 at both the stages. The lowest shoot lengths (1.43 and 2.81 cm, respectively at second and third month after planting) was recorded in H_6 (NAA@ 500 mg L^{-1}).

4.1.2.2.4 Number of leaves

The various pretreatment effects on the number of leaves of nursery plants from the root cuttings are presented in Table 23.

The pretreatments had significant influence on the number of leaves in plants from root cuttings. Among the treatments, H_1 (IAA@ 250 mg L^{-1}) recorded significantly higher number of leaves (2.15) in the plants. The leaf number remained almost the same at all stages of observation. This was found to be on par with H_2

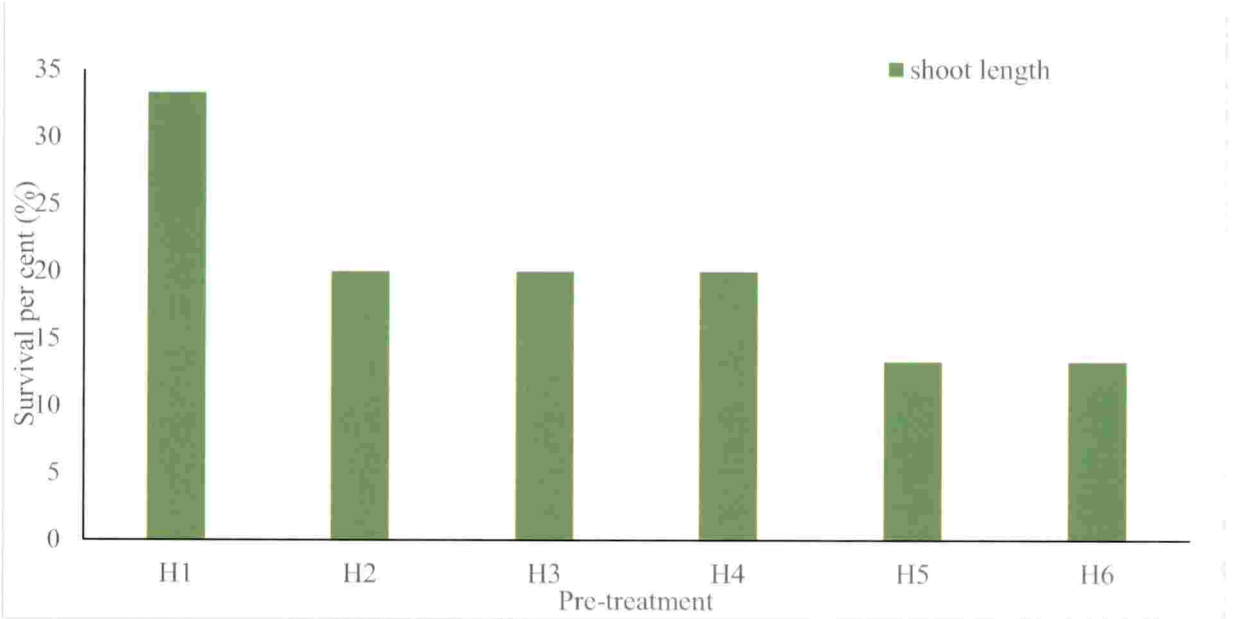

Fig 3. Effect of pre-treatments on survival per cent in root cuttings of *S. cochinchinensis*

H_1)IAA @250 mg L^{-1}, H_2) IAA@500 mg L^{-1}, H_3) IBA@250 mg L^{-1}, H_4) IBA@500 mg L^{-1}, H_5) NAA @250 mg L^{-1}, H_6)500 mg L^{-1}

Plate 6.Pretreatment using IAA@ 250 mg L^{-1}) a) Root cutting used for pretreatment b) plants from pretreated root cutting (after three months of planting)

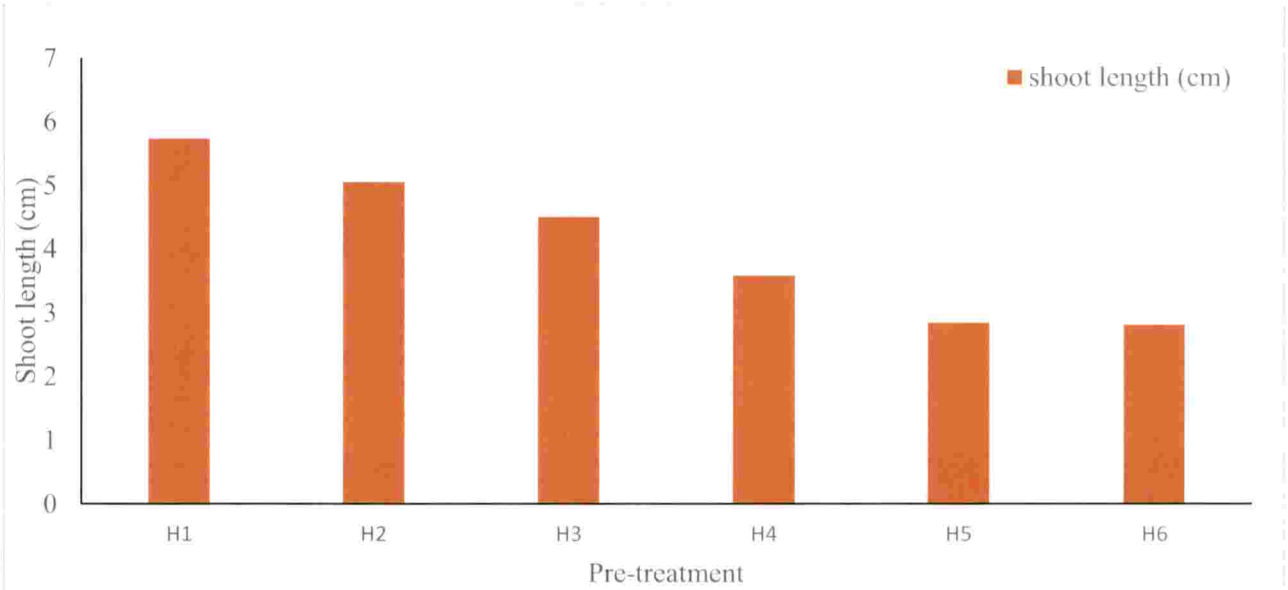

Fig 4. Effect of pre-treatments on shoot length in root cuttings of *S. cochinchinensis*

H_1)IAA @250 mg L^{-1}, H_2) IAA@500 mg L^{-1}, H_3) IBA@250 mg L^{-1}, H_4) IBA@500 mg L^{-1}, H_5) NAA @250 mg L^{-1}, H_6)500 mg L^{-1}

Table 22. Effect of pretreatments on shoot length of plants from root cuttings upto three months after planting

Treatment	Pretreatment	Shoot length (cm)		
		1 MAT	2 MAT	3 MAT
H_1	IAA @ 250 mg L^{-1}	2.80 ±0.76	3.41 ± 0.77	5.73 ±1.10
H_2	IAA @ 500 mg L^{-1}	2.03 ±0.35	2.98 ± 0.32	5.05 ± 0.39
H_3	IBA @ 250 mg L^{-1}	1.93 ± 0.44	2.60 ± 0.30	4.50 ± 0.48
H_4	IBA @ 500 mg L^{-1}	1.63 ± 0.17	2.00 ± 0.07	3.58 ± 0.10
H_5	NAA @ 250 mg L^{-1}	1.38 ± 0.37	1.48 ± 0.22	2.84 ±0.62
H_6	NAA @ 500 mg L^{-1}	1.05 ± 0.10	1.43 ± 0.27	2.81 ± 0.44
SEm (±)		0.423	0.394	0.605
C.D (0.05)		NS	1.228	1.885

Table 23. Effect of pretreatments on number of leaves in plants from root cuttings upto three months after planting

Treatment	Pretreatment	Number of leaves		
		1 MAP	2 MAP	3 MAP
H_1	IAA @ 250 mg L^{-1}	2.03 ± 0.07	2.07 ± 0.06	2.15 ± 0.03
H_2	IAA @ 500 mg L^{-1}	1.95 ± 0.03	2.03 ± 0.03	2.10 ± 0.03
H_3	IBA @ 250 mg L^{-1}	1.87 ± 0.02	1.91 ± 0.02	1.96 ± 0.02
H_4	IBA @ 500 mg L^{-1}	1.95 ± 0.03	2.03 ± 0.03	2.10 ± 0.03
H_5	NAA @ 250 mg L^{-1}	1.86 ± 0.03	1.89 ± 0.04	1.97 ± 0.04
H_6	NAA @ 500 mg L^{-1}	1.85 ± 0.03	1.90 ± 0.03	1.95 ± 0.03
SEm (±)		0.039	0.039	0.035
C.D (0.05)		0.123	0.121	0.111

(IAA@ 500 mg L^{-1}) and H_4 (IBA@ 500 mg L^{-1}). The lowest leaf number (1.95) was recorded in H_6 (NAA @500 mg L^{-1}), which was on par with H_5.

4.1.2.5 Basal shoot girth

The results of pretreatment effects on basal shoot girth in plants from root cuttings are presented in Table 24.

Among the basal shoot girth produced by root cuttings, higher value was observed with the treatment in H_3 (IBA @250 mg L^{-1}) at all stages of observation. The shoot girth values were 2.03 cm, 2.07 cm and 2.15 cm at first, second and third months after planting. This was found to be on par with H_4 (IBA@ 500 mg L^{-1}) at all stages of observation. The lowest shoot girth was observed in H_6 (NAA@ 500 mg L^{-1}) at all stages of observation. The shoot girth of H_6 being 1.85 cm, 1.90 cm and 1.95 cm respectively at first, second and third month after planting.

4.2 EVALUATION OF POTTING MEDIA ON PLANT ESTABLISHMENT

The three month old plants obtained from hardwood cuttings pretreated with salicylic acid @ 20 mg L^{-1} were transplanted into polybags comprising of potting media and supplemented microbial inoculants (Plate 7). The potting media tried were two basal media *viz.*, soil: coirpith compost: cow dung (1:1:1) (B_1) and soil: coirpith compost: vermicompost (1:1:1) (B_2) and basal media supplemented with microbial inoculants viz., PGPR (Plant Growth Promoting Rhizobacteria) Mix I, *Azospirillum*, PSB (Phosphate Solubilising Bacteria) and AMF (Arbuscular Mycorrhizal Fungi) @ 5g $plant^{-1}$. The effect of potting media supplemented with microbial inoculants on parameters *viz.*, morphological, physiological, phytochemical and nutrient content of plants were observed in the study.

Table 24. Effect of pretreatments on basal shoot girth of plants from root cuttings upto three months after planting

Treatment	Pretreatment	Basal shoot girth (cm)		
		1 MAP	2 MAP	3 MAP
H_1	IAA @ 250 mg L^{-1}	1.86 ± 0.03	1.89 ± 0.04	1.98 ± 0.04
H_2	IAA @ 500 mg L^{-1}	1.85 ± 0.02	1.91 ± 0.03	1.96 ± 0.02
H_3	IBA @ 250 mg L^{-1}	2.03 ± 0.07	2.07 ± 0.07	2.15 ± 0.03
H_4	IBA @ 500 mg L^{-1}	1.98± 0.02	2.03 ± 0.03	2.10 ± 0.03
H_5	NAA @ 250 mg L^{-1}	1.87 ± 0.04	1.93 ± 0.04	1.97 ± 0.04
H_6	NAA @ 500 mg L^{-1}	1.85 ± 0.03	1.90 ± 0.03	1.95 ± 0.03
SEm (±)		0.039	0.039	0.035
C.D (0.05)		0.123	0.121	0.111

Plate 7: Hardwood cuttings at the time of transplanting in different potting media a) B_1 (Soil:CoirpithCompost:Cowdung) b) B_2 (Soil : CoirpithCompost: Vermicompost) c) B_1 + PGPR Mix 1 d) B_1 + *Azospirillum* e) B_1 + PSB f) B_1 + AMF g) B_2 + PGPR Mix 1 h) B_2 + *Azospirillum* i) B_2 + PSB j) B_2 + AMF

4.2.1 Morphological parameters

4.2.1.1 Shoot length

The data on the effect of different potting media on shoot length of nursery plants at monthly intervals up to 4 months are presented in Table 25 and fig 5.

The potting media significantly influenced shoot length of the nursery plants. At all stages of observation, the nursery plants raised in T_7 (B_2 + PGPR mix 1) recorded significantly higher shoot length of 7.08 cm (1 MAT), 8.50 cm (2 MAT), 9.64 cm (3 MAT) and 11.50 cm (4 MAT). These values were on par with the shoot length recorded in T_8 (B_2+*Azospirillum*) at all months of observation. At 3 MAT and 4 MAT, the shoot lengths were on par with those of T_{10} (B_2+AMF). At fourth month, all the B_2 medium supplemented with various microbial inoculants (T_7 to T_{10}) were found to be on par with respect to shoot length. The lowest shoot lengths (2.31 cm, 3.17cm, 4.18 cm and 4.94 cm, respectively) were recorded at first, second, third and fourth month after transplanting in T_1 (B_1-soil: coirpith compost: cow dung). T_2 (B_2-soil: coirpith compost: vermicompost) have a higher shoot length compared to T_1 at all stages of observation.

4.2.1.2 Number of branches

The results of the effect of different potting media on number of branches of nursery plants at monthly intervals are presented in Table 26.

The number of branches of nursery plants were significantly influenced by the effects of different potting media at all stages of observation, except during the first month after transplanting. The nursery plants raised in T_8 (B_2 + *Azospirillum*) and T_{10} (B_2+AMF) produced significantly higher number of branches (1.75) at second month after planting. This was on par with T_7 (B_2+PGPR Mix I) and T_9 (B_2+PSB). In the

Table 25. Effect of potting media on shoot length of nursery plants upto four months after transplanting

Treatment	Potting media	Shoot length (cm)			
		1 MAT	2 MAT	3 MAT	4 MAT
T_1	Soil: coirpith compost : cow dung (B_1)	2.31 ± 0.42	3.17 ± 0.60	4.18 ± 0.58	4.94 ± 0.85
T_2	Soil: coirpith compost : vermicompost (B_2)	4.18 ± 0.58	4.73 ± 0.49	5.60 ±0.47	7.86 ± 0.69
T_3	B_1+ PGPR Mix1	4.50 ± 0.30	5.34 ± 0.57	5.70 ± 0.44	8.00 ± 0.95
T_4	B_1+*Azospirillum*	4.75 ± 1.24	5.33 ± 1.48	6.66 ± 2.32	8.23 ± 2.49
T_5	B_1 + PSB	3.75 ± 0.38	4.76 ± 0.20	5.70 ± 0.10	6.57 ± 0.33
T_6	B_1+AMF	3.89 ± 0.64	5.35 ± 0.88	6.26 ± 0.97	7.12 ± 0.96
T_7	B_2+PGPR MIX 1	7.08 ± 0.67	8.50 ± 0.41	9.64 ± 0.33	11.50± 0.36
T_8	B_2 + *Azospirillum*	6.40 ± 0.98	6.90 ± 1.22	8.00 ± 1.35	11.38± 1.01
T_9	B_2 + PSB	4.38 ± 0.21	5.13± 0.29	6.01 ± 0.40	9.47± 1.66
T_{10}	B_2 + AMF	4.85 ± 0.18	6.22 ± 0.59	7.81 ± 0.77	9.70 ± 0.87
SEm (±)		0.645	0.776	0.988	1.183
C.D(0.05)		1.917	2.305	2.936	3.515

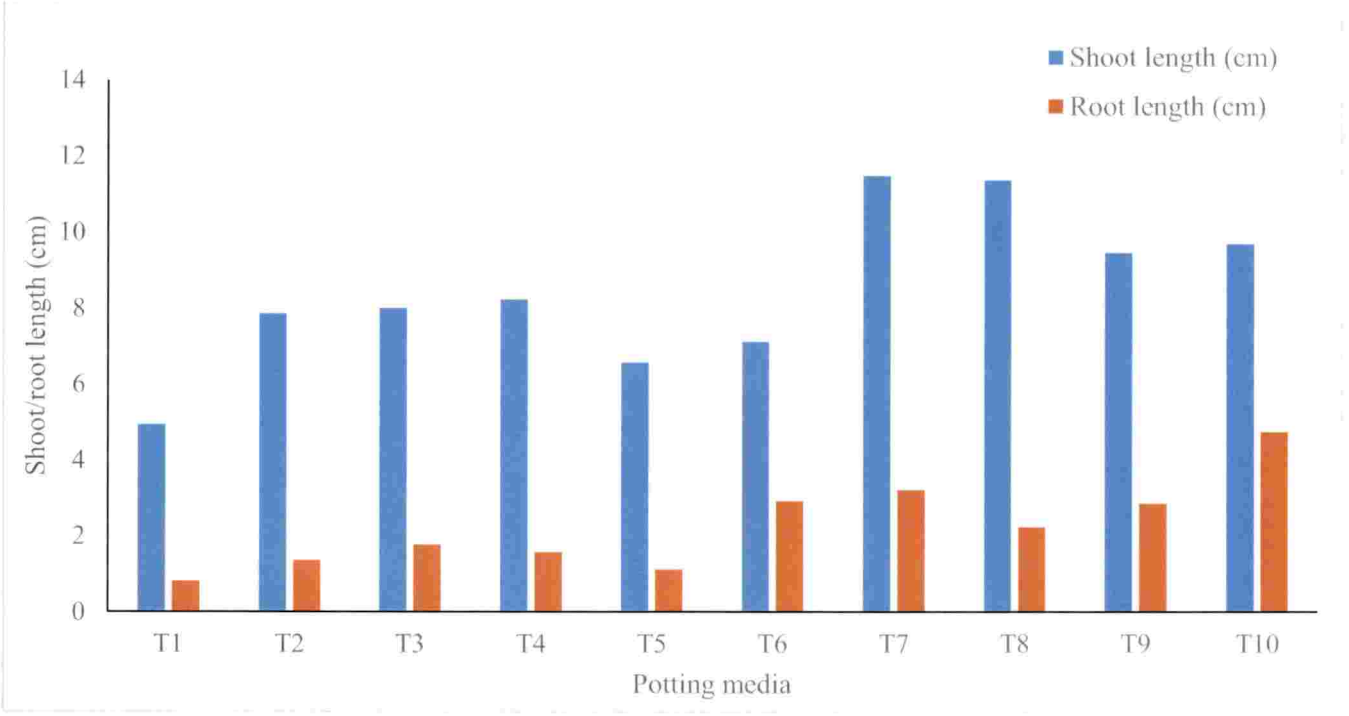

Fig 5. Effect of potting media on shoot and root length of nursery plants of *S. cochinchinensis* after transplanting

T_1) B_1 (Soil: Coirpith Compost:Cowdung) ,T_2) B_2 (Soil : Coirpith Compost: Vermicompost), T_3) B_1 + PGPR Mix 1 T_4) B_1 + *Azospirillum*, T_5) B_1 + PSB T_6) B_1 + AMF T_7) B_2 + PGPR Mix 1 ,T_8) B_2 + *Azospirillum* T_9) B_2 + PSB T_{10}) B_2 + AMF

Table 26. Effect of potting media on number of branches of nursery plants upto four months after transplanting

Treatment	Potting media	Number of branches			
		1 MAT	2 MAT	3MAT	4 MAT
T_1	Soil: coirpith compost : cow dung (B_1)	1.25±0.00	1.25±0.00	1.17±0.08	1.17±0.08
T_2	Soil: coirpith compost : vermicompost (B_2)	1.17±0.08	1.17±0.08	1.08±0.08	1.08±0.08
T_3	B_1+ PGPR Mix1	1.25±0.00	1.17±0.08	1.08±0.08	1.08±0.08
T_4	B_1+*Azospirillum*	1.67±0.22	1.67±0.22	1.75±0.14	1.75±0.14
T_5	B_1 + PSB	1.50±0.14	1.50±0.14	1.25±0.14	1.25±0.14
T_6	B_1+AMF	1.33±0.08	1.33±0.08	1.25±0.14	1.25±0.14
T_7	B_2+PGPR MIX 1	1.67±0.08	1.50±0.00	1.58±0.08	1.67±0.08
T_8	B_2 + *Azospirillum*	1.75±0.14	1.75±0.00	1.92±0.08	1.92±0.08
T_9	B_2 + PSB	1.58±0.36	1.50 ±0.29	1.50±0.29	1.50±0.29
T_{10}	B_2 + AMF	1.67±0.22	1.75 ±0.14	1.75±0.14	1.75±0.14
SEm (±)		0.171	0.139	0.142	0.142
C.D (0.05)		NS	0.414	0.422	0.422

third and fourth month after planting, the highest number of branches was observed in T_8, which was on par with T_4, T_7, T_9, and T_{10}. The result indicates the positive influence of *Azospirillum* on inducing of branches. The media T_4 (B_1 +*Azospirillum*) and T_8 (B_2 +*Azospirillum*) gave better number of branches while T_1 (B_1) and T_2 (B_2) without supplementary microbial inoculants gave the lowest values (1.17 and 1.08, respectively) in terms of number of branches.

4.2.1.3 Number of leaves

Table 27 shows the effect of different potting media on the number of leaves of nursery plants at monthly intervals up to four months after transplanting.

The higher number of leaves were produced with the nursery plants raised in the media T_7 (B_2+PGPR Mix1) irrespective of the stages of observation. It produced 8.41, 9.33, 10.33 and 10.50 number of leaves at first, second, third and fourth month after transplanting, respectively. The above treatment was on par with T_8, T_9 and T_{10} at first and fourth month after transplanting, and with T_8 and T_{10} at second and third month after transplanting. The lowest number of leaves was recorded in T_1, which was on par with T_2, T_3, T_4, T_5 and T_6. The result indicates the superiority of the treatments involving soil, coirpith and vermicompost in combination with microbial inoculants, with respect to the number of leaves formed in the nursery plants.

4.2.1.4 Collar girth

The data on the effect of different potting media on collar girth of nursery plants at monthly intervals up to four months are presented in Table 28.

Table 27. Effect of potting media on number of leaves of nursery plants upto four months after transplanting

Treatment	Potting media	Number of leaves			
		1 MAT	2 MAT	3 MAT	4 MAT
T_1	Soil: coirpith compost : cow dung (B_1)	3.50±0.52	3.75±1.04	4.82±0.73	5.17±0.58
T_2	Soil: coirpith compost : vermicompost (B_2)	4.82±0.22	5.28±0.81	5.67±1.12	5.75±1.01
T_3	B_1+ PGPR Mix1	4.95±1.13	5.75±1.01	6.67±1.08	7.40±0.90
T_4	B_1+*Azospirillum*	3.83±0.96	5.50±1.01	6.33±1.04	7.23±1.02
T_5	B_1 + PSB	4.25±0.88	4.33±0.36	4.75±0.38	6.10±0.83
T_6	B_1+AMF	3.58±0.60	5.00±0.75	5.33±0.46	5.67±0.73
T_7	B_2+PGPR MIX 1	8.41±0.73	9.33±0.08	10.33±0.51	10.50±1.03
T_8	B_2 + *Azospirillum*	7.08±1.31	7.33±0.58	7.75±1.26	8.61±0.51
T_9	B_2 + PSB	6.20±0.72	6.58±0.60	6.83±1.02	8.19±1.48
T_{10}	B_2 + AMF	7.15±0.86	7.28±0.93	8.18±0.89	8.88±0.89
SEm (±)		0.845	0.777	0.899	0.935
C.D (0.05)		2.512	2.309	2.671	2.778

Table 28. Effect of potting media on collar girth of nursery plants upto four months after transplanting

Treatment	Potting media	Collar girth (cm)				Increase in girth (per cent)
		1 MAT	2 MAT	3 MAT	4 MAT	
T_1	Soil: coirpith compost : cow dung (B_1)	3.38±0.06	3.56±0.08	3.74±0.08	3.93±0.09	16.12±1.28
T_2	Soil: coirpith compost : vermicompost (B_2)	3.13±0.04	3.55±0.05	3.68±0.08	3.88±0.09	17.00±2.28
T_3	B_1+ PGPR Mix1	3.40±0.06	3.61±0.06	3.80±0.07	3.99±0.06	17.46±0.85
T_4	B_1+*Azospirillum*	3.42±0.04	3.65±0.04	3.82±0.07	4.01±0.06	17.40±1.46
T_5	B_1 + PSB	3.29±0.05	3.52±0.02	3.68±0.03	3.84±0.04	16.88±2.20
T_6	B_1+AMF	3.41±0.05	3.46±0.16	3.83±0.095	3.98±0.07	16.68±0.89
T_7	B_2+PGPR MIX 1	3.61±0.04	3.83±0.06	4.11±0.02	4.29±0.02	18.86±0.58
T_8	B_2 + *Azospirillum*	3.59±0.07	3.78±0.02	4.05±0.07	4.25±0.05	18.48±2.08
T_9	B_2 + PSB	3.52±0.06	3.76±0.06	4.00±0.05	4.15±0.03	18.14±1.22
T_{10}	B_2 + AMF	3.45±0.05	3.72±0.06	3.90±0.07	4.10±0.06	18.87±2.02
SEm (±)		0.076	0.072	0.067	0.061	1.598
C.D (0.05)		0.156	0.213	0.198	0.181	NS

The potting media tried had significant effect on collar girth at all stages of observation. The collar girth of nursery plants raised in T_7 (B_2+PGPR Mix I) recorded higher basal shoot girth (3.61 cm, 3.83 cm, 4.11 cm and 4.29 cm, respectively) at first, second ,third and fourth month after transplanting, which was on par with T_8, T_9 and T_{10}. The lowest collar girth (3.13 cm, 3.55 cm, 3.68 cm and 3.88cm, respectively) was recorded in T_2 (B2-soil: coirpith compost: vermicompost) at first, second, third and fourth month respectively.

4.2.1.5 Root length

The data on the effect of different potting media on root length of nursery plants at fourth month after transplanting are presented in Table 29 and fig 5.

The data indicated that among the different potting media tried, the nursery plants raised in the potting medium T_{10} (B_2+AMF) produced significantly longer roots (4.77 cm). The root length was the lowest (0.82 cm) in the medium containing T_1 (soil, coirpith compost and cowdung). This was on par with T_2, T_3, T_4 and T_5. Among the treatments comprising of B_1 (soil: coirpith compost and cow dung) with microbial inoculants, B_1+ AMF, showed a higher value, indicative of the positive influence of AMF on root growth (plate 8).

4.2.1.6 Root girth

The data on the effect of different potting media on root girth of nursery plants at fourth month after transplanting are presented in Table 29.

The data revealed that root girth was the highest (0.30 cm) with the nursery plants raised in T_{10} medium (B_2+AMF). This was found to be on par with T_7 (B_2 + PGPR Mix I). The lowest root girth (0.18 cm) was observed in T_1 (soil: coirpith compost: cow dung).

Table 29. Effect of potting media on root parameters of nursery plants four months after transplanting

Treatment	Potting media	Root length (cm)	Root girth (cm)
T_1	Soil: coirpith compost : cow dung (B_1)	0.82 ±0.17	0.18 ± 0.010
T_2	Soil: coirpith compost : vermicompost (B_2)	1.37 ±0.27	0.21 ±0.005
T_3	B_1+ PGPR Mix1	1.78 ±0.12	0.27 ± 0.006
T_4	B_1+*Azospirillum*	1.58 ±0.25	0.27 ± 0.001
T_5	B_1 + PSB	1.12 ±0.28	0.26 ±0.006
T_6	B_1+AMF	2.92 ±0.120	0.26 ±0.006
T_7	B_2+PGPR MIX 1	3.22±0.295	0.29 ±0.002
T_8	B_2 + *Azospirillum*	2.25 ±0.09	0.27 ±0.003
T_9	B_2 + PSB	2.87 ±0.47	0.27 ±0.007
T_{10}	B_2 + AMF	4.77 ± 1.19	0.30 ±0.004
SEm (±)		0.447	0.006
C.D (0.05)		1.329	0.018

Plate 8. Rooting in nursery plants in AMF supplemented medium

4.2.1.7 Fresh weight of shoot

The data on the effect of different potting media on fresh weight of shoot of nursery plants at fourth month after transplanting are presented in Table 30.

The fresh weight of shoot was the highest (21.35 g) with potting medium T_7 (B_2+PGPR Mix 1) which was on par with T_8 (B_2+Azospirillum-19.68 g), T_9 (B2+PSB-18.76 g) and T_{10} (B_2+AMF -21.04 g). However, T_1 (soil, coirpith compost and cow dung (B_1) produced the lowest fresh weight of shoot of 13.48 g.

4.2.1.8 Dry weight of shoot

Table 30 shows the effect of different potting media on dry weight of shoots of nursery plants at fourth month after transplanting.

The data revealed that different potting media had significantly influenced the shoot dry weight of nursery plants. The plants raised in the medium T_7 (B_2+ PGPR Mix 1) recorded the highest dry shoot weight (4.78 g) and it was on par with T_{10} (B2+ AMF). The shoot dry weight was the lowest (3.32 g) with T_1 (soil, coirpith compost and cow dung).

4.2.1.9 Fresh weight of root

Table 31 shows the effect of different potting media on fresh weight of roots of nursery plants at fourth month after transplanting.

Among the potting media tried for nursery plants, T_{10} (B_2+AMF) recorded significantly higher fresh weight of root (3.28 g). The lowest root fresh weight was observed in T_1 (0.09 g), which was on par with T_2, T_5 (B_1+PSB) and T_9.

Table 30. Effect of potting media on fresh and dry weight of shoots of nursery plants four months after transplanting

Treatment	Potting media	Fresh weight (g)	Dry weight (g)
T_1	Soil: coirpith compost : cow dung (B_1)	13.48 ±0.27	3.32 ±0.15
T_2	Soil: coirpith compost : vermicompost (B_2)	16.45 ±0.21	3.58 ±0.02
T_3	B_1+ PGPR Mix1	18.28 ±2.17	3.94 ±0.16
T_4	B_1+*Azospirillum*	17.42 ±0.53	3.74 ±0.05
T_5	B_1 + PSB	16.95 ±1.06	3.67 ±0.15
T_6	B_1+AMF	17.09 ±0.54	3.69 ±0.07
T_7	B_2+PGPR MIX 1	21.35 ±0.47	4.78 ±0.295
T_8	B_2 + *Azospirillum*	19.68 ± 0.20	4.02 ±0.26
T_9	B_2 + PSB	18.76± 1.095	4.01 ±0.17
T_{10}	B_2 + AMF	21.04 ± 0.28	4.53 ±0.12
SEm (±)		0.898	0.166
C.D (0.05)		2.667	0.494

Table 31. Effect of potting media on fresh and dry weight of roots of nursery plants four months after transplanting

Treatment	Potting media	Fresh weight of roots (g)	Dry weight of roots (g)
T_1	Soil: coirpith compost : cow dung (B_1)	0.08 ±0.020	0.001 ±0.00
T_2	Soil: coirpith compost : vermicompost (B_2)	0.21 ±0.020	0.020 ±0.004
T_3	B_1+ PGPR Mix1	1.21 ±0.190	0.040 ±0.009
T_4	B_1+*Azospirillum*	1.08 ±0.340	0.050 ±0.003
T_5	B_1 + PSB	0.27 ±0.030	0.020 ±0.004
T_6	B_1+AMF	1.16 ±0.170	0.022 ±0.02
T_7	B_2+PGPR MIX 1	2.50 ±0.170	0.053 ±0.004
T_8	B_2 + *Azospirillum*	1.38 ±0.095	0.051 ±0.005
T_9	B_2 + PSB	0.33 ±0.020	0.054 ±0.009
T_{10}	B_2 + AMF	3.28 ±0.250	0.092 ±0.01
SEm (±)		0.168	0.009
C.D (0.05)		0.498	0.026

4.2.1.10 Dry weight of root

Table 31 shows the effect of different potting media on dry weight of roots of nursery plants at fourth month after transplanting.

The results revealed that different potting media significantly influenced the root dry weight of nursery plants. The plants raised in the medium T_{10} (B_2+ AMF) recorded significantly higher dry root weight of 0.092 g .The root dry weight was the lowest (0.001g) with the medium T_1 (soil, coirpith compost and cow dung). This was on par with T_2 (soil, coirpith compost and vermicompost) and T_5 (B_2+ PSB).

4.2.2 Physiological parameters

4.2.2.1 Leaf Area Index (LAI)

Table 32 shows the effect of different potting media on Leaf Area Index (LAI) of nursery plants at monthly intervasl up to four months after transplanting. The LAI did not show significant variation in the first month after transplanting. However in the subsequent months, significant variation was noticed in LAI, among the treatments tried. The LAI was the highest in the nursery plants in T_7 (B_2 + PGPR mix 1) at all stages of observation. At second month after transplanting, the LAI (0.88) of plants in T_7 was found to be significantly superior to all other treatments. The LAI of T_7 (0.95) was found to be on par with that of T_8 at third month of transplanting. At fourth after transplanting, the LAI of plants raised in T_7 (1.36) was found to be on par with T_8, T_9 and T_{10}. The lowest LAI (0.39 and 0.64, respectively) was recorded in T_1 at third and fourth months after planting. At fourth month after planting it was found to be on par with treatments from T_2 to T_6.

Table 32. Effect of potting media on leaf area index (LAI) of nursery plants upto four months after transplanting

Treatment	Potting media	Leaf area index			
		1 MAT	2 MAT	3 MAT	4 MAT
T_1	Soil: coirpith compost : cow dung (B_1)	0.10 ±0.03	0.37 ±0.05	0.39±0.06	0.64 ±0.07
T_2	Soil: coirpith compost : vermicompost (B_2)	0.12 ±0.02	0.46 ±0.08	0.47 ±0.02	0.73 ±0.14
T_3	B_1+ PGPR Mix1	0.08 ±0.02	0.32 ±0.08	0.48 ±0.07	0.80 ±0.11
T_4	B_1+*Azospirillum*	0.10 ±0.03	0.52 ±0.02	0.57 ±0.08	0.94 ±0.13
T_5	B_1 + PSB	0.12 ±0.03	0.48 ±0.08	0.67 ±0.11	0.97 ±0.12
T_6	B_1+AMF	0.12 ±0.02	0.44 ±0.04	0.46 ±0.06	0.74 ±0.095
T_7	B_2+PGPR MIX 1	0.50 ±0.29	0.88 ±0.09	0.95±0.008	1.36 ±0.07
T_8	B_2 + *Azospirillum*	0.22 ±0.02	0.64 ±0.11	0.83 ±0.09	1.17 ±0.12
T_9	B_2 + PSB	0.17 ±0.02	0.57 ±0.08	0.74 ±0.06	1.08 ±0.196
T_{10}	B_2 + AMF	0.18 ±0.02	0.59 ±0.07	0.66 ±0.06	1.13 ±0.07
SEm (±)		0.093	0.074	0.067	0.118
C.D (0.05)		NS	0.221	0.198	0.351

4.2.2.2 Leaf Area Duration (LAD)

Table 33 shows the effect of different treatments on Leaf Area Duration (LAD) of the potting media at monthly intervals up to four months.

The comparison of the effect of different potting media on leaf area duration revealed that the higher leaf area duration of 16.40, 27.33 and 34.63 days were recorded respectively at second, third and fourth month after transplanting in T_7 (B_2 + PGPR Mix1). This was on par with T_9 at second month after transplanting, T8 at third month after transplanting and T_8, T_9 and T_{10} at fourth month after transplanting. The leaf area duration was lower with medium containing soil, coirpith compost and cow dung (B_1) 7.03, 7.80 and 15.44 days at second, third and fourth month after transplanting.

4.2.3 Phytochemical and nutrient analysis in nursery plants

4.2.3.1 Carbohydrate

The results of the effect of different potting media on carbohydrate content of nursery plants four months after transplanting are presented in Table 34 & fig 6a. The treatments exhibited significant variation with respect to carbohydrate content of the plant tissue. The highest carbohydrate content (80.90 mg g^{-1})) was recorded in T_7 (B_2+PGPR Mix I) which was on par with T_8, T_9 and T_{10}. The lowest carbohydrate content (56.21 mg g^{-1}) was observed in T_1 (soil: coirpith compost: cow dung), which was on par with T_2 (soil: coirpith compost: vermicompost).

4.2.3.2 Chlorophyll

The data on the effect of different potting media on chlorophyll content of nursery plants are presented in Table 34 and fig 6b.

Table 33. Effect of potting media on leaf area duration of nursery plants upto four months after transplanting

Treatment	Potting media	Leaf area duration (days)		
		2 MAT	3 MAT	4 MAT
T_1	Soil: coirpith compost : cow dung (B_1)	7.03 ±1.18	7.80 ±3.49	15.44 ±1.04
T_2	Soil: coirpith compost : vermicompost (B_2)	8.67 ±1.41	13.93 ±1.46	17.92 ±2.43
T_3	B_1+ PGPR Mix1	6.05 ±1.38	11.92 ±2.15	19.07 ±2.63
T_4	B_1+*Azospirillum*	9.32 ±0.49	16.36 ±1.52	22.60 ±3.17
T_5	B_1 + PSB	8.96 ±1.72	17.13 ±2.83	24.52 ± 3.39
T_6	B_1+AMF	8.34 ±0.84	11.88 ±1.44	16.44 ±2.20
T_7	B_2+PGPR MIX 1	16.40 ±1.38	27.33 ±1.17	34.63 ±1.04
T_8	B_2 + *Azospirillum*	11.04 ±1.52	20.87 ±2.58	29.96 ±3.02
T_9	B_2 + PSB	12.35 ±2.097	20.80 ±2.39	27.36 ±3.80
T_{10}	B_2 + AMF	11.56 ±1.42	18.85 ±1.51	26.95 ±1.85
SEm (±)		1.407	2.175	2.614
C.D (0.05)		4.179	6.461	7.764

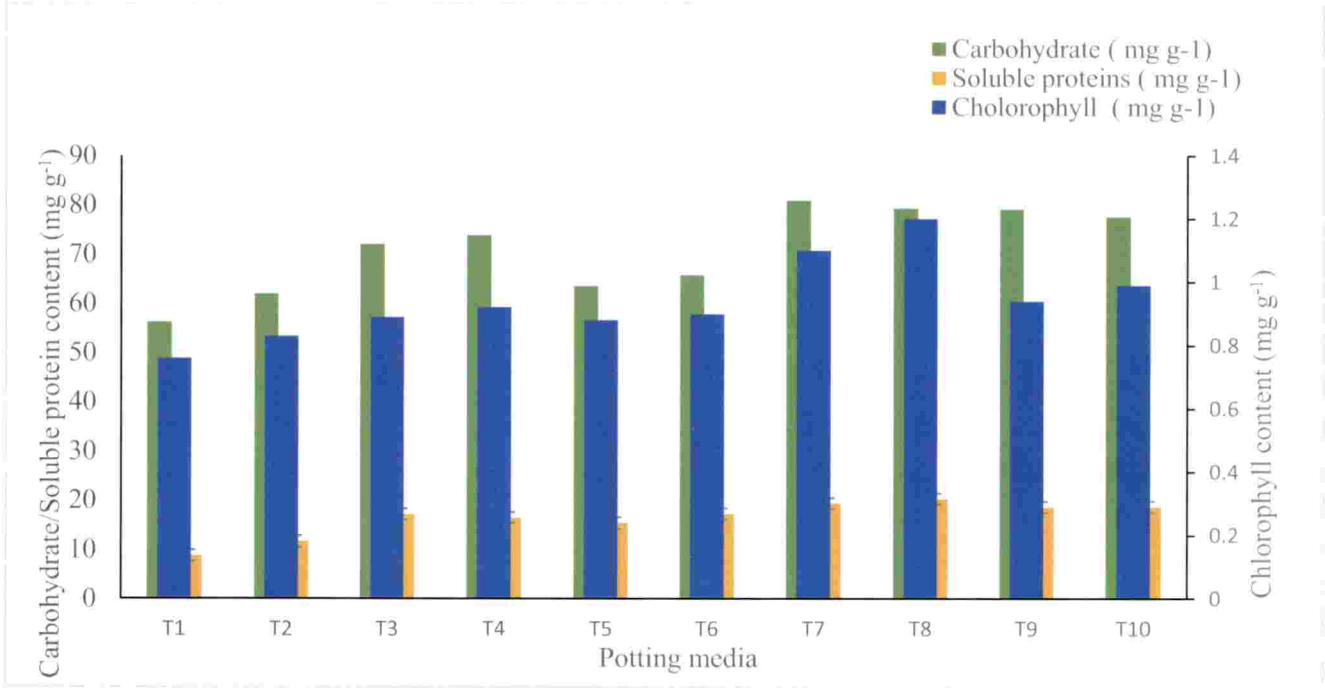

Fig 6. Effect of potting media on phytochemical content of nursery plants of *S. cochinchinensis* four months after transplanting

T_1) B_1 (Soil: Coirpith Compost:Cowdung) ,T_2) B_2 (Soil : Coirpith Compost: Vermicompost), T_3) B_1 + PGPR Mix 1 T_4) B_1 + *Azospirillum*, T_5) B_1 + PSB T_6) B_1 + AMF T_7) B_2 + PGPR Mix 1 ,T_8) B_2 + *Azospirillum* T_9) B_2 + PSB T_{10}) B_2 + AMF

Table 34. Effect of potting media on phytochemical constituents of nursery plants four months after transplanting

Treatment	Potting media	Phytochemical constituents		
		Carbohydrate (mg g^{-1})	Chlorophyll (mg g^{-1})	Soluble proteins (mg g^{-1})
T_1	Soil: coirpith compost : cow dung (B_1)	56.21 ±1.46	0.76 ±0.01	8.75 ±0.50
T_2	Soil: coirpith compost : vermicompost (B_2)	61.94 ±0.83	0.83 ±0.01	11.69 ±0.39
T_3	B_1+ PGPR Mix1	72.00 ±1.56	0.89 ±0.01	17.13 ±0.30
T_4	B_1+*Azospirillum*	73.80 ±2.70	0.92 ±0.01	16.42 ±0.35
T_5	B_1 + PSB	63.46 ±0.66	0.88 ±0.01	15.38 ±1.16
T_6	B_1+AMF	65.70 ±1.00	0.90 ±0.01	17.22 ±0.90
T_7	B_2+PGPR MIX 1	80.90 ±2.72	1.10 ±0.06	19.38 ±0.45
T_8	B_2 + *Azospirillum*	79.30 ±0.77	1.20 ±0.07	20.31 ±1.44
T_9	B_2 + PSB	79.16 ±3.92	0.94 ±0.06	18.61 ±0.75
T_{10}	B_2 + AMF	77.53 ±1.05	0.99 ±0.03	18.60 ±0.29
SEm (±)		1.965	0.035	0.755
C.D (0.05)		5.838	0.103	2.243

Nursery plants raised in potting media, T_8 (B_2 + *Azospirillum*) recorded significantly higher chlorophyll content (1.20 mg g^{-1}) among the different potting media. This was found to be on par with T_7 (B_2 + PGPR Mix 1 -1.10 mg g^{-1}). The chlorophyll content was lower in nursery plants raised in potting media without supplementary microbial inoculants, T_1 (0.76 mg g^{-1}) and T_2 (0.83 mg g^{-1}).

4.2.3.3 Soluble proteins

The results of the effect of different potting media on soluble proteins content of nursery plants is presented in Table 34 and fig 6c .

The nursery plants raised in the potting medium T_8 (B_2 + *Azospirillum*) had a higher soluble protein content of 20.31 mg g^{-1}. This was found to be on par in plants grown in T_7 (B_2 + PGPR mix 1 - 19.38 mg g^{-1}), T_9 (B2 + PSB -18.61 mg g^{-1}) and T_{10} (B_2 + AMF - 18.65 mg g^{-1}). The nursery plants raised in the potting medium T_1 (B_1) recorded lower value (8.75 mg g^{-1}) for soluble proteins.

4.2.3.4 Plant N, P, K

The effect of different potting media on plant N, P, K content of nursery plants is presented in Table 35.

The nursery plants raised in potting medium, T_8 (B_2 + *Azospirillum*) contained significantly higher plant nitrogen (2.22 per cent) and potassium (2.15 per cent) content. The potassium content (2.09 per cent) of T_7 (B_2 + PGPR Mix 1) was found to be on par with T_8. However, significantly higher phosphorus content (0.26 per cent) was found in the nursery plants raised in the potting medium T_9 (B_2 + PSB).

Table 35. Effect of potting media on nutrient content of nursery plants four months after transplanting

Treatment	Potting media	N (per cent)	P (per cent)	K (per cent)
T_1	Soil: coirpith compost : cow dung (B_1)	1.05 ±0.003	0.09 ±0.003	1.56 ±0.02
T_2	Soil: coirpith compost : vermicompost (B_2)	1.24 ±0.03	0.13 ±0.003	1.63 ±0.03
T_3	B_1+ PGPR Mix1	1.52 ±0.02	0.16 ±0.003	1.72 ±0.02
T_4	B_1+*Azospirillum*	1.63 ±0.02	0.20 ±0.006	1.80 ±0.02
T_5	B_1 + PSB	1.43 ±0.01	0.20 ±0.003	1.64 ±0.02
T_6	B_1+AMF	1.50 ±0.006	0.24 ±0.55	1.67 ±0.04
T_7	B_2+PGPR MIX 1	2.08 ±0.03	0.21 ±0.006	2.09 ±0.01
T_8	B_2 + *Azospirillum*	2.22 ±0.02	0.23 ±0.009	2.15 ±0.04
T_9	B_2 + PSB	1.99 ±0.01	0.26 ±0.007	2.03 ±0.04
T_{10}	B_2 + AMF	2.05 ±0.02	0.20 ±0.003	2.04 ±0.02
	SEm (±)	0.019	0.175	0.027
	C.D (0.05)	0.056	NS	0.08

4.2.4 Physicochemical analysis of the media

The physicochemical analysis of the media was conducted before and after the experiment. pH, electrical conductivity, nitrogen, phosphorus and potassium content of the media were analysed. Tables 36 and 37, respectively indicates the data before and after the experiment.

4.2.4.1 pH

The pH of the two basal media T_1 (B_1) and T_2 (B_2) were 6.7 and 6.4, respectively. After the experiment, all the media showed a slight increase in pH in the range of 6.43 to 7.23. The basal media T_1 and T_2 were found to have a pH of 7.09 and 6.80 respectively, after the experiment. However, the different treatments did not significantly influence the pH of the potting media after the experiment. The pH of all the potting media were found to be in a near neutral range.

4.2.4.2 Electrical Conductivity

The electrical conductivity of the basal media T_1 and T_2 before the experiment were 1.03 and 1.61 dS m^{-1}, respectively. The vermicompost containing media had higher EC before and after the experiment. The similar situation is observed even when the basal media were supplemented with the microbial inoculants. The EC of T_1 (B_1) and T_3 to T_6 (B_1 with microbial inoculants) were found to be on par. Similarly, the EC of T_2 (B_2) and T_7 to T_{10} (B_2 with microbial inoculants) were found to be on par. However, among the treatments tried, the highest EC (1.49 dS m^{-1}) was observed in T_8 (B_2+ *Azospirillum*). This was found to be on par with T_2, T_7, T_9 and T_{10}. The lowest value (0.84) was reported by T_1, which was found to be on par with T_3, T_4, T_5 and T_6. The data shows that all the EC value lies in a safe range for crop growth.

Table 36. Physicochemical analysis of media before planting

Treatment	Potting media	pH	EC ($dS\ m^{-1}$)	N ($mg\ kg^{-1}$)	P ($mg\ kg^{-1}$)	K ($mg\ kg^{-1}$)
T_1	Soil: coirpith compost : cow dung (B_1)	6.7	1.03	265.18	171.38	423.88
T_2	Soil: coirpith compost :vermicompost (B_2)	6.4	1.61	285.66	165.38	634.90

Table 37: Physicochemical analysis of media after four month of transplanting

Treatment	Potting media	pH	EC (dSm^{-1})	N ($mg\ kg^{-1}$)	P ($mg\ kg^{-1}$)	K ($mg\ kg^{-1}$)
T_1	Soil: coirpith compost : cow dung (B_1)	7.09	0.84	153.20	144.33	339.78
T_2	Soil: coirpith compost : vermicompost (B_2)	6.80	1.19	158.37	114.13	416.81
T_3	B_1+ PGPR Mix1	6.97	1.06	173.71	144.15	286.94
T_4	B_1+*Azospirillum*	6.86	0.93	183.92	142.68	388.37
T_5	B_1 + PSB	7.23	1.04	194.42	146.63	334.49
T_6	B_1+AMF	6.89	0.89	194.92	119.69	223.54
T_7	B_2+PGPR MIX 1	7.20	1.44	189.55	136.23	377.94
T_8	B_2 + *Azospirillum*	6.77	1.49	199.73	139.51	435.51
T_9	B_2 + PSB	6.91	1.43	210.35	142.66	318.78
T_{10}	B_2 + AMF	6.43	1.29	214.62	115.80	312.04
	SEm (±)	0.162	0.11	0.231	2.961	6.86
	C.D (0.05)	NS	0.328	0.69	8.84	19.96

4.2.4.3 NPK analysis of media before and after the experiment

The nitrogen and potassium content (285.66 mg kg^{-1} and 634.9 mg kg^{-1}, respectively) was higher in T_2 (soil, coirpith compost and vermicompost) and lower in T_1 (soil, coirpith compost and cowdung) with 265.18 mg kg^{-1} and 423.88 mg kg^{-1}, before the experiment. The phosphorus content (171.38 mg kg^{-1}) was higher in T_1 and lower (165.38 mg kg^{-1}) in T_2.

Significant variation was found in the available nitrogen, phosphorus and potassium content of the various potting media after the experiment.

Among different potting media, T_{10} (B_2 + AMF) recorded significantly higher available nitrogen content (214.62 mg kg^{-1}) and T_1 recorded the lowest nitrogen content (153.20 mg kg^{-1}). The microbial inoculant supplemented medium recorded higher nitrogen content compared to their respective basal media. The microbial inoculant supplemented in B_2 media (T_7 to T_{10}) showed higher nitrogen status than those supplemented in B_1 media. Also, it was observed that, both the basal media with *Azospirillum* and PGPR Mix I recorded lower nitrogen content compared to those with PSB and AMF.

Available phosphorus content recorded after the experiment was significantly higher (146.63 mg kg^{-1}) in T_5 (B1+PSB) which was on par with T_1, T_3, T_4, T_8 and T_9. The lowest phosphorus content (114.13 mg kg^{-1}) was recorded in T_2. This was found to be on par with AMF supplemented media, T_6 and T_{10}.

Among the treatments, the available potassium content (435.51 mg kg^{-1}) in T_8 (B_2+*Azospirillum*) which was on par relation with T_2 (soil, coirpith compost and vermicompost) and the lowest potassium content (223.54 mg kg^{-1}) was recorded in T_6 (B_1+AMF). However, it was observed that, in the treatments with *Azospirillum* (T_4 and

T_8), potassium content has higher and those with AMF (T_6 and T_{10}, it was lower when compared to the respective basal media and those supplemented with other inoculants.

4.2.5 Plant growth potential

The growth potential of nursery plants of *S. cochinchinensis* raised in different potting media was analysed using the recorded data of different parameters *viz.*, total dry matter production (dry weight of shoot and root), plant height (shoot length), collar girth and root length. Plant growth potential of nursery plants raised in various potting media are presented in a Table 38 and fig 7. The plants from hardwood cuttings in different potting media are presented in plate 9.

Among the various potting media tried, significant variation was observed in plant growth potential due to treatment effects. Significantly higher plant growth potential (0.522) was recorded by T_{10} (B_2+ AMF), followed by T_7 (B_2 + PGPR Mix I – 0.428). The lowest potential (0.018) was recorded by T_1 (soil, coirpith compost and cow dung), which was found to be on par with T_2 (soil, coirpith compost and vermicompost).

Table 38. Effect of potting media on plant growth potential of nursery plants four months after transplanting

Treatment	Potting media	Plant growth potential
T_1	Soil: coirpith compost : cow dung (B_1)	0.018
T_2	Soil: coirpith compost : vermicompost (B_2)	0.045
T_3	B_1+ PGPR Mix1	0.236
T_4	B_1+*Azospirillum*	0.203
T_5	B_1 + PSB	0.058
T_6	B_1+AMF	0.224
T_7	B_2+PGPR MIX 1	0.428
T_8	B_2 + *Azospirillum*	0.241
T_9	B_2 + PSB	0.068
T_{10}	B_2 + AMF	0.522
SEm (±)		0.028
C.D (0.05)		0.082

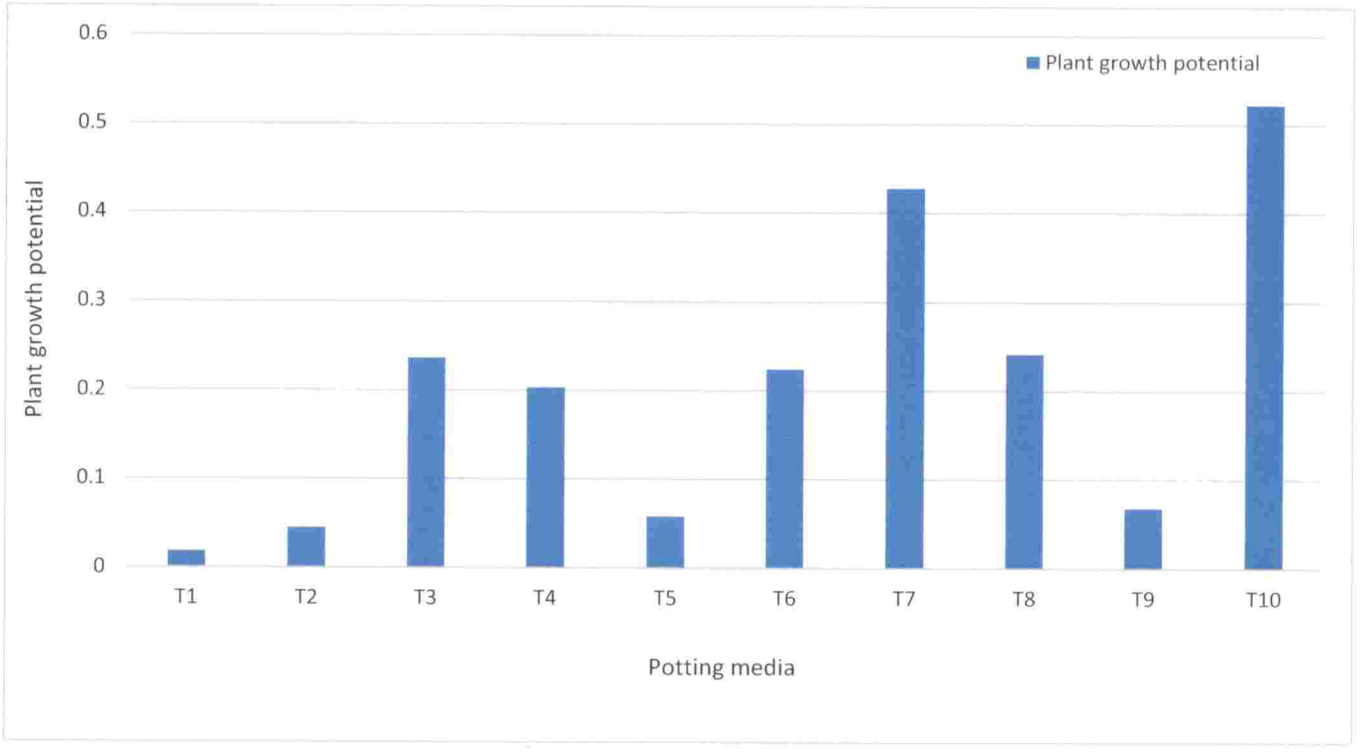

Fig 7 . Effect of different potting media on plant growth potential of nursery plants

T_1) B_1 (Soil: Coirpith Compost:Cowdung),T_2) B_2 (Soil : Coirpith Compost: Vermicompost), T_3) B_1 + PGPR Mix 1 T_4) B_1 + *Azospirillum*, T_5) B_1 + PSB T_6) B_1 + AMF T_7) B_2 + PGPR Mix 1 ,T_8) B_2 + *Azospirillum* T_9) B_2 + PSB T_{10}) B_2 + AMF

Plate 9: Hardwood cuttings at the time of transplanting in different potting media a) B_1(Soil:CoirpithCompost:Cowdung) b) B_2(Soil:CoirpithCompost: Vermicompost c) B_1 + PGPR Mix 1 d) B_1 + *Azospirillum* e) B_1 + PSB f) B_1 + AMF g) B_2 + PGPR Mix 1 h) B_2 + *Azospirillum* i) B_2 + PSB j) B_2 + AMF

DISCUSSION

5. DISCUSSION

The present study entitled "Standardisation of nursery management practices in pachotti (*Symplocos cochinchinensis* (Lour.) S. Moore)" was carried out during 2017-18 at the Department of Plantation Crops and Spices, College of Agriculture, Vellayani. The results of the study are discussed in this chapter.

5.1 EVALUATION OF PROPAGATION EFFICIENCY OF DIFFERENT PROPAGULES OF *SYMPLOCOS COCHINCHINENSIS*

The various propagules *viz.*, seeds, stem cuttings (hardwood, semihardwood and softwood cuttings) and root cuttings were tried to study their propagation efficiency. According to Yunchun *et al.* (2006) and Banu and Khasyap (2013), *Symplocos* has two propagation systems *viz.*, clonal reproduction through the formation of ramets and sexual reproduction *via* seeds. The efficiency of the two systems varies with the habitats. According to them, ample water, fertility and high canopy cover promotes clonal reproduction, and when these parameters are on the lower side, sexual reproduction is favoured. Meher-Homji (1975) and Banu *et al.* (2010) reported that plant dissemination occurred primarily through seeds, dispersed by birds or by wind.

5.1.1 Seeds

In the present study, seeds were extracted from the fruits. The fruit set during the two years were at different times of the year. It was collected during October 2017 and April 2018, from Wayanad district. This indicated that flowering and fruit set in *S. cochinchinensis* is climate oriented. However,

Almeida (1990), observed that *Symplocos* flowered during September to December followed by fruiting.

In the study, seeds of *S. cochinchinensis* did not give effective germination with different *in vivo* (physical treatments, chemical priming and bioprimimg) and *in vitro* seed treatments. Among the various treatments tried, only physical treatment, scarification with sand paper gave 22 per cent germination in the Petri plate indicated by the emergence of radicle. However, this response could be obtained only after two months of incorporation of treatments, probably due to the dormancy of the seeds. The scarified seed gave 2 per cent germination with intact leaves and roots, in protray but the seedlings did not survive for more than two weeks. Seed dormancy of *S. cochinchinensis* for more than 30 days was reported by Athugala *et al.* (2014). In *S. paniculata,* seed propagation is reported wherein seeds are sown as soon as they are ripe but will not germinate until second spring after sowing (Everett, 1982). Nagaraj (2014) reported seed propagation in *S. racemosa.* According to Shah *et al.* (2016), seeds of *S. racemosa* could retain viability for three months only. Maximum emergence of seedlings was observed in potting mixture comprising of soil: paddy husk: farm yard manure (1:1:1) and urea (1 per cent). But, due to inbreeding depression, weak seedlings were formed and subsequently, resulted in death of the seedlings. Kalidass (2014) reported that very low vegetative propagation, from root segments of *S. racemosa.* Also, it produced fruits with non-viable seeds. If viable seeds were produced, they remained viable only for three months.

Athugala *et al.* (2014) also observed that scarified seeds pretreated with 500 ppm GA_3 gave germination in 15 days but in our study pretreatment with GA_3 or any other chemical pretreatment did not evoke germination. *In vitro*

germination in MS medium supplemented with or without plant growth regulators also did not give any positive result.

Though seed is considered as the main source of plant dissemination in its natural habitat, low germination per cent and non-consistency in flowering would detrimentally affect the nursery raising of *S. cochinchinensis,* using seed as the propagule.

5.1.2 Vegetative propagules: Stem cuttings and Root cuttings

Vegetative propagation of trees calls in for genetic uniformity, for replicating clonal material and for the multiplication of stock. Clonal propagation is given significant emphasize for tree improvement and field afforestation programmes, as it offers the advantages of genetic uniformity and continuous availability of superior propagules for plantations. The shoot cuttings are the promising vegetative propagation material for tree species. Propagation *via* cuttings can avoid the problems of seed collection, its germination and subsequent survival of young seedlings. Stem cuttings are preferred as propagules because they may permit faster initiation of root primordia, from the undifferentiated tissues and also preformed buds. The advantage of vegetative propagation over seed propagation include faster growth rate, greater uniformity in plant stand and better response of genotypes to the field conditions (Bhatnagar, 1973). According to Thakur *et al.* (2018), for species with irregular seed setting, long gestation period, slow seedling growth and long seed dormancy, stem cuttings are the most preferred planting material for mass multiplication.

In the present study, stem cuttings, *viz.*, hardwood, semihardwood and softwood cuttings of *S. cochinchinensis* were pretreated with chemicals / hormones, to evaluate their propagation efficiency. All the three types of cuttings initiated sprouts in 10 to 13 days. The softwood cuttings gave very low response in terms of survival. It recorded a survival of only 6.67 per cent, three months after planting, when pretreated with SA @ 20 mg L^{-1}. With the same pretreatment, the hardwood and semihardwood cuttings gave a survival of 30 and 23.33 per cent, respectively. According to Weerakon *et al.* (2014), hardwood cuttings of *S. cochinchinensis* gave 40 per cent survival, when forest soil was used in the media. In contrast to our findings, they also reported about 30 per cent survival in the softwood cuttings raised in sand medium under semi glass house conditions. In agreement to our result, wherein softwood cuttings had lesser survival compared to hardwood cuttings, Mathew *et al.*, (2011) reported 36-40 per cent survival in hardwood cuttings compared to that of 13 per cent in softwood cuttings in *Ficus* sp. Similar trend was also reported in *Ginkgo biloba* by Gopichand and Meena (2015).

A large number (approximately 75 per cent) of cuttings sprouted in 15 to 20 days. However, at one month after planting maximum survival recorded was only 33.33 per cent. This was due to the drying up of sprouts. The high initial sprouting may be due to the utilisation of stored carbohydrate in the cuttings. Slow root initiation might have deprived the newly emerged leaves of the food supply and resulted in drying up and further shedding of leaves. Similar findings have been reported by Chakraborty (1989) in the cuttings of *Terminalia bellirica* and by Thakur *et al.* (2018) in that of *Acacia catechu*.

Among the pretreatment in hardwood cuttings, SA @ 10 & 20 mg L^{-1} gave better performance. SA is an endogenous phenolic compound, which has

profound influence on numerous physiological effects on plants. Exogenous application of SA promote growth and development of plants. It promoted shoot and root growth in cuttings of ornamentals plants (Li and Li, 1995; Sanaa *et al.*, 2002; Galal, 2012). The positive effect of SA on sprouting and further growth with respect to shoot length and number of leaves, in our study, may be attributed to its influence on root formation in the cuttings. The augmented influence of SA on root formation in stem cuttings were reported in Poinsettia (*Euphorbia pulcherrima*), Henna (*Lawsonia inermis*) etc. (Sardoei *et al.*, 2013; Sardoei and Shahdadneghad, 2015). However, Nanda and Kochhar (1985) reported inhibitory effect of endogenous SA on root formation in cuttings of *Bougainvillea glabra, Echitis caryophyllata and Jasminum pubescence*.

In the study, next to salicylic acid, better survival (25 per cent) of hardwood cuttings was observed in phloroglucinol. In contrast to this, Gopichand and Meena (2015) reported the inhibitory effect of phloroglucinol @ 10 mg L^{-1} when used along with IBA @250 mg L^{-1}. This gave lesser survival of 70 per cent than when IBA (91per cent) was used alone. However, the positive effect of phloroglucinol on shoot multiplication and root formation *in vitro* culture systems has been reported (Daud *et al.*, 2013; Jani *et al.*,2015; Sharifian *et al.*, 2009; Perez *et al.*, 2016). In the study, the various auxins *viz.*, IAA, NAA and IBA @ 250 and 500 mg L^{-1} gave a survival of 10 to 15 per cent only. This may be due to the slow initiation of roots in the cuttings exposed to these treatments. The inhibitory effect of higher concentration of auxins on rooting of cuttings has been reported in *Dalbergia sisoo* (Puri and Verma, 1996). Chettri and Rai (2014) reported that the concentration of auxins above optimum level declined the survival per cent, shoot length, shoot girth, number of leaves in the cuttings of *Aeschynanthus sikkimensis.* The establishment of cuttings gradually reduced with the increasing level of growth regulators from

the optimum. However, Shah *et al.* (2016) reported that IBA could induce rooting in cuttings of *Symplocos racemosa*.

In the present study, root cuttings of *S. cochinchinensis* were taken by digging out the roots from the base of the trees. These trees have a peculiar way of natural propagation by the formation of ramets in the roots. Ramets are clonal propagules of root origin. Hence, considering the plantlet forming potential of roots, the root cuttings were selected as a propagation entity for this study. The root cuttings pretreated with IAA @ 250 mg L^{-1} gave maximum survival and performance with respect to shoot length and number of leaves. This pretreatment recorded a survival of 33.33 per cent at three months after planting. The shoot length recorded was 5.73 cm and number of leaves, 2.15. The higher concentration of IAA @ 500 mg L^{-1} had an inhibitory effect on survival rate (13.33 per cent) in root cuttings. The other auxins tried, *viz.*, NAA and IBA also had inhibitory effect on survival per cent of root cuttings. However, it was observed that the control (without any pretreatment) did not survive at all. This indicates the positive effect of auxins on the sprouting and further growth of root cuttings of *S. cochinchiensis*. The auxin pretreatment might have induced formation of new roots and have facilitated the absorption of more nutrients leading to the morphological improvement in terms of shoot length and leaf number. Banjara (2017) reported that auxin treatment could accelerate the growth of leaf buds and early differentiation of buds, whereby triggering the hydrolysis of reserve carbohydrate in the cuttings and further rooting in *Terminalia*.

The stem cuttings sprouted in 11 to 13 days, while root cuttings took 13 to 19 days, after planting. However, the root cuttings of *S. cochinchinensis* gave a slightly better survival (33.33 per cent) compared to that of hardwood cuttings

(30.00 per cent). Similar findings where root cuttings (40-85 per cent) had a superiority over stem cuttings (40-65 per cent) in terms of establishment has been reported in *Rauvolfia serpentina* (Pandey and Mandal, 2010). However, the availability and scope of procurement of root cuttings were limited. Since the increase in survival percent of root cuttings over the hardwood cuttings was very meagre (3.33 per cent) and the availability and procurement of the latter was easy over the former, the hardwood cuttings were observed to be the feasible planting material of *S. cochinchinensis.*

In the study, hardwood cuttings were identified as the preferred planting material for the nursery establishment of *S. cochinchinensis*. The cuttings could be pretreated with salicylic acid @20 mg L^{-1} for initial establishment of nursery plants.

5.2 EVALUATION OF POTTING MEDIA ON PLANT ESTABLISHMENT OF *S. COCHINCHINENSIS*

The right type of potting medium need to be identified to produce quality planting materials in the nursery. An ideal rooting medium for cutting as propagation material, depends on the species, type of cutting and season (Fornes *et al.*, 2013). The changes in the composition of potting media and the addition of plant growth promoting rhizobacteria and biofertilisers, enhanced plant growth and development, which ultimately led to the production of quality planting material (Murugesan *et al.*, 2016). In our study, soil: coirpith compost: cowdung (1:1:1) (T_1) and soil: coirpith compost: vermicompost (1:1:1) (T_2) were used as the basal media to which microbial inoculants @ 5g $plant^{-1}$ were supplemented. The microbial inoculants tried in the study were PGPR Mix I, *Azospirillum*, PSB and AMF. The three month old plants raised from hardwood

cuttings pretreated with SA @ 20 mg L^{-1} were transplanted into polybags containing various potting media.

The better performance with respect to morphological and physiological parameters and phytochemical components was obtained with the media (T_2) containing vermicompost, between the two basal media (T_1 and T_2) tried. The better performance of the media might be attributed to nutrient rich and microbiologically active properties of the vermicompost. The most nutrients in vermicompost are in forms that are readily assimilable by plants. It harbours diverse and high microbial population (Singh *et al.*, 2009; Pathma and Sakthivel, 2012). According to Alidadi *et al.* (2014), it contains nitrogen, phosphorus and potassium five to ten times higher than plain soil.

In the study, it was observed that both the basal media with microbial inoculants gave better morphological performance than those without it, in the hardwood cuttings of *S. cochinchinensis*. However, significantly better performance with respect to morphological characters was obtained with the basal media consisting of vermicompost, supplemented with microbial inoculants (T_7 to T_{10}). At four months after planting, it was observed that the media, T_7 to T_{10} gave on par morphological performance with respect to shoot growth *viz.*, shoot length, number of branches and number of leaves. The fresh weight of shoots also showed a similar trend. The dry weight of shoot was found to be significantly higher with vermicompost containing basal media treated with AMF (T_{10}) and PGPR Mix 1 (T_7). The lower values for shoot growth parameters were obtained with basal media without microbial inoculants (T_1 and T_2), which were also on par with cow dung containing media with microbial inoculants (T_3 to T_6). Hence, it could be ascertained that vermicompost in the medium had profound influence in promoting shoot growth parameters. The positive influence of vermicompost on shoot growth parameters has been

reported in *Syzygium aromaticum* (Thankamani *et al.,* 1996), *Piper longum* (Sahoo and Gupta, 2017), *Lycopersicon esculentum* (Alidadi *et al.*, 2014) etc.

The physicochemical analysis indicated that the vermicompost containing medium (T_2) has higher nitrogen and potassium content compared to cow dung containing medium (T_1). The higher nitrogen status of vermicompost might be due to nitrogenous metabolic products of earthworms (Umamaheswari and Vijayalaksmi, 2003). Atiyeh *et al.* (2000) opined that earthworms have a great impact on nitrogen transformation in manure, by enhancing nitrogen mineralization, so that nitrogen is retained in the available form in the media. According to Taleshi *et al.* (2011), available nitrogen is greater in vermicompost compared to conventional manures. During the vermicomposting process, cast material contains high exchangeable K concentration due to enhanced microbial activity (Suthar, 2007). The phosphorus content was comparatively less in vermicompost containing medium. The pH of the medium containing vermicompost (T_2) was 6.4 while that containing cow dung (T_1) had a pH of 6.7. Similar trend wherein a slightly lower pH in vermicompost in comparison to cow manure was observed by Alidadi *et al.* (2014). The pH range was found to be from 5.41 to 6.32 in vermicompost with variable substrate (Yan *et al.*, 2013). In the study, the electrical conductivity of vermicompost containing medium is higher (1.61 dSm^{-1}) compared to that containing cow dung (1.03 dSm^{-1}). Earthworms have a role in enhancing the solubility of the minerals or its maintenance in absorbable form in the media (Chauhan *et al*, 2010; Alidafi *et al.*, 2014). According to Gomez *et al.* (2013), the EC values up to 4 dSm^{-1} is suitable for vermicompost to be utilized as organic soil amendments.

Biomass yield in terms of fresh and dry weight of shoot was found to be the highest in PGPR Mix I followed by AMF. PGPR Mix I used in the study is a consortium of nitrogen fixing (*Azospirillum lipoferum, Azotobacter chroococcum*), phosphorus solubilizing (*Bacillus megatherium*) and potash

solubilizing (*Bacillus sporothermodurans*) microorganisms. Ramamoorthy and Samiyappan (2001) and Raj *et al.* (2005) demonstrated that treatment with PGPR would improve shoot growth and subsequently shoot biomass in various crop plants including plantation crops and tree species. Arbuscular mycorrhizal fungi (AMF) is an obligate symbiont that provide the host plant with mineral nutrients and water, in exchange for photosynthetic products (Smith and Read, 2008). Higher root colonization by AMF promotes host fungus interaction and exchange of nutrients for better growth (Mallesha and Bagyaraj, 1990). The AMF mycelium that emerges from the root system being thinner can penetrate small pores and acquire nutrients from soil regimes that are inaccessible to roots (Smith *et al.*, 2000; Allen, 2011).

It was observed in the study that the root growth parameters *viz.*, root length, root girth, root biomass (both fresh and dry weight) were significantly higher in T_{10} (media containing vermicompost supplemented with AMF) at four months after transplanting. AMF is an imperative component of soil microbial biomass that influences essential processes at plant -soil interface (Rajan *et al.*, 2000). According to Urgiles *et al.* (2009), seedlings of tree species may associate with AMF to counteract the transplantation shock. Giananazzi *et al.* (2001) opined that the external application of mycorrhizal spores by adding AMF inoculum into the planting hole at time of transplanting, would lead to superior growth of nursery plants and their improved performance following planting in the field. Berrutti *et al.* (2016) reported shoot and root biomass increase on the application of AMF to the crop plants.

The physiological parameters *viz.*, leaf area index and leaf area duration were found to be higher in vermicompost containing medium supplemented with microbial inoculants. But these parameters did not show any variation among different microbial inoculants. The lowest values were recorded by the basal medium containing cow dung (T_1). This was found to be on par with the

cow dung containing media with microbial inoculants (T_3 to T_6) and the basal medium containing vermicompost without inoculants (T_1). Though the microbial inoculants with vermicompost gave superior performance, those inoculants in combination with cow dung did not have any positive influence on these physiological parameters. The improved leaf growth parameters is not due to the individual influence of vermicompost or the microbial inoculants but a combination of both. Hence, it can be concluded that the vermicompost containing media supplemented with the microbial inoculants could significantly improve leaf growth parameters.

Among the various microbial inoculants, the highest leaf area index was recorded by PGPR Mix 1. PGPR increases the nutrient concentration in the rhizosphere by fixing nutrients, thus preventing them from leaching out. PGPR plays an important role in enhancing plant growth through mechanism of abiotic stress tolerance, nutrient fixation for easy uptake by plant, production of plant growth regulators, siderophores, volatile organic compounds and the production of protection enzymes *viz.*, chitinase, glucanase, and ACC-deaminase for the prevention of plant diseases (Choudhary *et al.*, 2011; García-Fraile *et al.*, 2015). The positive influence of PGPR on plant growth parameters has been reported in plantation crops and tree species by (Meena, 2014). Ahamad et al (2016) demonstrated that PGPR could promote plant growth in terms of in terms of shoot length and root length in *Dalbergia sissoo*.

The better performance of PGPR Mix I with respect to shoot growth parameters in comparison to other microbial inoculants may due to the fact that it is a consortium of nitrogen fixing, phosphorus solubilizing and potash solubilizing microorganisms, which could fix all the three major nutrients required by the crop.

The phytochemical constituents, carbohydrate, chlorophyll and soluble protein content were significantly influenced by different potting media. The carbohydrate and soluble protein content was higher in vermicompost containing media with microbial inoculants (T_7 to T_{10}). Both the basal media recorded lower value for these two phytochemicals. However, the microbial inoculants supplemented in cow dung based media were also significantly higher in these phytochemicals compared to the media without the inoculants. This indicated the influence of microbial inoculants on carbohydrate and soluble protein content in the nursery plants. Significantly higher value for chlorophyll content was recorded in vermicompost medium supplemented with PGPR Mix I (T_7) and *Azospirillum* (T_{10}). Megala and Paranathman (2017) demonstrated that the application of PGPR would increase the carbohydrate, chlorophyll and protein content in *Solanum nigrum.* According to Saravanan *et al.* (2012), *Casuarina equisetifolia* seedlings inoculated with *Azospirillum* increased the chlorophyll and protein content over the control (uninoculated coirpith). Kuppurajendran (2012) also reported the similar effect of *Azospirillum* on *Erythrina indica* seedlings. *Azospirillum* in the media fixes nitrogen and makes it available to the plant. The stimulated supply of nitrogen would increase chlorophyll and amino acid synthesis, subsequently proteins and nucleic acids that would form a framework for chloroplast, thereby improving the photosynthetic activity as suggested by Aswathy *et al.* (2018). In consensus with the study, it was observed that the inoculation with AMF also improved proteins and carbohydrates content in *Anadenanthera colubrina* seedlings (Bonfim *et al.*, 2013) and *Bombax mori* seedlings (Shi *et al.*, 2016). According to Olivera *et al.* (2014), AMF favoured the accumulation of proteins and carbohydrates. He opined that the synthesis of secondary compounds is attributed to the increase in primary metabolites. In contrast to this, mycorrhization did not alter the protein content and soluble carbohydrates in *Amburana cearenis* seedlings, as reported

by Oliveria *et al.* (2015). Phosphate solubilizing bacteria (PSB) would bring about the mobilisation of insoluble phosphates and thus stimulate plant growth (Domey and Lippmann, 1989). The effect of bacterial inoculation of phosphate solubilizing bacteria on the phytoconstituents showed that the carbohydrate, chlorophyll and protein content of *Avicennia officinalis* increased with the addition of PSB, *Bacillus megaterium*. This stimulatory effect might be due to the ability of PSB to solubilize the inorganic phosphorus and making it available to the growing seedlings (Ravikumar *et al.*, 2010).

In the study, it was observed that plant nutrients, nitrogen and potassium was maximum in vermicompost containing medium supplemented with *Azospirillum* (T_8). Similar response wherein plant nutrient uptake was improved by application of *Azospirillum* was reported by Kuppurajendran (2012). While in case of plant phosphorus, significant variation could not be found among the treatments tried. However, the vermicompost containing medium supplemented with various microbial inoculants (T_7 to T_{10}) gave superior performance compared to that of cow dung containing medium (T_3 to T_6).

Nutrient analysis of the potting media before experiment indicated that nitrogen, phosphorus and potassium content were 265.18, 171.38 and 423.88 mg kg^{-1} respectively for cow dung containing medium (T_1) and 285.66, 165.38 and 634.9 mg kg^{-1} for vermicompost containing medium (T_2). After the experiment, the three nutrients were found to decrease in these two media. The microbial inoculant supplemented media also showed decreasing trend with respect to the nutrient content. This decrease may be attributed to the plant uptake. However, the nutrient content of the inoculant supplemented medium was on the higher side compared to those without inoculants. This increase in nutrient content may be due to fixing of atmospheric nitrogen, mobilizing of fixed nutrients or converting insoluble P in the soil into soluble forms, available

to the plants. Among the microbial inoculants supplemented vermicompost containing medium (T_7 to T_{10}), the maximum nitrogen content was recorded in T_{10} (AMF supplemented vermicompost containing medium) and lower in T_7 (PGPR Mix I supplemented) medium. Correspondingly, plant uptake would be expected to be higher in T_7. But in the study, the higher plant nitrogen was observed in T_8 (*Azospirillum* supplemented) medium followed by T_7. The phosphorus content of the medium was the highest in PSB supplemented medium (T_5 and T_9). This may be due to ability of PSB to convert insoluble phosphorus into soluble phosphorus available to the plant. The available P in the media after the experiment was the lowest in AMF supplemented medium. A higher uptake of P by the plants is normally expected. But the P content of the plants did not show any variation among the media tried. The potassium content of the medium was higher in T_8 (*Azospirillum* supplemented) medium. Among the vermicompost containing medium with inoculants, the lowest potassium content was recorded in T_{10} (AMF supplemented) medium. Correspondingly higher plant K is expected in T_{10} but higher plant K was recorded in T_8 (*Azospirillum* supplemented) medium followed by T_7. The discrepancies in the nutrient levels of the media after the experiment and the plant nutrient status may be attributed to the immobilization of the nutrients by the soil microbes for their multiplication and growth. However, the inoculants had played their role in improving the soil nutrient status, as indicated by higher nutrient level in the inoculant supplemented media, than that without them. The nutrient in the media and that supplemented by the inoculants might not have been utilized fully by the plant, a large part of it might have been immobilized by the microbes. The microorganisms in the rhizosphere utilizes the easily available carbon from the organics in the medium and depletes the remaining available nutrients by microbial uptake and immobilization, for their growth and multiplication (Zak *et al.*, 1990)

The growth potential of the nursery plants raised in different potting media was analysed. It was observed that the vermicompost containing media supplemented with AMF had high growth potential (0.522) which can be attributed to the increased root growth parameters. The lowest growth potential was recorded by potting media without microbial inoculants, T_1 (0.018) and T_2 (0.045). This indicated the necessity for supplementing basal media (T_1 and T_2) with microbial inoculants for better plant growth and establishment of the nursery plants of *S. cochinchinensis.*

In the study, hardwood cuttings pretreated with salicylic acid @ 20 mg L^{-1} gave maximum propagation efficiency in terms of survival per cent, morphological parameters and easiness in procurement. Among the various potting media tried, soil: coirpith compost: vermicompost (1:1:1) + AMF 5g $plant^{-1}$ was identified to be superior with respect to the growth potential of the nursery plants of *S. cochinchinensis.* Thus, the efficient propagule for raising the nursery along with the appropriate potting media has been brought out in the study.

Future lines of work

- Experiments need to be formulated to break seed dormancy and to improve seed germination efficiency in *S. cochinchinensis.*
- Research has to be directed towards improving the success rate of vegetative propagules.
- Micropropagation technique has to be standardized for the production of quality planting material of *S. cochinchinensis.*

SUMMARY

6. Summary

The present study entitled "Standardisation of nursery management practices in pachotti (*Symplocos cochinchinensis* (Lour.) S. Moore)" was carried out in the Department of Plantation Crops and Spices, College of Agriculture, Vellayani during 2017-18. The objective of the study was to evaluate the propagation efficiency of different propagules *viz*., seeds, stem cuttings and root cuttings and to standardise the potting media for the nursery plants of pachotti.

The propagules *viz.*, seeds, stem cuttings and root cuttings for the study were sourced from Jawaharlal Nehru Tropical Botanical Gardens and Research Institute, Palode, Thiruvananthapuram and from Wayand district.

The seeds were subjected to *in vivo* and *in vitro* germination studies. In *in vivo* study, among the pretreatments tried, *viz.,* physical treatments, chemical priming and bio priming, only physical treatment of scarification (with sand paper) responded with a very low germination of 2 per cent. The germination commenced after two months of the treatment. Other *in vivo* pretreatments as well as *in vitro* treatments did not give any germination.

In vegetative propagation, stem cuttings were exposed to hormone/chemicals (auxins, phloroglucinol and salicylic acid (SA)) pretreatments for two hours before planting. Observations on days to initial sprouting, survival per cent, shoot length, number of leaves and basal shoot girth were recorded.

The days to initial sprouting was found to be non-significant among the various pretreatments tried, in stem cuttings, *viz.*, hardwood, semihardwood and softwood cuttings. The days to initial sprouting recorded was 10-12 days.

The type of stem cuttings have significant influence on survival per cent, shoot length and basal shoot girth. S_1 (Hardwood cutting) has significantly higher survival percent (17.88) compared to S_2 (semihardwood cutting) (12.73). While S_2 (semihardwood cuttings) exhibited a higher value with respect to morphological parameters, shoot length (2.67 cm) and number of leaves (3.93), compared to hardwood cuttings. Among the various pretreatments tried, C_{10} (SA @ 20 mg L^{-1}) recorded the highest value in terms of survival (26.67 per cent) and morphological parameters (Shoot length-3.67; number of leaves-4.89). Survival per cent and number of leaves were found to be on par with C_9 (SA @ 10 mg L^{-1}). Pretreatments with salicylic acid @ 10 mg L^{-1} and 20 mgL^{-1} were found to be effective in the initial establishment (primary nursery) of *Symplocos.* The interaction effect of the type of stem cuttings and pretreatments indicated that there is no significant variation among treatments with respect to days to initial sprouting. At third month after planting, S_1C_{10} (hardwood cuttings pretreated with SA @20 mg L^{-1}) gave significantly higher survival of 30 per cent. The highest shoot length (3.72 cm) was recorded in S_2C_{10} (semihardwood cuttings pretreated with SA @20 mg L^{-1}) which was on par with S_1C_{10}. The number of leaves, basal shoot girth and percentage increase in shoot girth over the three months did not show any significant variation among the treatments tried.

The root cuttings were pretreated with different concentrations of various types of auxins. Observations on days to initial sprouting, survival per cent, shoot length, number of leaves and basal shoot girth were recorded. Root cuttings pretreated with IAA @ 250 mg L^{-1}, after three months of planting responded with 33.33 per cent survival with a shoot length of 5.73 cm. Though root cuttings had slightly higher survival percent and shoot length compared to hardwood cuttings, the availability and scope of procurement of the former is limited.

The three month old hardwood cuttings pretreated with SA @ 20 mg L^{-1} were used to evaluate the influence of potting media on plant establishment. The cuttings were transplanted to ten different potting media comprising of two basal media *viz.*, soil: coirpith compost: cowdung (1:1:1) (B_1) and soil: soirpith Compost:

vermicompost (1:1:1) (B_2), and each in combination with biofertilisers @ 5g plant^{-1} *viz.*, PGPR (Plant Growth Promoting Rhizobacteria) Mix I, *Azospirillum*, PSB (Phosphorus Solubilising Bacteria) and AMF (Arbuscular Mycorrhizal Fungi). The observations were recorded on morphological, physiological, phytochemical and nutrient content of plants.

At four months after transplanting, vermicompost based media supplemented with biofertilisers were found to be significantly superior to B_2 (vermicompost based media), B_1 (cowdung based media) and B_1 in combination with biofertilisers with respect to morphological parameters. B_2+PGPR Mix I recorded the highest shoot length (11.50 cm) and number of leaves (10.50) which was on par with B_2+*Azospirillum*, B_2+ PSB and B_2+AMF; the highest number of branches (1.92) was observed in B_2+ *Azospirillum* which was on par with the treatments, B_2+PGPR Mix I, B_2+ PSB and B_2+AMF. The fresh and dry weight of shoots were the highest (21.35 g and 4.78 g respectively) in B_2 + PGPR Mix I which was on par with B_2+ AMF. B_2+AMF recorded the highest values (4.77 cm, 0.30 mm, 3.28 g and 0.092 g, respectively) with respect to root growth parameters *viz.*, root length, root girth, fresh and dry weight of roots.

The physiological parameters, leaf area index (1.36) and leaf area duration (34.63 days) were the highest in B_2+PGPR Mix I which was on par with B_2 in combination with other biofertilisers.

The phytochemical analysis indicated that carbohydrate content (80.9 mg g^{-1}) of plant tissue was the highest in B_2+PGPR Mix 1, which was on par with B_2+ PSB, B_2+ *Azospirillum* and B_2+ AMF. Chlorophyll content was found to be the highest (1.20 mg g^{-1}) in B_2+ *Azospirillum* which was on par with B_2+ PGPR Mix I. The same treatment recorded the highest soluble protein content (20.31 mg g^{-1}) and it was on par with B_2 in combination other biofertilisers.

The nutrient analysis of plant tissue showed that nitrogen (2.22 per cent) and potassium (2.15 per cent) content were significantly higher in B_2+*Azospirillum*. B_2+PSB recorded higher phosphorus content (0.26 per cent) among the treatments.

The study indicated that nursery plants in the vermicompost based potting media in combination with biofertilizers gave better performance with respect to morphological parameters, physiological parameters, phytochemicals and plant nutrients. Among the various potting media tried, B_2+ AMF recorded significantly higher plant growth potential (0.522) followed by B_2 + PGPR Mix I (0.428).

In the study, hardwood cuttings were identified as the preferred planting material for the nursery establishment of pachotti. The cuttings could be pretreated with salicylic acid @ 20 mg L^{-1} for initial establishment of nursery plants. Soil : coirpith compost: vermicompost (1:1:1) + AMF (5g $plant^{-1}$) was found to be the appropriate potting media for raising the nursery plants of pachotti.

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7. REFERENCES

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STANDARDISATION OF NURSERY MANAGEMENT PRACTICES IN PACHOTTI (*Symplocos cochinchinensis* (Lour.) S. Moore)

by

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ABSTRACT

The study entitled "Standardisation of nursery management practices in pachotti (*Symplocos cochinchinensis* (Lour.) S. Moore)" was carried out in the Department of Plantation Crops and Spices, College of Agriculture, Vellayani during 2017-18. The objective of the study was to evaluate the propagation efficiency of different propagules *viz.*, seeds, stem cuttings and root cuttings and to standardise the potting media for the nursery plants of pachotti.

The propagules *viz.*, seeds, stem cuttings and root cuttings for the study were sourced from Jawaharlal Nehru Tropical Botanical Gardens and Research Institute, Palode, Thiruvananthapuram and from Wayand district.

The seeds were subjected to *in vivo* and *in vitro* germination studies. In *in vivo* study, among the pretreatments tried, *viz.*, physical treatments, chemical priming and bio priming, only physical treatment of scarification (with sand paper) responded with a very low germination of 2 per cent. The germination commenced after two months of the treatment. Other *in vivo* pretreatments as well as *in vitro* treatments did not give any germination.

In vegetative propagation, stem cuttings were exposed to hormone/chemicals (auxins, phloroglucinol and salicylic acid (SA)) pretreatments for two hours before planting. When pretreated with SA @ 10 and 20 mg L^{-1}, at three months after planting, the hardwood cuttings responded with 30 per cent survival, with a shoot length of 2.99 cm and 3.62 cm, respectively. The semihardwood cuttings pretreated with SA @ 20 mg L^{-1}responded with 23.33 per cent survival with a higher shoot length of 3.72 cm. Both the hardwood and semi hardwood cuttings pretreated with SA 20 mgL^{-1} had on par values with respect to shoot length. Root cuttings were pretreated with different concentrations of various types of auxins. Root cuttings pretreated with IAA @ 250 mg L^{-1}, after three months of planting responded with 33.33 per cent survival with a

shoot length of 5.73 cm. Though root cuttings had slightly higher survival percent and shoot length, hardwood cuttings were selected for the evaluation of potting media due to better availability and ease in procurement.

The three month old hardwood cuttings pretreated with SA @ 20 mg L^{-1} were then transplanted to ten different potting media comprising of two basal media *viz.*, soil: coirpith compost: cowdung (1:1:1) (B1) and soil: soirpith compost: vermicompost (1:1:1) (B2), and each in combination with biofertilisers @ 5g $plant^{-1}$ *viz.*, PGPR (Plant Growth Promotng Rhizobacteria) Mix I, *Azospirillum*, PSB (Phosphorus Solubilising Bacteria) and AMF (Arbuscular Mycorrhizal Fungi).

At fourth month after transplanting, B2 in combination with biofertilisers were found to be significantly superior to B2, B1 and B1 in combination with biofertilisers with respect to morphological parameters. B2+PGPR Mix I recorded highest shoot length (11.50 cm) and number of leaves (10.50) which was on par with B2+Azospirillum, B2+ PSB and B2+AMF; the highest number of branches (1.92) was observed in B2+ *Azospirillum* which was on par with the treatments, B2+PGPR Mix I, B2+ PSB and B2+AMF. The fresh and dry weight of shoots were the highest (21.35 g and 4.78 g respectively) in B2 + PGPR Mix I which was on par with B2+ AMF. B2+AMF recorded highest values (4.77 cm, 0.30 mm, 3.28 g and 0.092 g, respectively) with respect to root growth parameters *viz.*, root length, root girth, fresh and dry weight of roots.

The physiological parameters, leaf area index (1.36) and leaf area duration (34.63 days) were the highest in B2+PGPR Mix I which was on par with B2 in combination with other biofertilisers.

The phytochemical analysis indicated that carbohydrate content (80.9 mg g^{-1}) of plant tissue was the highest in B2+PGPR Mix 1, which was on par with B2+ PSB, B2+ *Azospirillum* and B2+ AMF. Chlorophyll content was found to be the highest (1.20 mg g^{-1}) in B2+ *Azospirillum* which was on par with B2+ PGPR Mix I. The same

treatment recorded the highest soluble protein content (20.31 mg g^{-1}) and it was on par with B2 in combination other biofertilisers.

The nutrient analysis of plant tissue showed that nitrogen (2.22 per cent) and potassium (2.15 per cent) content was significantly higher in B2+*Azospirillum*. B2+PSB recorded higher phosphorus content (0.26 per cent) among the treatments.

The study indicated that nursery plants in the potting media B2 in combination with biofertilizers gave better performance with respect to morphological parameters, physiological parameters, phytochemicals and plant nutrients.

Among the various potting media tried, B2+ AMF recorded significantly higher plant growth potential (0.522) followed by B2 + PGPR Mix I (0.428).

In the study, hardwood cuttings were identified as the preferred planting material for the nursery establishment of pachotti. The cuttings could be treated with salicylic acid @ 20 mg L^{-1} for initial establishment of nursery plants. The preferred potting media for transplanting the established cuttings for raising the nursery plants of pachotti is Soil : Coirpith compost: Vermicompost (1:1:1) + AMF (5g/plant).