STANDARDISATION OF PROPAGATION TECHNIQUES IN SCHEFFLERA

(*Schefflera arboricola* Hayata)

BY

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THESIS

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DECLARATION

I hereby declare that the thesis entitled **Standardisation of propagation techniques in schefflera (*Schefflera arboricola* Hayata)** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree diploma fellowship associateship or other similar title of any other university or society

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ABBREVIATIONS

BAP	benzyl ammo purine
°C	degree celsius
cm	centimeter
CW	coconut water
2 4 D	2 4 dichlorophenoxy acetic acid
g	gram(s)
h	hour(s)
HCl	Hydrochloric acid
IAA	indole 3 acetic acid
IBA	indole 3 butyric acid
2iP	2 isopentenyl adenine
mg l ^{1}	milli gram(s) per litre
min	minute(s)
ml	millilitre
mm	millimeter
MS	Murashige and Skoog s (1962) medium
N	Normality
NAA	naphthalene acetic acid
NaoH	Sodium hydroxide
pH	hydrogen ion concentration
psi	pounds per square inch
RH	relative humidity
TDZ	N phenyl N 1 2 3 thiadiazol 5 yl urea
v/v	volume in volume
WPM	Woody plant medium (Lloyd and McCown 1980)

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

15c Morphogenesis from callus in MS medium supplemented with silver nitrate 8 mg l^{-1} (Note only rhizogenesis noticed)

16 Rhizogenesis from callus even after the transfer of culture from medium supplemented with silver nitrate to medium containing BAP 3 5 mg l^{-1} (left) and basal medium (right)

17 Effect of nodal positions (N_5, N_4 and N_3 from left to right) on bud break in *S arboricola*

18a Bud sprout from nodal explant in MS medium supplemented with BAP 0 5 mg l^{-1}

18b Bud sprout from nodal explant in MS medium supplemented with kinetin 10 mg l^{-1}

19a Shoot growth in MS medium supplemented with BAP 5 mg l^{-1} after one month of culture period

19b Shoot growth in MS medium supplemented with BAP 5 mg l^{-1} after two months of culture period

20 *In vitro* rooting in MS medium supplemented with NAA 3 mg l^{-1} and IBA 0 3 mg l^{-1}

CONTENTS

Introduction

INTRODUCTION

The State of Kerala is blessed with such a salubrious climate which makes it possible to grow most of the ornamental plants, especially those which are popularly called as tropical exotics' Still, the floriculture industry is in its infancy in Kerala The commercial production of ornamental plants has been confined largely to orchids and very recently extended to anthuriums There is a need to diversify into other floricultural crops to sustain the floriculture industry in Kerala

In recent times, an increasing demand for all kinds of foliage plants for landscaping institutions and public places, indoor decorations of offices and homes etc is observed Both flowering and foliage plants have become an integral part of our modern concept of everyday life adding fresh beauty and living charm year round Man s impulse moves him toward living with nature and to transplant its greenery and allure indoors With the growing population lack of open space and development of multistoreyed housing systems, people have to depend largely on indoor plants for decorating their surroundings Besides a growing internal market there are considerable possibilities of export of live plants particularly foliage plants from Thiruvananthapuram and Kochi (Swarup 1993)

Kerala could very well be regarded as the Mecca of foliage plants considering the vast number of foliage plants abundantly grown here The demand for foliage plants in cities like Bangalore is met by the supply from Kerala There is a tremendous scope for export of schefflera to other cities as well

Schefflera is an important foliage plant of the genus *Schefflera* Belong ing to the botanical family, Araliaceae, it contains about 40 species of trees and

shrubs which are native to tropical and subtropical areas of Asia and South Sea Islands (Joiner 1981) Several species and their cultivars are grown commercially for use as interiorscape plants Important ornamental species among them are *Schefflera arboricola S actinophylla S angustifolia S venulosa S elliptica* and *S insularum* However *S arboricola* is the most important and commercially exploited species It has variegated and green types with common names Hawaiian Elf and Variegated Elf respectively

Schefflera arboricola is an excellant small to medium size specimen for well lighted end tables, desks, book shelves and used in dish gardens and also in larger pots for focal points in groupings It is also ideal specimen for preparation of bonsai The attractive shape and colour of the foliage have made schefflera an important garden plant Hardiness ease of cultivation suitability to interior conditions freedom from serious pests and diseases contribute much to the popularity of this ornamental shrub in Kerala

Schefflera is propagated from air layers and cuttings Propagation by seeds has also been reported (Joiner 1981) Air layering is a propagation method in which rooting is accomplished while the cutting remains attached to the parent plant Layering is useful for producing a large sized plant in a short time but it is laborious and expensive operation Cuttings are the most important means of propagation and these are used widely in commercial greenhouse propagation It is inexpensive rapid and simple and does not require the special techniques necessary in grafting budding or micropropagation However, development of an effective *in vitro* propagation method will create possibilities for mass multiplication of selected elite genotype avoiding variability caused by generative propagation

Vegetative propagation of *Schefflera arboricola* has not been properly documented. Propagation of foliage plants, including schefflera in Kerala till date has been largely from the guess work of nurserymen. Therefore there is a felt need for standardising propagation techniques for foliage plants like schefflera. The objectives of the present study were

i) to assess the rooting potential of different types of vegetative planting materials

ii) to study the effect of different growth regulators on rooting of stem cuttings and air layers

iii) to standardise a protocol for micropropagation

Review of Literature

2 REVIEW OF LITERATURE

Since literature available on propagation studies in *Schefflera* is meagre similar items of work in other foliage plants and ornamental plants have been reviewed in this chapter

2 1 Propagation through cuttings

2 1 1 Season of collection of cuttings

Season of collection of cuttings has been reported to be one of the key factors affecting rooting of cuttings in many plants Cuttings of jasmine planted during July recorded maximum rooting compared to January April and October (Bryzgalova 1974) Hardwood cuttings of *Ficus nitida* rooted best during March in the first year of study while in the next year rooting was maximum during February (Mohammed *et al* 1975) Nambisan *et al* (1977) observed better rooting in semi hardwood cuttings of oleander (*Nerium indicum*) when planted during July August During this period the number of roots and length of roots produced were also high

Cuttings of *Ixora banduca* recorded highest rooting during October and poorest in January regardless of the treatments with IBA IAA or NAA (Singh 1980) Singh and Motilal (1982) reported that in *Callistemon lanceolatus* highest rooting (95%) of softwood cuttings was observed during July while the semi hard wood cuttings rooted best (85%) during September In both the types of cuttings rooting was poor (60%) during February The seasonal influence on root production in cuttings with IBA and NAA treatment was illustrated by Archibald (1985) in bougainvillea The number of roots produced in all the treatments and varieties were more during rainy season than during summer season

2 1 2 Effect of growth regulators on rooting of cuttings

2 1 2 1 Treatment with growth regulators

Use of growth promoting substances on foliage plants has not been investigated thoroughly but such materials are used in the industry Most foliage plants root easily and for such plants, addition of auxins generally retard rooting So growth regulators should not be used before careful testing using proper concentrations at different seasons The auxins most commonly used and that have proved most successful are indole acetic acid (IAA) indole butyric acid (IBA and naphthalene acetic acid (NAA) Besides these auxins like 2 4 dichorophenoxy acetic acid (2,4 D) and various commercial preparations like Rootone Hormodin and Seradix are also used to a lesser extent

According to Shanmugavelu (1960) NAA was better than indole compounds in producing copious stouter thicker and longer root in hibiscus El Hakim *et al* (1962) found that IBA and NAA were more effective than IAA to induce rooting in *Phyllanthus*

Rooting hormones have been shown to improve root grade of some foliage plants IBA at 3000 mg l^{-1} improved root index of *Dracaena marginata* (Stevens 1976) Poole *et al* (1980) reported that in *Aphelandra* cv Dania *Dieffenbachia* cv Exotica *Ficus benjamina* *Polyscias balfouriana* and *Syngonium podophyllum*, application of commercial rooting powder (Hormodin 2) containing 0 3 per cent IBA had beneficial effect on rooting

In *Ficus elastica* the highest rooting percentage number of primary roots per cutting the maximum length of the largest primary root and best survival rate

transplanting were obtained with IBA at 4000 mg l^{-1} (Kumar 1982) Kamel and Nada (1986a) reported that in *Dieffenbachia picta* IAA at 500 and 1000 mg l^{-1} would improve rooting In *Dracaena bruantii*, they found that rooting was highest in single node cuttings treated with either IAA or IBA at 500 mg l^{-1} (Kamel and N da 1986b)

Jayasankar *et al* (1990) found that in the case of *Ficus infectoria* when the cuttings were placed under intermittent mist best rooting was obtained with NAA at 1000 mg l^{-1} and in a fibre glasshouse best result was obtained with IBA at 10 mg l^{-1} *Dracaena fragrans* cv Massangeana *D deremensis* cultivars Warneckii and Janet Craig *D marginata* and *Gardenia jasminoides* cuttings immersed in hot water (49°C) followed by a basal application of 0 8 per cent IBA had greater root length and weight In addition to enhancing rooting hot water + IBA also increased the number of shoots per cutting in *Anthurium andraeanum* cv Porcelain *D marginata* *D fragrans* *Plumeria* and *Cordyline terminalis* cv Tricolor cuttings (Hata *et al* 1994)

2 1 2 2 Method of application of growth regulators

Leafy cuttings of *Saintpaulia ionantha* were treated with 1 to 1000 mg l^{-1} solutions of IBA for 1 to 24 hours by Woszszynska and Borys (1976) for induction of rooting and they found that the effect of IBA increased with the concentration and maximum beneficial effect was obtained with 1000 g l^{-1} solution when the cuttings were soaked for 15 to 24 hours Kwack and Chung (1980) also obtained similar results in ornamental plants like coleus and hydrangea They also observed that prolonged dip for 24 hours was more effective than quick dip or powder treatment In bougainvillea Arshabi (1985) found that cuttings

basal ends of the cuttings in dilute solutions of IBA and NAA (100 300 and 500 mg l^{-1}) was more effective in producing more number of roots than quick dip in concentrated solution Whereas, in hibiscus Verghese (1984) reported that quick dip method was significantly superior to prolonged dip method with regard to rooting percentage

2 1 3 Environmental considerations

2 1 3 1 Propagation media

The propagation medium selected should be easily obtainable uniform and available in quantity so that plant propagators can use the same material repeatedly (Poole 1969)

The rooting media generally recommended are sand peat moss and water (Zimmerman, 1930, Smith 1944) Peat is a satisfactory medium for propaga tion of most foliage plants Vermiculite and sphagnum moss also have been found to be successful media in many plant species (Chadwick 1949 Creech *et al* 1955) *Philodendron scandens oxycardium* and golden pothos grown in German peat produced longer vines than cuttings placed in calcined clay (Poole 1969)

According to Higaki (1981) single node cuttings of *Dracaena goldieana* rooted equally well in peat moss, perlite, black cinder or vermiculite under intermittent mist condition Kamel and Nada (1986a and 1986b) observed that rooting of *Dieffenbachia picta* and *Dracaena bruantii* single node whole cuttings was highest in sand Rooting of *Ficus elastica* cuttings was best in peat moss or in 1 1 mixture (v/v) of peat moss and sand (Sultan *et al* 1990) Siraj Ahmad Abbasi (1993) reported that the best rooting response of *Schefflera actinophylla* and *Ficus*

benjamina was obtained in 50 per cent peat moss + 50 per cent sand and 75 per cent peat moss + 25 per cent sand, respectively

2 1 3 2 Light intensity

Rauch (1981) reported that *Schefflera arboricola* rooted best (96% rooting) in 72 per cent shade Whereas increasing the shading from 0 to 72 per cent had no effect on rooting in cuttings of *Cordyline terminalis* cv Nanus Beauty and in *Epipremnum aureum* cv Marble Queen

2 1 3 3 Water

Mist systems provide the best method of maintaining high water relation ships with in cuttings during rooting Kumsaki and Sagiwa (1971) studied the effect of intermittent mist on rooting of anthurium cuttings They found that the rooting percentage and average root length were much higher under mist A common mist cycle used in the foliage industry is 15 seconds of mist/30 minutes although 12 seconds/6 minutes has been shown best for *Dracaena* spp (Rauch 1976) He later on (1981) observed that *Schefflera arboricola* rooted best (96% rooting) with 24 seconds misting/6 minutes

2 1 3 4 Temperature

Day air temperatures of 25° to 35°C and night temperatures of 22 C are within the best range for propagation of most foliage plants A soil temperature of 25°C would enhance rooting in *Dieffenbachia picta* Cordyline cv Baby Doll and *Peperomia obtusifolia* whereas in *Rhaphidophora* cv Pothos and *Philodendron scandens oxycardium* that of 30°C accelerated rooting (Poole and Waters 1971)

Borowski *et al* (1987) reported that increasing the air temperature from 15 to 21°C accelerated rooting and increased the number of roots per cutting in chrysanthemum cv Horim and rose cv Garnette High temperatures in the rooting medium had a beneficial effect on the rate of rooting but did not enhance the number of roots formed

2 1 4 Effect of type of cuttings on rooting

Singh and Motilal (1979) obtained best rooting and highest survival with softwood cuttings of bougainvillea cv 'Thimma' compared to semihardwood cuttings

Leaf bud cuttings are particularly useful when propagating material is scarce because they will produce at least twice as many new plants from the same amount of stock material as can be started by stem cuttings Hansen (1986a) reported that in *S arboricola* cuttings with two or three fully developed leaves rooted much better giving more stronger and longer roots than smaller cuttings with one leaf and their subsequent growth was more vigorous

2 1 5 Effect of cutting position and stem length on rooting of cuttings

The positional differences in root formation in *S arboricola* (Hansen 1986b) are in agreement with the general statement by Hartmann *et al* (1993) that the best rooting of cuttings is usually found in cuttings from the basal portions of a shoot Basal cuttings in *Hedera helix* (Poulsen and Anderson 1980) and *S arboricola* (Hansen 1986b) develop longer shoots and more roots than apical cuttings

Hansen (1986b) reported that in *S arboricola* as stem length of cuttings increased from 0 5 to 3 0 cm percentages of rooting and bud break root number and plant height were increased Similar results were observed in *Prunus serrulata* (Veierskov 1978) *Hedera helix* (Poulsen and Andersen 1980) and *Acer rubrum* (Dirr and Henser 1987) where root number was dependent on the length of internode remaining on the cuttings or on the size of the cuttings In the case of golden pothos the most obvious effect of internode length of cuttings on plant growth was on leaf number and stem length Cuttings with a 3 cm or longer internode below the node produced leaves faster and had longer axillary shoots than those with shorter stems (Wang and Boogher 1988)

2 2 Propagation through air layering

Layering is the development of roots at the base of a shoot while it is still attached to the parent plant Major benefit of the technique includes the large plant size cuttings which can be rooted with a minimum of reduction in leaf area

2 2 1 Effect of season on air layers

Root formation during layering is influenced to a great extent by season In *Cassia javanica* Tewari and Pathak (1984) observed that the air layers rooted well in July to August when treated with Seradix B in lanolin paste Air layering was done in *Butea monosperma* during March, April May July and August Root initiation was observed after 30 days in the May, July and August treatments only with most rooting occurring in the May treatment (Kumar 1989)

Vegetative propagation of *Acacia auriculiformis* by air layering was found profoundly affected by season Rooting in the rainy season was more than 80 per cent while in the dry season rooting was only 10 per cent (Simsiri 1991) Sreelatha *et al* (1991) reported that in *Jasminum auriculatum* rooting was mainly confined to the layers which was done during the rainy season (June September)

2 2 2 Effect of growth regulators on rooting of layers

Application of root inducing substances in layering was found to be beneficial in various species of ornamentals although the method of application was different (Ching *et al* , 1956) They stated that application of the rooting substance to girdled cuts as a powder in lanolin or as a solution in 50 per cent alcohol produced successful layers in various species of ornamentals

In hollyhock (*Althea rosea*) IBA and NAA each at a concentration of 400 mg l^{-1} were found better in inducing roots in air layers compared to even higher concentrations of 2000 and 3000 mg l^{-1} (Lingaraj 1960) Rani *et al* (1969) reported that among the different growth substances tried in air layering of crossandra, Rootone was found to be the best for producing maximum number and length of roots A higher concentration of IBA (5000 mg l^{-1}) was reported to be the best in rooting of air layers in *Michelia champaka* (Venkatarayappa *et al* 1978 Channaveerappa and Gowda, 1984)

A lower concentration of IBA or NAA was reported to be the best in rooting of air layers in *Gardenia jasminoides* (Mitra *et al* 1980) They ringed uniform vigorous terminal shoots of 1 cm in diameter and treated with IBA or NAA each at 50 to 150 mg l^{-1} in lanolin paste and obtained 100 per cent rooting, whereas rooting was only 55 per cent in control even after 25th day of layering Mitra and

Majundar (1983) conducted vegetative propagation studies in *Peltophorum ferrugineum* *Bauhuria* sp and *Poinciana regia* The experiment was carried out to evaluate the effective concentrations of IBA IBA + IAA and IBA + IAA + NAA on rooting of air layers From the studies they concluded that IBA IAA and NAA at 6000 mg l^{-1} proved to be the best for rooting of *Peltophorum* air layers Mixture of IBA + IAA at 4000 mg l^{-1} was the best for air layers of *Poinciana regia*

2 2 3 Effect of wounding method on rooting of air layers

Another important factor in the layering process is the type of cut that is made on the parent plant Two common methods are removal of a 2 cm wide ring of bark and cutting one or more upward slanting slits into the bark and xylem Rooting was best in double slit *Ficus elastica*, but girdling produced a greater number of roots in *F benjamina* *S arboricola* and *Dracaena marginata* Girdling *D marginata* stems induced coarse unbranched roots while a finer more fibrous root system was produced on double slit plants (Broschat and Donselman 1983)

2 2 4 Effect of propagation media on the rooting of layers

The quality of the rooting medium, especially texture porosity and water holding capacity greatly influences the extent of rooting (Hartmann *et al* 1983) The rooting medium must provide sufficient moisture and aeration and must be pathogen free

Virupaksha (1961) tried the effect of different rooting media on air layering in hibiscus He compared vermiculite, leaf mould compost leaf mould plus farm yard manure and farm yard manure with earth and sand as rooting media He concluded that the quickest rooting of air layers took place in compost as rooting

medium Grappelli *et al* (1985) reported about the rooting experiments on layers of *Ficus elastica Dieffenbachia amoena Cordyline terminalis* and *Dracaena deremensis* by employing earthworm castings Layers rooted better when casting alone was used as rooting medium

2 3 *In vitro* propagation

Plant tissue culture is the aseptic culture of plant tissue such as proto plasts cells meristems shoot tips embryos, ovules roots or stem and leaf sections in a vessel containing a microbe free nutrient medium under environmental condi tions suitable for plant development (Joiner, 1981) Culture of isolated plant cells was attempted as early as in 1902 by Haberlandt Micropropagation is a popular and expanding area for commercial production, because it allows rapid production of genetically identical plant material and facilitates the production of disease free plants (Buddendorf Joosten and Woltering, 1994)

Literature on micropropagation aspect of schefflera has been scanty Sc reports on micropropagation of other ornamental plants are also reviewed here under

2 3 1 Routes of *in vitro* propagation

According to Murashige (1977) there are three possible routes available for *in vitro* propagule multiplication, namely

a) Enhanced release of axillary buds

b) Production of adventitious shoots through (somatic) organogenesis

c) Somatic embryogenesis

2 3 1 1 Enhanced release of axillary buds

The enhanced axillary branching method of shoot multiplication may be initially slower than the other two methods but with each passage the number of shoots increases logarithmically and within a year astronomical figures can be arrived at (Bhojwani and Razdan 1983) Morel (1960) reported the application of shoot apex culture for rapid clonal multiplication of plants for the first time The greatest success using this technique has been achieved in herbaceous horticultural plants The success may be due to the weak apical dominance and strong root regenerating capacity of the herbaceous plants (Hu and Wang 1983)

2 3 1 2 Somatic organogenesis

Somatic organogenesis may be direct or callus mediated (Evans *et al* 1981) In general the most desirable method of multiplication would be adventitious organogenesis because it enables a substantially faster increase in propagules (Debergh and Maene 1981) There are several drawbacks in callus mediated organogenesis which should be avoided in clonal propagation of a cultivar The most serious objection against the use of callus cultures for shoot multiplication is the genetic instability of their cells (Bhojwani and Razdan 1983) Another disadvantage is that, though callus may be obtained from virtually any species only in a few cases the plants be regenerated The reason for this inability may be due to the high proportion of polyploid or aneuploid cells in those callus (Smith and Street 1974)

2 3 1 3 Somatic embryogenesis

In vitro embryogenesis from somatic cells presents several advantages and limitations Its synchronized stages and bipolar structures are more amenable to

fundamental study and practical purposes due to low labour requirement at least in its early stages Somatic embryogenesis is the most common expression of tissue culture of monocotyledenous species The first case of somatic embryogenesis was reported by Reinert (1959) on a dicotyledenous species after initiating cell division from carrot tissues by 2,4 D giving rise to callus cells which evolved into somatic embryos when transferred to a medium free of 2 4 D There are two types of somatic embryogenesis as described by Sharp *et al* (1980) The first in which embryos are formed directly from the explant without the callus formation and the second where it requires formation of callus on which the embryos are formed

2 3 2 Callus mediated organogenesis

Callus is an undifferentiated and unorganised mass of parenchymatous cells formed from a wound Evidence for the morphogenetic activity in callus cultures of many plant species was reported by several workers (Rao *et al* 1976 Bott 1980 Sutter and Laghans 1981 Kumari and Saradhi 1992)

2 3 3 *In vitro* shoot multiplication

Regeneration of shoots can be either directly from the explant or through callus mediated process As far as clonal multiplication is the aim the former is the most efficient and rapid method of *in vitro* regeneration (Hussey 1978)

2 3 4 Factors influencing induction of morphogenesis

The successful induction of morphogenesis in plant cells and tissue cultures has been found to be influenced by several factors such as explant media and its components and culture conditions (Murashige 1974 Hughes 1981)

2 3 4 1 Explant

An explant is a piece of tissue or organ which is excised from the plant for the purpose of culture The success in culturing the explant is influenced by number of factors inherant to the explant such as source of explant its size and physiological age (Hughes 1981)

The plant tissues differ in their degree of determination and their ability to undergo morphogenesis Kobza and Vachunova (1991) reported that in the case of *Dracaena concina* stem explants with a dormant bud were suitable for *in vitro* propagation whereas leaf explants were not suitable From the different kinds of explant (stem leaf and petiole) tested Debergh and Wael (1977) observed that the leaf fragments containing rib material were the best suited explant material for mass propagation of *Ficus lyrata* Kukulczanka *et al* (1977) reported that in regeneration of *Peperomia scandens* the main regeneration zone comprises the leaf blade basis and the petiole Pindel and Pindel (1992) found that in asparagus fern the most promising explant materials were the shoot apices and sections of shoot with a node

As a rule larger the size of explant the more rapid the growth and the greater are the rates of survival (Hussey 1983) If the explant size is small the cut surface volume ratio is high and there will be difficulty in the survival of the explant But in meristem culture for virus elimination explants of length 0 1 0 5 mm are used (Hussey 1978)

In English ivy Banks *et al* (1979) found that embryos juvenile stems and embryo organs had a high regenerative capacity and they concluded that culture

of the youngest and less differentiated tissues was successful in a wide range of species

2 3 4 1 1 Surface sterilization

The objective of surface sterilization is to remove all the microorganisms present on the explant with minimum damage to the plant tissue To check bacterial and fungal contamination antibiotics and fungicides respectively are used either surface sterilant or medium additive

The most commonly used surface sterilant is an aqueous solution of sodium hypochlorite This being toxic to plant cells it is necessary to wash the treated tissue twice or thrice with sterile water (Hu and Wang 1983) Concentrations ranging from 1 0 per cent (Minocha 1980) to 10 0 per cent (Kuo and Lin 1977) have been reported for various plant species

Ethanol and mercuric chloride are the other popular surface sterilant According to Marotti and Levi (1977) it was better to rinse first with ethanol (45°c) for three minutes followed by a 10 minutes bleach treatment (5 0 to 10 0%) and finally three rinses with sterile water Alcohol alone has also been used for surface sterilization (Bonga 1982) Lakshmi Sita et al (1986) used 0 1 per cent mercuric chloride for 10 to 12 minutes for sterilization of seedling explants of *Dalbergia latifolia* Mercuric chloride 0 10 to 0 15 per cent gave better sterilization of explants than sodium hypochlorite and absolute alcohol Reghunath (1989) and Dev (1992) reported the use of mercuric chloride 0 1 per cent for better surface sterilization of cardamom and *Dendrobium* respectively

2 3 4 2 Culture medium

2 3 4 2 1 Basal medium

A wide variety of plant tissue and cell culture media have been reported The earliest and widely used basal media were White's (1943) and Heller (1953) media Since 1960 however most researchers have been using MS (Murashige and Skoog 1962) Gamborg's (Gamborg *et al* 1968) or SH (Schenk and Hildebrandt 1972) media But after 1980 the most popular media are DCR (Gupta and Durzan 1985) and WPM (Lloyd and McCown 1980) especially for woody species The MS salt composition is used very widely particularly if the desired objective is plant regeneration Another medium designated as N_6 (Chu 1978) was developed for cereal anther culture and is being recognised as a suitable medium for tissue culture of cereal crops

2 3 4 2 2 Growth regulators

The general concept given by Skoog and Miller (1957) is that organ differentiation in plants is regulated by an interplay of two groups of hormones auxins and cytokinins A higher cytokinin to auxin ratio promotes shoot formation and a higher auxin to cytokinin ratio favours root differentiation But no universal ratio of auxin and cytokinin has so far been developed for root or shoot induction The exogenous requirements for the hormone depend on the endogenous levels in the plant system which is variable with the tissue explant type and the phase of plant growth (Bhojwani and Razdan 1983)

Hempel (1979) opined that in majority of the cases callus growth was best on auxin and cytokinin containing medium though some bulbous plant like lilium and hyacinth regenerated *in vitro* without the presence of any phytohormones He further noticed that considerable variability existed between taxa and genotype in the optimum requirement of phytohormones for morphogenesis Hasegawa (1980) reported that high concentration of auxin may not only inhibit axillary bud proliferation but also induce callus formation In callus mediated organogenesis of *Dracaena fragrans* shoot elongation and rooting were strongly inhibited by BAP and stimulated by auxins IBA and NAA (Vinterhalter 1989)

For axillary shoot proliferation cytokinin has been utilised to overcome the apical dominance of shoot and to enhance the branching of lateral buds from leaf axils (Murashige 1974) Badzian *et al* (1989) reported that benzyl adenine amenable cytokinin to *Brassaia actinophylla* cv Amate multiplication via tissue culture using shoot explants as a start plant material Al Juboory *et al* (1991) reported about the influence of growth regulators on root and shoot development of micropropagated Algerian Ivy There was a significant naphthalene acetic acid x thidiazuron interaction for shoot count Multiple shoots did not form without NAA and TDZ in the medium There was also a significant NAA x TDZ interaction for the ability to induce ivy rooting *in vitro* NAA was necessary for root development without NAA there was no root formation

2 3 4 2 3 Carbon and energy sources

The most commonly used carbon source is sucrose at a concentration of 2 5 per cent Glucose and fructose are also known to support good growth of some tissues (Bhojwani and Razdan 1983) In general excised dicotyledonous roots grow

best with sucrose whereas those of monocots do best with glucose Some other forms of carbon that plant tissues are known to utilize include maltose galactose inositol and lactose (Gautheret 1959)

2 3 4 2 4 Vitamins

Most cultured plant cells are capable of synthesizing all essential vitamins but apparently in sub optimal quantities (Czosnowski 1952 Paris 1955 1958) To achieve the best growth of the tissue it is often essential to supplement the medium with one or more vitamins Of these thiamine has generally proved to be an essential ingredient and usually added in plant tissue culture media at levels of 0 1 mg l^{-1} to 1 0 mg l^{-1} Other vitamins especially pyridoxine nicotinic acid calcium pantothenate and inositol are also known to improve the growth of cultured plant materials (Bhojwani and Razdan 1983)

2 3 4 2 5 Other organic compounds

Numerous complex nutritive mixtures of undefined composition like casein hydrolysate coconut milk corn milk malt extract tomato juice and yeast extract have been used to promote the growth of certain calli and organs

In a preliminary study Al Khayri *et al* (1992) has shown that the addition of 15 per cent (v/v) coconut water to the culture medium significantly improved callus growth shoot regenerative capacity and shoot growth in leaf disc cultures of spinach

The addition of activated charcoal to the culture media may have beneficial effect Makino *et al* (1977) had found adding activated charcoal to the

beneficial to rooting of *Ficus benjamina* In the case of *in vitro* propagation of *Philodendron tuxtlanum* the rooting medium was supplemented with activated carbon (Jambor Benczur and Marta Riffer 1990)

However the use of these natural extracts should be avoided as far as possible Different samples of these substances especially the fruit extracts may affect the reproducibility of results because the quality and quantity of the growth promoting constituents in these extracts often vary with the age of the tissue and the variety of the donor organism Moreover it should be possible to effectively replace these substances by a single aminoacid For example for maize endosperm callus Straus (1960) could substitute yeast extract and tomato juice by l sprmgine alone

2 3 4 3 Culture conditions

The culture conditions play an important role in the success of tissue culture The physical form of medium pH light temperature and relative humidity are important in growth and differentiation

Light requirement for differentiation involves a combination of several components namely intensity quality and duration High light intensity has been shown to be inhibitory for shoot bud formation in tobacco (Skoog 1944 Thorpe and Murashige 1970) Optimum light intensity for shoot multiplication in Gerbera and many other herbaceous species was reported by Murashige (1974) to be 1000 lux 300 lux being adequate intensities at 3000 lux or more were strongly inhibitory In low light intensities the shoots are greener and taller (Murashige 1977) For some plants high light intensity from the beginning of elongation stage

is not advised On *Dracaena* spp and *Cordyline* spp for example it induces bud clumps comparable to apical dominance one bud of the cluster elongates and suppresses the development of the other buds This can be avoided by giving a few weeks of low light intensity until the buds start to elongate followed by higher light intensity (Debergh and Maene 1981) Callus of *Pelargonium hortorum* differentiates shoots only under alternating light and dark periods (15 16 h day proved best) Callus maintained under continuous light remains whitish and does not exhibit organogenesis (Pillai 1968) The quality of light also influences organogenic differentiation (Weis and Jaffe 1969) Blue light promotes shoot bud differentiation whereas red light stimulates rooting in tobacco (Letouze and Beauchesne 1969)

Skoog (1944) studied the effect of a range of temperature (5 33 C) on tobacco callus growth and differentiation Growth of the callus increased with rise in temperature up to 33°C but for shoot bud differentiation 18 C was optimum and no bud formation occurred at 33°C However most tissue cultures are grown successfully at temperature around 25 ± 2°C Schneider Moldricky and Heim (1984) reported that in *in vitro* propagation of *Kalanchoe blossfeldiana* the minimum temperature for shoot regeneration was 18°C with the optimum at 24 C

Relative humidity is rarely a problem except in arid climates where rapid drying occurs Hu and Wang (1983) reported that air humidity is infrequently controlled and when it is controlled, 70 per cent has been found to be the most frequent setting

2 3 5 *In vitro* rooting

Adventitious and axillary shoots developed in cultures in the presence of

a cytokinin generally lack roots To obtain full plants the shoots must be transferred to a rooting medium which is different from the shoot multiplication medium especially in its growth regulator composition

Generally auxin favours rhizogenesis Among the auxins NAA has been the most effective one for induction of rooting (Ancora *et al* 1981) Mee (1978) observed that in *Cordyline terminalis* no roots were induced by 2 4 D whereas addition of NAA improved root growth Pierik and Sprenkels (1984) reported that in gerbera IAA had little effect on rooting but with NAA 100 per cent rooting was obtained Whereas in some other cases rooting was influenced by IAA In *Ficus benjamina* the frequencies of rhizogenesis and root production were higher with IAA than with NAA (del Amo Marco and Picazo 1994) Sometimes a combination of growth regulators are used for rooting in cultures Podwyszynski (1992) reported that in *Aglaonema* sp the best quality of roots was found with IBA in combination with IAA Occasionally as in gladiolus (Hussey 1977 Hussain 1995) and Narcissus (Seabrook *et al* 1976) shoots are readily rooted on a hormone free medium

A low salt medium is found satisfactory for rooting of shoots in a large number of plant species Often where shoot multiplication was induced on full strength MS medium the salt concentration was reduced to half (Gurland and Stoltz 1981 Zimmerman and Broome 1981) or a quarter (Skirvin and Chu 1979) for rooting

In *Chamaelaucium uncinatum* the best rooting occurred on half strength MS medium (Damiano *et al* 1986) and also in *Monotagma smaragdum* best rooting took place on half strength MS medium (Mo *et al* 1990)

2 3 6 Acclimatization and planting out

Acclimatization is one of the important phases of micropropagated plants The success in acclimatization depends upon not only post transfer conditions but also the pre transfer culture conditions (Ziv 1986)

Hu and Wang (1983) suggested a period of humidity acclimatization for the newly transferred plantlets to make them adapted to the external environment In the case of micropropagation of rose, Bhat (1992) reported that plantlets were acclimatized by incubating them initially at 70 80 per cent RH for 7 days and then at 50 per cent RH for 3 days before planting in vermiculite Del Amo and Pinto (1992) reported that in *Ficus benjamina* the rooted plants were transferred to pots covered with plastic bags for 6 weeks and then moved to the green house

Material and Methods

3 MATERIALS AND METHODS

The present study Standardisation of propagation techniques in *Schefflera arboricola* was carried out in the Department of Pomology and Floriculture College of Horticulture Kerala Agricultural University Vellanikkara Thrissur during the period 1994 to 1996 The materials used and methodology adopted for the study are described in this chapter

Plant material

Schefflera is an important foliage plant of the genus *Heptapleurum* which was known earlier by the generic name *Brassaia* This genus consists of about forty species of trees and shrubs Among this *S arboricola* has greater ornamental value But it has not obtained popularity and has not been studied well So *S arboricola* was picked up for the present study Both variegated and green types of schefflera (Plates 1a and 1b) were used for the study

S arboricola is a subtropical freely branching plant of dwarf habit It has flexible wiry stems which become scandent with age The glossy green palmate foliage is arranged in a circle of seven to eight soft leathery leaflets It is very charming in appearance and has good decorative value

Macropropagation studies

3 1 Propagation studies through cuttings

3 1 1 Effect of types of cuttings on rooting

Herbaceous single noded cuttings having a length of 10 25 cm and double noded cuttings having a length of 20 50 cm were used for the study Shoots

Plate 1a *Schefflera arboricola* (Variegated) grown in pot

Plate 1b *Schefflera arboricola* (Green) grown in pot

with leaves intact were used Cuttings were prepared in such a way that a flat cut on the top and a slanting cut at the base of the node were made

3 1 2 Effect of growth regulators on rooting of cuttings

The following different concentrations of indole acetic acid (IAA) indole butyric acid (IBA) and naphthalene acetic acid (NAA) were tried to study the effect of growth regulators on rooting of stem cuttings Eight cuttings each from variegated and green type of schefflera were treated with IAA IBA or NAA using two methods namely prolonged dip and quick dip method As per previous reports (Hartmann *et al* 1993) lower concentrations were used for prolonged dip and higher concentrations for quick dip method For prolonged dip the basal portion of the cuttings were soaked for a period of six hours and for quick dip they were dipped for five seconds The untreated cuttings (control) were dipped in distilled water for the respective periods for prolonged dip and quick dip methods Details of the treatments are given below

Growth regulators and their concentrations tried for rooting of cuttings

Method of application	Growth regulators		
	IAA mg l^{-1}	IBA mg l^{-1}	NAA mg l^{-1}
Prolonged dip	50	50	50
	100	100	100
	200	200	200
Quick dip	500	500	500
	1000	1000	1000
	2000	2000	2000

Preparation of growth regulators

Chemically pure crystalline salts of IBA IAA and NAA were used for the preparation of growth regulator solutions The growth regulators were first dissolved in minimum quantity of 0 1N NaOH solution and then slowly adding distilled water the volume was made up to half litre Treatment solutions of the required concentrations were prepared from the stock solution by proper dilution with distilled water These solutions were used within two days of preparation and kept in refrigerator whenever not in use

Preparation of potting mix

A rooting medium consisting of one part of soil two parts of sand and one part of well rotten powdered cattle manure was prepared by thorough mixing of the above ingredients

Planting of the cuttings

The cuttings were planted in pots filled with the potting mix immediately after treatment with the growth regulators A layer of sand was evenly spread on the surface of the potting mix The pots were kept inside a mist chamber with a misting frequency of 2 minutes/15 minutes

Observations recorded

The following observations were recorded

1 Number of days taken for rooting

2 Number of roots per cutting

3 Length of the longest root

4 Average length of roots

5 Number of new leaves

6 Fresh weight of roots

7 Dry weight of roots

8 Percentage success

The design of the experiment was a two factor complete randomized design There were forty treatment combinations involving two factors namely type of cuttings and growth regulators Eight cuttings were used under each treatment and five cuttings were taken for recording observations

3 2 Propagation studies through air layering

The experiment was carried out at the Department of Pomology and Floriculture College of Horticulture Vellanikkara and also at the Agricultural Research Station Mannuthy

3 2 1 Effect of the methods of wounding on rooting of layers

Air layering was done by removing a ring of bark with 2 0 cm from around the stem In addition to this slanting slit method was also tried In the method a slanting upward cut was made on both sides of the stem about 2 5 cm long keeping the two surfaces apart by a piece of wood

3 2 2 Effect of growth regulators on rooting of layers

Three growth regulators viz IBA IAA and NAA

concentration of 50 100 and 200 mg l^{-1} were tried for the study The details of the treatments are given below

T_0	Control
T_1	IBA 50 mg l^{-1}
T_2	IBA 100 mg l^{-1}
T_3	IBA 200 mg l^{-1}
T_4	NAA 50 mg l^{-1}
T_5	NAA 100 mg l^{-1}
T_6	NAA 200 mg l^{-1}
T_7	IAA 50 mg l^{-1}
T_8	IAA 100 mg l^{-1}
T_9	IAA 200 mg l^{-1}

Preparation of growth regulators

For each treatment the required quantity of growth regulators was weighed separately and dissolved in few ml of alcohol and then mixed thoroughly with petroleum jelly

3 2 3 Effect of rooting medium on rooting of layers

Layering was done by using sphagnum moss coconut fibre and sawdust Rooting medium with sawdust was made by mixing sawdust with sand in the proportion of 3 1

Layering operation

Six to eight months old young potted plants with [illegible] 20

3 5 cm were used for air layering Air layering was done either by using girdling or by slanting slit method and the wound was made at a distance of 15 20 cm from the tip of the plant The growth regulators in petroleum jelly was applied to the upper part of the wounded portions The rooting medium was taken in polythene sheet of 250 guage and was wrapped around the wounded portion and the two ends were carefully tied using a gunny thread

Observations recorded

The following observations were recorded

1 Number of days taken for rooting
2 Number of roots
3 Length of the longest root
4 Average length of roots
5 Fresh weight of roots
6 Dry weight of roots
7 Percentage success

The design of the experiment was a three factor completely randomized design There were sixty treatment combinations involving three factors viz media type of cut and growth regulators Eight layers were done under each treatment and five layers were taken for recording observations

3 3 *In vitro* propagation studies

The *in vitro* propagation studies were carried out in the Tissue Culture Laboratory of the All India Co ordinated Floriculture Improvement Project College of Horticulture Vellamkkara The main aspects of the study consisted of

a) Induction of callus and regeneration

b) Induction of multiple shoots

c) Rooting of *in vitro* regenerated shoots

The details of the study are presented below

3 3 1 Collection of explants

The explants were collected from young plants maintained in the net house attached to Department of Pomology and Floriculture In order to control the microbial contamination the plants were regularly sprayed with a contact fungicide Fytolan at 0 2 per cent concentration at weekly intervals

3 3 2 Source of explant

In the present study leaves formed the explant source for shoot initiation For standardising the age of the leaf explants immature (L_1) young (L_2) and mature (L_3) leaves were used For induction of multiple shoots shoot tips and nodal explants (N_1 to N_6) were used Nodal explant N_1 was positioned just beneath the shoot tip Similarly N_2 N_3 N_4 N_5 and N_6 were positioned just beneath the preceding nodal explants

3 3 3 Surface sterilization of explants

The leaf explants were first washed thoroughly with tap water containing a few drops of surfactant extran followed by rinsing with distilled water

The nodal explants and shoot tips were first washed with tap water containing a few drops of extran and then treated with 0 1 per cent emisan for

10 min Then washed with distilled water blotted and wiped with cotton dipped in 70 per cent alcohol Further sterilization procedures were carried out under the perfect aseptic condition maintained in a laminar air flow cabinet The explants were surface sterilized in beakers using different surface sterilants at various concentrations and duration

For leaf explants 0 1 per cent mercuric chloride was tried for different durations of 5 10 and 15 min and for shoot tips an initial dipping in 50 per cent alcohol for 1 min followed by mercuric chloride treatment for different durations of 10 12 and 14 mm were tried The different sterilants used for nodal explants are given below

Sterilants used their concentration and duration of treatment for *in vitro* culture of nodal explants of *S arboricola*

Surface sterilants	Duration of surface sterilization (minutes)
5% Domestos	5
	10
10% Domestos	5
	10
0 1% mercuric chloride	5
	10
50% alcohol dipping for 1 min + 0 1% mercuric chloride	12
	15
	18

In all the treatments the explants were submerged in the sterilant for required period with frequent agitation After surface sterilization the culture drained off and the explants were washed four times using sterile water

3 3 4 Culture media

MS medium (Murashige and Skoog 1962) and Woody Plant Medium (WPM) (Lloyd and McCown 1980) were used for the study The composition of different basal media tried are given in Appendix V

3 3 4 1 Medium preparation

The various chemicals used for preparation of medium were of analytical grade from SISCO Research Laboratories (SRL) British Drug House (BDH) Merck and Sigma Standard procedures (Gamborg and Shyluk 1981) were followed for the preparation of the medium Stock solutions of major and micronutrients were prepared first and were stored under refrigerated condition in labeled bottles The growth regulators and vitamin stocks were prepared separately and the fresh stocks were prepared at six week interval

An aliquot of different stock solutions was pipetted out into a clean vessel which was rinsed with distilled water Sucrose and inositol were added first and dissolved Required quantities of growth regulators were also added and the solution was made up to the required volume The pH of the solution was adjusted between 5 5 and 5 8 using 1N NaOH or HCl Agar was then added to the medium and stirred thoroughly

The solutions were then melted by keeping [illegible] at a temperature of 90-95 C until the medium became clear. After the addition of the medium was poured hot to oven sterilized culture tubes which were previously rinsed twice with distilled water. The containers with the medium were then tightly plugged with non absorbant cotton wool plugs. Borosilicate test tubes of size 15.0 x 2.5 cm and 10.0 x 2.5 cm were used as the containers.

The medium was autoclaved by applying 15 psi pressure for 20 min. After sterilization the culture tubes were stored in an air conditioned culture room for further use.

3.3.5 Inoculation process

Inoculation was carried out under strict aseptic condition in a laminar air flow cabinet. Sterilized forceps, petridishes, surgical blades and [illegible] were used.

In the case of leaf explants after the surface sterilization [illegible] about one cm^2 size were separated from the intact leaves and cultured.

Shoot tips having the size of 2-5 mm were used for [illegible]. To prepare the nodal explants for inoculation 0.5-1.0 cm long immature shoot pieces containing an intact axillary bud was excised using a sterile knife and [illegible] to the medium.

3.3.6 Culture conditions

The cultures were incubated in a culture room provided with [illegible]

lamps to give a light intensity of 3 000 lux for 16 hours light period The cultures for the initiation of callus were kept under dark The temperature was maintained at 27 ± 2 C

3 3 7 Callus mediated organogenesis

Callus formation was studied using immature young and mature leaf explants on different media supplemented with auxins (2 4 D and NAA) and cytokinin (BAP) Coconut water was used as medium supplement to improve the callus growth Treatments tried are given below

1) Basal MS medium
2) MS with 2 4 D at five levels 0 25 0 5 1 0 2 0 and 4 0 mg l^{-1}
3) MS with 2 4 D at 1 mgl^{-1} with coconut water at 3 levels 10 15 and 20 per cent
4) MS with NAA at 9 levels 1 2 4 6, 8 10 12 14 and 16 mg l^{-1}
5) MS with 2 4 D at 1 0 mg l^{-1} with BAP at 3 levels 0 5 0 75 and 1 0 mg l^{-1}

The leaf pieces were grown on the medium supplemented with the growth regulators for a period of one month and the following observations were recorded

Observations

1 Survival percentage of explants
2 Number of days for initiation of callus
3 Number and percentage of cultures exhibiting callus initiation

3 3 7 1 Organogenesis

Trial was conducted to obtain regeneration from callus tissue by transferring them on to

1) MS with BAP at 4 levels viz 3 5 5 0 10 0 and 15 0 mg l^{-1}
2) MS with BAP at 15 mg l^{-1} and adenine sulphate at 3 levels (0 80 and 100) mg l^{-1}
3) MS with kinetin at 3 levels 6 8 and 10 mg l^{-1}

Callus regeneration was not obtained by using the above treatment combinations and hence the following different media manipulations were performed

1) MS with silver nitrate at 5 levels 2 4 6 8 and 10 mg l^{-1} Then incubate the culture for different periods like 2 3 and 4 weeks After that transferred it to basal medium and also to the medium with BAP at 3 5 mg l^{-1}

2) Liquid medium was also tried for the regeneration of callus MS with BAP at 2 levels 5 and 10 mg l^{-1}

3) Another trial was done by increasing the nitrogen source in the MS stock 1 to 1 1/4th and 1 1/2 times along with BAP at 2 levels 5 and 10 mg l^{-1}

4) A pulsing treatment with stock solutions of BAP was also given to the callus For this stock solutions of BAP at different levels like 12 5 25 0 50 0 and 200 0 mg l^{-1} were made and the callus placed in it and kept on in orbital horizontal shaker for different periods like half an hour one hour and one night After pulsing treatment the callus was transferred to the medium with BAP at 3 5 mg l^{-1}

3 3 8 3 *In vitro* rooting

The *in vitro* developed shoots were transferred to the media supplemented with auxins like NAA and IBA The treatments tried are given below

1 MS + IBA at 3 levels 0 3 0 5 and 0 7 mg l^{-1}
2 MS + NAA at 1 0 mg l^{-1} + IBA at 0 3 mg l^{-1}
3 MS + NAA at 2 0 mg l^{-1} + IBA at 0 3 mg l^{-1}
4 MS + NAA at 3 0 mg l^{-1} + IBA at 0 3 mg l^{-1}
5 MS + NAA at 4 0 mg l^{-1} + IBA at 0 3 mg l^{-1}

Observations recorded

1 Number of days taken for initiation of root
2 Number of roots
3 Root length

Results

4 RESULTS

The results of the study on Standardisation of propagation techniques in *Schefflera arboricola* are sequentially presented below

4 1 Cuttings (Variegated)

Effect of growth regulators and the type of cuttings on number of days taken for rooting number of roots length of the longest root total length of roots average length of roots fresh and dry weight of roots are given below

4 1 1 Number of days taken for rooting

Main effect of growth regulators and type of cuttings were significant The data presented in Table 1 showed that IBA at 1000 and 2000 mg l^{-1} were significantly superior to other treatments except IBA at 50 200 and 500 mg l^{-1} and NAA at 50 500 and 2000 mg l^{-1} (Fig 1) Double noded cuttings on an average rooted earlier compared to single noded cuttings

Interaction effect of growth regulators x type of cuttings was also significant From the interaction effect it was clear that single noded cuttings treated with IBA at 200 and 2000 mg l^{-1} were significantly superior to most of the treatments except IBA at 100 and 1000 mg l^{-1} and NAA at 50 500 and 2000 mg l^{-1} Whereas in the case of double noded cuttings NAA at 100 mg l^{-1} was found to be superior except IBA at 50 500 and 1000 mg l^{-1} and NAA at 500 mg l^{-1} and IAA at 2000 mg l^{-1} and control (quick dip)

Table 1 Effect of growth regulators and type of cuttings on number of days taken for rooting of variegated cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	20 20^{lmp}	17 20^{prs}	18 70^{ijk}
IBA 100	19 20^{npq}	29 00^{d}	24 [illegible]^{cd}
IBA 200	16 20^{q}	19 60^{mnp}	17 90^{kl}
IBA 500	21 00^{ijn}	16 80^{prs}	18 90^{ijk}
IBA 1000	18 00^{npq}	17 40^{prs}	17 70^{k}
IBA 2000	16 40^{q}	18 80^{mnpr}	17 60^{k}
NAA 50	18 80^{npq}	21 00^{imn}	19 90^{hijk}
NAA 100	26 60^{cg}	15 20^{s}	20 90^{efhi}
NAA 200	20 40^{lm}	20 00^{lmnp}	20 20^{fhij}
NAA 500	19 00^{npq}	18 60^{nprs}	18 80^{ijk}
NAA 1000	20 20^{lmp}	20 00^{lmnp}	20 10^{fhij}
NAA 2000	19 00^{npq}	19 40^{mnp}	19 20^{ijl}
IAA 50	20 80^{ij}	23 40^{hij}	23 10^{cdef}
IAA 100	23 20^{ij}	22 20^{hijm}	22 70^{fg}
IAA 200	23 80^{gi}	19 40^{mnp}	21 60^{efgh}
IAA 500	30 00^{c}	25 40^{fh}	27 70^{bc}
IAA 1000	23 00^{ijk}	36 20^{b}	29 60^{b}
IAA 2000	44 20^{a}	15 60^{rs}	29 90^{b}
Control (Prolonged dip)	26 60^{cg}	27 40^{df}	27 00^{cd}
Control (Quick dip)	31 60^{c}	18 40^{nprs}	25 00de
Mean	23 01^{b}	21 05^{a}	

*Treatment means in a column with same letter do not differ significantly

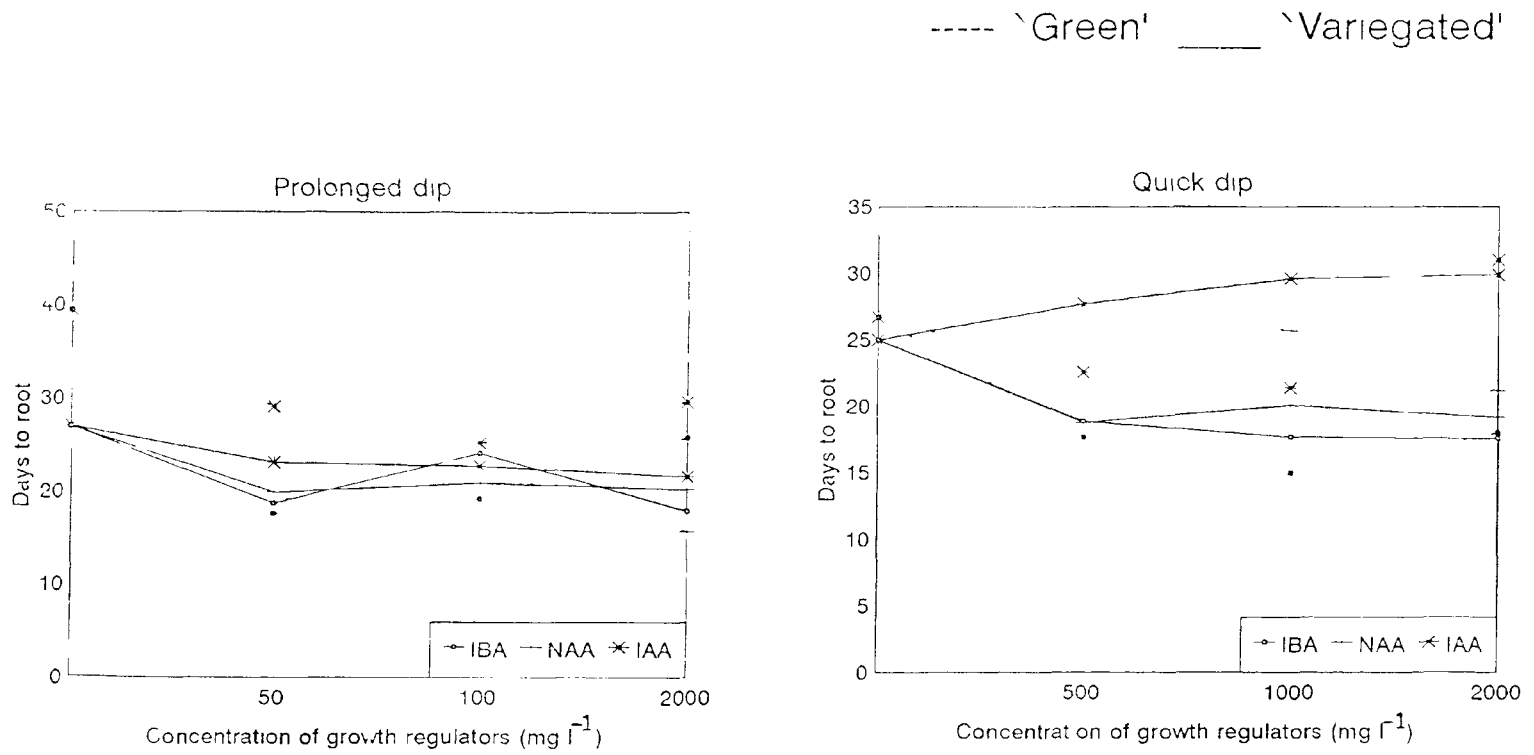


Fig 1 Number of days taken for rooting n cuttings as influenced by concentration of growth regulators

4 1 2 Number of roots

Main effects were statistically significant The number of roots were significantly high (35 9) with IBA at 200 mg l^{-1} (Table 2 Fig 2 Plate 2) On an average double noded cuttings gave significantly higher number of roots compared to single noded cuttings (Fig 3 Plate 3)

Interaction effects were also found to be significant In the case of single noded cuttings IBA and NAA both at 200 mg l^{-1} were found to be equally effective whereas in the case of double noded cuttings, IBA at 200 mg l^{-1} gave significantly higher number of roots and was superior to all other treatments

4 1 3 Length of the longest root

Main effect of growth regulators was significant where [illegible] type of cuttings was not significant Interaction effects of these factors were significant

The data presented in Table 3 showed that NAA at 500 and 1000 mg l^{-1} were significantly superior to other treatments except with IBA and NAA both 50 100 200 and 2000 mg l^{-1} and IBA at 500 and 1000 mg l^{-1} and IAA at 50 mg l^{-1} and control (prolonged dip)

Length of the longest root did not vary significantly among the double noded and single noded cuttings

Single noded cuttings treated with NAA at 500 mg l^{-1} [illegible] found [illegible] superior to most of the other treatments except with IBA at 200 500 mg

Table 2 Effect of growth regulators and type of cuttings on number of roots of variegated cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	13 60^{ghij}	21 80^{bcd}	17 70^{bcd}
IBA 100	16 40^{g}	24 00^{bc}	20 20^{bc}
IBA 200	28 20^{b}	43 60^{a}	35 90^{a}
IBA 500	16 20^{gh}	14 00^{defgi}	15 10^{cdef}
IBA 1000	11 20^{ghij}	20 20^{bcd}	15 70^{cde}
IBA 2000	15 00^{ghi}	25 80^{b}	20 40^{bc}
NAA 50	13 80^{ghij}	19 40^{bcdef}	16 60^{bcd}
NAA 100	10 00^{ghij}	26 60^{b}	18 30^{bcd}
NAA 200	28 00^{b}	16 60^{cdefg}	22 30^{b}
NAA 500	13 20^{ghij}	14 40^{defgi}	13 80^{def}
NAA 1000	12 60^{ghij}	15 60^{cdefg}	14 10^{def}
NAA 2000	13 40^{ghij}	14 60^{defg}	14 00^{def}
IAA 50	6 20^{ij}	13 80^{defgi}	10 00^{efgh}
IAA 100	9 80^{ghij}	8 20^{gi}	9 00^{fgh}
IAA 200	6 60^{ij}	6 20^{i}	6 40^{gh}
IAA 500	9 60^{ghij}	10 40^{fgi}	10 00^{efgh}
IAA 1000	7 00^{hij}	7 60^{gi}	7 30^{gh}
IAA 2000	5 20^{i}	19 60^{bcdef}	12 40^{defg}
Control (Prolonged dip)	5 20^{i}	5 40^{i}	5 30^{h}
Control (Quick dip)	7 80^{ghij}	5 20^{i}	6 50^{gh}
Mean	12 45^{b}	16 65^{a}	

*Treatment means in a column with same letter do not differ significantly

Table 3 Effect of growth regulators and type of cuttings on length of the longest root of variegated cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	13 46^{cdghij}	20 20^{abc}	16 83^{abc}
IBA 100	15 80^{cdghij}	16 62^{abcd}	16 21^{abc}
IBA 200	18 50^{acdgh}	18 60^{abc}	18 55^{ab}
IBA 500	17 06^{acdghi}	14 90^{cdk}	15 98^{abc}
IBA 1000	14 84^{cdghij}	21 12^{abc}	17 98^{ab}
IBA 2000	17 84^{acdghi}	20 50^{abc}	19 17^{ab}
NAA 50	21 12^{acd}	17 20^{abcd}	19 16^{ab}
NAA-100	9 74^{hij}	25 60^{ab}	17 67^{abc}
NAA 200	17 60^{acdghi}	16 20^{bcd}	16 90^{abc}
NAA 500	26 00^{a}	15 66^{cd}	20 83^{a}
NAA 1000	22 00^{ac}	22 76^{abc}	22 38^{a}
NAA 2000	16 10^{cdghij}	16 10^{bcd}	16 10^{abc}
IAA 50	18 30^{acdgh}	15 90^{bcd}	17 10^{abc}
IAA 100	8 40^{ij}	14 10^{cdk}	11 25^{cde}
IAA 200	10 60^{ghij}	5 70^{kl}	8 15de
IAA 500	11 70^{dghij}	15 60^{cd}	13 65^{bcd}
IAA 1000	11 00^{ghij}	8 10^{ikl}	9 55de
IAA 2000	6 50^{j}	20 60^{abc}	13 55^{bcd}
Control (Prolonged dip)	19 62^{acdg}	19 50^{abc}	19 56^{ab}
Control (Quick dip)	9 88^{ghij}	4 12^{l}	7 00^{e}
Mean	15 30^{d}	16 45^{d}	

*Treatment means in a column with same letter do not differ significantly

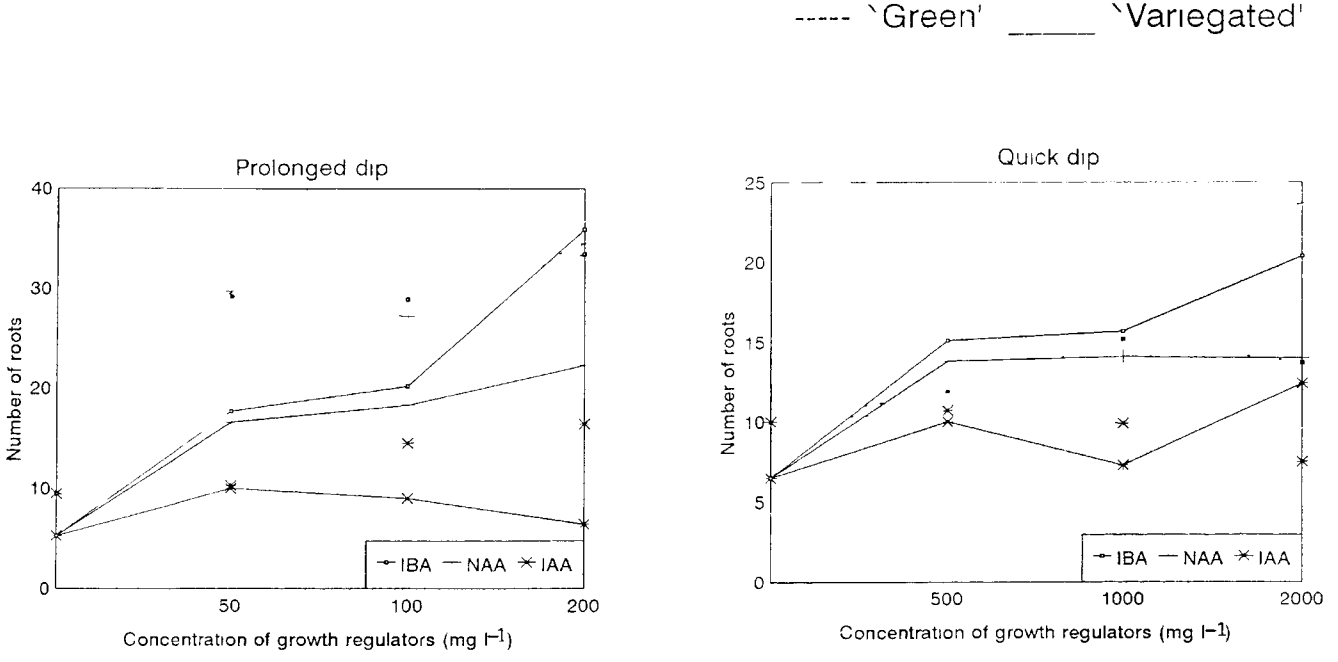


Fig 2 Number of roots in cuttings as influenced by concentration of growth regulators

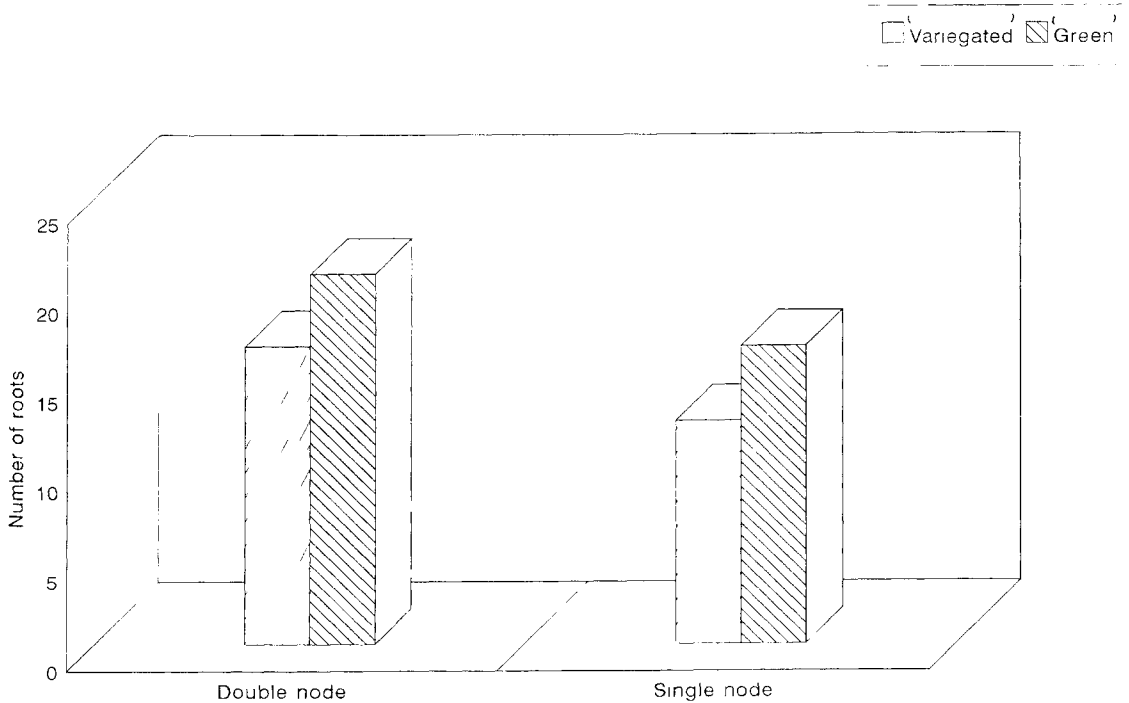
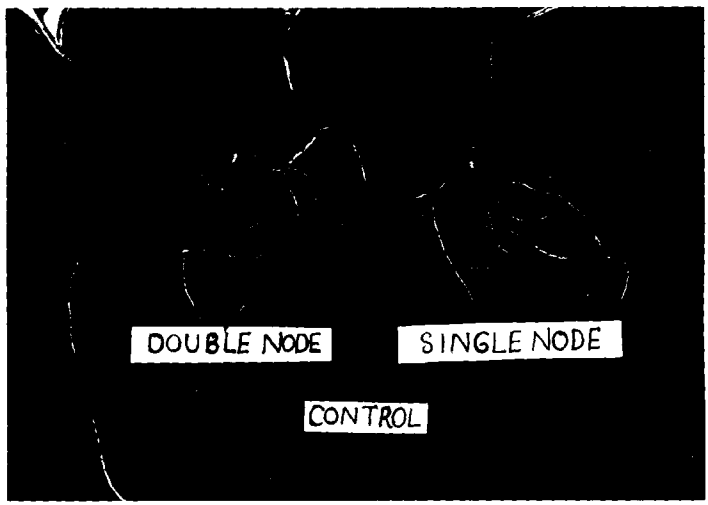


Fig 3 Number of roots in cuttings as influenced by type of cuttings

Plate 2 Effect of IBA 200 mg l^{-1} on root production in cuttings of *S. arboricola* ('Variegated')

Plate 3 Effect of type of cuttings on root production in *S. arboricola*


DOUBLE NODE
SLOW DIP
CONTROL
IBA 200


DOUBLE NODE
SINGLE NODE
CONTROL

2000 mg l^{-1} and NAA at 50 200 and 1000 mg l^{-1} and IAA at 50 mg l^{-1} and control (prolonged dip) In double noded cuttings NAA and IBA both at 50 100 200 1000 and 2000 mg l^{-1} and IAA at 50 and 2000 mg l^{-1} and control (prolonged dip) appear to be identical treatments

4 1 4 Total length of roots

Main effects and interaction effects were statistically significant

IBA at 200 mg l^{-1} was the most effective (300 3 cm) and significantly superior treatment (Table 4 Fig 4) On an average total length of roots was higher in double noded cuttings than in single noded cuttings (Fig 5 Plate 3)

From the interaction effect it was found that in single noded cuttings NAA at 200 mg l^{-1} was superior to most of the other treatments except with NAA at 50 500 and 1000 mg l^{-1} and IBA at 200 500 and 2000 mg l^{-1} Where as double noded cuttings IBA at 200 mg l^{-1} was found to be the best treatment

4 1 5 Average length of roots

Main effect of growth regulators was significant whereas the main effect of type of cuttings was not significant The data presented in Table 5 showed that NAA at 500 mg l^{-1} was superior to most of the other treatments except with NAA at 1000 mg l^{-1} and IBA at 500 1000 and 2000 mg l^{-1} and IAA at 50 mg l^{-1} and control (prolonged dip) Double noded and single noded cuttings did not vary significantly in the average length of roots produced

Interaction effect of growth regulators x type of cuttings was significant Single noded cuttings treated with IBA at 50 500 1000 and 2000 mg l^{-1} and NAA

Table 4 Effect of growth regulators and type of cuttings on total length of roots of variegated cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	102 8^{cjkl}	210 3^{bcc}	156 6^{bcd}
IBA 100	110 9^{cjkl}	160 8^{bccfgi}	135 9^{bcdc}
IBA 200	202 3^{bcdc}	398 3^{a}	300 3^{d}
IBA 500	153 5^{cdej}	131 8^{cfgik}	142 7^{bcdc}
IBA 1000	113 1^{cjkl}	177 9^{bccfg}	145 5^{bcdc}
IBA 2000	130 3^{dejkl}	262 6^{b}	196 4^{b}
NAA 50	136 4^{cdcjk}	132 3^{cfgik}	134 3$^{b\ d}$
NAA 100	68 14^{ikl}	238 5^{bc}	153 3$^{b\ d}$
NAA 200	230 8^{bcd}	92 12^{fgikm}	161 5^{bc}
NAA 500	157 2^{cdcg}	141 0^{cefgik}	149 1^{bcd}
NAA 1000	125 1^{dejkl}	164 5^{bccfg}	144 8^{bcdc}
NAA 2000	105 2^{ejkl}	112 6^{cfgikm}	108 9^{cdef}
IAA 50	55 76^{ikl}	117 9$^{cf_{g}ikl}$	86 81$^{def_{g}}$
IAA 100	44 62^{kl}	70 20$^{s_{ikm}}$	57 41$^{f_{g}}$
IAA 200	38 90^{kl}	33 40^{km}	36 15^{g}
IAA 500	66 74^{ikl}	85 20$^{gil\ m}$	75 97$^{ef_{g}}$
IAA 1000	48 5^{ikl}	55 00^{ikm}	51 75$^{f_{g}}$
IAA 2000	26 10^{l}	196 9^{bccf}	111 5^{cdef}
Control (Prolonged dip)	40 82^{kl}	63 80^{ikm}	52 31$^{f_{g}}$
Control (Quick dip)	53 40^{ikl}	12 00^{m}	32 7^{g}
Mean	100 53^{b}	142 85^{a}	

*Treatment means in a column with same letter do not differ significantly

Table 5 Effect of growth regulators and type of cuttings on average length of roots of variegated cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	8 30^{bdegj}	8 94^{abcch}	8 62^{bcdef}
IBA 100	7 52^{degj}	6 06^{hkl}	6 79^{defgh}
IBA 200	6 96^{degj}	8 78^{abcch}	7 87^{bcdef}
IBA 500	9 88^{abdc}	8 82^{abcch}	9 35^{bcd}
IBA 1000	10 38^{abd}	8 94^{abcch}	9 66^{bc}
IBA 2000	9 04^{abdeg}	10 08^{abcc}	9 56^{abc}
NAA 50	10 24^{abd}	6 86^{cchk}	8 55^{bcdef}
NAA 100	6 96^{degj}	8 86^{abcch}	7 91^{bcdef}
NAA 200	8 28^{bdegj}	5 46^{hkl}	6 87^{defgh}
NAA 500	12 10^{ab}	10 70^{abc}	11 40^{a}
NAA 1000	9 40^{abdeg}	10 44^{abc}	9 92^{ab}
NAA 2000	8 14^{degj}	7 22^{cchk}	7 68^{bcdef}
IAA 50	9 94^{abde}	8 48^{bcch}	9 21^{abcde}
IAA 100	4 58^{l}	8 80^{abcch}	6 69^{defgh}
IAA 200	5 90^{gj}	4 38^{kl}	5 14^{gh}
IAA 500	6 72^{degj}	9 00^{abcch}	7 86^{bcdef}
IAA 1000	6 70^{degj}	6 28^{chk}	6 49^{fgh}
IAA 2000	4 72^{l}	9 74^{abcc}	7 23^{cdefg}
Control (Prolonged dip)	7 98^{degj}	12 34^{a}	10 16^{ab}
Control (Quick dip)	5 90^{gj}	2 48^{l}	4 19^{i}
Mean	7 98^{a}	8 13^{a}	

*Treatment means in a column with same letter do not differ significantly

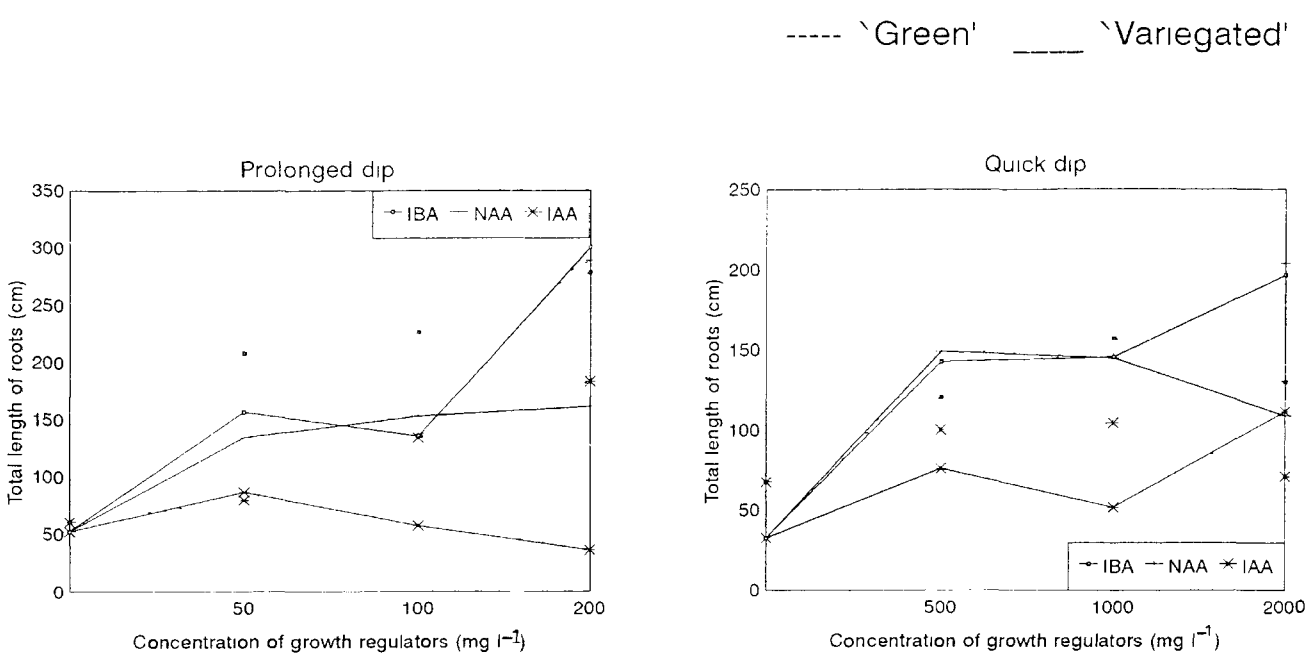


Fig 4 Total length of roots in cuttings as influenced by concentration of growth regulators

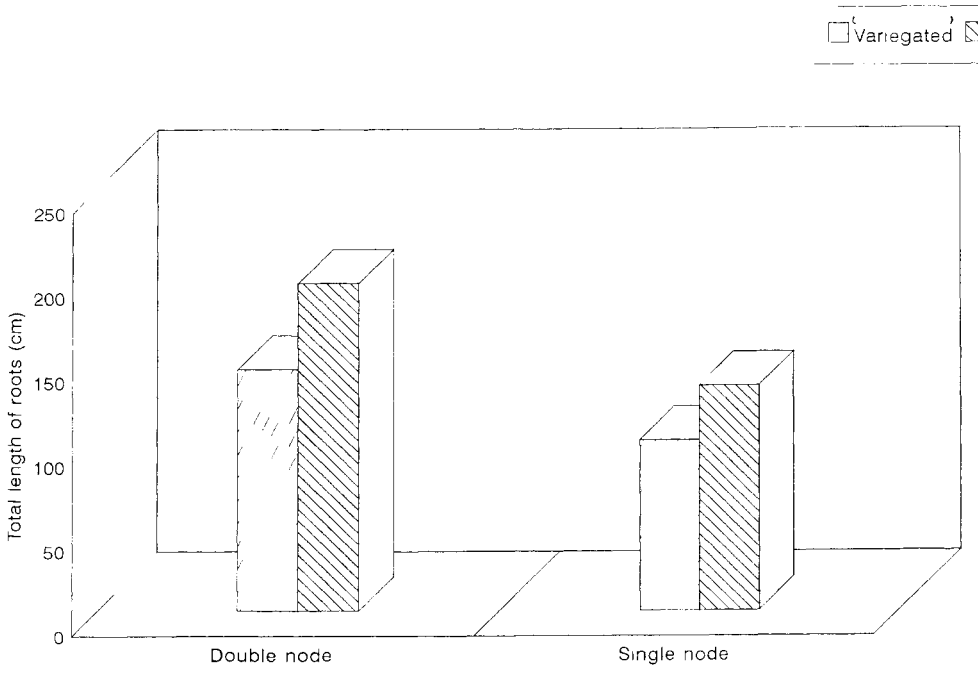


Fig 5 Total length of roots in cuttings as influenced by type of cuttings

at 50 200 500 and 1000 mg l $^{-1}$ and IAA at 50 mg l $^{-1}$ were superior to other treatments and control Whereas in double noded cuttings IBA at 50 200 500 1000 and 2000 mg l $^{-1}$ and NAA at 100 500 and 1000 mg l $^{-1}$ and IAA at 100 500 and 2000 mg l $^{-1}$ and control were found to be superior to other treatments

4 1 6 Fresh weight of roots

Main effects and interaction effects were statistically significant

IBA at 200 mg l $^{-1}$ (4 85 g) gave higher value for fresh weight of roots (Table 6) The results in Table 6 suggest that double noded cuttings recorded a higher fresh weight of roots on an average when compared with single noded cuttings

From the interaction effect it was found that in single noded cuttings NAA at 200 mg l $^{-1}$ was the best compared to other treatments except with NAA at 50 and 500 mg l $^{-1}$ and IBA at 200 mg l $^{-1}$ Double noded cuttings treated with IBA at 200 mg l $^{-1}$ recorded higher fresh weight of roots

4 1 7 Dry weight of roots

Main effects and interaction effects were significant

Dry weight of roots was higher in the case of cuttings treated with IBA at 200 mg l $^{-1}$ (Table 7) Double noded cuttings had significant influence on dry weight of roots compared with single noded cuttings

From the interaction effect it was clear that in single noded cuttings NAA at 200 mg l $^{-1}$ was superior to other treatments except with IBA and NAA

Table 6 Effect of growth regulators and type of cuttings on fresh weight of root of variegated cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	1 546^{hij}	3 238^{bcdefg}	2 392^{bcdefg}
IBA 100	1 706^{hij}	3 618^{bcde}	2 662^{bcdef}
IBA 200	2 832^{cdefgh}	6 866^{a}	4 849^{a}
IBA 500	1 438^{hij}	1 662^{ghijk}	1 550^{defghi}
IBA 1000	1 038^{hij}	3 954^{bcd}	2 496^{bcdefg}
IBA 2000	1 454^{ghij}	3 782^{bcde}	2 618^{bcdefg}
NAA 50	1 978^{defghij}	2 240^{cdefghij}	2 109^{bcdefg}
NAA 100	1 528^{ghij}	4 722^{b}	3 125^{bc}
NAA 200	3 836^{cd}	2 664^{cdefgh}	3 250^{b}
NAA 500	2 010^{defghij}	2 294^{cdefghij}	2 152^{bcdefg}
NAA 1000	1 770^{ghij}	1 856^{cdefghijk}	1 813^{cdefgh}
NAA 2000	1 458^{ghij}	2 138^{cdefghij}	1 798^{cdefgh}
IAA 50	0 584^{ij}	1 954^{defghijk}	1 269^{efgh}
IAA 100	0 214^{j}	0 942^{hijk}	0 578^{gh}
IAA 200	0 356^{ij}	0 120^{k}	0 238^{h}
IAA 500	1 048^{hij}	1 560^{ghijk}	1 304^{efgh}
IAA 1000	0 582^{ij}	1 000^{hijk}	0 791^{fgh}
IAA 2000	0 340^{ij}	3 754^{bcde}	2 047^{bcdefg}
Control (Prolonged dip)	0 646^{ij}	0 634^{ijk}	0 640^{gh}
Control (Quick dip)	1 048^{hij}	0 054^{k}	0 551^{h}
Mean	1 385^{b}	2 438^{a}	

*Treatment means in a column with same letter do not differ significantly

Table 7 Effect of growth regulators and type of cuttings on dry weight of roots of variegated cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	0 188^{efg}	0 536^{bc}	0 362^{bc}
IBA 100	0 276^{efg}	0 514^{bcc}	0 395^{bc}
IBA 200	0 414^{ef}	1 190^{a}	0 802^{a}
IBA 500	0 272^{efg}	0 232^{ccfg}	0 252^{bcd}
IBA 1000	0 202^{efg}	0 558^{bc}	0 380^{bc}
IBA 2000	0 279^{efg}	0 574^{bc}	0 427^{bc}
NAA 50	0 274^{efg}	0 266^{ccfg}	0 270^{bcd}
NAA 100	0 200^{efg}	0 694^{b}	0 447^{bc}
NAA 200	0 516^{c}	0 416^{bccf}	0 466^{b}
NAA 500	0 284^{efg}	0 268^{ccfg}	0 276^{bcd}
NAA 1000	0 262^{efg}	0 306^{ccfg}	0 284^{bcd}
NAA 2000	0 200^{efg}	0 296^{ccfg}	0 248^{bcd}
IAA 50	0 120^{fg}	0 320^{ccfg}	0 220^{cd}
IAA 100	0 042^{g}	0 176^{efg}	0 109^{d}
IAA 200	0 066^{fg}	0 048^{g}	0 057^{d}
IAA 500	0 154^{fg}	0 322^{ccfg}	0 238^{bcd}
IAA 1000	0 098^{fg}	0 144^{fg}	0 121^{d}
IAA 2000	0 072^{fg}	0 676^{b}	0 374^{bc}
Control (Prolonged dip)	0 148^{fg}	0 094^{fg}	0 121^{d}
Control (Quick dip)	0 150^{fg}	0 016^{g}	0 083^{d}
Mean	0 211^{b}	0 382^{a}	

*Treatment means in a column with same letter do not differ significantly

both at 50 100 500 1000 and 2000 mg l^{-1} and IBA at 200 mg l^{-1} Double noded cuttings treated with IBA at 200 mg l^{-1} gave higher value for dry weight of roots

4 2 Cuttings ('Green')

Effect of growth regulators and the type of cuttings on number of days taken for rooting number of roots length of the longest root total length of roots average length of roots fresh and dry weight of roots in green type of schefflera are given below

4 2 1 Number of days taken for rooting

Main effect of growth regulators was significant whereas main effect of type of cuttings was not significant

Data which show the effect of growth regulators and type of cuttings on number of days taken to root are presented in Table 8 The cuttings treated with IBA at 1000 mg l^{-1} (15 days) and NAA at 200 mg l^{-1} (15 7 days) rooted in shortest time and hence equally effective with respect to earliness in rooting (Fig 1) Type of cuttings did not have any significant influence on days taken for rooting

Interaction effect of growth regulators x type of cuttings was also significant Early rooting was noticed in the case of double noded cuttings treated with IBA at 1000 mg l^{-1} and NAA at 50 mg l^{-1} Whereas in the case of single noded cuttings IBA at 2000 mg l^{-1} and NAA at 200 and 1000 mg l^{-1} were found to be superior to most of the other treatments except with IBA at 50 100 500 and 1000 mg l^{-1}

Table 8 Effect of growth regulators and type of cuttings on number of days take for rooting of green cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	17 60^{l}	17 60^{lm}	17 60^{h}
IBA 100	18 20^{lkl}	20 20^{l}	19 20^{h}
IBA 200	24 20^{h}	27 40^{ef}	25 80^{f}
IBA 500	17 20^{l}	18 20^{ll}	17 70^{h}
IBA 1000	17 00^{l}	13 00^{n}	15 00^{i}
IBA 2000	15 80^{l}	20 20^{l}	18 00^{h}
NAA 50	27 20^{cg}	11 40^{n}	19 30^{h}
NAA 100	20 40^{l}	15 60^{m}	18 00^{h}
NAA 200	16 20^{l}	15 20^{m}	15 70^{i}
NAA 500	31 40^{d}	24 00^{i}	27 70^{dc}
NAA 1000	16 20^{l}	35 20^{b}	25 70^{f}
NAA 2000	25 20^{gh}	17 20^{lm}	21 20^{s}
IAA 50	29 00^{c}	29 20^{c}	29 10^{cd}
IAA 100	25 20^{gh}	25 20^{fgi}	25 20^{f}
IAA 200	36 40^{b}	22 80^{i}	29 60^{bc}
IAA 500	19 20^{l}	26 00^{fg}	22 60^{g}
IAA 1000	19 00^{l}	23 80^{i}	21 40^{s}
IAA 2000	24 80^{gh}	37 20^{b}	31 00^{b}
Control (Prolonged dip)	33 60^{c}	45 20^{a}	39 40^{a}
Control (Quick dip)	29 40^{dc}	24 00^{i}	26 70^{ef}
Mean	23 16^{a}	23 43^{a}	

*Treatment means in a column with same letter do not differ significantly

4 2 2 Number of roots

Main effect of growth regulators and type of cuttings and interaction effects of these factors were significant

The data presented in Table 9 and depicted in Fig 2 showed that NAA at 200 mg l^{-1} (34 5) was found to be superior to most of the other treatments except with NAA at 50 mg l^{-1} (29 7) and IBA at 50 (29 2) 100 (28 9) and 200 mg l^{-1} (33 4)

The type of cuttings significantly influenced the number of roots produced and on an average double noded cuttings recorded the maximum number of roots (Fig 3)

From the interaction effect it is evidenced that double noded cuttings treated with IBA at 200 mg l^{-1} was the best compared to other treatments except with IBA at 50 mg l^{-1} and NAA at 50 100 200 and 1000 mg l^{-1} Single noded cuttings treated with IBA at 100 mg l^{-1} and NAA at 200 mg l^{-1} were superior in performance

4 2 3 Length of the longest root

Main effects and interaction effects were statistically significant

As evidenced from the data furnished in Table 10 NAA at 50 and 200 mg l^{-1} and IAA at 200 mg l^{-1} were superior treatments On an average double noded cuttings recorded significantly higher value for length of the longest root compared to single noded cuttings

Table 9 Effect of growth regulators and type of cuttings on number of roots of guava cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	24 20^{dc}	34 20^{bc}	29 20^{ab}
IBA 100	31 80^{ad}	26 00^{cdefgh}	28 90^{abc}
IBA 200	28 20^{dc}	38 60^{b}	33 40^{ab}
IBA 500	10 20^{jn}	13 60^{ijkln}	11 90^{fg}
IBA 1000	12 00^{jn}	18 40^{ghijkl}	15 20^{ef}
IBA 2000	11 40^{jn}	16 00^{hijkln}	13 70^{fg}
NAA 50	26 00^{dc}	33 40^{bc}	29 70^{abc}
NAA 100	24 00^{dc}	30 40^{bcd}	27 20^{bcd}
NAA 200	39 60^{a}	29 40^{bcd}	34 50^{a}
NAA 500	13 60^{jn}	17 40^{ghijkl}	15 50^{ef}
NAA 1000	13 60^{jn}	29 40^{bcd}	21 50de
NAA 2000	20 60^{ej}	26 80^{cdefg}	23 70^{cd}
IAA 50	10 80^{jn}	9 80^{kln}	10 30^{fg}
IAA 100	6 80^{n}	22 20^{efghi}	14 50^{fg}
IAA 200	12 80^{jn}	20 00^{efghik}	16 40^{ef}
IAA 500	12 40^{jn}	9 00^{ln}	10 70^{fg}
IAA 1000	9 00^{n}	10 80^{kln}	9 90^{fg}
IAA 2000	9 40^{n}	5 60^{n}	7 50^{g}
Control (Prolonged dip)	6 80^{n}	12 20^{ijkln}	9 50^{fg}
Control (Quick dip)	9 40^{n}	10 60^{kln}	10 00^{fg}
Mean	16 63^{b}	20 69^{a}	

*Treatment means in a column with same letter do not differ significantly

Table 10 Effect of growth regulators and type of cuttings on length of the longest root of green cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	16 26^{fh}	23 98^{bdc}	20 12^{cdc}
IBA 100	21 26^{cdf}	15 06^{eh}	18 16$^{cd fh}$
IBA 200	18 50^{dfh}	20 60^{dcg}	19 55^{cdef}
IBA 500	16 70^{fh}	23 38^{bdc}	20 04^{cdc}
IBA 1000	19 70^{cdf}	20 70^{dcg}	20 20^{cdc}
IBA 2000	23 60^{cdf}	19 54^{dcg}	21 57^{cd}
NAA 50	29 20^{c}	27 70^{bd}	28 45^{ab}
NAA 100	16 02^{fh}	19 48^{dcg}	17 75^{defgh}
NAA 200	20 00^{cdf}	41 50^{a}	30 75^{a}
NAA 500	16 00^{fh}	18 60^{dcg}	17 30^{defgh}
NAA 1000	21 96^{cdf}	20 58^{dcg}	21 27^{cdc}
NAA 2000	27 50^{cd}	17 70^{dcg}	22 60^{bcd}
IAA 50	13 80^{fh}	14 62^{egh}	14 21^{efgh}
IAA 100	14 88^{fh}	20 34^{dcg}	17 61^{defgh}
IAA 200	18 50^{dfh}	31 40^{b}	24 95^{abc}
IAA 500	16 40^{fh}	17 40^{dcg}	16 90^{defgh}
IAA 1000	22 26^{cdf}	24 62^{bdc}	23 44^{bcd}
IAA 2000	17 50^{dfh}	16 00^{cg}	16 75^{defgh}
Control (Prolonged dip)	13 70^{fh}	10 54^{g}	12 12^{h}
Control (Quick dip)	8 50^{h}	16 60^{egh}	12 55^{fgh}
Mean	18 61^{b}	21 02^{a}	

*Treatment means in a column with same letter do not differ significantly

From the interaction effect it can be seen that the double noded cuttings treated with NAA at 200 mg l^{-1} produced the longest roots (Plate 4 I Single noded cuttings IBA at 100 1000 and 2000 mg l^{-1} and NAA at 50 200 1000 and 2000 mg l^{-1} and IAA at 1000 mg l^{-1} were equally effective treatment

4 2 4 Total length of roots

Main effect of growth regulators and type of cuttings were statistically significant

NAA at 50 (295 5 cm) and 200 mg l^{-1} (288 8 cm) and IBA at 200 mg l^{-1} (278 4 cm) were significantly superior to other treatments (Table 11 Fig 4 Plate 5) On an average total length of roots was higher in the case of double noded cuttings than in the single noded cuttings (Fig 5)

The interaction effect of growth regulators x type of cuttings was also significant Double noded cuttings treated with NAA at 50 and 200 mg l^{-1} and IBA at 200 mg l^{-1} were significantly superior to other treatments and recorded higher value for total length of roots Whereas in single noded cuttings IBA at 100 mg l^{-1} was superior to most of the treatments except with IBA at 200 mg l^{-1} and NAA at 50 100 200 and 2000 mg l^{-1}

4 2 5 Average length of roots

Main effect of growth regulators and type of cuttings and their interaction effect were significant

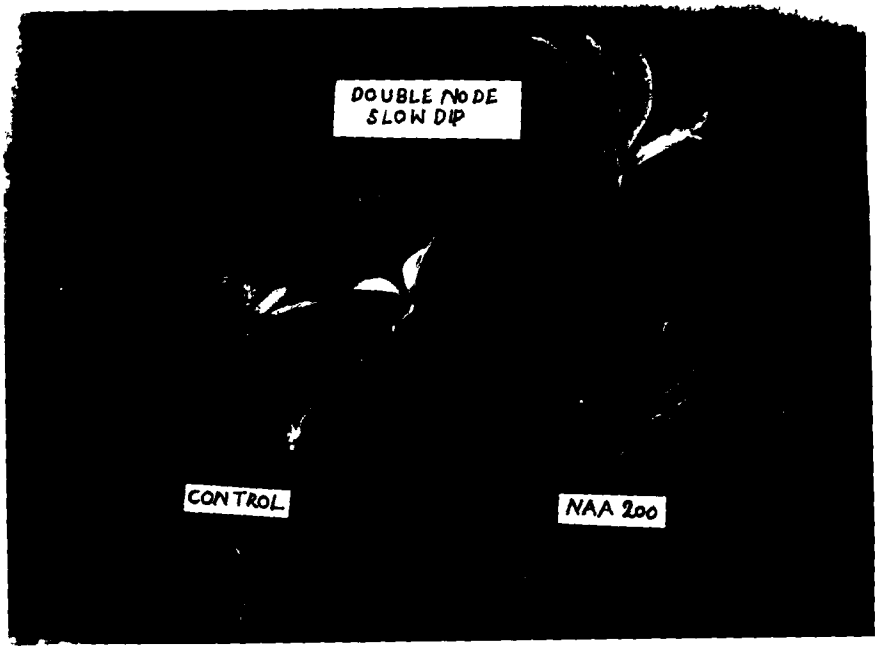
Table 11 Effect of growth regulators and type of cuttings on total length of roots of green cuttings

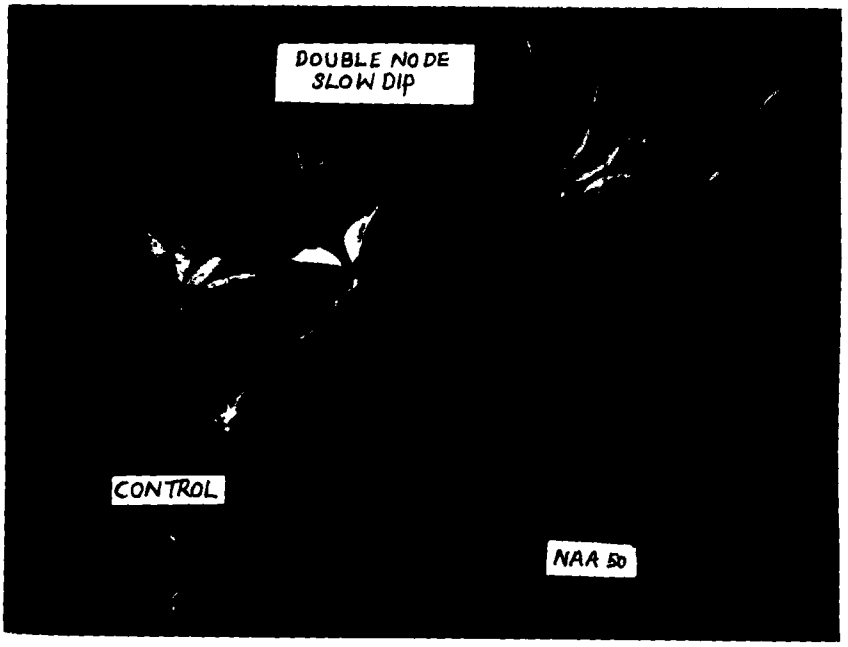
Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	131 5^{imnp}	284 4^{bd}	208 0^{cd}
IBA 100	253 2^{cg}	200 0^{dfhkl}	226 6^{bc}
IBA 200	232 0^{cgi}	324 8^{ab}	278 4^{ab}
IBA 500	77 94^{np}	163 1^{hkno}	120 9^{efgh}
IBA 1000	116 6^{mnp}	197 5^{dfhk}	157 1^{def}
IBA 2000	127 9^{mnp}	131 6^{knop}	129 8^{efgh}
NAA 50	251 4^{cg}	339 7^{ab}	295 5^{a}
NAA 100	181 3^{gimn}	247 0^{bdfh}	214 1^{cd}
NAA 200	189 6^{gim}	388 0^{a}	288 8^{ab}
NAA 500	106 5^{mnp}	150 2^{hknop}	128 4^{efgh}
NAA 1000	131 1^{imnp}	294 2^{bd}	212 6^{cd}
NAA 2000	227 6^{cgi}	179 9^{fhkn}	203 80^{cd}
IAA 50	73 56^{p}	85 60^{nop}	79 58^{gh}
IAA 100	61 60^{p}	207 1^{dfhk}	134 4^{efg}
IAA 200	98 88^{mnp}	267 9^{bdf}	183 4^{cde}
IAA 500	115 4^{mnp}	84 75^{nop}	100 1^{fgh}
IAA 1000	88 50^{mnp}	120 1^{knop}	104 3^{fgh}
IAA 2000	85 20^{np}	56 80^{p}	71 00^{gh}
Control (Prolonged dip)	53 66^{p}	67 76^{op}	60 71^{h}
Control (Quick dip)	51 12^{p}	84 32^{nop}	67 72^{gh}
Mean	132 73^{b}	193 74^{a}	

*Treatment means in a column with same letter do not differ significantly

Plate 4 Double noded cuttings treated with NAA 200 mg l^{-1} showing longest roots in *S arboricola* (Green)

Plate 5 Effect of NAA 50 mg l^{-1} on root length in cuttings of *S arboricola* ('Green)


DOUBLE NODE
SLOW DIP
CONTROL
NAA 200


DOUBLE NODE
SLOW DIP
CONTROL
NAA 50

From Table 12 it is clear that IBA at 500, 1000 and 2000 mg l^{-1} and NAA at 50, 200, 1000 and 2000 mg l^{-1} and IAA at 100, 200, 500, 1000 and 2000 mg l^{-1} were equally effective and superior treatments. Average length of roots was more in the case of double noded cuttings than in single noded cuttings.

From the interaction effect it can be seen that double noded cuttings treated with IBA at 500 mg l^{-1} and NAA at 200 mg l^{-1} and IAA at 200 and 1000 mg l^{-1} were the superior treatments. In single noded cuttings IBA at 100 and 2000 mg l^{-1} and NAA at 50, 1000 and 2000 mg l^{-1} and IAA at 100, 500, 1000 and 2000 mg l^{-1} were of similar in performance.

4.2.6 Fresh weight of roots

Main effects and interaction of the growth regulators and type of cuttings were significant.

A critical scaning of Table 13 showed that IBA at 200 mg l^{-1} (4.39 g) and NAA at 50 mg l^{-1} (5.41 g), 100 (4.50 g) and 200 mg l^{-1} (4.61 g) were equally effective and superior to the rest of the treatments.

Compared to single noded cuttings, double noded cuttings produced higher fresh weight of roots.

From the interaction effect it was observed that double noded cuttings treated with NAA at 50 and 200 mg l^{-1} were significantly superior to most of the treatments except with IBA at 200 and 1000 mg l^{-1} and NAA at 1000 mg l^{-1}. In single noded cuttings IBA at 100, 200, 500 and 2000 mg l^{-1} and NAA at 50, 100 and 2000 mg l^{-1} were the superior treatments.

Table 12 Effect of growth regulators and type of cuttings on average length of roots of green cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	5 26^{m}	8 10^{fgik}	6 68^{f}
IBA 100	7 76^{hkm}	7 42^{gik}	7 59^{ef}
IBA 200	8 26^{ehkm}	8 50^{fgik}	8 38^{bcdef}
IBA 500	7 76^{hkm}	12 38^{abc}	10 07^{abcd}
IBA 1000	9 68^{cdeh}	10 76^{bcfg}	10 22^{abcd}
IBA 2000	11 62^{cde}	8 38^{fgik}	10 00^{abcd}
NAA 50	9 80^{cdeh}	10 54^{cfg}	10 17^{bc}
NAA 100	7 58^{hkm}	8 06^{fgik}	7 82^{def}
NAA 200	5 04^{m}	13 70^{ab}	9 37^{abcde}
NAA 500	7 54^{hkm}	9 12^{cfgik}	8 33^{bcdef}
NAA 1000	9 16^{cdehk}	10 08^{cfgi}	9 62^{abcde}
NAA 2000	11 94^{cd}	6 96^{ik}	9 45^{abcde}
IAA 50	7 18^{hkm}	8 98^{fgik}	8 08^{cdef}
IAA 100	8 84^{dehk}	9 26^{cfgi}	9 05^{bcde}
IAA 200	8 20^{hkm}	14 02^{a}	11 11^{a}
IAA 500	9 62^{cdeh}	9 78^{cfgi}	9 70^{abcde}
IAA 1000	9 96^{cdeh}	11 16^{abcf}	10 56^{ab}
IAA 2000	9 12^{cdehk}	10 26^{cfgi}	9 69^{abcde}
Control (Prolonged dip)	7 20^{hkm}	5 84^{k}	6 52^{f}
Control (Quick dip)	5 92^{km}	7 60^{gik}	6 76^{f}
Mean	8 37^{b}	9 55^{a}	

*Treatment means in a column with same letter do not differ significantly

Table 13 Effect of growth regulators and type of cuttings on fresh weight of [illegible] green cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	2 450^{hijmn}	3 504^{dfik}	2 977^{defg}
IBA 100	4 130^{cegh}	4 346^{bdf}	4 238^{bc}
IBA 200	3 724^{eghij}	5 056^{abd}	4 390^{abc}
IBA 500	3 838^{cegh}	3 044^{bdfi}	3 891^{bcd}
IBA 1000	2 460^{hijmn}	5 482^{ab}	3 971^{bcd}
IBA 2000	3 786^{cghij}	2 924^{fikl}	3 355^{cdef}
NAA 50	4 314^{cg}	6 508^{d}	5 411^{a}
NAA 100	4 656^{c}	4 242^{bdf}	4 490^{abc}
NAA 200	2 648^{ghijm}	6 572^{a}	4 610^{ab}
NAA 500	2 516^{hijm}	4 244^{bdf}	3 380^{def}
NAA 1000	2 128^{ijmno}	5 222^{ab}	3 675^{bcde}
NAA 2000	4 794^{c}	2 465^{iklm}	3 630^{bcde}
IAA 50	1 442^{mno}	1 844^{klm}	1 643^{hij}
IAA 100	2 002^{mno}	3 214^{fik}	2 608^{defgh}
IAA 200	2 666^{ghijm}	3 128^{fikl}	2 897^{defg}
IAA 500	2 370^{ijmn}	1 836^{klm}	2 103^{gh}
IAA 1000	2 466^{hijmn}	2 548^{iklm}	2 507^{fgh}
IAA 2000	2 428^{hijmn}	1 494^{lm}	1 961^{ghi}
Control (Prolonged dip)	0 804no	1 191^{m}	0 998^{ij}
Control (Quick dip)	0 542^{o}	1 076^{m}	0 809^{j}
Mean	2 808^{b}	3 542^{a}	

*Treatment means in a column with same letter do not differ significantly

4 2 7 Dry weight of roots

Main effects of growth regulators and type of cuttings and their interaction effects were significant

Dry weight of roots was higher in the case of treatments IBA 100 200 500 and 1000 mg l^{-1} and NAA at 50 100 200 1000 and 2000 mg l^{-1} (Table 14)

On an average double noded cuttings were significantly superior single noded cuttings in terms of dry weight of roots produced

From the interaction effect it was clear that double noded cuttings treated with NAA at 50 and 200 mg l^{-1} were superior to other treatments except IBA at 100 200 500 and 1000 mg l^{-1} and NAA at 1000 mg l^{-1} Whereas in single noded cuttings NAA at 2000 mg l^{-1} was found to be superior to other treatments except with IBA at 100 and 500 mg l^{-1} and NAA at 100 mg l^{-1}

4 2 8 Percentage success in cuttings

Percentage success in rooting of cuttings (Table 15 Plate 6) depended on the growth regulator employed In double noded variegated cuttings IBA NAA and IAA treatments recorded a percentage success of 91 6 85 4 and 68 7 respectively and in double noded green cuttings these treatments recorded respective percentage success of 91 6 95 8 and 68 7 For single noded variegated cuttings the values were 81 2 77 1 and 62 5 for IBA NAA and IAA respectively and for green cuttings the respective values were 87 5 89 5 and 64 5 With increased

Table 14 Effect of growth regulators and type of cuttings on dry weight of roots of green cuttings

Growth regulators	Type of cuttings		
	Single node	Double node	Mean
IBA 50	0 246^{gklm}	0 362^{defgijl}	0 304^{cdef}
IBA 100	0 510^{bfg}	0 530^{acdef}	0 520^{ab}
IBA 200	0 341^{fgklm}	0 671^{ac}	0 506^{ab}
IBA 500	0 521^{bf}	0 511^{acdefg}	0 517^{ab}
IBA 1000	0 338^{fgklm}	0 554^{acde}	0 446^{abcd}
IBA 2000	0 350^{fgkl}	0 298^{efgijlm}	0 324^{cdef}
NAA 50	0 388^{fgk}	0 738^{a}	0 563^{a}
NAA 100	0 486^{bfg}	0 434^{cdefgi}	0 460^{abcd}
NAA 200	0 254^{gklm}	0 758^{a}	0 506^{ab}
NAA 500	0 278^{fgklm}	0 404^{defgij}	0 341^{bcdef}
NAA 1000	0 202^{klm}	0 605^{abcd}	0 403^{abcde}
NAA 2000	0 706^{b}	0 252^{gijlm}	0 479^{abc}
IAA 50	0 164^{klm}	0 210^{ijlm}	0 187^{fgh}
IAA 100	0 249^{gklm}	0 372^{defgijl}	0 310^{cdef}
IAA 200	0 274^{fgklm}	0 344^{defgijl}	0 309^{cdef}
IAA 500	0 246^{gklm}	0 219^{ijlm}	0 233^{efgh}
IAA 1000	0 303^{fgklm}	0 274^{fgijlm}	0 288^{defg}
IAA 2000	0 268^{fgklm}	0 152^{jlm}	0 210^{fgh}
Control (Prolonged dip)	0 108^{lm}	0 129^{lm}	0 119^{gh}
Control (Quick dip)	0 074^{m}	0 136^{jlm}	0 105^{h}
Mean	0 315^{b}	0 398^{a}	

*Treatment means in a column with same letter do not differ significantly

Table 15 Effect of growth regulators and type of cuttings on the percentage success in cuttings

Growth regulators	Method	Type of cuttings	Percentage success	
			Variegated	Green
1	2	3	4	5
IBA 50	PD	DN	100 0	100 0
		SN	75 0	100 0
IBA 100	PD	DN	100 0	100 0
		SN	87 5	100 0
IBA 200	PD	DN	100 0	100 0
		SN	100 0	100 0
IBA 500	QD	DN	75 0	75 0
		SN	87 5	75 0
IBA 1000	QD	DN	87 5	87 5
		SN	62 5	75 0
IBA 2000	QD	DN	87 5	87 5
		SN	75 0	75 0
NAA 50	PD	DN	87 5	100 0
		SN	75 0	100 0
NAA 100	PD	DN	100 0	100 0
		SN	62 5	100 0
NAA 200	PD	DN	100 0	100 0
		SN	100 0	100 0
NAA 500	QD	DN	75 0	87 5
		SN	75 0	75 0
NAA 1000	QD	DN	75 0	100 0
		SN	75 0	75 0
NAA 2000	QD	DN	75 0	87 5
		SN	75 0	87 5
IAA 50	PD	DN	75 0	62 5
		SN	62 5	62 5
IAA 100	PD	DN	62 5	75 0
		SN	62 5	62 5

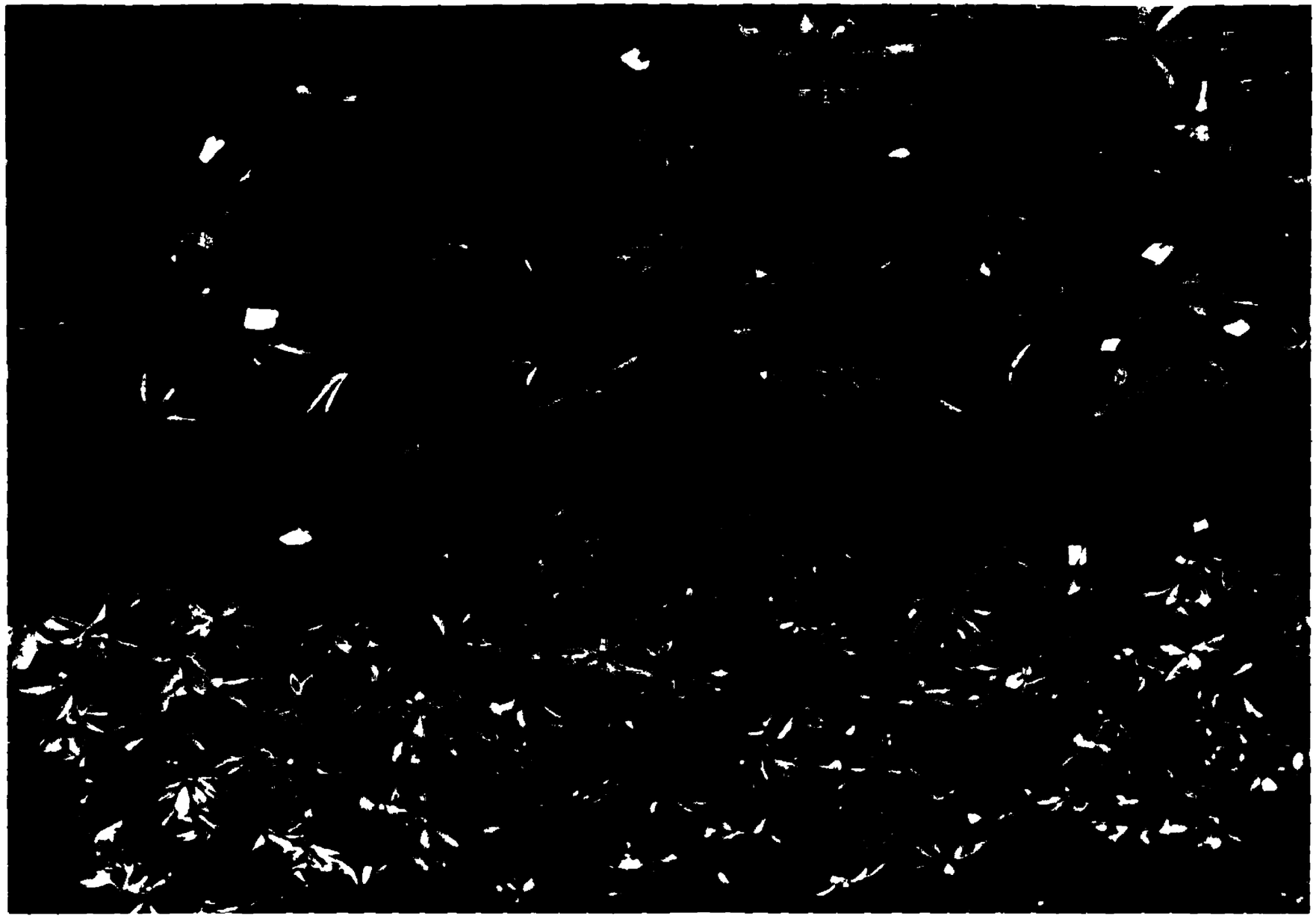
Contd

Table 15 Continued

1	2	3	4	5
IAA 200	PD	DN	62 5	87 5
		SN	62 5	75 0
IAA 500	QD	DN	62 5	62 5
		SN	62 5	62 5
IAA 1000	QD	DN	62 5	62 5
		SN	62 5	62 5
IAA 2000	QD	DN	87 5	62 5
		SN	62 5	62 5
Control	PD	DN	62 5	62 5
		SN	62 5	62 5
Control	QD	DN	62 5	62 5
		SN	62 5	62 5

PD Prolonged dip QD Quick dip DN Double node SN Single node

Plate 6 Well established cuttings growing in polybags



cuttings (control) the percentage success obtained in both double noded and single noded variegated and green cuttings was only 62 5

4 3 Layering ('Variegated')

Effect of growth regulators media and type of cut on number of days taken for rooting number of roots length of the longest root total length of roots average length of roots fresh and dry weight of roots of layers are presented below

4 3 1 Number of days taken for rooting

Main effect of growth regulators and media was significant whereas that of type of cut was not significant Interaction effect of growth regulators x media was significant whereas interaction effect of growth regulators x type of cut and media x type of cut was not significant

Untreated (no growth regulator) layers recorded minimum number of days (34 6) for rooting (Table 16) Among the growth regulator treatments NAA at 50 mg l^{-1} showed earliness (44 43 days) in rooting

Comparing the effect of different media on an average early rooting was noticed with sphagnum moss and sawdust (Fig 6)

From the interaction effect early rooting was noticed in untreated layers with sphagnum moss and sawdust as media whereas with coconut fibre early rooting was noticed with NAA at 50 mg l^{-1} and IBA at 100 mg l^{-1} and untreated layers

Type of cut used for layering did not have any significant influence on the number of days taken for rooting

Table 16 Effect of growth regulators media and type of cut on number of days taken for rooting of variegated' layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	52 90^{chi}	41 70^{k}	55 60^{d}	50 07^{b}
IBA 100	49 20^{hik}	64 00^{cd}	45 30^{k}	52 83^{b}
IBA 200	58 10^{c}	62 20^{cd}	63 70^{bd}	61 33^{a}
NAA 50	44 60^{ik}	47 30^{jk}	41 40^{k}	44 43^{c}
NAA 100	52 10^{chi}	45 30^{jk}	63 10^{bd}	53 50^{b}
NAA 200	59 20^{c}	50 70^{j}	73 60^{a}	61 17^{a}
IAA 50	53 40^{ch}	64 40^{c}	72 90^{a}	63 57^{a}
IAA 100	47 30^{hik}	47 90^{jk}	68 10^{ab}	54 43^{b}
IAA 200	52 90^{chi}	41 40^{k}	57 20^{d}	50 50^{b}
Control	28 30^{l}	32 10^{l}	43 40^{k}	34 60^{d}
Mean	49 80^{b}	49 70^{b}	58 43^{a}	
Type of cut			Mean	
Girdling			51 95^{a}	
Slanting slit			53 33^{a}	

*Treatment means in a column with same letter do not differ significantly

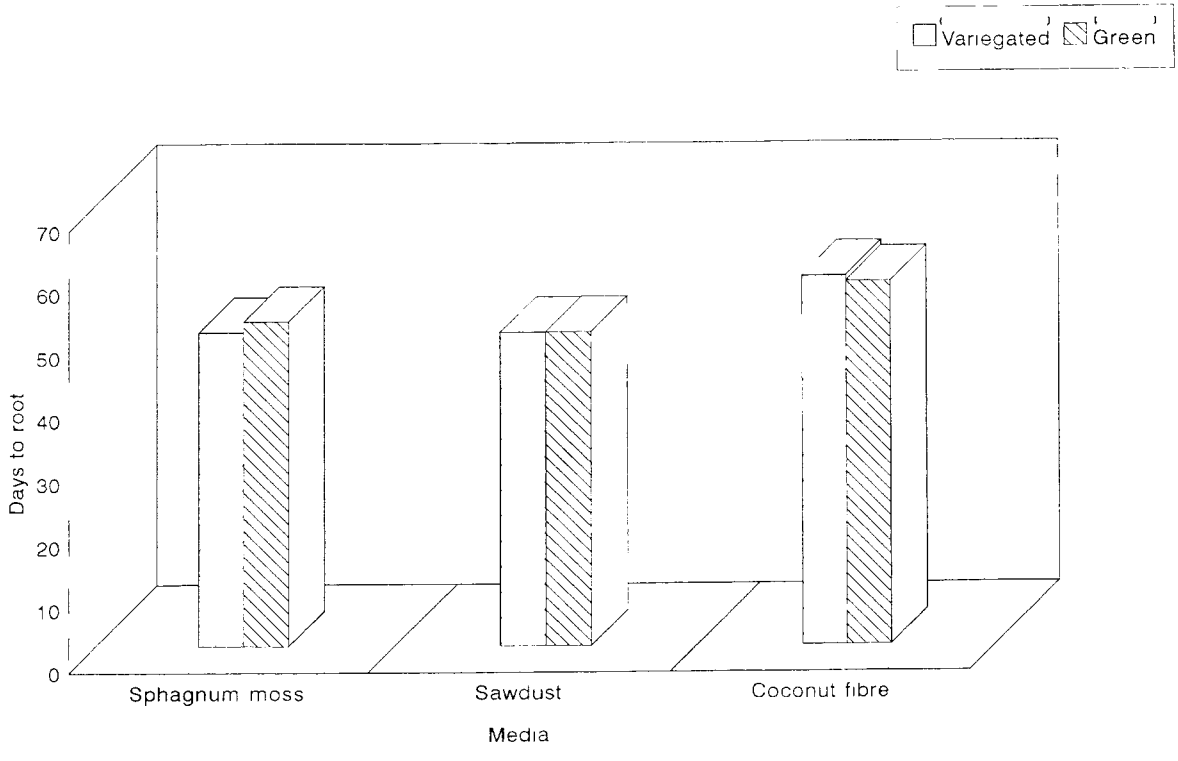


Fig 6 Number of days taken for rooting in layers as influenced by different media

4 3 2 Number of roots

Main effect of growth regulator media and type of cut was significant whereas interaction effect of growth regulators x media growth regulators x type of cut and media x type of cut was not significant

The data presented in Table 17 and depicted in Fig 7 showed that number of roots produced was higher (Plate 7) in layers which were treated with NAA at 50 mg l^{-1} (22 83)

Of the different media used sawdust and sphagnum moss produced significantly higher number of roots (Fig 8 Plate 8)

The method of wounding used for layering had significant influence on number of roots produced On the average girdling produced higher number of roots compared to slanting slit method (Fig 9, Plate 9)

4 3 3 Length of the longest root

Main effect of growth regulators and media was significant whereas main effect of type of cut was not significant Interaction effect of growth regulators x media was significant

IBA at 50 mg l^{-1} and NAA at 50 and 100 mg l^{-1} and IAA at 100 mg l^{-1} were equally effective and produced longest roots (Table 18)

On an average the roots produced were longer when sphagnum moss was used as the medium

Table 17 Effect of growth regulators, media and type of cut on number of roots of variegated layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
Growth regulator				
IBA 50	16 10^{cf}	13 80^{cch}	8 9^{hj}	12 93^{bc}
IBA 100	13 50^{cfgh}	16 80^{cc}	10 30^{fhj}	13 53^{bc}
IBA 200	15 30^{cfg}	11 70^{ehj}	6 9^{j}	11 30^{cd}
NAA 50	23 80^{b}	26 60^{a}	18 10^{d}	22 83^{a}
NAA 100	10 00^{fgh}	10 50^{ehj}	10 80^{fhj}	10 43^{cd}
NAA 200	8 80^{gh}	9 00^{hj}	5 80^{j}	7 87^{d}
IAA 50	10 20^{fgh}	5 60^{j}	7 70^{hj}	7 83^{d}
IAA 100	7 40^{h}	11 4^{ehj}	6 80^{j}	8 53^{d}
IAA 200	19 90^{bc}	18 90^{c}	8 00^{hj}	15 60^{b}
Control	13 00^{cfgh}	15 80^{cc}	11 40^{fhj}	13 67^{bc}
Mean	13 88^{a}	14 01^{a}	9 47^{b}	

Type of cut	Mean
Girdling	13 33^{a}
Slanting slit	11 58^{b}

*Treatment means in a column with same letter do not differ significantly

Table 18 Effect of growth regulators media and type of cut on length of the longest root of variegated layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	14 24^{a}	11 78^{c}	5 38^{gh}	10 47^{a}
IBA 100	8 64^{f}	8 88^{def}	7 74^{g}	8 42^{bc}
IBA 200	8 92^{f}	8 55^{ef}	7 63^{g}	8 37^{bc}
NAA 50	13 47^{ab}	11 27^{cd}	6 43^{gh}	10 39^{a}
NAA 100	8 86^{f}	8 75^{def}	10 78^{c}	9 46^{ab}
NAA 200	8 81^{f}	8 58^{ef}	6 71^{gh}	8 03^{bc}
IAA 50	12 80^{ab}	4 86^{h}	7 73^{g}	8 46^{bc}
IAA 100	11 50^{b}	8 47^{ef}	7 37^{gh}	9 11^{ab}
IAA 200	6 80^{f}	10 48^{cde}	7 68^{g}	8 32^{bc}
Control	7 35^{f}	7 63^{f}	7 62^{g}	7 53^{c}
Mean	10 14^{a}	8 93^{b}	7 51^{c}	

Type of cut	Mean
Girdling	9 11^{d}
Slanting slit	8 61^{a}

*Treatment means in a column with same letter do not differ significantly

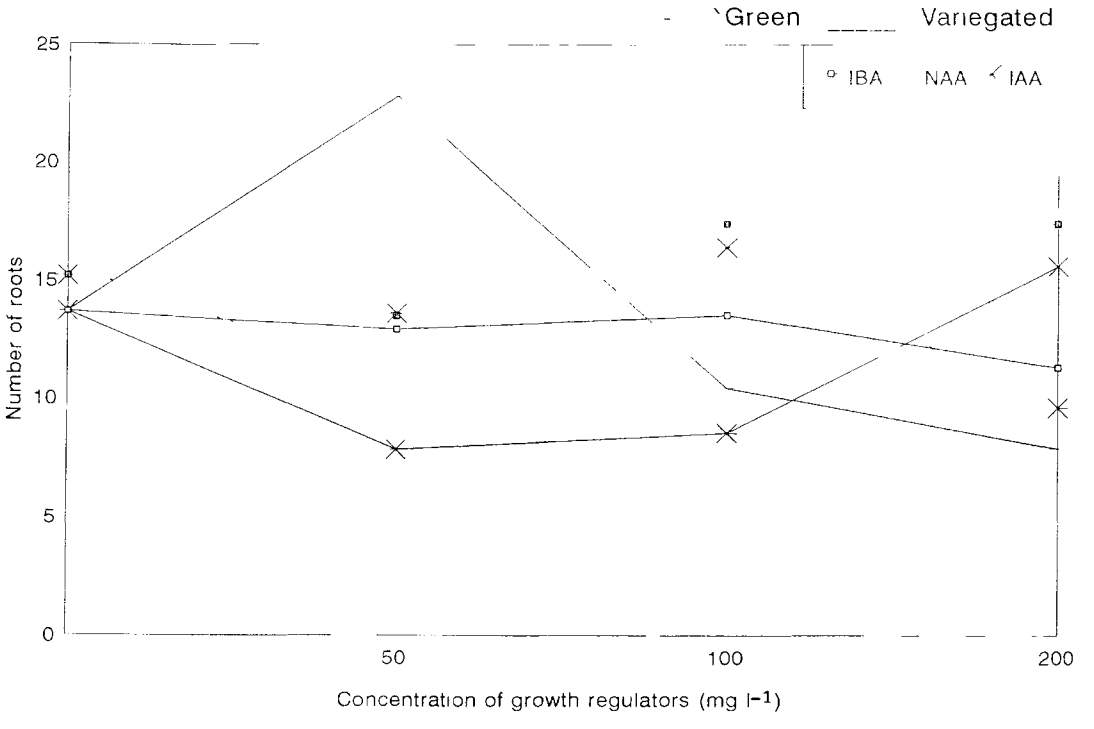


Fig 7 Number of roots in layers as influenced by concentration of growth regulators

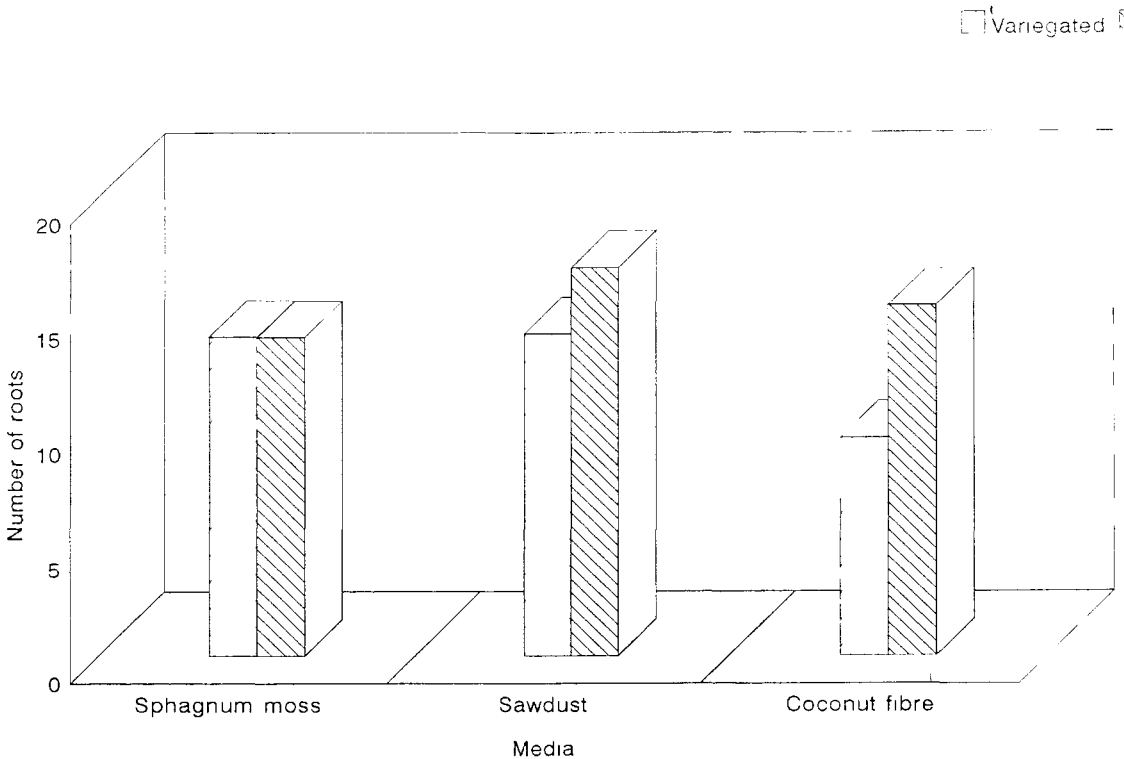


Fig 8 Number of roots in layers as influenced by different media

Plate 7 Effect of different concentrations of NAA on root production of air layers of *S arboricola* (Variegated')

Plate 8 Effect of different media on rooting of air layers of *S arboricola* (Variegated)

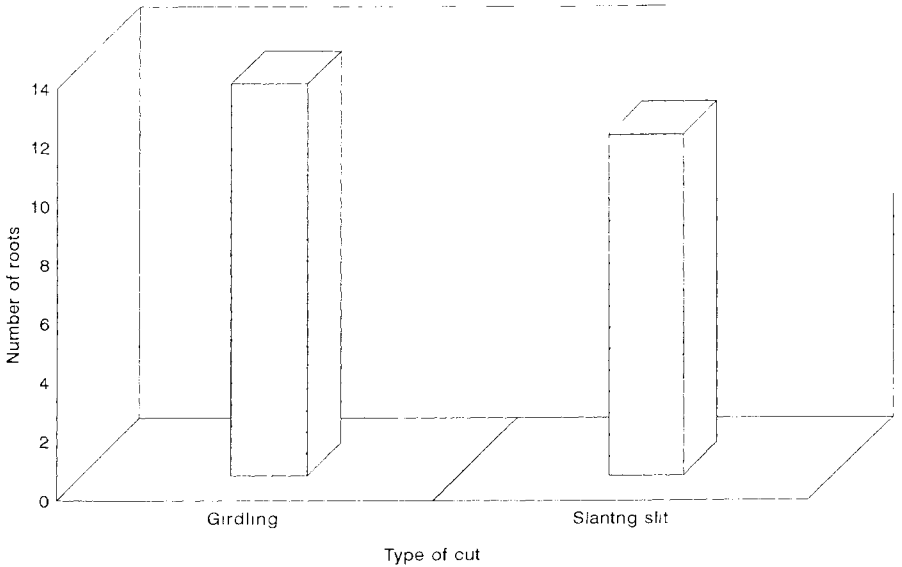


Fig 9 Number of roots in `variegated' layers as influenced by type of wounding method

Plate 7 Effect of different concentrations of NAA on root production of air layers of *S arboricola* (Variegated')

Plate 8 Effect of different media on rooting of air layers of *S arboricola* (Variegated)


CONTROL
NAA 50
NAA 100
NAA 200


COIR FIBRE
SPHAGNUM MOSS
SAWDUST

Plate 9 Effect of wounding method on rooting of air layers of *S. arboricola* (Variegated)


SLANTING SLIT
GIRDLING

From the interaction effect it was clear that longest roots were produced with 50 mg l^{-1} concentration of IBA NAA and IAA with sphagnum moss as medium When sawdust was used as the medium IBA and NAA at 50 mg l^{-1} and IAA at 200 mg l^{-1} were found to be beneficial Whereas with coconut fibre NAA at 100 mg l^{-1} was found to be the superior treatment

Type of cut used for layering did not have any significant influence on length of the longest root produced

4 3 4 Total length of roots

Main effect of growth regulators and media was significant whereas main effect of type of cut was not significant Interaction effect of growth regulators x media was significant

NAA at 50 mg l^{-1} gave higher value (146 2 cm) for total length of roots (Table 19 Fig 10)

On an average total length of roots recorded by sphagnum moss and sawdust treatment did not differ significantly but these media were superior to coconut fibre (Fig 11)

NAA at 50 mg l^{-1} both with sphagnum moss and sawdust as media gave higher value for total length of roots whereas with coconut fibre no significant difference was seen among the treatments

The wounding method used for layering did not have any significant influence on total length of roots

Table 19 Effect of growth regulators media and type of cut on total length of roots of variegated layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	99 01^{c}	85 64^{bdc}	37 57^{fg}	74 07^{b}
IBA 100	78 46^{cc}	93 57^{bd}	50 94^{dfg}	74 32^{b}
IBA 200	86 82^{cc}	64 18^{bdch}	37 33^{fg}	62 78^{bc}
NAA 50	183 8^{a}	180 8^{a}	74 17^{df}	146 2^{a}
NAA 100	54 86^{ceh}	59 45^{deh}	60 22^{dfg}	58 18^{bc}
NAA 200	47 62^{eh}	49 87^{deh}	25 37^{g}	40 95^{c}
IAA 50	67 47^{ce}	20 07^{h}	41 14^{fg}	42 80^{c}
IAA 100	46 85^{eh}	58 61^{deh}	33 21^{fg}	46 22^{c}
IAA 200	84 47^{cc}	108 3^{b}	35 05^{fg}	75 93^{b}
Control	65 16^{ceh}	77 84^{bdc}	51 97^{dfg}	64 99^{bc}
Mean	81 45^{a}	79 83^{a}	44 70^{b}	
Type of cut			Mean	
Girdling			74 07^{a}	
Slanting slit			63 25^{a}	

*Treatment means in a column with same letter do not differ significantly

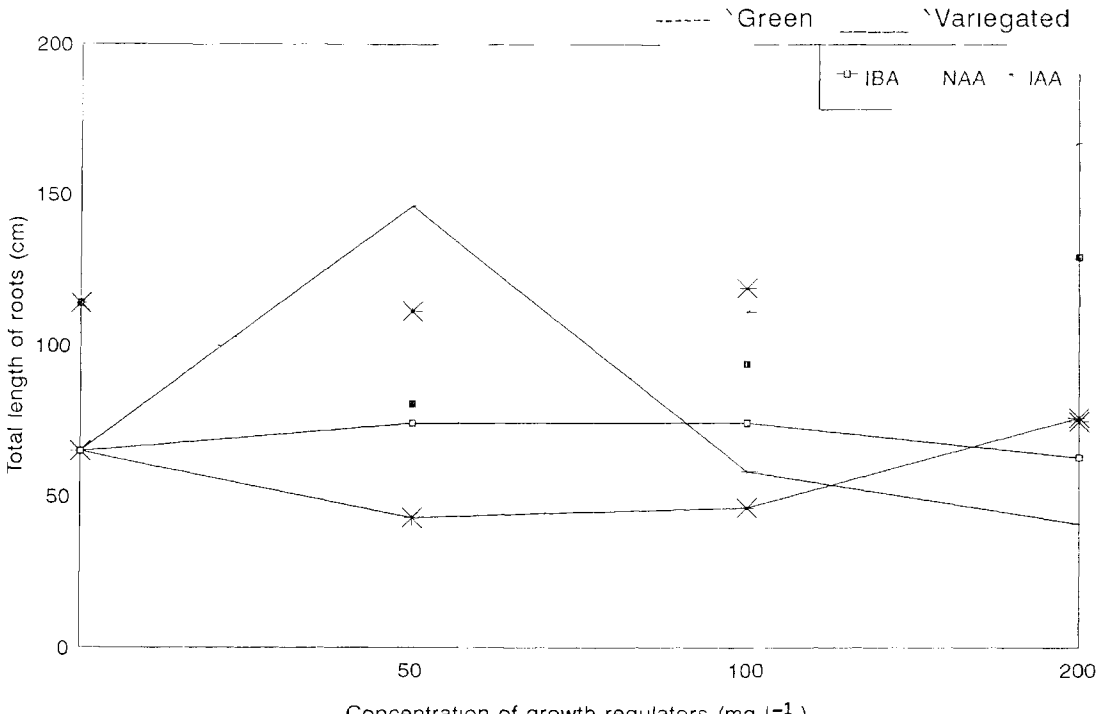


Fig10 Total length of roots in layers as influenced by concentration of growth regulators

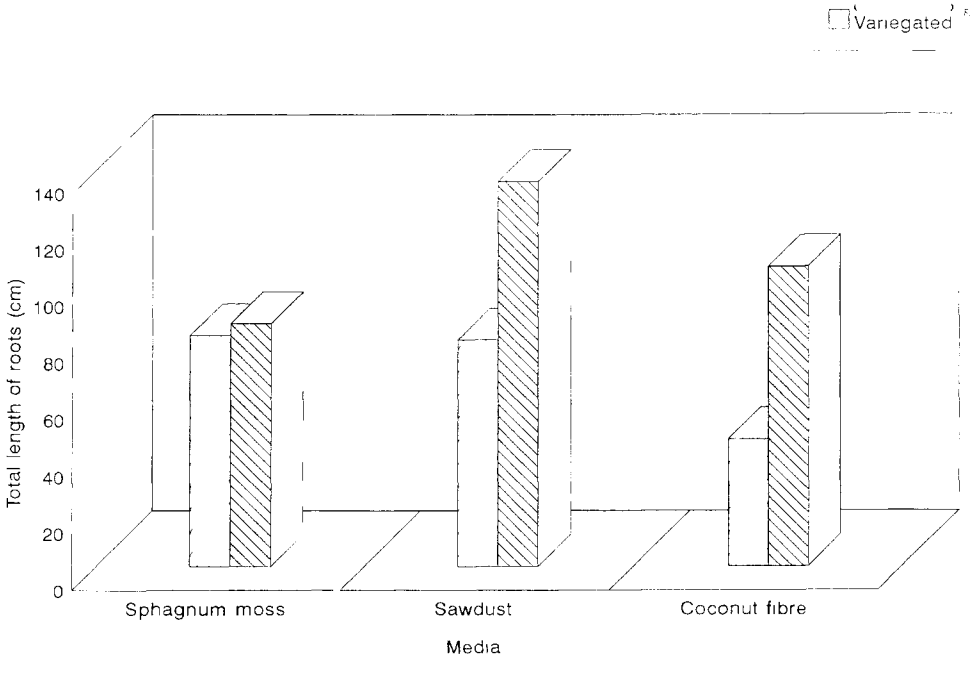


Fig 11 Total length of roots in layers as influenced by different media

4 3 5 Average length of roots

Main effect of growth regulators and media was statistically significant whereas main effect of type of cut was not significant IBA and NAA at 50 100 and 200 mg l^{-1} and IAA at 100 mg l^{-1} appear to be similar in performance (Table 20)

On an average sphagnum moss and sawdust treatment did not differ significantly but were superior to coconut fibre

Interaction effect of growth regulators x media was significant From the interaction effect it was found that with sphagnum moss as media IBA and NAA at 50 100 and 200 mg l^{-1} and IAA at 50 and 100 mg l^{-1} and with sawdust IBA and NAA at 50 100 and 200 mg l^{-1} and IAA at 200 mg l^{-1} appear to be superior treatments Whereas with coconut fibre IBA at 200 mg l^{-1} and NAA and IAA at 100 mg l^{-1} appear to be beneficial treatments

The method of wounding used for layering did not influence the average length of roots

4 3 6 Fresh weight of roots

Main effect of growth regulators and media was significant whereas main effect of type of cut was not significant Interaction effect of growth regulators and media was statistically significant

NAA at 50 mg l^{-1} (3 04 g) was found to be the superior treatment with regard to fresh weight of roots (Table 21)

Table 20 Effect of growth regulators, media and type of cut on average length of roots of variegated layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	6 24^{ac}	6 29^{ac}	3 76^{e}	5 43^{b}
IBA 100	5 57^{acd}	5 25^{ac}	4 79de	5 20^{ab}
IBA 200	5 30^{acd}	5 55^{ac}	5 11^{bde}	5 32^{ab}
NAA 50	6 62^{a}	5 87^{ac}	4 24de	5 58^{ab}
NAA 100	5 40^{acd}	5 48^{ac}	6 28^{b}	5 72^{a}
NAA 200	5 45^{acd}	6 73^{a}	4 51de	5 56^{ab}
IAA 50	6 51^{a}	3 54^{f}	4 38de	4 81^{b}
IAA 100	6 27^{ac}	4 93^{ef}	4 93^{bde}	5 38^{ab}
IAA 200	4 28^{d}	5 49^{ac}	4 34de	4 70^{b}
Control	4 67^{cd}	4 85^{ef}	4 55de	4 69^{b}
Mean	5 630^{a}	5 398^{a}	4 689^{b}	

Type of cut	Mean
Girdling	5 26^{a}
Slanting slit	5 22^{a}

*Treatment means in a column with same letter do not differ significantly

Table 21 Effect of growth regulators media and type of cut on fresh weight of roots of variegated layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	1 554^{dc}	3 356^{a}	1 539^{dc}	2 150^{b}
IBA 100	2 030^{bdc}	3 128^{ac}	1 573^{dg}	2 243^{b}
IBA 200	2 172^{bd}	1 419^{dcg}	1 087^{dg}	1 559^{bc}
NAA 50	4 395^{a}	3 763^{a}	0 964^{dg}	3 040^{a}
NAA 100	0 921de	0 534^{eg}	0 647^{dg}	0 701^{d}
NAA 200	0 723^{dc}	0 410^{g}	0 225^{g}	0 452^{c}
IAA 50	0 889^{dc}	0 411^{g}	0 764^{dg}	0 688^{dc}
IAA 100	0 550^{c}	0 529^{cg}	0 442^{g}	0 507^{dc}
IAA 200	1 665^{dc}	1 874^{cdc}	0 414^{g}	1 318^{cd}
Control	1 022^{dc}	1 574^{dcg}	1 051^{dg}	1 216^{cdc}
Mean	1 592^{a}	1 700^{a}	0 871^{b}	
Type of cut			Mean	
Girdling			1 549^{a}	
Slanting slit			1 226^{a}	

*Treatment means in a column with same letter do not differ significantly

On an average sawdust and sphagnum moss were equally effective treatments with respect to fresh weight of roots

The interaction effect showed that NAA at 50 mg l^{-1} with sphagnum moss as medium gave higher value for fresh weight of roots and with sawdust IBA at 50 and 100 mg l^{-1} and NAA at 50 mg l^{-1} were superior treatments Whereas with coconut fibre no significant difference was seen among the treatment combinations

No significant influence of the method of wounding used for layering on the fresh weight of roots was noticed

4 3 7 Dry weight of roots

Main effect of growth regulators and media was significant but main effect of type of cut was not significant Interaction effect of growth regulators x media was significant

NAA at 50 mg l^{-1} (0 45 g) was the superior treatment in terms of dry weight of roots (Table 22)

On an average sawdust and sphagnum moss were equally effective media

From the interaction effect it was noticed that dry weight of roots was higher with NAA at 50 mg l^{-1} with sphagnum moss as medium whereas with sawdust IBA at 50 and 100 mg l^{-1} and NAA at 50 mg l^{-1} appear to be equally effective treatments In the case of coconut fibre there was no significant difference among the different treatment combinations

Table 22 Effect of growth regulators media and type of cut on dry weight of roots of variegated layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	0 183^{c}	0 471^{ab}	0 163^{c}	0 272^{b}
IBA 100	0 269^{c}	0 466^{ab}	0 182^{c}	0 306^{b}
IBA 200	0 255^{c}	0 153^{c}	0 112^{c}	0 173^{bc}
NAA 50	0 604^{d}	0 659^{d}	0 099^{c}	0 454^{d}
NAA 100	0 104^{c}	0 054^{c}	0 091^{c}	0 083^{c}
NAA 200	0 065^{c}	0 061^{c}	0 041^{c}	0 056^{c}
IAA 50	0 062^{c}	0 018^{c}	0 154^{c}	0 078^{c}
IAA 100	0 019^{c}	0 048^{c}	0 011^{c}	0 026^{c}
IAA 200	0 218^{c}	0 225^{bc}	0 035^{c}	0 159^{bc}
Control	0 115^{c}	0 298^{bc}	0 094^{c}	0 169^{bc}
Mean	0 189^{d}	0 245^{d}	0 098^{b}	

Type of cut	Mean
Girdling	0 204^{d}
Slanting slit	0 151^{d}

*Treatment means in a column with same letter do not differ significantly

The wounding methods used for layering did not have any influence on dry weight of roots

4 4 Layering ('Green')

Effect of growth regulators media and type of cut on number of days taken for rooting number of roots length of the longest root total length of roots average length of roots, fresh and dry weight of roots in green type of schefflera are presented below

4 4 1 Number of days taken for rooting

Effect of growth regulators media and the type of cut (main effects) was significant Interaction effect of growth regulators x media was also significant whereas interaction effect of growth regulators x type of cut and media x type of cut was not significant

The data presented in Table 23 show that untreated layers took minimum period (25 8 days) for rooting

On an average sphagnum moss and sawdust were equally effective in effecting earliness in rooting of layers (Fig 6)

From the interaction effect it was noticed that untreated layers with coconut fibre sphagnum moss and sawdust as media showed earliness in rooting

The type of cut used for layering significantly influenced the days taken for rooting and on an average rooting was earlier in the case of girdling method compared to slanting slit cut method (Fig 12)

Table 23 Effect of growth regulators, media and type of cut on number of days taken for rooting of 'green' layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	52 10^{fhi}	50 10^{hi}	56 60^{c}	52 93^{cd}
IBA 100	52 50^{fhi}	48 60^{hi}	56 30^{c}	52 47^{cd}
IBA 200	65 20^{ad}	53 40^{hi}	68 20^{bc}	62 27^{ab}
NAA 50	45 60^{hi}	56 00^{h}	60 80^{bcc}	54 13^{c}
NAA 100	44 10^{i}	69 10^{a}	59 70^{bcc}	57 63^{bc}
NAA 200	50 10^{fhi}	42 60^{i}	51 50^{e}	48 07^{d}
IAA 50	56 70^{dfh}	47 00^{hi}	69 00^{b}	57 57^{bc}
IAA 100	48 80^{fhi}	53 70^{hi}	58 10^{cc}	53 53^{cd}
IAA 200	74 10^{a}	52 70^{hi}	68 50^{bc}	65 10^{a}
Control	26 00^{j}	24 40^{j}	26 90^{j}	25 77^{e}
Mean	51 52^{b}	49 76^{b}	57 56^{a}	

Type of cut	Mean
Girdling	51 71^{a}
Slanting slit	54 18^{b}

*Treatment means in a column with same letter do not differ significantly

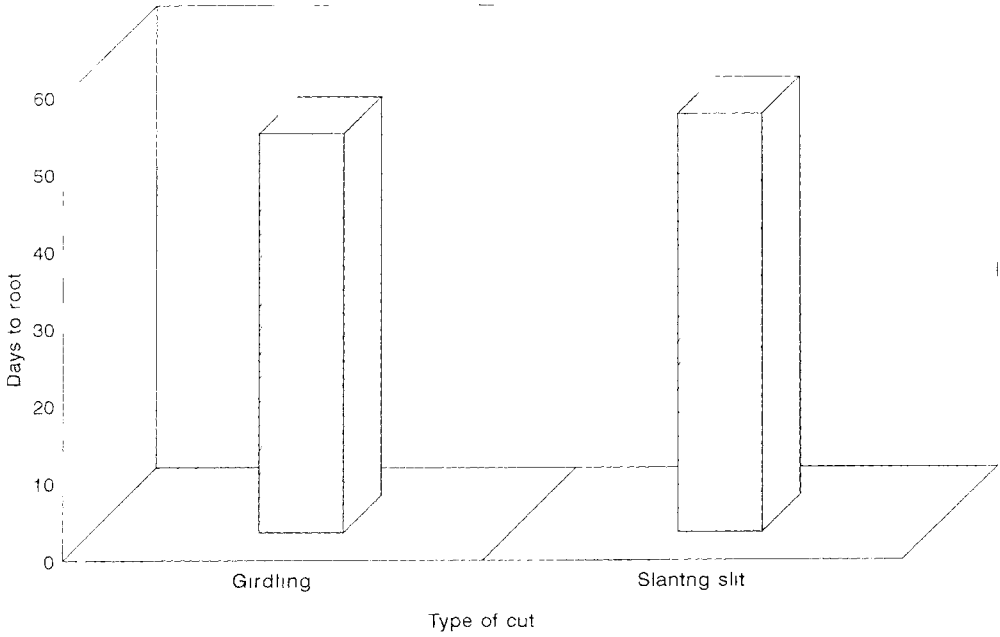


Fig 12 Number of days taken for rooting in `green layers as influenced by type of wounding method

4 4 2 Number of roots

Main effect of growth regulators and media was significant whereas main effect of type of cut was not significant Interaction effect of growth regulators x media was significant

From the data presented in Table 24 and depicted in Fig 7 NAA and IBA at 100 and 200 mg l^{-1} and IAA at 100 mg l^{-1} and untreated layers appeared to be similar in performance

Of the different media used on an average sphagnum moss and sawdust differed in their effect while performance of coconut fibre did not differs from these two media like sawdust and coconut fibre Sawdust was found to be the best medium with respect to number of roots (Table 24 Fig 8 Plate 10)

From the combinations of different growth regulators with media NAA at 100 and 200 mg l^{-1} and untreated layer with sphagnum moss as medium and IBA and IAA at 50 and 100 mg l^{-1} and NAA at 50 100 and 200 mg l^{-1} and untreated layer with coconut fibre as medium appeared to be similar in performance Whereas with sawdust as medium IBA and NAA at 200 mg l^{-1} produced significantly higher number of roots compared with untreated layers

The number of roots produced was not influenced by the type of wounding method used for layering

4 4 3 Length of the longest root

Length of the longest root was significantly influenced by the growth

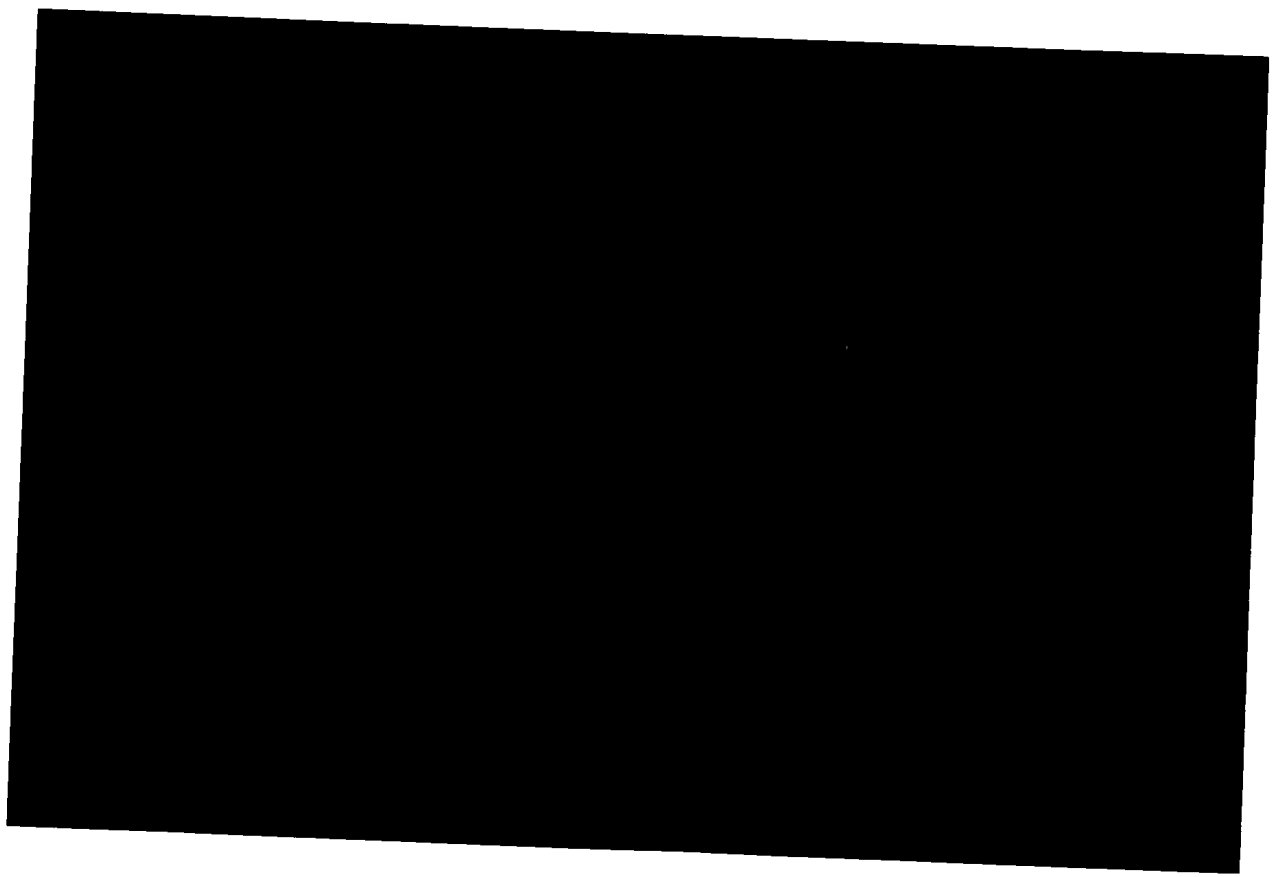
Table 24 Effect of growth regulators, media and type of cut on number of roots of green layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	11 60^{fh}	14 80^{cdh}	14 10^{cch}	13 50^{bcd}
IBA 100	13 60^{cfh}	17 10^{cd}	21 60^{c}	17 43^{ab}
IBA 200	12 80^{cfh}	28 30^{a}	11 10^{ch}	17 40^{ab}
NAA 50	7 10^{h}	11 90^{dh}	14 90^{cch}	11 30^{cd}
NAA 100	26 70^{b}	15 50^{cdh}	14 20^{cch}	18 80^{a}
NAA 200	18 80^{bccf}	21 20^{acd}	20 10^{cc}	20 03^{a}
IAA 50	13 10^{cfh}	13 40^{cdh}	14 30^{cch}	13 60^{bcd}
IAA 100	9 60^{fh}	17 80^{bcd}	21 90^{c}	16 43^{ab}
IAA 200	7 50^{h}	14 20^{cdh}	7 20^{h}	9 63^{d}
Control	17 80^{bccf}	14 80^{cdh}	12 90^{cch}	15 17^{bc}
Mean	13 86^{b}	16 90^{a}	15 23^{ab}	

Type of cut	Mean
Girdling	16 09^{d}
Slanting slit	14 57^{d}

*Treatment means in a column with same letter do not differ significantly

Plate 10 Effect of different media on rooting of air layers of *S arboricola* (Green)



regulators and media The interaction effect of these factors was also significant Whereas main effect of type of cut was not sigmficant

On the whole NAA at 200 mg l^{-1} and IAA at 50 and 100 mg l^{-1} gave higher value for length of the longest root (Table 25)

On an average, sawdust and coconut fibre were equally effective as media in influencing the length of the longest root

From the interaction effect it was clear that with sphagnum moss as medium IBA at 50 and 100 mg l^{-1} and NAA at 100 and 200 mg l^{-1} and IAA at 50 mg l^{-1} and untreated layer were superior treatments Using sawdust as medium IBA and NAA at 200 mg l^{-1} and IAA at 100 and 200 mg l^{-1} were effective treatments Whereas with coconut fibre NAA at 200 mg l^{-1} and IAA at 50 and 100 mg l^{-1} were beneficial

The wounding method used for layering did not have significant influence on length of the longest root

4 4 4 Total length of roots

Main effect of growth regulators and media and their interaction effects were sigmficant However, the main effect of type of cut was not significant

Total length of roots was significantly high (167 1 cm) with NAA at 200 mg l^{-1} (Table 26 Fig 10 Plate 11)

Of the different media tried on an average sawdust was found to be the best medium (Fig 11)

Table 25 Effect of growth regulators media and type of cut on length of the longest root of green layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	9 60^{fh}	10 85^{dh}	11 30^{cdh}	10 58^{d}
IBA 100	9 44^{fh}	8 60^{h}	10 90^{cdh}	9 65^{d}
IBA 200	8 870^{h}	14 27^{bd}	11 26^{cdh}	11 47^{bcd}
NAA 50	8 79^{h}	10 11^{dh}	10 35^{dh}	9 75^{d}
NAA 100	10 26^{fh}	10 77^{dh}	11 00^{cdh}	10 68^{d}
NAA-200	12 34^{fh}	17 82^{b}	14 90^{acd}	15 05^{a}
IAA-50	14 49^{bf}	11 64^{dh}	15 78^{ac}	13 97^{ab}
IAA 100	7 49^{h}	14 63^{d}	18 48^{a}	13 53^{abc}
IAA 200	9 07^{h}	14 66^{bd}	10 17^{dh}	11 30^{cd}
Control	13 45^{bf}	12 65^{d}	9 52^{h}	11 87^{bcd}
Mean	10 38^{b}	12 60^{a}	12 38^{a}	

Type of cut	Mean
Girdling	11 92^{a}
Slanting slit	11 65^{a}

*Treatment means in a column with same letter do not differ significantly

Table 26 Effect of growth regulators media and type of cut on total length of roots of green layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	61 67^{eg}	93 85^{b}	86 09^{ce}	80 54^{cd}
IBA 100	83 29^{ceg}	96 33^{b}	101 7^{bce}	93 77^{bcd}
IBA 200	73 64^{ceg}	243 8^{a}	70 50^{ce}	129 3^{b}
NAA 50	44 39^{g}	89 75^{b}	136 6^{bce}	90 26^{bcd}
NAA 100	142 9^{c}	93 79^{b}	96 65^{bce}	111 1^{bcd}
NAA 200	110 1^{ceg}	250 4^{a}	140 7^{bc}	167 1^{a}
IAA 50	101 3^{ceg}	114 2^{b}	118 4^{bce}	111 3^{bcd}
IAA 100	55 06^{g}	133 7^{b}	168 1^{b}	119 0^{bc}
IAA 200	47 85^{g}	119 0^{b}	57 00^{e}	74 63^{d}
Control	136 7^{cc}	124 1^{b}	80 77^{ce}	113 9^{bcd}
Mean	85 7^{b}	135 9^{a}	105 7^{b}	
Type of cut			Mean	
Girdling			116 30^{a}	
Slanting slit			101 86^{a}	

*Treatment means in a column with same letter do not differ significantly

Plate 11 Effect of different concentrations of NAA on root length of air layers of *S arboricola* ('Green')

Plate 12 Effect of wounding method on rooting of air layers of *S arboricola* ('Green')


CONTROL
NAA-50
NAA-100
NAA 200


GIRDLING
SLANTING CUT

The interaction effects showed that with sphagnum moss as medium IBA and NAA at 100 and 200 mg l^{-1} and IAA at 50 mg l^{-1} and untreated layers are superior treatments. With sawdust IBA and NAA both at 200 mg l^{-1} were beneficial. Whereas with coconut fibre IBA at 100 mg l^{-1}, NAA at 50, 100 and 200 mg l^{-1} and IAA at 50 and 100 mg l^{-1} appear to be superior in performance.

Data on the influence of the method of wounding used for layering did not differ significantly (Table 26, Plate 12).

4.4.5 Average length of roots

Main effect of growth regulators and media and interaction effect of these factors were significant whereas main effect of type of cut was not significant.

On the whole, NAA at 200 mg l^{-1} and IAA at 50 and 200 mg l^{-1} were effective treatments (Table 27).

Of the different media tried, sawdust was found to be best medium.

From the interaction effect it was evidenced that with coconut fibre as medium NAA at 50 and 200 mg l^{-1} and IAA at 50, 100 and 200 mg l^{-1} and with sawdust as medium NAA at 200 mg l^{-1} appeared to be effective treatments. With sphagnum moss as medium IBA at 100 mg l^{-1} and IAA at 50 and 200 mg l^{-1} and untreated layer appeared to be beneficial treatments.

Type of cut used for layering did not influence the average length of roots of layers.

Table 27 Effect of growth regulators media and type of cut on average length of roots of green layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	5 34[i]	6 30[cdh]	5 93[fgi]	5 86[e]
IBA 100	6 30[cdh]	5 45[h]	5 44[i]	5 73[e]
IBA 200	5 84[i]	7 87[b]	6 37[efg]	6 69[d]
NAA 50	6 12[fh]	7 54[bc]	7 57[cc]	7 08[cd]
NAA 100	5 14[i]	5 64[h]	6 26[efgi]	5 68[e]
NAA 200	5 89[i]	11 43[a]	7 40[ccfg]	8 24[a]
IAA 50	7 63[bcf]	8 45[b]	8 24[c]	8 11[ab]
IAA 100	5 92[i]	7 24[bc]	6 76[cefg]	6 64[d]
IAA 200	6 48[cfh]	8 41[b]	8 19[c]	7 69[abc]
Control	7 76[bc]	8 28[b]	6 23[efgi]	7 42[bcd]
Mean	6 24[c]	7 66[a]	6 84[b]	

Type of cut	Mean
Girdling	7 07[a]
Slanting slit	6 76[a]

*Treatment means in a column with same letter do not differ significantly

4 4 6 Fresh weight of roots

Main effect of growth regulators and media and their interaction effect were significant whereas main effect of type of cut was not significant

As evidenced from the data presented in Table 28 NAA at 200 mg l^{-1} recorded the maximum (5 97 g) fresh weight of roots

Comparing the different media on an average sawdust was found to be as the best medium

From the interaction effect it was clear that fresh weight of root produced was higher in layers which were treated with IBA at 100 mg l^{-1} and NAA at 200 mg l^{-1} and IAA at 50 and 100 mg l^{-1} with coconut fibre as medium and in the case of sawdust NAA at 200 mg l^{-1} was found to be superior treatment With sphagnum moss as medium there was not much difference among the treatments

The wounding method used for layering did not have significant influence on fresh weight of roots

4 4 7 Dry weight of roots

Main effect of growth regulators and media and interaction effect of these factors were significant However main effect of type of cut was not significant NAA at 200 mg l^{-1} (0 73 g) was found to be as superior treatment (Table 29)

Of the different media tried on an average sawdust and coconut fibre were found to be better than sphagnum moss

Table 28 Effect of growth regulators, media and type of cut on fresh weight of roots of green layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	1 010^{gh}	2 395^{h}	1 929^{fh}	1 778^{bc}
IBA 100	1 124^{gh}	2 061^{h}	2 487^{cfh}	1 891^{bc}
IBA 200	1 173^{gh}	7 372^{b}	1 383^{h}	3 309^{b}
NAA 50	0 801^{gh}	1 444^{h}	1 985^{fh}	1 410^{c}
NAA 100	3 623^{g}	2 135^{h}	1 601^{fh}	2 453^{bc}
NAA 200	2 289^{gh}	11 22^{a}	4 412^{cf}	5 974^{a}
IAA 50	1 900^{gh}	2 014^{h}	4 998^{c}	2 971^{b}
IAA 100	0 838^{gh}	3 241^{ch}	5 109^{c}	3 063^{b}
IAA 200	0 531^{h}	5 218^{bc}	1 147^{h}	2 299^{bc}
Control	3 249^{gh}	2 493^{ch}	1 144^{h}	2 295^{bc}
Mean	1 654^{c}	3 959^{a}	2 619^{b}	

Type of cut	Mean
Girdling	2 999^{a}
Slanting slit	2 490^{a}

*Treatment means in a column with same letter do not differ significantly

Table 29 Effect of growth regulators media and type of cut on dry weight of root of green layers

Growth regulators	Media			
	Sphagnum moss	Sawdust	Coconut fibre	Mean
IBA 50	0 083^{g}	0 331^{dg}	0 222^{g}	0 212^{b}
IBA 100	0 113^{fg}	0 279^{g}	0 291^{g}	0 228^{b}
IBA 200	0 125^{fg}	0 977^{ab}	0 161^{g}	0 421^{b}
NAA 50	0 103^{fg}	0 158^{g}	0 496^{cg}	0 252^{b}
NAA 100	0 568^{f}	0 286^{g}	0 224^{g}	0 359^{b}
NAA 200	0 292^{fg}	1 289^{a}	0 606^{c}	0 729^{a}
IAA 50	0 221^{fg}	0 238^{g}	0 758^{c}	0 406^{b}
IAA 100	0 081^{g}	0 470^{dg}	0 834^{c}	0 462^{b}
IAA 200	0 047^{g}	0 753^{bd}	0 206^{g}	0 336^{b}
Control	0 429^{fg}	0 319^{dg}	0 131^{g}	0 293^{b}
Mean	0 206^{b}	0 510^{a}	0 393^{a}	
Type of cut			Mean	
Girdling			0 403^{a}	
Slanting slit			0 337^{a}	

*Treatment means in a column with same letter do not differ significantly

Dry weight of roots was higher with NAA at 50 and 200 mg l^{-1} or IBA at 50 and 100 mg l^{-1} with coconut fibre as medium whereas with sawdust as medium IBA and NAA at 200 mg l^{-1} were found to be beneficial treatments With sphagnum moss as medium there was not much difference among the treatments

Type of cut used for layering did not have significant influence on dry weight of roots

4 4 8 Percentage success in layers

Percentage success in rooting of layers (Table 30 Plate 13) depended on the growth regulator media and type of wounding method employed In untreated layers (variegated and green) the percentage success obtained was only 75 whereas in both variegated and green type the percentage success obtained in rooting of layers with NAA treatment was 87 5

4 5 *In vitro* propagation

The results of various experiments carried out to standardise the *in vitro* propagation technique in *S arboricola* are presented in this section

4 5 1 Surface sterilization of explants

The results of the trial on surface sterilization of explants are presented in Table 31 and 32 Of the different surface sterilants tried mercuric chloride 0 1 per cent was found to be effective for all the explants In the case of nodal explants and shoot tips contamination was found to be a serious problem So in all treatment was given with emisan 0 1 per cent for 10 minutes and then wiped with cotton dipped in 70 per cent alcohol An initial dipping of nodal explants and shoot

Table 30 Effect of growth regulators, media and type of cut on the percentage success in layers

Growth regulators	Media	Type of cut	Percentage success	
			Variegated	Green
1	2	3	4	5
IBA 50	SM	G	75 0	75 0
		SS	75 0	75 0
IBA 100	SM	G	87 5	75 0
		SS	62 5	62 5
IBA 200	SM	G	75 0	75 0
		SS	75 0	75 0
IBA 50	SD	G	75 0	75 0
		SS	75 0	75 0
IBA 100	SD	G	87 5	87 5
		SS	75 0	75 0
IBA 200	SD	G	62 5	100 0
		SS	75 0	75 0
IBA 50	CF	G	75 0	75 0
		SS	62 5	75 0
IBA 100	CF	G	75 0	75 0
		SS	62 5	62 5
IBA 200	CF	G	62 5	75 0
		SS	62 5	62 5
NAA 50	SM	G	100 0	62 5
		SS	75 0	62 5
NAA 100	SM	G	75 0	100 0
		SS	75 0	75 0
NAA 200	SM	G	75 0	87 5
		SS	62 5	75 0
NAA 50	SD	G	100 0	87 5
		SS	75 0	75 0
NAA 100	SD	G	87 5	87 5
		SS	62 5	75 0

Contd

Table 30 Continued

1	2	3	4	5
NAA 200	SD	G	75 0	87 5
		SS	75 0	75 0
NAA 50	CF	G	87 5	87 5
		SS	75 0	62 5
NAA 100	CF	G	75 0	75 0
		SS	62 5	62 5
NAA 200	CF	G	62 5	75 0
		SS	62 5	62 5
IAA 50	SM	G	62 5	75 0
		SS	62 5	75 0
IAA 100	SM	G	62 5	75 0
		SS	62 5	62 5
IAA 200	SM	G	87 5	62 5
		SS	75 0	62 5
IAA 50	SD	G	62 5	75 0
		SS	62 5	75 0
IAA 100	SD	G	75 0	87 5
		SS	62 5	62 5
IAA 200	SD	G	87 5	75 0
		SS	75 0	75 0
IAA 50	CF	G	75 0	75 0
		SS	62 5	62 5
IAA 100	CF	G	62 5	75 0
		SS	62 5	75 0
IAA 200	CF	G	75 0	62 5
		SS	62 5	62 5
Control	SM	G	75 0	62 5
		SS	62 5	62 5
Control	SD	G	75 0	75 0
		SS	62 5	62 5
Control	CF	G	62 5	62 5
		SS	62 5	62 5

SM - Sphagnum moss SD Sawdust CF Coconut fibre
G - Girdling, SS Slanting slit

Table 31 Effect of different surface sterilants and duration of surface sterilization on survival rate of nodal explants of *S arboricola*

Surface sterilants	Duration of surface sterilization (minutes)	% survival after 2 weeks
5% Domestos	5	Nil
	10	Nil
10% Domestos	5	Nil
	10	Nil
0 1% Mercuric chloride	5	16 6
	10	33 3
*50% Alcohol dipping for 1 min 0 1% Mercuric chloride	12	37 5
*	15	50 0
*	18	75 0

* An initial treatment with emisan (0 1%) and then wiping with cotton dipped in alcohol (70%) were given

Table 32 Standardisation of surface sterilization treatment for leaf explants of *S. arboricola*

Surface sterilant	Duration of surface sterilization (min.)	% survival after 2 weeks
0.1% Mercuric chloride	5	40.0
	10	93.3
	15	Nil

Plate 13 Well established air layers growing in polybags

tips in 50 per cent alcohol for 1 minute followed by mercuric chloride treatment for a period of 18 minutes for nodal explants and 12 minutes for shoot tips resulted in the least rate of contamination Whereas in the case of leaf explants mercuric chloride treatment for a period of 10 minutes was found to be effective

4 5 1 1 Contamination rate and culture establishment as influenced by season of collection of explants

The rate of contamination and establishment of cultures varied with the season of collection of explants (Table 33) Better survival of cultures and less contamination was noticed with explants collected during the period from January to April Whereas May to December was found to be conducive season for the growth of micro organisms and the consequent microbial load on the explants which resulted in poor establishment of cultures

4 5 2 Culture media

Two different basal media viz MS and WPM were tried for callus mediated organogenesis MS was found to be good for the growth of cultures and callus induction (Table 34) Thus it was used as the basal medium for direct organogenesis

4 5 3 Callus mediated organogenesis

4 5 3 1 Callus induction

Immature (L_1) and young (L_2) leaves were found to be good for the initiation of callus (Table 35)

Table 33 Seasonal variations in the rate of contamination and culture establishment in *S arboricola*

Month	Contaminated (%)		Uncontaminated (%)		Culture establishment (%)	
	Leaf explants	Nodal explants	Leaf explants	Nodal explants	Leaf explants	Nodal explants
January	15 0	40 0	85 0	60 0	40 0	30 0
February	10 0	30 0	90 0	70 0	50 0	35 0
March	7 0	25 0	93 0	75 0	60 0	40 0
April	8 0	28 0	92 0	72 0	55 0	38 0
May	80 0	95 0	20 0	5 0	5 0	1 0
June	90 0	100 0	10 0	Nil	Nil	Nil
July	90 0	100 0	10 0	Nil	Nil	Nil
August	80 6	90 5	19 4	9 5	2 0	Nil
September	80 2	90 0	19 8	10 0	2 0	Nil
October	75 0	85 0	25 0	15 0	4 0	2 0
November	65 0	80 0	35 0	20 0	8 0	3 0
December	60 0	80 0	40 0	20 0	10 0	3 0

Nodal explants An initial treatment with cmisan (0 1%) followed by wiping with alcohol (70%) were given After that gave a 1 mm dip in alcohol (50%) and then treated with $HgCl_2$ (0 1%) for 18 mm

Leaf explants Treated with mercuric chloride (0 1%) for 10 min

Table 34 Effect of different basal media on callus growth in *S. arboricola*

Basal media	Callus growth	Colour of callus
MS	+ +	Cream
WPM	+	White

The basal media was supplemented with 2 4 D 1 mg l
+ + 0 6 cm diameter
+ 0 25 cm diameter

Table 35 Effect of leaf position on callus formation in *S. arboricola*

Leaf position	Number of days taken for callus initiation	% of cultures callused	Callus growth after 3 weeks
L_1	13 15	75	+ +
L_2	15 18	75	+ +
L_3		Nil	

L_1 Immature leaf
L_2 Young leaf
L_3 Mature leaf

+ + 0 6 cm diameter
No growth

The positioning of the leaves on the medium was found to have influence on callus initiation When the leaf explants were placed with the adaxial surface touching the medium the culture dried with in 5 7 days and when the orientation was abaxial surface touching the medium, it resulted in callus formation (Table 36)

The callus initiation was observed in about 13 15 days of culturing and the callus showed rapid growth rate upto 7 10 days Thereafter the growth slowed down The callus was cream friable and watery nature (Plate 14) and the quantum of callus produced was comparatively less in this crop The culture medium was supplemented with coconut water to enhance the production of callus But there was no further improvement in the production of callus (Table 37) Of the different levels of growth regulators tried, 2,4 D at 1-2 mg l^{-1} and NAA at 10 12 mg l^{-1} were found to be good for callus production (Table 38)

4 5 3 2 Organogenesis

The callus was transferred to medium containing different levels of BAP and Kinetin Even in the cytokinin rich medium also there was no shoot initiation and only rhizogenesis was noticed (Table 39) Incorporation of adenine sulphate into the medium was also tried along with a high level (15 mg l^{-1}) of cytokinin to induce shoot regeneration But rhizogenesis continued in all the treatments tried (Table 40)

The callus was cultured on to a medium incorporated with silver nitrate Silver nitrate was given at different levels (2 4 6 8 and 10 mg l^{-1}) and the cultures were incubated in this medium for different periods (2 3 and 4 weeks) But only

Table 36 Effect of positioning of the leaves on callus formation in *S. arborticola*

Positioning of the leaves on the medium	Response
Abaxial surface	Callus formation
Adaxial surface	Leaves dried

Table 37 Effect of coconut water on callus growth of *S arboricola*

Media	Response
MS + 2 4 D 1 mg l	Cream coloured friable and watery callus of 0 6 cm diameter
MS + 2 4 D 1 mg l + CW 10%	No improvement in callus growth than above
MS + 2 4 D 1 mg l + CW 15%	
MS + 2 4 D 1 mg l + CW 20%	

Table 38 Effect of growth regulators on callus initiation in leaf explants of *S arboricola*

Growth regulators	Days taken for callus initiation	Callus growth after 3 weeks
2 4 D 0 25 mg l^{-1}	16 18	No further growth
2,4 D 0 5 mg l	16-18	No further growth
2 4 D 1 mg l	13 15	+ +
2 4 D 2 mg l	14 16	+ +
2 4 D 4 mg l	14 18	+
NAA 1 mg l		
NAA 2 mg l		
NAA 4 mg l	17	No further growth
NAA 6 mg l	16 17	No further growth
NAA 8 mg l	16 17	No further growth
NAA 10 mg l	11 12	+
NAA 12 mg l	13 15	+ +
NAA 14 mg l	14-15	+
NAA 16 mg l	14 15	+
2 4 D 1 mg l + BAP 0 5 mg l^{-1}		
2,4 D 1 mg l + BAP 0 75 mg l	-	
2 4 D 1 mg l + BAP 1 mg l^{-1}		
Basal MS medium		

+ + 0 6 cm diameter + 0 25 cm diameter Leaf explants dried

TEST

Table 39 Effect of growth regulators on organogenesis from callus of *S. arboricola*

Growth regulators	Morphogenic response
BAP 3.5 mg l	Rhizogenesis
BAP 5 mg l	Rhizogenesis
BAP 10 mg l	Rhizogenesis
BAP 15 mg l	Rhizogenesis
Kinetin 6 mg l	Rhizogenesis
Kinetin 8 mg l	Rhizogenesis
Kinetin 10 mg l	Rhizogenesis
Basal MS medium	Rhizogenesis

Table 40 Effect of adenine sulphate on organogenesis from callus of *S. arboricola*

Media	Morphogenic response
MS + BAP 15 mg l^{-1} + Adenine sulphate 60 mg l^{-1}	Rhizogenesis
MS + BAP 15 mg l^{-1} + Adenine sulphate 80 mg l^{-1}	Rhizogenesis
MS + BAP 15 mg l^{-1} + Adenine sulphate 100 mg l^{-1}	Rhizogenesis

Table 41 Effect of nodal position on axillary bud break and growth of cultures of *S. arboricola*

Nodal position	Axillary bud break	Growth response
N_1		
N_2		
N_3	+	Poor growth
N_4	+	Good growth
N_5	+	Best growth
N_6	+	Best growth

\+ Presence
\- Absence

N_1 Node just below the shoot tip
N_2 to N_6 Nodal explants taken from tip to base of stem

Plate 14 Callus growth from leaf explants in MS medium supplemented with 2 4 D 1 mg l^{-1}

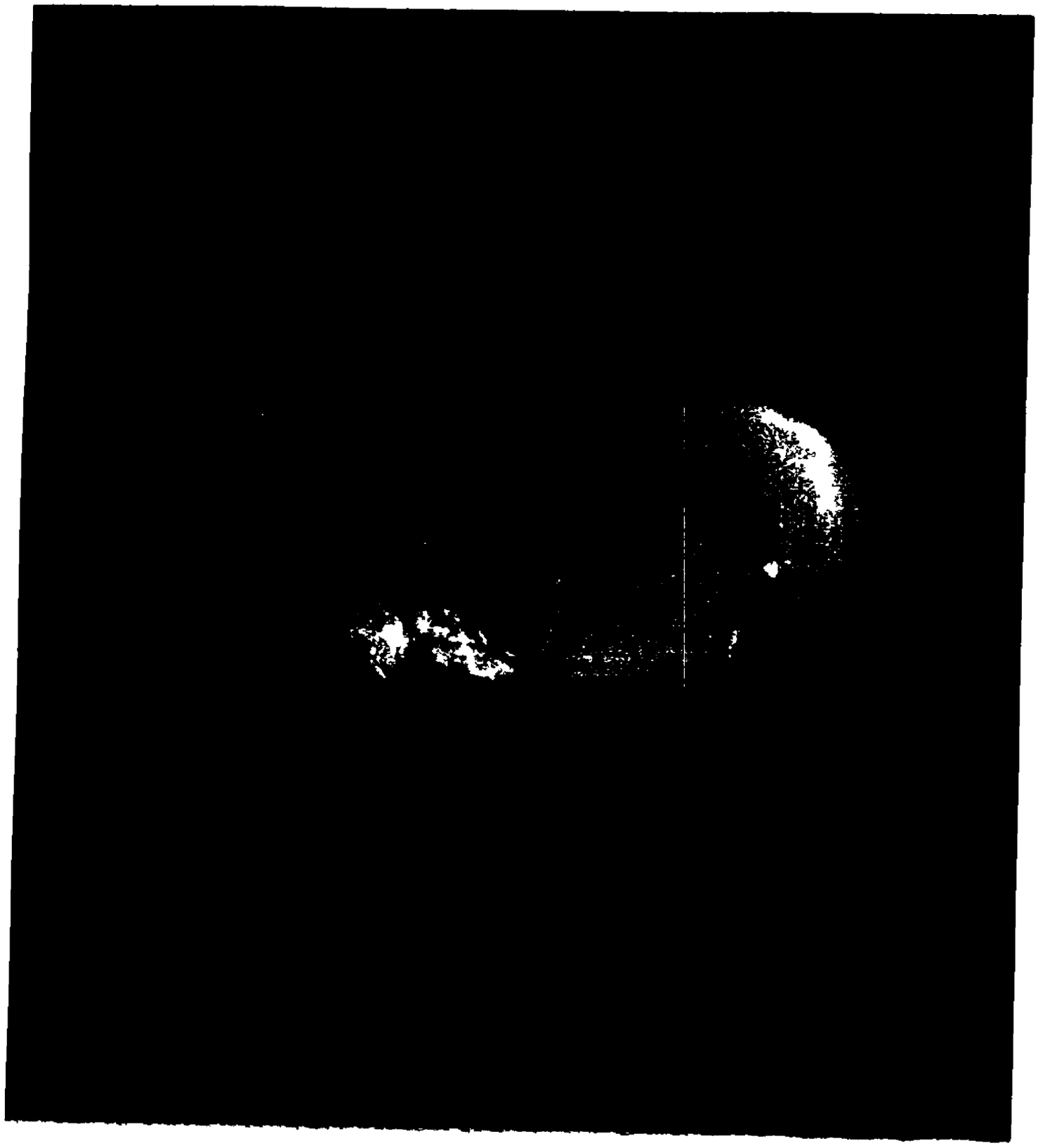


Table 42 Effect of different levels of cytokinins on culture establishment of nodal explants of *S arboricola*

Growth regulators	Response		
	Axillary bud break	Shoot elongation	Formation of leaves
BAP 0 5 mg l	+ (8-10 days)	+ (0 5 cm)	+ (4 leaves)
BAP 1 5 mg l	+ (8-12 days)	-	+ (1 leaf)
BAP 2 5 mg l	+ (8 12 days)		+ (1 leaf)
BAP 3 5 mg l	+ (9 12 days)		+ (2 leaves)
BAP 5 mg l	+ (10 16 days)		+ (2 leaves)
BAP 10 mg l	+ (10 15 days)		+ (3 leaves)
Kinetin 5 mg l	+ (12 17 days)		
Kinetin 10 mg l	+ (12 14 days)		+ (2 small leaves)

+ Presence
Absence

Basal medium Full strength MS

Plate 15a Effect of 2 4 6 8 and 10 mg l^{1} of silver nitrate (from left to right) on morphogenesis from callus

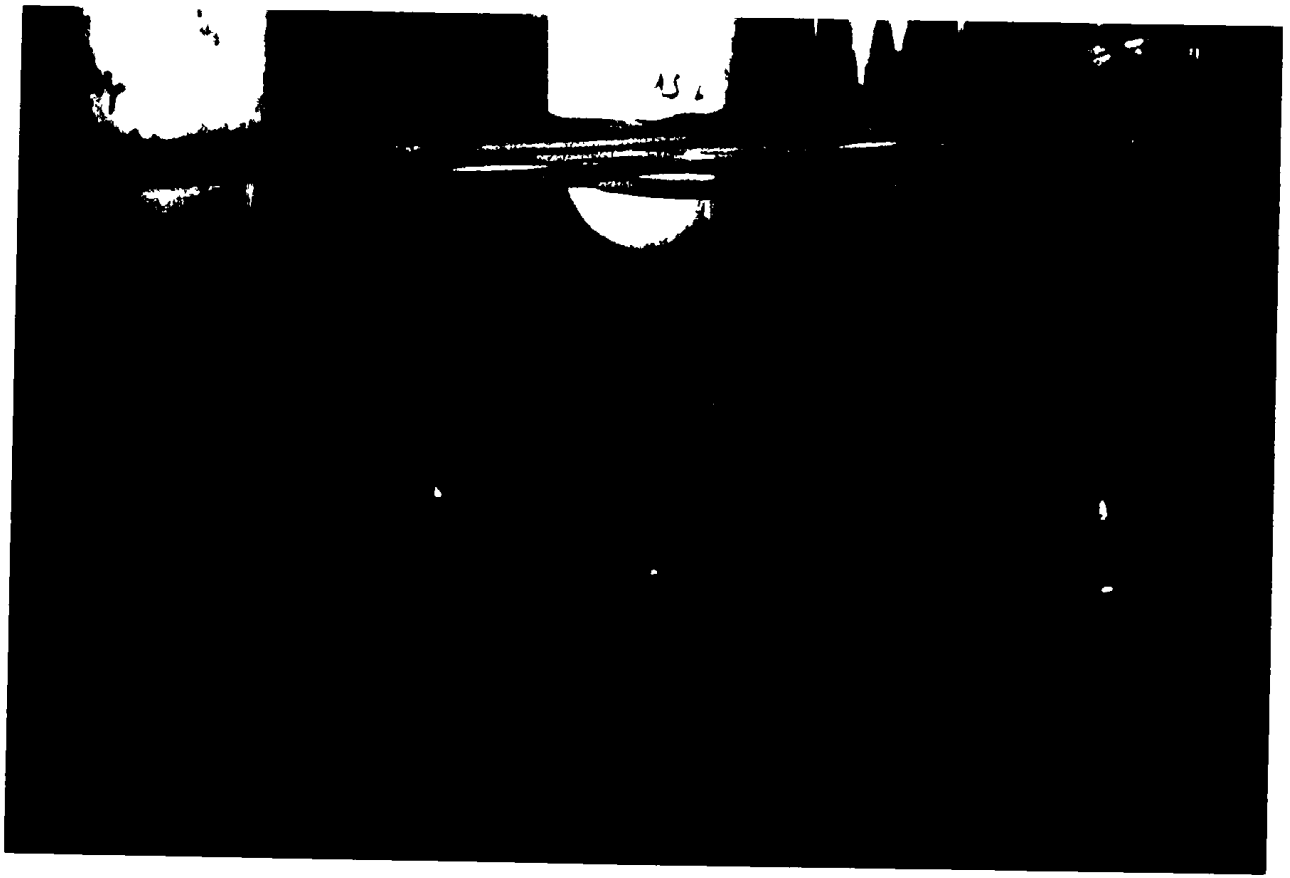


Plate 15b Morphogenesis from callus in MS medium supplemented with silver nitrate 6 mg l^{-1}
(Note only rhizogenesis noticed)

Plate 15c Morphogenesis from callus in MS medium supplemented with silver nitrate 8 mg l^{-1}
(Note only rhizogenesis noticed)

Plate 16 Rhizogenesis from callus even after the transfer of culture from medium supplemented with silver nitrate to medium containing BAP 3 5 mg l^{1} (left) and basal medium (right)

Plate 17 Effect of nodal positions (N_3, N_4 and N from left to right) on bud break in *S. arboricola*

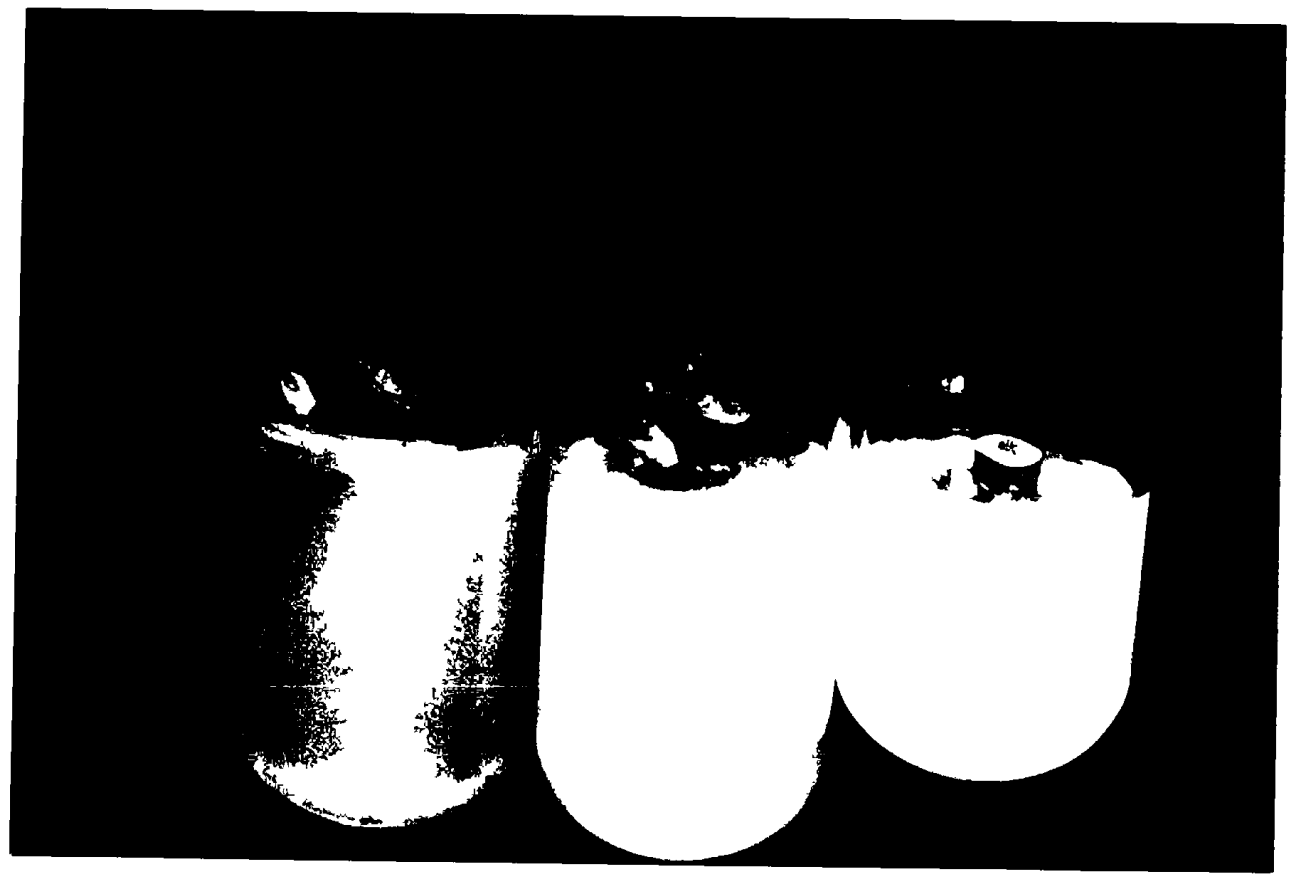
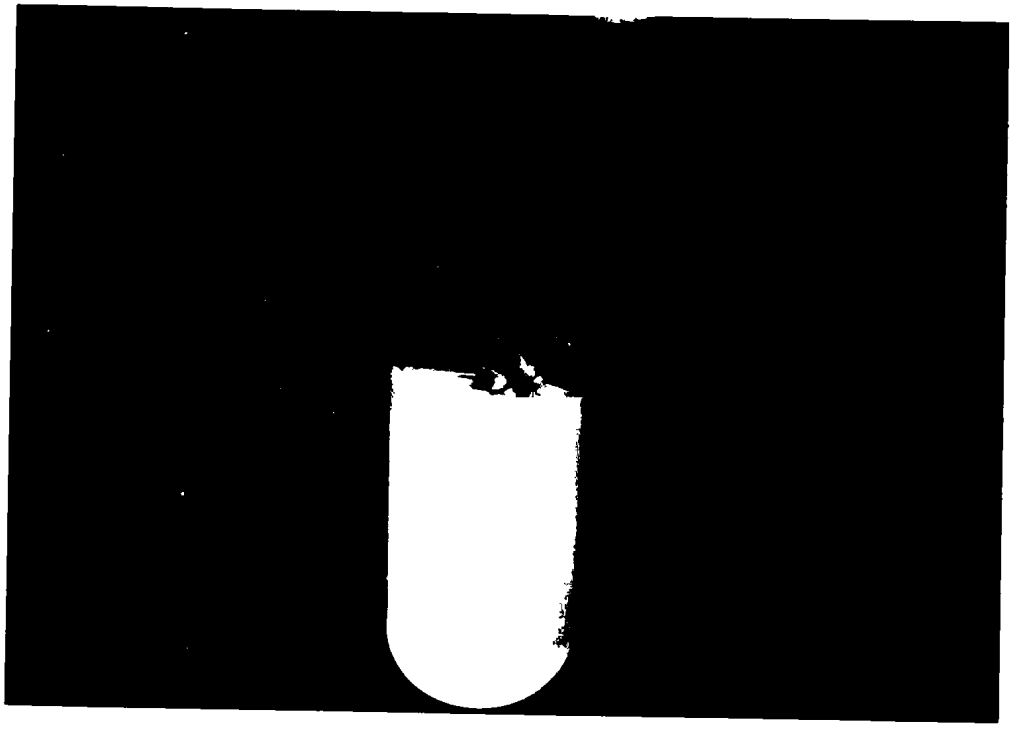


Plate 18a Bud sprout from nodal explant in MS medium supplemented with BAP 0 5 mg l^{-1}



was obtained also in medium with kinetin but no secondary shoots were formed in the axillary bud break and only 2 small leaves were formed (Table 15b)

4.5.4.2 Shoot multiplication

The established cultures showed best growth in the medium with BAP at 5 mg l^{-1} (Table 13). The growth of shoot in one month is shown in Plate 19a and within two months time the new shoot attained a height of 4 cm with new leaves were also formed (Plate 19b). In all the media tried the rate of shoot multiplication

4.5.4.3 *In vitro* rooting

In vitro developed shoots were rooted in media containing NAA and IBA and the optimum concentrations were found to be 1 mg l^{-1} respectively. The shoots rooted (Table 16) within 1 to 1½ half months. 20.5 roots having a total length of 105.4 cm were formed.

Preliminary studies on hardening of the *in vitro* regenerated plantlets were successful. Soilrite was found to be as the best medium for ex *vitro* establishment of the plantlets. The plantlets were covered with polythene and maintained for hardening. However further studies are required for standardising the protocol at stage IV of micropropagated schefflera plantlets

Table 43 Effect of growth regulators on growth of established cultures of *S arboricola*

Growth regulators	Growth response
BAP 1 5 mg l	Good growth
BAP 2 5 mg l	Good growth
BAP 3 5 mg l	Better growth
BAP 5 mg l	Best growth
BAP 3 5 mg l + NAA 0 1 mg l	Good growth
BAP 5 mg l + NAA 0 1 mg l	Good growth

Basal medium Full strength MS

Table 44 Effect of growth regulators on *in vitro* rooting of *S. arboricola*

Growth regulators	Response	Days to root	No. of roots	Total root length (cm)
IBA 0.3 mg l	No rooting			
IBA 0.5 mg l	No rooting			
IBA 0.7 mg l	No rooting			
NAA 1 mg l + IBA 0.3 mg l	No rooting			
NAA 2 mg l + IBA 0.3 mg l	Rooting	16.3	10.6	46.2
NAA 3 mg l + IBA 0.3 mg l	Rooting	14.1	20.5	105.4
NAA 4 mg l + IBA 0.3 mg l	Rooting	15.7	14.2	72.5

Basal medium: Full strength MS

Plate 18b Bud sprout from nodal explant in MS medium supplemented with kinetin 10 mg l^{-1}

Plate 19a Shoot growth in MS medium supplemented with BAP 5 mg l^{-1} after one month of culture period

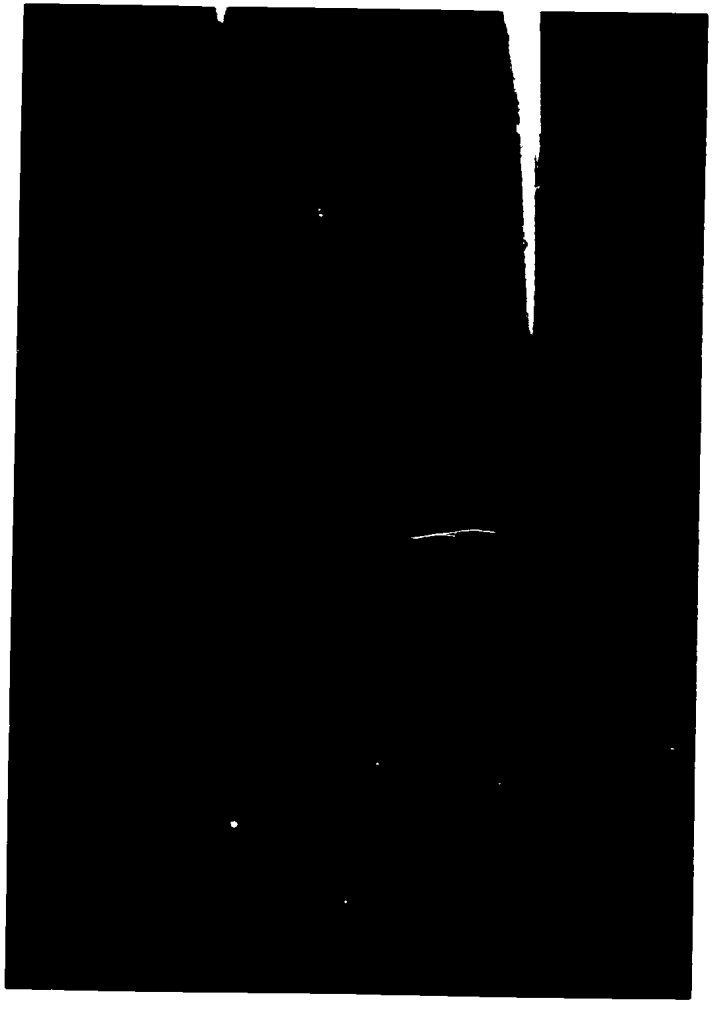


Plate 19b Shoot growth in MS medium supplemented with BAP 5 mg l^{-1} after two months of culture period

Plate 20 *In vitro* rooting in MS medium supplemented with NAA 3 mg l^{-1} and IBA 0 3 mg l^{-1}

Discussion

5 DISCUSSION

The results of the present investigations carried out to standardise the propagation techniques in *S arboricola* are discussed in this chapter

5 1 Cuttings

The results showed that in the case of variegated and green type of schefflera the cuttings treated with IBA and NAA, rooted in the shortest time

The rooting efficiency of growth regulators are generally assessed by the number of roots produced by the cuttings and their length and weight since these parameters ultimately decide the final percentage of establishment of the rooted cuttings in the main field (Hartmann *et al* 1993) The results of the present study revealed that auxin treatment had a pronounced effect on number length and weight of roots produced by cuttings In *Ficus elastica* rooting percentage number and length of roots was improved with IBA treatment (Kumar 1982) Read and Hoysler (1968) also reported increased root weight due to growth regulator application in dahlia, chrysanthemum and geranium cuttings

Girouard (1967) stated that IBA and NAA was superior because of their chemical stability and their low mobility in the plant In the case of variegated type of *S arboricola* quantity and quality of roots was best with the treatment of IBA at 200 mg l^{-1} (Tables 2 4 and 6 Plate 2) The beneficial effect of dipping the stem cuttings in IBA solution was also observed by Kachecheba (1975) in *Hibiscu rosa sinensis*

In green type of schefflera with respect to number length and weight of roots NAA at 50 and 200 mg l^{-1} and IBA at 200 mg l^{-1} were similar in performance (Tables 9 11 and 13) However IBA 200 mg l^{-1} recorded more number of days for rooting The lower concentration of NAA at 50 mg l^{-1} could be fixed as the optimum level of growth regulator in green type of schefflera (Plate 5) From the studies, it was clear that NAA treated cuttings produced more number of thicker and stouter roots This is in conformity with the findings in hibiscus (Shanmugavelu 1960)

Percentage success in rooting of cuttings depended on the growth regulator employed In variegated type of schefflera the percentage success obtained in rooting of double noded and single noded cuttings could be improved with an IBA treatment and in green type NAA treatment was found to be beneficial

So in schefflera growth regulators had a marked influence on improving the rooting efficiency in cuttings The beneficial effects of growth regulators on rooting of cuttings have been reported in different ornamental plants *Dracaena marginata* (Stevens, 1976) *Aphelandra Dieffenbachia Ficus benjamina Polyscias balfouriana* and *Syngonium podophyllum* (Poole *et al* 1980) *Ficus elastica* (Kumar 1982) *Ficus infectoria* (Jayasankar *et al* 1990) *Dracaena fragrans D deremensis D marginata* and *Gardenia jasminoides* (Hata *et al* 1994) Not much information on the effect of growth regulators on rooting of cuttings of the genus *Schefflera* or members of botanical family Araliaceae is available in the literature till date The external application of growth regulators would have perhaps increased the meristematic activity and root differentiation as has been reported by

Pontikis *et al* (1979) The growth regulators also help in the mobilization of reserve food materials and passing the metabolised sugars to the site of root initiation (Nanda 1970)

In both variegated' and green type of schefflera double noded cuttings proved to be superior to the single noded cuttings (Plate 3) This is in agreement with Hansen (1986a) who reported that in *S arboricola* cuttings with two or three fully developed leaves rooted much better giving stronger and longer roots than smaller cuttings with one leaf

The method of treatment of cuttings with growth regulators has been found to be a deciding factor in rooting of cuttings in many species (Woszczynska and Borys 1976 Kwack and Chung 1980) In the present study it was found that prolonged dip was more effective method of treatment in both green and variegated type of cuttings than quick dip The ultimate effect of a growth regulator treatment is decided by the amount of substance absorbed by the cuttings and not by the concentration alone (Gorecka 1979) In a prolonged dip treatment the higher amount of growth regulators absorbed perhaps directly effected a better rooting than in quick dip treatment

5 2 Layering

The present investigation showed that in the case of variegated type of schefflera with regard to number length fresh and dry weight of roots the treatment with growth regulators was found to be superior to untreated layers Among the different growth regulators tried NAA at 50 mg l^{-1} produced maximum rooting (Tables 17 19 and 21 Plate 7)

The present study also showed that in green type of schefflera with regard to quality of roots produced the growth regulator treatment was found to be superior to untreated layers Those treated with NAA at 200 mg l^{-1} tended to produce longer and stouter roots (Tables 26 and 28 Plate 11)

Percentage success in rooting of layers depended on the growth regulator medium and type of wounding method employed The percentage success obtained in rooting of layers could be improved with an NAA treatment using sawdust as the medium and girdling as the wounding method

Increased rooting of air layers treated with growth regulator has been reported in hollyhock (Lingaraj 1960), crossandra (Raman *et al* 1969) *Carissa jasminoides* (Mitra *et al* 1980) and *Peltophorum ferrugineum Bauhinia* sp and *Poinciana regia* (Misra and Majundar 1983) No report of use of growth regulators in layering in schefflera was seen in the literature The beneficial effect of growth regulators in rooting may be attributed to the hormonal effect and accumulation of other internal rooting substances at the layered portion Rooting is also governed by physiological factors inherant in the layered shoot (Argles 1969)

In both green and variegated type of schefflera the number of days taken for rooting of layers was less in the case of untreated layers However considering the number and length of roots produced growth regulator treatment was found to be beneficial in layers

The present investigation revealed that the media used for layering also have influence on the number and quality of roots produced In variegated type of schefflera sphagnum moss and sawdust were the best media (Tables 17 19 and 21)

whereas in green type sawdust was found to be the best medium for layering (Tables 24 26 and 28) Sufficient moisture content at the layered portion would enhance rooting Sphagnum moss and sawdust possess good moisture holding capacity and this might have enhanced the rooting process

Another important factor in the layering process is the type of cut that is made on the parent plant The present investigation showed that in variegated type of schefflera the number of roots produced and in green type days taken for rooting were influenced by the type of cut used for layering In both the cases girdling was found to be superior to slanting slit method (Plates 9 and 12) Broschat and Donselman (1983) reported that girdling produced greater number of roots in S *arboricola*

5 3 ***In vitro*** **propagation**

5 3 1 Surface sterilization

Microbial interference was the major problem in establishing *in vitro* culture of *S arboricola* Results of the present study have indicated 0 1 per cent mercuric chloride as effective surface sterilization agent and the duration of treatment varied with the type of explant The duration of treatment for leaf explants was 10 minutes, for shoot tips 12 minutes and for nodal explants it was 18 minutes Effective use of mercuric chloride as a surface sterilant at 0 1 per cent level has been reported in *Dalbergia latifolia* (Lakshmi Sita *et al* 1986) *Elettaria cardamomum* (Reghunath 1989) and in *Dendrobium* (Devi 1992)

Microbial infection is a serious problem in nodal explants and shoot tips as well So an initial treatment with emisan followed by wiping with alcohol and

then surface sterilization with a combination of alcohol (50%) + mercuric chloride (0 1%) were given for nodal explants and shoot tips

Seasonal variation was observed for the microbial contamination of *in vitro* cultures The cultures showed least contamination during the months of January to April whereas May to December was found to be favourable season for the growth of microbes (Table 33) In general during rainy season the contamination rate was high and in relatively dry periods microbial population was less in cultures

5 3 2 Culture initiation

MS medium was found to be a good basal medium for the initiation of cultures in schefflera The basal MS medium has proved satisfactory for many ornamental plants In *Peperomia stolonifera variegata* (Diaz 1983) syngonium (Scaramuzzi and Imbo 1984) *Ficus elastica* (Battle and Mele 1984) *Brassaia actinophylla* (Badzian *et al* , 1989) and *Ficus benjamina* (Kristiansen 1992) MS was used as the basal medium

5 3 3 Callus mediated organogenesis

Callus mediated organogenesis is an alternate method of micropropagation Wherever applicable this is often the fastest method of shoot multiplication and has been suggested as a potential method of cloning plant species (Murashige 1974 1977) The most serious objection against the use of callus culture is the possible genetic instability of their cells However callus mediated organogenesis as a method of clonal propagation has been reported in several ornamental species Propagation through callus culture has been reported in *Cordyline terminalis* (Mee 1978) *Kalanchoe blossfeldiana* (Schneider Moldrickx and Horn 1984) *Ficus lyrata*

(Jona and Gribaudo 1988) and *Sansevieria trifasciata* (Abou Mandour and Czygan 1991)

Immature and young leaves were found to be good explants for the initiation of callus (Table 35) Young explants consisting of meristematic and mitotically active cells are highly favourable for callus initiation and subsequent regeneration and the morphogenic competence of any tissue decrease with maturity (Pierik *et al* 1974) The positioning of the leaves on the medium was found to have an influence on callus initiation and when the abaxial surface of the leaves touched the medium the callus was formed (Table 36) This may be due to the better absorption of medium through the midrib portion 2 4 D at low concentration (1 2 mg l^{-1}) and NAA at high concentration (10 12 mg l^{-1}) were found to be good for the callus production (Table 38)

Generally cytokinins will favour differentiation of adventitious shoots from callus but in the case of schefflera, even with cytokinin rich medium rhizogenesis was noticed (Table 39) Auxins, which are essential for callus induction play a negative role in plant regeneration and are generally reduced or excluded from culture medium used for shoot regeneration Auxins can strongly promote the endogenous production of ethylene and ethylene inhibited the shoot primordium formation in callus cultures Purnhauser *et al* (1987) suggested that in non regenerating callus cultures auxin induced ethylene production might be responsible for the suppression of shoot regeneration and by the use of ethylene inhibitors like silver nitrate they were able to induce shoot regeneration in wheat In the light of this report silver nitrate was added in the medium at various concentrations and the cultures were incubated for different periods But only rhizogenesis was observed

(Plates 15a 15b and 15c) A pulsing treatment with stock solutions of BAP was also given None of the media combinations tried in the present study could induced shoot regeneration in schefflera Some of the researchers have reported recalcitrant nature of schefflera under *in vitro* conditions (D Souza 1997 Personal communication)

The increased rhizogenesis observed in the present study might have been due to the high level of endogenous auxins However further biochemical studies to find out the level of endogenous auxins and of cytokinins in the plant system and the judicious incorporation of growth regulators into *in vitro* systems may perhaps yield fruitful results

5 3 4 Direct organogenesis

Nodal explants were found to be good for multiple shoot formation and those taken from mature portions of stem showed best response (Table 41)

The results of the present study clearly indicated that BAP at 0 5 mg l^{-1} was the best level for axillary bud break (Table 42) The established cultures had a better growth in the medium incorporated with BAP at 5 mg l^{-1} (Plates 19a and 19b) A wider survey of the existing literature however suggested that BAP was the most useful and reliable cytokinin and should be tested first for a new system (Hussey 1980) In the case of *Brassaia actinophylla*, Badzian *et al* (1989) reported that BAP is an amenable cytokinin for multiplication of shoot explants However in the present study shoot multiplication was not obtained with BAP Further studies have to be conducted to find out the role of different types of cytokinins and combinations of cytokinins and auxins in shoot multiplication in schefflera

In vitro developed shoots were transferred to the medium containing NAA and IBA and the shoots were rooted (Plate 20) Bhojwani and Razdan (1983) pointed out that among the auxins, IBA and NAA are widely used for *in vitro* rooting

The low success recorded for *in vitro* propagation of *S. arboricola* in the present study could be attributed to various factors Among them the microbial interference during the culture establishment stage was the main constraint in studying the response of cultures to various media combinations Previous attempts and successful reports on *in vitro* propagation of this commercially important foliage plant are lacking and the study was taken up for the first time without knowing its behaviour under *in vitro* conditions

Further research work has to be carried out to study aspects like caulogenesis from callus *in vitro* shoot multiplication and hardening of the tissue culture derived plantlets

Summary

SUMMARY

The investigations were carried out at the Department of Pomology and Floriculture College of Horticulture Vellanikkara and Agricultural Research Station Mannuthy from March 1994 to February 1996 to standardise the propagation techniques in schefflera (*S. arboricola*) The salient findings of the investigations are summarised below

1 In both 'green' and 'variegated' type of schefflera double noded cuttings performed better than single noded cuttings

2 Effective concentration of growth regulator in variegated type of cuttings in terms of number and quality of roots produced was IBA at 200 mg l^{-1} Whereas in green type of schefflera NAA at 50 mg l^{-1} was found to be an effective treatment

3 Prolonged dip was the most effective method of growth regulator treatment in both green and variegated' type of cuttings

4 In variegated type of schefflera the percentage success obtained in rooting of double noded and single noded cuttings could be improved with IBA treatment and in green type, NAA treatment was found to be beneficial

5 Among the different growth regulators tried NAA at 50 mg l^{-1} produced maximum rooting in layers of variegated type of schefflera In green type of schefflera layers treated with NAA at 200 mg l^{-1} tended to produce longer and stouter roots

6 In variegated type of schefflera, sphagnum moss and sawdust were the best media whereas in 'green' type, sawdust was found to be best medium for layering

7 In variegated type of schefflera, girdling i e the type of cut which was made on the parent plant produced more number of roots In green type of schefflera the days taken for rooting was less in the case of girdling method

8 The percentage success obtained in rooting of layers (variegated and green) could be improved with an NAA treatment, using sawdust as the medium and girdling as the wounding method

9 For micropropgation the explants were effectively surface sterilized with 0 1 per cent mercuric chloride The optimum duration of surface sterilization was 10 minutes 12 minutes and 18 minutes for leaf explants shoot tips and nodal explants respectively An initial treatment with emisan followed by wiping with alcohol and then surface sterilization with a combination of alcohol (50%) + mercuric chloride (0 1%) were given for nodal explants and shoot tips

10 Seasonal variation was observed for the microbial contamination of *in vitro* cultures The cultures showed least contamination during the months from January to April, whereas May to December was found to be favourable season for the growth of microbes

11 MS medium was found to be a good basal medium for the initiation and growth of cultures in schefflera

12 For callus mediated organogenesis immature and young leaves were found to be good for the induction of callus

13 The positioning of the leaves on the medium was found to have influence on callus initiation and only when the abaxial surface of the leaves touched the medium the callus was formed

14 2 4 D at low concentration (1 2 mg l^{-1}) and NAA at high concentration (10 12 mg l^{-1}) were found to be good for the callus production

15 Callus production was comparatively less in this crop and supplementing the medium with coconut water did not improve the growth of callus

16 Cytokinin rich medium was used to induce shoot regeneration from callus But only rhizogenesis was noticed The use of adenine sulphate as a synergistic resulted only in formation of roots

17 Silver nitrate (2 4 6 8 and 10 mg l^{-1}) was used to induce shoot regeneration A pulsing treatment with stock solutions of BAP (12 5 25 0 50 0 and 200 0 mg l^{-1}) was also given But none of the media combinations tried in the present study could induce shoot regeneration in schefflera

18 In direct organogenesis the explants taken from the 5th and 6th node showed best response

19 BAP at 0 5 mg l^{-1} was found to be the optimum level for axillary bud break and the time taken for this was 8 10 days The established cultures showed best growth in the medium incorporated with BAP at 5 mg l^{-1} In all the media tried no shoot multiplication could be obtained

20 *In vitro* developed shoots were rooted within 14.1 days time in the medium supplemented with NAA at 3 mg l^{-1} + IBA at 0.3 mg l^{-1} and 20.5 roots having a total length of 105.4 cm were formed within 1.7 months time

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STANDARDISATION OF PROPAGATION TECHNIQUES IN SCHEFFLERA

(*Schefflera arboricola* Hayata)

BY

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ABSTRACT OF A THESIS

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ABSTRACT

The study was carried out at the Department of Pomology and Floriculture College of Horticulture Vellanikkara and Agricultural Research Station Mannuthy from March 1994 to February 1996 to standardise the propagation techniques in schefflera (*Schefflera arboricola*)

Schefflera a member of the botanical family Araliaceae is valued for its ornamental foliage Not much information is available in the literature on agrotechniques for the commercialization of this important foliage plant Hence the present study Standardisation of propagation techniques in schefflera has great relevance

In both green and variegated type of schefflera double noded cuttings performed better than single noded cuttings The number and quality of roots produced were improved with growth regulator treatments and the polythene tent method was found to be the best in both green and variegated type of schefflera The best growth regulator and its optimum concentration for rooting of cuttings in variegated type was IBA at 200 mg l^{-1} whereas in green type NAA 200 mg l^{-1} was found to be an effective treatment Percentage success in rooting of cuttings depended on the growth regulator employed In variegated type of schefflera the percentage success obtained in rooting of double noded and single noded cuttings could be improved with IBA treatment and in green type NAA treatment was found to be beneficial

In layering also growth regulator treatment was found to be beneficial In variegated type NAA at 50 mg l^{-1} produced maximum rooting whereas in green type NAA at 200 mg l^{-1} produced longer and stouter roots The media used and the method of wounding adopted in layering were found to have significant influence on rooting behaviour Girdling was found to be more effective compared to slanting slit method The best media were sphagnum moss and sawdust in variegated type whereas in green type sawdust was the best medium Percentage success in rooting of layers depended on the growth regulator media and type of wounding method employed The percentage success obtained in rooting of layers (variegated and green) could be improved with an NAA treatment using sawdust as the medium and girdling as the wounding method

A comparison of the methods of propagation revealed that in softwood cuttings could be adopted as reliable and successful propagation method to produce large number of plants in a short time from limited amount of planting materials

In micropropagation callus was formed from immature and young leaves and the callus production was good with 2 4 D at 1 2 mg l^{-1} and NAA at 0 12 mg l^{-1} but the calli did not respond to caulogenesis In direct organogenesis bud break from nodal explants was noticed in MS medium with BAP at 0 5 mg l^{-1} and the shoot growth was the best with BAP at 5 mg l^{-1} The *in vitro* developed shoots were rooted in the medium supplemented with NAA at 3 mg l^{-1} and IBA at 0 3 mg l^{-1} Further studies are needed to standardise a complete protocol for micropropagation of *S arboricola*

Appendices

APPENDIX I

Analysis of variance table for Variegated cuttings

Source	Degrees of freedom	Mean squares						
		Days to root	No of roots	Length of longest root	Total length of roots	Average length of roots	Fresh weight of roots	Dry weight of roots
Growth regulator	19	157 17**	504 78**	174 07**	40308 56**	31 15**	12 77**	0 30**
Type of cutting	1	192 08**	882 00**	66 24	89549 12**	1 4	55 50**	1 47**
Growth regulator x Type of cutting	19	185 24**	123 19**	100 66**	16489 96**	15 80**	5 57**	0 F**
Error	160	5 30	35 91	39 30	4835 94	6 20	1 63	0 05

* Significant at 5% level

** Significant at 1% level

APPENDIX II

Analysis of variance table for Green cuttings

Source	Degrees of freedom	Mean squares						
		Days to root	No of roots	Length of longest root	Total length of roots	Average length of roots	Fresh weight of roots	Dry weight of roots
Growth regulator	19	382 30**	800 27**	224 45**	56462 15**	18 50**	15 35**	0 0**
Type of cuttings	1	3 65	824 18**	289 .0**	186107 95**	68 80**	2 93**	34**
Growth regulator x Type of cutting	19	180 83**	110 25**	119 92**	14527 31**	21 37**	5 77**	11*
Error	160	3 03	49 01	45 83	4529 08	4 71	1 22	0 03

* Significant at 5% level

** Significant at 1% level

APPENDIX III

Analysis of variance table for 'Variegated layers

Source	Degrees of freedom	Mean squares						
		Days to root	No of roots	Length of longest root	Total length of roots	Average length of roots	Fresh weight of roots	Dry weight of roots
Growth regulator	9	2252 19**	612 25**	28 93**	27421 40**	4 29*	2 10**	0 53**
Media	2	2511 66**	667 94**	173 53**	43127 32**	24 07**	20 33**	0 55**
Growth regulator x Media	18	551 63**	63 53**	49 36**	4655 99*	6 97**	4 0**	1 4*
Type of cut	1	142 83	228 81*	18 40	8782 59	0 16	7 85	0
Growth regulator x Type of cut	9	63 58	30 71	3 28	1660 26	0 78	1 34	0 05
Media x Type of cut	2	9 99	6 32	0 08	307 37	0 10	0 12	0 1
Growth regulator x Media x Type of cut	18	57 91	20 34	8 94	1071 96	1 04	87	0 07
Error	240	67 39	39 27	8 44	2766 25	2 27	2 07	0 08

* Significant at 5% level
** Significant at 1% level

APPENDIX IV

Analysis of variance table for Green layers

Source	Degrees of freedom	Mean squares						
		Days to root	No of roots	Length of longest root	Total length of roots	Average length of roots	Fresh weight of roots	Dry weight of roots
Growth regulator	9	3474 75 **	330 50 **	100 74 **	21635 26 **	27 47 **	40 43 **	0
Media	2	1673 65 **	231 79 *	149 32 **	63875 67 **	50 76 **	134 07 **	3
Growth regulator x Media	18	478 28 **	234 55 **	57 28 **	19936 26 **	9 55 **	12 70 **	0 84 **
Type of cut	1	456 33 *	171 76	5 20	15620 97	6 93	19 4	0
Growth regulator x Type of cut	9	78 07	33 61	5 78	1861 14	1 21	2 0	0 10
Media x Type of cut	2	90 81	12 22	35 99	1088 64	1 36	0 61	0 0
Growth regulator x Media x Type of cut	18	41 68	28 98	8 04	1430 87	0 56	2 01	0 00
Error	240	112 61	78 02	21 85	5363 61	2 16	7 04	0 18

* Significant at 5% level
** Significant at 1% level

APPENDIX V

Composition of different basal media tried for *in vitro* culture of *Schefflera arbor col*

Macronutrients	mg l^{-1}	Micronutrients	mg l^{-1}	Organic constituents	mg l^{-1}
(a) MS medium (Murashige and Skoog, 1962)					
KNO_3	1900	$MnSO_4$ $4H_2O$	22 30	Myo inositol	100
NH_4NO_3	1650	$ZnSO_4$ $7H_2O$	8 60	Thiamine HCl	0 1
$CaCl_2$ $2H_2O$	440	H_3BO_3	6 20	Nicotinic acid	0 5
$MgSO_4$ $7H_2O$	370	KI	0 83	Pyridoxine HCl	0 5
KH_2PO_4	170	$CuSO_4$ $5H_2O$	0 025	Glycine	2 0
		NA_2MoO_4 $2H_2O$	0 25		
		$CoCl_2$ $6H_2O$	0 025		
		$FeSO_4$ $7H_2O$	27 80		
		Na_2EDTA $2H_2O$	37 30		
(b) Woody Plant medium (Lloyd and McCown 1980)					
NH_4NO_3	400	$MnSO_4$ H_2O	22 30		
$Ca(NO_3)_2$ $4H_2O$	556	$ZnSO_4$ $7H_2O$	8 60		
$CaCl_2$ $2H_2O$	22	H_3BO_3	6 20		
$MgSO_4$ $7H_2O$	1850	$CuSO_4$ $5H_2O$	0 25		
KH_2PO_4	340	NA_2MoO_4 $2H_2O$	0 25		
		$FeSO_4$ $7H_2O$	27 80		
		Na_2EDTA $2H_2O$	37 30		

APPENDIX V

Composition of different basal media tried for *in vitro* culture of *Schefflera arboricola*

Macronutrients	mg l^{-1}	Micronutrients	mg l^{-1}	Organic constituents	mg l^{-1}
(a) MS medium (Murashige and Skoog 1962)					
KNO_3	1900	$MnSO_4\ 4H_2O$	22 30	Myo inositol	100
NH_4NO_3	1650	$ZnSO_4\ 7H_2O$	8 60	Thiamine HCl	0 1
$CaCl_2\ 2H_2O$	440	H_3BO_3	6 20	Nicotinic acid	0 5
$MgSO_4\ 7H_2O$	370	KI	0 83	Pyridoxine HCl	0 5
KH_2PO_4	170	$CuSO_4\ 5H_2O$	0 025	Glycine	2 0
		$NA_2MoO_4\ 2H_2O$	0 25	Sucrose	30 000
		$CoCl_2\ 6H_2O$	0 025		
		$FeSO_4\ 7H_2O$	27 80		
		$Na_2EDTA\ 2H_2O$	37 30		
(b) Woody Plant medium (Lloyd and McCown, 1980)					
NH_4NO_3	400	$MnSO_4\ 4H_2O$	22 30	Myo inositol	100
$Ca(NO_3)_2\ 4H_2O$	556	$ZnSO_4\ 7H_2O$	8 60	Thiamine HCl	1 0
$CaCl_2\ 2H_2O$	96	H_3BO_3	6 20	Nicotinic acid	0 5
$MgSO_4\ 7H_2O$	370	$CuSO_4\ 5H_2O$	0 25	Pyridoxine HCl	0 5
KH_2PO_4	170	$NA_2MoO_4\ 2H_2O$	0 25	Glycine	2 0
		$FeSO_4\ 7H_2O$	27 80	Sucrose	30 000
		$Na_2EDTA\ 2H_2O$	37 30		