STANDARDISATION OF PROPAGATION TECHNIQUES IN BADUVAPULI

(*Citrus pennivessiculata* Tan.)

By

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THESIS

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VELLANIKKARA, THRISSUR

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DECLARATION

I hereby declare that this thesis entitled "Standardisation of Propagation Techniques in Baduvapuli (Citrus pennivessiculata Tan.) *" is a bonafied record of the 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, associateship, fellowship or other similar title of any other university or society.*

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Certified that this thesis entitled **"Standardisation of Propagation Techniques in Baduvapuli** (***Citrus pennivessiculata*** **Tan.)"** is a record of research work done independently by **Smt. Sereena J.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

LIST OF ABBREVIATIONS

cm	-	Centimeter
m	-	meter
l	-	litre
ml	-	millilitre
g	-	gram
mg	-	milligram
IAA	-	Indole acetic acid
IBA	-	Indole butyric acid
NAA	-	Naphthalene acetic acid
No.	-	Number
CV	-	Cultivar
CD	-	Critical difference
^{o}C	-	Degree celsius
Fig	-	Figure
viz	-	Namely
%	-	Per cent
N	-	Nitrogen
C	-	Carbon
DAP	-	Days after planting
et al	-	and others

INTRODUCTION

INTRODUCTION

Baduvapuli (Citrus pennivessiculata Tan.) is the poor man's pickling citrus species of Kerala. Traditionally, it is an essential pickle ingredient of the dietary habitat and its demand peaks in the festive Onam season. The pomp and splendour of the festival of Kerala is regarded incomplete without a touch of this valued pickle.

The warm humid tropical climate prevents commercial cultivation of acid lime which is most valued among Citrus species for pickling. Isolated stray occurrence of fruiting of acid lime is noticed in the state but the fruits produced are undersized with small juicy vessicles. Hence, the requirement of Kerala is met by flow from across its border. It is in this context that Baduvapuli, a fruit of minor importance among Citrus species, gains importance and acceptability. Further, it flowers and fruits luxuriously and is well adapted to the warm humid tropical climate that prevails in the state. Production and productivity being guarantted, it become imperative to probe the major constraints that limits its further spread.

With the increasing awareness that the firmness of the peel can be reduced by refinements in the pickling procedure, the demand is only bound to increase further. Augmenting research and standardising protocols in this direction will definitely tilt the balance in favour of Baduvapuli Kerala.

Today, it is confined to the homesteads, mostly perpetuated by seeds and hence carries with it all the deficiencies of seed propagation. It is against this background and impending necessity that the present studies have been taken up in the Department of Pomology and Floriculture with the objective to standardise the vegetative propagation techniques using cutting, budding, layering and grafting, to identify the best root stock and the best season for each technique.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

The perpetuation of citrus through seeds has been a common method from time immemorial, due to wide occurence of polyembryony in most of the common citrus fruits. Though apomictic, seed propagation is limited by numerous disadvantages like loss of viability, difficulty in germination, more gestation period and slower growth. Different vegetative methods of propagation have been tried in Citrus sp. to get true to type plants and to combine the positive effects of a root stock. This review attempts to survey at length the different vegetative propagation methods tried in Citrus sp. and to catalogue and classify them under appropriate heads.

1. CUTTINGS

Citrus propagation through cuttings is possible as most Citrus sp exhibit a tendency of adventitious rooting. Citron and sweet lime root readily while others like grapefruit and sweet orange are difficult to root (Nanda and Kochar, 1991).

1.1 Effect of type of cuttings on rooting

Studies by Singh (1962) revealed that semi hard wood cuttings of Karna Khatta produced similar results as hard wood cuttings. According to Singh (1963), hard wood cuttings of sweet lime gave better results than that of Kagzi lime. In contrast, Gangwar and Singh (1965) showed that semi hard wood cuttings rooted better than hard wood cuttings in sweet lime. Fontazza in 1968 found that two year old branches of Poncirus trifoliata were superior to one year old branches.

Naser and Abdul Hameed (1971) reported the better performance of juvenile stem cuttings of Washington Navel Orange taken from one year old seedlings over those from fifteen year old trees. Cuttings from middle portion of one year old shoots rooted better than those from above or below, in lemon (Gabricidze, 1971). Juvenile three leaf cuttings of Citrumelo produced more roots in comparison to mature ones (Ferguson et al., 1985). Sixty seven per cent rooting was obtained from younger wood cuttings of Meyer lemon while older wood gave 44 per cent rooting (Gorgoshidze and Kartvelishvili, 1985). Apical and basal cuttings of Citrus junos proved to be more efficient in rooting (Kim et al., 1992).

1.2 Effect of Hormone and its concentration

The practial use of synthetic auxin in stimulating root formation from the basal part of cuttings was demonstrated about five decades ago by several workers Thimann and Went 1934; Went, 1934; Cooper, 1935; Hitchcock and Zimmermann, 1936; Pearse, 1938). Though different growth regulators were used by them, today the most commonly used growth regulators in inducing rooting are IAA, IBA and NAA.

Dikshit (1956) found that treatment of Kagzi lime cuttings with 250-300 mg l^{-1} IAA gave upto 65 per cent rooting. Sen and Bose (1962) reported that IAA and IBA, in general, showed a root promoting effect in lemon and lime cuttings. The effect of IBA, however, appeared to be better. Lemon cuttings treated with IAA 200 mg l^{-1} or IBA 75 mg l^{-1} rooted in 15-20 days (Gabricidze, 1971). Best rooting responses were reported in Citrumelo cuttings treated with IBA and NAA, both at 3000 mg l^{-1} (Ferguson et al., 1985). In cuttings of Baramasi, Kagzi kalan and Eureka lemon, NAA at 4000, 3000 and 2000 mg l^{-1} respectively proved to be the best (Arora and Yamdagni, 1985). IBA 2000 mg l^{-1} gave 70 per cent rooting in Troyer Citrange cuttings (Mendilcioglu and Karakir, 1986) and IBA 100 mg l^{-1} gave 36-67 percent rooting in sweet lime (Sandhu and Zora Singh, 1986).

Ninety five per cent rooting was observed in lemon cuttings pretreated with Ferulic acid at 200 mg l^{-1} and then with NAA 5000 mg l^{-1} (Debnath et al., 1986). Meyer lemon cuttings treated with IAA 0.02 per cent + Ascorbic acid 20.00 per cent for 12 hours rooted in 15-20 days (Arslanov 1994).

With regard to method of treatment, quick dip application of 2000 mg l^{-1} of IBA showed a marked improvement in rooting and sprouting of Sweet lime cuttings (Singh,1963). Dipping Washington Navel orange cuttings in IBA 1000 or 2000 mg l^{-1} for 10 seconds proved to be the best (Shafrir, 1973).

In respect of qualitative aspects of rooting, Shafrir (1973) found significant increase in the number of roots per cutting, proportion of cuttings suitable for transplanting and the survival rate in Washington Navel Orange treated with IBA 1000 or 2000 mg l^{-1}. IBA 100 mg l^{-1} gave the highest root number and the longest root per cutting in sweet lime (Bajwa et al., 1977). In Assam lemon 400 mg l^{-1} IAA gave the highest results with regard to percentage bud break, rooting and survival, primary root number, length, diameter and fresh weight (Pandey and Gupta, 1990). IBA 1000-4000 mg l^{-1} had the greatest effect on rooting percentage and root length in *Citrus junos* (Kim et al., 1992).

Gibberellins have also been reported to promote rhizogenesis in lemons. Though GA 0.0001 per cent gave 53 per cent rooting in lemon cuttings, the root system developed was poor (Arzyamova and Agakishiev, 1985).

1.3 Effect of number of nodes on rooting of cuttings

Rajput and Haribabu (1993) recommends citrus cuttings of 10-15 cm long with at least 3-4 well mature plump buds for planting

1.4 Effect of mist spray on rooting of cuttings

Intermittent mist has been used in propagation since 1940's. An increase in the relative humidity prevents desiccation of cuttings and provides more favourable environmental conditions for root formation. Beneficial effect of mist on rooting in a wide variety of difficult-to-root plant species has been recorded by Erickson and Bitters (1953) and Hartmann (1956). Higher percentage of rooting under mist in cuttings of difficult-to-root fruit trees and many ornamental plants has been reported by Sen *et al*., (1965); Bose *et al*, (1970) and Bose and Mondal (1970).

Better root formation under intermittent mist was reported in *Citrus limonia* var *variegata* (Bose *et al*, 1970) and in Pummelo cuttings (Bose and Sandhu, 1974). Singh and Dhar (1981) obtained rooting in 35 cuttings out of 50 in acid lime under intermittent mist. Meyer lemon cuttings gave 98 per cent rooting under mist in plastic green houses (Umarov, 1983). Rooting of cuttings under mist has also been reported in Meyer lemon (Grogoshidze and Kart velishvili, 1985), Trifoliate orange, Sour orange and Troyer citrange (Mendilcioglu and Karakir, 1986) and in *Citrus junos* (Kim *et al*, 1992).

1.5 Seasonal influence on rooting of cuttings

Season exerts a very significant influence in rooting of cuttings.

Hayes (1957) suggested that the proper time of planting of evergreen cuttings of lime and lemon is either late summer or early spring. The overall success of sweet lime cuttings was better in late summer planting during September than late winter planting in January or February (Singh 1959). Hormone treated cuttings of Sweet lime and Sour lime planted in August gave rooting within 3 weeks after planting whereas cuttings planted in February showed rooting after 8 weeks only (Bhambota, 1959). In sweet lime cuttings, summer planting proved to be superior to winter planting (Singh and Singh, 1961). Choudhry et al., (1963) reported that sweet lime cuttings planted during February proved superior to September planting. In sweet lime, another report by Gangwar and Singh (1965) showed that July was better than September for rooting of cuttings. Singh (1968) found that cuttings of sweet lime and sour lime planted during rainy season performed much better than those planted in February. Mid-March in case of spring propagation and early September in case of autumn propagation have been identified as optimum time with growth regulator treatment whereas July gave the best percentage of rooting in C junos (Kim et al., 1992). The best time for striking of roots in Meyer lemon cuttings was found to be early August (Arslanov, 1994).

1.6 Effect of retention of leaves on rooting of cuttings

It has long been known that the presence of leaves on cuttings exerts a strong stimulating influence on root initiation.

Apical half leaf cuttings rooted better than whole leaf cuttings of local citrus cultivars Elachi lemon, Seedless lemon and

Kagzi lime (Faruque and Mahamood, 1973). Ferguson *et al.*, (1985) found that juvenile three leaf cuttings of Citrumelo produced more roots than mature three leaf cuttings. Two to three leaf cuttings rooted best (84 to 88 per cent) in Meyer lemon, as reported by Gorgoshidze and Kartvelishvilli (1985). Pandey and Gupta (1990) reported 64 per cent rooting of leaf cuttings in Assam lemon.

The stimulatory effect of leaves on rooting in stem cuttings of Avacado was shown by Renveni and Raviv in 1981.

1.7 Effect of Etiolation or banding on rooting of cuttings

The earliest report of etiolation as a propagation tool is that of Reid (1923) with the discovery that etiolation accelarates rooting in cuttings. Etiolation of shoots prior to preparation of cuttings promotes better rooting (Hermann and Hess, 1963 and Hartman *et al.*, 1993).

The literature on effects of etiolation in *Citrus sp*. are not available and wanting.

Other fruit crops

Gardner (1937) banded shoots of apple trees upto one year before taking cuttings and found a tremendous increase in rooting percentage. Etiolation, together with proximal ring barking, induced root formation upto 98 per cent in cuttings of Apple (Delargy and Wright, 1978).

Mukherjee and Chatterjee (1979) reported that invigouration of two months old shoots of jack followed by etiolation, ringing, and dipping in IBA at 5000-10,000 mg l^{-1} for 30 seconds and planting under intermittent mist produced 84 per cent rooting response. Studies by Dhua et al. (1983) showed that ringing and etiolation for 30 days combined with treatment with IBA 3000 mg l^{-1} + ferulic acid 2000 mg l^{-1} gave the highest rooting (90 per cent) and plant survival (100 per cent) in Jack.

Bid and Mukerjee (1972) noted better root formation in the cuttings of Mango from forced shoots and that etiolation improved rooting.

Biran and Halevy (1973) shaded stock plants of three Dahlia cultivars before banding with Aluminium foil and achieved marked improvement in rooting percentage.

The difficult-to-root fruit trees like Mango & Jack could be made to root under intermittent mist with ringing and etiolation (Basu et al., 1968 and Dhua et al., 1983).

1.8 Survival of cuttings

In Washington Navel Orange, the survival rate was significantly increased when the cuttings were treated with IBA 1000 or 2000 mg l^{-1}. According to Pandey and Gupta (1990), IAA 400 mg l^{-1} gave good results regarding the survival in case of Assam lemon.

Umarov (1983) showed that, in case of Meyer lemon, only plants from July planted cuttings reached standard size quickly and were suitable for permanent transplanting.

Cent per cent plant survival was obtained in Jack cuttings which were given ringing and etiolation for thirty days combined with treatment with IBA 3000 mg l^{-1} + Ferulic acid 2000 mg l^{-1} (Dhua et al., 1983).

2. LAYERING

Air layering is not commonly employed for multiplication of Citrus varieties on commercial scale, except in case of Lime, Lemon, Citron, Pummelo and Sweet lime (Dutta, 1962; Shankar, 1965; Bhan, 1972; Hulamani and Reddy, 1974 and Mishra and Agrawal, 1975).

2.1 Effect of type of shoot on rooting of air layers

The age of the layered shoot as well as the age of the tree on which layering was done were found to have considerable influence on the capacity to root.

No studies has been so far reported regarding the standard type of shoot for layering in citrus but identical works are available on other crops.

In Cashew, Rao (1958) could obtain a higher percentage of success with one year old shoots than with current season's shoot. Aiyadurai (1968) recommended pencil thick shoots for air layering in Cashew. Later, reports on cashew in layering also emphasised the use of one year old shoots for higher rooting (Peixoto, 1960; Damodaran, 1984 and Palaniswami, et al., 1984).

Results of a work in air layering of jack reported by Srinivasan (1961) showed that 100 per cent success was obtained on two year old plants with hard wood. Intermediate wood gave 96 per cent success whereas green wood was found completely unsuitable showing no initiation of rooting. But, Lingarajappa (1982) found that in jack layers juvenile shoots formed roots 30 days earlier than mature shoots.

2.2 Effect of rooting media on the rooting of layers

The quality of the rooting medium especially texture, porosity and water holding capacity greatly influence the extent of rooting (Hartman et al., 1993). The rooting medium must provide sufficient moisture and aeration and must be pathogen free.

Reports on the effect of rooting media in the rooting of citrus layers are not available

Other fruit crops

Among the eight different media tried by Rao and Hassan (1957) in Cashew air layering, wood shavings, coconut coir husk, coir husk dust and sand proved to be the best, while materials like a mixture of red earth and leaf mould which developed sticky condition proved unsuitable. A mixture of 50 per cent cowdung and 50 per cent sand was found to be the most suitable medium for Cashew air layering in Assam (Aiyadurai, 1966). Similar studies conducted by Damodaran, 1984 in Cashew showed that sand, saw dust, wood shavings, Vermiculite (coarse) and vermiculite (fine) did not have any significant difference in rooting.

2.3 Effect of growth regulators in layering

The plant growth regulators like IBA, IAA and NAA have been reported to be effective for the rooting of Citrus air layers (Prasad and Govind 1972). They found the best rooting response in Mossambi treated with IBA 1000 mg l^{-1}. Telang (1983) reported that layers treated with IBA 500 mg l^{-1} or IBA + NAA (each at 250 mg l^{-1}) gave 95.46 and 88.64 per cent rooting respectively. However, the success of air layers to growth regulator treatment depends on it's use at optimum concentration, type of plant material and time of application (Sharma et al., 1975). While lower concentrations are ineffective and higher concentrations mostly toxic, it is imperative to standardise the optimum concentration of growth regulator.

Rooting and subsequent establishment were superior in Kagzi kalan layers treated wiht IBA 750 mg l^{-1} + NAA 750 mg l^{-1} (Mishra and Agarwal, 1975). The highest number of roots per air layer and greatest survival was obtained in seedless lemon treated with IBA + NAA each at 1000 mg l^{-1} Patil and Chakrawar, (1979) found that rooting was best in Seedless lemon air layers prepared on 15th July.

2.4 Effect of Etiolation/Banding on layering

Although etiolation is defined as the total exclusion of light, etiolation as it is used by the plant propagator also refers to forcing new shoot growth under conditions of heavy shade [Haissig et al., 1988]. The beneficial effects of etiolation and banding have been reviewed a number of times [Frolich, 1961; Herman and Hess, 1963; Kawase, 1965; Ryan, 1969; Delargy and Wright, 1978 and Harrison - Murray, 1982].

Cent per cent rooting was observed in marcots ringed and etiolated for 2 months in Pummelo [Hulamani and Reddy, 1974].

Other fruit crops

Uthaiah et al. (1976) found that pre conditioning treatments such as etiolation and layering of shoots 30 days before layering in Sapota were especially helpful in increasing the number of roots and cumulative length of roots.

Lingarajappa (1982) from his studies on air layering in Jack fruit reported that the percentage of layers which rooted successfully, the number of roots per layer, the length, the weight of roots and survival of the layers were greater when the stem were pregirdled and etiolated.

2.5 Survival of layers

Mishra and Agrawal (1975) found that the establishment of kagzi kalan layers was superior when treated with IBA + NAA each at 750 mg l^{-1}. The greatest survival was obtained in seedless lemon layers treated with IBA + NAA each at 750 mg l^{-1}.

Other fruit crops

The establishment of layered plants after their separation from the parent trees is a difficult task in most fruit crops. High mortality of separated cashew layers have been observed by Rao, (1958).

The low percentage of survival of air layers has also been reported in Mango. Ledin and Rouhle (1954) found that the roots of Mango layers were so brittle that few plants survived after planting.

In Sapota, the survival of air layers was as low as 5 per cent and the high mortality seemed to be due to inadequate development of root system (Singh et al., 1962).

3. GRAFTING

Grafting is one of the most widely used propagation method as far as fruit crops are concerned. Various successful methods of grafting have been reported in citrus.

On citrus types like Tangor cv. Murcott and Sweet lime cv. Hamlin, a tongued approach grafting proved to be successful (Takahar *et al.*, 1981). According to Kim *et al.*, (1987), top working Okitsu Early Satsuma on to Hayshi Unshui trees on Trifoliate organge stock, simultaneous replacement of whole canopy by bark grafting and side grafting proved most successful and much better than simple replacement of the main branches by bark grafting. A winter grafting procedure in green house was described by Arslanov (1994) in three to four month old Mayer lemon cuttings.

3.1 Effect of rootstock on the success of grafting

In vegetative propagation methods like grafting and budding, the rootstocks play an important role in the graft or bud union. Only compatible rootstocks form successful union. Incompatible union may survive for some years but they eventually fail showing off the signs of incompatibility (Hartmann *et al.*, 1993). This group may be categorised as delayed incompatibility. Hence, selection of rootstock in grafting and budding studies assumes utmost importance.

Rough lemon and sour organge proved to be the most outstanding among the various citrus rootstocks tried in a tongued approach grafting study. The scions grew four to five time faster when tongue grafted on to a vigorous rootstock compared to ungrafted controls (Takahara *et al*., 1981)

Other fruit crops

Popenoe (1920) found that though Mangosteen unites with about 20 species of Garcinia, only a few could be recommended as promising stock plants. Naik (1948) opined that grafts on *Garcinia tinctoria* rootstock appeared to be the most promising ones. Thayer (1961) showed that Mangosteen could be successfully grafted on *Garcinia spicata*, *Garcinia tinctoria*, *Rheedia aristata* and *Clusia rosea*. In Mammey apple and Kokam, when the same species was employed as root stock, best results were obtained (Arriaga and Maldonal do, 1976 and Hadangar *et al*, 1991).

In custard apple, studies by Khan and Rao (1953) revealed that *Annona reticulata* could be more efficiently employed as root stock than custard apple itself.

Trials conducted by Nambiar (1954) in Sapota showed that grafting on *Mimusops hexandra* had made considerably more growth than those grafted on Sapota seedlings themselves. Kulwal *et al*. (1985) revealed that *Calcarpum sapota* and *Mimusops hexandra* could be successfully used as root stocks for Sapota. Bhuva et al. (1990) showed that when Minusops hexandra was used as rootstock for Sapota, a maximum of 90 per cent survival was obtained with inarched grafts.

In Nutmeg, Sundarraj and Varadarajan (1956) reported that 60 per cent success was obtained when grafted on Myristica malabarica and Myristica beddomii. In Clove, Eugenia cordata and Psidium guajava were found to be promising rootstocks (Sriram, 1977).

Jack when propagated on the same species and on Artocarpus hirsuta rootstocks by inarching, the growth on the latter was poor and many of the grafts dried within two years of planting (kannan and Nair, 1960).

3.2 Effect of rootstock on the vigour and growth of scion

The Citrus root stock scenario in India had been reviewed by Singh (1963); Aiyappa and Srivastava (1967); Chadha (1970); Agarwal (1982); Randhawa and Srivastava (1986) and Patil (1987).

Rough lemon was found to be the best root stock for Blood red Orange (Singh and Singh, 1944; Singh, 1954 and Bhullar and Nauriyal 1974 and 1975). Being Vigorous, Das (1948) considered

Rough lemon as the best root stock for Sweet Oranges and Mandarin and Sour orange next to it. In another trial, Rough lemon proved to be the best root stock followed by Kodakithuli (Aiyappa, 1967). Among 19 rootstocks evaluated, Acid lime on South African rough lemon, Indian rough lemon, Troyer and Puthugraman lemon root stocks proved vigorous (Raj et al., 1972).

Plants of Sweet orange showed the highest tree volume on Rangpur lime (Chaudhari et al, 1974). Tree volume of Mossambi was maximum on Rangpur lime and Rough lemon followed by Kodakithuli and Cleopatra among 9 rootstocks (Haleem 1984). Kinnow on Troyer citrange had maximum tree volume followed by Rangpur lime, Rough lemon, Cleopatra and Trifoliate orange (Jaliko et al., 1986) where as the studies of Tayde and Joshi (1986) showed kinnow trees on Rangpur lime, Jambhiri and Karna khatta were vigorous than on other trees.

Wan et al., (1991) in a study on the performance of 3 Pummelo cultivars on different rootstocks found Pummelo or Sour orange rootstocks to be more vigorous. Misra and Singh (1991) found that shoot length was significantly affected by rootstock and the highest shoot length was obtained for trees on their own roots.

3.3 Effect of prior defoliation of scion shoots on grafting success

Maiti and Biswas (1980) reported that in Mango, scion shoots defoliated seven days ahead of grafting operation, while still attached to the mother plant gave higher percentage of successful grafts than scions with intact leaves. In Mango, Singh and Singh (1981) suggested defoliation 10 days prior to grafting for highest success. According to them, 100 per cent success was obtained in 'in-situ' soft wood grafting in Mango by wedge method when the scions were defoliated ten days prior to the grafting operation. On the other hand, Amin (1978) found that the success in establishment of soft wood grafts was less if the grafts was prepared using a leafless branch retained on the tree for not less than 8 to 10 days or more on the mother tree and still not sprouted on the tree itself.

In wedge grafting in Cashew, scions with and without defoliation produced almost the same effect (Bhandary et al., 1974) whereas Nagabhushanam (1982) reported that for stone grafting in cashew, the scion shoot selected for grafting should be defoliated about a week before grafting.

3.4 Seasonal influence on successful graft uptake

Early March proved the most suitable time for grafting Trifoliate orange rootstocks grown in a nursery bed in a green house (Iguchi et al., 1985). The best period for top working in Satsuma mandarin and Navel oranges was from mid-February to early April and the survival was found to be 95.6 to 96.6 per cent (Liu 1992).

Other fruit crops

Amin (1978) recommended in situ soft wood grafting in mango and reported to be successful during March-Septemebr. Singh and Sreevastava (1980) reported that the best results in Mango soft wood grafting (84 per cent) was obtained in July. Patel and Amin (1981) pointed out that grafting from the 3rd week of May to 3rd week of August resulted in 95-100 per cent take. Singh and Sreevastava (1982) worked out various factors influencing softwood grafting in Mango and emphasised the effect of season on the success of grafting. They found August as the best time for soft wood grafting in Mango (90 per cent success) followed by September (70 per cent). Singh et al., (1984) found 100 per cent success in June grafting in Mango. This was further confirmed by the finding of Srevastava (1985).

Highest mean success (83.66 per cent) was obtained in August and 83 per cent in April and 22.2 per cent in December in Cashew (Sawki et al., 1985) Swamy et al., (1990) found that softwood grafting success in Cashew was positively correlated with monthly minimum temperature, monthly mean relative humidity and number of rainy days per month. Monsoon season was found to be the best period for commercial multiplication of cashew as the per centage success was quite high (more than 60 per cent) during this period as compared to other months. Investigations by Sarada et al., (1991) revealed that August, September and January months were suitable for soft wood grafting in Cashew.

4. BUDDING

Among the various vegetative methods used to perpetuate the Citrus, budding is by far the most common method practised universally in Citriculture.

4.1 Method of Budding

'T' or shield budding is the most common and best method employed for propagation of Citrus trees in almost all the countries (Rajput and Haribabu, 1993).

4.2 Seasonal uptake

The bud uptake has a direct relationship with the internal physiology of the stock and scion and hence, if they are externally stimulated the process can be hastened besides increasing the success rate. Ziegler and Wolfe (1961) suggested that budding can be done at any time of the year provided there is free flow of sap, the bark readily slips and dormant buds are available.

Singh (1957) found that June was a better season for citrus budding as compared to that in March, April, September and October under saharanpur conditions. On the other hand, highest percentage success of 83 per cent was obtained in Kagzi lime on *Citrus karna* when the budding was done in April as compared to that in any other month (Singh, 1979).

'T' budding of Sweet Orange Var. Pineapple on Jatti khatti rootstock in Delhi conditions revealed October as the best month for percentage success (Kukherjee and Singh, 1966). 'T' budding during March-April and October gave the percentage success of 85 and 80 respectively in Kinnow mandarin when budded on one year old *Citrus jambhiri* (Bhullar *et al.*, 1980). Bud take, bud sprouting and bud survival were best in February and September budded plants of *Citrus karna* (Sen and Kapadia, 1984). Mid December gave 62.2 per cent success in bud take in Jambhiri and Rangpur lime (Rakhonde and Tayde 1987).

4.3 Exogeneous application of growth regulators

Pre treatment of buds with hormones also affects the time of bud burst. However, the use of growth regulators specifically in budding is scanty.

A two fold increase in bud break was found when GA_3 applied trunk was budded in Citrus trees (Sagee *et al.* 1990).

Samish and Gur (1962) experimenting with Avocado budding immersed bud wood in IAA 25 mg l^{-1} for 24 hours. This improved the take of bud grafts, particularly when older root stocks were used.

5. Anatomical changes during rooting of cuttings

The rooting pattern in any crop is largely governed by the anatomy of the stem (Priestly and Swingle, 1929; Mahlstede and Watson, 1951; Esau, 1958 and Hartman *et al.*, 1993). The developmental anatomical changes that occur in adventitious root formation are dedifferentiation, formation of root initials, subsequent development into root primordia and emergence of the primordia outwards and formation of vascular connections (Hartman *et. al.*, 1993).

The precise site of origin or genesis of adventitious roots intrigued plant anatomists for centuries. In woody perennial plants, adventitious roots usually originate from living parenchymatous cells, primarily in the young secondary phloem. Medullary rays, cambium, lenticles and pith have also been reported to give rise to adventitious roots (Ginzburg, 1967).

Within the species itself, different tissues can function as the site of origin of roots. In *Citrus limon*, roots were found to be originating from secondary pholem, cambium, pericycle and from medullary rays in xylem (Yadava *et al.*, 1968). In karna Khatta (*Citrus karna*), Kagzi lime (*C. aurantifolia*) and Sweet lime (*C. limettioides*), roots were seen originating from any tissue from the pericycle upto the cambium region and even deeper in the medullary ray (Singh and Singh 1968).

Origin of adventitions roots was found to be secondary phloem in association with pericycle and cambuim in Mulberry (Yadava _et al._, 1966); medullary rays in Vitis (Jackson, 1988) and pholem parenchyma in apple (Harbage _et al._, 1993).

5.1 Stem structure and rooting

The initiation and development of root initials in any crop is largely governed by the anatomy of the stem (Priestly and Swingle, 1929; Malstede and Watson, 1951; Esau, 1958 and Hartman _et. al._, 1993). A correlation between extensive sclerification and poor rooting of shoots have been reported by several anatomists.

Ciampi and Gellini (1958) found that stem cuttings of Olive with continous. sclerenchymatic tissue rooted poorly. These thick walled cells interrupted the emergence of adventitious root primordia. Beakbane (1961) pointed out that shoots of 'shy' rooting Apple and Pear trees were frequently characterized by a high degree of sclerification. Gellini (1964) considered the poor rooting characteristic of matrue shoots of _Ficus carica_ to be related to lignification of cell walls and formation of sclereids and not neessarily related to the continuity or discontinuity of a scleren chymatous tissue. Sachs _at al._, (1964) on the other hand suggested that the ease of rooting is related to the ease with which root initials are formed and not to the restriction of developing root primordia by sclerenchyma.

6. Biochemical changes during rooting

Regeneration of adventitious roots on cuttings greatly depends on the morphological, physiological and biochemical characteristics of the regenerating organ.

The direct and indirect effects of sucrose on initiating rooting has been confirmed by many experiments. In *Populus nigra*, Nanda *et al.* (1968) observed that sucrose alone did not induce rooting, but it increased the effectiveness of applied auxins. Arslanov (1980) reported that break down of sugars and starch with a simultaneous increase in respiration rate and rise in catalase and peroxidase activity was observed during callusing and beginning of root growth in lemon cuttings.

A decrease in the carbohydrate content in cuttings is generally observed during the first few days of the rooting period [Haissig, 1982 and Vierskov *et al.*, 1982]. However, a net accumulation of carbohydrates normally occurs unitl roots emerge from the cuttings [Lovell *et al.*, 1974; Davis and Potter, 1981; Veierskov *et al.*, 1982 and Spellenberg, 1985). Accumulation of sugars and starch in cuttings begins in the leaves, at a later point in the stem and lastly in the base of the cutting (Haissig, 1982 and Veierskov *et al.*, 1982).

Ghosh and Basu (1973) observed that carbohydrate levels showed no change during first phase of regeneration of Justicia cuttings but the carbohydrate level fell in the second stage (0-10 days) and third stage (10-30 days).

Basu et al., (1968) recorded that total nitrogen in the bark and wood decreased during root formation. The soluble nitrogen rose during precallusing and callusing stage but fell before root mergence when there was a net synthesis of proteins.

A balance between carbohydrate and nitrogen reserves appear to be better for root development. Basu (1960) and Sen et al., (1965) have shown that a high C/N ratio is beneficial for rooting of cuttings. Stock plants with low C/N ratio produce cuttings with low rooting potential [Reid, 1924 and Knoblauch, 1979].

Though the net synthesis of Proteins has been found to fall down during the regeneration of roots [Basu et al., 1967 and Roychoudhari, 1971] observations of other workers pointed out that protein synthesis was a prerequisite for root formation [Knypyl, 1966 and Kamineck, 1968]. New proteins were synthesised during root initiation in Mango cuttings and in those proteins, certain amino acids were preferentially incorporated (Basu et al., 1967).

So also concentration of free amino acids like aminobutyric acis, aspartic acis, alanine and glutanic acid increased from zero to ten days. Aspartic acid concentration fell between 10-30 days while that of others increased further. Leucine, serine and glycine were more at 10-30 days.

Determinations in rooted cuttings revealed that proline was the most abundant amino acid in newly rooted cuttings where as in intact plants, aspargine was predominent (Suzuki, 1982).

Haissig [1974) suggested that rooting ability was reflected in the amino acid composition in such a way that poor rooters contained a relatively high content of arginine, histidine and especially alpha butyric acid.

MATERIALS AND METHODS

MATERIALS AND METHODS

The present studies on "standardisation of propagation techniques in Baduvapuli (*Citrus pennivessiculata* Tan.)" was carried out in the Department of Pomology and Floriculture, College of Horticulture; the Central Nursery and ARS Mannuthy situated with in the main campus of the Kerala Agricultural University from September 1993 to August 1995.

1. CUTTINGS

1.1 Standardisation of type of cuttings, hormone and its concentration

1.1.1 Preparation of cuttings

Soft wood, semihard wood and hard wood cuttings of diameter 1.5cm, 2.0 cm and 3.0 cm, respectively, having 3 nodes each were prepared. The leaves were clipped from the cuttings prepared.Ten cuttings each were prepared for each type.

1.1.2 Preparation of hormones

IAA, IBA and NAA each at 500 mg l^{-1}, 1000 mg l^{-1}, 1500 mg l^{-1} and 2000 mg l^{-1} was prepared by dissolving 2g of the growth regulator first in a few ml of alcohol and then made up to one litre using double distilled water. Further concentrations were prepared by diluting the stock solution with distilled water.

1.1.3 Method of hormone dip

The prepared soft wood, semi hard wood and hard wood cuttings were given a quick dip in each of the growth regulator solutions for 5 minutes.

1.1.4 Planting of the treated cuttings

The growth regulator treated cuttings were planted immediately in a media containing soil, sand and dried cowdung in equal proportions filled in pots. Each treatment having 10 cuttings was planted in pots and the pots were kept inside a mist chamber.

1.1.5 Observations taken

The following observations were taken at monthly intervals.

Percentage rooting

Days to root

Number of roots per cutting

Length of the longest root (cm)

Number of leaves

Number of shoots

1.1.6 Standardisation of concentration

Based on the results generated in the preliminary study, the range of maximum efficiency of hormones were identified. Finer treatments within this range were fixed to identify the concentration of hormone yielding maximum efficiency. At first, the concentrations tried were, IBA, IAA and NAA each at 500 mg l^{-1}, 1000 mg l^{-1}, 1500 mgl^{-1} and 2000 mg l^{-1}. The concentrations further tried were IAA from 200 mg l^{-1} to 1500 mg l^{-1} and IBA from 1000 mg l^{-1} to 2000 mg l^{-1}.

1.1.7 Synergism/Antagonism of hormones

From the above three plant hormones, combinations of two growth regulators at 500, 1000, 1500 mg l^{-1}, resulting in 27 treatments, were tried using all the three type of cuttings. Each treatment was replicated 10 times. Further, combinations of higher and lower concentrations were tried as follows:

IBA 1500 + IAA 1000 mg l^{-1}

IBA 2000 + IAA 1000 mg l^{-1}

IBA 2500 + IAA 1000 mg l^{-1}

IBA 1500 + IAA 1100 mg l^{-1}

IBA 2000 + IAA 1100 mg l^{-1}

IBA 2500 + IAA 1100 mg l^{-1}

IBA 1500 + IAA 1200 mg l^{-1}

IBA 2000 + IAA 1200 mg l^{-1}

IBA 2500 + IAA 1200 mg l^{-1}

IBA 1500 + IAA 1300 mg l^{-1}

IBA 2000 + IAA 1300 mg l^{-1}

IBA 2500 + IAA 1300 mg l^{-1}

IBA 1500 + IAA 1400 mg l^{-1}

IBA 2000 + IAA 1400 mg l^{-1}

IBA 2500 + IAA 1400 mg l^{-1}

IBA 1500 + IAA 1500 mg l^{-1}

IBA 2000 + IAA 1500 mg l^{-1}

IBA 2500 + IAA 1500 mg l^{-1}

A selection was made from the individual and combination treatments and repeated on 10 cuttings each of softwood, semi hard wood and hard wood type. The selected treatments were IBA 1800 mg l^{-1}, IBA 1900 mg l^{-1}, IBA 2500 + IAA 1300 mg l^{-1}, IBA 2500 + IAA 1500 mg l^{-1}, IBA 2000 + IAA 1200 mg l^{-1}, IBA 1500 + IAA 1000 mg l^{-1}, IBA 2000 mg l^{-1}, IAA 1000 + IBA 1000 mg l^{-1}, IAA 1500 + IBA 1000 mg l^{-1}, NAA 500 + IBA 1500 mg l^{-1} and NAA 500 + IBA 500 mg l^{-1}.

1.2 <u>Standardisation of number of nodes per cutting</u>

Single, two, three, four and five noded cuttings were prepared using soft wood, semi hard wood and hard wood cuttings. The prepared cuttings were treated with the most effective hormone at the most effective concentration (IBA 1900 mg l^{-1}) and kept inside the misting unit. The misting was given at the rate of one minute for every 15 minutes. Ten cuttings were prepared for every treatment.

1.3 <u>Effect of misting</u>

Fourty cuttings each of the softwood, semihard wood and hard wood types were prepared and given dip in IBA 1900 mg l^{-1}. Twenty cuttings each were placed inside and outside the mist chamber in pots. The number of cuttings rooted and the percentage rooting were recorded at 2 months and 4 months after planting. The misting was done at the rate of 1 minute for every 15 minutes.

1.4 Identifying the best season

The three types of cuttings i.e. hard wood, semi hard wood and soft wood, were prepared with 3 nodes. They were treated with IBA 1900 mg l^{-1} and planted from January to December and kept inside the mist chamber. Observations on percentage rooting, days to root, number of roots per cutting, length of the longest root and number of leaves were made for each month.

1.5 Leafy Vs Leafless cuttings

Five noded terminal soft wood cuttings were prepared with leaves and treated with IBA 1900 mg l^{-1}. Similarly five noded leafless cuttings were prepared and treated with IBA 1900 mg l^{-1}. Both the leafy and leafless cuttings were kept inside the mist chamber. Observations on number of cuttings rooted, number of primary roots, number of secondary roots, length of the longest root were recorded. Twenty cuttings each were planted and this was recorded during June, July and August.

1.6 Banding/Etiolation on rooting of cuttings

Soft wood, semi hard wood and hard wood part of 50 long shoots were made free of leaves and thorns. These shoots were covered with Aluminium foil and tied firmly using thin coir. These shoots were cut 15, 30 and 45 days after banding procedure. After cutting the shoots, they were prepared to 3 node cuttings of soft wood, semi hard wood and hard wood. Ten cuttings of each type were treated with IBA 1900 mg l^{-1} by quick dip for 5 minutes and were planted and retained inside the mist chamber. Observations on percentage rooting, days to root, number of roots and length of the longest root were recorded.

1.7 Survival of cuttings

Rooted cuttings were separated from the pots carefully, without injuring the roots, two months after application of treatment. They were replanted in polythene bags filled with soil, sand and dried cowdung in equal proportions. The bagged plants were initially retained inside the mist chamber for a week and then they were transferred to the field. The percentage survival of the cuttings was observed at two stages - two months and six months after planting. This was done in June-July and repeated in August-September, October-November, December-January, February-March and April-May.

2. LAYERING

2.1 Method of layering

Straight, healthy and uniform shoots were selected on a mother tree. A ring of bark of 2-5 cm width was completely removed without damaging the tissues beneath. At the middle portion of the ringed area, a knot was made with a gunny thread. The ringed region was covered with a media and wrapped tightly using a transparent polythene sheet. The two ends were tied firmly using gunny thread.

2.2 Identification of most responsive shoot or wood

Layering was done on soft wood, semi hard wood and hard wood portions of healthy shoots. For each type of wood, 10 shoots were layered. The size of shoots selected were 1.5 cm for soft wood, 2.0 cm for semi hard wood and 3.0 cm in diameter for hard wood. The most responsive wood was identified based on efficiency of layers to strike roots. Observations were taken on percentage rooting, days to root, number of roots produced, length of the longest root, fresh weight of roots and dry weight of roots.

2.3 Standardisation of most suitable media for rooting

Layering was done on soft wood, semi hard wood and hard wood portions of shoots using four different media namely sphagnum moss, retted coconut fibre, coir dust and saw dust. Treatments were tried on 10 shoots each and observations were taken on rooting efficiency, quantitative and qualitative aspects of rooting media.

2.4 Standardisation of hormone.

After ringing of all the three types of shoots, growth regulator was applied at the upper end of the ring and covered with coconut fibre which was found to be the best media. The growth regulators were applied in powder form using talc and paste form using petroleum jelly. After covering with media, it was wrapped with polythene film and end secured with gunny thread. Ten shoots each were layered for each growth regulator treatment and the same observations were recorded.

2.4.1 Preparation of hormone

IBA, IAA and NAA were used for layering. The concentrations tried were 100 mg l^{-1}, 250 mg l^{-1}, 500 mg l^{-1} and 2000 mg l^{-1} for each of the hormone. Combination treatments were also done with two growth regulators each in all possible combinations. For preparation of hormone, the required amount of the hormone was first dissolved in a few drops of alcohol and then mixed uniformly with petroleum jelly. The same was done by mixing with talc also.

2.5 Identification of the most suitable season

Layering was done at monthly intervals with all the four media in all the three types of shoots. The treatments were done on 10 shoots each. Observations were taken for each month regarding the percentage of rooting, number of roots per layer, length of the longest root, fresh weight and dry weight of the roots.

2.6 Banding and layering

As in the case of cuttings, banding of shoots were done. Here, only the area to be layered were banded. Soft wood, semi hard wood and hard wood portions on healthy shoots were covered with a piece of Aluminium foil and both ends secured tightly. Layering was done at the banded portions at 15, 30, 45, 60, 75 and 90 days intervals after banding. The treatments were tried on 10 shoots each. Simultaneously, 10 shoots each of soft wood, semi hard wood and hard wood were also layered without any banding and all observations recorded.

2.7 Banding & Ringing

The area of layering was banded for 45 days and that area was ringed (bark removed as a ring) for each type of wood. Layering was done on those ringed portions at 3 intervals ie. 5 days, 10 days and 15 days of ringing. Each treatment was done on 10 shoots each and all observations on rooting recorded.

2.8 Survival of layers

Successful layers were separated from the mother plant after 2 months when all the roots have emerged and were clearly visible throgh the polythene sheet. The separated layers were then immediately planted in polythene bag filled with sand, soil and dried cowdung in equal proportions. They were kept in shade for 15 days and then kept under open field conditions. The percentage establishment recorded at 3 months and 6 months after planting. This planting was done in all months in a calendar year and observations on rooting recorded at the above timings.

3. GRAFTING

3.1 Method of soft wood grafting

One year old stock plants wre raised and maintained in the nursery. Fifteen to twenty cm long young terminal shoots of 3 months age were cut and used as scion (Plate 1). The leafy portion of the stock was cut at 10-15 cm from the base. A V-shaped cut was made at the top of the prepared stock (Plate 2). The base of the scion was made into the shape of a wedge (Plate 2). The wedge shaped scion was inserted into the stock and wrapped firmly with a polythene strip (Plates 3 & 4). The grafted plants were placed in a mist chamber for about one month (20-30 days) and later transferred to shade.

Plate No. 1

Root stock and scion ready for grafting

Plate No. 2

V shaped cut made at the top of root stock and bottom of scion prepared in the shape of a wedge

Plate No. 3

Scion inserted into root stock

Plate No. 4

Root stock and scion tied firmly with a polythene strip

3.2 Identification of most suitable root stock

Four root stocks were studied to find the most appropriate root stock for Baduvapuli. The rootstocks tried were 1½ year old seedlings of Rough lemon (Citrus jambhiri) Rangpur lime (Citrus limonia), Acid lime (Citrus aurantifolia) and Malta lemon (Citrus limon). Twenty root stocks of each type were grafted with the young scion collected from Baduvapuli. The percentage success and survival were found out for the different root stocks.

3.3 Vigour and growth of scion

To compare the effects of root stocks on the vigour and growth of scion, 10 grafts each were made on all the four root stocks. Observations were taken on the total height, girth of stock and girth of scion. The observations were taken at monthly intervals for 6 months.

3.4 Standardising precuring techniques

On the mother plant, 50 young terminal shoots were selected as scion material. They were defoliated and tagged. Ten shoots of each of these were separated at 5, 10, 15, 20 and 25 days after tagging and were grafted on to Rangpur lime root stocks. Simultaneously, another 10 shoots were also defoliated at the time of grafting and grafted on to rough lemon. This was done in June, July and August and comparitive effects were analysed on the basis of percentage survival.

3.5 Seasonal effect on graft union

Grafting was done at monthly intervals from January to August with Rangpur lime as the root stock. Ten grafts were made every month using Rangpur lime root stock. Observations were made on the percentage success.

4. BUDDING

Among the different vegetative methods tried, budding is the most common one practised world wide in citrus.

4.1 Standardisation of type of budding

T-budding, chip-budding and Patch budding were tried in Baduvapuli.

4.1.1 T-budding

One year old rough lemon and Malta lemon seedlings were raised and maintained in the nursery. T-budding were done on 20 rough lemon and 20 Malta seedlings with buds taken from Baduvapuli.

4.1.1 Preparation of stock

A vertical cut of about 2.5 cm long was made in the stock first with a sharp knife. Then a horizontal cut was made about one third the distance around the stock. The knife was slightly twisted to open the two flaps of bark.

4.1.1.2 Preparation of scion/bud

Starting about 1.2 cm below the bud, a slicing cut was made under and about 2.5 cm beyond the bud. About 2 cm above the bud, a horizontal cut was given through the bark and into the wood permitting the removal of the bud piece.

The bud was inserted by pushing it downward under the two flaps of bark until the horizontal cuts on the bud and stock were even. The bud union was then tightly tried with a polythene strip with the bud exposed out. The budded plants were then kept inside a mist chamber.

4.1.2 Chip budding

One year old rough lemon and Malta seedlings were raised and maintained in the nursery. Chip budding was done on 20 rough lemon and 20 malta seedlings with buds taken from Baduvapuli.

4.1.2.1 Preparation of stock

A cut was given at 45° angle about one quarter through the stock. About 2.5 cm above the first cut, a second cut was made going downward and inward until it connects with the first cut.

4.1.2.2 Preparation of bud

The cuts removing the bud from the bud shoot were made just as those in the stock. The lower cut was given about 0.5cm below the bud. The second cut was given about 1.2 cm above the bud coming downward behind the bud and connecting with the first bud, thus permitting the removal of the bud piece with a piece of wood.

The prepared bud was inserted into the stock and finally wrapped with a strip of polythene. The budded plants were then placed inside the mist chamber. Observtions were made on the percentage of bud uptake.

4.1.3 Patch budding

4.1.3.1 Preparation of stock

Two vertical cuts of 2.5 cm long were made upwards. Then two cross cuts were made connecting the two vertical cuts. The bark was thus removed in the form of rectangular patch.

4.1.3.2 Preparation of bud

The bud was removed from the shoot in the form of a patch of bark with the bud in the centre.

The bud was then inserted into the stock and wrapped with a polythene strip. The budded plants were placed inside the mist chamber and observed for the percentage success.

4.2 Seasonal uptake

The budding procedure was repeated in October, January and March with different root stocks. The percentage bud uptake was noticed.

4.3 Age of bud

T-budding and chip budding were done on 20 rough lemon seedlings of 1 year with mature buds (buds from previous season) and young buds (buds from current season). The mature buds were collected from the hard wood region with less thorns and young buds collected from the soft wood regions. The budded plants were placed in mist chamber.

4.4 Hormone treatment of the buds

GA was prepared at 1 mg l^{-1}, 3 mg l^{-1} and 5 mg l^{-1}. Ten buds prepared each were given treatment with the 3 concnetration of GA for 30 minutes and then budded on to rough lemon by chip budding and T budding. The budded plants were then kept inside mist chamber. The percentage bud uptake was observed.

5 ANATOMICAL STUDIES

5.1 Cuttings

Soft wood, semi hard wood and hard wood cuttings witl 3 nodes which were planted in pots filled with sand, soil an dried cowdung in equal proportions formed the material for study.

Hand sections made daily from base of cuttings from
10th day of planting onwards

↓

Saffranin stain prepared by dissolving 1 ml in 5ml of water

↓

Sections kept in stain for 2 minutes

↓

Washed in water for 1 minute

↓

Section mounted in glycerin on a glass slide and
covered with a cover slip

↓

Section observed through a light microscope

The photomicrographs were made using a microscope (Model Leitz Biomed Leic wild MPS 28/32) at magnification of 4x, 10x or 100x for different sections. The sections were observed from 10th day onwards daily upto final stage of emergence to find out the anatomical changes during rooting.

5.2 Grafting

Soft wood grafting was done on four different rootstocks viz Rough lemon, Rangpur lime, Malta and Acid lime. Compatible and incompatible grafts were identified. The graft union from both compatible and incompatible grafts were cut and separated to study the anatomical basis of compatibility or incompatibility. The hand sections were made from the region of graft union using the same procedure as in cuttings given above and microphotographs taken.

6. BIOCHEMICAL STUDIES

Priliminary anatomical studies were made to ascertain the approximate time of various stages of rooting. Based on this, biochemical studies were done at the time of planting, 15 days after planting (at the time of root initiation) 18 days after planting (at the time of root primordia formation) and 22 days after planting (at root emergence) of cuttings. This was done for each of soft wood, semi hard wood and hard wood cuttings. Leaf samples (2nd and 3rd leaves from tip) were used at the time of planting and at root emergence while stem base were used at all the 4 stages.

6.1 Starch

The starch estimation in leaves and base of stem (1-2cm) were carried out by Acid hydrolysis (McCreddy et al., 1958) at the time of planting, 15, 18 and 22 days after planting using softwood, semi hard wood and hard wood cuttings.

6.2 Carbohydrates

The total carbohydrates present in the leaves and base of stem were analysed by Anthrone method (Dubois _et al_., 1951). This was done at the time of planting, 15, 18 and 22 days after planting using softwood, semihard wood and hard wood cuttings.

6.3 Total Nitrogen

Estimation of total Nitrogen was done in leaves and base of stem by Microkjeldhal method (Jackson, 1973). This was also done at the time of planting, 15, 18 and 22 days after planting using softwood, semihard wood and hard wood cuttings.

6.4 Protein

From the total N content, the protein content in the leaves and base of stem were found out by multiplying N content by 6.25 (Simpson _et al_., 1965).

6.5 Amino acids

The amino acid content in the leaves and stem base of the cutting were analysed by paper chromatography at the time of planting, 15,18 and 22 days after planting of the cuttings. This was done for each of softwood, semihard wood and hard wood.

6.5.1 Paper chromatography

6.5.1.1. Preparation of solvent

The solvent was prepared by mixing Butanol, water and Acetic acid in the ratio 4:1:5. The solvent was poured into the tray inside the chamber.

6.5.1.2 Preparation of paper strips

Whatmann No.1 filter paper was cut into strips of 3.5 cm width.

6.5.1.3 Preparation of standard amino acids

10 mg each of the 24 amino acids were weighed and dissolved in 5 ml of 10% iso propanol.

6.5.1.4 Preparation of plant samples

The plant samples (leaves and stem bases) were ground with 5ml of 10% Isopropanol using a mortar and pestle. The ground samples were centrifuged for 20 minutes. The supernatent were then collected in glass vials.

6.5.1.5 Spotting of standard amino acid and plant samples

Each of the standard amino acids (24) and the plant samples representing each stage of rooting were spotted on to the filter paper strips prepared using a fine capillary tube at a distance of 2 cm from the tip of the strips. It was then dried using a hair drier. Spotting was done 5 times on each strip.

The strips were then hung to a rod using clips and the rod fixed inside the chamber with the strips just touching the solvent in the tray. After 10 hours, the strips were taken out and air dried for 15 minutes. The distance travelled by solvent was marked. Fresh Ninydrin 0.1% was sprayed on to the strips from tip upwards using a hand sprayer. The strips were then dried inside a chromatography oven at 90°C for 30 minutes. The strips were then taken out and air dried.

The purple coloured spots in the strips were marked and the distance travelled by each amino acid were marked for the standard acid in the sample strips.

The Rf value was calculated by the following formula

$$\text{Rf value} = \frac{\text{Distance travelled by the Amino acid}}{\text{Distance travelled by the solvent}}$$

The Rf values obtained for each sample strip were then compared with the Rf value for standard amino acids. The amino acids were thus identified.

7. STATISTICAL ANALYSIS

The data on different aspects of propagation through cuttings, layering and grafting were analyed using ANOVA technique for split plot technique in CRD. The data were transformed appropriately before analysis. The effect of misting was analysed using X^2 technique.

RESULTS

RESULTS

The results of the study on "standardisation of propagation techniques in Baduvapuli" are sequentially presented below.

1.CUTTINGS

1.1. Standardisation of type of cutting, hormone and its concentration

Data on the effect of type of wood on percentage of rooting is presented in tables 1,2,3 and 4. Though soft wood cuttings gave higher percentage of rooting at wider concentrations; hard wood cuttings performed better when intermediate concentrations and combinations were tried. Early rooting was observed in soft wood cuttings but the effect was not significant.

1.1.1 Percentage of rooting

The data of the preliminary trial using wider concentration of plant hormones are presented in table 1. The data clearly reveals that IBA at 1500 mgl^{-1} gave the highest rooting percentage (43.3) which was on par with IBA 2000 mgl^{-1} (30) and significantly superior to other treatments. The results of further studies using narrow range of concentrations of the effective growth regulators (IBA and IAA) are given in Table 2 which indicate that

TABLE - 1

EFFECT OF GROWTH REGULATORS ON PERCENTAGE ROOTING AND DAYS TO ROOTING OF CUTTINGS

Treatments ($mg\ l^{-1}$)	Soft Wood		Semi hard wood		Hard wood		Mean	
	% rooting	Days to root	% rooting	Days to root	% rooting	Days to root	% rooting +	Days to root ++
IAA 500	10	26	10	31	20	33	13.33(0.37)	30(5.52)
IAA 1000	20	27	20	31	20	35	20(0.46)	31(5.61)
IAA 1500	0	-	20	32	0	-	8.33(0.26)	10.7(2.37)
IAA 2000	20	28	0	-	10	34	10.8(0.31)	20.67(3.97)
IBA 500	20	28	10	30	10	32	13.3(0.37)	30(5.52)
IBA 1000	0	-	10	30	20	32	10.8(0.31)	20.67(3.98)
IBA 1500	50	25	40	31	40	30	43.3(0.72)	28.67(5.39)
IBA 2000	50	25	20	32	20	30	30(0.57)	29(5.42)
NAA 500	20	27	10	32	0	-	10.8(0.31)	19.67(3.88)
NAA 1000	0	-	20	32	0	-	8.33(0.26)	10.67(2.372)
NAA 1500	0	-	0	-	0	-	0(0.16)	-
NAA 2000	0	-	0	-	0	-	0(0.16)	-
Mean	17.08	17.83	14.17	23.42	12.92	18.83		

CD (0.05) for growth regulator - % rooting - 0.124, Days to root - 1.56
Figures in paranthesis shows transformed values
\+ Angular transformation
++ Square root transformation

TABLE - 2

EFFECT OF GROWTH REGULATORS ON PERCENTAGE ROOTING AND DAYS TO ROOTING OF CUTTINGS

Treatments ($mg\ l^{-1}$)	Soft Wood		Semi hard wood		Hard wood		Mean	
	% rooting	Days to root	% rooting	Days to root	% rooting	Days to root	% rooting +	Days to root ++
IAA 200	0	-	0	-	20	30	8.33(0.26)	10(2.31)
IAA 300	0	-	0	-	20	30	8.33(0.26)	10(2.31)
IAA 400	0	-	0	-	20	30	8.33(0.26)	10(2.31)
IAA 500	0	-	0	-	10	30	5(0.21)	10(.231)
IAA 600	0	-	0	-	20	30	8.33(0.26)	10.(2.31)
IAA 700	0	-	0	-	20	30	8.33(0.26)	10(2.31)
IAA 800	10	25	10	30	20	30	10.8(0.32)	28.3(5.37)
IAA 900	10	26	10	-	20	30	10.8(0.32)	18.67(3.79)
IAA 1000	0	-	10	32	20	30	10.8(0.4)	20.67(3.98)
IAA 1100	0	-	20	35	30	30	17.5(0.36)	21.67(4.06)
IAA 1200	0	-	20	35	20	30	14.17(0.4)	21.67(4.06)
IAA 1300	0	-	30	35	20	30	17.5(0.36)	21.67(4.06)
IAA 1400	10	28	30	35	10	30	17.5(0.36)	31(5.61)
IAA 1500	10	28	20	35	10	30	14.17(0.4)	31(5.61)
IBA 1000	0	-	20	35	40	30	20.8(0.44)	21.67(4.06)
IBA 1100	0	-	30	35	30	29	20.8(0.44)	21.3(4.02)
IBA 1200	0	-	20	35	30	29	14.17(0.4)	21.3(4.03)
IBA 1300	0	-	40	35	20	30	20.8(0.44)	21.67(4.06
IBA 1400	10	25	70	35	20	29	33.3(0.59)	29.67(5.48)
IBA 1500	20	25	60	35	60	29	46.67(0.75)	29.67(5.48)
IBA 1600	30	25	70	35	60	29	53.3(0.82)	29.67(5.48)
IBA 1700	40	25	70	32	70	28	60(0.89)	28.33(5.36)
IBA 1800	50	25	70	32	70	28	63.3(0.92)	28.33(5.36)
IBA 1900	80	25	100	32	90	28	90(1.31)	28.33(5.36)
IBA 2000	20	25	20	35	20	30	20(0.46)	25(5.31)
Mean	12.9 (0.31)	11.28 (2.65)	28.7 (0.53)	24.52 (4.43)	30.8 (0.57)	29.56 (5.48)		

CD (0.05) for growth regulator - % rooting - 0.23,
CD (0.05) for wood - % rooting - 0.08
Figures in paranthesis shows transformed values
\+ Angular transformation
++ Square root transformation

IBA 1900 mgl^{-1} was the most effective (90 percent) and significantly superior treatment. IBA at 1500 mgl^{-1}, 1600 mgl^{-1}, 1700 mgl^{-1} and 1800 mgl^{-1} were on par and significantly superior to IBA at 2000 mgl^{-1}.

Among the combinations of the different growth regulators tried (Table 3), IAA 1000 mgl^{-1} + IBA 1000 mgl^{-1} gave significantly higher percentage of rooting (26.67) and was on par with IAA 1500 mgl^{-1} + IBA 1000 mgl^{-1} and IAA 1500 mgl^{-1} + IBA 1500 mgl^{-1}. When further combinations at higher and lower concentrations of these treatments were tried (Table 4), the effects were neither superior nor significant.

Table 5 gives an evaluation of the most effective treatments, ie., the effect of individual and combination treatments of growth regulators. IBA at 1900 mgl^{-1} gave the highest value (81.67%) but the percentage rooting did not vary significantly from IBA 1800 mgl^{-1}, IBA 2500 mgl^{-1} + IAA 1300 mgl^{-1} and IBA 2500 mgl^{-1} + IAA 1500 mgl^{-1}

1.1.2 <u>Days to rooting</u>

Data pertaining to the mean number of days taken for rooting is also presented in tables 1 to 5. Neither the concentration of the different growth regulators tried nor their combinations showed any significant influence on the number of days taken for rooting.

TABLE - 3

EFFECT OF GROWTH REGULATORS ON PERCENTAGE ROOTING AND DAYS TO ROOTING OF CUTTINGS

Treatments (mg l^{-1})	Soft Wood		Semi hard wood		Hard wood		Mean	
	% rooting	Days to root	% rooting	Days to root	% rooting	Days to root	% rooting +	Days to root ++
IAA500 + IBA500	0	-	10	32	40	27	17.5(0.38)	19.67(3.88)
IAA500 + IBA1000	10	30	0	-	0	-	5(0.21)	10(2.3)
IAA500 + IBA 1500	10	30	0	-	20	28	10.8(0.39)	19.3(3.8)
IAA1000 + IBA500	0	-	10	32	40	28	17.5(0.39)	20(3.92)
IAA1000 + IBA1000	20	30	10	30	50	30	26.67(0.52)	30(5.52)
IAA1000 + IBA1500	50	28	40	30	70	30	53.3(0.82)	26(5.46)
IAA1500 + IBA500	0	-	0	-	30	29	11.67(0.29)	20.33(3.95)
IAA1500 + IBA1000	10	30	10	32	60	32	26.67(0.52)	31.3(5.64)
IAA1500 + IBA1500	0	-	0	-	50	34	21.67(0.40)	11.33(2.43)
NAA500 + IBA500	0	-	0	-	50	35	18.33(0.37)	11.67(2.46)
NAA500 + IBA1000	10	30	0	-	20	35	10.8(0.32)	21.67(4.06)
NAA500 + IBA 1500	10	30	0	-	60	35	24.17(0.46)	21.67(4.06)
NAA1000 + IBA500	0	-	0	-	20	35	5(0.21)	11.67(2.46)
NAA1000 + IBA1000	0	-	10	32	20	35	10.8(0.32)	22.3(4.12)
NAA1000 + IBA1500	0	-	0	-	20	35	8.33(0.26)	11.67(2.46)
NAA1500 + IBA500	10	30	0	-	10	35	7.5(0.27)	21.67(4.06)
NAA1500 + IBA1000	0	-	0	-	10	35	5(0.21)	11.67(2.46)
NAA1500 + IBA1500	0	-	0	-	10	28	5(0.21)	9.33(2.25)
IAA500 + NAA500	0	-	0	-	20	29	7.5(0.26)	9.67(2.28)
IAA500 + NAA1000	10	30	10	32	40	29	20(0.44)	30.33(5.55)
IAA1000 + NAA1500	0	-	0	-	10	32	5(0.21)	10.67(2.37)
IAA1000 + NAA500	10	-	0	-	0	-	5(0.21)	10(2.37)
IAA1000 + NAA1000	0	-	0	-	10	32	5(0.21)	10.67(2.37)
IAA1500 + NAA1500	0	-	0	-	0	-	0(0.16)	-(0.707)
IAA1500 + NAA500	0	-	0	-	30	32	11.67(0.3)	10.67(2.37)
IAA1500 + NAA1000	0	-	0	-	10	34	5(0.21)	11.33(2.43)
IAA1500 + NAA1500	10	30	0	-	0	34	5(0.21)	21.33(4.03)
Mean	7.407 (0.25)	12.15 (2.66)	5.56 (0.21)	9.33 (2.17)	26.67 (0.5)	28.44 (5.14)		

CD (0.05) for growth regulator - % rooting - 0.224
CD (0.05) for wood - % rooting - 0.074, Days to root -1.21
Figures in paranthesis shows transformed values
+ Angular transformation
++ Square root transformation

TABLE - 4

EFFECT OF GROWTH REGULATORS ON PERCENTAGE ROOTING AND DAYS TO ROOTING OF CUTTINGS

Treatments ($mg\ l^{-1}$)	Soft Wood		Semi hard wood		Hard wood		Mean	
	% rooting	Days to root	% rooting	Days to root	% rooting	Days to root	% rooting +	Days to root ++
IBA1500 + IAA1000	10	30	20	36	60	30	30(0.56)	32(5.69)
IBA2000 + IAA1000	0	-	10	-	20	35	8.33(0.26)	11.67(2.46)
IBA2500 + IAA1000	0	-	20	38	40	30	20.8(0.44)	22.67(4.15)
IBA1500 + IAA1100	0	-	40	35	40	30	27.5(0.51)	21.67(4.06)
IBA2000 + IAA1100	40	25	20	38	0	-	20.8(0.44)	21(3.99)
IBA2500 + IAA1100	20	26	20	38	40	31	26.67(0.54)	31.67(5.66)
IBA1500 + IAA1200	20	30	0	-	20	35	14.16(0.37)	21.67(4.06)
IBA2000 + IAA1200	0	-	20	38	60	30	27.5(0.5)	22.67(4.15)
IBA2500 + IAA1200	40	30	40	35	40	32	40(0.69)	32.33(5.73)
IBA1500 + IAA1300	20	28	20	38	40	32	26.67(0.54)	32.67(5.75)
IBA2000 + IAA1300	20	28	0	-	40	32	20.8(0.44)	20(3.92)
IBA2500 + IAA1300	40	30	20	38	60	30	40(0.69)	32.67(5.75)
IBA1500 + IAA1400	20	26	20	38	0	-	14.17(0.36)	21.33(4.02)
IBA2000 + IAA1400	0	-	0	-	0	-	0(0.16)	-(0.71)
IBA2500 + IAA1400	20	30	0	-	40	30	20.8(0.44)	20(3.92)
IBA1500 + IAA1500	20	28	0	-	20	32	14.17(0.36)	20(3.92)
IBA2000 + IAA1500	40	28	40	35	20	35	33.33(0.61)	32.67(5.75)
IBA2500 + IAA1500	60	28	10	36	20	35	30(0.56)	33(5.78)
Mean	21.25 (0.44)	20.38 (4.07)	16.94 (0.39)	24.6 (4.31)	31.53 (0.57)	26.6 (4.86)		

CD (0.05) for wood - % rooting - 0.14
Figures in paranthesis shows transformed values
\+ Angular transformation
++ Square root transformation

TABLE - 5

EFFECT OF GROWTH REGULATORS ON PERCENTAGE ROOTING AND DAYS TO ROOTING OF CUTTINGS

Treatments (mg l^{-1})	Soft Wood		Semi hard wood		Hard wood		Mean	
	% rooting	Days to root	% rooting	Days to root	% rooting	Days to root	% rooting +	Days to root ++
IBA 1800	60	22	60	28	100	30	72.5(1.06)	26.67(5.02)
IBA 1900	50	20	100	28	100	28	81.67(1.2)	25.33(5.07)
IBA2500 + IAA1300	80	23	50	26	100	28	75.83(1.1)	25.67(5.11)
IBA2500 + IAA1500	70	20	80	22	80	28	76.67(1.12)	23.33(4.87)
IBA2000 + IAA1200	50	23	0	-	50	28	34.17(0.58)	17(3.63)
IBA1500 + IAA1000	50	23	40	26	40	24	43.33(0.72)	24.33(4.98)
IBA2000	50	25	50	28	30	26	43.33(0.71)	26.35(5.18)
IAA1000 + IBA1000	30	24	30	26	20	28	26.67(0.54)	26(5.15)
IAA1500 + IBA1000	20	26	30	28	20	28	23.35(0.51)	27.33(5.28)
NAA500 + IBA1500	30	25	30	26	20	28	26.67(0.54)	26.33(5.18)
NAA500 + IBA500	10	26	20	28	30	28	20(0.46)	27.33(5.28)
Mean	45.45 (0.73)	23.36 (4.88)	44.55 (0.73)	24.48 (4.79)	52.95 (0.85)	27.64 (5.3)		

CD (0.05) for growth regulators - % rooting - 0.36
Figures in paranthesis shows transformed values
+ Angular transformation
++ Square root transformation

1.1.3 Number of roots

As evidenced from the data furnished in Table 6, IBA at 1900 mgl^{-1} produced significantly higher number of roots (2.28) and was in par with IBA 1800 mgl^{-1} (2.18). Hard wood cuttings treated with IBA 1800 mgl^{-1} produced the highest number of roots and was on par with IBA 1900 mgl^{-1}. Hardwood cuttings gave significantly higher number of roots compared to other types.

1.1.4 Length of the longest root

The length of the longest root was significantly high with IBA 1900 mgl^{-1} (4.17cm) and this was significantly high two months after planting (Table 6). Semi hard wood and hard wood cuttings treated with IBA 1900 mgl^{-1} gave the longest root and was on par with hard wood cuttings treated with a combination of IBA 2500 mgl^{-1} and IAA 1300 mgl^{-1}. Hard wood cuttings gave significantly higher value for length of longest root, both one month and two months after planting.

1.1.5 Number of leaves

IBA 1900 mgl^{-1} gave the highest number of leaves which was on par with IBA 1800 mgl^{-1}, IBA 2500 mgl^{-1} + IAA 1500 mgl^{-1} (Table 6). IBA 1900 mgl^{-1} and IBA 1800 mgl^{-1} produced similar results two months after planting with regard to the number of leaves. Significantly higher number of leaves was produced when hard wood cuttings were treated with IBA 1800 mgl^{-1} and this was

TABLE - 6

EFFECT OF SELECTED GROWTH REGULATORS, TYPE OF CUTTINGS AND TIME ON NUMBER AND LENGTH OF ROOTS, NUMBER OF LEAVES AND NUMBER OF SHOOTS

Treatments (mg l^{-1})		No. of roots SW	SHW	HW	Mean	Length of longest root SW	SHW	HW	Mean	No. of leaves SW	SHW	HW	Mean	No. of shoots SW	SHW	HW	Mean
IBA 1800	1MAP	1	0.5	3.9	1.8	1.53	0.35	0	0.63	2.6	1.6	5.1	3.1	0.6	0.8	1.1	0.83
	2MAP	1.5	1.3	4.9	2.57	2.0	1.5	3.76	2.42	3.2	2.3	6.4	3.97	0.8	1.4	1.6	1.27
	Mean	1.25	0.9	4.4	2.18	1.77	0.93	1.88	1.52	2.9	1.95	5.75	3.53	0.7	1.1	1.35	1.05
IBA 1900	1MAP	1	2	2.9	1.97	2.0	4.66	4.5	3.72	2.2	3.7	4.0	3.3	0.8	1.9	1.2	1.3
	2MAP	1.2	2.9	3.7	2.6	2.37	5.7	5.75	4.61	2.3	5.1	5.3	4.23	0.9	2.1	1.6	1.53
	Mean	1.1	2.45	3.3	2.28	2.19	5.18	5.13	4.17	2.25	4.4	4.65	3.77	0.85	2.0	1.4	1.42
IBA2500+IAA1300	1MAP	1	0.6	0.6	0.73	1.57	1.65	6.73	3.32	2.5	2.1	4.0	2.87	1.2	0.5	1.1	0.93
	2MAP	1.8	1	0.7	1.17	2.07	1.95	3.35	2.46	2.9	2.7	4.4	3.33	1.4	0.6	1.4	1.13
	Mean	1.4	0.8	0.65	0.95	1.82	1.8	5.04	2.89	2.7	2.4	4.2	3.1	1.3	0.55	1.25	1.03
IBA2500+IAA1500	1MAP	0.2	1.6	0.8	0.87	0.65	2.41	3.85	2.30	1.7	3.2	2.7	2.53	0.4	1	0.7	0.7
	2MAP	1.2	2.7	2.4	1.77	1.2	3.15	2	2.12	3.4	3.6	3.4	3.47	0.8	1.3	1.2	1.1
	Mean	0.7	2.15	1.1	1.32	0.93	2.78	2.93	2.21	2.55	3.4	3.05	3.0	0.6	1.15	0.95	0.9
IBA2000+IAA1200	1MAP	0.3	0	0.4	0.23	0.9	0	2.42	1.11	1.7	0.	0.9	0.87	0.8	0	0.2	0.33
	2MAP	0.9	0	1.2	0.7	1.32	0	1.15	0.83	2.0	0	1.4	1.13	1.0	0	0.5	0.5
	Mean	0.6	0	0.8	0.47	1.11	0	1.79	0.97	1.85	0	1.15	1.0	0.9	0	0.35	0.42
IBA1500+IAA1000	1MAP	0	0.1	0.6	0.23	0	0.4	1.5	0.63	1.2	2.2	2.3	1.9	0.3	0.5	0.6	0.47
	2MAP	0.5	1.2	0.8	0.83	0.175	0.85	1.4	0.81	1.5	2.5	2.3	2.1	0.4	0.7	0.6	0.57
	Mean	0.25	0.65	0.7	0.53	0.09	0.63	1.45	0.72	1.35	2.35	2.3	2.0	0.35	0.6	0.6	0.52
IBA 2000	1MAP	0.4	0.2	0.3	0.3	0.7	0	0.05	0.25	1.9	1.6	1.37	0.5	0.5	0.3		0.43
	2MAP	1.1	0.5	0.5	0.7	1.175	0.1	0.4	0.56	2.1	1.6	0.6	1.43	0.5	0.5	0.3	0.43
	Mean	0.75	0.35	0.4	0.5	0.94	0.05	0.23	0.40	2.0	1.6	0.6	1.4	0.5	0.5	0.3	0.43
Control	1MAP	0	0	0	0	0	0.3	0	0.1	0	0	0	0	0	0	0	0
	2MAP	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	Mean	0	0	0	0	0	0.15	0	0.05	0	0	0	0	0	0	0	0
OverallMean		0.76	0.91	1.42		1.105	1.44	2.3		1.95	2.01	2.71		0.65	0.74	0.78	
Means of	1MAP	0.49	0.63	1.19		0.92	1.22	2.38		1.73	1.8	2.45		0.58	0.65	0.65	
	2MAP	1.03	1.2	1.65		1.29	1.66	2.23		2.18	2.23	2.98		0.73	0.83	0.9	

	No. of roots	Length of longest root	No. of leaves	No. of shoots
CD (0.05) for wood	0.44	0.59	NS	NS
CD (0.05) for growth regulator	0.72	0.97	1.15	0.34
CD (0.05) for time	0.1	0.25	0.127	0.062
CD (0.05) for wood x growth regulator	1.24	1.69	1.99	NS
CD (0.05) for growth regulator x time	0.29	0.70	0.36	0.174
CD (0.05) for wood x time	NS	0.43	0.219	NS

SW - Soft wood
SHW - Semi hard wood
HW - Hard wood
MAP - Months after planting

on par with hard wood cuttings treated with IBA 1900 mgl^{-1} or IBA 2500 mgl^{-1} + IAA 1300 mgl^{-1} and semihard wood cuttings treated with IBA 1900 mgl^{-1}. Hard wood cuttings in general gave higher number of leaves (2.98) two months after planting.

1.1.6 Number of shoots

A critical analysis of the data in Table 6 proved IBA 1900 mgl^{-1} to be superior in producing more number of shoots and this was comparatively high two months after planting (1.53). Hard wood, semi hard wood and soft wood cuttings did not vary significantly in the number of shoots produced with either the growth regulators used or months after planting.

In general, the results reveal the comparitive superiority of cuttings treated with IBA 1900 mgl^{-1} in terms of rooting percentage, other quantitative and qualitative aspects of rooting and shooting.

1.2 Standardisation of number of nodes per cutting

Percentage of rooting was significantly high with higher number of nodes in the cutting (Plates 5,6 & 7). Table 7 and figure-1 shows that five noded cuttings produced highest percentage of rooting (73.33) and the least was in single noded cutting (5.0%). Percentage of rooting was more or less similar in all the three types of woods.

Plate No. 5

Effect of no. of nodes on rooting of Soft Wood Cuttings

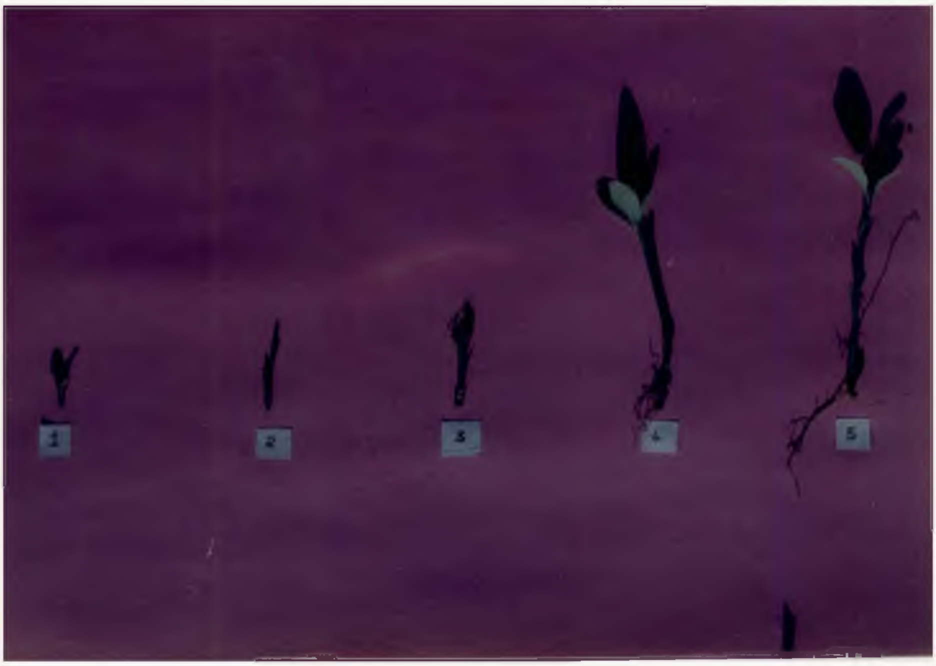

1
2
3
4
5

Plate No. 6

Effect of no. of nodes on rooting of Semi Hard Wood Cuttings

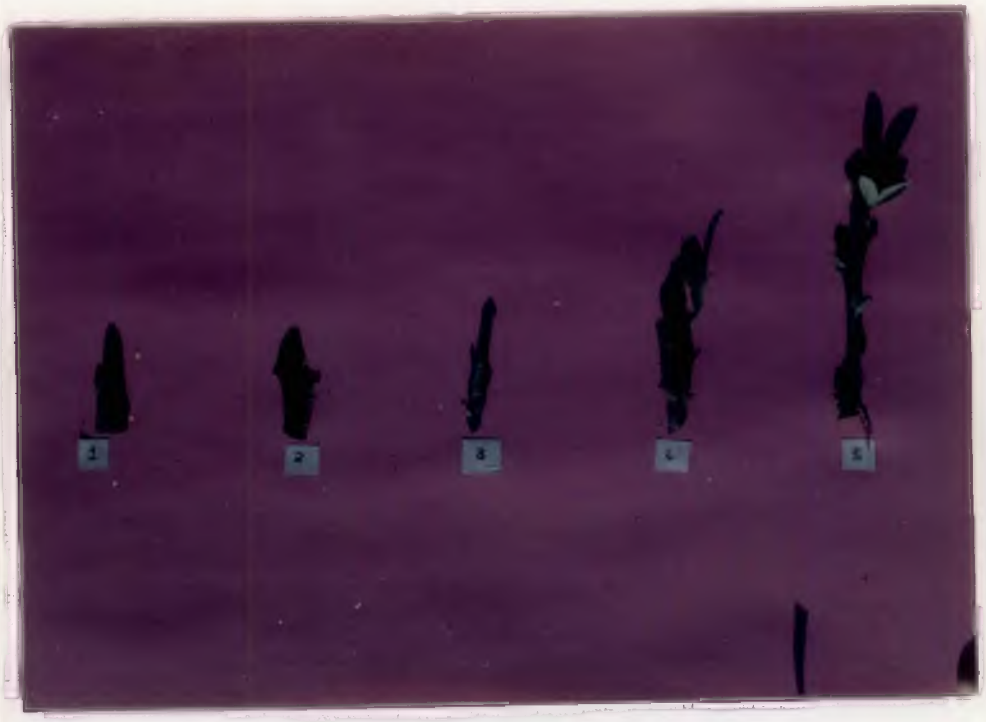

1
2
3
4
5

Plate No. 7

Effect of no. of nodes on rooting of Hard Wood Cuttings


1
2
5

The number of days taken for rooting did not vary significantly with the number of nodes in the cutting (Table 7 and figure 1). It was lowest in single noded cutting and highest in the case of five noded cuttings. Soft wood, semi hard wood and hard wood cuttings also did not show any significant variation in the number of days to root.

Five noded semi hard wood cuttings gave significantly higher number of roots (7.2) two months after planting (Table 8). The length of longest root was also highest for five noded semihard wood cuttings two months after planting though the effect of the type of wood, type of wood x number of nodes and number of nodes x time interaction effects were not significant (Table 8).

The highest number of leaves (3.6) were produced in case of five noded semihard wood cuttings on an average and maximum was observed two months after planting (Table 8). The number of leaves produced by the semi hard wood cuttings two months after planting was on par with that of soft wood cuttings produced two months after planting. Hence it may be referred that 5 noded cuttings showed relative superiority as planting material.

1.3 <u>Misting for rooting</u>

Intermittent mist proved to be an essential practice for rooting of cuttings. The X^2 values were significantly higher in

TABLE - 7

EFFECT OF NUMBER OF NODES ON PERCENTAGE ROOTING AND DAYS TO ROOTING OF CUTTINGS

No. of Nodes	Soft wood		Semi hard wood		Hard wood		Mean	
	% rooting	Days to root	% rooting	Days to root	% rooting	Days to root	% rooting +	Days to root ++
1	0	0	0	0	10	30	5.0 (0.21)	10.0 (2.31)
2	0	0	10	23	20	32	10.8 (0.32)	18.33 (3.75)
3	80	20	70	25	50	28	66.67 (0.96)	24.33 (4.97)
4	70	22	70	28	50	26	63.33 (0.92)	25.33 (5.08)
5	80	21	80	26	60	24	73.33 (1.03)	23.33 (4.91)
Mean	47.0 (0.71)	12.6 (3.07)	46.5 (0.71)	20.4 (4.22)	38.0 (0.65)	28.0 (5.33)		

CD (0.05) for nodes - % rooting - 0.271

Figures in paranthesis shows transformed values

+ Angular transformation

++ Square root transformation

TABLE - 8

EFFECT OF NUMBER OF NODES RETAINED ON DIFFERENT TYPES OF WOOD ON THE NUMBER OF ROOTS, LENGTH OF LONGEST ROOT AND NUMBER OF LEAVES

Treatments		No. of roots				Length of longest root				No. of leaves			
		SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean
1 Node	1MAP	0	0	0.2	0.0067	0	0	0.15	0.05	0	0	0	0
	2MAP	0	0	0.2	0.0067	0	0	0.2	0.016	0	0	0.05	0.017
	Mean	0	0	0.2	0.0067	0	0	0.18	0.015	0	0	0.025	0.0083
2 Node	1MAP	0	0.2	0.4	0.2	0	0.35	0.45	0.27	0	0.2	0.1	0.1
	2MAP	0	0.3	0.5	0.27	0	0.4	0.55	0.32	0	0.2	0.15	0.12
	Mean	0	0.25	0.45	0.23	0	0.38	0.5	0.29	0	0.2	0.13	0.108
3 Node	1MAP	1.7	1.9	0.8	1.47	1.6	1.5	1.2	1.43	2	1.8	1.7	1.83
	2MAP	2.7	2.8	1.3	2.27	2.45	2.01	1.5	1.99	2.8	1.9	1.7	2.13
	Mean	2.2	2.35	1.05	1.87	2.03	1.76	1.35	1.71	2.4	1.85	1.7	1.98
4 Node	1MAP	1.4	1.2	0.6	1.07	1.45	1.4	1.05	1.3	1.6	2.3	1.4	1.77
	2MAP	2.3	2.2	1.6	2.03	2.0	2.15	1.65	1.93	2.1	2.7	1.8	2.2
	Mean	1.85	1.7	1.1	1.55	1.73	1.78	1.35	1.62	1.85	2.5	1.6	1.98
5 Node	1MAP	1.2	5.7	3.0	3.3	2.45	3.45	2.85	2.92	2.5	2.7	1.9	2.37
	2MAP	2.3	7.2	3.8	4.43	2.95	4.25	3.5	3.57	2.6	3.6	3.3	3.17
	Mean	1.75	6.45	3.1	3.87	2.7	3.85	3.18	3.24	2.55	3.15	2.6	2.77
Overall Mean		1.16	2.15	1.24		1.29	1.55	1.31		1.36	1.54	1.21	
Means of	1MAP	0.86	1.8	1.0	1.22	1.1	1.34	1.14	1.19	1.22	1.4	1.02	1.21
	2MAP	1.46	2.5	1.48	1.81	1.48	1.76	1.48	1.57	1.5	1.68	1.4	1.53

	No. of roots	Length of longest root	No. of leaves
CD (0.05) for wood	0.71	NS	NS
CD (0.05) for Nodes	0.91	0.81	0.76
CD (0.05) for MAP	0.14	0.09	0.15
CD (0.05) for wood x nodes	1.58	NS	NS
CD (0.05) for Nodes x time	NS	NS	NS
CD (0.05) for wood x time	0.24	0.16	0.25

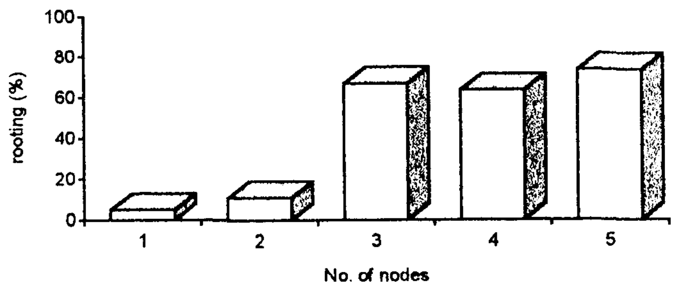
SW - Soft wood

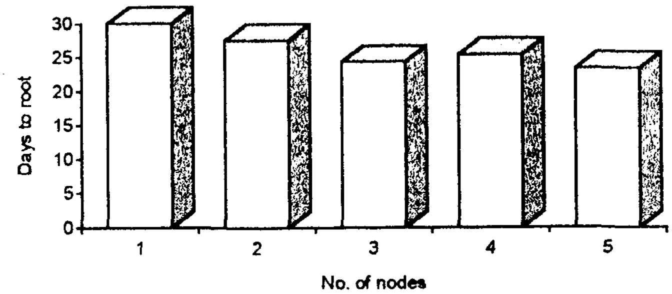
SHW - Semi hardwood

HW - Hard wood

MAP - Months after planting

Fig. 1 Effect of number of nodes on rooting of cuttings





case of misting for all the three type of cuttings showing the comparitive superiority of misting over nonmisting (Table 9).

1.4 Identification of best season

Data on the influence of seasons on success of cuttings are furnished in Tables 10 and 11. February to October was the best period in respect of percentage of rooting (Figure 2). In the study involving a full calendar year (Table 10); earliest rooting was observed during the month of June (22.33 days) but this was on par with those during February, April, May, July and August. The number of days taken for rooting was highest in January (32.67 days).

Soft wood, semi hard wood and hard wood did not vary significantly in rooting percentage (Figure 2). However, hard wood cuttings gave better percentage of rooting through out the year whereas they varied significantly in the number of days to root with soft wood showing earliest rooting (23.92 days).

An overall assessment of number of roots produced by different types of cuttings reveal the superiority of hard wood cuttings followed by semi hard wood cuttings, but the differences were not statistically significant (Table 11). The maximum number of roots were produced by soft wood cuttings during the month of September and this was on par with semi hard wood cuttings during

TABLE - 9

EFFECT OF MISTING ON ROOTING OF CUTTINGS

Months	No. Planted	Soft Wood				Semi hard wood				Hard wood			
		2 MAP		4MAP		2MAP		4MAP		2MAP		4MAP	
		with mist	without mist	with mist	without mist	with mist	without mist	with mist	without mist	with mist	without mist	with mist	without mist
JAN	20	4	0	4	0	6	0	6	0	6	0	6	0
FEB	20	16	2	16	2	12	3	12	2	15	1	16	1
MAR	20	18	0	18	0	15	2	15	3	18	1	18	1
APR	20	17	0	17	0	10	0	10	0	15	0	15	0
MAY	20	19	0	19	1	17	0	17	1	18	0	18	0
JUNE	20	18	0	18	0	18	0	18	0	20	0	20	0
JULY	20	15	0	15	0	15	0	15	0	18	0	18	0
AUG	20	12	0	12	0	10	0	10	0	15	0	15	0
SEP	20	15	0	15	0	15	0	15	0	18	0	18	0
OCT	20	10	0	10	0	12	0	13	0	15	0	15	0
NOV	20	8	0	8	0	10	0	10	0	8	0	8	0
DEC	20	2	0	2	0	5	0	5	0	5	0	5	0
No sprouted		154	2	154	3	145	5	146	6	171	2	172	2
X^2		77.34**		274.6**		38.66**		6812.6**		7837.5**		7668.6	

TABLE - 10

EFFECT OF MONTHS ON PERCENTAGE ROOTING AND DAYS TO ROOTING IN CUTTINGS TREATED WITH IBA 1900mgl^{-1}

Months	Soft wood % rooting	Soft wood Days to root	Semi hard wood % rooting	Semi hard wood Days to root	Hard wood % rooting	Hard wood Days to root	Mean % rooting +	Mean Days to root ++
JAN	20	32	30	31	30	35	26.67(0.54)	32.67(5.71)
FEB	50	20	100	28	100	22	81.67(1.2)	23.2(4.82)
MAR	90	25	50	29	80	30	73.33(1.05)	28.0(5.29)
APR	100	19	80	20	80	29	85.83(1.21)	22.67(4.74)
MAY	90	21	70	23	50	26	73.33(1.01)	23.22(4.83)
JUNE	100	20	80	23	80	24	85.83(1.21)	22.33(4.72)
JULY	80	21	50	26	50	30	60.0(0.89)	25.67(5.05)
AUG	40	22	70	25	60	30	56.67(0.85)	25.67(5.05)
SEP	50	26	50	28	80	32	60.0(0.89)	28.67(5.35)
OCT	50	25	60	29	70	31	60.0(0.39)	28.33(5.32)
NOV	40	26	50	32	40	35	43.33(0.72)	31.0(5.56)
DEC	10	30	20	32	20	32	16.67(0.42)	31.33(5.59)
Mean	59.58 (0.91)	23.92 (4.87)	58.96 (0.89)	27.17 (5.2)	61.46 (0.92)	29.67 (5.44)		

CD (0.05) for months - % rooting - 0.33
- days to root - 0.35
CD (0.05) for wood - days to root - 0.174
Figures in paranthesis shows transformed values
+ Angular transformation
++ Square root transformation

TABLE - 11

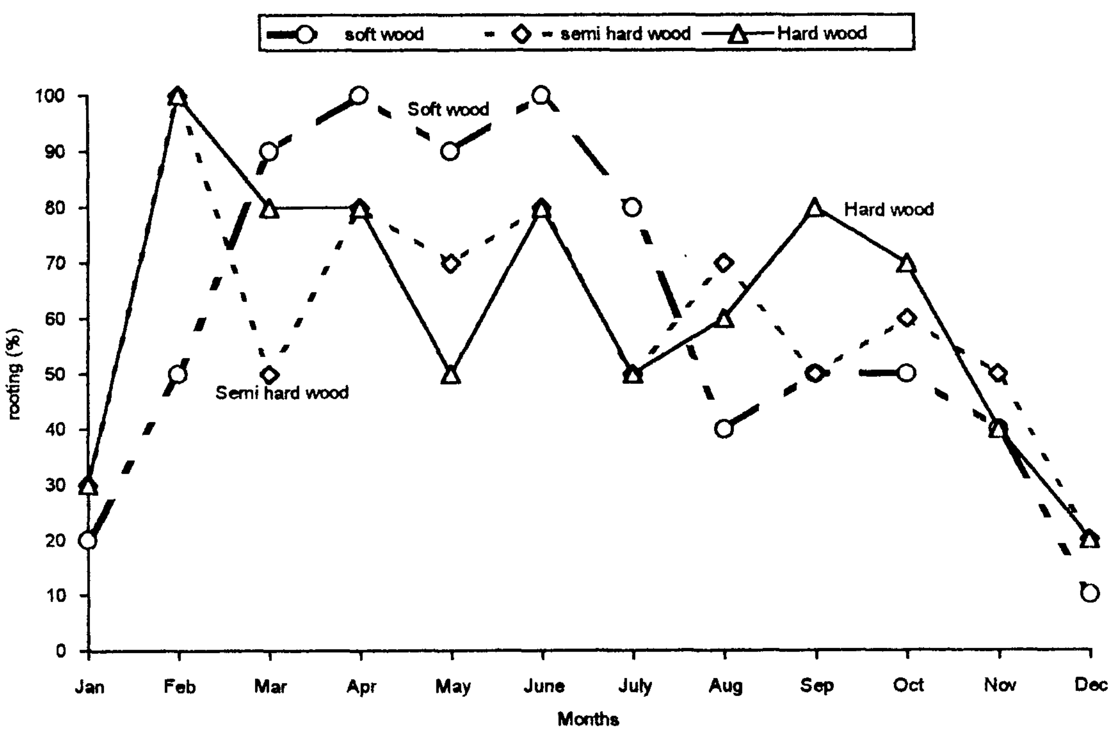
SEASONAL EFFECT OF DIFFERENT TYPES OF CUTTINGS ON NUMBER OF ROOTS, LENGTH OF LONGEST ROOT, AVERAGE LENGTH OF ROOTS AND NUMBER OF LEAVES

Months		No. of roots				Length of longest root				Average length of roots				No. of leaves			
		SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean
JAN	1MAP	0.3	1.1	0.6	0.67	0.65	1.1	0.65	0.9	0.58	0.72	0.48	0.59	0.7	0.5	1.1	0.77
	2MAP	1.0	2.0	2.9	1.97	2.05	4.66	5.75	4.15	1.56	3.56	5.09	3.4	2.7	2.2	4.4	3.1
	Mean	0.65	1.55	1.75	1.32	1.35	2.88	3.2	2.48	1.06	2.14	2.79	1.99	1.7	1.35	2.75	1.93
FEB	1MAP	1.4	1.4	1.5	1.43	2.5	2.7	3.85	3.01	1.75	1.6	3.37	2.24	2.4	1.4	2.4	2.07
	2MAP	2.9	3.7	3.1	3.23	3.0	2.25	3.4	2.88	2.03	1.45	2.52	2.00	3.4	3.9	2.7	3.33
	Mean	2.15	2.55	2.3	2.33	2.75	2.48	3.63	2.95	1.89	1.53	2.95	2.12	2.9	2.65	2.55	2.7
MAR	1MAP	2.5	1.9	0.8	1.73	2.25	1.5	1.2	1.65	1.45	0.82	0.88	1.05	2.8	1.8	1.7	2.1
	2MAP	5.6	3.9	3.7	4.4	4.29	3.87	2.18	3.45	3.00	2.2	1.57	2.26	4.2	3.8	2.5	3.5
	Mean	4.05	2.9	2.25	3.07	3.27	2.68	1.69	2.55	2.23	1.52	1.22	1.66	3.5	2.8	2.1	2.8
APR	1MAP	1.4	1.4	1.5	1.43	2.28	0.85	1.8	1.64	1.57	0.57	1.53	1.23	2.3	1.2	2.3	1.93
	2MAP	1.5	2.1	1.6	1.73	0.7	1.25	1.8	1.25	0.43	0.9	1.31	0.88	1.5	1.9	1.6	1.67
	Mean	1.45	1.75	1.55	1.58	1.48	1.05	1.8	1.45	0.99	0.74	1.42	1.05	1.9	1.55	1.95	1.8
MAY	1MAP	1.3	1.6	3.5	2.13	1.95	1.65	2.89	2.16	1.73	0.93	1.84	1.49	1.8	2.0	2.7	2.17
	2MAP	1.2	2.9	3.2	2.43	1.5	1.95	2.1	1.85	1.3	1.24	1.69	1.41	1.3	2.5	2.3	2.03
	Mean	1.25	2.25	3.35	2.28	1.73	1.8	2.49	2.01	1.51	1.09	1.77	1.46	1.55	2.25	2.5	2.1
JUNE	1MAP	0.9	1.6	1.4	1.3	1.1	1.45	0.9	1.15	0.88	0.88	0.6	0.78	0.9	1.9	0.8	1.2
	2MAP	0.3	0.5	0.2	0.33	0.2	0.35	0.45	0.33	0.13	0.33	0.24	0.23	0.4	0.5	0.5	0.47
	Mean	0.6	1.05	0.8	0.82	0.65	0.9	0.68	0.74	0.5	0.61	0.42	0.51	0.65	1.2	0.65	0.83
JULY	1MAP	0.3	1.3	0.8	0.8	0.8	1.35	1.05	1.06	0.59	0.83	0.84	0.76	0.7	0.5	0.9	0.7
	2MAP	1.2	2.9	3.7	2.6	2.38	5.7	6.73	4.94	1.85	4.36	4.17	3.46	2.2	2.3	5.3	3.27
	Mean	0.75	2.1	2.25	1.7	1.59	3.53	3.89	3.0	1.22	2.6	2.5	2.1	1.45	1.4	3.1	1.98
AUG	1MAP	2.3	1.4	2.0	1.9	3.6	3.78	4.9	4.09	2.37	2.68	4.18	3.08	2.9	2.2	3.6	2.9
	2MAP	4.1	5.2	4.5	4.6	3.88	3.25	4.17	3.77	2.6	2.3	3.22	2.7	4.6	4.4	2.4	3.8
	Mean	3.2	3.3	3.25	3.25	3.74	3.52	4.54	3.93	2.491	2.49	3.7	2.9	3.75	3.3	3.0	3.35
SEP	1MAP	3.9	3.4	1.8	3.03	2.9	2.2	2.2	2.43	2.09	1.41	1.47	1.66	3.8	2.5	2.4	2.9
	2MAP	8.1	5.4	4.8	6.1	5.3	4.62	2.35	4.09	4.02	2.97	1.44	2.81	6.1	4.9	3.8	4.93
	Mean	6.0	4.4	3.3	4.57	4.1	3.41	2.28	3.26	3.05	2.19	1.46	2.24	4.95	3.7	3.1	3.92
OCT	1MAP	2.8	1.5	2.0	2.1	2.9	1.35	2.15	2.13	2.41	0.7	1.21	1.44	2.0	1.7	2.4	2.03
	2MAP	1.3	2.6	2.1	2.0	1.0	1.95	2.35	1.76	0.82	1.48	1.42	1.24	1.5	2.5	1.8	1.93
	Mean	2.05	2.05	2.05	2.05	1.95	1.65	2.25	1.95	1.61	1.09	1.32	1.34	1.75	2.1	2.1	1.98
NOV	1MAP	1.6	2.0	3.8	2.47	2.8	2.7	3.6	3.03	2.39	1.67	2.75	2.27	2.4	2.0	2.8	2.4
	2MAP	1.5	3.8	3.9	3.07	2.15	2.6	2.95	2.57	1.6	1.77	2.32	1.9	1.8	3.0	3.1	2.63
	Mean	1.55	2.9	3.05	2.77	2.48	2.65	3.28	2.8	2.0	1.73	2.54	2.09	2.1	2.5	2.95	2.51
DEC	1MAP	1.5	2.0	1.6	1.7	1.65	1.95	1.2	1.6	1.3	1.46	0.98	1.25	1.4	2.5	0.9	1.6
	2MAP	0.4	0.5	0.3	0.4	0.25	0.48	0.6	0.44	0.13	0.38	0.33	0.28	0.4	3.0	0.5	0.4
	Mean	0.95	1.25	0.95	1.05	0.95	1.21	0.9	1.02	0.72	0.92	0.65	0.76	0.9	1.4	0.7	1.0
OverallMean		2.05	2.33	2.3		2.17	2.31	2.5		1.61	1.55	1.89		2.26	2.18	2.29	
Means of	1MAP	1.68	1.71	1.77		2.11	1.88	2.19	1.59	1.19	1.68			2.0	1.68	2.0	
	2MAP	2.45	2.95	2.83		2.22	2.74	2.9		1.62	1.92	2.11		2.5	2.68	2.58	

	No. of roots	Length of longest root	Average length of roots	No. of leaves
CD (0.05) for wood	NS	NS	NS	NS
CD (0.05) for month	0.93	0.99	0.77	0.97
CD (0.05) for MAP	0.24	0.23	1.98	0.25
CD (0.05) for wood x month	1.62	NS	NS	NS
CD (0.05) for MAP x Month	0.82	0.79	0.68	0.88
CD (0.05) for MAP x Wood	NS	0.39	0.34	NS

SW - Soft Wood, SHW - Semi Hard Wood, HW - Hard Wood.

Fig.2 Seasonal effects on rooting of cuttings



the same month. The number of roots counted one month and two months after planting did not vary among the three types of cuttings. The number of roots were highest in all the three types of cuttings during September (4.57).

The qualitative effect of type of wood on the length of the longest root were not significant (Table 11). The length of longest root was significantly high in semi hard wood and hard wood cuttings taken two months after planting. The longest roots were observed during the month of August but this was on par with that during February, July and September.

The average length of roots was significantly high in semihard wood and hard wood cuttings 2 months after planting (1.92 cm and 2.11 cm respectively) (Table 11). Planting of cuttings in August and September was the best for average root length (2.9 cm and 2.24, cm respectively).

The number of leaves did not vary with the type of wood used. All the three types of cuttings produced almost similar number of leaves during the different months of the year and their number did not vary significantly during the two periods of study after planting. The effect of season was pronounced with August and September recording the highest number of leaves (3.35 and 3.92 days).

1.5 Leafy Vs leafless cuttings

Hundred per cent rooting were obtained with leafy cuttings during the months of June, July and August (50,80 and 40% respectively) whereas the rooting was poor for leafless cuttings during the same period (Table 12). During June, leafy cuttings took 18 days for rooting whereas leafless cuttings during August took 26 days.

Presence and absence of leaves showed significant influence on the various rooting characters like number of roots, length of the longest root and number of secondary roots (Table 12 and Plate 8) which were significantly higher for leafy cuttings. Months had no significant influence on rooting of leafy or leafless cuttings. When the interaction of leafyness and months were considered, leafy cuttings during August gave highest number of roots (5.9) while leafy cuttings during July gave the longest root (5.5 cm) and leafy cutting during June gave more number of secondary roots (7.8).

1.6 Banding/Etiolation on rooting of cuttings

The data presented in Table 13 show that as the number of days of banding increased, the percentage rooting increased. Fourty five days of banding gave the highest percentage of rooting (86.67) which was significantly superior to all other treatments. (Figure 3).

TABLE - 12

EFFECT OF LEAFINESS ON THE ROOTING OF CUTTINGS

Months	% rooting			Dtr			No. of roots			Length of longest			No. of secondary root		
	Leafy	Leafless	Mean	Leafy	Leafless	Mean	Leafy	Leafless	Mean	Leafy	Leafless	Mean	Leafy	Leafless	Mean
June	93.51 (75.21)	44.98 (50.00)	60.09	10	20	15	3.1	5.6	4.35	4.65	4.29	4.47	7.8	1.9	4.85
July	90.4 (71.92)	26.52 (30.98)	51.45	13.33	20.33	16.83	5.4	1.4	3.4	5.5	2.25	3.88	3.7	1.3	2.5
August	95.0 (77.05)	13.01 (21.14)	49.09	20.67	25.33	23	5.9	1.3	3.6	3.25	0.95	2.1	2.9	0.6	1.75
Mean	74.73	32.37		14.67	21.89		4.8	2.77		4.47	2.9		4.8	1.27	
CD (0.05) for months			-5.25		3.01				NS		NS			NS	
CD (0.05) for presence of leaves			-4.29		2.46				1.54		0.98			2.41	
CD (0.05) for Months x presence of leaves			-7.43		4.26			2.67		1.71			4.18		

Values in paranthesis show transformed values

+ - Angular transformation

Dtr - Days to root

Plate No. 8

Leafy Vs leafless cutting

A - leafy

B - leafless


A
B

Soft wood cuttings showed a better response to banding (Plate 9) with the percentage of rooting (82.5%) being significantly superior to semi hard wood (70.0%) and hard wood cuttings (67.5%).

Maximum number of days (25.67 days) was taken for rooting when banding was not done and the least (19.33 days) by the treatment with 45 days of banding (Table 13). Soft wood and semi hard wood cuttings were on par and significantly superior to hard wood regarding the days to rooting.

The number of roots was significantly lower when banding was not done (Table 14). The highest value of 4.68 was observed with 45 days of banding. Semi hard wood cuttings showed a better performance than hard wood and soft wood cutting though the effect was not significant. Soft wood cuttings with 45 days of banding proved to be better than semi hard wood and hard wood cuttings with 0, 15, 30 or 45 days of banding.

With regard to length of the longest root, soft wood cuttings showed a better performance (Table 14). Significantly superior values were obtained with 45 days of banding and observations taken two months after planting.

TABLE - 13

EFFECTS OF BANDING/ETIOLATION ON THE PERCENTAGE ROOTING AND DAYS TO ROOTING OF CUTTINGS

Days of banding	SW % rooting	SW Dtr	SHW % rooting	SHW Dtr	HW % rooting	HW Dtr	Mean % rooting +	Mean Dtr ++
0	80	21	50	26	50	30	60(0.89)	25.67(5.05)
15	80	19	70	22	70	24	73.33(1.03)	21.67(4.65)
30	80	20	70	26	70	28	73.33(1.03)	24.67(4.95)
45	90	18	90	20	80	20	86.67(1.2)	19.33(4.39)
Mean	82.5 (1.14)	19.5 (4.47)	70 (1.0)	23.5 (4.8)	67.5 (0.97)	25.5 (5.02)		

CD (0.05) for days of banding - % rooting - 0.148
days to root - 0.09

CD (0.05) for wood % rooting - 0.128
days to root - 0.08

Dtr - days to root

TABLE - 14

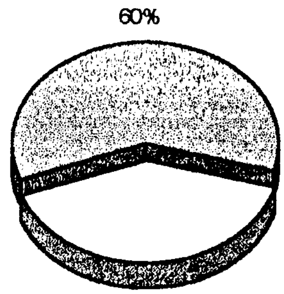
EFFECT OF BANDING/ETIOLATION ON NUMBER OF ROOTS, LENGTH OF LONGEST ROOT AND NUMBER OF LEAVES IN CUTTING

Days of banding		No. of roots				Length of longest root				No. of leaves			
		SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean
0	1MAP	1.4	1.4	1.5	1.43	2.25	0.95	1.8	1.67	2.3	1.2	2.3	1.93
	2MAP	1.4	1.5	1.7	1.53	2.55	1.1	2.0	1.88	2.3	1.2	2.3	1.93
	Mean	1.4	1.45	1.6	1.48	2.4	1.03	1.9	1.78	2.3	1.2	2.3	1.93
15	1MAP	2.6	4.5	3.2	3.43	5.4	3.35	2.7	3.82	2.6	2.6	2.7	2.63
	2MAP	3.4	5.2	3.8	4.13	6.0	3.75	3.4	4.38	3.2	3.2	3.1	3.17
	Mean	3.0	4.85	3.5	3.78	5.7	3.55	3.05	4.1	2.9	2.9	2.2	2.9
30	1MAP	3.7	3.3	4.1	3.7	2.45	4.55	4.75	3.92	2.2	2.2	2.3	2.23
	2MAP	4.6	4.1	4.4	4.37	3.2	5.25	5.15	4.53	2.8	2.2	3.4	2.8
	Mean	4.15	3.7	4.25	4.03	2.83	4.9	4.95	4.23	2.2	2.2	2.35	2.52
45	1MAP	4.5	4.9	3.9	4.43	7.7	4.45	5.65	5.93	3.5	2.2	2.5	2.72
	2MAP	5.4	4.9	4.5	4.93	8.64	5.43	6.63	6.9	4.3	3.4	4.4	4.03
	Mean	4.95	4.9	4.2	4.68	8.18	4.94	6.14	6.42	3.9	2.85	3.45	3.4
Overall Mean		3.38	3.73	3.39		4.78	3.6	4.01		2.9	2.29	2.88	
Means of	1MAP	3.05	3.53	3.18		4.45	3.33	3.73		2.65	2.08	2.45	
	2MAP	3.7	3.92	3.6		5.1	3.88	4.29		3.15	2.5	3.3	

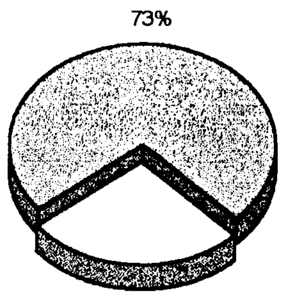
	No. of roots	Length of longest root	No. of leaves
CD (0.05) for wood	NS	NS	NS
CD (0.05) for days of banding	1.33	1.58	NS
CD (0.05) for time	0.19	0.09	0.28
CD (0.05) for wood x days	NS	NS	NS
CD (0.05) for wood x time	NS	NS	NS
CD (0.05) for days x time	NS	0.19	0.56

SW - Soft wood
SHW - Semi hardwood
HW - Hard wood

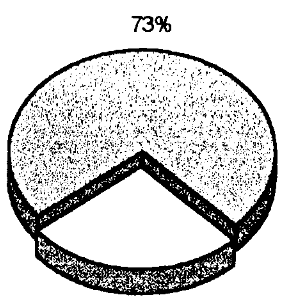
Fig.3 Effect of banding on % rooting of cuttings



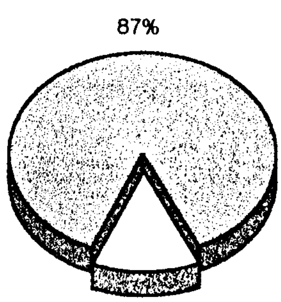
Zero banding



15 days banding



30 days banding



45 days banding

Plate No. 9

Banded Vs non-banded Soft Wood Cutting

A - non-banded

B - banded


A
B

Though the effect of the different treatments on the number of leaves was not significant, higher values were observed for soft wood cuttings with 45 days of banding (Table 14).

1.7 Survival of cuttings

February-March planted cuttings gave the highest percentage establishment, both 3 months (84.67%) and 6 months (68.33%) after planting (Table 15). They were significantly superior in efficiency of establishment to all other times of planting. February-March and April-May planted cuttings were equally efficient in percentage of establishment 3 months after planting but at 6 months, February-March planted cuttings were significantly superior (Plate 10). The different types of cuttings did not vary in their percentage survival.

2. LAYERING

2.1 Standardisation of the most responsive wood, media and season for layering

The media exhibited different response during the same as well as during different months (Table 16 and Figure 4). When coconut fibre was used as the medium the percentage of rooting was significantly high during March, April and July but there was significant variation in the number of days to rooting. Lowest

TABLE - 15

SURVIVAL RATE OF CUTTINGS

Months	Three months after planting % survival	Six months after planting % survival
June - July	53.00 (0.82)	48.67 (0.77)
Aug - Sep	60.00 (0.89)	45.33 (0.74)
Oct - Nov	59.00 (0.88)	33.33 (0.62)
Dec - Jan	43.33 (0.72)	36.67 (0.65)
Feb - Mar	84.67 (1.17)	68.33 (0.98)
Apr - May	72.67 (1.02)	59.33 (0.88)
Wood		
SW	56.83 (0.87)	45.50 (0.74)
SHW	65.33 (0.94)	47.83 (0.76)
HW	64.17 (0.94)	52.50 (0.81)
CD		
Months	0.22	0.054
Wood	NS	NS

Plate No. 10

Survival of Cuttings

percentage of rooting was recorded in January (5.0). Similarly, the type of wood also did not exert any significant influence in either the percentage rooting or days to rooting.

However, significantly superior percentage of rooting was observed during September and October. When sphagnum moss was used as the medium there was no rooting in January (Table 16). Semi hard wood and hard wood showed similar percentage rooting whereas softwood was significantly inferior. Effect of months and type of wood on days to rooting was non significant with sphagnum moss as media.

September proved to be the superior month with regard to percentage of rooting of layers (80%) when coir dust was used as the medium (Table 16). Soft wood gave significantly lowest percentage rooting when compared to semi hard wood and hard wood. Days to rooting did not vary significantly during the different months whereas significantly early rooting was observed in case of soft wood.

Layering done during different months did not vary significantly in the percentage rooting and days to rooting with saw dust as media though slightly better values for percentage of rooting were observed during April and July.

TABLE - 16

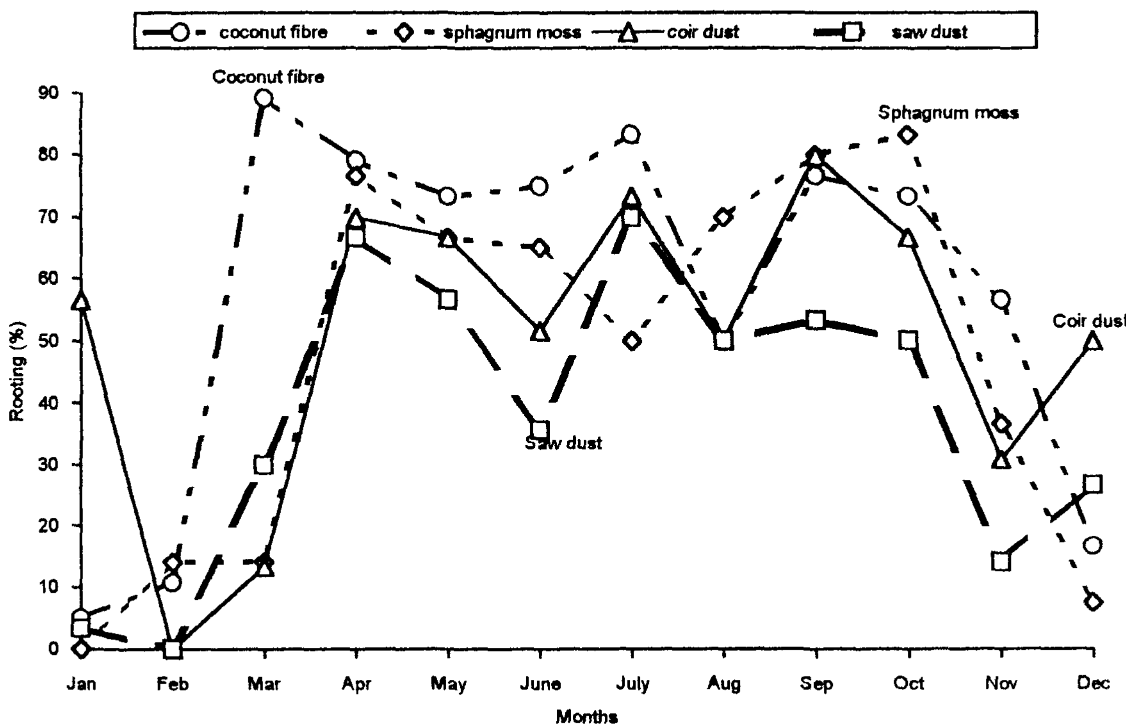
EFFECT OF MEDIA, WOOD AND MONTHS ON PERCENTAGE ROOTING AND DAYS TO ROOTING IN LAYERS

Months	Coconut Fibre		Sphagnum moss		Coir dust		Saw dust	
	% rooting +	Dtr ++	% rooting +	Dtr ++	% rooting +	Dtr ++	% rooting +	Dtr ++
JANUARY	5(0.21)	13.33(2.5)	0(0.12)	-	56.66(0.59)	45(6.75)	33.33(0.61)	45(6.75)
FEBRUARY	10.83(0.42)	35.33(5.11)	14.17(0.32)	40(5.42)	0(0.12)	-	0(0.12)	-
MARCH	89.17(1.26)	25(5.05)	14.17(0.32)	18.67(3.79)	13.33(0.28)	30(5.52)	30(0.56)	31.67(5.81)
APRIL	79.17(1.14)	25(5.05)	76.67(0.75)	30(5.52)	70(0.66)	30.67(5.64)	66.67(0.9)	35(5.96)
MAY	73.33(1.04)	25(5.05)	66.67(0.65)	27.33(5.28)	66.67(0.59)	25.33(5.08)	56.67(0.86)	28(5.34)
JUNE	75(1.08)	28(5.34)	65(0.63)	30(5.52)	51.67(0.48)	31.33(5.64)	35.7(0.63)	30(5.52)
JULY	83.33(1.17)	26.33(5.18)	50(0.62)	27.33(5.27)	73.33(0.76)	29(5.43)	70(0.99)	28.3(5.37)
AUGUST	50(0.79)	25(5.05)	70(0.71)	25.67(5.12)	50(0.59)	19(5.18)	50(0.79)	26(5.75)
SEPTEMBER	76.67(1.08)	27(5.24)	80(0.81)	28(5.34)	80(0.84)	28(5.34)	53.3(0.82)	28(5.34)
OCTOBER	73.33(1.03)	25(5.05)	83.33(082)	26(5.15)	66.67(0.59)	26(5.15)	50(0.79)	26(5.15)
NOVEMBER	56.67(0.86)	30(5.52)	36.67(0.45)	29.33(5.46)	30.83(0.5)	22.67(4.15)	14.17(0.36)	21.33(4.04)
DECEMBER	16.67(0.42)	40.67(6.41)	7.5(0.33)	78.3(4.61)	50(0.56)	45(6.74)	26.67(0.53)	45.6(6.74)
Means for wood								
Soft wood	52.77(0.8)	26.33(5.02)	40.63(0.08)	18.67(5.02)	40.63(0.08)	26.17(3.79)	34.17(0.59)	27.23(4.8)
Semi hard wood	58.13(0.88)	27.83(5.11)	52.29(0.79)	29.5(5.11)	50.63(0.78)	29.33(5.23)	40.63(0.68)	29.42(5.26)
Hard wood	61.25(0.94)	22.25(5.06)	50.21(0.78)	29.6(5.06)	51.88(0.79)	29.33(5.26)	50.42(0.75)	29.5(5.26)
CD(0.05) for wood	NS	NS	0.37	NS	0.29	NS	NS	NS
CD(0.05) for months	0.152	NS	0.187	NS	0.144	0.73	NS	0.71

Figures in paranthesis shows transformed values

\+ Angular transformation
++ Square root tranformation

Fig.4 Seasonal effects on rooting of layers



Tables 17, 18 and 19 show the data on number of roots, length of the longest root and fresh and dry weight of roots produced using different types of media on different types of wood in different months. Coconut fibre, saw dust and sphagnum moss produced almost similar number of roots with coir dust being significantly inferior.

The types of wood used were significantly different from each other in their effects on number of roots, with hard wood cuttings giving the highest value (Plates 11,12 and 13). Hard wood in all the four media tried and semi hard wood in sawdust medium produced significantly higher number of roots with soft wood in coir dust producing the lowest number of roots (Table 18). April month was the best in initiating maximum number of roots and this was significantly superior to all other months (Table 17). The highest number of roots was produced by hard wood during the month of April. It was significantly superior to all other combinations followed by hard wood during June and semi hard wood during April. Soft wood during February failed to produce roots and best response was observed in June. Coconut fibre during March and Sphagnum moss, coir dust and saw dust during April gave significantly higher number of roots. In all the four media, poor performance of rooting was observed from November to February (Table 19).

TABLE - 17

INTERACTION EFFECT OF DIFFERENT TYPES OF WOOD AND MONTHS IN LAYERING

Months	No. of roots				Length of longest root				Fresh wt of roots				Dry wt of roots			
	SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean
JAN	3.42	3.08	2.67	3.06	3.4	4.0	2.83	3.41	0.26	0.28	0.16	0.23	0.07	0.08	0.04	0.06
FEB	0	1.42	1.25	0.89	0	0.5	1.08	0.53	0	0.17	0.05	0.07	0	0.07	0.01	0.03
MAR	5.83	14.58	14.42	11.61	1.55	4.27	4.08	3.3	0.18	0.58	0.74	0.5	0.01	0.13	0.28	0.14
APR	14.75	32.92	42.33	30.0	3.77	6.04	6.04	5.28	1.35	1.51	1.55	1.47	0.33	0.41	0.47	0.4
MAY	6.08	11.08	24.42	13.86	2.96	3.4	4.29	3.55	0.2	0.34	0.94	0.49	0.02	0.03	0.18	0.08
JUNE	11.75	23.5	34.33	23.19	3.75	5.58	5.7	5.01	0.51	0.93	1.41	0.95	0.13	0.22	0.4	0.25
JULY	18.25	13.42	18.0	16.56	3.58	4.29	4.04	3.97	0.37	0.27	0.53	0.39	0.02	0.03	0.03	0.03
AUG	5.75	12.25	12.33	10.11	5.9	6.58	5.84	6.11	0.42	0.87	0.9	0.73	0.1	0.37	0.32	0.27
SEP	6.33	11.08	12.5	9.97	7.93	5.02	6.98	6.64	0.47	0.64	0.82	0.64	0.16	0.24	0.27	0.23
OCT	6.42	10.42	11.83	9.56	7.88	7.5	6.95	7.44	0.48	0.68	0.58	0.58	0.15	0.27	0.24	0.22
NOV	4.08	7.33	6.5	5.97	2.58	6.26	4.54	4.46	0.22	0.46	0.51	0.40	0.06	0.17	0.22	0.15
DEC	2.00	5.33	5.58	4.31	6.75	2.98	4.71	4.81	0.36	0.24	0.37	0.32	0.2	0.41	0.16	0.26
Mean	7.06	12.2	15.51		4.17	4.7	4.76		0.4	0.58	0.71		0.1	0.2	0.22	

	No. of roots	Length of longest root	Fresh wt of root	Dry wt of roots
CD (0.05) for wood	1.48	NS	NS	0.06
CD (0.05) for months	2.97	1.24	0.24	0.12
CD (0.05) for wood x months	5.14	2.15	0.41	0.21

SW - Soft Wood, SHW - Semi Hard Wood, HW - Hard Wood.

The length of longest root was significantly low in Sphagnum moss while the others produced almost similar values and saw dust gave the highest value (Table 17,18 and 19). The effect of wood was not significant. All the three types of wood in coconut fibre and coir dust and hard wood in saw dust produced similar length of longest roots and they were significantly superior to those produced by any other combinations of media and wood. October produced the highest value for length of the longest, root but was on par with that during September.

A comparison of differential effects of months in initiating longer roots revealed that hard wood during April, September and October, Semi hard wood during April, August, October and November and soft wood during August, September, October and December produced significantly high values for length of longest root. No rooting occurred in soft wood during February. Length of longest root was highest with coir dust medium during October and December (Table 19). It was significantly superior to all other combinations.

The fresh weight of roots was significantly high with saw dust medium all the other media produced almost similar values (Table 18). All the three types of wood were significantly different from each other and hard wood produced the highest fresh weight of roots. The fresh weight of roots were similar in hard

TABLE - 18

INTERACTION EFFECT OF DIFFERENT TYPES OF WOOD AND MEDIA IN LAYERING

Media	No. of roots				Length of longest root				Fresh wt of roots				Dry wt of roots			
	SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean
Coconut fibre	8.22	12.92	16.08	12.41	4.7	4.93	4.49	4.71	0.35	0.61	0.73	0.57	0.1	0.3	0.24	0.21
Sphagnum moss	7.61	11.22	16.08	11.64	2.65	4.15	3.87	3.56	0.33	0.51	0.65	0.5	0.06	0.15	0.14	0.12
Coir dust	5.81	10.14	14.28	10.07	5.31	5.15	5.49	5.31	0.4	0.49	0.68	0.52	0.14	0.15	0.25	0.18
Saw dust	6.58	14.53	15.61	12.24	4.03	4.58	5.18	4.6	0.53	0.71	0.78	0.67	0.12	0.21	0.25	0.19
Mean	7.06	12.2	15.51		4.17	4.7	4.76		0.4	0.58	0.71		0.1	0.2	0.22	

	No. of roots	Length of longest root	Fresh wt of root	Dry wt of roots
CD (0.05) for wood	1.48	0.62	0.12	0.06
CD (0.05) for media	1.71	0.72	0.14	0.07
CD (0.05) for wood x media	2.97	1.24	0.24	0.12

SW - Soft Wood, SHW - Semi Hard Wood, HW - Hard Wood.

wood with all the four media and in semi hard wood with coconut fibre and saw dust. A split up of the months (Table 17) shows that the highest fresh weight of roots was observed during the month of April followed by that during June. The effect in April was at par with hardwood in June and significantly superior to all other combined effects. Saw dust in April and coconut fibre in March produced significantly superior values for fresh weight (Table 19).

Dry weight of roots produced by hardwood and semi hard wood were almost similar and superior to that of soft wood (Table 18). The table also reveals that among the media, coconut fibre, coir dust and saw dust produced significantly higher and similar values compared to sphagnum moss.

Seasonal effects were also equally pronounced with April giving significantly higher value for dry weight of roots (Table 17). A comparison within the type of woods confirm that the dry weight was significantly higher for hard wood during March, April, June, August and September for semi hard wood during April, August, October, December and for soft wood during April compared to all other interactions.

The interaction effect of media and months was also significant (Table 19) with coir dust media during April being the

TABLE -19

INTERACTION EFFECT OF MONTHS AND DIFFERENT MEDIA IN LAYERING

Months	No. of roots CF	SM	CD	SD	Mean	Length of longest root CF	SM	CD	SD	Mean	Fresh wt of roots CF	SM	CD	SD	Mean	Dry wt of roots CF	SM	CD	SD	Mean
JAN	0.22	0	5.56	6.44	3.06	0.83	0	5.77	7.04	3.41	0.04	0	0.44	0.45	0.23	0	0	0.13	0.11	0.06
FEB	0.67	2.89	0	0	0.89	0.78	1.33	0	0	0.53	0.09	0.19	0	0	0.07	0.04	0.06	0	0	0.03
MAR	37.89	2.33	3.22	3.0	11.61	5.26	1.33	3.83	2.79	3.3	1.49	0.05	0.22	0.23	0.5	0.42	0.03	0.06	0.05	0.14
APR	14.33	36.67	35.11	33.89	30.0	5.08	4.78	4.83	6.44	5.28	1.03	1.42	1.47	1.97	1.47	0.47	0.29	0.58	0.27	0.4
MAY	17.22	17.56	13.11	7.56	13.86	4.11	3.98	2.72	3.39	3.55	0.52	0.6	0.55	0.29	0.49	0.03	0.09	0.16	0.02	0.08
JUNE	19.78	18.22	30.11	24.67	23.19	6.14	4.46	4.72	4.72	5.01	0.62	0.59	1.41	1.16	0.95	0.05	0.04	0.53	0.38	0.25
JULY	19.11	21.33	11.67	14.11	16.56	2.83	4.06	5.0	4.0	3.97	0.29	0.64	0.24	0.37	0.39	0.02	0.03	0.02	0.04	0.03
AUG	13.22	8.22	4.56	14.44	10.11	7.22	6.31	6.67	4.23	6.11	0.92	0.53	0.39	1.08	0.73	0.4	0.18	0.13	0.36	0.27
SEPT	9.22	13.33	6.22	11.11	9.97	7.11	5.64	6.52	7.29	6.64	0.65	0.81	0.42	0.69	0.64	0.21	0.3	0.13	0.26	0.23
OCT	8.67	10.67	5.33	13.56	9.56	8.33	4.28	9.83	7.32	7.44	0.49	0.61	0.45	0.77	0.58	0.22	0.25	0.14	0.28	0.22
NOV	6.67	7.22	2.56	7.44	5.97	4.95	5.46	5.17	2.27	4.46	0.43	0.45	0.24	0.46	0.4	0.14	0.13	0.11	0.22	0.15
DEC	1.89	1.22	3.44	10.67	4.31	3.83	1.06	8.7	5.67	4.81	0.22	0.06	0.45	0.56	0.32	0.52	0.01	0.19	0.31	0.26
Mean	12.41	11.64	10.07	12.24		4.71	3.56	5.31	4.6		0.57	0.5	0.52	0.67		0.21	0.12	0.18	0.19	

	No. of roots	Length of longest root	Fresh wt of roots	Dry wt of roots	
CD (0.05) for months	2.97	1.24	0.14	0.07	CF-Coconut Fibre
CD (0.05) for media	1.71	0.72	0.24	0.12	SM-Sphagnum Moss
CD (0.05) for months x media	5.94	2.48	0.48	0.25	CD-Coir dust
					SD-Saw dust

CF - Coconut Fibre, CD - Coir dust, SM - Sphagnum moss, SD - Saw dust

Plate No. 11

Effect of Media on rooting of layers in Soft Wood portion


SPHAGNUM MOSS
COCONUT FIBRE
COIR DUST
SAW DUST

Plate No. 12

Effect of media on rooting of layers in Semi Hard Wood portion

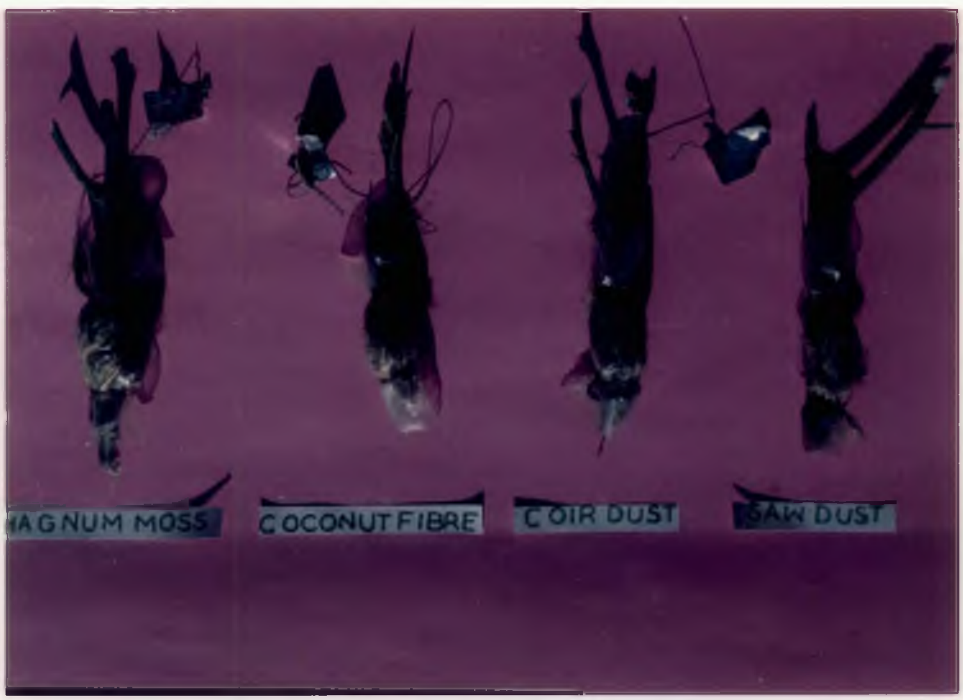

HAGNUM MOSS
COCONUT FIBRE
COIR DUST
SAW DUST

Plate No. 13

Effect of media on rooting of layers in Hard Wood portion


COCONUT FIBRE
SPHAGNUM MOSS
COIR DUST
SAW DUST

TABLE - 20

EFFECT OF GROWTH REGULATORS ON THE PERCENTAGE ROOTING OF LAYERS

Growth regulators (mgl^{-1})	Percentage rooting Soft wood Feb B	Feb T	Apr B	Apr T	June B	June T	Aug B	Aug T	Percentage rooting Semi hard wood Feb B	Feb T	Apr B	Apr T	June B	June T	Aug B	Aug T	Percentage rooting Hard wood Feb B	Feb T	Apr B	Apr T	June B	June T	Aug B	Aug T
IAA100	0	10	0	0	0	0	0	0	20	10	10	0	10	0	0	0	10	10	10	0	10	0	0	0
IAA250	0	10	0	0	10	0	0	0	10	0	10	0	10	0	0	0	0	10	10	0	10	0	0	0
IAA500	30	10	0	0	10	10	0	0	40	10	10	0	0	0	0	0	50	0	10	0	0	0	0	0
IAA1000	30	20	10	10	10	10	10	0	40	30	20	10	20	10	10	0	60	20	10	10	20	20	20	0
IAA1500	80	20	20	20	20	20	10	10	90	20	30	20	30	10	20	20	90	30	30	30	20	10	20	10
IAA2000	30	20	0	0	0	0	0	0	40	20	0	0	0	0	0	0	50	10	0	0	0	0	0	0
IBA100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	10	10	0	10	0	0	0
IBA250	20	10	10	0	20	0	0	0	0	10	10	0	10	0	0	0	0	20	10	0	10	0	0	0
TBA1000	20	40	10	30	20	10	10	10	70	50	10	20	30	20	10	10	70	30	20	20	10	20	10	10
IBA1500	50	60	20	20	30	10	20	10	70	90	30	20	20	10	20	10	80	70	30	20	20	10	20	20
IBA2000	20	40	0	30	10	0	0	0	30	20	0	20	0	0	0	0	20	0	0	20	10	0	0	0
NAA100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
NAA250	0	10	0	0	0	0	0	0	0	10	10	0	0	0	0	0	0	10	10	0	0	0	0	0
NAA500	0	20	0	0	10	0	0	0	0	20	10	0	10	0	0	0	0	10	10	0	0	0	0	
NAA1000	30	20	0	0	10	0	20	0	20	30	10	0	0	10	20	0	40	20	20	0	0	20	10	0
NAA1500	50	40	20	0	10	10	10	10	50	40	10	0	20	20	10	10	60	40	20	0	10	20	20	0
NAA2000	30	0	10	0	0	0	0	0	20	0	0	0	0	0	0	0	20	10	0	0	0	0	0	0
Control	10	10	80	80	50	50	40	40	10	10	100	100	80	80	50	50	20	20	60	60	95	95	60	60

B - Biolin
T - Talc

TABLE - 21

EFFECT OF GROWTH REGULATOR COMBINATIONS ON PERCENTAGE ROOTING OF LAYERS

Growth regulators (mgl^{-1})	Percentage rooting					
	Soft wood		semi hard wood		hard wood	
	B	T	B	T	B	T
IAA 500 + IBA 500	0		0	0	0	0
IAA 500 + NAA 500	0	10	0	0	10	0
IAA 500 + IBA 1000	0	10	0	20	20	10
IAA 500 + NAA 1000	0	10	10	0	20	0
IAA 1000+ IBA 500	10	10	10	10	10	10
IAA 1000+ NAA 500	10	0	10	0	10	10
IAA 1000+ IBA 1000	10	10	20	10	20	10
IAA 1000+ NAA 1000	30	20	20	10	10	0
IAA 1500+ IBA 500	20	10	10	10	10	0
IAA 1500+ NAA 500	10	20	20	10	30	10
IAA 1500+ IBA 1000	20	10	30	10	20	0
IAA 1500+ NAA 1000	10	10	20	10	10	10
IAA 2000+ IBA 500	10	10	0	0	0	0
IAA 2000+ NAA 500	0	0	0	0	0	0
IAA 2000+ IBA 1000	0	0	0	0	10	0
IAA 2000+ NAA 1000	20	0	20	0	20	0
IAA 500+ IBA 1500	10	10	20	0	10	0
IAA 500+ NAA 1500	30	10	20	0	30	20
IAA 500+ IBA 2000	0	10	20	10	0	0
IAA 500+ NAA 2000	0	0	0	0	0	0
IAA 1000+ IBA 1500	10	0	20	0	30	0
IAA 1000+ NAA 1500	20	0	10	20	10	10
IAA 1000+ IBA 2000	0	0	0	0	10	0
IAA 1000+ NAA 2000	0	0	0	0	0	0
IAA 1500+ IBA 1500	20	0	10	0	10	0
IAA 1500+ NAA 1500	0	0	0	0	0	0
IAA 1500+ IBA 2000	0	0	0	0	0	0
IAA 1500+ NAA 2000	0	0	0	0	0	0
IAA 2000+ IBA 1500	0	0	10	0	10	0
IAA 2000+ NAA 1500	0	0	0	0	0	0
IAA 2000+ IBA 2000	0	0	0	0	0	0
IAA 2000+ NAA 2000	0	0	0	0	0	0
Control	80	80	100	100	60	60

B - Biolin, T - Talc

best and at par with that during June, coconut fibre during March, April, August, December and sawdust during June and August.

2.2. Banding/Etiolation in layering

Fourty five days of banding before layering gave the highest percentage of rooting (Table 22). This was at par with 15 and 30 days of banding. Ninety days of banding produced the lowest percentage rooting (33.35). Among the types of wood used, soft wood recorded slightly higher values.

Earliest rooting was observed with 45 days of banding (Table 22). A comparison between types of cutting indicated that the effects of different types of wood was not significant. However, softwood cuttings showed slightly earlier rooting.

Soft wood showed a better response to banding (Table 23) with significantly superior number of roots (15.04). The highest number of roots was produced with 60 days of banding. Soft wood with 60 days of banding gave significantly higher number of roots (31.66).

The effect of type of wood on length of longest root was not significant (Table 23). 30 days of banding gave the highest value of length but did not differ greatly from 45 and 60 days of banding. The interaction effect of wood and days of banding was also not significant.

TABLE - 22

EFFECT OF BANDING ON PERCENTAGE ROOTING AND DAYS TO ROOTING IN LAYERS.

Days of banding	Soft wood % rooting	Soft wood Dtr	Semi hard wood % rooting	Semi hard wood Dtr	Hard wood % rooting	Hard wood Dtr	Mean % rooting +	Mean Dtr ++
0	70	27	70	27	90	27	76.67(1.08)	27(5.19)
15	100	22	80	23	80	24	85.83(1.21)	23(4.79)
30	100	18	90	20	80	22	89.17(1.26)	20(4.47)
45	100	19	100	20	90	20	95 (1.36)	19.67 (4.43)
60	80	25	60	27	50	28	63.33(0.92)	26.67(5.10)
75	50	25	50	25	40	24	46.67(0.75)	24.67(4.9
90	40	28	30	27	30	27	33.33(0.62)	27.33(5.23)
Mean	76.07 (1.12)	23.43 (4.83)	68.27 (1.00)	24.14 (4.9)	65.71 (0.97)	24.57 (4.95)		

	Percentage rooting	Days of rooting
C D (0.05) for days of banding	0.20	0.19
C D (0.05) for wood	NS	N.S

Figures in paranthesis shows transformed values

\+ Angular transformation

++ Square root transformation.

TABLE - 23

EFFECT OF BANDING ON NUMBER OF ROOTS, LENGTH OF LONGEST ROOT, FRESH WEIGHT AND DRY WEIGHT OF ROOTS IN LAYERS

Days of banding	No. of roots				Length of longest root				Fresh weight of				Dry weight of roots			
	SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean	SW	SHW	HW	Mean
0	7.00	9.66	4.00	6.89	6.50	5.6	2.75	4.95	0.43	0.61	0.26	0.43	0.12	0.21	0.1	0.15
15	9.33	13.66	14.66	12.56	4.4	3.36	3.33	3.7	0.68	0.55	0.64	0.63	0.26	0.15	0.22	0.21
30	15	19	17	17	6	4.33	4	6.44	0.7	1.28	0.97	0.98	0.22	0.55	0.33	0.37
45	22.6	16	19	19.22	4.06	7.33	5.9	5.8	3.05	0.65	1.1	1.6	1.85	0.45	0.33	0.88
60	31.66	22.33	15.3	23.14	7.5	6.5	5.17	6.4	1.0	1.02	0.86	0.96	0.07	0.07	0.09	0.07
75	14	7.33	1.66	7.64	6	3.83	4.66	4.83	0.44	0.12	0.15	0.23	0.03	0.007	0.015	0.02
90	5.66	2.66	2	3.44	3.33	1.33	3.33	2.67	0,2	2.63	0.24	0.15	0.01	0.0003	0.02	0.01
Mean	15.04	12.95	10.52		5.4	4.61	4.88		0.93	0.61	0.6					

	No. of roots	Length of longest root	Fresh weight of roots	Dry weight of roots
CD (0.05) for wood	2.63	NS	0.21	NS
CD (0.05) for days of banding	4.02	1.93	0.33	0.28
CD (0.05) for wood x days	6.96	NS	0.56	0.49

SW - Soft wood, SHW - Semi hard wood, HW - Hard wood

The type of wood, days of banding and their interaction had a significant influence on the fresh weight of roots (Table 23). Soft wood with 45 days of banding gave significantly superior values but was on par with semi hard wood with 90 days banding.

There was no significant difference in the dry weight of roots when different types of wood were used (Table 23) but significant variation was produced by the interaction effects of banding with type of wood. Significantly superior values for the dry weight of roots was observed with soft wood given 45 days of banding.

2.3 Banding + ringing in layering

Soft wood region showed significantly higher percentage of rooting than semi hard wood and hard wood. Five days ringing was found to be superior to the other ringing treatments (Table 24). When days to rooting was considered, soft wood and semi hard wood were on par and took less time to root while hard wood took more time to root (Table 24). Least days duration to root was observed in 5 days ringing treatment. When the interaction was analysed, it was found that soft wood and semi hard wood with 5 days ringing took less number of days to root.

2.4 Survival of layers

The percentage survival of layers 3 months after planting was similar when planted during the months of June to December

TABLE - 24

EFFECT OF BANDING + RINGING ON ROOTING OF LAYERS

Days of	% rooting SW	SHW	HW	Mean	Days to root SW	SHW	HW	Mean
5	86.76 (68.63)	89.07 (70.66)	80.69 (63.9)	67.74	17.67	17	21.67	18.78
10	80.69 (63.9)	50 (44.98)	50 (44.98)	51.29	26	28	28	27.44
15	50 (44.98)	32.78 (34.91)	34.94 (36.22)	38.71	27.67	28	28	27.89
Mean	59.17	50.19	48.37		23.78	24.44	25.89	

CD (0.05) for wood 6.25
CD (0.05) for days of ringing 6.25
CD (0.05) for wood x days of ringing NS

Plate No. 14

Survival of layers

TABLE - 25

EFFECT OF MEDIA, MONTHS AND WOOD ON THE SURVIVAL OF LAYERS.

Months	Percentage establishment 3 M A P	6 M A P	Media x wood 3 M A P	6 M A P
JAN	30 (0.55)	12.5 (0.35)	59.17(0.89)	53.3 (0.83)
FEB	19.17 (0.43)	10.83 (0.33)	59.17(0.89)	53.3 (0.83)
MAR	23.33(0.46)	20.3 (0.43)	50.00(0.78)	45.0 (0.73)
APR	31.67 (0.58)	30.00 (0.56)	48.33(0.76)	47.5 (0.75)
MAY	35.83 (0.62)	35.00 (0.61)	45.00 (0.71)	37.5 (0.63)
JUNE	69.17 (0.93)	69.17 (1.00)	41.67 (0.61)	29.17 (0.54)
JULY	65.83 (0.96)	63.33 (0.93)	46.67 (0.75)	38.33 (0.66)
AUG	54.17 (0.84)	53.33 (0.83)	46.67 (0.75)	35.33 ((0.63)
SEP	68.33 (0.99)	65.83 (0.97)	45.83 (0.73)	38.33 (0.65)
OCT	51.67 (0. 0)	41.67 (0.69)	41.67 (0.69)	34.17 (0.61)
NOV	55.83 (0.85)	32.7 (0.59)	38.33 (0.66)	34.17 (0.61)
DEC	49.17 (0.78)	36.67 (0.64)	31.67 (0.58)	25.00 (0.50)

Media			CD	3 MAP	6 MAP
Coconut fibre	56.11 (0.85)	50.56 (0.79)	Months	0.29	0.28
Sphagnummoss	45.00 (0.69)	38.06 (0.64)	Media	NS	NS
Coir dust	46.39 (0.74)	37.5 (0.65)	Wood	0.08	0.07
Saw dust	37.22 (0.64)	31.11 (0.57)	Media x wood	NS	NS
Wood					
SW	48.96 (0.77)	43.33 (0.71)			
SHW	47.3 (0.75)	40.21 (0.67)			
HW	42.3 (0.67)	34.38 (0.60)			

MAP - Months after planting, SW - soft wood, SHW - semi hard wood, HW - Hard wood.

whereas at 6 months after planting, similar values were observed only in June, July and September months (Table 25 and Plate 14). The media tried did not vary significantly both at 3 months and at 6 months after planting. Soft wood proved to be significantly superior than semi hard wood and hard wood. The interaction effect of media and wood was not significant at both the stages.

3. GRAFTING

3.1 Establishment rate

The data on soft wood grafting are furnished in Table 26. Rangpur lime proved to be the best root stock showing 85 percentage success and 85 percentage survival 6 months after grafting (Plate 15). The lowest establishment rate was when rough lemon was used as the root stock (50 per cent).

3.2 Growth of the scion

The height of the graft with Rangpur lime as root stock was significantly more but on par with the graft using rough lemon as root stock (Plate 16). The best height was observed 6 months after grafting for all the rootstocks. As expected, height taken from the combination of Rangpur lime as rootstock 6 months after grafting proved to be significantly superior.

3.3 Girth of stock and scion

The girth of rootstock was significantly high when

TABLE - 26

EFFECT OF ROOT STOCK ON SUCCESS OF SOFT WOOD GRAFTING, HEIGHT, GIRTH OF STOCK AND SCION

Root stock	Success of grafting				Height of the graft					Girth of stock					Girth of Scion				
	2 MAG	4MAG	6MAG	Mean	AG	2MAG	4MAG	6MAG	Mean	AG	2MAG	4MAG	6MAG	Mean	AG	2MAG	4MAG	6 MAG	Mean
Rough lemon	65.06 (53.74)	50 (44.98)	50 (44.98)	47.9	17.45	19.5	22.5	24.4	20.9	2.08	2.36	2.56	2.65	2.41	1.15	1.54	1.74	2.00	1.61
Rangpur lime	85 (67.19)	87.44 (69.21)	85.23 (67.38)	67.93	19.5	21.2	25.6	28.1	23.6	2.3	2.66	2.72	2.86	2.64	1.48	2.07	2.2	2.45	2.05
Acid Lime	75.11 (60.05)	75.71 (60.45)	60.0 (50.75)	57.08	16.82	17.2	17.9	18.6	17.6	2.2	2.3	2.6	2.7	2.44	1.45	1.85	2.12	2.38	1.95
Malta	65.06 (53.74)	60,64 (51.12)	55.0 (47.85)	50.9	15.88	16.15	16.6	17.0	16.4	2.1	2.22.37		2.56	2.31	1.29	1.47	1.58	1.88	1.56
Mean	58.68	56.44	52.74	17.41	18.5	20.7	22.0		2.17	2.38	2.56	2.68		1.34	1.73	1.91	2.18		
CD																			
Root stock		6.39			3.54				NS						0.32				
Time		5.40			0.67				0.05						0.07				
Root stock x Time		10.81			1.34				0.09						0.14				

AG - At grafting, MAG - Months after grafting.
Figures in paranthesis shows transformed values
+ Angular transformation.

Plate No. 15

Best root stock Rangpur lime showing high percentage success in Soft Wood Grafting

Plate No. 16

Effect of different root stock on the height and vigour of the grafts

Rangpur lime was used as root stock at 4 and 6 months after grafting. Rangpur lime and Acid lime produced similar values for the girth of scion 6 months after grafting.

3.4 Precuring of scion

Date on the effect of precuring treatments of the scion in grafting success are presented in Table 27. Scion without any defoliation was significantly superior to all the precuring treatments. The percentage success in grafting was very poor when the scion was defoliated.

3.5 Seasonal influence on graft uptake

May and June months were significantly superior to all the other months regarding the percentage grafting success (Table 28) while January was significantly inferior to the other months showing the poorest performance.

4. BUDDING

Though budding was done using different methods (T-budding, Patch budding and Chip budding) and different root stocks, there was absolutely no bud uptake. The seasonal influence was also tried but yielded no positive results. When the buds of different age groups were used, there was no response at all. The buds were further tried to be induced by giving different GA treatment but efforts did not show any success.

TABLE - 27

EFFECT OF PRECURING TREATMENTS OF SCION ON GRAFTING SUCCESS

Days of defoliation Prior to grafting	% success +
5	10.93(19.29)
10	10(18.43)
15	6.49(14.75)
20	5.0(12.92)
25	5.0(12.92)
At grafting	8.16(16.59)
Control (No defoliation)	78.5(62.38)

CD (0.05) for days of defoliation - 6.13

TABLE - 28

EFFECT OF SEASON ON GRAFTING SUCCESS

Months	% success +
JAN	10(18.43)
FEB	29.67(32.99)
MAR	29.67(32.99)
APR	50.00(44.98)
MAY	88.43(70.09)
JUNE	91.84(73.37)
JULY	39.35(38.84)
AUG	50.00(44.98)

CD (0.05) for days of defoliation - 14.45

Values in paranthesis shows transformed values + Angular transformation.

5. ANATOMICAL STUDIES

5.1 Cuttings

Histo chemical analysis to locate the precise genesis of root initials revealed that in all the three types of cuttings, the initials were found to originate from the pericycle. The stages of rooting were identified as follows.

Root initiation - 15 days after planting (Plate 17)

Root primiordia formation - 18 days after planting (Plate 18)

Root emergence - Starting from 22 days after planting (Plate 19). The duration for the physiological stages in rooting was similar in all the three types of cuttings. The banded tissues did not show any difference from the normal tissues in thickness or continuity of cells.

5.2 Layering

The appearance of initials and that of primordia were seen to overlap. The stage of primordia formation was identified to be the 11th day after layering in soft wood (Plate 20).

5.3 Grafting

Good graft union with proper interlocking of cells with all the 4 root stocks was obtained (Plate 21) but some showed poor union and hence dried up. Histological examination of the grafts with poor union revealed that the initial stage of graft union were more or less similar to that in a compatible stionic combination but

Plate No. 17

Root initiation in cuttings (15 days after planting)

RI - Root initial, E - Endodermis, P - Pericycle

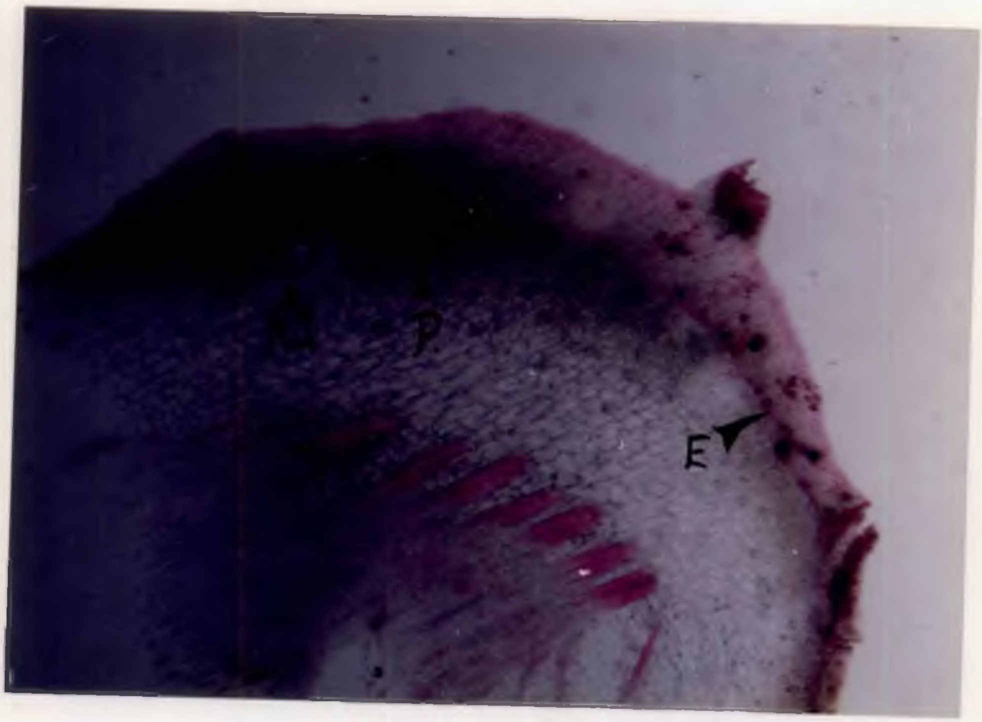

E

Plate No. 18

Root primordia formation in cuttings (18 days after planting)

RP - Root primordia, RC - Root cap

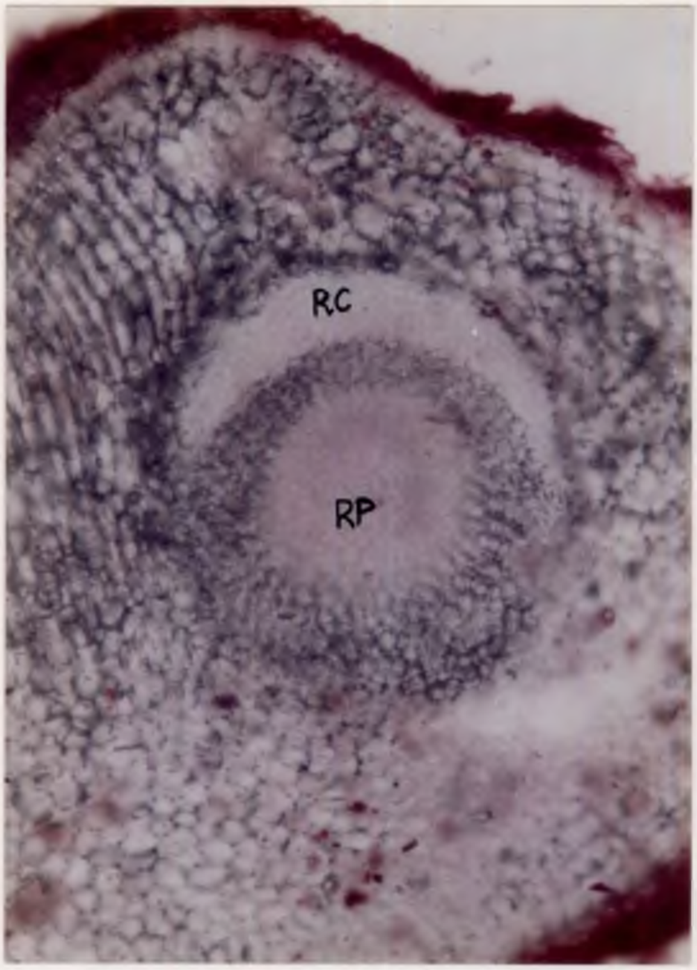

RC
RP

Plate No. 19

Root emergence in cuttings (22 days after planting)

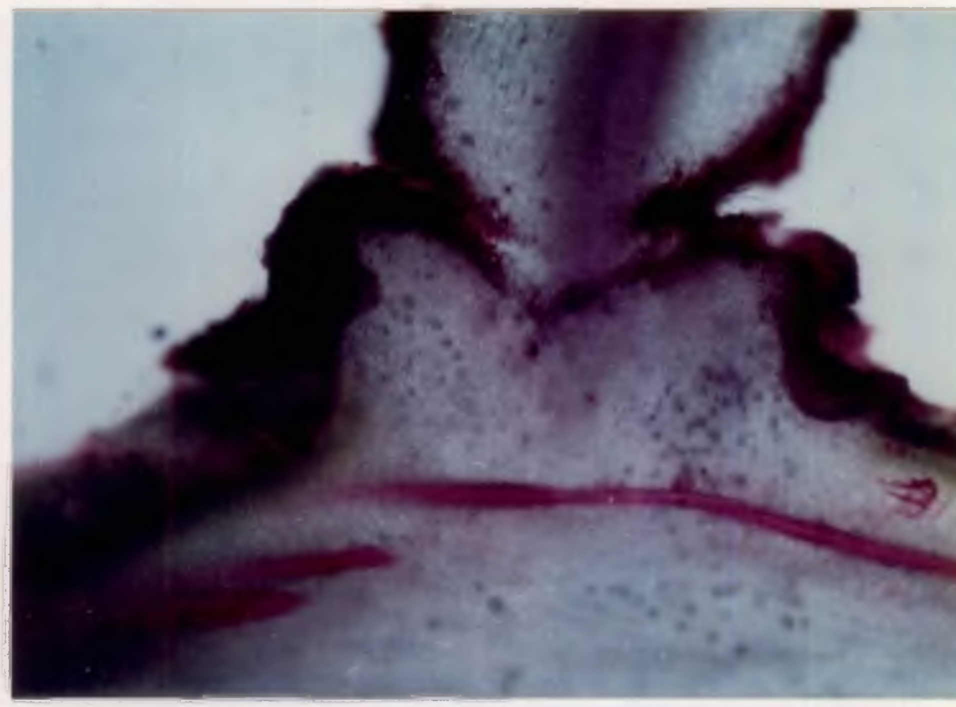


Plate No. 20

Root primordia formation in layers (11 days after layering)

RP - Root primordia

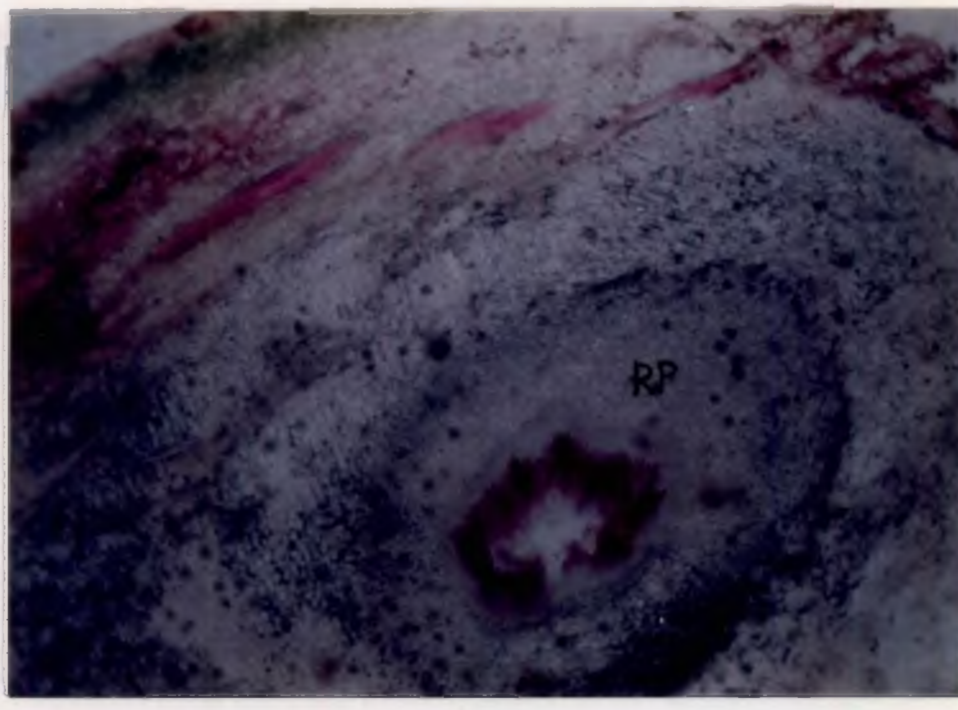

RP

Plate No. 21

A successful graft union with Rangpur lime as root stock

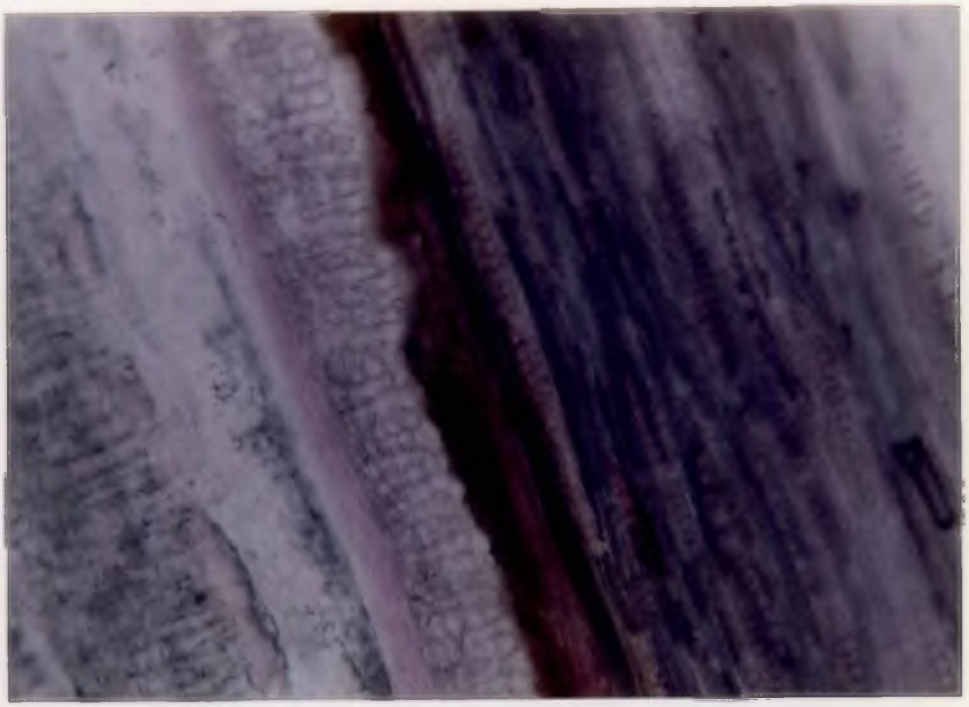


Plate No. 22

In compatibility symptoms with Acid lime as root stock - cellular senescence

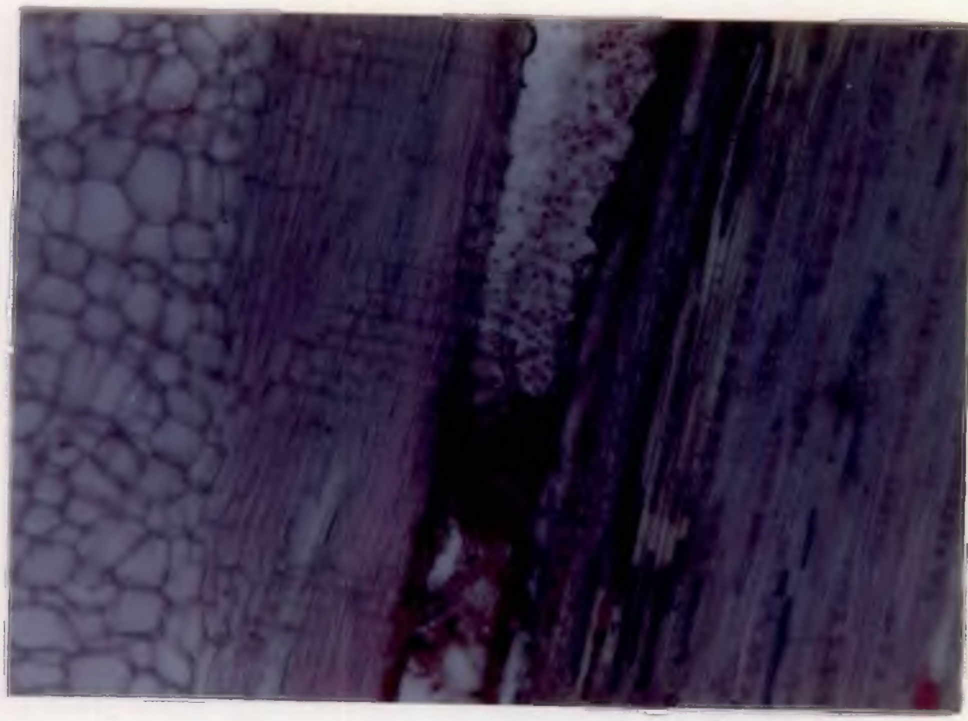


Plate No. 23

In compatibility symptoms with Acid lime as root stock - cellular deassembly

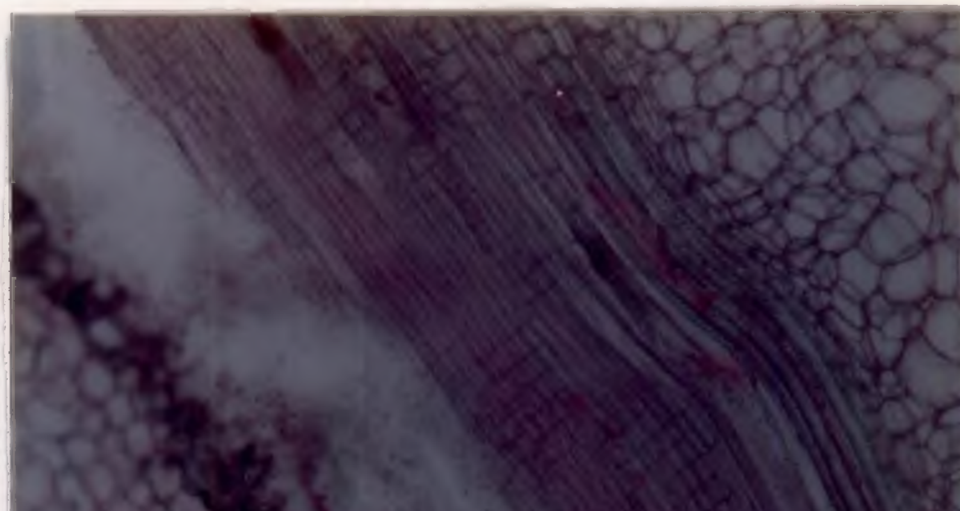
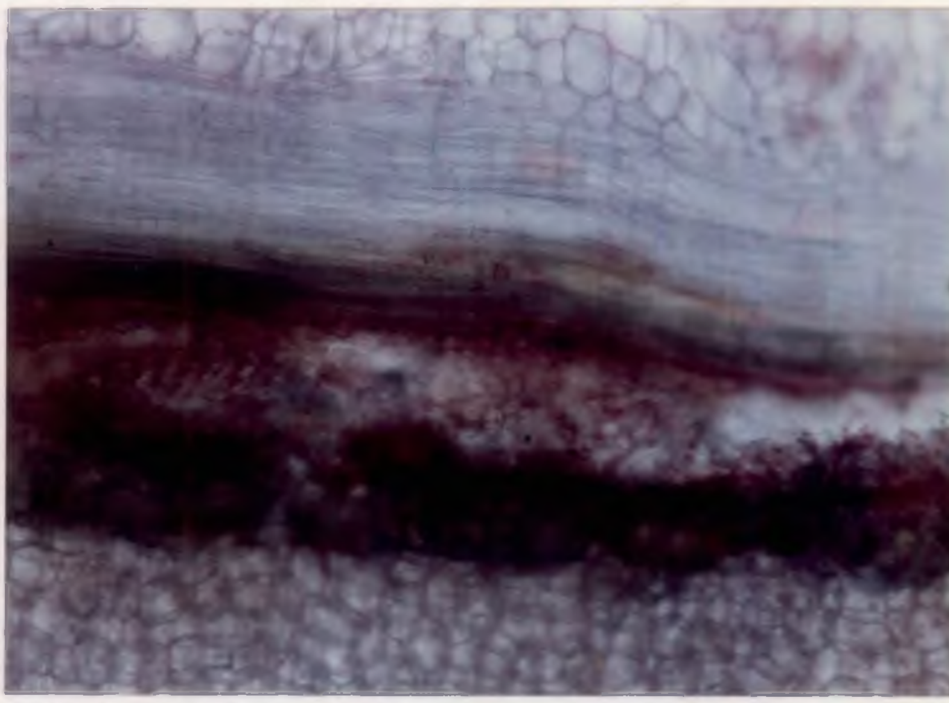


Plate No. 24

In compatibility symptoms with Acid lime as root stock - collapse & formation of a necrotic layer of black dead cells



gradually the cells at graft interface began to develop cellular senescence, cellular deassembly, collapse and finally leading to a necrotic layer of black dead cells at the graft interface (Plates 22,23 and 24).

6. BIOCHEMICAL STUDIES

6.1 Starch

Analysis of the bark of the basal part of cuttings in soft wood and semi hard wood cuttings showed a gradual rise in starch content to the final stage of root emergence but in hard wood cuttings a decrease was observed at the root emergence (Table 30 and Figure 5). In leaf samples, there was a steep fall in the starch content during root emergence.

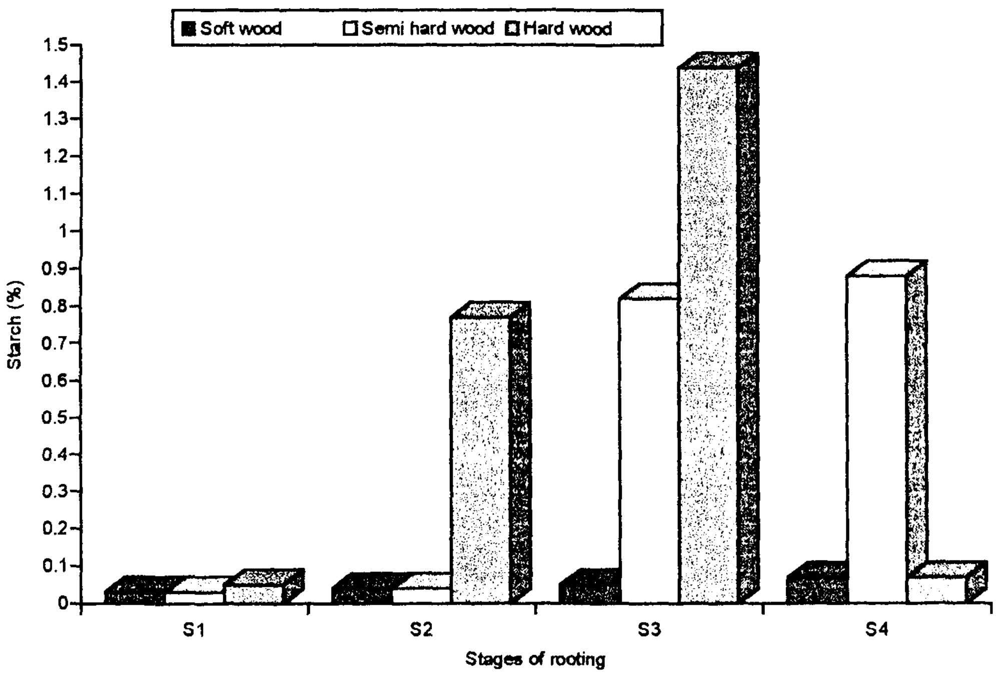
6.2 Carbohydrates

The total carbohydrate content in the base of stem was found to increase steadily during root initiation and remained like that up to the primordia formation but during root emergence, there was a sudden decline observed in all the three types of cuttings (Table 30 and Figure 6). In leaf samples also during root emergence, there was a fall in carbohydrate content.

6.3 Nitrogen

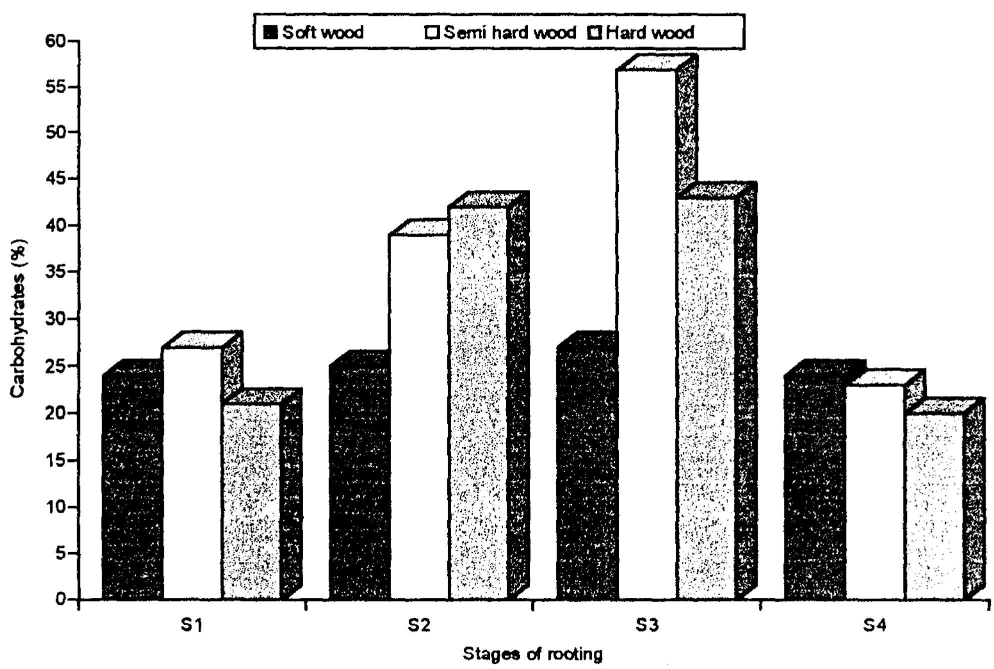
The Nitrogen content showed a gradual increase upto root primordia formation and then there was a fall during root emergence

Fig.5 Changes in starch content during different stages of rooting



S_1 - Before rooting
S_2 - Root initiation
S_3 - Root primordia formation
S_4 - Root emergence

Fig.6 Changes in total carbohydrate content during different stages of rooting



S_1 - Before rooting
S_2 - Root initiation
S_3 - Root primordia formation
S_4 - Root emergence

(Table 30 and Figure 7) in stem samples of all the three types of cuttings. The leaf samples also showed a decline in Nitrogen content from root initiation to emergence.

6.4 Protein

Similar results as those for nitrogen content were observed in the case of protein content also in the three types of cuttings. (Table 30 and Figure 8). The highest protein content was during the root primordia formation stage.

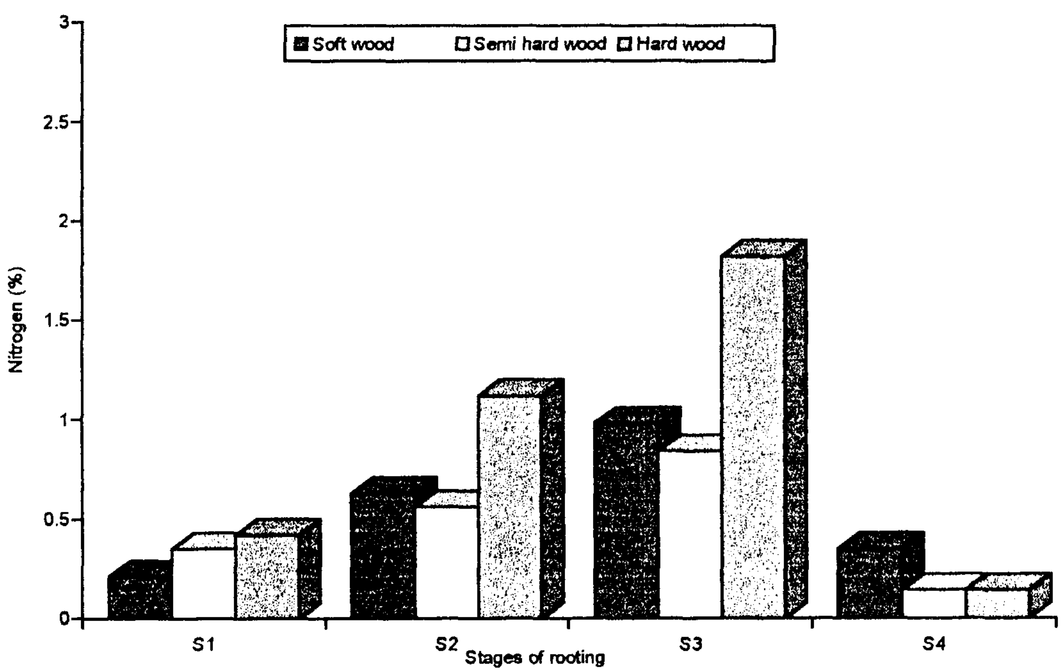
6.5 C/N ratio

As in the case of carbohydrates and Nitrogen, the C/N ratio increased upto root primordia formation and then declined during root emergence (Table 30).

6.6 Amino acids

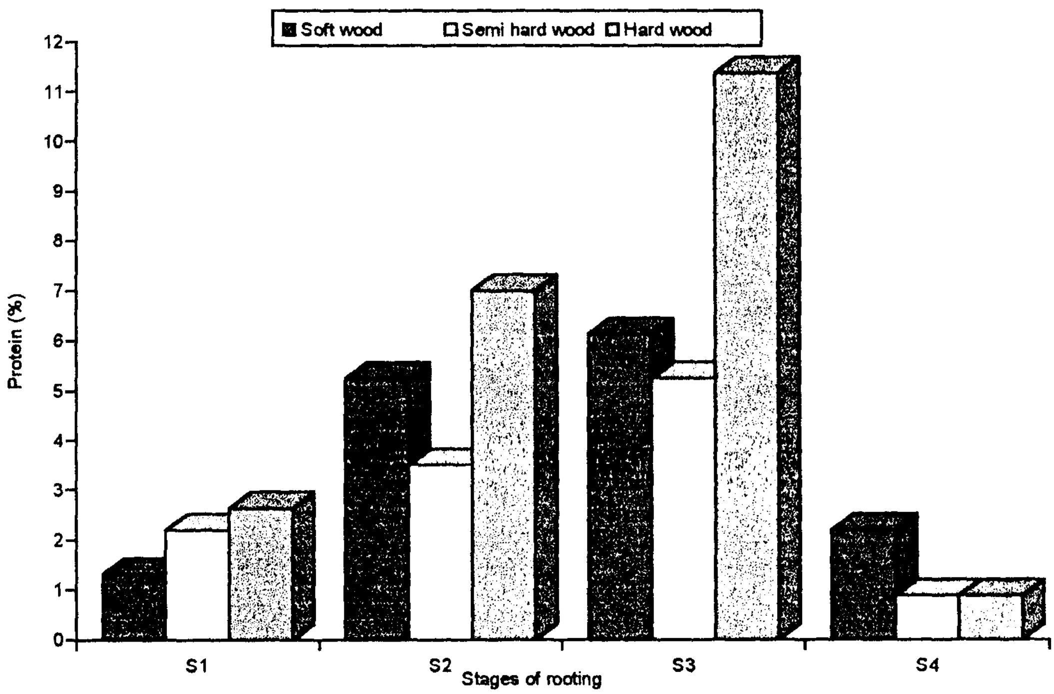
Table 29 shows the different amino acids present at different stages of rooting in softwood, semi hard wood and hard wood cuttings. There were many remarkable changes in the amino acid contents of the different types of wood during the different stages of rooting. It was found that, more number of amino acids were observed in the base of stem during root initiation in all the three types of cuttings (Nor leucine, valine, DL-Alanine, Threonine, Proline, Methionine and L-Leucine). A further increase in the number was observed during the primordia formation (Tryptophan,

Fig.7 Changes in nitrogen content during different stages of rooting



S_1 - Before rooting
S_2 - Root initiation
S_3 - Root primordia formation
S_4 - Root emergence

Fig.8 Changes in protein content during rooting



S_1 - Before rooting
S_2 - Root initiation
S_3 - Root primordia formation
S_4 - Root emergence

TABLE - 29

AMINO ACIDS PRESENT AT DIFFERENT STAGES OF ROOTING IN DIFFERENT TYPES OF CUTTINGS

	L1			S1			S2			S3			S4			L4		
Amino acids	SW	SHW	HW	SW	SHW	HW	SW	SHW	HW	SW	SHW	HW	SW	SHW	HW	SW	SHW	HW
Nor lencine	+	+	-	-	-	-	-	+	+	+	-	+	-	-	-	+	-	+
L-cystine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DL-Valine	+	-	+	-	-	-	+	+	-	+	+	+	-	-	-	+	-	+
3DL-Alanine	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-
DL-B-Phenylalanine	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-
L-Hydroxy proline	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DL-Serine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Glycine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DL-Threonine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L-Glutamic acid	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
L-Cysteine-hydrochloride	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L-Lysine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L-Histidine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L-proline	-	+	-	-	-	-	-	-	+	-	+	-	-	-	-	-	+	+
DL-Alanine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DL-Methionine	+	-	-	+	+	+	-	-	+	+	+	+	+	+	+	-	+	+
DL-Aspartic acid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DL-Tryptophan	-	-	+	+	+	+	-	-	-	-	+	+	+	+	+	+	+	+
L-Tyrosine	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
L-Arginine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DL-2-Aminobutyric acid	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L-Ornithine	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
DL-Isoleucine	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L-Leucine	-	+	+	-	-	-	+	-	+	-	-	-	-	-	-	-	-	-

Stages of rooting

L1 - Root initiation (in leaves)
S1 - Root initiation (in stem)
S2 - Root primordia formation (in stem)
S3 - Root elongation (in stem)
S4 - Root emergence (in stem)
L4 - Root emergence (in leaves)

TABLE - 30

CHANGES IN THE CONTENTS OF TOTAL CARBOHYDRATES, STARCH, NITROGEN, PROTEIN AND C/N RATIO DURING THE DIFFERENT STAGES OF ROOTING.

Stages of rooting	Carbohydrates			Starch			Nitrogen			Protein			C/N ratio		
	SW	SHW	HW	SW	SHW	HW	SW	SHW	HW	SW	SHW	HW	SW	SHW	HW
Root initiation (leaf)	21	18	26	0.05	0.14	0.11	1.54	2.38	1.54	9.63	14.88	9.63	1.36	7.5	16.88
Root initiation (stem)	24	27	21	0.03	0.03	0.05	0.21	0.35	0.42	1.31	2.19	2.63	1114.29	77.14	50.0
Root Primordia formation (stem)	25	39	42	0.09	0.04	0.77	0.63	0.56	1.12	5.25	3.5	7.0	39.68	69.64	37.5
Root elongation (stem)	27	57	43	0.05	0.82	1.44	0.98	0.84	1.82	6.13	5.25	11.38	27.55	67.86	23.63
Root emergence (stem)	24	23	20	0.07	0.88	0.07	0.35	0.14	0.14	2.19	0.88	0.88	68.57	164.29	148.85
Root emergence (leaf)	17	19	18	0.03	0.04	0.06	1.12	0.98	0.84	7.00	6.13	5.25	15.18	19.39	21.43

SW - Soft wood

SHW - Semi hard wood

HW - Hard wood.

Tyrosine, Glutamic acid) in soft wood and semi hard wood. In contrast, it remained constant in hard wood cuttings. All the three types of wood showed a decrease in the number of amino acids present during root emergence. Contrary to this, analysis of leaf samples revealed that the number of amino acids were found to increase during root emergence.

DISCUSSION

DISCUSSION

The results of the present investigations carried out to standardise propagation methods in Baduvapuli are discussed in this chapter.

CUTTINGS

Type of wood, hormones and rhizogenesis

Propagation with stem cuttings is generally attempted in fruit crops, as this method is inexpensive and easy. The use of growth regulators is also now in practice for enhancing the rooting efficiency in cuttings. In the present study, attempts to propagate the cuttings without growth regulator treatment failed showing that propagation through cuttings is possible only with hormonal treatment.

Among the growth regulators tried, IBA was found to be more effective than IAA and NAA. Ninety per cent rooting was obtained with IBA 1900 mg l^{-1}. The quality of roots and shoots were also best with the same concentration. The superiority of IBA to IAA and NAA in rooting of stem cuttings was established as early as in 1939 by Hitchcock and Zimmerman. The reduced root promoting activity of IAA compared to IBA and NAA has been attributed to the fact that plant tissues possess several metabolic mechanisms that remove IAA from the growth regulating system (Leopold and Kriedemann 1975). Hitchcock and Zimmerman (1939) found that although IBA was more effective than NAA, comparison of the two auxins is not simple because many factors influence auxin efficacy. Proebsting (1984) reports that a particular species may react differently when treated with equivalent concentration of different auxins.

The study also reveals that there is strong synergistic effect in the combination of IBA and IAA among the combinations tried though the effect was inferior to IBA used alone. This sort of synergism, though not in the same crop, has been reported by Hitch cock and Zimmerman (1940), Singh et al., (1962) and Sharma et al., (1975).

The optimum auxin concentration to be applied is dependent on the genotype and other variables such as type of auxin carrier, position and depth of application, duration and frequency of treatment, and the water status of the cutting as determined by the moisture loss between collection and treatment of the cutting, all of these interacting to determine the dose reaching responsive tissues.

While comparing the type of cuttings, it was found that although soft wood cuttings were early in rooting, the percentage rooting and other qualitative aspects such as number of roots, length of longest root and number of shoots were best in hard wood cuttings. High adventitious rooting potential is considered as a juvenile characteristic. The loss of rooting potential with maturation is particularly severe in many long lived tree species. The type of wood used for cuttings is immaterial in the species of plants which are easy-to-root but it is a matter of great importance in the difficult-to-root material. Though the developmental pattern of root initiation was the same in juvenile and mature cuttings, the process is slower in mature than juvenile cuttings. This may be the reason for earliness in softwood cuttings. The study showed that there was marked chemical differences in the different types of cuttings. The carbohydrate content in the hard wood cuttings was more and this would have accumulated at the base of the shoots and should be one of the reasons for the positive response obtained. In soft wood cuttings, carbohydrates were not sufficiently present and rooting was found to be better if the tip portion of shoots together with foliage was taken.

The differential response in other crop species have also been explained in terms of anatomical differences. But while examining the three types of wood, there was no anatomical differences between them and no anatomical barriers could be located.

Five noded cuttings proved to be superior both quantitatively and qualitatively. This was in accordance to Nanda and Kochar (1991) who showed that longer cuttings root better than the shorter ones. This may be due to the fact that the carbohydrate reserves are more in longer cuttings.

The present investigation showed that rooting of cuttings occured only when kept inside a mist chamber and given intermittent misting. It is well known that misting maintains a film of water on the leaves which not only result high humidity surrounding the leaf but also maintains turgidity and optimum temperature. Intermittent misting prevented the desiccation of the cuttings. The cuttings which were kept outside the mist chamber dried within few days. Under relatively dry conditions, desiccation and death should have occurred by excessive water loss before the roots were formed.

There was pronounced seasonal influence as revealed by the time of taking the cuttings on the rooting of cuttings. Marked beneficial response on root formation was observed with the cuttings planted from February to October. Among these 9 months, August and Septemebr turned to be the best months for rooting. The mean rainfall, temperature and humidity during these two months were moderately high. During November, December and January, rooting was very poor. The rainfall during these months was very poor. There was absolutely no rain during December and January. The seasonal changes in rooting of cuttings have also been ascribed to morpho physiological status of branches which is determined by endogenous level of nutrition and auxin which inturn is influenced by light, temperature and humidity.

Leaf Vs Leafless cuttings

The study proves beyond doubt that the presence of lamina on the cutting enhance rooting efficiency and quality of roots. This result can be argued from three angles. Firstly, it is a known fact that photsynthesis by cuttings positively influences rooting. Photosynthesis during rooting provides carbohydrates to the base of the cuttings and they accumulate in the base during the rooting period (Altman and Wareing, 1975 and Haissig, 1982). Secondly, under low photosynthetic activity, auxin transport or synthesis may be reduced [Heide, 1968 and Vardar, 1968] thus indirectly influencing rooting. Thirdly, rooting cofactors normally originate in leaves and buds and may be transported to the base of the cutting where they promote rooting.

Banding technique

Fourty five days of banding resulted in higher rooting percentage and other root and shoot characters when compared to non banded cuttings. There was lack of chlorophyll, increase in inter nodal length, increased succulence and decreased mechanical strength of stem tissues making them to react strongly to applied auxins. All these might have stimulated rooting. Identical results have been obtained in the findings of Stoutemyer (1961) and Hess (1969). Etiolation greatly enhance the stem's sensitivity to auxin and it is also associated with change in phenolic substances that may act as a rooting co-factor.

Histological examinations revealed that there was not much anatomical and biochemical differences in the banded shoots from normal shoots. It was also noticed that banded soft wood cuttings performed better than banded semi hard wood and hard wood cuttings. Without banding, the performance of soft wood cuttings was poor. Promotive effect of juvenility in combination with etiolation have been commercially exploited in many plant species like Apple [Gardner, 1937 and Howard, 1982] and French bean [Herman, 1967].

February and March planted cuttings gave the highest percentage survival, both at 3 months and 6 months after planting. Though the rainfall was less during these two months, it increased tremendously from March onwards. The mean temperature and mean humidity were moderately high during these two months. It shows that the cuttings do not prefer very high temperature, high rainfall and humidity for establishment. Similar conclusions have also been made by Choudhary et al., (1963) in Sweet lime cuttings where it was observed that February was superior to September planting.

LAYERING

As in cuttings, the hard wood shoots were found to be the most suitable for layering. The biochemical analysis showed higher carbohydrate content in hard wood shoots which may be the reason for its better performance as compared to soft wood shoots. The four media tried showed differential responses during the same month and during the different months. Coconut fibre was found to be the most suitable during March, April and July. Saw dust performed better during April and July. The different root qualities were also the best for saw dust and coconut fibre. Though sphagnum moss performed well in Septemebr and October, the different root qualities were poor. Coir dust was found to be good in September but it did not show much favourable effects on root qualities. This indicates that saw dust and coconut fibre are the best media for layering. Both these media are porous enough to allow good aeration and possess high water holding capacity. They are locally available, less costly and available throughout the year. Sphagnum moss being very costly and not available through out the year, the results provide a sound basis of low cost technology using indigenously occurring natural materials. Though coir dust is cheap, it is only available in coastal areas.

Good rooting was obtained from March to October while rooting was poor from November to February. This was in accordance to Nanda and Kochar (1990) who generalised that short days, low temperatures and low light intensities reduce the photosynthetic output of leaves and the mobilisation of reserve food materials due to a decrease in the activity of hydrolysing enzymes limiting thereby the supply of available nutrition which is necessary for the initiation and development of roots. This is evident from seasonal changes in cambial activity which decrease usually during winter months. The increased biosynthesis of auxin in the active season and of inhibitory substances during winter dormancy also occur.

Maximum success in layering was in April. The month received a moderate mean rainfall (165.2mm), mean temperature (30°C) and mean relative humidity (74 %). Nanda and Kochar (1991) also remarked that lower and higher extremes of climatic factors cause a delay in rooting and result in the death of the shoots.

In the banding treatments given before layering, 45 days of banding gave higher percentage and early rooting. Beyond 45 days of banding, rooting was found to decrease. The etiolation of plant parts in general causes a decrease in starch content, reduces the amount of mechanical tissue, decreases the thickness of cell wall and cell wall deposits and also the total amount of vascular tissue thereby making rooting easy. In this study also, soft wood responded more to banding. Gardner (1937) found in Apple that light must be excluded early in the ontogeny of the shoot, before the cells derived from shoot meristem had differentiated for early rooting. Similarly Howard (1982) observed in Apple that blanching the stem apex was more effective than basal blanching.

Five days ringing on 45 days banded shoots showed improved rooting but the effect was almost the same as in 45 day banding alone. Ringing stimulated the effect of rooting in conjunction with etiolation. The rooting stimulus may be brought about by interruption of transport of active substances for root formation through the bark besides giving a better C/N balance. Ringing has been associated with changes both in content of growth hormones and of carbohydrates. In Citrus, ringing was accompanied by accumulation of gibberellin above the ring (Goren et al., 1971). Wellerstein et al., 1974 confirmed this result and showed that ringing interfered with either production of gibberillin or its translocation to the roots. This particular aspect was not probed during the course of this investigation., Six months after planting the layers, the percentage survival was high when planted during the months of June, July and September. Generally layers are known for the high field mortality as the adventitious roots find it difficult to withstand any unfavourbale condition. However, the months of June, July and September, coinciding with peak showers of the two monsoon periods, provided a congenial climate which satisfied the basic pre-requisites for high success.

Application of hormones during layering did not show any positive effect on rooting. During February, there was a slight increase in rooting response when growth regulator was applied. The success of layering as a propagation method without hormonal application has been well proved in Baduvapuli (Shankar, 1965).

GRAFTING

Soft wood grafting was successfully carried out in Baduvapuli using Rangpur lime, Rough lemon, Malta and Acid lime as root stocks. The percentage establishment, height, root stock girth and scion girth were high when Rangpur lime was used as the rootstock thus proving that Rangpur lime is the best root stock for Baduvapuli Rangpur lime has been successfully used as promising root stocks for budding Blood red sweet orange (Chohan et al., 1982); Mosambi (Chohan and Kumar, 1983); Sathgudi (Haleem, 1984) and Kinnow (Tayde and Joshi, 1986). Rangpur lime is a very prolific variety hardier than true limes and hence it is mostly used as a root stock in India. The high percentage of success with Rangpur lime may be due to the fact that being hardy, it performs well under humid conditions. Reports from IIHR show that Rangpur lime is best in Chethali, Coorg which experiences almost similar climate as that of Kerala.

When different forcing treatments were given to the scion by clipping the leaves, it was found that grafting was successful only when full leaves were present in the scion. No union occurred when leafless scion was used. It may be because, leaves are needed for current photosynthesis. It also proves that scions do not require any forcing treatments and such forcing treatments rather had only negative effect on graft uptake.

May-June proved to be the best season for grafting, the mean temperature being 31°C and relative humidity 88%. This temperature is favourable for cellular activity, callus formation and healing during graft union for most tropical fruit species. There was high humidity during these months in the vicinity of the cambial region of the graft union. Nanda and Kochar (1991) also suggested a similar climatic condition for successful grafting.

BUDDING

Though different methods of budding with different pretreatments were carried out in different seasons, there was no success at all. It may be due to the unique nature of the bud which is situated very close to the thorns. Unlike other Citrus species, in the native Baduvapuli, thorns arise adjacent to leaf bases and the thorns are strong and stout due to the growth of wood into the central core region. Hence when the scion is taken, the thorn that remains close to the bud acts as a mechanical barrier. The bud can be taken only after clipping the thorn and the removal of thorn results in a large hole near the bud (Plate 25). Within days of budding, the part that was near to the base of thorn begins rotting.

The failure of budding in Baduvapuli can only be argued in the context of the physical location of the thorn and the wood growth into the thron with the development.

ANATOMICAL STUDIES

The anatomical studies showed that the root initials originate from the pericycle. Priestly and Swingle (1929) while studying the vegetative propagation, comprehensively from the plant anatomy stand point, suggested the origin of roots from pericycle

Plate No. 25

Prepared buds of Baduvapuli and Rough lemon

BP - Baduvapuli, RL - Rough Lemon


BP
RL

on young stem and their origin in neighbourhood of cambium on older stems. Pericyclic origin of the roots has been reported to be in between fibro vascular bundles in the case of coleus (Carlson 1929). The results of the present study are in full confirmity with the above works and the suggestion of Janhari (1963) who reported that the roots arose from a part of the pericycle in Mulberry stem cuttings.

The different stages of rooting obtained were almost in confirmity with the findings of White and Lovell (1984) in Agathis. They found root initiation by 16-17 days, primordia formation by 18th day and root emergence by 27th day. In cuttings, the stages of rooting were clear and separate while in the layers, the different stages were not clear and they were overlapping.

BIOCHEMICAL STUDIES

The carbohydrate content in the stem increased steadily during root initiation upto primordia formation but showed a sudden decline at root emergence. This was in confirmation with the studies of Lovell et al., (1974); Hansen et al., (1978); Davis and Potter (1981) and Spellengberg (1985) who found a net accumulation of carbohydrates normally occur until root emerge from cuttings.

The nitrogen content also showed a similar trend as that of the carbohydrates during the different stages of rooting.

Identical results have also been reported by Basu _et al._, (1968) showing that total nitrogen in the bark decreased during root formation. The soluble N rose during the precallusing and callusing stage, but fell before root emergence when there was a net synthesis of proteins.

As in the carbohydrates and N content, C/N ratio also revealed a similar variation during the stages of rooting. The high C/N ratio observed during the early stages of rooting declined at the final stage of emergence of the roots. Sen and Sen (1960) and Sen _et al._, (1965) have shown that a high C/N ratio was beneficial for rooting of cuttings.

Starch content increased from initiation to emergence in soft wood and semi hard wood cuttings but there was a fall in starch during the last stage in hard wood cuttings. Leaf samples also showed a similar fall in starch at root emergence.

The number of amino acids in all the three types of cuttings was more at root initiation and this was further increased at primiordia formation but showed a fall during emergence. Transmination and deamination are necessary steps in the production and accumulation of plant metabolites. Hence the increase in number of amino acids upto primordia formation can only be due to transmination and the fall due to deamination. Measurements in cuttings have shown that the content of aminoacids changed little during rooting (Hansen _et al_., 1978 and Haissig, 1982).

Cuttings are normally unable to increase the content of nitrogen after excision, atleast until new roots are formed, but they alter the different pool levels (amino acids,proteins). Determination in rooted cuttings revealed that Proline was the most abundant amino acid in newly rooted cuttings (Suzuki, 1982). The present investigation showed the presence of Proline at the root emergence stage in semihard wood and hard wood cuttings. The presence of proline actually serves as a viable indicator of the plant to survive even under unfavourable conditions. Arginine, Histidine and Alpha-amino butyric acid were not present during any of the rooting stages. Haissig (1974) suggested that rooting ability was reflected in the amino acid composition in such a way that poor rooters contained a relatively high content of arginine, histidine and especially alpha-amino butyric acid. The increase in amino acid upto primordia formation may be an indicator of accumulation and the sudden fall reflects the utilisation for the development of root.

The protein content showed a gradual rise upto primordia formation and then there was a fall at root emergence. It appears likely that auxins initiate synthesis of structural or enzyme proteins in the process of adventitious root formation. The results support the observations of Knypl (1966) that protein synthesis is a pre-requisite for root formation.

SUMMARY

SUMMARY

The investigations were carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara; Central Nursery, Vellanikkara and ARS, Mannuthy from September 1993 to August 1995 to standardise the propagation techniques in Baduvapuli (*Citrus pennivessiculata* Tan.). The salient findings of the investigations are summarised below:

1. Hard wood cuttings performed better than semi hard wood and soft wood cuttings.

2. IBA was superior to IAA and NAA in inducing rooting of cuttings.

3. IBA 1900 mg l^{-1} proved to be the most promising concentration for treating all type of stem cuttings.

4. IBA 1800 mg l^{-1}, IBA 2500 mg l^{-1} + IAA 1300 mg l^{-1} and IBA 2500 mg l^{-1} + IAA 1500 mg l^{-1} also yielded good results.

5. Five noded cuttings showed relative superiority as planting material.

6. Intermittent mist was a necessity for propagation through cuttings.

7. Months from February to October were suitable for propagation through cuttings with August and Septemebr being the best.

8. Presence of leaves was a must for enhancing rooting efficiency and quality of roots in soft wood stem cuttings

9. Banding for fourty five days resulted in enhanced and earlier rooting

10. The percentage establishment of cuttings was highest when planted during February-March.

11. Hard wood shoots were most suited for layering than semi hard wood and soft wood shoots.

12. The best media for layering were coconut fibre and saw dust.

13. Layering can be done from March to October with April being the best month.

14. Banding the shoots for 45 days gave higher percentage and early rooting.

15. Five days ringing on 45 days banded shoots showed better rooting efficiency but the effect was almost same as 45 days banding alone.

16. Survival of layers was high when planted during June, July and September.

17. Soft wood grafting was successfully performed in Baduvapuli using Rangpur lime, Rough lemon, Malta and Acid lime as root stocks.

18. Rangpur lime was the best rootstock for Baduvapuli showing better results for different characters.

19. Removal of leaves from scion resulted in to failure of grafting.

20. May-June was the most suitable season for grafting.

21. Budding methods like T-budding, Patch budding and chip budding were a failure in Baduvapuli though different pretreatments were given to the buds and performed during different months.

22. The anatomical studies in cuttings showed that root initials originate from the pericycle in all the three types of cuttings

23. The root initials developed 15 days after planting, the primordia formed 18 days after planting and the root emerged on the 22th day of planting.

24. Root primordia were found in layers on the 11th day of layering in case of soft wood.

25. There were no structural anatomical changes observed in banded plant parts used as cuttings or for layering.

26. Anatomy of graft union showed that union did not take place in some grafts due to cellular senescence and collapse and formation of necrotic layer.

27. Biochemical studies revealed that the number of amino acids in all three type of cuttings increased during root initiation and formation of primordia but reduced during emergence. The protein content, total N content, carbohydrate content, C/N ratio and starch content also showed a similar trend.

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*- Originals not seen.

APPENDICES

APPENDIX 1

Analysis of variance table for effect of growth regulators on percentage rooting and days to rooting of cuttings

Percentage rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	0.007	0.417
Growth regulator	11	0.079	4.941**
Error	22	0.016	

Days to rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	3.659	1.083
Growth regulator	11	10.261	3.038*
Error	22	3.378	

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

APPENDIX 2

Analysis of variance table for effect of growth regulators on percentage rooting and days to rooting of cuttings

Percentage rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	0.505	25.916**
Growth regulator	24	0.215	11.018**
Error	48	0.019	

Days to rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	51.433	17.445**
Growth regulator	24	4.718	1.600
Error	48	2.948	

* Significant at 5% level

** Significant at 1% level

APPENDIX 3

Analysis of variance table for effect of growth regulators on percentage rooting and days to rooting of cuttings

Percentage rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	0.684	36.767**
Growth regulator	26	0.060	3.221**
Error	52	0.019	

Days to rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	68.357	15.520**
Growth regulator	26	4.881	1.108
Error	52	4.404	

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

APPENDIX 4

Analysis of variance table for effect of growth regulators on percentage rooting and days to rooting of cuttings

Percentage rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	0.151	3.451*
Growth regulator	17	0.056	1.278
Error	34	0.044	

Days to rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	2.984	0.616
Growth regulator	17	5.500	1.136
Error	34	4.844	

* Significant at 5% level

APPENDIX 5

Analysis of variance table for effect of growth regulators on percentage rooting and days to rooting of cuttings

Percentage rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	0.053	1.165
Growth regulator	10	0.237	5.249**
Error	20	0.045	

Days to rooting

Source	Degrees of freedom	Mean square	F value
Wood	2	0.814	1.271
Growth regulator	10	0.655	1.022
Error	20	0.641	

** Significant at 1% level

APPENDIX 6

Analysis of variance table for effect of selected growth regulators, type of cuttings and time on number and length of roots, number of leaves and number of shoots

Source	Degrees of freedom	Mean squares				F value			
		No. of roots	Length of longest root	No. of leaves	No. of shoots	No. of roots	Length of longest root	No. of leaves	No. of shoots
Wood	2	19.189	61.329	28.675	0.68	4.797**	8.234**	2.763	0.712
Growth regulator	7	41.961	116.736	108.319	12.503	10.490**	15.674**	10.438**	13.517*
Wood x growth regulator	14	14.249	18.201	20.115	2.567	3.562**	2.4444*	1.938*	2.776
Error1	216	4.000	7.447	10.377	0.925				
Time	1	33.075	5.655	26.133	4.408	104.143**	2.955*	52.218**	37.195**
Wood x time	2	0.131	4.222	0.108	0.108	0.413	2.206*	0.217	0.194
Growth regulator x time	7	1.113	9.897	2.324	0.399	3.505*	5.173**	4.643**	3.365*
Wood x growth regulator x time	14	0.591	7.260	0.877	7.023	1.860*	3.794**	1.753*	0.593
Error	216	0.317	1.913	0.500	0.119				

* Significant at 5% level

** Significant at 1% level

APPENDIX 7

Analysis of variance table for effect of number of nodes on percentage rooting and days to rooting of cuttings

Source	Degrees of freedom	Means squares		F value	
		Percentage rooting	Days to rooting	Percentage rooting	Days to rooting
Wood	2	0.006	6.428	0.303	2.933
Number of nodes	4	0.460	4.226	22.242**	1.928
Error	8	0.021	2.191		

** Significant at 1% level

APPENDIX 8

Analysis of variance table for effect of number of nodes retained on different types of wood on the number of roots, length of longest root and number of leaves

Source	Degrees of freedom	Mean Squares			F Value		
		No. of roots	Length of longest root	No. of Leaves	No. of roots	Length of longest root	No. of Leaves
Wood	2	30.243	2.110	2.730	4.730**	0.428	0.618
Number of nodes	4	140.933	98.429	92.235	22.043**	19.959**	20.880**
Wood x Number of nodes	8	24.506	2.379	1.682	3.833*	0.482	0.381
Error1	135	6.394	4.931	4.417			
Time	1	26.403	10.868	7.363	70.513**	63.160**	17.999**
Wood x Time	2	0.303	0.004	0.008	0.810	0.244	0.204
Number of nodes x Time	4	4.137	1.530	1.603	11.048**	8.892**	3.918**
Wood x Number of nodes x Time	8	0.174	0.132	0.760	0.465	0.765	1.859
Error	135	0.374	0.172	0.409			

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

APPENDIX 10

Analysis of variance table for seasonal effect of different types of cutting on number of roots, length of longest root, average length of roots and number of leaves.

Source	Degrees of freedom	Mean squares				F value			
		No. of roots	Length of longest root	Average length of roots	No. of leaves	No. of roots	Length of longest root	Average length of roots	No. of leave
Wood	2	5.755	8.920	8.087	0.693	0.845	1.178	1.741	0.093
Seasons	11	67.945	53.549	28.361	46.910	9.981**	7.074**	6.106*	6.334**
Wood x Seasons	22	10.907	8.793	6.153	6.782	1.602*	1.161	1.325	0.915
Error1	324	6.808	7.569	4.644	7.405	69.048**	22.862**	15.489**	28.576**
Time	1	185.034	56.140	28.360	86.113	1.432	3.846*	3.997*	1.447
Wood x time	2	3.838	9.443	7.319	4.362	11.609**	17.312**	13.354**	7.661**
Season x time	11	31.110	42.512	24.450	23.088	1.295	2.298*	1.967*	1.679*
Wood x Season x time	22	3.469	5.644	3.603	5.061				
Error	324	2.679	2.456	1.831	3.013				

* Significant at 5% level

** Significant at 1% level

APPENDIX 9

Analysis of variance table for effect of months on percentage rooting and days to rooting in cuttings treated with IBA 1900 mgl^{-1}

Source	Degrees of freedom	Means squares		F value	
		Percentage rooting	Days to rooting	Percentage rooting	Days to rooting
Wood	2	0.003	0.951	0.068	22.387**
Months	11	0.195	0.368	5.109**	8.671**
Error	22	0.038	0.042		

** Significant at 1% level

APPENDIX 11

Analysis of variance table for effect of leafiness on the rooting of cuttings

Source	Degrees of freedom	Mean squares					F Value				
		Percentage rooting	Days to root	No. of roots	Length of largest root	No. of secondary roots	Percentage rooting	Days to root	No. of roots	Length of largest root	No. of secondary roots
Months	2	201.367	105.389	62.017	58.214	187.267	11.559**	18.418**	6.989**	16.087**	8.613**
Leafiness	1	8074.774	234.723	5.017	30.405	52.317	463.510**	41.019**	0.565**	8.402**	2.406
Months x Leafiness	2	249.615	10.722	77.517	10.849	21.017	14.328**	1.874	8.737**	2.997	0.967
Error	12	17.421	5.722	8.872	3.619	21.741					

** Significant at 1% level

APPENDIX 12

Analysis of variance table for effect of banding on the percentage rooting and days to rooting of cuttings

Source	Degrees of freedom	Means squares		F value	
		Percentage rooting	Days to rooting	Percentage rooting	Days to rooting
Wood	2	0.034	0.403	6.17*	16.43**
Days of banding	3	0.048	0.268	8.79*	10.94**
Error	6	0.005	0.025		

* Significant at 5% level

** Significant at 1% level

APPENDIX 13

Analysis of variance table for effect of banding on the number of roots, length of longest root and number of leaves of cuttings.

Source	Degrees of freedom	Mean Squares			F Value		
		No. of roots	Length of longest root	No. of Leaves	No. of roots	Length of longest root	No. of Leaves
Wood	2	3.154	28.295	9.612	0.233	1.486	0.889
Days of banding	3	116.637	215.849	23.015	8.609**	11.337**	2.131
Wood x Days of banding	6	6.871	34.648	2.040	0.507	1.819	0.189
Error 1	108	13.546	19.039	10.801			
Time	1	14.504	21.064	21.004	26.892**	140.108**	17.323**
Wood x Time	2	0.379	0.005	1.029	0.703	0.333	0.849
Days of banding x Time	3	1.137	1.425	4.048	2.109	9.477**	3.339*
Wood x Days of banding x Time	6	0.429	0.092	0.724	0.796	0.613	0.597
Error	108	0.539	0.150	1.213			

* Significant at 5% level

** Significant at 1% level

APPENDIX 14

Analysis of variance table for survival rate of cuttings

Source	Degrees of freedom	Means squares		F value	
		3 MAP	6 MAP	3 MAP	6 MAP
Wood	2	0.011	0.008	0.745	0.977
Months	5	0.078	0.056	5.428*	6.545**
Error	10	0.014	0.009		

MAP - Months after planting
* Significant at 5% level
** Significant at 1% level

APPENDIX 15

Analysis of variance table for effect of media, wood and months on percentage rooting

Source	Degrees of freedom	Mean squares							
		Coconut fibie		Sphagnum moss		Coir dust		Saw dust	
		% rooting	Dtr	% rooting	Dtr	% rooting	Dtr	% rooting	Dtr
Wood	2	0.060	0.023	2.010	8.497	1.994	0.846	0.073	0.634
Months	11	0.355	2.281	0.191	5.617	0.118	7.239	0.188	7.515
Error	22	0.032	2.296	0.049	2.435	0.029	0.734	0.035	0.703

Source	Degrees of freedom	F Value							
		Coconut fibie		Sphagnum moss		Coir dust		Saw dust	
		% rooting	Dtr	% rooting	Dtr	% rooting	Dtr	% rooting	Dtr
Wood	2	1.87	0.01	41.38**	3.41	68.69**	1.15	2.08	0.90
Months	11	11.05**	0.99	3.93	2.31	4.08**	9.85**	5.37**	10.68**
Error	22								

* Significant at 5% lelvel

** Significant at 1% lelvel

APPENDIX 16

Analysis of variance table for interaction effect of different types of wood media and months in layering

Source	Degrees of freedom	Mean squares				F Value			
		No. of roots	Length of longest root	Fresh wt. of roots	Dry wt. of roots	No. of roots	Length of longest root	Fresh wt. of roots	Dry wt. of roots
Wood	2	2615.90	15.12	3.49	0.55	63.29**	2.10**	13.15**	7.61**
Media	3	122.11	57.54	0.62	0.18	2.95**	7.97**	2.35**	2.48**
Wood x Media	6	39.61	7.60	0.06	0.07	0.96**	1.05**	0.24**	0.96**
Months	11	2566.87	118.98	4.85	0.48	62.11**	16.48**	18.28**	6.62**
Wood x Months	22	293.04	16.07	0.36	0.06	7.09**	2.23**	1.35**	0.9**
Media x Months	33	453.16	25.98	0.84	0.15	10.96**	3.60**	3.15**	2.05**
Wood x Media x Months	66	127.14	11.20	0.40	0.1	3.08**	1.55**	1.49**	1.32**
Error	288	41.33	47.217	0.27	0.007				

** Significant at 1% level

APPENDIX 17

Analysis of variance table for effect of banding on percentage rooting and days to rooting in layers

Source	Degrees of freedom	Means squares		F value	
		Percentage rooting	Days to rooting	Percentage rooting	Days to rooting
Wood	2	0.042	0.027	3.3	2.47
Days of banding	6	0.227	0.341	17.64**	30.8**
Error	12	0.013	0.011		

* Significant at 5% level

** Significant at 1% level

APPENDIX 18

Analysis of variance table for effect of banding on number of roots, length of longest root, fresh weight and dry weight of roots in layers

Source	Degrees of freedom	Mean squares				F value			
		No. of roots	Length of longest root	Fresh wt. of roots	Dry wt. of roots	No. of roots	Length of longest root	Fresh wt. of roots	Dry wt. of roots
Wood	2	107.635	3.357	0.736	0.249	6.044**	0.819	6.338**	2.841
Days of banding	6	471.106	17.639	2.335	0.842	26.452**	4.307**	20.086**	9.603**
Wood x Days of banding	12	52.208	7.627	0.778	0.333	2.931**	1.862	6.691**	3.792**
Error	42	17.809	4.095	0.116	3.683				

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

APPENDIX 19

Analysis of variance table for effect of banding + ringing on rooting of layers

Source	Degrees of freedom	Means squares		F value	
		Percentage rooting	Days to rooting	Percentage rooting	Days to rooting
Wood	2	597.841	237.482	47.852**	116.584**
Days of ringing	2	1907.289	10.481	7.557**	5.145**
Wood x days of ringing	4	301.231	6.759	2.29	3.318**
Error	18	91.423	2.037		

** Significant at 1% level

APPENDIX 20

Analysis of variance table for effect of media, wood and months on survival of layers

Source	Degrees of freedom	Mean squares		F value	
		3 months after planting	6 months after planting	3 months after planting	6 months after planting
Months	11	0.462	0.641	3.518**	5.697**
Media	3	0.290	0.312	2.208	2.772
Error	33	0.131	0.112		
Wood	2	0.136	0.142	3.737*	4.936**
Media x Wood	6	0.011	0.026	0.308	0.905
Error	88	0.036	0.029		

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

APPENDIX 21

Analysis of variance table for effect of root stock on success of soft wood grafting height and girth of stock and scion

Source	Degrees of freedom	Mean squares				F value			
		Success of grafting	Height	Girth of stock	Girth of scion	Success of grafting	Height	Girth of stock	Girth of scion
Root stock	3	704.708	427.465	0.747	2.409	20.369**	7.036**	1.749	4.765
Error 1	36	34.597	60.757	0.427	0.505				
Time	3	107.976	173.925	2.017	4.925	2.770	76.304**	169.83**	196.111
Root stock x Time	9	29.651	29.204	0.003	0.008	0.761	12.812**	3.166**	3.537
Error	108	38.975	2.279	0.001	0.002				

** Significant at 1% level

APPENDIX 22

Analysis of variance table for effect of precuring treatments of scien and seasonal effect on grafting success

Percentage treatment

Source	Degrees of freedom	Mean square	F value
Days of defoliation	6	947.92	78.379**
Error	14	12.09	

Seasonal effect

Source	Degrees of freedom	Mean square	F value
Months	7	1056.67	15.159**
Error	16	69.71	

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

STANDARDISATION OF PROPAGATION TECHNIQUES IN BADUVAPULI

(*Citrus pennivessiculata* Tan.)

By

SEREENA J.

ABSTRACT OF THE THESIS

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VELLANIKKARA, THRISSUR

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ABSTRACT

Investigations were carried out at the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara; Central Nursery, Vellanikkara and ARS, Mannuthy to standardise the propagation techniques in Baduvapuli (Citrus pennivessiculata Tan.) from September 1993 to August 1995.

From the study, it was found that cuttings, layering and soft wood grafting can be adopted as reliable and successful propagation methods in Baduvapuli. Though budding is the universal method of propagation in Citrus, it was not successful in Baduvapuli.

In cuttings, five noded hard wood cuttings and terminal soft wood leafy cuttings treated with IBA 1900 mg l^{-1} was found to be the most successful in respect of percentage sprouting and all other qualitative root characters. The treated cuttings planted from February to October gave good results, with August and September proving the best months. For early rooting of cuttings, 45 days of banding was found to be the most reliable method. Planting the cuttings during February-March showed the highest percentage survival.

In layering, hard wood shoots layered with coconut fibre or saw dust during March to October revealed the best results regarding rooting efficiency and qualitative aspects of rooting. Early and higher rooting percentage was obtained with shoots which were banded for 45 days. The survival of layers were high when planted during the rainy months of June, July and September.

Soft wood grafting (hither to not reported in case of Citrus) was very successful in Baduvapuli with Rangpur lime, Rough lemon, Malta and Acid lime as root stocks. Rangpur lime was found to be the best root stock for Baduvapuli. For grafting, the scion should be prepared with leaves. The most successful month for grafting was May-June.

The root initials were found to be originating from pericycle in cuttings. The different anatomical stages of rooting were clearly identified in cuttings. Biochemical analysis of the cuttings revealed that the amino acids, proteins, nitrogen, carbohydrates, C/N ratio and starch content increased during initiation of roots and priniordia formation but decreased during root emergence.