INDUCTION OF ORTHOTROPS IN VEGETATIVELY PROPAGATED NUTMEG (*Myristica fragrans* Houtt.) PLANTS

By

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Master of Science in Horticulture

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DECLARATION

I hereby declare that the thesis entitled Induction of orthotrops in vegetatively propagated nutmeg (*Myristica fragrans* Houtt.) plants" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled"Induction of orthotrops in vegetatively propagated nutmeg (*Myristica fragrans* Houtt.) plants" is a record of research work done independently by **Ms.Rani,T.G.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship.

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Introduction

INTRODUCTION

Th. fame of Indian spices is older than the recorded history. The lure of Indian spices brought many seafarers to the shores of India. Indian spices are recognised for their quality and are the most preferred items in both continental and Indian cuisine. It is interesting to note that India is the world's largest producer, consumer and exporter of spices. Though India exports only 5 per cent of the total production, this accounts for more than one third of the international trade in spices (Menon, 1994).

Nutmeg, (*Myristica fragrans* Houtt.) belonging to family Myristicaceae is one of the important tree spices. *M. fragrans* is a native of Moluccas, now cultivated in many tropical countries of both hemispheres like Malaysia, Indonesia, West Indies, India and Sri Lanka. It is traded internationally in nearly the same quantity (14,000 tonnes/year) as the cardamom (Peter, 1994). The crop was introduced to India towards the close of the 18th century and is at present grown in certain pockets of Tamil Nadu, Kerala, Karnataka and Assam with more than 90 per cent of the area being distributed in Kerala (Spices Board, 1991).

M. fragrans requires a hot and moist climate with a rainfall of 150-300 cm per annum. It grows best at low elevations in alluvium formed of deep friable loam with good drainage, well sheltered from high winds. The crop does not thrive above an attitude of 750 metres. In Kerala, nutmeg is mainly cultivated as a homestead crop in coconut and arecanut gardens.

The tree yields two distinct spices, nutmeg which is the dried seed and mace which is the dried aril. Both nutmeg and mace are used as spice and in medicine. In eastern countries, they are used more as a drug than as a spice. Nutmeg is said to have stimulative, carminative, astringent and aphrodisiac properties. However, excessive dose is reported to have a narcotic effect. The husk (pericarp) is made into sweet meats, jellies, beverages, candy, jam, pickles etc. The flavour and therapeutic properties of nutmeg come from its volatile oil. Alcoholic extracts of nutmeg show antibacterial activity against *Micrococcus* var. *aureus*. Myristicin present in the kernel may be employed as an additive to pyrethrum to enhance the toxicity of the latter to houseflies. The volatile oil from the leaf has weedicidal properties.

Nutmeg is a spreading dioecious evergreen tree with dimorphic branching system. Due to almost complete dioecy, seedling progeny will segregate into male and female in 1:1 ratio (Nichols and Pryde, 1958). The sex cannot be determined until the trees flower at 5-8 years of age. Thus dioecy is an important bottleneck in the cultivation of nutmeg. It is customary to cutout the surplus males at the flowering stage leaving one male to ten females. This results in irregular spacing and economic loss to the growers.

Several attempts were made to identify the sex at the seedling stage, on the basis of its morphological and physiological attributes (Prestoe, 1948; Zachariah *et al.*, 1986 and Krishnamoorthy *et al.* , 1992). But none of these methods tried were found reliable.

On account of the uncertainity in predicting the sex in nutmeg seedlings, vegetative methods for propagating female plants have a distinct advantage and the methods have been standardised by various workers.

In commercial vegetative propagation, the scarcity of orthotropic shoots is a serious limiting factor. As a result plagiotropic shoots are collected as the scion material for vegetative propagation. But such plants have peculiar spreading habit resulting in squatty plants with stunted growth compared to the seedlings of the same age. Therefore the fruiting area is comparatively less resulting in low yield.

At present, there exists great demand for nutmeg grafts which are orthotropic in nature. There are very few reports on successful budding. The present study is taken up with the main intention of inducing orthotropic growth habit in vegetatively propagated nutmeg plants. Different methods of bud grafting will be tried with the bud patch taken from orthotrops. Attempts will also be made to induce orthotrops on young nutmeg plants approach grafted with plagiotropic shoots. The study has great practical utility since the results obtained could simultaneously solve the three major problems that restrict large scale cultivation in nutmeg namely dioecy, long juvenile phase and peculiar growth habit of grafts.

Review of Literature

2. REVIEW OF LITERATURE

Literature pertaining to sex inheritence, vegetative propagation through grafting and budding, methods to induce orthotrops in nutmeg, and some other tree crops, anatomy of stem and bud union are briefly dealt in this chapter.

2.1 Dioecism in nutmeg

Nutmeg is a spreading dioecious ever green tree. Due to the almost complete dioecy, seedling progeny will give about 50 per cent of each sex and these cannot be determined until the trees flower at 5 to 8 years of age (Purseglove, 1974).

According to Flach (1966) nutmeg might possess a sex mechanism involving four pairs of chromosomes. According to this, the female sex is heterogametic with four of the supposed eight sex chromosomes showing facultative nucleolar properties which show up in meiosis when the nucleolus orientates these four chromosomes to one side. The different male flowering tree types would then have to be explained by partial failure of the mechanism of orientation.

Deinum (1931) found that on an average 55 per cent of mature seeds of nutmeg was female, 40 per cent male and 5 per cent bisexual. Nichols and Pryde (1958) after reviewing the literature on sex inheritance concluded that female and male trees are produced in approximately equal numbers. According to Flach (1966) there are two different sexes, a female flowering sex and a male flowering sex. The latter is subdivided into four different groups - males, bisexual males, bisexuals and bisexual females.

2.2 Variability

A high amount of variability has been reported in growth rate, productivity, size and shape of leaves, flowers and fruits (Flach and Cruickshank, 1969 and Sriram, 1977).

There exist no varietal classification for nutmeg in India. But there are two basic types of nutmeg available in the world trade. They are the West Indian and East Indian types. The flavour and aroma of the West Indian nutmeg compares favourably with the East Indian product in general. On the whole, East Indian nutmegs are highly aromatic and superior. Similarly West Indian mace dries to a pale yellow colour, possessing a characteristic flavour. On the other hand, East Indian mace possess a brilliant orange colour with rich flavour (Shanmugavelu and Rao, 1977).

A survey conducted by the Central Plantation Crops Research Institute (C.P.C.R.I.) in Kerala and Tamil Nadu in 1976 indicated wide variability for yield characteristics, sex expression and morphological characters among the nutmeg trees. In Burliar, besides staminate and pistillate trees, hermaphrodite forms also occur. But the hermaphrodite trees produce only smaller number of fruits and fairly high percentage of double nuts. The weight of individual nuts varying from 2 g to 15 g were collected during the survey and also trees yielding fruits from few to about 10,000 were observed (Philip, 1979).

2.3 Identification of sex

Janse (1898) reported that male trees possess smaller leaves and less horizontal branches, but as young trees showed these characters less clearly, it was not possible to determine the sex at early stages using this method.

Prestoe (1948) stated that the leaves of female nutmeg plants less than 30 cm height were nearly elliptical with more or less straight veins, while the leaves of male plants were nearly obovate with their veins round to the more pronounced point of the leaf. Flach (1966) thinks it worth investigating since he found slight difference in tree size between female and male trees while studying secondary sex characters among four year old seedlings. He showed that the female trees had a significantly higher stem diameter during the pre-bearing stage, there was no significant difference between either sex for plant height. He has postulated a hypothesis on sex determination in nutmeg which includes the possibility of sexing the young seedling by a root tip method and also thinks that nutmeg might possess a sex mechanism involving four pairs of chromosomes.

Flach and Cruickshank (1969) suggested that controlled crosses between highly producing mother trees and various types of male flowering trees held possibilities of diminishing the per cent of male trees in the off spring.

Phadnis and Choudhari (1971) reported colour difference in the leaf extracts of male and female nutmeg plants in their trials using 0.1 g leaf sample and ammonium molybdate. They also observed that colour differences were more marked in the fifth leaf collected from old flushes than the second leaf from the new flush.

Nayar *et al.* (1977) postulated a method for distinguishing the sex by the shape of calcium oxalate crystals in the lower epidermal cells of leaves of plants of at least two years age. Male plants show a single large rhomboidal or prismatic crystal with rectangular or square flat faces. Female plants have a large cluster of small crystals.

Krishnamoorthy *et al.* (1992) studied the suitability of some of the earlier reported methods to identify the sex at the nursery stage. The study of crystal patterns in the epidermal cells of the leaves revealed that the crystal differentiation was very clear in the mature leaves in almost 70 per cent of male and 78 per cent of female plants, whereas in the case of seedlings, the crystal pattern was not definite and hence the sex could not be differentiated in seedlings based on crystal pattern. The detailed study of morphological traits like sprout colour, days for germination, leaf shape, size, venation, etc. led to the conclusion that none of these characters can be taken as a guide to sex the nutmeg seedlings. Out of the various colour tests carried out on the leaf exudates or alcoholic leaf extracts of male and female trees, the ammonium molybdate alone gave satisfactory differentiation between male and female nutmeg trees.

This test gave a 'faint green' colour with the male and a 'sea green' colour with the female plant. However, this test was reproducible in the case of all the trees tested, but not in the seedlings.

Thus the studies so far made do not give a clear picture on the sex inheritence in nutmeg and none of the methods tried could differentiate sex at seedling stage.

2.4 Modification of growth pattern

Nutmeg is a spreading dioecious evergreen tree with dimorphic branching system. The tree exhibits orthotropy in the trunk and plagiotropy in the branches. Various attempts have been made in different crops to modify the growth pattern of emerging shoots.

2.4.1 Induction of orthotrops

In coffee, Fernie (1940) described the production of orthotropic shoots for use as cuttings. The primary branches of the bushes were removed and the stems were pegged down in a horizontal position from which grew up several suckers for cuttings.

In conifers, reaction wood can be induced by the application of auxin to one side of an upright stem (Wershing and Bailey, 1942).

Decapitation of the shoot commonly results in an upward movement of leaves and lateral branches, and application of an auxin to the stem stump can either maintain or increase the normal angle of orientation of such lateral organs depending upon the concentration applied (Snow, 1945, 1947; Verner, 1955; Preston and Barlow, 1950; Jankiewiez *et al.*, 1961; Palmer and Phillips, 1963).

According to Leopold (1964), woody stems in conifers which are oriented other than vertically tend to form reaction wood, a xylem tissue on one side of the stem consisting of short tracheids, rounder than usual, with intercellular spaces, an altered pattern of wall thickening. In *Phyllanthus*, with its dimorphic branches, Bancilhon (1965) has demonstrated that the plagiotropic orientation of a lateral bud meristem depends on the meristem of the orthotropic axis which formed it. If a lateral meristem formed by an orthotropic meristem is removed, after a sufficient period, from the latter's influence, it continues to function indefinitely in a plagiotropic mode. Further, he demonstrated that the reversal to an orthotropic mode occurs even after a period of plagiotropic growth due to the organiser property of orthotropic branches. This shows clearly that although the lateral meristems have been exposed to a 'plagiotropizing' inlfuence, of itself this is insufficient to induce the self maintenance of the plagiotropic mode of growth.

Rehm *et al.* (1978) observed in six month old arabica coffee seedlings grown in green house that apical dominance was broken and growth of orthotropic shoots was induced from secondary or serial buds by GA_3 alone.

According to Halle *et al.* (1978), irreversible plagiotropy is most pronounced when spiral phyllotaxy is retained on orthotropic shoots in contrast to the distichous leaves of plagiotropic shoots.

Mathew (1985) reported orthotropic response in plagiotropic shoots of four year old nutmeg seedlings kept in the nursery that exhibited vigorous growth and also the development of erect growing shoots at the proximal end of plagiotropic branches close to the trunk, after beheading of female trees when the branches were cut retaining a stub of about 30 cm long. He has observed that nutmeg trees of over 50 years old showed the formation of orthotropic shoots from plagiotropic axes located at levels at or below the horizontal plane on lower branches farther from the trunk. He could obtain orthotropic shoots at the base of previously plagiotropic growth of budded nutmeg plants by bending the root stock. Farrel *et al.* (1986) in their trial to reduce the initial plagiotropic growth of softwood fraser fir cuttings tried different treatments like auxin treatment and staking. Staking reduced abaxial concave bending, but post-severance auxin treatment had no effect.

In cocoa, the possibility of modifying the growth of the main stem of bud-grafted cocoa plants was investigated by Martinez *et al.* (1992). They applied GA_3 in lanolin paste at 0, 1, 10, 100, 200 or 400 ppm to the bud sixteen days after budding. They reported that the control and treated plants showed ½ phyllotaxy (Plagiotropic) after 30 days, whereas after 45 days all treated plants begin to show 3/8 (orthotropic) phyllotaxy.

2.4.2 Stimulation of shoot formation

Champagnat (1954) opined that the buds in the apical region are predisposed toward fast growth, whereas buds at the shoot base are predisposed toward dormancy. During dormancy the correlation between buds may change fundamentally and some buds may gain advantage over others (Champagnat, 1961). The beneficial effect of pruning to stimulate shoot formation in walnuts has been reported by Mayatskaya (1977). Walnut trees of age 20 to 25 years produced only upto 100 buds per tree suitable for budding. By pruning down three to four year old wood and irrigating, bud production in the year following pruning was increased to over 400 per tree.

Mika (1986) opined that pruning removes apical dominance, releases buds from correlative inhibition and changes the branching pattern and tree structure. He also opined that on an unheaded shoot, the first bud produces upright growth and lower buds develop into laterals with wide croch angles; on a headed shoot, the croch angles are narrow. Strong apple shoots have well developed buds along three fourths of the upper shoot length, but at the shoot base the buds are not well developed.

2.5 Vegetative propagation

Vegetative propagation has been attempted in nutmeg since long back (Ridley, 1912; Oxley, 1948).

2.5.1 Bud grafting in nutmeg

Different budding methods tried in nutmeg are briefly reviewed here.

Postma (1935) reported 30 per cent success with budding on root stocks of *Myristica succedana* in Indonesia. The growth of such trees appeared healthy, but some what stunted (Deinum, 1949). Nichols and Cruickshank (1964) reviewed the available methods of propagation in nutmeg and have reported the feasibility of other species of *Myristica* for use as root stocks.

In New Guinea, budding was tried with *M. fragrans* and *M. argentia* as root stocks, but they were not successful in the long run (Flach, 1966). Mathew and Joseph (1979) tried forkert method of budding in *M. fragrans* and *M. beddomei* rootstocks and observed that percentage of success was very low (4 per cent) in both the root stocks. Maximum success was obtained during the months of March, July and August. In another study reported by Mathew (1979), only limited success has been obtained with forkert budding in nutmeg. The buds remained green under mist but none survived when taken out. Budding during July gave maximum take. Mathew and Joseph (1980) further noted that maximum bud take was in May which coincided with the flushing season in nutmeg. A good amount of success has been reported with forkert method of budding on *M. fragrans* and *M. beddomei* rootstocks by Mathew *et al*. (1984). The buds remained alive even for one year without sprouting. They also reported rainy season (July) as the ideal season for budding.

Manithottam (1994) opined that budding can be done on plants within two to five years of planting. In Kerala, July-August months were reported to be the best for budding. Budding can also be done on plants grown in pots and polybags when they are 18 months and above.

Beena (1994) reported forkert method as the best method of budding on new sprouts of nutmeg for top working as well as on hard trunk. She could get cent percent initial success with budding on three year old plants. July was observed to be the best season for budding and maximum success was obtained with buds selected from brown bud wood with fallen leaves. She has stressed the need for adjusting the size of bud patch in nutmeg. According to her, the relative size of the bud patch is to be slightly smaller than the patch made on the rootstock.

2.5.2 Bud grafting methods in other tree crops

Green budding of rubber was first developed in North Borneo (Hurov, 1961). For this only the buds from the leaf axils of the terminal and the two preceeding whorls of leaves of a shoot, as well as the scale buds, could be used without any significant difference in budding success or in rate of emergence and growth of scion (Gener, 1966; Samaranayake and Gunaratne, 1977; Leong and Yoon, 1979). Ooi *et al.* (1976) reported 90 per cent success in this method. Sena Gomes (1984) tried brown and green budding in the field and nursery and found that field budding on brown tissue gave the best results. Young budding on two month old seedlings of rubber and cutting back after one month gave only 48 per cent survival (Gan and Chew, 1988). In rubber, brown budding was done on seedling stocks of similar age and size as that of the bud sticks. Shoots having the bark turning from green to brown was used as scion. Brown budding is the popular method done earlier in the field or in the nursery for the production of budded stumps (Webster and Baulkwill, 1989).

In cashew, Phadnis *et al.* (1971) reported that budding was more successful on one year or older seedlings than grafting. But Ferraz *et al.* (1974) have opined that patch budding on eight month old seedlings gave the best results. Palaniswamy and Hameed (1976) reported 71 per cent success with patch budding and they observed that the bud sprouting was early and plants grew vigorously. However, Nagabhushanam and Rao (1977) could get only very low success when seedlings of 15 to 20 days and six month old were used for patch budding in cashew. They later (1985) reported success with patch budding when done on six month and one year old seedlings during the months of April to June. Valsa akumari *et al.* (1985) reported the best season for patch budding as May - June and September - October. Under Vittal conditions, patch budding cashew *in situ* gave better results as compared to that in polybags (Nagabhushanam, 1985). According to Rao (1985), patch budding gave the best result with 41 per cent success among different methods of budding tried under Bapatla conditions, while, Palaniswamy *et al.* (1985) reported 75 per cent success in patch budding during July at Vriddhachalam. Gowda and Melanta (1988) reported patch budding to be better than other methods of budding tried in cashew.

In cocoa, Magalhaes (1974) opined shield budding to be successful with an initial success of 60 per cent, but the final survival when field planted was only 40 per cent. With modified forkert budding, 90 to 100 per cent success was reported in cocoa by Giesberger and Coster (1977). Kumaran and Nair (1982) also obtained the best bud take (60 to 73 per cent) with modified forkert method of budding. Subsequent attempts yielded 90 to 95 per cent success with this method. Another budding trial in cocoa with shield and inverted 'T' methods of budding, yielded 52 to 92 per cent bud take when the budded seedlings were arched and kept under a polyethylene tunnel until bud take (Kadje and Ndjama, 1982). Kesavachandran and Nair (1985) could obtain 60 per cent success with forkert budding on eight and nine month old seedlings. With green budding highest success (100 per cent) was obtained for the forkert method on three month old seedlings. Relatively low success rate (35 per cent) for patch budding has been reported by Nagabhushanam and Nair (1988). They obtained highest success percentage in June.

In mango, preliminary trials on budding at Kodur showed that shield budding gave highest success in comparison to the other six different methods tried (Naik, 1941). However, Singh and Srivastava (1962) observed forkert method to be more ideal for budding mango seedlings.

In guava, Srivastava (1962) observed that both forkert and patch budding methods gave complete bud take and also found that the plants propagated by forkert method grew better than those by the patch method. Chandra (1965) also reported forkert budding to be better than shield or patch budding in guava. According to Singh *et al*. (1978) the bud take was highest (69 per cent) with patch budding during April - May.

In Jack (*Artocarpus heterophyllus*), Singh *et al*. (1982) reported the highest take (90 per cent) with patch budding during June - July. Konhar *et al*. (1990) in their trials with different budding methods and seasons, also obtained the highest budding success (80 per cent) with patch budding during July - August. Kelaskar *et al*. (1990) in their trials to study the effect of container size and *in situ* budding on success and growth of patch bud grafts in jack obtained a linear increase in success and growth of bud grafts with an increase in size of polyethylene bags. They also obtained the highest per cent of sprouting (80.00 per cent) and survival (78.6 per cent) with *in situ* budding.

The success of patch budding over the other methods has also been reported in other crops like aonla (Keskar *et al.* 1991) and tamarind (Pathak *et al.*, 1992). This method is recommended for large scale multiplication in tamarind.

2.5.3 Successful methods other than budding in nutmeg

In addition to budding, air layering and inarching have been attempted in various parts of the world with different degrees of success.

In India, inarching or approach grafting was successfully done on rootstocks of *M. fragrans*, *M. malabarica* and *M. beddomei* (Sundararaj and Varadarajan, 1956). Trials conducted at Kallar and Burliar in Tamil Nadu during 1954 have shown that the months of May, June and July recorded a take of 60 to 100 per cent when inarching was done on *M. malabarica*, *M. beddomei* and *M. fragrans*. Successful top working of male parents with shoots collected from female trees as scion material has been reported by Kannan (1973). Shanmugavelu and Rao (1977) also reported 60 to 100 per cent success in approach grafting in all the three rootstocks, *M. malabarica, M. beddomei* and *M. fragrans*. Sriram (1977) reported 60 to 100 per cent success by inaching during May - July and January - March using the same rootstocks. Rasalam (1978) claimed 100 per cent success in approach grafting on seedlings of cultivated and wild species of nutmeg. When erect branches of female nutmeg trees were used as the scion, flowering commenced in the second year after grafting. Mathew (1979) obtained successful take using one and half to two year old rootstock for approach grafting (95 per cent). But for side grafting eight to twelve month old seedling and nine month old scion was most suited and best season was found to be July. Wedge grafting done on one year old seedlings as rootstock gave maximum success during March.

Epicotyl grafting in nutmeg using *M. beddomei* and *M. malabarica* as rootstocks has been reported (CPCRI, 1981, Mathew and Joseph, 1982). Cleft grafting using leafy scions gave 48 per cent and 40 per cent take with *M. beddomei* and *M. malabarica* respectively. Chellappan and Roche (1982) reported that for clonal propagation of nutmeg, a combination of *M. fragrans* on its own rootstock was found successful.

Mathew and Joseph (1982) in their trials on epicotyl grafting observed that rootstock of first leaf stage having a thick stem (diameter of 0.4 cm or more) with sufficient length to give a cut of 5.0 cm long and the scions collected from the female plants having a stem diameter of 0.3 to 0.5 cm gave more success. Krishnamoorthy and Mathew (1985) reported that large scale multiplication of *M. fragrans* could easily and successfully be carried out by epicotyl grafting on the same rootstock. Beena (1994) reported that for success of top working the male trees by cleft grafting in sprouts emerging on beheaded trees, the scion shoots should have mature leaf with full green stem and stock plants of two months age. Success was observed only during March.

2.6 Effect of physical treatments and factors on bud take and sprouting

Among the different methods tried for activating the scion buds in mango, Jauhari and Singh (1970) reported beneficial effect of lopping the stock one week after budding and using white polyethylene for wrapping the bud portion. They also reported the beneficial effect of seasoning the bud wood, two weeks prior to budding.

Anadoliev (1971) reported a rapid method of apricot and plum plant production on Myrobalan seedling root stocks. After eight to ten days of budding, the root stocks were bend over, so that scion buds were on top and 20 to 25 days after budding they were cut back to one to two cm above the union. In rose, stumping the root stock a month after budding stimulated early scion growth in autumn and the following spring (Estcourt, 1974).

The relationship between rootstock nutrition and successful bud union in chest nut has been reported by Izaki *et al.* (1973). The percentage of successful union was higher in the well fertilised plots. Mathew (1985) reported that in nutmeg, after budding, defoliation, decapitation, notching or stimulation with liquid manure failed to induce orthotropy in the case of plagiotropic shoots. Bending the rootstock at the budded portion however induced the rise of orthotropic shoots at the base of previously plagiotropic growth. In cocoa, bending the rootstock by pegging the top to the ground before budding, had a significant effect on the length and diameter of bud sprouts and on the number of leaves, but not on bud burst (Subronto and Hutomo, 1987).

Gan and Chew (1988) on their trials with young budding in rubber demonstrated the value of fertiliser treatment to enhance growth of young buddings. High fertiliser concentration at the time of scion bud sprouting caused severe die back.

Siagian and Sunarwidi (1988) studied the effect of root stock leaf conditions on the success of *Hevea* budding. Root stocks were budded at three stages of leaf development, flushing, expanding and fully expanded leaves. There was no effect of root stock leaf condition on these parameters and budding could be carried out at any of the three stages, the success rate being 80-92 per cent.

In a study on shoot initiation of *Eucalyptus ficifolia* from the lower trunk of mature trees, Salmom (1990) observed that girdling had no effect on bud break.

Beena (1994) reported that for successful bud union in nutmeg, the bud should be placed in the bud patch leaving space on all four sides. She also reported that physical and chemical treatments tried to induce bud break, were ineffective.

2.7 Effect of chemical treatments on bud take and sprouting

Parups (1971) reported that on green house grown roses 0.5 per cent 6 benzyl amino purine (BA) and 0.5 per cent adenine in lanolin could cause bud break and shoot development in 34 to 60 per cent of the treated buds.

Boswell and Storey (1974) could obtain induced sprouting of axillary buds on 42 to 50 per cent of Macadamia seedlings sprayed weekly one to four times with 6 (benzyl amino) -9-(tetrahydropranyl) - 9 H purine (PBA) at 250 to 1000 ppm with the apex either removed or intact.

Application of BA to quiescent buds on single leader citrus plants increased the percentage of buds initiating active growth (Nauer and Boswell, 1981).

Kathiravetpillai and Kulasegaram (1981) in their trials to activate axillary shoots of tea reported that IAA (0.5 per cent) in lanolin applied to decapitated stumps and BA (50-250 ppm) induced the plants to remain active and produce more and longer shoots. However IAA suppressed the production of side shoots.

Jaafar (1982) observed that the bud patches of budded stumps of rubber sprayed with BA (2,000 ppm) or dikegulac - Sodium (2,000 ppm) showed that former induced more bud emergence than dikegulac - Sodium but later this trend was reversed.

In walnut grafts, GA at 250 ppm followed by urea at 0.5 per cent gave good shoot growth of 50.8 cm and 47.9 m respectively (Joshi *et al.*, 1986).

Hushny *et al.* (1986) studied the effect of 0 to 6,000 ppm IBA and 0 to 60 ppm GA_3 on bud sprouting and growth of budded stumps in Hevea. They observed that IBA increased the sprouting percentage of the buds, plant height, stem diameter and root numbers, while GA_3 increased the sprouting percentage of the buds and plant height alone.

In cocoa bud grafting, application of growth regulators (Kinetin, ethrel, GA or IBA) did not have a significant effect on the scion (ICS 60) bud length, number of leaves and bud diameter, but it had a highly significant positive effect on the per cent of bud burst, especially IBA at 100 ppm (Subronto and Hutomo, 1987).

Salmon (1990) investigated the effect of BA treatments (0.06, 0.12, 0.4, 0.6 and 1.2 per cent in 0.5 moles of HCl) on shoot initiation of *Eucalyptus ficifolia* from the lower trunk of mature trees. All BA treatments except 0.06 per cent solution induced some bud activity. The per cent of bud break was highest (70) with 1.2 per cent BA.

Halim *et al.* (1990) reported that buds of orange cv. valencia budded on rootstock of *Poncirus trifoliata* remain dormant for variable periods. The results of soaking in the buds in solution before budding killed some buds, especially when GA_3 was used. Under moist conditions, BA promoted earlier bud burst.

Wiebel *et al.* (1992) studied the influence of applied growth regulators (GA_3, GA_4, GA_{4+7}, BA, NAA and GA_{4+7} + BA) on bud dormancy and growth of one to three year old mangosteen seedlings and four year old orchard trees. All treatments with gibberellin were effective in over coming bud dormancy when applied directly on bud. GA_{4+7} + BA gave the best results (100 per cent bud break within a week) on both branched and unbranched seedlings.

Beena (1994) tried physical and chemical treatments in nutmeg bud grafts to force the bud to sprout (stumping, half ringing, full ringing, urea 0.5 per cent, dimethyl sulphoxide 5 and 10 per cent). None of the treatments were effective in inducing bud burst. However, dimethyl sulphoxide (5 per cent) was found to be the best which helped in the retention of viability for a longer period (7 months).

2.8 Anatomy of wood and bud union

The important stages involved in the formation of a successful union after graftage are

i) Close cambial contact between the stock and scion.

ii) The outer exposed layers of cells in the cambial region of both scion and stock, the parenchymatous cells which soon intermingles and interlock, this is commonly called as callus tissue.

iii) Certain cells of the newly formed callus tissue which are in line with the cambial layer of the intact scion differentiate into new cambium cells.

iv) These new cambium cells produce new vascular tissue, xylem towards the inside and phloem towards the outside (Hartmann and Kester, 1989).

Very few attempts have been reported on the anatomy of nutmeg. Garrat (1933) based on the nature of the secondary xylem suggested that Myristicaceae was closely related with Lauraceae and observed that the tanniferous tubes present in the medullary rays provided a diagnostic feature for the family.

Beena (1994) made detailed study on the anatomy of mature stem of nutmeg plants. Transverse sections from seedling stem revealed a comparatively wide pith which is parenchymatous. In the secondary xylem, solitary or occasional groups of two to three multiple vessels were found arranged in radial rows. Closely spaced uniserial homogenous rays often plugged with gummy infilteration separated by two to three rows of fibre tissues could be traced. A distinct cambial zone and many small tanniferous cells, sieve tubes and companion cells constituted secondary phloem. Most of the cells in the secondary xylem except those adjacent to the cambium were lignified, vessels are often plugged with tylosis. Profuse occurrence of tannin containing vessels is a remarkable feature of the anatomy of this species.

She had attempted budding for top working the male nutmeg trees and had studied the anatomy of the bud union. Low callus development, sparse differentiation of vascular tissues in the bud shield, presence of necrotic tissues hindering the formation of callus and lack of union between old and new callus have been described as the probable reasons for bud failure (Beena, 1994).

The anatomy of bud union has been described in detail in various other crops. Mendel (1936) carried out anatomical studies of the bud union in citrus. The six stages described in the healing of T-bud union in citrus were stage 1 (24 hours) cell division, stage 2 (5 days) callus bridge, stage 3 (10 days) differentiation in the callus of bark flaps and callus of shield, stage 4 (5 days) occurrence of xylem tracheids in the callus of shield, stage 5 (25-30 days) lignification of callus completed in the bark flaps, stage 6 (30-40 days) lignification of callus completed in the bark flaps and in the bark shield. Callus formation began in all the tissues adjacent to wound. Lignification occurred gradually in the course of differentiation.

In walnut different stages of bud union was reported by Nedev (1969). Grafted buds began to form callus in 5 to 10 days. In those buds the isolation layer (a deep brown line) began to be reabsorbed in some places in the first few days after budding. Vascular elements began to form 20 to 25 days after budding. The differentiation of scar tissues was most active close to the two sides of the bud shield and the vascular tissue differentiated more slowly inside the callus and complete union was obtained in 60 to 65 days.

Wagner (1969) reported that in Malus, with in 15 minutes of the bud being set the grafted material had developed a necrotic plate of material released from mechanically ruptured cells. Callus parenchyma cells began to develop from the root stock xylem rays after two days and broke through the plate after four days. Callus cells from the scion similarly ruptured the necrotic region but at this stage there was no cytoplasmic connection between the root stock and scion.

The developmental pattern of graft union in douglas-fir has been reported by Copes (1969). According to him, the union was complete within 17 days after grafting.

Soule (1971) made detailed study on bud union of chip budded mango stocks. He observed four stages in the formation of bud union. They were: pre-callus stage (within 4 days after budding), callus stage (within 8 days), cambial bridge stage (12 days after budding) and the healed union stage (6 to 8 months). Vascular differentiation was observed within 36 to 48 days and it took 6 to 8 months for complete healing of bud union.

Soule (1971) studied graft union of 'Langra' var. of mango. Subsequent to inarching, he observed excessive growth of parenchymatous tissue between stock and scion, distortion of xylem elements and blockage of vessels. These features seriously hindered lateral transfer of water from stock to scion. In transverse and radial sections of chip buds he observed excessive callus development and impregnation of large areas of tissue by wound gum. This was found more frequent in cambial layers which were not in close alignment and in tissues which were crushed or otherwise damaged to a depth of several layers of cells adjascent to the cut ends.

Chakrabarthi and Sadhu (1985) are of the opinion that there are three main stages of union for splice grafting in mango. The graft union was complete within 60 days.

Jose (1989) found four distinct stages in the formation of graft union in jack. Proper graft union was obtained 90 days after the grafting operation, callus proliferation was mostly from the pith cells.

Materials and Methods

3. MATERIALS AND METHODS

The present study was conducted at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during the period 1993-94. The nutmeg grafts, seedlings and mature trees available at College of Horticulture, Vellanikkara and State Seed Farm, Mannuthy were utilised for the study. The weather data for the period under study is given in Appendix-I..

Two experiments were conducted so as to induce orthotrops in vegetatively propagated nutmeg plants. One experiment consisted of using orthotrops as scion part and the other consisted of inducing orthotrops on young grafted plants which were otherwise growing as plagiotrops.

The methodology followed in each experiment is described below.

3.1 Standardisation of budding

The age and type of rootstock, season and method of budding were the main factors considered in this study. A minimum number of thirty plants with ten plants each under three replications were utilised under each treatment.

3.1.1 Type of rootstock

The trial was conducted to find out the most suitable rootstock for budding *Myristica fragrans*. Two types of rootstocks were used

i) *Myristica fragrans*

ii) *Myristica beddomei* (wild nutmeg)

3.1.2 Age of rootstock

The objective of this experiment was to obtain the optimum age of rootstock for budding. Nutmeg seedlings of age group one, two and three years were used for this purpose. Seedlings of one and two year old were grown in polythene bags of size 20 x 12 cm and 58 x 28 cm respectively filled with potting mixture. Three year old *Myristica fragrans* rootstocks planted in the coconut garden as an intercrop were used as rootstock and *in situ* budding was done.

The rootstocks maintained in polythene bags were given proper care and maintanence by providing partial shade and irrigation. For obtaining vigorous growth, groundnut cake was applied at the rate of 50 g per bag. Three year old plants used as rootstock for *in situ* budding were maintained as per Package of Practices (KAU, 1993).

3.1.3 Collection of bud wood

The buds were taken from the orthotropic shoots at the brown bark stage, matching the size of root stock from selected high yielding, healthy, female trees of *Myristica fragrans*. Only viable buds with a visible bud core inside were used for budding. The bud sticks collected were used either on the same day or on the next day.

3.1.4 Methods of budding

Three methods of budding were tried to identify the ideal one for nutmeg.

i) T budding

ii) Patch budding

iii) Forkert budding

The methods adopted are depicted in figure 1.

3.1.4.1 T budding

A transverse incision of about 3 to 4 cm was made on the root stock. A small slit of about 1 to 1.5 cm was given on the upper end of the incision to make a T-like appearance. The bud patch was inserted in the T-like slit of the stock. The budded portion was carefully wrapped with polythene tape.

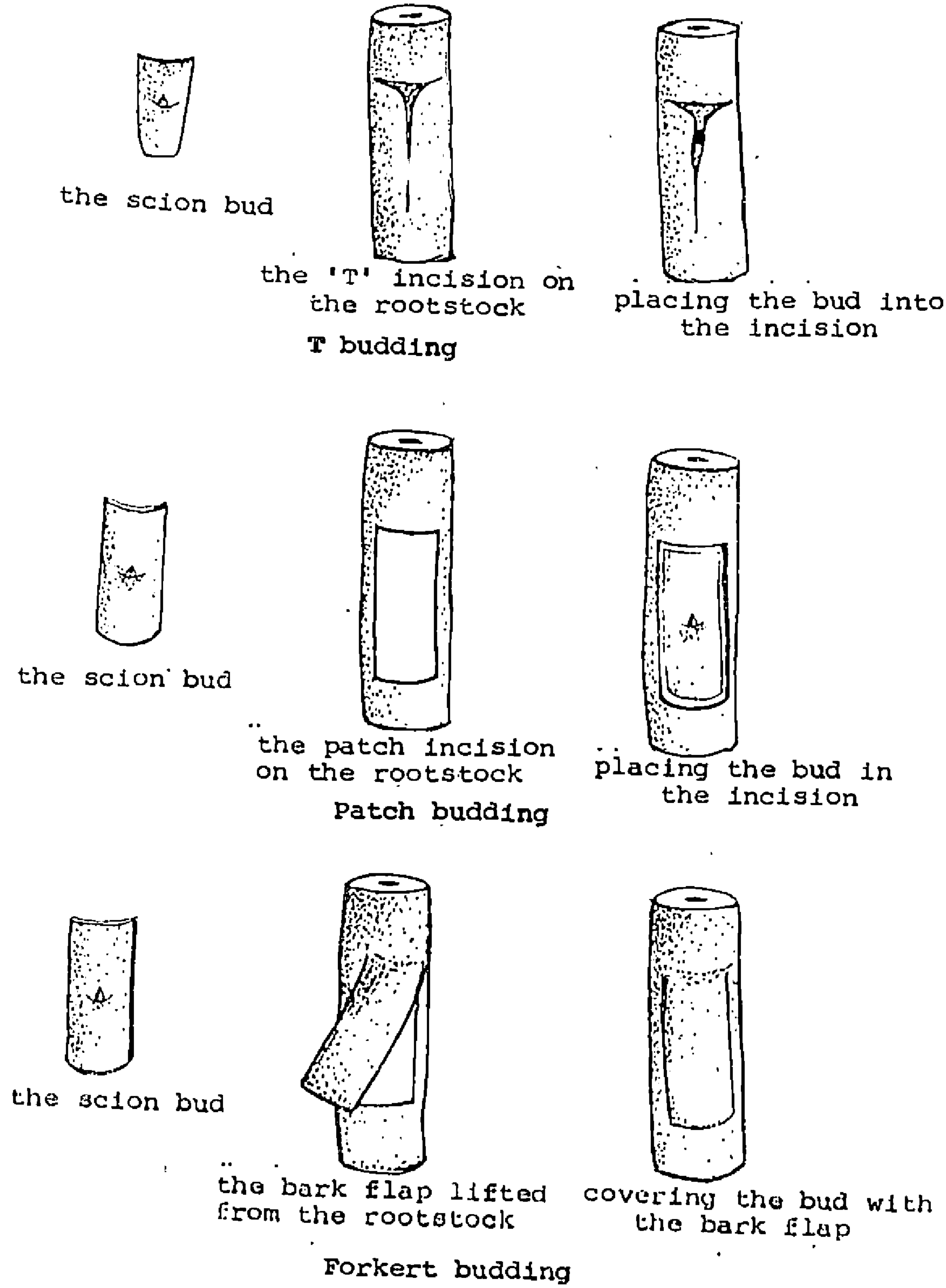


Fig. 1. Budding methods

3.1.4.2 Patch budding

A rectangular patch of about 3 to 6 cm length and 1 to 3 cm width was marked on root stock according to its girth. From the budwood, a bud patch was removed by cutting a rectangular patch and inserted into the stock. Then budded portion was wrapped and tied carefully with polythene tape.

3.1.4.3 Forkert budding

A transverse incision of 1 to 3 cm was made in the bark of root stock. Two parallel cuts of 3 to 6 cm starting from the two ends of the transverse incision were made upwards and the bark was carefully peeled to form a flap. The bud patch was inserted into the slit made on the root stock and the bark flap brought back to position so that it covers the bud patch. The whole portion was tightly wrapped and tied with polythene tape.

In situ budding was attempted on three year old nutmeg plants (two years after field planting) interplanted in a coconut garden (Plate 1). Budding was tried above or below the whorl of lower leaves so as to study the effect of retention of leaves on bud take. In the case of one and two year old seedlings, budding was done in the brown bark at a height of about 15 cm from the soil level.

Plate 1. *In situ* budded three year old nutmeg plant

In all the methods tried, the bark was slightly peeled to test whether it is in the bark slipping stage. The root stocks and scion at the bark slipping stage only were used for budding. The area selected for budding on rootstock was scraped to remove the loose bark and dust. The scion was also treated in the same way. Incisions were made on the bark of root stock and bud stick with a sharp knife according to the method of budding. The bud patch was carefully lifted out of the bud stick and was handled with care to avoid interference with dust or water particles. The bark on rootstock was carefully peeled out and the bud patch was inserted immediately into the slit on the stock. Bud patch was smaller (0.2 mm less on all four sides) than the incision made on rootstock so that when inserted, some space was left on all the four sides (Plate 2).

The bud was inserted with care observing its polarity and was wrapped immediately with polythene tape.

3.1.5 Treatments given to bud patch

Observations made 21 days after budding showed browning and blackening at bud union in many cases. Suspecting phenolic interference different treatments were tried to enhance bud union.

Plate 2. A patch budded nutmeg stock with the scion dimensions slightly smaller than the incisions on the stock

T_1 The sap oozing out from the incisions on the root-stock was wiped off with tissue paper and the bud patch was given a pulse dip in NAA (0.5 ppm) solution, drained on a tissue paper and inserted into the root stock.

T_2 The sap oozing out from the root stock was wiped off with tissue paper and the bud patch was washed in distilled water, drained on a tissue paper and inserted into the root stock.

T_3 Control - Bud patch directly inserted into the root stock without any treatment.

3.1.6 Season of budding

To identify the best season, budding was done during the period August 93 to August 94 in polybag plants and November 93 to August 94 in field plants.

3.1.7 Conditions provided after budding

The budded plants were maintained in a mist chamber (except for field grown seedlings) and in partial shade to find out the best condition for obtaining maximum success. In the mist chamber, regular water sprays during morning and evening hours were given to maintain high humidity. The temperature inside the mist chamber recorded a range of 35 to 40°C and that under partial shade 26 to

$29^{\circ}C$. The humidity inside the mist chamber ranged from 90 to 95 per cent and that under partial shade 60 to 80 per cent.

3.1.8 Observations recorded

The polythene wrap was removed from the budded plants after one month. The bud was examined for initial success by light scratching with the tip of knife. The retention of green colour indicated success and this was expressed as initial success percentage.

The plants showing initial success were stumped above the bud union one week after assuring bud take by three different methods to study the effect of retention of leaves on sprouting of buds. The methods of stumping are the following.

(i) Stumping the rootstock above the bud union retaining a whorl of leaves below the bud union.

(ii) Stumping the rootstock retaining a whorl of leaves above the bud union.

(iii) Stumping the rootstock without retaining any leaves at all.

The plants were observed for sprouting and later performance.

3.1.9 Anatomical study of bud union

The anatomical changes contributing to bud take and bud sprouting were studied by observing the microtome sections of the relevant parts from budded plants that showed bud take and bud failure.

Stem pieces of three to four cm length accomodating the bud patch were taken for anatomical studies of bud union. Five samples were selected each for bud take and bud failure. Immediately after collection, the samples were processed and preserved as per the procedure described by Cutler (1978).

Fresh stem pieces were used as sample and uniform sections of 40 μ thickness were taken using 'Reichert Sliding Microtome' as per standard microtomy suggested for hardwood (Cutler, 1978). The schedule prescribed by Johansen (1940) was followed for fixing and staining the sections.

Sections
↓
70% alcoholic safranin (5-10 minutes)
↓
80% alcohol (2 minutes)
↓
90% alcohol (2 minutes)
↓
95% alcohol (1 minute)
↓
Absolute alcohol (1 minute)
↓
Pure xylene (1 minute)
↓
Mounted using DPX mountant
↓
Microscopic examination

3.2 Induction of orthotrops

3.2.1 Induction of orthotrops on mature trees

3.2.1.1 Pruning

This trial was conducted with the objective of studying the effect of different physical treatments on the induction of orthotrops in mature trees. Bearing nutmeg trees at the State Seed Farm, Mannuthy were utilised for this study. Plagiotropic and orthotropic branches of three to four years growth and about 10 to 15 cm girth were selected and the following physical treatments were tried -

i) Pruning of plagiotropic branch close to the tree trunk leaving a stump of 30 cm (T_1)

ii) Pruning of plagiotropic branch 150 cm away from the tree trunk (T_2)

iii) Pruning the tip of plagiotropic branch (T_3)

iv) Bending the plagiotropic branch and pegging it to the ground (T_4)

v) Pruning orthotropic branch close to the tree trunk leaving a stump of 30 cm (T_5)

The pruned portions were immediately dressed with a paste of Bavistin. At the time of pruning the main branch, the existing secondary and tertiary shoots were removed in all the above treatments, except in T_3.

3.2.1.2 Staking

The experiment was done to study the effect of staking in converting plagiotropic shoots to orthotropic shoots. Nutmeg shoots of three age groups were utilised for the study. They are mature shoots of two to three years age, immature brown shoots of one to two years age and young green shoots of less than six months. The shoots were staked using long wooden poles so as to support the plagiotropic shoots upto the tip (Plate 3).

Plate 3. A plagiotropic shoot staked on a wooden pole

Response to pruning was observed for a period of five months and the nature of shoots produced were recorded.

3.2.2 Induction of orthotrops in nutmeg grats

This trial was conducted to induce orthotrops on nutmeg grafts from plagiotropic shoots. Both physical and chemical treatments were attempted for the purpose. Grafted plants of two age groups were used for the study. Approach grafted plants (6 months old) maintained in polybags and those (3 years) planted in the main field were used. A minimum number of thirty plants with ten plants each under three replications were utilised under each treatment.

3.2.2.1 Physical treatments

The following physical treatments were given

3.2.2.1.1 Bending (M_1)

The main shoot of the graft was bent and pegged to the ground using small bamboo pegs and jute threads. All the sprouts behind the bent portion were removed.

3.2.2.1.2 Snapping (M_2)

Either the main shoot alone or together with one or two side shoots were snapped at a height of 15 to 20 cm from the graft union, but not removed.

3.2.2.1.3 Ringing (M_3)

A ring of bark of size 0.5 cm was removed from the main shoot at a height of 15 to 20 cm from the graft union.

3.2.2.1.4 Notching (M_4)

A 'V' shaped notch of size 0.5 cm was made on the main shoot at a height of 15 to 20 cm from the graft union.

3.2.2.1.5 Stumping (M_5)

The main branch of the graft or selected shoots were stumped at a height of 15 to 20 cm from graft union.

3.2.2.2 Chemical treatments

This experiment was done to find the effect of growth regulators in inducing orthotrops in grafted nutmeg plants.

Preliminary studies were made on current season shoots of mature trees to observe the influence of growth regulators on bud break. Based on the observations, the following treatments were given:

i) Indole acetic acid (IAA) - 10 ppm (S_1)

ii) Gibberellic acid - 10 ppm (S_2)

iii) Kinetin - 5 ppm (S_3)

iv) Control (Water) - (S_4)

The growth regulators at the prescribed concentrations were sprayed on the physically treated grafts at an interval of three months.

3.2.2.3 Observations

Monthly observations were taken for the number and nature of new shoots, shoot length, its girth and number of leaves. Angle of divergence was observed for the staked shoots, three months after imposing the treatment.

3.3 Anatomical studies

Anatomical difference of plagiotropic, orthotropic and staked shoots were studied.

Plagiotropic and orthotropic shoots were collected from three year old seedlings and staked shoots from experiment as detailed in 3.2.1.2. The shoots were marked with marking pen for the adaxial side before separation from the plant. The shoots were then boiled for 10 minutes in distilled water to soften the tissues. Hand sections were taken using sharp razor blades. Sections were stained using 70 per cent alcoholic safranin and microscopically examined.

Results

RESULTS

The results of the experiments done to induce orthotrops in vegetatively propagated nutmeg plants are detailed below.

4.1 Standardisation of budding

Budding was done at monthly intervals for a period of one year from August, 1993 so as to standardise the budding method in nutmeg. Different rootstocks were used for the purpose and bud patches from orthotrops alone were used a scion.

4.1.1 Growth parameters of rootstocks at different ages

The growth parameters of the two types of root-stocks viz., *Myristica fragrans* and *Myristica beddomei* at three ages, viz., one, two and three years are given in Table 1.

The mean plant height recorded for one year old *M. fragrans* was 30.4 cm, while it was 63.3 cm by the third year. The girth at collar region was only 2.66 cm in the first year, while it developed to an average of 4.03 cm by the third year. A substantial increase was also observed for the mean number of leaves in three year old nutmeg plants. On an average, there was only 14 leaves in the first year, while it retained 56 leaves by the third year. However, the rate of growth was observed to be more during the second year. The data indicates 50 per cent increase in plant height, 28 per cent increase in plant girth and 96 per cent increase in the number of leaves for the second year.

Almost the same growth habit was observed for seedlings of *M. beddomei*. The mean plant height for first year was 36.3 cm, while it developed to 68.1 cm in the third year. The mean girth at collar region recorded for three year old plant was 4.59 cm, while the number of leaves retained were only 13.9. The increase in growth parameters was found to be more during the second year. The growth parameters for the rootstocks are graphically represented in Figures 1, 2, 3 and 4.

4.1.2 Effect of age and type of rootstock

The bud take recorded for rootstocks of different age groups is presented in Table 2. The bud take was rather nil in rootstocks of both the species upto two years growth. Success could be obtained only in three year old plants, the success rate being 46 to 100 per cent. Maximum bud take was observed when budding was done on field plants (*in situ* budding) of three years growth (100 per cent). The girth at collar region recorded for such

Table 1. Growth parameters of polybagged rootstocks at different ages

Sl. No.	Type of rootstock	Plant height (cm)			Girth at 1 cm height (cm)			Number of leaves		
		1 year	2 year	3 year	1 year	2 year	3 year	1 year	2 year	3 year
1	*Myristica fragrans*	30.40	60.35	63.30	2.66	3.74	4.03	13.50	32.90	55.80
2	*Myristica beddomei*	36.30	59.60	68.10	3.21	3.95	4.59	7.10	7.70	13.90

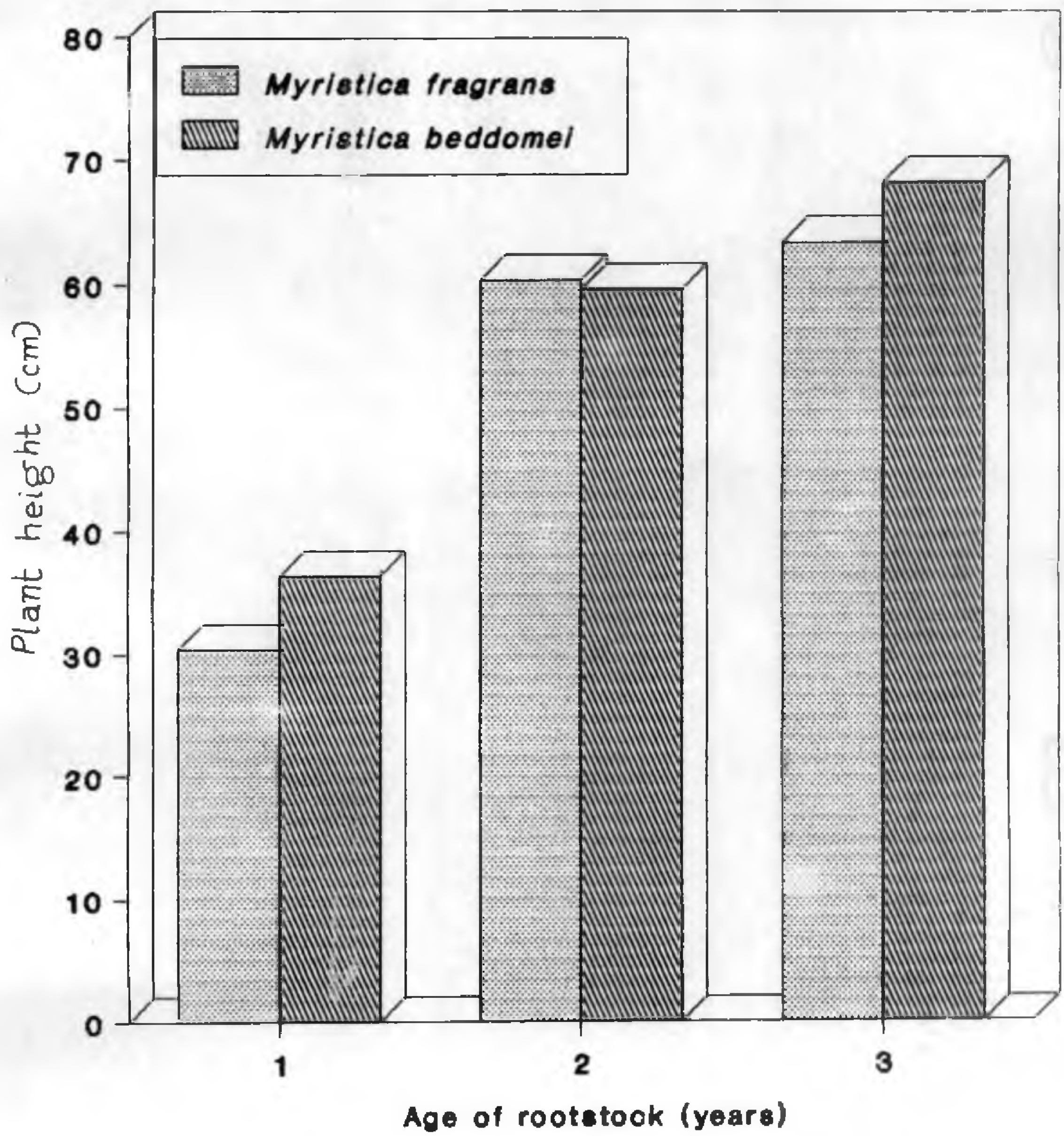


Fig. 2 Comparison of plant height for rootstocks at different ages

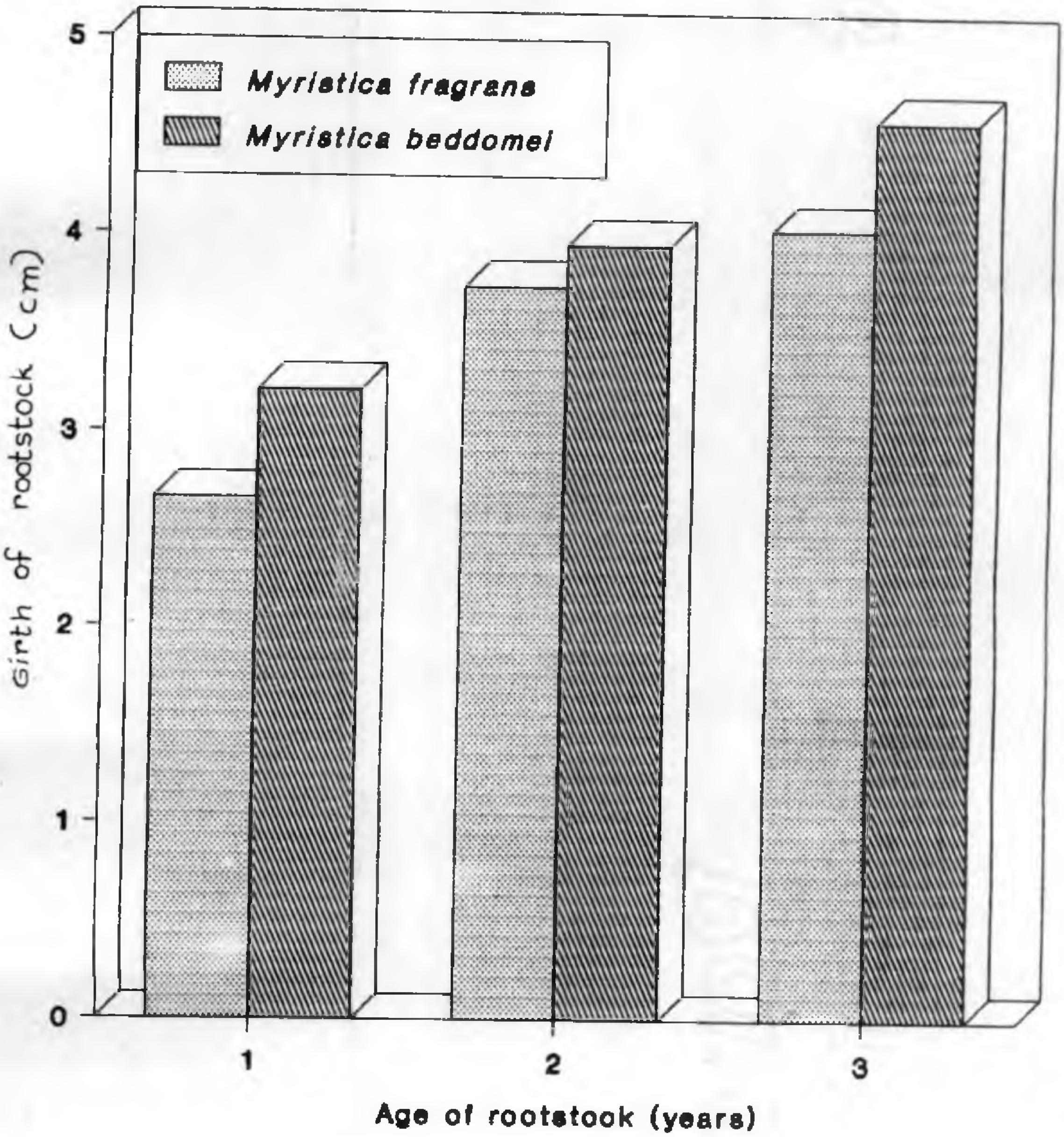


Fig. 3 Comparison of girth for root-stocks at different ages

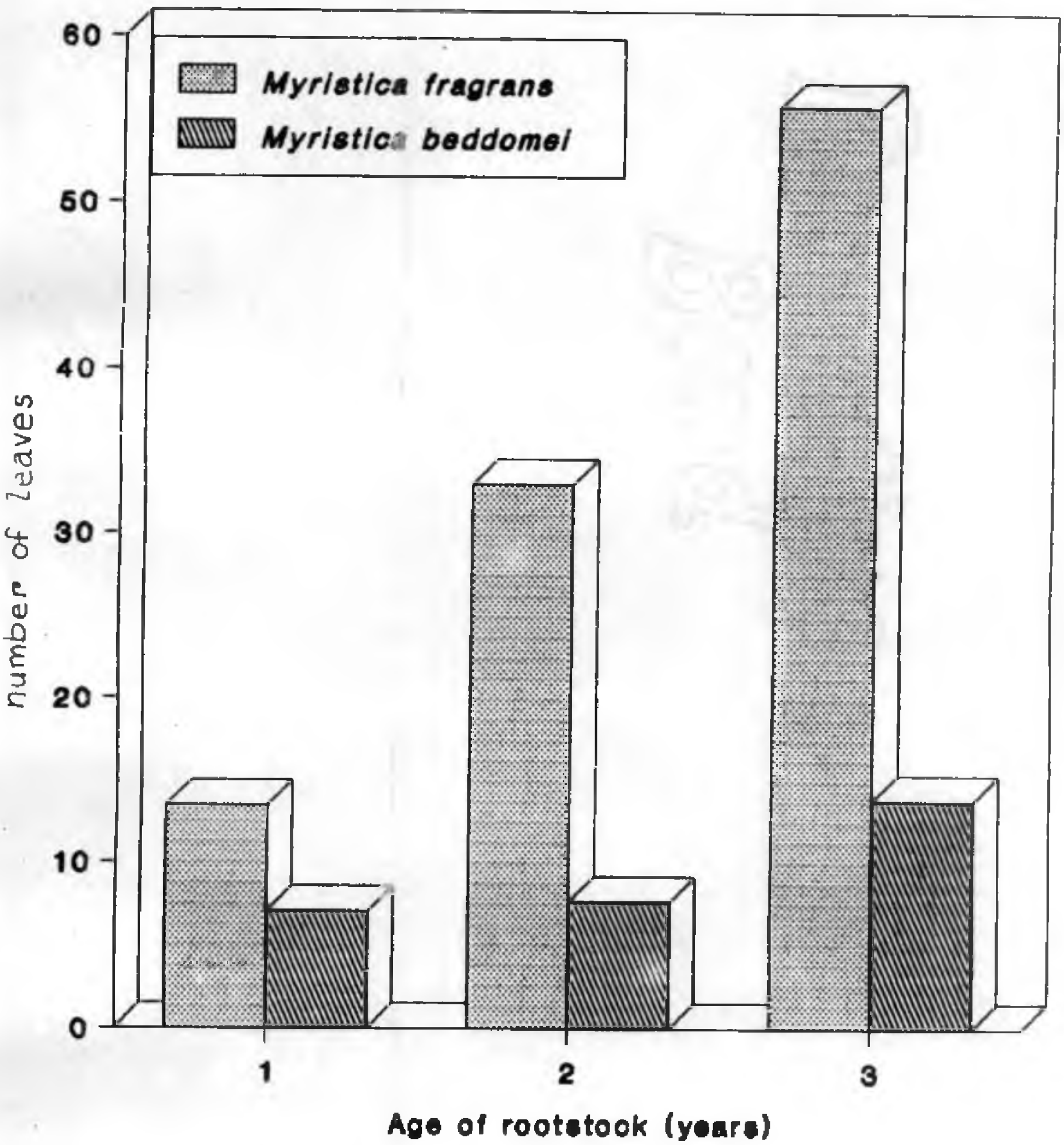


Fig. 4 Comparison of number of leaves for rootstocks at different ages

Table 2. Effect of different types and ages of root on budding

Type of rootstock	Age of rootstock (years)	Girth (cm)	Max percentage initial success
Myristica fragrans			
a) Polybag plants	One	2.55	Nil
	Two	3.75	Nil
	Three	4.03	53.85
b) Field plants	Three	5.80	100.00
Myristica beddomei			
a) Polybag plants	One	3.21	Nil
	Two	3.95	Nil
	Three	4.59	46.15

plants was 5.8 cm. when the root stocks were retained as polybag plants, *M. fragrans* recorded a better bud take (53.85 per cent) than *M. beddomei* (46.15 per cent).

4.1.3 Effect of method of budding

The data on initial success of budding for the three different methods tried, viz. Patch, Forkert and T budding are presented in Table 3. In *M. fragrans* as root stock, patch method gave an initial success of 25.0 per cent, whereas forkert method gave 32.25 per cent. In *M. beddomei*, patch method and forkert method gave an initial success of 26.31 and 23.81 per cent respectively. In both the root stocks, T budding gave no success at all.

Chi-square test was done to compare the influence of methods of budding on initial success. Both patch and forkert budding were found ideal for nutmeg and there was no significant difference among the two methods for initial bud take.

4.1.4 Effect of season of budding

The percentage initial success obtained during different months, ie., from August 1993 to August 1994 are presented in Table 4. In field plants (*in situ* budding), nearly 87 per cent success was obtained during November 1993, with the results still improving and touching cent per cent success in August 1994. Three year old polybag

Table 3. Effect of different methods of buddingin 3 year old rootstocks

Sl. No.	Type of rootstock	Method of budding	Percentage of success (mean)
1	*Myristica fragrans*		
		a) Patch	25.00
		b) Forkert	32.35
		c) T	0
2	*Myristica beddomei*		
		a) Patch	26.31
		b) Forkert	23.81
		c) T	0

Calculated value of chi-square to compare the method of budding, for patch budding = 0.05^{NS} and for forkert budding = 0.41^{NS}

NS - Non significant

Table 4. Effect of season on budding

Sl. No.	Month	Percentage initial success			
		1 year polybag plants	2 year polybag plants	3rd year	
				Polybag plants	Field plants
1	1993 August	0	0	0	ND
2	" September	0	0	0	ND
3	" October	0	0	0	ND
4	" November	0	0	ND	86.66
5	1994 April	0	0	0	0
6	" May	0	0	0	ND
7	" June	0	0	0	8.00
8	" July	0	0	50.00	50.00
9	" August	0	0	31.57	100.00

ND - Not done

plants when used as root stocks, recorded a maximum bud take (50 per cent) in the month of July. It was 32 per cent in the month of August and the result was less encouraging with no bud take in the rest of the months. The bud take was rather nil throughout the year when polybag plants of one and two year old were used as root stocks.

4.1.5 Bud take and later establishment

Bud take and later establishment in three year old rootstocks is presented in Table 5. *In situ* budding in field plants of *M. fragrans* (Plate 4) recorded better mean initial success of 44 per cent. Budding when done on poly bag plants, both *M. fragrans* and *M. beddomei* gave a mean initial success of 25.33 per cent. *In situ* budding recorded a maximum initial success of cent per cent in the month of August, while it was only 50 per cent for polybag plants in the month of July.

Normal healthy sprouts with orthotropic growth pattern emerged out of the *in situ* budded scion with in two months after bud take (Plate 5).

Mean percentage of sprouting was better (55.0 per cent) in the *in situ* budded plants of *M. fragrans* and a maximum sprouting of 84.61 per cent was obtained for plants budded during November 1993. Sprouting was not

Plate 4. *In situ* budded field grown plant showing bud take

Plate 5. Normal healthy orthotropic sprout emerging out of the *in situ* budded scion

Table 5. Bud take and later establishment in three year old rootstocks

Sl. No.	Metho of budding	Girth of rootstock (cm)	Percentage initial success		Percentage sprouting	
			Mean	Max.	Mean	Max.
1	*In situ* budding in field plants	5.80	44.00	100.00	55.00	84.61
2	Budding in poly-bag plants	4.31	25.33	50.00	Nil	Nil

Calculated value of chi-square to test the independence of initial success with

budding = 0.0062 ^{NS}

NS - Non significant

observed in any of the budded plants maintained in the polybags.

The Chi-Square test to ascertain the dependence of initial success revealed that there exists no significant difference in bud take for polybag plants and field plants. However, the bud sprouting and later establishment were significantly higher in *in situ* budding.

4.1.6 Effect of bud patch treatment

Washing the bud patch to make it free of phenolic exudates or treating with growth regulator solution to enhance callusing did not favour bud take in nutmeg, rather, such treatments were found to adversely affect the bud union (Table 6).

4.1.7 Effect of stumping method on sprouting of buds

The results on the effect of leaf retention at the time of stumping on sprouting of buds are presented in Table 7. When stumping was done retaining a lower whorl of leaves below the bud union, cent per cent sprouting and later survival was obtained. When a whorl of leaves were retained above the bud union, the percentage sprouting was only 66.66 per cent and all the sprouted shoots survived later. When no leaves were retained in the root stock, sprouting percentage was reduced to 60.0 per cent and the

Table 6. Effect of bud patch treatment

Sl. No.	Bud patch treatment	Percentage initial success
1	T_1	Nil
2	T_2	Nil
3	T_3 (Control)	86.66

T_1: The sap oozing out from incision made on rootstock was wiped with tissue paper and bud patch was given a pulse dip in NAA ().5 ppm) solution, drained and inserted into the rootstock

T_2: The sap oozing out from rootstock was wiped off with tissue paper and bud patch was washed in distilled water, drained and inserted into the rootstock

T_3: Bud ptach directly inserted into the rootstock with out any treatment given to both

Table 7. Effect of leaf retention at the time of stumping on sprouting of buds

Sl. No.	Methods of stumping	Percentage sprouting	Percentage survival recorded after three months
1	Leaves retained below the bud union	100.00	100.00
2	Leaves retained above the bud union	66.66	100.00
3	Leaves not retained in rootstock	60.00	33.33

Plate 6. Sprouted bud in the root stock which is stumped above the union retaining lower whorl of leaves

survival was further reduced to 33.33 per cent.

4.1.8 Effect of conditions provided after budding

Conditions provided after budding was found critical in determining the bud take. Maintaining the budded plants under partial shade was found to be better than the mist chamber condition provided under the study. Bud take was rather nil under the artificial conditions provided (Table 8).

4.1.9 Growth parameters of bud sprouts

The growth parameters viz., percentage of buds sprouted, height, girth, number of total leaves, new leaves and the number of side shoots recorded during the first six months after bud take are presented in Table 9.

Sprouting was complete with in two months after bud take. The average length of shoots recorded from the third month after bud take, increased from 4.55 cm to 25.32 cm with a standard deviation of 2.42 to 8.84 cm by the sixth month. During the same period, the girth of the sprouts recorded a three fold increase. Within six months after bud take, the shoot developed on an average 45.27 healthy leaves with a standard deviation of 26.66, whereas the average number of new leaves produced during the sixth month was 13.73. The peculiar pattern of branching of

Table 8. Effect of conditions provided after budding

Sl. No.	Conditions provided	Percentage of initial success
1	Mist chamber	8.70
2	Partial shade	25.33

Table 9. Growth parameters of bud sprouts in *in situ* budding

Sl. No.	Growth parameters	Period after bud take (months)					
		1	2	3	4	5	6
1	Percentage of buds sprouted	63.64	36.36				
2	Height (cm)	-	-	4.55 (2.42)	18.45 (6.90)	21.48 (6.89)	25.32 (8.84)
3	Girth (cm)	-	-	1.07 (0.15)	2.38 (0.27)	2.80 (0.81)	3.27 (0.45)
4	Total number of leaves	-	-	1.27 (1.42)	17.82 (14.67)	31.73 (19.87)	45.27 (26.66)
5	Number of new leaves	-	-	1.27 (1.42)	16.46 (14.27)	14.36 (13.79)	13.73 (8.98)
6	Number of side shoots	-	-	-	4.36 (2.36)	4.28 (2.70)	5.72 (2.73)

Values in parantheses indicate standard deviation orthotrops was observed by the fourth month after bud take. On an average, six side shoots were produced in the first tier by the sixth month. The growth parameters of sprouts are graphically represented in Figure 5.

Vigorous growth pattern was observed for the scion shoot. With in one year it attained the girth almost equal to that of the stock. The canopy spread was also found ideal as compared to that of a seedling plant of same age (Plate 7a and 7b).

4.1.10 Anatomy of the bud union

The earliest stage at which the bud components could be handled without separation was seven days after budding. The following sequence of union could be noticed when the budded nutmeg plants were examined anatomically at the budded portion.

Seven days after budding, the stock and scion were found to lie in close contact at certain regions only (Plate 8). Close examination of such regions revealed the presence of cambial cells in both stock and scion. A brown necrotic line could be noticed at the point of contact of the components. After 14 days, a close alingment of the stock and scion could be observed with the necrotic line still lying in between the components. Callus cells were found to proliferate from both the stock and scion side. A

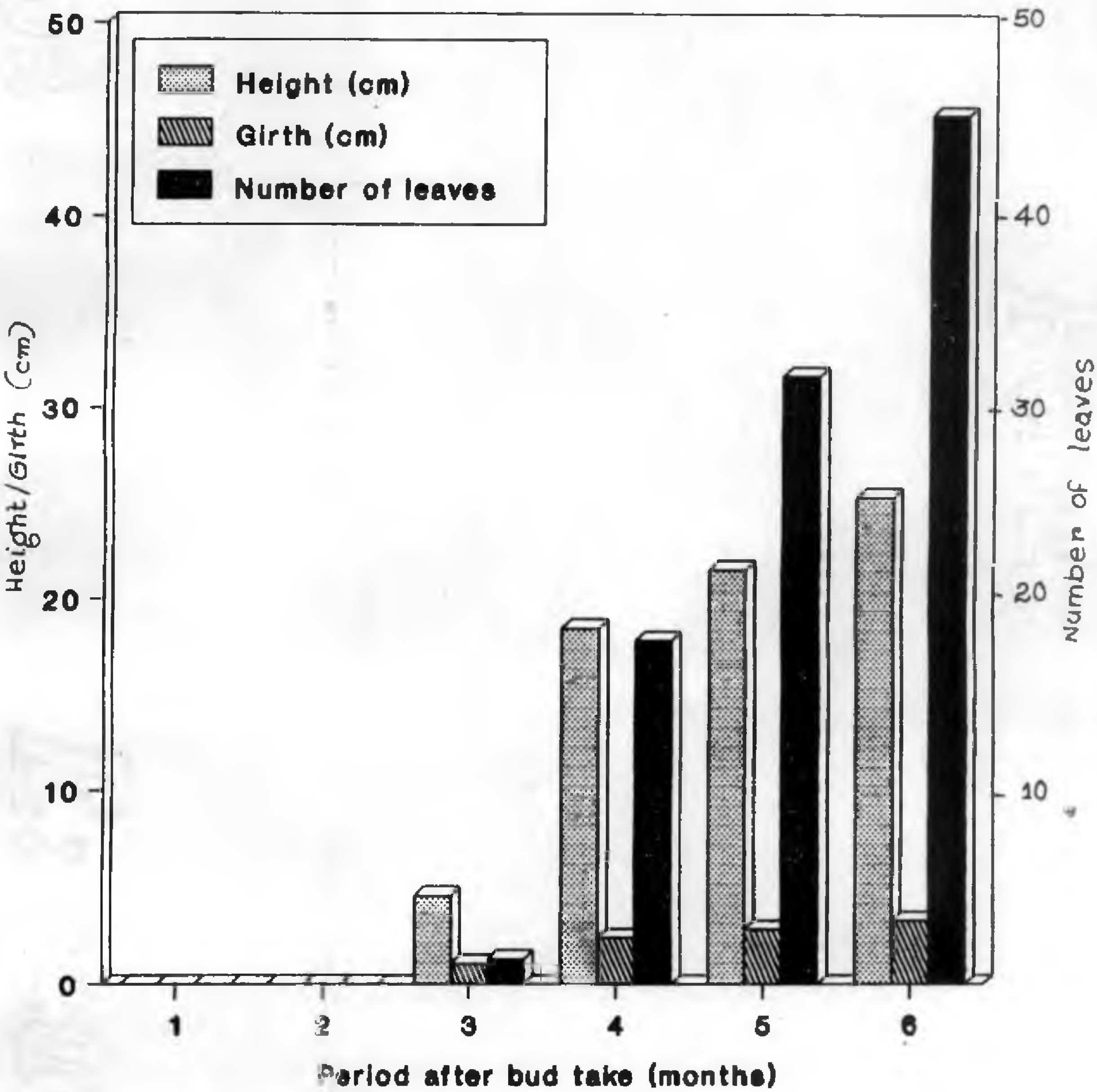


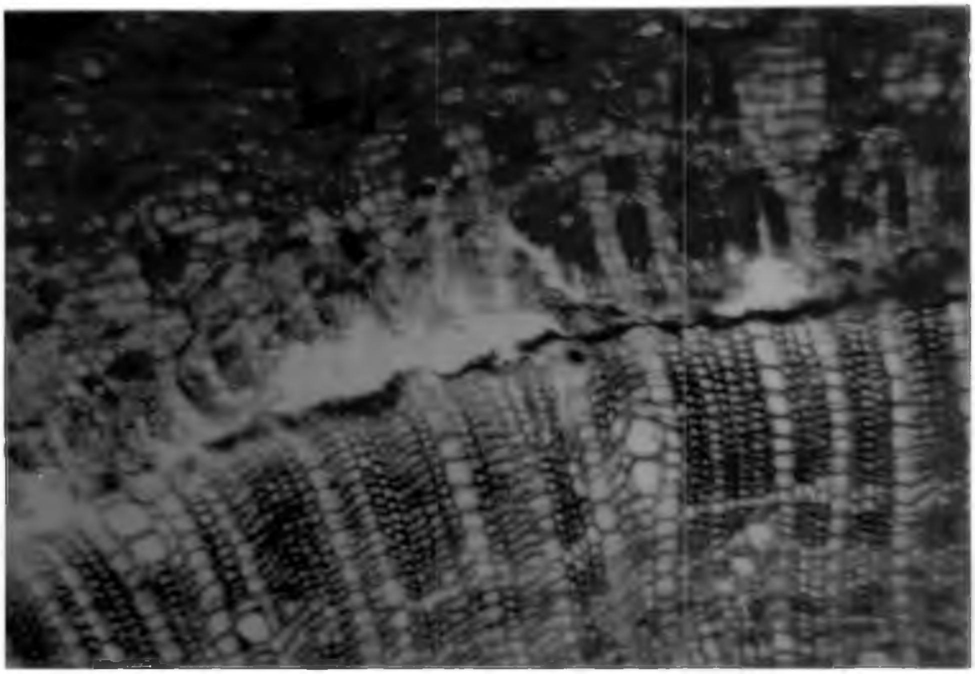
Fig. 5 Growth parameters of bud sprouts in *in situ* budding

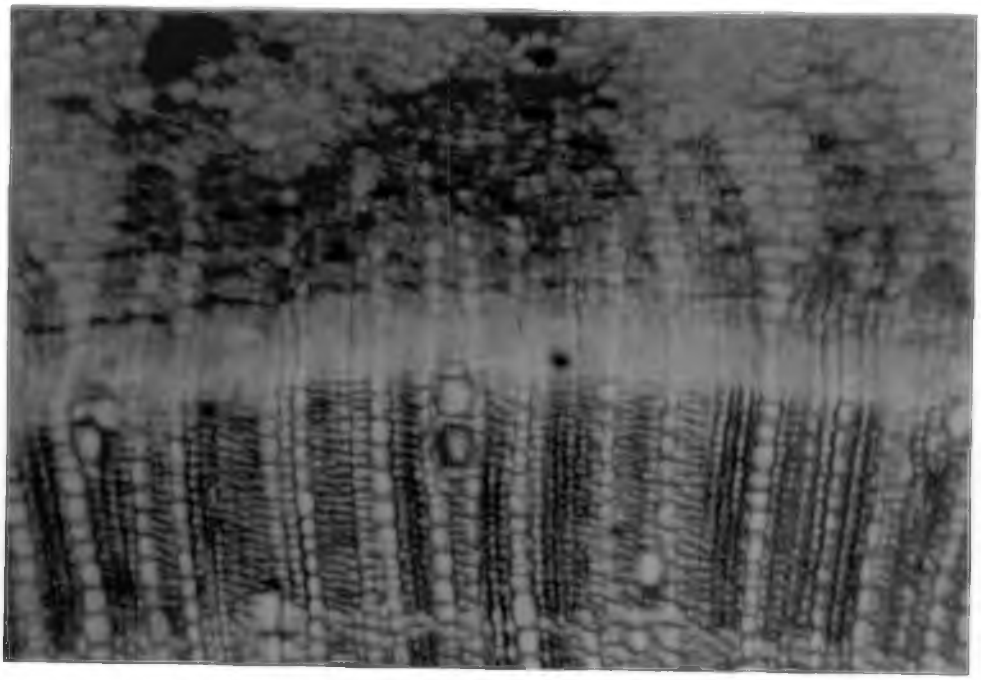
Plate 7a. *In situ* budded plant showing vigorous growth pattern as that of the nutmeg seedling of the same age

Plate 7b. Nutmeg seedling planted in the field

Plate 8. Bud union 7 days after budding
Note the phenol layer and gap between stock and scion

Plate 9. Establishment of callus bridge between stock and scion





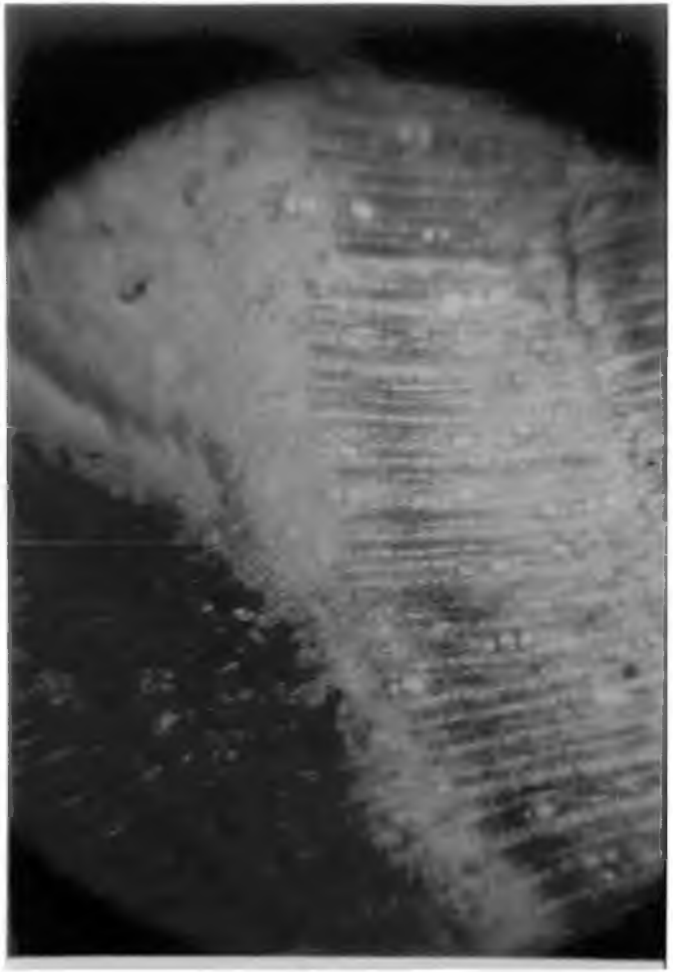
callus bridge establishment between the stock and scion ensured the bud take in nutmeg (Plate 9). This stage was noticed 21 days after budding. The necrotic line was fully absorbed at this stage. The bud union was again anatomically examined six months after budding. Development of a new cambium in line with the original cambial layer of scion and stock could be noticed (Plate 10). The new cambial layer differentiated new secondary xylem towards inside and secondary phloem towards outside thus establishing vascular connection between the stock and scion.

4.1.11 Failure of bud union

The budded seedlings showing no bud take were also anatomically examined to study the reasons for failure. It was observed that callusing was absent in the stock or scion or both. Thick necrotic layer was also observed at the bud union (Plate 11). In some samples, callusing was noticed from only the rootstocks (Plate 12). A wide gap could also be noticed between stock and scion (Plate 13). Close examination of such bud failures revealed the absence of cambium in either stock or scion. Union was observed in certain regions where cambial layers were present in the stock and scion.

Plate 10. Development of new cambial layer at the stock-scion union

Plate 11. Development of necrotic layer at the bud union



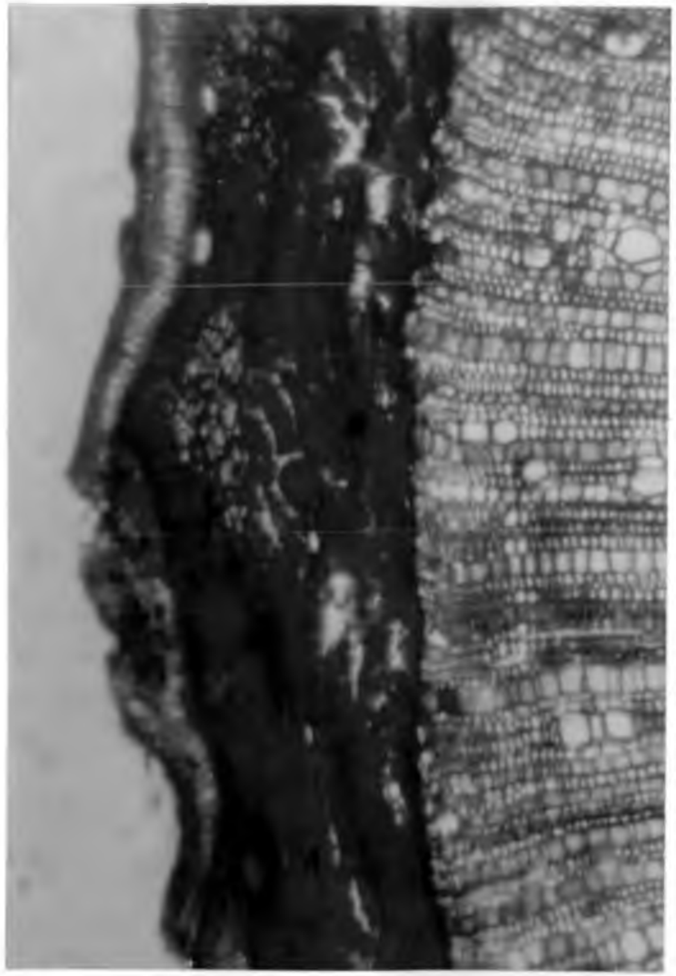
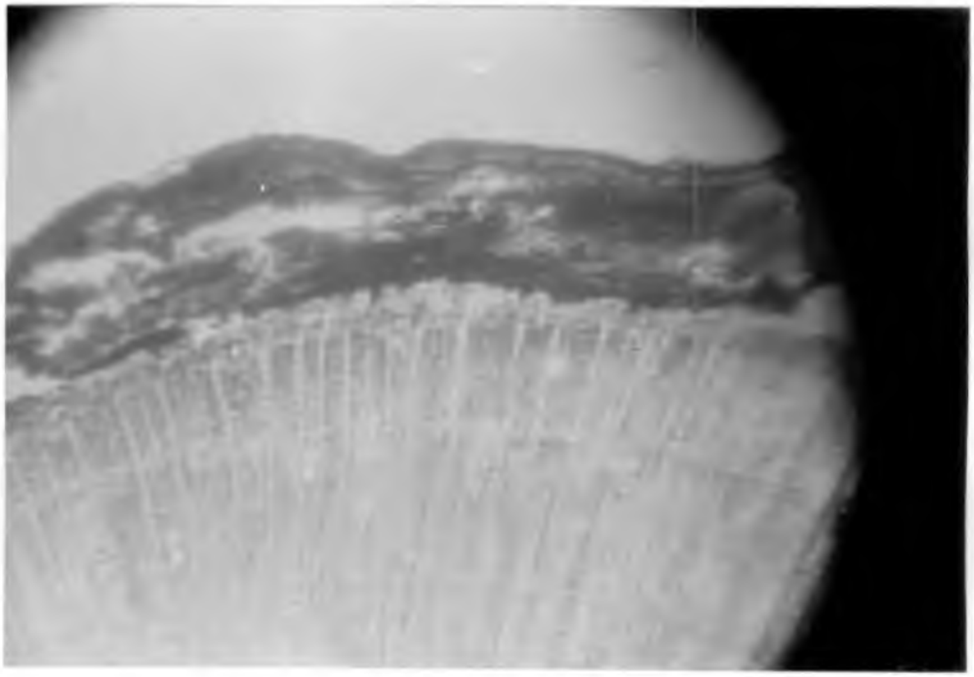
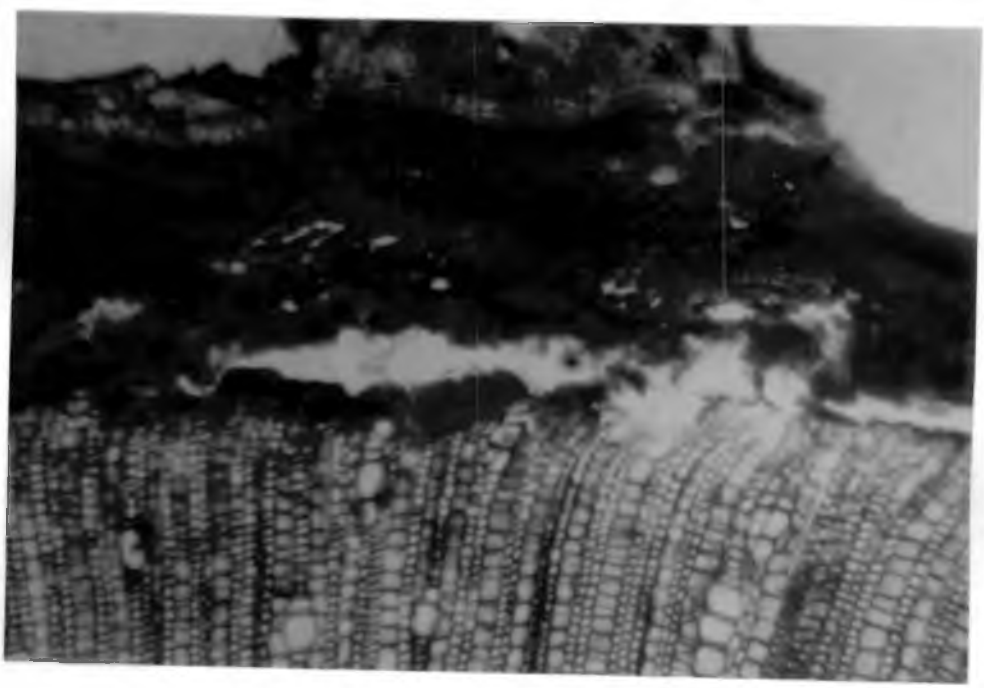


Plate 12. Development of callus only from the rootstock

Plate 13. Wide gap between the stock and scion





4.2 Induction of orthotrops

4.2.1 Effect of physical treatments on induction of orthotrops on field grown plants

4.2.1.1 Pruning

The results of the pruning experiment done to induce orthotrops on branches of mature trees are presented in Table 10. Among the five physical treatments tried, treatment T_5 (pruning of orthotropic branch close to the trunk leaving a stump of 30 cm) was identified as the best method to induce orthotrops on mature branches of nutmeg trees. In this treatment, pruning could initially induce only few shoots (3 to 5). However, all the shoots produced during this period (within 2 months) were orthotrops. Subsequently, more number of shoots were produced (17), but the frequency of orthotrops was found to be less (88 per cent). Pruning the plagiotrops in a similar fashion could also induce orthotrops (Plate 14), but at a low frequency (23 per cent). It was observed that there was increase in the number of orthotrops induced on a plagiotropic branch (T_1) whereas a decreasing trend was observed for orthotropic branch (T_5). Though treatment T_2 (pruning of plagiotropic branch 150 cm away from the trunk) could induce maximum number of sprouts, none of them happened to be an orthotrop. All the other treatments tried failed to induce orthotrops.

Table 10. Effect of different physical treatments on induction of orthotrops in mature branches of the tree

Sl. No.	Physical treatment	Total number of sprouts after				Percentage orthotropic shoots after			
		2 months	3 months	4 months	6 months	2 months	3 months	4 months	6 month
1	T_1	2	15	20	26	0	13	15	23
2	T_2	19	23	29	32	0	0	0	0
3	T_3	0	5	5	7	0	0	0	0
4	T_4	2	4	5	8	0	0	0	0
5	T_5	3	5	17	17	100	100	88	88

T_1 : Pruning of plagiotropic branch close to the trunk leaving a stump of 30 cm

T_2 : Pruning of plagiotropic branch 150 cm away from the trunk

T_3 : Pruning the tip of plagiotropic branch

T_4 : Bending the plagiotropic branch and pegging it to the ground

T_5 : Pruning of orthotropic branch close to the trunk leaving a stump of 30 cm

Plate 14. The shoots emerging from a mature plagiotropic branch pruned at 30 cm length

Plate 15. A staked nutmeg graft immediately after removal of stake

4.2.1.2 Staking

The results of the staking experiment to induce orthotrops in nutmeg shoots of different age groups, viz., mature shoots of two to three years age, immature brown shoots of one to two years age and young green shoots of less than six months are presented in Table 11. The angle of divergence of staked shoots recorded three months after staking revealed that, the angle of immature brown shoots was reduced from 37.5° to 15° and that of young green shoots from 42° to 14°. For the mature shoots, the divergence was only from 67.5° to 55°, while the angle was again measured one month after removing the stake, the mature shoots were observed to regain their initial angle (67.5°), whereas the immature brown and young green shoots maintained the angle they acquired due to staking. The altered growth pattern after staking of an otherwise plagiotropic nutmeg graft is shown in Plate 15.

4.2.2 Effect of physical treatments on induction of orthotrops in nutmeg grafts

All the five physical treatments tried, viz., bending (M_1), snapping (M_2), ringing (M_3), notching (M_4) and stumping (M_5) failed to induce orthotrops in young nutmeg grafts.

Table 11. Effect of staking on induction of orthotrops

Sl. No.	Nature of treated shoots	Angle of divergence of staked shoots (degree)		
		Initial angle	3 months after staking	1 month after removal of stake
1	Mature shoots of 2-3 years age	67.5	55	67.5
2	Immature brown shoots of 1-2 years	37.5	15	15.0
3	Young green shoots of less than 6 months	42.0	14	14.0

The response of scion shoots to physical treatments at bimonthly intervals is presented in Table 12.

After a period of two months, the treatment stumping M_5, recorded the maximum number of shoots per plant (1.367), followed by bending - M_1 (0.701) and least in ringing - M_3 (0.155). The difference observed among the treatments were found to be significant.

After a period of four months, the treatment M_5, still maintained the highest value (1.707) followed by M_4 (1.243) and least in M_3 (0.975). But the treatments were not significantly different at this stage.

The data collected six months after imposing treatment also showed that stumping is superior, but the difference observed was not significant.

The response of stock and scion to the different physical treatments tried are presented in Table 13.

The grafted plants could not survive many of the treatments tried. The mortality was high for the treatment ringing, M_3 (75%). The percentage survival of grafts in response to the treatments was maximum in bending, M_1 (48.33%), followed by stumping, M_5 (45.00%).

Table 12. Effect of physical treatment on number of shoots per plant

Sl. No.	Months after treatments	Number of shoots per plant					
		Physical treatment					
		M_1	M_2	M_3	M_4	M_5	CD
1	Two	0.701	0.442	0.153	0.680	1.367	0.72
2	Four	1.236	1.181	0.975	1.243	1.707	NS
3	Six	1.673	1.247	0.985	1.418	1.897	NS

NS - Non significant

Table 13. Response of stock and scion to physical treatments (after six months)

Sl. No.	Physical treatments	Stock		Scion		
		Number of additional sprouts per plant	Percentage orthotrops	Percentage survival	Number of additional sprouts per plant	Percentage orthotrops
1	Bending (M_1)	1.00	100	48.33	1.67	0
2	Snapping (M_2	0.90	100	33.33	1.25	0
3	Ringing (M_3)	0.87	100	25.00	0.99	0
4	Notching (M_4)	1.38	100	35.00	1.42	0
5	Stumping (M_5)	1.67	100	45.00	1.90	0

Calculated value of chi-square to compare the different treatments on percentage survival of grafts = 12.24^{NS}

NS - Non significant

The nature of emerging shoots in the treatments stumping, snapping and bending are illustrated in Plates 16, 17 and 18, the new shoots from all the treatments were plagiotrops, however, it was interesting to note the upright orientation of the newly emerged plagiotrops in the treatment bending (Plate 18).

The response of root stocks to physical treatments was also observed. All the treatments tried could induce sprouts from the root stocks and irrespective of the treatments tried, all the shoots induced were orthotrops (Plate 19). As for the scion, stumping, M_5 could induce maximum number of new shoots (1.67 sprouts per plant).

One sample chi-square test was done to compare the different treatments on percentage survival of grafts. The test revealed that the methods differed significantly on percentage survival.

4.2.3 Effect of chemical treatments on induction of orthotrops in nutmeg grafts

The results on the effect of chemical treatment, viz., IAA - 10 ppm (S_1) GA_3 - 10 ppm (S_2), Kinetin - 5 ppm (S_3) and water (S_4 - control) are presented in Table 14. The observations were recorded at bimonthly intervals.

Plate 16. Plagiotrops emerging after stumping treatment

Plate 17. Plagiotrops emerging after snapping treatment

Plate 18. Plagiotrops with upright growth pattern emerging after bending treatment

Plate 19. The orthotropic off-shoots emerging from the rootstock of the approach grafted nutmeg plant

Table 14. Effect of chemical treatments on number of shoots per plant

Sl. No.	Months after treatment	Chemical treatments				CD
		S_1	S_2	S_3	S_4	
1	Two	0.622	0.350	0.933	0.769	0.41
2	Four	1.289	0.917	1.561	1.308	NS
3	Six	1.589	1.089	1.627	1.472	NS

NS - Non significant

After a period of two months, the maximum number of shoots per plant was produced in treatment S_3 (0.933), followed by S_4 (0.769) and the least in S_2 (0.350). The treatments were found to differ significantly.

After four months, the treatment S_3 recorded maximum shoots per plant (1.561), followed by S_4 (1.308) and the least in S_2 (0.917). However, the treatments were not significantly differing from each other.

After six months, the maximum number of shoots per plant were recorded in S_3 (1.627) followed by S_1 (1.589) and the least number in S_2 (1.089). Here again, the treatments were not differing significantly from each other.

4.2.4 Effect of Physical x Chemical treatments on induction of orthotrops in nutmeg grafts

The interaction effect of physical and chemical treatments on the number of shoots per plant during two, four and six months after treatment are presented in Table 15.

After a period of two months, the number of shoots per plant was maximum in M_5S_1 (1.667) followed by M_5S_4 (1.610) and the least in M_3S_1 (0.000). There was no significant difference between the different treatment combinations.

Table 15. Interaction effect of physical and chemical treatments on number of shoots from the scion part

Sl. No.	Treatments	Number of shoots per plant		
		Period after treatment (months)		
		2	4	6
1	M_1S_1	0.777	1.333	2.223
2	M_1S_2	0.333	1.083	1.500
3	M_1S_2	0.943	1.250	1.583
4	M_1S_4	0.750	1.277	1.387
5	M_2S_1	0.000	1.333	1.000
6	M_2S_2	0.167	1.167	1.333
7	M_2S_3	1.000	1.223	1.223
8	M_2S_4	0.600	1.000	1.433
9	M_3S_1	0.333	0.833	0.833
10	M_3S_2	0.000	0.333	0.333
11	M_3S_3	0.167	1.667	1.667
12	M_3S_4	1.110	1.067	1.107
13	M_4S_1	0.333	1.000	1.333
14	M_4S_2	0.333	1.000	1.167
15	M_4S_3	1.278	1.720	1.720
16	M_4S_4	0.777	1.253	1.453
17	M_5S_1	1.667	1.943	2.553
18	M_5S_2	0.917	1.000	1.110
19	M_5S_3	1.277	1.943	1.943
20	M_5S_4	1.610	1.943	1.980
F value		NS	NS	NS

Four months after treatment, M_5S_1, M_5S_3 and M_5S_4 recorded the maximum number of shoots per plant (1.943) and the least in M_3S_2 (0.333). The treatment combinations were at par statistically.

After six months of treatment, the data revealed that the treatment M_5S_1 produced maximum number of shoots per plant (2.553) followed by M_1S_1 (2.223) and the least in M_3S_2 (0.333). However, the treatments were not significantly different.

4.2.5 Anatomy of the stem

The anatomy of the seedling stem was studied in detail.

Transverse section of the seedling stem was studied anatomically. The outer cortex layer consists of a well defined hypodermis and the epidermal layer lined with cuticle. Below the cortex lies four to five layers of cambial cells which are arranged in a ring. The cambial cells cut secondary phloem towards outside in thickness and secondary xylem towards innerside during secondary growth. The secondary phloem consists of many small tanniferous cells, sieve tubes and companion cells. Well defined lignified phloem fibres are noticed. Secondary xylem consists of one or two layers of serially arranged tracheids alternating with a layer of parenchymatous cells. Solitary or occasional groups of two to three multiple vessels were found arranged in radial rows. The parenchymatous cells towards the centre are larger in size and constitute the pith.

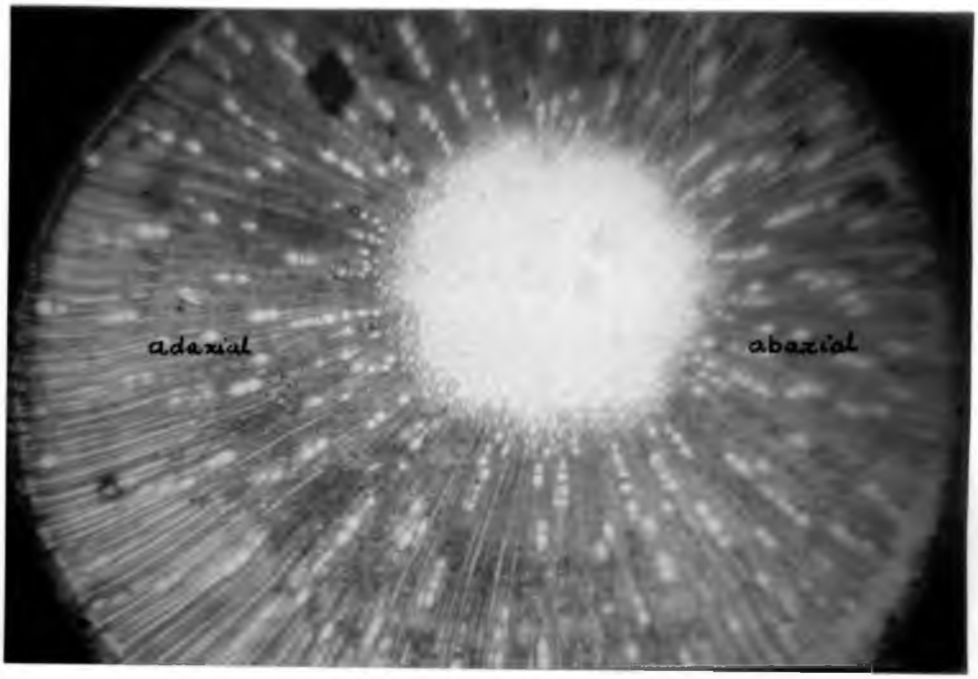
4.2.6 Anatomy of orthotropic and plagiotropic shoots

Two different types of branches namely orthotrops and plagiotrops were examined in detail with respect to their anatomy. It was generally observed that the orthotropic branches have a clear disproportionate development of secondary xylem. The amount of wood formed towards the adaxial side was more than that formed towards the abaxial side (Plate 20).

In the case of plagiotrops, the development of wood was more or less uniform on either side of the branch namely lower (abaxial) and upper (adaxial) (Plate 21). However, in some cases, it was observed that there was a slight disproportion in the development of secondary xylem and a little wood was noticed on lower side. On examining the staked plagiotrops after three months of staking, it was observed that the staked plagiotrops behaved morphologically like the orthotrops. The amount of wood formed towards the adaxial side was comparatively more than that towards the abaxial side as earlier observed for orthotrops (Plate 22).

Plate 20. Anatomy of orthotropic stem showing the development of more wood towards the adaxial side than towards the abaxial side

Plate 21. Anatomy of plagiotropic stem showing the proportionate development of wood on both adaxial and abaxial sides


adaxial
abaxial

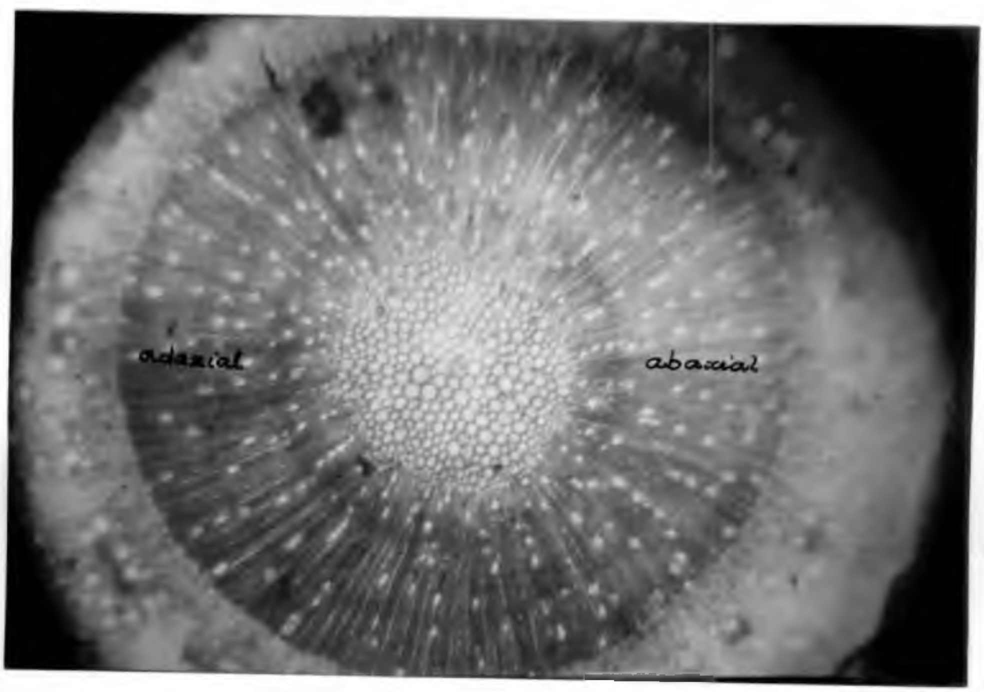
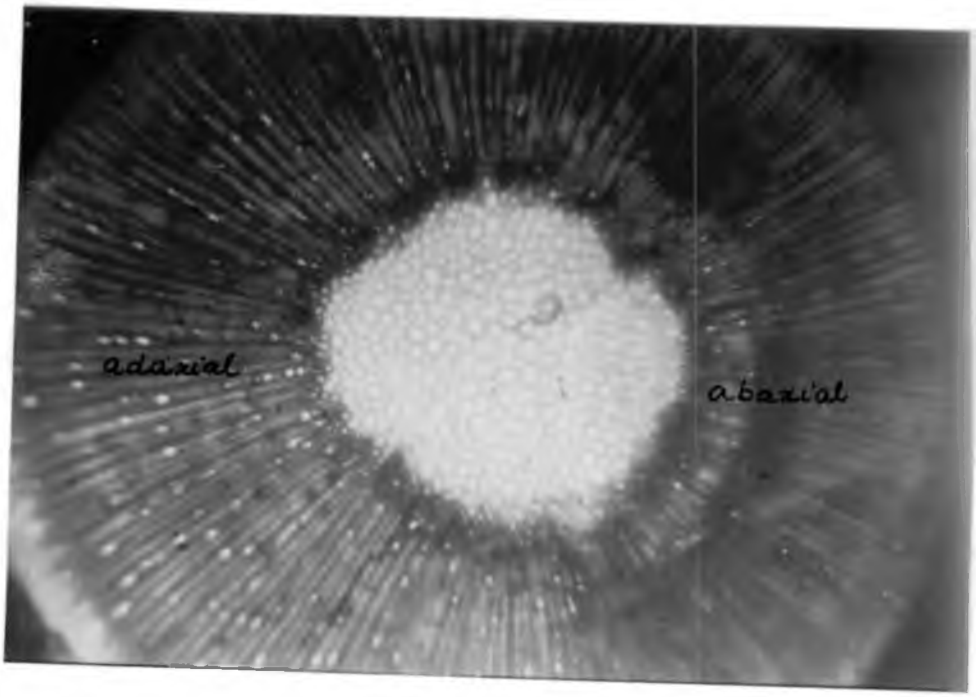

adaxial
abaxial

Plate 22. Anatomy of staked shoot showing development of more wood towards adaxial side than towards the abaxial side.



adaxial
abaxial

Discussion

DISCUSSION

The main problem facing the nutmeg (*Myristica fragrans* Houtt.) cultivation at present is the seggregation of seedlings into male and female in 1:1 ratio resulting in 50 per cent of unproductive male trees. At present, reliable methods are not available to determine the sex at seedling stage. While undertaking nutmeg cultivation on plantation basis, it is uneconomic for the farmers to maintain the unproductive trees upto four to five years in the field. Vegetative propagation has distinct advantage to overcome this problem. Though inarching is a popular method for vegetative propagation in nutmeg, due to the dimorphic branching system of the tree, scion taken from plagiotropic shoots give rise to plants having a squatty nature and low yield. Orthotropic shoots when used as scion results in erect plants with high yield. However, the availability of orthotropic shoots is limited in nutmeg.

The present study was undertaken to simultaneously solve the three main problems facing nutmeg cultivation namely, dioecy, long juvenile phase and dimorphic pattern of growth. Investigations were made to standardise the method of budding in nutmeg and to induce orthotrops in nutmeg grafts which are otherwise having plagiotropic growth pattern.

5.1 Standardisation of budding

The budding methods viz., Patch, Forkert and T budding were tried on two different rootstocks, *Myristica fragrans* and *M. beddomei* of one, two and three years age during different months of the years.

Observations on growth parameters of the rootstocks revealed that the rate of growth of plants were more during the second year for both types (Table 1). However, maximum girth was recorded for the three year old field plants (5.8 cm). Better performance of field palnts as compared to polybag plants of same age could be due to the availability of better surface area for root development. Shallow spreading nature of roots in nutmeg has been referred by Flach (1966) and Joseph (1980). Very limited success has been reported earlier for budding in nutmeg with different rootstocks like *M. fragrans, M. argentia* and *M. beddomei* (Flach, 1966; Mathew and Joseph, 1979; Mathew, 1979). However, a good amount of success has been reported recently with forkert method of budding on *M. fragrans* and *M. beddomei* rootstocks (Mathew *et al.*, 1984; Beena, 1994).

5.1.2 Effect of age and type of rootstock on budding

The results indicated that the bud take is rather nil in rootstocks of both the species upto two years age. However, three year old field plants of *M. fragrans* showed a maximum success rate of cent per cent. At the same time, relatively low success was recorded for the polybag plants of *M. fragrans* (53.85%) and *M. beddomei* (46.15%) of the same age. Girth of the rootstock could be a critical factor in determining the success rate of budding in nutmeg. Field plants recorded a girth of 5.8 cm, while polybag plants of *M. fragrans* and *M. beddomei* recorded 4.03 and 4.59 cm respectively. Nutmeg plants could be budded successfully when they attain atleast three years age with a stem diameter of not less than 4.0 cm. The effect of stem diameter of rootstock on bud take has been reported earlier by Lundstand (1973) in *Rosa canina*. He observed that greatest per cent of bud take was obtained for rootstock with the largest (8 to 12 mm) stem diameter. Similarly, Pandey and Srivastava (1974) obtained the greatest survival, final height and diameter of budded plants of peach, plum and apricot on the thickest rootstock.

ng done in polybag plants. The superiority of *in situ* budding over nursery budding has also been reported in other crops like rubber (Sena Gomes, 1984), cashew (Nagabhushanam,1985) and jack (Kelaskar *et al.*, 1990). Luxurient growth of the field plants than the polybag plants would have contributed to the higher success rate. Nutmeg is a shallow rooted plant with spreading roots. The growth may be restricted in the case of polybag plants whereas the roots of field plants can forage large areas for nutrients. In jack, Kelaskar *et al.* (1990) found that there was a linear increase in success and growth of bud grafts with an increase in size of polythene bags. They also observed the highest per cent of sprouting and survival with *in situ* budding.

In nutmeg, Manithottam (1994) opined that budding can be done on plants within two to five years of planting. Beena (1994) in her attempt to topwork the nutmeg trees reported cent per cent success with budding on three year old nutmeg plants.

5.1.3 Effect of method and season of budding

Among the budding methods tried over different months, forkert budding recorded the maximum mean bud take

(32.25%) in *M. fragrans*, while it was patch budding (26.31%) in *M. beddomei*. However, no significant difference was observed between the two methods for initial bud take. T budding did not give any success at all in both the rootstocks at all the stages of growth. In T budding, chances of dripping water sweeping down the trunk to enter into the slit causing decay and failure of bud may be high. In both patch and forkert methods of budding, the dripping water is allowed to drain out resulting in good bud take. Another reason could be that, the rate of callusing from the exposed tissue in the rootstock is rather low in the case of T budding as compared to the other methods tried. The results obtained while studying the anatomy of bud union further confirms this statment. The callusing rate was found to be rather low in nutmeg. Thus both patch and forkert methods of budding was found ideal in nutmeg. A good amount of success has been reported with forkert method of budding on *M. fragrans* and *M. beddomei* rootstocks by Mathew *et al.* (1984). Manithottam (1994) reported patch budding to be more successful than other methods in nutmeg, while Beena (1994) obtained high success with forkert budding on new sprouts for top working as well as on hard trunk. In other tree crops like cocoa (Kesavachandran and Nair, 1985), mango (Singh and Srivastava, 1962) and guava (Srivastava, 1962; Chandra, 1965), high rate of bud take has been reported with forkert budding. At the same time, superiority of patch budding over other budding methods has been reported in tree crops like cashew (Ferrez *et al.*, 1974; Palaniswamy and Hameed, 1976; Valsalakumari *et al.*, 1985; Nagabhushanam 1985; Rao, 1985; Palaniswamy *et al.*, 1985; Gowda and Melanta, 1988), jack (Singh *et al.*, 1982; Konhar *et al.*, 1980), aonla (Keskar *et al.*, 1991) and tamarind (Pathak *et al.*, 1992). Little damage to the cambial layer and better callusing can be expected in both patch and forkert budding and this would have helped to increase the success rate.

The *in situ* budded field plants recorded maximum bud take (100%) in the month of August, followed by November (87%). Three year old polybag plants recorded maximum bud take during the month of July (50%) followed by August (32%) (Table 4).

In the humid tropical climate of Kerala, rainy season was found ideal for budding nutmeg. Vegetative propagation methods generally yields higher success during rainy season in many other crops also. The high success rate obtained during these months can be attributed to the active growth stage of stock and scion, increased sap flow and favourable climatic conditions favouring a fast and easy union. In nutmeg, Mathew *et al.* (1984), Beena (1994) reported maximum bud take during the month of July. Manithottam (1994) has opined that under Kerala conditions, July-August months are the best for budding. In other crops like cashew (Palaniswamy *et al.*, 1985) and jack (Singh *et al.*, 1982; Konhar *et al.*, 1990) rainy season has been reported to be the best for budding. High atmospheric humidity prevent desiccation of buds. Warm and humid climatic conditions and active growth of stock plant in June-July might have helped the union of stock and scion in nutmeg. The total rainfall recorded for the months of July and August were 1002.1 and 509.2 mm. They also recorded a high relative humidity of 91 and 85 per cent respectively (Appendix I).

Although no significant difference was observed with respect to bud take between polybag plants and field plants, a higher sprouting percentage (84.61%) was recorded for *in situ* budded field plants (Table 5). The polybag plants failed to show any sprouting at all although they remained green for a long period. Poor sprouting after bud take has also been reported by Mathew (1979) in nutmeg. She observed that none of the buds survived when taken out of the mist condition artificially provided. Thus it is observed that nutmeg seedlings having three years growth and a collar girth of minimum 4.0 cm could give good bud take. However, the sprouting was very poor in those rootstocks maintained in polybags (Table 5). It is worthwhile here to recollect the growth performance of rootstocks maintained in polybags. Maximum growth rate was observed for two year old seedlings (Table 1), i.e., subsequent to their transfer to large sized polybags of 58 x 28 cm size. In the third year, while the budding was done on these plants, the growth rate was considerably low. However, the plants managed to attain the minimum collar girth for budding. The poor growth rate in the third year might be reflecting the low vigour and food reserves in the stock plant. Hence, eventhough there was good bud take due to normal girthing, the stock plants maintained in polybags were not capable to make the 'taken buds' sprout.

The treatments given to enhance callusing and to make the bud free of phenolic exudates did not favour bud take in nutmeg. Washing the buds with NAA or sterile water was found to damage the buds. When the bud patch is peeled off from the scion and when bark is lifted from the rootstock, a few layers of cambial cells are retained with both scion and stock. Close cambial contact between the stock and scion was described as the initial stage in a successful union during graftage (Hartmann and Kester, 1989). Thus in nutmeg, the bud patch as well as the wound on rootstock should be handled with utmost care so that the cambial cells are not damaged by hand nails, knife tip, dust or water particles. Occurrence of large number of tanniferous vessels is reported as a remarkable feature in the bark of nutmeg by Beena (1994). Hence the cell sap oozing from the wounded cells at the time of budding would contain large amount of phenolic substances. These phenols on oxidation changes into quinones that can cause cell damage. In normal budding, the toxic exudates will be absorbed by the tissue newly formed at the bud union. If the exudation exceeds the toxic limit, it become fatal to the bud, thus causing bud failure. Presence of considerably large number of tanniferous vessels might be another reason for poor bud take in nutmeg.

5.1.4 Effect of stumping method on sprouting of buds

The method of stumping the rootstocks after bud take was found to have great influence on bud sprout. After bud take when stumping was done retaining a whorl of leaf below the bud union, the sprouting and later survival of sprouts was cent per cent. When a whorl of leaf was left above the bud union, the sprouting percentage was only 66.66 per cent and all the sprouted buds survived later. Still lower success rate (60%) and survival (33.33%) were recorded when stumping was done without retaining any leaves on rootstock. Hence leaf retained at the time of stumping and its relative position can be considered as important factors that determine sprouting of 'taken buds'. The leaves retained on the rootstock may nourish the developing buds upto a stage when the sprouts putforth new leaves and become self sufficient. Similar response and strong relation between bud sprout and leaf retention has been reported in *Theobroma cacao*. In this crop, the foliage from the stock plants can be completely removed only when the newly formed leaves of bud sprout get hardened (Nair *et al.*, 1993).

5.1.5 Effect of conditions provided after budding

Maintaining the budded plants under partial shade was found to be better than the mist chamber conditions. Although Mathew (1979) could obtain a limited percentage of bud take inside the mist chamber, none of them sprouted while taken out. Under high humid conditions of mist chamber there are better chances for bud decay. The high temperature prevailing in the mist chamber would again be fatal due to its favourable influence on phenolic interference.

5.1.6 Growth parameters of bud sprouts

The growth performance of the bud sprouts in nutmeg was found satisfactory. Within three months after sprouting the increase in length was 20.77 cm with a three fold increase in the girth and addition of 44 leaves. The *in situ* budded plants one year after budding could easily requip the biomass lost at the time of stumping (Plate 7a). The undisturbed root system helps the budded plant to regain its vegetative growth within a short period. The highly encouraging growth performance of the *in situ* budded plants confirms the viability of this particular method of budding as a means of vegetative propagation for nutmeg.

The nutmeg growers can be advised to plant healthy and vigorous seedlings in the mainfield and to undertake patch or forkert budding in July to November season when they attain atleast 4 cm girth. Age becomes a limiting factor when girthing is less due to poor management.

5.1.7 Anatomy of bud union

When the bark is lifted from the root stock, a few layers of cambium will be retained with the wood of root stock. Similarly, when the bud patch is removed from the scion bud stick, a few layers of cambium will ordinarily be left with the inside of bud patch. Close cambial contact between the stock and scion has been described as the first stage in the formation of a successful union after graftage by Hartmann and Kester (1989). The presence of wounded necrotic cells during the early stage of bud union has been reported by several workers (Nedev, 1969; Wagner, 1969; Soule, 1971; Jose, 1989; Beena, 1994). In the present study, within a period of seven days, cell division has started and callus development was observed. Beena (1994) could also notice callus induction in the early stages of bud union in nutmeg. In nutmeg seedlings where bud take was observed, in the present study a complete callus bridge was noticed in three weeks after budding. At this stage, the necrotic line was found completely absorbed. The presence of callus bridge has also been reported by Mendel (1936) in citrus T-bud union, Wagner (1969) in Malus, Copes (1969) in douglas-fir graft union, Soule (1971) and Chakrabarthi and Sadhu (1985) in mango graft union. Differentiation of the new cambium cells producing secondary xylem towards inside and secondary phloem towards outside has been described as the final stage of graftage union by Hartmann and Kester (1989). In nutmeg also, the cambial differentiation could be observed at the bud union thus establishing complete connection between stock and scion.

In cases of bud failure, the anatomy of bud union revealed a little or no callusing from either the stock or scion resulting in a wide gap between stock and scion, cambial layers were found damaged and incomplete union was observed according to the severity of damage. Low callus development and sparse differentiation of vascular tissues in the bud shield has been attributed to bud failure in nutmeg by Beena (1994). In mango chip buds, Soule (1971) observed that damaged tissues and non-alignment of cambial layers of stock and scion hindered the bud union. In jack graft, Jose (1989) also attributed the graft failure to absence of callus formation leading to a wide gap between stock and scion and non-differentiation of cambium. In the present investigation when buds were pretreated, poor bud take was observed. Thus it is further proved that the scion and stock should be handled carefully while wounding so that no damage is caused to the cambial cells. The presence of thick necrotic layer hindered bud union in nutmeg. When the wounds were made, damage may be caused to several layers of cells causing the necrotic layer very thick. This also favours phenolic exudation which may be another factor for bud failure. In general, the amount of phenolic exudation was observed to be more in one and two year old nutmeg seedlings compared to the three year old plants.

5.2 Effect of physical treatments on induction of orthotrops

Among the different pruning methods tried on mature trees of nutmeg, treatment T_5 (pruning of orthotropic branch close to the trunk leaving a stump of 30 cm) was identified as the best method to induce orthotrops. Pruning could initially (within 2 months) induce only a few shoots, but all the shoots were orthotrops. Subsequently, more number of shoots were produced, but the frequency of orthotrops was found to be less (88%). Pruning the plagiotrops in a similar fashion induced orthotrops at a low frequency (23%). All the other treatments tried failed to induce orthotrops. Mathew (1985) reported orthotropi response in plagiotropic shoots of four year old nutmeg seedlings and also the development of erect growing shoots at the proximal end of plagiotropic branches close to the trunk, after pruning the branches retaining about 30 cm long. He has also noticed orthotropy in nutmeg grafts made from plagiotropic scions by severe pruning of old plagiotropic branches. By pruning, the dormancy of buds towards the base of branch are broken and bud release occur. Mika (1986) opined that pruning removes apical dominance, releases buds from correlative inhibition and changes the branching pattern and tree structure. According to him, in strong shoots of apple,well developed buds occur along three-fourths of the upper shoot length, but at the shoot base the buds are not well developed. So in the present study also this difference may account for the strong regrowth which occurred when the branches were cut by almost three-fourths. This may also account for the growth of orthotrops from both orthotropic and plagiotropic branches when they were cut leaving a stump of 30 cm.

Bacilhon (1965) opined that the reversal to an orthotropic mode occurs in Phyllanthus, even after a period of plagiotropic growth due to the organiser property of orthotropic branches. This may account for the development of orthotrops by pruning the plagiotropic branches.

He attributed strong shoot growth after severe pruning mainly to the removal of certain amount of wood and not alone to removal of apical dominance. Removal of the dominant bud on a dormant shoot is also reported to change the pattern of branching. Severe pruning also cause hormonal inbalance which can ultimately change the branching pattern (Wareing , 1965). The response obtained for pruning in nutmeg also confirms with the results reported earlier in other woody plants.

When nutmeg shoots of different age groups, were staked, it was noticed that the immature brown shoots of one to two years age and young green shoots of less than six months acquired a reduced angle with the vertical, after three months of staking (37.5° to 15° and 42° to 14° respectively). The angle of divergence for the mature shoots of two to three years age after staking was relatively low with the vertical (67.5° to 55°). Although, these mature shoots, regained their initial angle one month after removal of stake, the immature brown and young green shoots were found to maintain the acquired angle when observed one month after removal of stake. So it was observed that nutmeg shoots of less than two years age respond to staking by reducing their initial plagiotropic nature of growth. However, the phyllotaxy was never observed to be changed. The orthotrops maintained its spiral leaf arrangement, while the plagiotrops always had an alternate phyllotaxy. By staking, the reaction wood may be formed which tends to make the growth of shoots vertical. The anatomical study of staked nutmeg shoots of less than two years age revealed the presence of more wood towards the adaxial side than the abaxial side (Plate 22). In woody stems of conifers, which are oriented other than vertically tend to form reaction wood on one side of the stem (Leopold, 1964). Farrel *et al.* (1986) could reduce the initial plagiotropic growth of softwood fraser fir cuttings by staking.

5.2.1 Effect of physical treatments on induction of orthotrops in nutmeg grafts

The physical treatments tried viz., bending (M_1), snapping (M_2), ringing (M_3), notching (M_4) and stumping (M_5) gave varied response in nutmeg grafts. The grafts used for the purpose were the inarched plants (3 months after inarching) with laterals as the scion which are therefore programmed for plagiotropic growth pattern. Since the treatments were imposed immediately after graft union, many of the plants could not thrive over the physical treatments. Treatment M_3 (ringing) recorded high rate of mortality (75%), while the survival rate was more for bending (48%). The treatments could induce sprouting on the surviving plants at varying intensities. Stumping gave the best result followed by bending. However, the difference observed was not statistically significant.

Stumping totally removes the apical dominance and favours better allocation of growth substances like cytokinin among the buds retained. The activity of bud-breaking hormone, gibberillins is reported to be enhanced by more than cent per cent in pruned shoots of woody plants (Wareing et *al*., 1977). Thus the superiority of stumping over other physical treatments on shoot induction is self-explanatory. The ringing treatment would have interfered with the vascular transport in nutmeg grafts. The inadequate vascular connection at graft union along with the interference at the girdled region would have increased the severity of response causing high rate of mortality.

Though the physical treatments tried could stimulate shoot induction in nutmeg grafts, the purpose of the study was not satisfied since, none of the treatments could revert the pattern of growth. All the shoots induced on plagiotropic grafts remained as plagiotrops. It was further observed that in contrast to the development of only plagiotropic shoots from the scion part, only orthotrops developed from the rootstocks. The main shoots of rootstocks are set in an orthotropic mode of growth, whereas, the scion shoots are plagiotropic and are set in that mode. According to Halle *et al.* (1978) irreversible plagiotropy is most pronounced when spiral phyllotoxy is retained on orthotropic shoots in contrast to the distichous leaves of plagiotropic shoots. This condition is applicable in nutmeg. Thus the general experience indicates a non-reversible nature of plagiotropy in nutmeg. Here it is interesting to recollect the treatments, imposed on mature woody shoots that could induce orthotrops. The factors that induced orthotrops on mature shoots were not found functioning in young nutmeg grafts. Mathew (1985) noticed orthotropy in nutmeg grafts from plagiotropic scions by severe pruning of old plagiotropic branches. Similar performance is also observed in cocoa seedlings bud grafted with buds taken from fan branches (Greathouse and Laetsch, 1969). Orthotrops arise from the plagiotropic shoots when the latter attain a particular stage of maturity. Mathew (1985) has also observed that bending of nutmeg rootstocks at the budded portion initially induced plagiotropic shoots and after a period of ten months of scion growth, orthotropic shoots were seen arising from the base of previous plagiotropic growth. Thus, here we can take the maturity of wood or food reserves inside the wood tissue as a critical factor. According to the present study and previous reports, it is evident that vertical shoots can be induced in nutmeg grafts only when they attain a particular stage of growth.

5.2.2 Effect of chemical treatments on induction of orthotrops

Among the different chemical treatments tried viz., IAA 10 ppm (S_1), GA_3 10 ppm (S_2), kinetin 5 ppm (S_3) and water (S_4), none of the treatments induced orthotrops in grafts. However, after six months, the treatment S_3 (Kinetin 5 ppm) recorded the maximum number of shoots per plant. However treatments were not differing significantly from each other. According to Greathouse and Laetsch

(1969) high levels of auxin may be responsible for orthotropy of plagiotropic meristem. Halle *et al.* (1978) mentioned that 'apical control' through hormones are involved in branch dimorphism of trees. In the present study, the concentration of growth regulators were fixed based on preliminary studies made on current season shoots of mature trees. However, the concentration of the chemicals applied may not be sufficient to stimulate the induction of orthotrops in nutmeg grafts.

The interaction of various physical treatments with chemical treatments indicated stumping with IAA 10 ppm to have a better influence on induction of shoots, though not significantly different from other treatment combinations. The superiority of stumping over other physical methods has been discussed earlier. Stumping completely removes the apical dominance simultaneously reducing the auxin level in the plant tissue. The externally applied auxin would have helped better release of axillary buds in stumped nutmeg grafts.

5.3 Anatomy of stem

ransverse section of seedling stem of nutmeg revealed the presence of a well defined outer cortex layer with hypodermis and epidermis lined with cuticle. The cambial layers lie below the cortex in a ring of four or five layers. The cambial cells cut secondary xylem towards inside and secondary phloem toward outside during secondary growth. Secondary phloem consists of many small tanniferous cells, sieve tubes, companion cells and lignified phloem fibres. Secondary xylem consists of one or two layers of serially arranged tracheids alternating with a layer of parenchymatous cells. Multiple vessels are arranged in radial rows. A wider pith constituted by large parenchymatous cells could also be noticed.

Beena (1994) also could notice the presence of similar elements on examining the anatomy of mature stem of nutmeg plants. She could notice profuse occurrence of tannin containing vessels and also lignified vessels in the secondary xylem plugged with tylosis.

The anatomy of orthotropic and plagiotropic shoots were studied. It was generally observed that in orthotropic shoots, the amount of wood formed towards the adaxial side was more than that was formed towards the abaxial side. In the case of plagiotrops, the development of wood was more or less uniform on either side of the branch namely lower (abaxial) and upper (adaxial). The disproportionate wood formation in orthotrop may be due to accumulation of auxin on the adaxial side of the stem. Since auxin is photosensitive, the amount of auxin reaching the base of shoot may be comparatively less in the abaxial side than in the adaxial side. However, in the case of plagiotrops, this disproportionate auxin accumulation may not occur and both lower and upper sides develop wood equally on both sides. While the plagiotrops were staked for a period of three months, young shoots were found to behave against the set pattern. The anatomy of such staked shoots revealed formation of reaction wood on the adaxial side of the stem. According to Wilson and Archer's (1977) hypothesis, the compression wood formation occur within a branch in response to gravitational disorientation to restore it to an inherent equilibrium position. In staked softwood fraser fir cuttings, Farrell *et al.* (1986) noticed abaxial concave bending by greater production of compression wood and total xylem on adaxial than on abaxial sides of the cuttings. Results of the present study thus indicates an inherent set pattern of growth for nutmeg which can be altered a little.

Summary

SUMMARY

Investigations were carried out at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara during the period 1993-94 with an objective to induce orthotrops in vegetatively propagated nutmeg (*Myristica fragrans* Houtt.) plants. The following experiments were carried out to induce orthotrops in nutmeg.

1. Standardisation of budding method using orthotrops as the scion
2. Induction of orthotrops in nutmeg grafts which are otherwise plagiotropic

The salient findings obtained during the course of study are summarised below.

Budding was done on rootstocks of *Myristica fragrans* and *Myristica beddomei* of one, two and three years age, grown in polybags and three year old field grown plants of *M. fragrans* during a period of one year. Initial success could be obtained only in three year only plants. Cent per cent bud take was obtained with three year old field plants (*in situ* budding during August). Three year old polybag plants of *M. fragrans* and *M. beddomei* recorded a maximum bud take of 53.85 per cent and 46.15 per cent respectively.

Among the three methods of budding tried, viz. patch, forkert and T, the maximum initial success was obtained with forkert method (32.25%) in *M. fragrans*, and with patch budding (26.31%) in *M. beddomei* although the results were statistically on par. Irrespective of the rootstocks, T budding was not successful.

The month of August was identified as the best season for *in situ* budding (100% bud take) followed by November (87%) and the month of July for budding in polybag plants (50%). Although no significant difference was found with respect to bud take between polybag plants and field plants, the maximum sprouting of buds was obtained with *in situ* budded field plants (84.61%) when budded during November. The polybag plants failed to show any sprouting at all.

Bud patch treatments like wiping the wound and washing with growth regulator solution (NAA 0.5 ppm) or with sterile water hindered bud union in nutmeg indicating that the buds should be handled with care causing no damage to the cambial layers of stock and scion. Partial shade was found ideal for better bud take in nutmeg than the mist chamber conditions. After bud take, stumping the rootstock above the bud union leaving a whorl of leaf below the bud union was found advantageous for sprouting and later survival (cent per cent) than leaving a whorl of leaf above the union or retaining no leaves at all.

Sprouting of buds was complete within two months after bud take. After a period of six months, the average length of shoots were 25.32 cm, with a girth of 8.84 cm. By that time, the sprouts developed on an average, 46 healthy leaves and six side shoots.

The anatomy of stem and bud union was studied in detail. The sequence of union are callus formation stage, callus bridge stage and cambial differentiation stage, which could be clearly noticed six months after budding. Absence of callusing, damage to cambial layers of stock or scion, thick necrotic layer and wide gap between stock and scion and phenolic exudation were attributed to the probable reasons for bud failure in nutmeg.

Pruning experiments were done on branches of mature trees to induce orthotrops. Maximum number of orthotrops were induced when an orthotropic branch was cut close to the trunk leaving a stump of 30 cm (88% orthotrops) followed by pruning a plagiotrop in the same manner (23%). All the other treatments tried failed to induce orthotrops.

Staking the immature brown shoots of one to two years age and young green shoots of less than six months acquired a reduced angle with the vertical. They maintained the acquired angle even one month after the removal of the stake.

Various physical treatments were tried to induce orthotrops in nutmeg grafts which would otherwise be plagiotropic. Treatment, ringing (M_3) recorded high rate of mortality of grafts (75%), while the survival rate was more for bending (48%). The treatments could induce sprouting on the surviving plants at varying intensities. Stumping gave the best result followed by bending. However, the difference observed was not statistically significant. The purpose of study was not satisfied, since none of the treatments viz., physical and chemical could revert the pattern of growth. It was further observed that in contrast to the development of only plagiotropic shoots from the scion part, only orthotrops developed from the rootstocks.

Anatomy of orthotropic and staked plagiotropic shoots revealed the formation of more wood towards the adaxial side than towards the abaxial side. In plagiotropic shoots the wood formation was more or less proportionate on both sides.

The results drawn out from the present investigation clearly indicate the suitability and stability of *in situ* budding in nutmeg. The same is to be popularised among the nutmeg growers. The best season identified was the period between July to November and the main limiting factors that influenced bud take was the girth of the stock plant and the rootzone available for it.

Attempts made to alter the dimorphic growth pattern of nutmeg plants indicate that severe pruning can induce orthotrops on otherwise plagiotropic shoots. Age of the wood was the main deciding factor in induction of orthotrops. Just for the same reason, physical or chemical treatments imposed could not induce orthotrops on nutmeg grafts having one year old plagiotrop as the scion part. The response to physical treatments is to be watched further for a period of two or three years to ascertain whether the plagiotropy in nutmeg could be reversed. As the plagiotropic scion part progressively increases its girth, there may be better chances for induction of orthotrops. With respect to the chemical treatments imposed, wide and varied concentrations are to be tried further to obtain conclusive results.

References

REFERENCES

Anadoliev, G. 1971. Accelerated production of fruit tree planting material. *Gradinarska i Lozarska Nauta*. 8(8):3-9

*Bancilhon, L. 1965. Sur la mise en evidence d'un role 'organisateur' du me'riste'me apical de l'axe orthotrope de *Phyllanthus*. *Compates rendus hebdomadaires des se'ances de l' Acadimie des Sciences*, Paris Serie D. 260:5327-5329

Beena, S. 1994. Standardisation of top working in nutmeg (*Myristica fragrans* Houtt.). M.Sc.(Hort.) thesis submitted to Kerala Agricultural University, Vellanikkara, Kerala.

Boswell, S.B. and Storey, W.B. 1974. Cytokinin - induced axillary bud sprouting in macadamia. *HortSci*. 9(2):115-116

Chakrabarthy, U. and Sadhu. 1985. Anatomy of graft union of epicotyl grafting in mango. *Indian J. Agric. Sci*. 53(8):637-641

*Champagnat, P. 1954. Les correlations sur le rameau d'un an des vegetauxligneux. *Phyton*. 4:1-102

*Champagnat, P. 1961. Dominance apicale, tropismes, epinastie. In: W. Ruhland (ed.), *Handbuch Pflanzen Physiologie*. 14:872-877

Chandra, D. 1965. Recent advances in clonal propagation of guava. *Allahabad Fmr.* 39:137-139

Chellappan, K. and Roche, J.I. 1982. Studies on clonal propagation of nutmeg (*Myristica fragrans* Houtt.). *S. Indian Hort.* 30(2):156-158

Copes, D.A. 1969. Graft union formation in Douglas fir. *Amer. J. Bot.* 65(3):285-289

C.P.C.R.I. 1981. Central Plantation Crops Research Institute, Research Highlights, Kasargod. p.8

Cutler, D.F. 1978. *Applied Plant Anatomy* 3rd ed. Longman Group Ltd., London.

*Deinum, H. 1931. De noot musaat Cultur op de Banda, (Nutmeg culture in Banda Islands). *Landbow. J.* 1:467-492

*Deinum, H. 1949. Nutmeg and Mace. *Delandboum in de Indischa Archipel.* 2:655-683

*Estcourt, D.E. 1974. The influence of snagging methods on the growth of roses in a nursery trial. *Ann. J. Royal Newzealand Inst. Hort.* 2:12-15

Farrel, C.W., Blazich, F.A. and Hinseley, L.E. 1986. Reduction of initial plagiotropic growth of softwood fraser fir cuttings. *J. Amer. Soc. Hort. Sci.* 111(1):21-26

Fernie, L.M. 1940. The rooting of softwood cuttings of *Coffea arabica. E. Afr. agric. J.* 5(4):323-329

*Ferraz, L., Souza, M.M.De., Dantas, A.P., Wanderley, M.De.B. and Pedrosa, A.C. 1974. Methods of grafting cashews [Metodos de enxertia em cajueiro (*Anacardium occidentale* L.)]. *Boletim Technico do Instituto de Pesquisas Agrononaicas.* Recife, Brazil. (67):p.17

*Flach, M. 1966. Nutmeg cultivators and sex problems. *Eng. Summ. Meded. Landb. Hogesh.* 66:1

Flach, M. and Cruickshank, A.M. 1969. Nutmeg, *Myristica fragrans* Houtt. and *Myristica argentea* Warb. In: *Outlines of Perennial Crop Breeding in the Tropics*. Ferweda, F.P. and Wilt, F. (Eds.). Mics. Pap. Landbhogeseh Wageningen. 329-338

Gan, L.T. and Chew, O.K. 1988. Experience with the young budding technique in rubber. *Planter*. 64(751):439-451

*Garratt, G.A. 1933. Bearing of wood anatomy on the relationships of the Myristicacea. *Trop. Woods*. 36:20-44

*Gener, P. 1966. Le greffage de l'Hevea: Influence des stades de pousse foliare due greffon et du porte-greffe sur la reussite du greffage. *Rapport Technique Service Agronomique de l' Institut Recherches Caustchouc de l' Afrique*.

Giesberger, G. and Coster, W.A. 1977. Green budding and grafting in cacao nurseries. *Acta Hort*. (53):263-271

Gowda, B.J. and Melanta, K.R. 1988. Vegetative propagation of cashew (*Anacardium occidentale* L.) by grafting and budding. *Cashew Bull*. 25(11):17-20

Greathouse, D.C. and Laetsch, W.M. 1969. Structure and development of the dimorphic branch system of *Theobroma cacao*. *Amer. J. Bot*. 56(10):1143-1151

Halim, H., Kumar, D.R., Coombe, B.G. and Aspinall, D. 1990. Response of buds of *Citrus sinensis* (L.). Osbeck inserted into rootstock stems to exogenous growth substance. *Newzealand J. Crop Hort. Sci*. 18(2):121-126

Halle, F., Oldemann, R.A.A. and Tomlinson, P.B. 1978. *Tropical Trees and Forests*. Springer Verlag, Berlin. pp.441

Hartmann, H.T. and Kester, D.E. 1989. *Plant Propagation - Principles and Practices* 4th ed. Prentice Hall of India Private Limited, New Delhi. p.351

Hurov, H.R. 1961. Green bud strip budding of two to eight month old rubber seedlings. In: *Proceedings of the Natural Rubber Research Conference*, Kuala Lumpur, 1960, 419-429

*Hushny, Z., Yahya, S., Wattimena, G.A. and Harran, S. 1986. Application of indole butyric acid and gibberellic acid on budded stumps of Hevea (Penggunaan Zat tumbuh asam indotbutriat den asam gibberellat pada bahan tanam Karet Okulasi mata tidur). *Bulletin Perkaretan.* 4(2):31-36

Izaki, M., Hiyama, H., Ishiyuka, Y. and Hoshino, M. 1973. Studies on budding chestnuts. Part 7. The relationship between rootstock nutrition and successful bud union. *Agric. Hort.* 58(10):83-84

Jaafar, H.B. 1982. Release of bud dormancy in budded stumps and maxi stumps using growth substances. *J. Rub. Res. Inst.,* Malaysia. 32:73-81

Jankiewicz, L.S., Szpunar, H., Baranska, R., Rumplowa, R. and Fiutowska, K. 1961. The use of auxin to widen crotch angles in young apple trees. *Acta Agrobot.* 10:151

*Janse, J.M. 1898. De mootmuskat cultuur inde Minahasa en op de Bande cilanden. *Med's lands Plantent.* 28:1-233

Jauhari, O.S. and Singh, R.D. 1970. Effect of bud activation, lopping and wrapping materials on budding in mango (*Mangifera indica* L.) var. Langra. *Punjab Hort. J.* 10(314):198-202

Johansen, D.A. 1940. *Plant Microtechniques* 2nd ed. MC Graw Hill, New York. p.62-113

Jose, M. 1989. Standardisation of epicotyl and soft wood grafting in jack (*Artocarpus heterophyllus* (Lam.). M.Sc.(Hort.) thesis submitted to the Kerala Agricultural University, Thrissur Dist., Kerala.

Joshi, K.R., Seth, J.N., Tiwari, J.P. and Tripathi, S.P. 1986. A note on the effect of some plant growth regulators and urea on the growth of walnut grafts in the nursery. *Progve. Hort.* 18(3-4):324-325

Kadje, A. and Ndjama, J.H.N. 1982. Developmental trial of a grafting method for cocoa. In: *Proceedings, 8th International Cocoa Research Conference*, Lagos, Nigeria. Cocoa Producer's Alliance: 49-55

Kannan, K 1973. Top working as a means of converting male into female plants in nutmeg. *Arecanut and Spices Bull.* 4(4):14-16

Kathiravetpillai, A. and Kulasegram, S. 1981. Effect of some growth regulators on growth and apical dominance of young tea (*Camellia sinensis* (L.) O. Kuntze.). I. Effect of IAA, BA and ethrel. *Tea Quarterly* 50(3):138-146

Kelaskar, A.J., Desai, A.G. and Salvi, M.J. 1990. Effect of container size and *in situ* budding on success and growth of patch bud grafts in jack fruit (*Artocarpus heterophyllus*). *Indian J. Agric. Sci.* 60(4):265-267

Keshavachandran, R. and Nair, P.C.S. 1985. Standardisation of vegetative propagation in cocoa. *Indian Cocoa Arecanut Spices J.* 9(2):29-34

Keskar, B.G., Dhawale, B.C., Karale, A.R. and Kale, P.N. 1991. Propagation technique in aonla. *J. Maharashtra agric. Univ.* 16(2):282

Konhar, T., Murmu, S. and Maharana, T. 1990. A study on the budding methods of propagation of jack fruit. *Orissa J. Agric. Res.* 3(2):115-119

Krishnamoorthy, B. and Mathew, P.A. 1985. Epicotyl grafting in nutmeg using *Myristica fragrans* as root stock. *Indian Cocoa Arecanut Spices J.* 9(2):50-51

Krishnamoorthy, B., Zachariah, T.J., Ravindran, P.N. and Gopalam, A. 1992. Identification of sex of nutmeg seedlings based on morphological and chemical characters. *J. Plantn. Crops.* 20(Supplement):194-199

Kumaran, K. and Nair, P.C.S. 1982. Curing budwood and method of budding on budtake in cocoa var. Forestero (*Theobroma cacao* L.). *Agric. Res. J. Kerala.* 20(1):81-83

Leong, S.K. and Yoon, P.K. 1979. Effects of bud types on early scion growth of Hevea. *J. Rub. Res. Inst., Malaysia.* 27(1):1-7

Leopold, A.C. 1964. Plant growth hormones. In: *The Hormones*, Vol.IV, Pincus, G., Thimann, K.V. and Astwood, E.B. (eds.). Academic Press, New York. p.1-66

*Lundstad, A. 1973. The influence of the collar size of rose rootstock on the bud take. *Meldinger Fra Norges Landbru Kshgskole*, 52(33):9

*Magalhaes, W.S. 1974. Cacao vegetative propagation (*Reproducao assexuada do cacaveiro*). *Cacau Ataolidades.* 11(1):21-23

Manithottam, J. 1994. Vegetative propagation in nutmeg. *Spice India.* 7(2):5-7

Martinez, M., Cedeno-Maldonado, A. and Vasquez, F. 1992. Effect of gibberellic acid on phyllotaxy of bud grafted cacao (*Theobroma cacao* L.). *J. Agrl. Univ. PeurtoRico*. 76(1):33-34

Mathew, K.L. 1979. Propagation studies in nutmeg. M.Sc.(Hort.) thesis submitted to the Kerala Agricultural University, Vellanikkara, Kerala.

Mathew, P.A. 1985. A case of reversible plagiotropy in nutmeg. *J. Plantn. Crops*. 13(2):147-151

Mathew, P.A. and Joseph, J. 1979. Standardisation of vegetative methods of propagation in tree spices. *CPCRI Annual Report*. p. 141-142

Mathew, P.A. and Joseph, J. 1980. Standardisation of vegetative propagation in tree spices. *CPCRI Annual Report*. p.110

Mathew, P.A. and Joseph, J. 1982. Epicotyl grafting in nutmeg (*Myristica fragrans* Houtt.). *J. Plantn. Crops*. 10(1):61-63

Mathew, P.A., Nair, M.K., Joseph, J. and Vikrakthamath, B.C. 1984. Standardisation of vegetative methods of propagation in tree spices. *CPCRI Annual Report*. p.105

yatskaya, A.D. 1977. Stimulation of shoot formation in walnuts. *Resp. Mezhved. Temat. Nauch. Sbornik*. 48:75-79

Mendel, K. 1936. The anatomy and histology of the bud union in citrus. *Palestine J. Bot. Hort. Sci.* 7(2):13-46

Menon, K.P.G. 1994. Emerging technologies, products and markets in the spice sector. *Women Enterpreunership in Spice Industry*. Spices Board, Cochin, p.36

Mika, A. 1986. Physiological responses of fruit trees to pruning. *Hort. Rev.* 5:337-378

Nagabhushanam, S. 1985. Vegetative propagation in cashew - a review of work done in Vittal. *Acta Hort.* 108):57-63

Nagabhushanam, S. and Nair, R.V. 1988. Asexual propagation of cocoa (*Theobroma cacao* L.). *J. Plantn. Crops.* 16(2):143-145

Nagabhushanam, S. and Rao, P.V. 1977. Propagation trials in cashew (*Anacardium occidentale* Lin.). *Indian Cashew J.* 11(3):7-11

Naik, K.C. 1941. Studies on propagation of the mango, *Mangifera indica* L. *Indian J. Agric. Sci.* 11:736-768

Nair, R.V., Mallika, V.K., Sunitha, S. and Santhy, V. 1993. Improvement of cocoa through vegetatively propagated planting material. *Indian Cocoa Arecanut Spices J.* 16(3&4):93-96

Nauer, E.M. and Boswell, S.B. 1981. Stimulating growth of quiescent citrus buds with 6-benzl amino purine. *HortSci.* 16(2):162-163

Nayar, B.K., Rai, R. and Vatsala, P. 1977. A simple morphological technique for distinguishing the sex of nutmeg seedlings. *Curr. Sci.* 46(5):156-157

Nazeema, K.K. 1992. Standardisation of softwood and epicotyl grafting in *Garcinia cambogia* Dessr. M.Sc.(Hort.) thesis submitted to Kerala Agricultural University, Vellanikkara, Kerala.

*Nedev, N. 1969. Studies on the duration of the stages of union in walnut budding. *Grad. Lozar.* Nauka. 6(2):3-9

*Nichols, R. and Cruickshank, A.M. 1964. Vegetative propagation of nutmeg (*Myristica fragrans*) in Grenada, West Indies. *Trop. Agric. Trin.* 41(2):141-146

Nichols, R. and Pryde, J.F.P. 1958. The vegetative propagation of nutmeg (*Myristica fragrans*) by cuttings. *Trop. Agric.* 35:119-129

Ooi, C.B., Leong, S.K. and Yoon, P.K. 1976. Vegetative propagation techniques in Hevea. In: *Proceedings of the National Plant Propagation Sympsoium, 1976, Rubber Research Institute of Malaysia,* Kuala Lumpur. p.116-131

*Oxyley, T. 1948. Some account of the nutmeg and its cultivation. *J. Ind. Archipel. E. Asia.* 2:641-642

Palaniswamy, V. and Hameed, A.S. 1976. Study of the propagation of cashew (*Anacardium occidentale* L.) by patch budding. *S. Indian Hort.* 23(1):24-25

Palaniswamy, V., Hameed, A.S. and Vijayakumar, M. 1985. Vegetative propagation in cashew - work done at Vriddhachalam. *Acta Hort.* (108):67-70

Palmer, J.H. and Phillips, I.D.J. 1963. The effect of the terminal bud, indole acetic acid and nitrogen supply on the growth and orientation of the petiole of *Helianthus amnuus*. *Physiol. Plant.* 16:572-584

Pandey, D. and Srivastava, R.P. 1974. Propagation of fruit plants in the hills of Uttar Pradesh. II. Effect of thickness of stock on the success and growth of peach, plum and apricot plants. *Progve. Hort.* 6(1):19-23

Parups, E.V. 1971. Use of 6-benzyl amino purine and adenine to induce bottom breaks in greenhouse roses. *HortSci*. 6(5):456-457

Pathak, R.K., Ojha, C.M. and Dwivedi, R. 1992. Adopt patch budding for quicker multiplication in tamarind. *Spice India*. 5(1):17

Peter, K.V. 1994. Gearing up spices research to meet the emerging challenges. *Indian Hort*. 39(3):7-10

Phadnis, N.A. and Choudhari, K.G. 1971. Sex determination in the seedling stage of nutmeg (*Myristica fragrans* Houtt.). *Trop. Sci*. 13(4):265-274

Philip, J. 1979. Prospects, problems and research needs of nutmeg (*Myristica fragrans*) cultivation in India. *Indian Spices*, 16(1):2-5

*Postma, A. 1935. Budding the nutmeg (Voorloopige mededeeling over hat oculceven van noot noot muskaat). *Landbouw*. 11:450-452

*Prestoe, 1948. Sexes of nutmeg trees. *Gardener's Chronicle*. 148(1):315

Preston, A.P. and Barlow, H.W.B. 1950. The use of growth substances to widen crotch angles. *Rep. East Malling Res. Sta.* No.76

Purseglove, J.W. 1974. *Tropical Crops - Dicotyledons*, Vol.1 and 2 combined. Longman Group Ltd., London. p.391-394

Rao, S.N. 1985. Vegetative propagation of cashew - a review of work done at Bapatla. *Acta Hort*. (108):64-66

Rasalam, S.J. 1978. *Practical Research in the Field of Agriculture (Budding, Grafting, Layering)* (in Malayalam). Atma Nilayam, Parasala, Trivandrum. p.36

*Rehm, S., Zayed, E.A. and Espig, A. 1978. Effect of gibberellic acid on the sprouting and growth of secondary buds of *Coffea arabica* stimulated by other growth regulators. *Zeitschrift fur' Pflanzenphysiologie* 89(1):1-10

Ridley, H.N. 1912. Nutmegs and mace. *Spices*. Macmillan and Co., London. p.94-154

Salmon, A.D. 1990. Clonal propagation of the red flowering gum. *Aust. Hort.* 88(5):63-68

Samaranayake, C. and Gunaratne, R.B. 1977. The use of 'leaf buds' and 'scale buds' in the vegetative propagation of Hevea. *J. Rubb. Res. Inst.*, Sri Lanka. 54(1):65-69

*Sena-Gomes, A.R. 1984. Influence of preparation and planting techniques on vegetative development of rubber (*Hevea brasiliensis* Clone Fx 2261). [Influence do metodo de preparo e plantio de mudas no desenvolvimento vegetative da seringueira (*Hevea brasiliensis*) Clone Fx 2261]. *Revista Theobroma.* 14(2):115-126

Shanmugavelu, K.G. and Rao, V.N.M. 1977. *Spices and Plantation Crops*. Popular Book Depot, Madras. p.30-40

*Siagin, N. and Sunarwidi. 1988. Effect of rootstock leaf conditions on the success of *Hevea* budding. *Bulletin Perkaretan.* 6(1):3-8

Singh, U.R., Pandey, I.C., Upadhyay, N.P. and Prasad, R.S. 1978. Propagation of guava by budding. *Punjab Hort. J.* 18(½):68-71

Singh, U.R., Pandey, I.C., Upadhyay, N.P. and Prasad, R.S. 1982. Propagation of jack fruit by budding. *Punjab Hort. J.* 22(½):103-105

Singh, J.R. and Srivastava, R.P. 1962. Studies in budding of mango. I. *Indian J. Hort.* 19(3&4);130-134

¯ ow, R. 1945. Plagiotropism and correlative inhibition. *New Phytol.* 39:177-184

Snow, R. 1947. Further experiments on plagiotropisms and correlative inhibition. *New Phytol.* 46:254-257

Soule, J. 1971. Anatomy of the bud union in mango (*Mangifera indica* L.). *J. Amer. Soc. Hort. Sci.* 96(3):380-383

Spices Board, 1991. Spices in different states (Facts and Figures). Trade Information Services; Spices Board, Ministry of Commerce, Government of India, Cochin. p.14

Sriram, T.A. 1977. Tree Spices - retrospect and research needs. *Arecanut and Spices Bull.* 8:97-100

Srivastava, R.P. 1962. Further studies in budding of guava. *Sci. Cult.* 28:433-434

*Subronto and Hutomo, T. 1987. Comparitive study between stumping and bending of rootstock and application of growth regulators on cocoa bud grafting. *Buletin Perkebunan.* 18(1):29-33

Sundararaj, J.S. and Varadarajan, E.N. 1956. Propagation of nutmeg on different rootstocks. *S. Indian Hort.* 4:85-86

Valsalakumari, P.K., Vidyadharan, K.L. and Damodaran, V.K. 1985. A comparative study of different methods of vegetative propagation of cashew. *Acta Hort.* (108):289

* Verner, L. 1955. Hormone relations in the growth and training of apple trees. *Res. Bull. Idaho Agric. Exp. Sta.* No.8

* Wagner, D.F. 1969. Ultrastructure of the bud graft union in Malus. *Diss. Abstr. Sect. B.* 29:4556

Wareing, P.F. 1965. Dormancy in plants. *Sci. Prog.* 53:529-537

Wareing, P.F., Horgan, R., Henson, J.F.E. and Davis, P. 1977. Cytokinin relation in whole plants. In: *Plant Growth Regulation.* Pilot, P.E. (ed.). Springer-Verlag, Berlin. p.147-153

Webster, C.J. and Baulkwill, W.J. 1989. *Rubber.* Longman Scientific and Technical U.K. Limited, New York.

Wershing, H.F. and Bailey, I.W. 1942. Seedlings as experimental material in the study of "Redwood" in conifers. *J. Forestry.* 40:411-414

Wiebel, J., Downton, W.J.S. and Chacko, E.K. 1992. Influence of applied growth regulators on bud dormancy and growth of mangosteen (*Garcinia mangostana*). *Scientia Horticulturae.* 52(1&2):27-35

Wilson, B.F. and Archer, R.R. 1977. Reaction wood: induction and mechanical action. *Ann. Rev. Plant Physiol.* 28:23-43

Zachariah, T.J., Gopalam, A., Krishnamoorthy, B. and Ravindran, P.n. 1986. Steroid degradation compound associated with sex expression in nutmeg (*Myristica fragrans* L.). In: *Proc. Indian Natn. Sci. Acad. B.* 52(5):685-688

* Originals not seen

Appendix

Appendix-I
Weather data of Vellanikkara
Rain in mm and Sunshine in hours

Element	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Year 1993												
Rain	0.0	6.6	0.0	32.1	131.1	700.3	661.8	276.7	85.3	519.0	74.6	18.0
Mean RH (%)	53	62	63	69	74	86	87	87	81	83	73	66
Sunshine	8.1	9.4	9.0	9.1	6.5	3.3	2.4	4.8	6.4	4.8	5.8	7.5
Year 1994												
Rain	19.4	1.7	21.0	165.2	124.2	955.1	1002.1	509.2	240.5	358.2		
Mean RH (%)	58	59	59	74	75	90	91	85	78	80		
Sunshine	9.1	8.7	9.3	8.0	8.0	2.1	2.1	1.4	3.0	7.3		

INDUCTION OF ORTHOTROPS IN VEGETATIVELY PROPAGATED NUTMEG (*Myristica fragrans* Houtt.) PLANTS

By

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ABSTRACT OF A THESIS

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ABSTRACT

Investigations were made to induce orthotrops in vegetatively propagated nutmeg (*Myristica fragrans* Houtt.) plants at the Department of Plantation Crops and Spices, College of Horticulture, Vellanikkara, Thrissur during the period 1993-'94.

Budding orthotropic scions on three year old nutmeg plants alone showed bud take. *In situ* budding on three year old field plants gave the maximum bud take and bud sprouting. Among the different methods tried, maximum initial success was obtained with patch method in *M. fragrans* and forkert method in *M. beddomei*. The month of August was found to be the best season for *in situ* budding and July for budding in polybag plants.

Partial shade was found ideal for better bud take than the mist chamber conditions in nutmeg. Stumping the rootstock above the bud union retaining the whorl of lower leaves gave better sprouting and later survival.

The anatomical studies of bud union revealed the sequence of bud union as the callus formation stage, callus bridge stage and cambial differentiation stage. Absence of callusing, damage to cambial layers of stock or

scion, thick necrotic layer and a wide gap between stock and scion and phenolic exudation were attributed to the probable reasons for bud failure.

On mature branches of nutmeg trees, maximum number of orthotrops were induced when an orthotrop was cut close to the tree trunk leaving 30 cm stump. Staking the immature brown shoots of one to two years age and young green shoots of less than six months of nutmeg grafts acquired a reduced angle with the vertical even one month after removal of stake.

Among the physical and chemical treatments tried to induce orthotrops in nutmeg grafts of plagiotropic nature, the treatments stumping and application of 5 ppm kinetin was found superior with respect to the number of shoots produced per plant. However, none of the shoots were found to have orthotropic growth pattern.

Anatomy of orthotropic and staked stems revealed the production of more wood towards the adaxial side than towards the abaxial side. Plagiotropic stem have more or less proportionate wood formation on both sides.