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Vegetative propagation of major tree spices - a review

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Abstract

Vegetative propagation of major tree spices grown in India namely, nutmeg (*Myristica fragrans*), clove (*Syzygium aromaticum*), cinnamon (*Cinnamomum verum*), cassia (*C. aromaticum*), allspice (*Pimenta dioica*), cambogia (*Garcinia gummi-gutta*), kokam (*G. indica*), tamarind (*Tamarindus indica*) and pomegranate (*Punica granatum*) are reviewed. The propagation methods reviewed include cuttings, air layering, budding, grafting and micropropagation.

Key words: allspice, cambogia, cassia, cinnamon, clove, kokam, nutmeg, pomegranate, tamarind, vegetative propagation.

Introduction

Tree spices constitute a group of diverse crops where the products of commerce are predominantly used as spice. Among the various tree spices grown in India (Table 1), the major ones are nutmeg, clove, cinnamon, cassia, allspice, cambogia, kokam, tamarind, pomegranate and curry leaf. A substantial quantity of these spices are imported into the country leading to drain of valuable foreign exchange. Hence to attain self sufficiency in production of tree spices, the area under these crops need to be increased by planting superior quality material in traditional and non traditional areas and by adopting improved cultural practices. Planting of superior quality material is essential since tree spices are perennial and a majority of them are open pollinated. Standardisation of vegetative propagation methods would help in rapid multiplication of true to type superior planting material. Vegetative propagation could also be utilised for propagation of rootstocks and scions which are generally in short supply and also to shorten the pre-bearing period of these crops. Due to the high degree of heterozygosity, vegetative propagation can be resorted to in conservation of germplasm of tree spices for use in breeding programmes. Adoption of vegetative propagation in tree spices has increased substantially in recent years and all the major tree spices have been propagated by this method with varying degrees of success. This paper reviews the information

Table 1. Tree spices grown in India

Botanical name	Family	Common name	Part used as spice
Averrhoa bilimbi L.	Averrhoaceae	Bilimbi	Fruit
A. carambola L.	Averrhoaceae	Carambola	Fruit
Cinnamomum aromaticum Nees	Lauraceae	Chinese cassia	Bark, Leaf
C. tamala Nees	Lauraceae	Tejpat, Indian cassia	Leaf, Bark
C. verum Bercht & Presl.	Lauraceae	Cinnamon	Bark, Leaf
Garcinia gummi-gutta (L.) Robs.	Clusiaceae	Garcinia, Cambogia	Pericarp of fruit
G. indica (Thouars) Choisy	Clusiaceae	Garcinia, Kokam	Pericarp of fruit
Illicum verum Hook.	Illiciaceae	Star anise	Fruit
Juniperus communis L.	Cupressaceae	Juniper	Fruit
Laurus nobilis L.	Lauraceae	Bay leaf	Leaf
Mangifera indica L.	Anacardiaceae	Mango	Rind of immature fruit
Murraya koenigii (L.) Sprengel	Rutaceae	Curry leaf	Leaf
Myristica fragrans Houtt.	Myristicaceae	Nutmeg	Kernel, Aril
Pimenta dioica (L.) Merr.	Myrtaceae	Allspice, Jamaica pepper	Immature fruit, Leaf
Punica granatum L.	Punicaceace	Pomegrante	Dried seed (with flesh)
Syzygium aromaticum (L.) Merr. & Perry	Myrtaceae	Clove	Flower bud
Tamarindus indica L.	Caesalpiniaceae	Tamarind	Fruit

available on vegetative propagation of major tree spices and also suggests possible approaches for further improvement. Curry leaf has not been included in the review since the crop is generally propagated by root suckers.

Nutmeg

Nutmeg (*Myristica fragrans* Houtt.), indigenous to Moluccas Islands in Indonesia, produces two distinctly different spices namely, nutmeg and mace. Nutmeg is the dried kernel of the seed and mace the dried aril surrounding the seed. Nutmeg is commonly propagated through seeds. The tree being obligatory cross pollinated (Deinum 1949), variations exist in its seedling progenies. Wide variability is observed in fruit shape, size, colour (Krishnamoorthy *et al.* 1991b; Krishnamoorthy & Rema 1994c), quality (Gopalam & Sayed 1988) and yield (Krishnamoorthy *et al.* 1991b). Nutmeg trees are dioecious and segregation of sex of seedling progenies into unisexual male, unisexual female and bisexual types have been reported (Prestoe 1884; Nichols & Pryde 1958; Flach 1966; Krishnamoorthy *et al.* 1996). Identification of sex of nutmeg trees is difficult till they come to flowering. Identification of sex at the seedling stage on the basis of leaf form and venation (Prestoe 1884), colour of young sprouts, seedling vigour, chromosome morphology (Krishnamoorthy *et al.* 1992 b), shape of calcium oxalate crystals of leaf epidermis (Nayar *et al.* 1977) and chemical constituents (Phadnis & Choudhary 1971; Zachariah *et al.* 1986; Packiyosothy *et al.* 1991; Krishnamoorthy *et al.* 1992b) are not reliable.

Propagation of nutmeg through seeds, though taken up on a large scale is not an ideal method due to the reasons already enumerated. Besides, seeds loose their viability soon after harvest if not stored under proper conditions (Flach 1966; Shanmugavelu & Rao 1977). Most of the unique characters of the parent are lost in the progenies when propagated through this method. To get uniformly high yielding and desirable populations of nutmeg, vegetative propagation is the only alternative. Experiments on grafting of nutmeg were carried out as early as 1894 in the Botanical Gardens at Bogor, Indonesia (Deinum 1932). Various vegetative propagation methods like cuttings (Nichols & Pryde 1958), air layering (Nichols & Cruickshank 1964), budding (Postma 1935; Deinum 1949), approach grafting (Ridley 1912; Sundararaj & Varadarajan 1956; Mathew 1979) and epicotyl grafting (Mathew & Joseph 1982) have been reported.

Cuttings

Propagation of nutmeg through cuttings is difficult. Rooting of semi-hardwood cuttings was reported to be successful in Trinidad and Grenada (Nichols & Pryde 1958; Nichols & Cruickshank 1964). However, rooting and establishment of such plants in the field were very poor. Reports from Wageningen on rooting of cuttings in a hot house with mist humidifier were also not encouraging (Flach 1966). No reports are available on this aspect from India. The high amount of tannins and phenolic compounds present in the stem may probably hinder root formation. Standardisation of methods for rooting of cuttings in nutmeg is very important for production of clonally identical rootstocks for grafting and budding. At present grafting and budding are carried out on root stocks raised from seeds.

Very little work has been done on rooting of cuttings. Pretreatment with auxin combinations, environmental manipulations, physiological status of cuttings, season (Hartmann & Kester 1972), maturity of cuttings (Halliwal 1970) etc. are reported to influence rooting in tree crops; therefore, there is wide scope for further studies for production of adventitious roots in nutmeg by manipulation of these factors.

Air layering

Air layering of nutmeg was reported to be successful in Grenada, West Indies (Nichols & Cruickshank 1964) and New Guniea. In New Guinea, about 60 per cent rooting was reported in a period of 6 months but the rooted layers failed to establish in the field (Deinum 1949). A very low success (8.5 per cent) was reported by Nichols & Cruickshank (1964) in Grenada.

Budding

Beena & Kurian (1996) reported that budding in nutmeg on 3 year old rootstocks by forket method can be carried out in July with 30 per cent success. However, the success reported in budding is too low for commercial application. The authors presume that phenolic compounds present in the plant would have interfered with bud-take. Anatomical studies of the budded region revealed that the failure in bud-take was due to blockage of vessels with tylosis which caused deleterious effects on the newly inserted bud and hindered the union (Beena *et al.* 1996). The authors also attribute 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 calli for delay in bud burst and lack of bud union in budded trees. The physiological status of the mother plant also would have played a major role on bud take, bud burst and scion growth. Girdling the bud wood prior to bud collection was reported to enhance budtake. Girdling increases gibberellic acid (GA), indoleacetic acid (IAA) and starch concentrations in the bud wood and reduces cytokinins (Poll *et al.* 1993), thus favouring bud take. Rootstocks other than *M. fragrans* have also been used for budding nutmeg. *M. beddomei* King, *M. malabarica* Lam. and *M. succedanea* were used as rootstocks for *M. fragrans* and a success of 26 per cent was obtained on *M. succedanea* (Postma 1935). The influence of rootstock on bud-take, growth, yield, fruit size and survival has been reported on many trees of horticultural importance (Glucina et al. 1992); however, no such reports are available in nutmeg.

Grafting

Grafting is the most successful vegetative propagation method in nutmeg and epicotyl grafting is widely used for commercial multiplication.

Inarching

Inarching of *M. fragrans* was successful on eight species of *Myristica* namely, *M. malabarica*, *M. beddomei*, *M. attenuata* Wall., *M. contorta* Ward., *M. magnifica* Bedd., *M. canarica* King., *M. fragrans* and *M. laurifolia* Bedd. (Aiyadurai 1966). Inarching on *M. fragrans*, *M. beddomi* and *M. malabarica* was reported with 40-80 per cent success; however, the success depended upon the season of grafting (Sundararaj & Varadarajan 1956). Inarching of *M. fragrans* on *M. fragrans* resulted in 62 per cent success and the grafts took about 180 days for perfect union (Chellappan & Roche 1982). Inarching though successful, is expensive and laborious since benches have to be erected and rootstocks brought to the mother plant for carrying out grafting.

Epicotyl grafting

Epicotyl grafting (Mathew & Joseph 1982) is the most widely adopted propagation technique in nutmeg. Epicotyl grafting has been reported on the cultivated species of nutmeg, *M. fragrans* (Krishnamoorthy & Mathew 1985) and also on wild species, *M. beddomei* and *M. malabarica* (Mathew & Joseph 1982). However, *M. fragrans* was found to be the most ideal rootstock. Though grafting could be carried out during all the seasons, on *M. fragrans*, the best result (80 per cent) was obtained when the seedlings were 20-30 days old (Krishnamoorthy & Mathew 1985).

Very little studies have been conducted to understand the influence of rootstock on the performance of grafts. Moreover, due to the lack of an efficient clonal propagation technique through cuttings or layering, the rootstocks used in the grafting studies are mostly seedlings. The performance of the grafts need not be identical in such cases. Clonal propagation of rootstocks through cuttings or layering need to be standardised for obtaining uniform rootstocks for grafting and budding. Epicotyl grafts have been evaluated for their performance in the field at Peruvannamuzhi (Kerala). The grafts started yielding from the third year of planting and produced an average of 800 fruits per graft per year during the initial years. The short stature of the grafts facilitates easy harvest and other cultural operations.

Nutmeg trees exhibit branch dimorphism and have more of plagiotropic shoots than orthotropic shoots. An orthotropic shoot when used for grafting gives rise to a graft which resembles the mother plant or seedling in its growth habit, whereas a plagiotropic scion gives rise to a graft which is more of a bushy nature. Experiments conducted for reversion of plagiotropy to orthotropy indicated that bending the rootstocks at the budded portion induced the production of orthotropic shoots at the base of the plagiotropic growth (Mathew 1985). The bending of the stem would have interfered with hormonal transport and assisted in dedifferentiation of the plagiotropic stem. Defoliation, notching or repeated spraying with growth hormones like gibberellin or cytokinins did not aid in the production of orthotropic shoots. Factors like vigour of the scion tree, physiological condition of the scion, the relative position of the scion in the tree crown, or the multiple nature of the axillary buds giving rise to different types of shoots (Greathouse & Laetsch 1969) or variability in the rootstock may be involved in this phenomenon. However, spontaneous production of orthotropic shoots could be observed in some of the plagiotropic grafts.

Production of a large number of orthotropic scions/shoots for grafting would be another approach for obtaining erect growing grafts. Detopping female trees at 2 m above the ground resulted in the production of large number of orthotropic shoots (average 38 shoots) from the main trunk (NRCS 1990). Terminal portions of the shoots could be made use of for grafting. Each of the beheaded shoot had the potential to produce three or more orthotropic shoots, which could be further made use of in grafting or the buds could be used for budding. Maintaining a clonal orchard of elite clones of nutmeg would thus help in the continuous production and supply of shoots for grafting. Such an orchard has been established at Indian Institute of Spices Research (IISR), Calicut.

Top working of male trees

Identification of sex of nutmeg in the seedling stage is not feasible with the available information. The sex of the trees can be identified only after 6-7 years when they begin to flower. Generally male and female trees are produced in a 1:1 ratio. Since one male tree is sufficient for every 10 female trees for pollination, the rest of the male trees available in the plantation can be made productive by converting them to female trees by top working. Top working can be done by budding (Beena & Kurian 1996) or by grafting (NRCS 1993). The top worked trees yield from the third year onwards. One or two branches of the female trees can also be top worked with male scions so as to avoid planting of male trees.

Micropropagation

Micropropagation of nutmeg would be an ideal method for rapid propagation of female trees. *In vitro* experiments are in progress at IISR, Calicut, Indian Cardamom Research Institute (ICRI), Myladumpara and Kerala Agricultural University (KAU), Vellanikara to develop protocols for multiplication of nutmeg. However, no published report on successful micropropagation of nutmeg is available.

Clove

Clove (*Syzygium aromaticum* (L) Merr. & Perry) which is also indigenous to Moluccas Islands, is an aromatic evergreen tree and the unopened flower buds (clove), clove oil and oleoresin are the products of commerce. Clove is commercially propagated through seeds. A major problem in its propagation is the short storage life of seeds (Sutarno & Utami 1984). Freshly harvested clove seeds are best suited for sowing to obtain maximum germination. Viability in clove seeds can be extended to some extent by storing them in charcoal, sawdust or coconut husk (Chaniago *et al.* 1981) or by hormonal treatments (Hasanah *et al.* 1984).

Self pollination is reported to be the more probable mechanism for pollination in clove as maximum pollen viability and stigma receptivity are attained simultaneously (Nair *et al.* 1974; Sritharan & Bavappa 1981; Pool & Bermavie 1986). However, the flowers are frequently visited by thrips, ants, and bees suggesting the possiblity of transfer of pollen from anther to stigma of the same flower (Pool & Bermavie 1986) or cross pollination (Tidbury 1949). Though clove is a predominantly self pollinated crop, morphological variants like king clove, dwarf and bushy clove and small leaved clove are known to exist (Pool *et al.* 1986; Kuriachan *et al.* 1992; Krishnamoorthy & Rema 1994b). Reports indicate that clove can be successfully propagated through cuttings, layering and approach grafting.

Cuttings

Softwood cuttings taken with a heel were reported to be successful in producing adventitious roots in clove (Fernie 1946). Hardwood cuttings treated with indolebutyric acid (IBA) at low concentrations (50 and 100 ppm) and high concentrations (2000 ppm) gave cent per cent rooting in Tamil Nadu, India (Chezhiyan 1996). However, Rema & Krishnamoorthy (1994) reported that hardwood, semi-hardwood and softwood cuttings from etiolated and non etiolated shoots treated with hormones failed to develop adventitious roots in the conditions prevailing in Kerala.

Air layering

Air layering has been reported on young branches in clove (Maistre 1964; Zulkifli 1986; Rema & Krishnamoorthy 1994). A success of 65 per cent was reported in Bogor, Indonesia by marcotting 1 cm diameter shoot, using a mixture of sand, soil, leaf and humus immediately after ringing. Rooting was reported in clove with hormonal treatments. IBA in combination with napthaleneacetic acid (NAA) and IAA were reported to be ideal for layering in clove with cent per cent rooting in Tamil Nadu (Chezhiyan 1996). However, studies conducted elsewhere indicated that the survival of these layers in the field was very poor (Pool *et al.* 1991) which could be attributed to the physiological condition of the marcotted shoots, the type of root produced and hardening of the layers.

These factors play an important role in field establishment and further growth of the layers.

Budding

Forket method of budding, with the bud taken from a woody stem of 1.0-1.5 cm girth was successful in clove. The success percentage could be increased by ringing the bark and excision of growing points of budwood grafts (Pool *et al.* 1992) which aids in increasing carbohydrate reserves and improving bud take. Budding was also carried out on rootstocks of related genera of *Syzygium* species. Incompatibility was reported in budding between *S. aromaticum* and 27 related species (Jarvie *et al.* 1986). The reasons for incompatability and techniques to overcome this problem need to be worked out. Standardisation of a dwarf rootstock would be ideal for obtaining short statured plants which would facilitate easy harvest since harvesting in clove is a tedious and expensive cultural operation.

Grafting

Reports are available on different methods of grafting in clove. Approach grafting on clove rootstocks (Aiyer 1960; Rema & Krishnamoorthy 1994) was the most successful method for vegetative propagation of clove. Approach grafting can be carried out thoughout the year with a maximum success of 87 per cent during September-November (Rema & Krishnamoorthy 1994). Epicotyl grafting, softwood grafting and cleft grafting were also reported to be successful in clove (Menon & Nair 1992; Rema & Krishnamoorthy 1994); however, the rate of success was very low by these methods, when compared to approach grafting.

Attempts to graft clove on related species like *E. brasiliensis* Lam., *E. uniflora* L. and *S. cumini* (L.) Skeels in Madagascar and on *E. jambolana* Lam. (syn. *S. cumini*) in India were reported. Approach grafting on inter related species were also reported between *S. aromaticum* and three other species namely, *S. muelleri, S. pycnanthum* Merr. & Perry and *Psidium guajava* L. seedlings in Indonesia (Jarvie *et al.* 1986) and on *S. cumini* in Madagascar (Dufournet & Rodriquez 1972). Cleft grafting on seedlings of *S. cumini* (Rema & Krishnamoorthy 1994), *S. fruiticosum* (Roxb.) DC., *S. lanceolatum and S. zeylanicum* (L.) DC. was successful in India (IISR 1997). Though, *P. guajava* and clove were compatible for grafting, their survival in the field was very low (May 1949). Graft survival may be correlated with quality and endogenous levels of soluble sugars, starch, C: N ratio and nitrogen content of the scion (Ding & Xi 1993).

Application of certain chemicals and hormones on the cut surface of the scion and rootstock at the time of grafting was reported to hasten graft union in certain tree crops. Dimethyl sulfoxide was reported to improve graft union in chestnut (Makhmet & Katsalap 1979). The cut surface of both rootstock and scion of clove could be treated with dimethyl sulfoxide (1%) before grafting for better graft union.

Micropropagation

Micropropagation of clove from seedling explants have been reported (Mathew & Hariharan 1990; Superman & Blake 1990; NRCS 1993); however, there are no reports on successful micropropagation of clove from mature shoot explants. Studies on micropropagation of clove are in progress at IISR, Calicut, ICRI, Myladumpara and KAU, Vellannikkara.

Cinnamon

Cinnamon (*Cinnamomum verum* Bercht & Presl.) is one of the oldest known tree spices grown in India and was introduced from Sri Lanka. The dried inner bark is the product of commerce. Leaf and bark oil of cinnamon are also commercially important.

Cinnamon is commonly propagated though seeds. The viability of seeds is lost when sowing is delayed and maximum germination is obtained when the seeds are sown immediately after harvest. Sowing of seeds on the third day after harvest resulted in about 94 per cent germination whereas the viability was completely lost after 5 weeks of storage (Kannan & Balakrishnan 1967).

Cinnamon is a cross pollinated crop (Joseph 1981) and wide variability has been observed in yield (Ponnuswami *et al.* 1982; Krishnamoorthy *et al.* 1992a), quality of produce (Krishnamoorthy *et al.* 1988), oil content (Krishnamoorthy *et al.* 1991a; Paul & Sahoo 1993) and other morphological characters in the seedling progenies (Krishnamoorthy *et al.* 1992a). Cinnamon being cross pollinated, vegetative propagation is necessary for producing uniformly high yielding populations and for propagating elite lines. Reports on vegetative propagation indicate that it could be propagated easily through cuttings and layering. No other conventional method of vegetative propagation has been reported in cinnamon.

Cuttings

Adventitious root formation in cinnamon is relatively easy, when compared to other tree spices reviewed in this paper. Single noded cuttings with 1 or 2 leaves could be made to root within 40 days under humid conditions (CPCRI 1985). Rooting could also be enhanced by the use of growth regulators. IBA and IAA @ 2000 ppm was effective for rooting of terminal shoots with 73 and 65 per cent success, respectively (Rema & Krishnamoorthy 1993). Softwood cuttings treated with NAA 5000 ppm resulted in 22.5 per cent rooting whereas hardwood cuttings treated with IBA 2500 resulted in 45.0 per cent rooting (Vadivel *et al.* 1981). The rooting could be further increased by hormonal treatment of the etiolated cuttings. Etiolated cuttings treated with IAA 2000 ppm resulted in 82 per cent success (NRCS 1990).

Wide variability exists in the rooting response of various cinnamon lines (Rema & Krishnamoorthy 1993). Similar variations in rooting among cultivars have also been reported in other tree crops (Eccher & Annoni 1984). Variation in rooting during different seasons and among different lines could be associated with the endogenous level of auxins, reducing and non reducing sugars, nitrogen, carbohydrate, C:N ratio, phenols, etc. (Purushotham *et al.* 1986; IISR 1996).

Air layering

Semi-hardwood was found to be ideal for air layering in cinnamon (Ranaware *et al.* 1994; Rema & Krishnamoorthy 1993). Air layering of cinnamon using gallic acid (100 ppm), a phenolic compound, resulted in 80 per cent rooting (Banerjee *et al.* 1982). Rooting could also be obtained in non girdled shoots treated with NAA 2500 ppm (Hegde *et al.* 1989) or in combination with IBA 1000 ppm (Bhat *et al.* 1989). Application of IBA 3000 ppm resulted in 70 per cent rooting in semi-hardwood cuttings (NRCS 1990). Girdling enhances physiological activity which is manifested by increased starch and IAA in the girdled region (Poll *et al.* 1991). Various rooting materials can be used for layering depending upon their availability and capacity to retain moisture. Evaluation of different rooting media for layering indicated that sphagnum moss was the most ideal (89 per cent success) followed by soil (Ranaware *et al.* 1994). Seasonal variation was also observed in rooting of air layers. A rooting of 88 per cent was observed in July followed by 65 per cent in June in Maharashtra with no rooting during January and February (Ranaware *et al.* 1995)

Micropropagation

Clonal propagation of cinnamon through seedling explants (Rai & Chandra 1987) and mature tissues (IISR 1996) have been reported. Woody Plants Medium (WPM) supplemented with cytokinins (BAP 3 mgl^{-1}+ Kin 1 mgl^{-1}) and auxins (IBA 0.5 mgl^{-1} + NAA 0.5 mgl^{-1}) favoured multiple shoot induction and root initiation, respectively.

Cassia

Chinese cassia (*Cinnamomum aromaticum* Nees) is closely related to *C. verum*, the true cinnamon. As in cinnamon, the inner bark is the product of commerce in cassia. Cassia bark dif-fers from that of true cinnamon in its aroma, pungency and texture. Cassia is cultivated mainly in China and is gene-rally propagated through seeds. Wide variability is observed in seedling proge-nies of cassia. Very few trees of cassia are available in India and clonal multiplication of this economically important cross pollinated crop is necessary for producing good quality planting material.

Cuttings

Rooting of semi-hardwood cuttings of cassia was achieved by treating with IBA (500, 1000, 2000 ppm) (IISR 1996). High variability was observed in the rooting of different lines of cassia. The variability in rooting may probably be due to the differences in the essential oil contents in the stem and the reasons attributed in cinnamon.

Air layering

Air layering in 2 year old plants of cassia has been reported with 88 and 50 per cent rooting during July and November respectively, with 100 per cent establishment in the field (Krishnamoorthy & Rema 1994a).

Micropropagation

Micropropagation of cassia has been reported with a multiplication rate of 5-6 shoots in a preliminary trial. WPM supplemented with cytokinins (BAP 3 mgl^{-1}+ Kin 1 mgl^{-1}) induced multiple shoots from nodal segments of mature trees (IISR 1996).

Allspice

Allspice (*Pimenta dioica* (L.) Merr.) also known as Jamaican pepper, is indigenous to West Indies. The flavour of allspice resembles a mixture of cinnamon, clove, nutmeg and black pepper. The dried unripe but mature berries of *P. dioica* is the spice of commerce. The leaves are aromatic and are used in the preparation of essential oil. The berries are used for the production of essential oil and oleoresin.

Allspice is commonly propagated through seeds. Allspice seeds loose their viability soon after harvest but their viability can be maintained at 50 per cent for 9 weeks by storing them at 21-30°C (Devadas & Manomohandas 1988). Allspice is polygamodioecious and it is difficult to identify the functional male and female trees till they flower and hence clonal propagation is necessary to obtain uniformly high yielding trees. Though reports are available on vegetative propagation of allspice, none of the methods are commercially feasible since the success rate is too low.

Cuttings

Cuttings of allspice could be rooted in 7 to 8 months. Though semi-hardwood and terminal shoots of 15-20 cm can be rooted with hormonal application (IBA 500 ppm), the rooting percentage is low (IISR 1997). Juvenile cuttings of allspice can be rooted by application of Quicroot, a commercial rooting hormone with 50 per cent success (NRCS 1993). The physiological status of the cuttings plays a major role in enhancing the rooting percentage and accelerating root growth in juvenile plants (Hartman & Kester 1972; Blomme & Vanwezer 1986).

Difficulty in root formation in cuttings of hard to root plants are mainly due to lack of activity of one or more of the internal co-factors although natural hormones may or may not be present in adequate amounts necessary for root formation. Hence application of auxins alone may give little or no response owing to the absence of one or more of the root promoting factors in the stem cuttings. Etiolation and blanching of stock plants prior to taking cuttings, application of adjuvants like charcoal, ascorbic acid etc. to the cut surface to remove phenols and other compounds which inhibit rooting were reported to be successful in many woody plants (Maynard & Bassuk 1987). These methods could also be experimented in allspice to produce adventitious roots.

Air layering

Layering of softwood and semi-hardwood shoots with hormones (IBA 4000 ppm + NAA 4000 ppm) aided in rooting of allspice (IISR 1995). Studies on air layering in Maharashtra indicated that rooting is a slow process taking 18-28 months and January was the best season for the same (Haldanker *et al.* 1995)

Stooling

Stooling, which is successfully practiced in a related genus namely, *P. guajava* was effective in allspice. Detopping mature shoots and application of rooting hormone (IBA 500 ppm) on the newly formed shoots after removal of the bark and mounting the shoots with pure sand helped in rooting (IISR 1994). However this is a cumbersome procedure when compared to other methods of propagation.

Budding

Propagation of allspice through chip budding is also possible though the percentage of success is low (30 per cent) (Chapman 1967).

Grafting

Approach grafting of allspice was reported with 90 per cent success in Jamaica (Chapman 1967). However approach grafting on its own rootstock or on related species like *S. jambolana* was not successful in India. The effect of environment, rootstock, disbudding, growth regulators, anti tranpirants etc. on grafting could also be studied.

Micropropagation

Work on micropropagation of allspice is in progress at IISR, Calicut.

Cambogia and Kokam

Cambogia (*Garcinia gummi-gutta* (L.) Robs) (syn. *G. cambogia* (Gaertn) Desr.) is an evergreen tree grown for its dried rind (pericarp of the under ripe fruits) which is a popular spice used as a substitute for tamarind in cookery. The dried rind of *G. indica* (Thouars) Choisy known popularly as kokam, a related species of *G. gummi-gutta,* is also used as a spice in cookery.

Cambogia and kokam are dioecious with the male and female flowers found in separate plants. These species thrive well in the evergreen forests of Konkan, stretching southwards to the Kerala Coast and Western Ghats up to 180 m in the Nilgiris. Cambogia and kokam are commonly propagated through seeds. Seeds of *G. gummi-gutta* are dormant and take a long time for germination. However, soaking the seeds without the seed coat in GA (500 ppm) for 12 h increases germination (Nazeema 1992). The seedling takes 6 to 7 years for flowering and the sex of the trees is unknown till it flowers. Vegetative propagation is the only method for propagation of high yielding clones, with an added advantage of early flowering and short stature. Softwood grafting is the only successful method available for vegetative propagation of *G. indica* and *G. gummi-gutta*. Layering was not successful in these two species (George *et al.* 1994). The authors presume that the yellow resin exudates from the stem would have interfered with the production of adventitious roots. Phenolic compounds are reported to act as rooting co-factors or rooting synergists in root initiation of cuttings. Compounds like ferulic acid and p-hydroxybenzoic acid were reported to be successful in lemon (Debnath *et al.* 1986) which could also be probably successful with garcinia. The ability of anti-gibberlin like growth regulators could be tested to promote adventitious root formation in many of the difficult to root crops. Paclobutrazole is one such chemical which is reported to aid in adventitious root production.

Softwood grafting

Softwood grafting was reported to be ideal for propagation of *G. gummi-gutta* (Nazeema 1992; Nazeema *et al.* 1993; George *et al.* 1994) and *G. indica* (Oscar 1983; Haldanker *et al.* 1992). Softwood grafting could be carried out in June on 18 year old *G. gummi-gutta* rootstock using 9 month old scion of 6-8 cm length (Nazeema 1992; Nazeema *et al.* 1993). Grafting can be done throughout the year in *G. indica* but October is the best period (93 per cent success) with 86 per cent survival in the field (Haldanker *et al.* 1991). Various rootstocks like *G. indica, G. gummi-gutta* and *G. tinctoria* (DC) E. F. Wight (Nazeema 1992) could be used for softwood grafting of *G. gummi-gutta*. The effect of rootstocks on yield, height of the plant and flowering behavoiur need to be studied.

Micropropagation

Work on micropropagation of *Garcinia* spp. is in progress at ICRI, Myladumpara.

Tamarind

Tamarind (*Tamarindus indica* L.) is a hardy tree, distributed throughout the plains and sub Himalayan tracts of India and is valued for its edible fruits and wood. The fruit pulp is the main product of commerce and is used for culinary purpose in India as a spice. Tamarind is commonly propagated through seeds. Being a cross pollinated crop, it does not breed true resulting in variations in size and quality of fruits and necessitates clonal propagation of elite trees. Various vegetative propagation methods are reported in tamarind and high yielding varieties are distributed through vegetative propagation.

Cuttings

Tamarind is dfficult to root through cuttings. Etiolated semi-hardwood cuttings treated with IBA gave a very low rooting (19 per cent). Rooting of cutings was slightly higher when rooted in mist chamber after hormonal treatment with IBA (Navaneethan *et al.* 1990). Rooting was also reported when IBA and NAA combinations were used (Samiullah *et al.* 1993). However, this method of propagation is not commercially viable for production of planting material. Pre-rooting requirements of the cuttings are poorly understood. However, treating the cuttings with an antioxidant would probably help in increased rooting by protecting the natural hormones from oxidation.

Air layering

Tamarind can be successfully air layered (Gowda 1983; Samiullah *et al.* 1993). IBA alone or a combination of IBA and NAA (2500 ppm) gave 90 per cent success. The ideal season for layering was June-July using wet sphagnum moss. Roots developed in 80 to 85 days when 8-10 month old shoots of pencil thickness were air layered. A combination of etiolation in April followed by IBA 1000 ppm applied in May was also successful with about 75 per cent rooting (Navaneethan *et al.* 1991).

Budding

Budding was reported to be an ideal method for vegetative propagation in tamarind. Patch budding and modified ring budding on 9 month old rootstock of *T. indica* were reported with 96 and 94 per cent success, respectively (Pathak *et al.* 1992).

Grafting

Approach grafting has been attempted in tamarind with 60-90 per cent success (Swaminath & Ravindran 1989). Softwood grafting and veneer grafting were also reported in tamarind with 68 and 49 per cent success, respectively (Purushotham & Rao 1990). Tamarind is currently propagated commercially through approach grafting on its own rootstock.

Micropropagation

Micropropagation of tamarind was reported from nodal explants of mature trees (Venkateswarlu & Mukhopadhyaya 1995). Direct organogenesis from epicotyl and hypocotyl segments of 12 day old seedling has also been achieved (Gulati 1995).

Pomegranate

Pomegranate (*Punica granatum* L.) is one of the favourite table fruits cultivated in tropical and subtropical regions and is generally known as a fruit crop. However, the dried seed along with the aril is used as a spice for garnishing culinary preparations and the spice is commercially marketed as *anardana*, the source of which is mostly from trees growing wild in parts of Jammu, Himachal Pradesh and Punjab in India. Pomegranate can be easily raised from seeds. Published reports on vegetative propagation of this tree (wild form) are meagre. Nevertheless the methods applicable to the cultivated from is also presumably suited to the wild form used as spice. Hence the review is mainly on the cultivated form.

Cuttings

Hardwood cuttings, 25-30 cm long from previous season's growth are used for propagation of pomegranate. Since auxins improve rooting and survival of cuttings in tree crops, hormones alone or in combination with synergists are helpful in better rooting of cuttings. Pre-treating hardwood cuttings with auxins and auxin synergists like p-hydroxy benzoic acid, p-coumaric acid and ferulic acid are reported to promote auxin induced rooting in trees. Reddy & Ramalakshmi (1993) reported 73 per cent rooting with profuse root system when a combination of auxin and auxin synergist (IBA 200 ppm + p-hydroxy - benzoic acid) were applied to hardwood cuttings. February and October were ideal for rooting of cuttings (Navaneethan 1964).

Air layering

Pomegranate could also be propagated through air layering. Pre-girdled and etiolated shoots form an ideal material for air layering. Such air layered shoots resulted in 85 and 95 per cent rooting during May and July, respectively (Hore & Sen 1994). Treating the shoots with p-hydroxybenzoic acid (1000 ppm) gave cent per cent rooting in air layers during July (Hore & Sen 1995).

Micropropagation

Micropropagation of pomegranate through shoot tip cultures was reported on Lloyd and Mc Crown Woody Plants Medium. Micropropagated plantlets were transferred to rooting medium with 80 per cent success (Mahishni *et al.* 1991).

Conclusion

Tree spices can be propagated vegetatively by several methods. However, the commercial viability of these methods depend upon, need for specialised equipments, multiplication rate, labour requirement, uniformity of planting material obtained, establishment in the field, pre-bearing period, etc. Epicotyl grafting can be adopted for commercial multiplication of nutmeg; approach grafting for clove and tamarind; semi-hardwood cuttings for cinnamon and cassia; air layering in cinnamon, cassia, clove, pomegranate and tamarind and softwood grafting in kokam and cambogia. Even though commercial methods are available for propagation of these crops, the optimum conditions required for their propagation need to be worked out for high yielding lines that have been identified, since considerable variability exists in their rate of success even within the same species. Though work on micropropagation has been initiated in these group of crops, no success has been achieved for their commercial adoption. Work on standardising micropropagation protocols for the species used as rootstocks also needs to be initiated since *in vitro* grafting is a technique which can be adopted for quick results. Crops like clove, nutmeg, kokam and cambogia are difficult to root by cuttings or layering. Investigations need to be undertaken to study the role of structural or biochemical barriers that may inhibit the production of adventitious roots in these crops. The reasons for incompatibility in grafting and budding especially within related species/genera is almost unknown in these crops and techniques to overcome incompatibility has to be standardised. Vesicular arbuscular mycorrhizae (VAM) have been reported to enhance root production and growth in many fruit trees. VAM could also be utilised in tree spices to attain sufficient thickness of the rootstock within a short period for budding and grafting. With the advancement of molecular biology, understanding the mechanisms which trigger root formation in these crops would also form an interesting area for future research. Very little information is available on the performance of most of the vegetatively propagated tree spices in the field. Information on this aspect has also to be generated to exploit the full potential of vegetative propagation techniques.

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