STANDARDISATION OF SOFTWOOD AND EPICOTYL GRAFTING IN *Garcinia cambogia* Desr.

By

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THESIS

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DECLARATION

I hereby declare that this thesis entitled "Standardisation of softwood and epicotyl grafting in *Garcinia cambogia* Desr." is a bonafide record of research work done by me during the course of research and this thesis has not previously formed the basis for award of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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Certified that this thesis entitled **"Standardisation of softwood and epicotyl grafting in *Garcinia cambogia* Desr"**. is a record of research work done independently by **Miss Nazeema, K.K.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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We, the undersigned, members of the Advisory Committee of **Miss Nazeema, K.K.**, a candidate for the degree of Master of Science in Horticulture agree that the thesis entitled **"Standardisation of softwood and epicotyl grafting in *Garcinia cambogia* Desr"**. may be submitted by Miss Nazeema, K.K. in partial fulfilment of the requirement for the degree.

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INTRODUCTION

Garcinia cambogia, named by the French Botanist, Desrousseaux and referred to, in vernacular, as *Kodumpuli* , is a medium sized tree with rounded crown, horizontal or drooping branches and dark green shiny, elliptical or obovate leaves. The tree is found commonly in the evergreen forests of Western Ghats from Konkan southwards to Travancore and in Shola districts of Nilgiris upto an elevation of 6000 ft.

The tree occupies the backyards of Kerala's homesteads more often as one among the miscellaneous tree crops. The tree is dioecious in nature with male and hermaphrodite plants separate (Plates 1 and 2). It flowers during the hot season and fruits and seeds become mature during the rainy season (Plates 3 and 4). The fruits have a unique use in the State. In Kerala, it is being exclusively preferred in cuisine involving fish. The processed rind is also used as a condiment for flavouring curries in place of tamarind or lime. The fruit is rich in acids and possesses marked antiseptic properties. The seeds of the fruits contain edible fat resembling kokam butter from G. indica. The tree yields a transluscent yellow resin (gamboge) which forms an yellow varnish with terpentine. A decoction of the fruit rind is given in rheumatism. It is also employed in veterinary medicine as a rinse for diseases of mouth in cattle.

Plate 1 A female tree of *Garcinia cambogia*

Plate 2 A male tree of *Garcinia cambogia*

Plate 3 Ripe fruits of _Garcinia_ _cambogia_

Plate 4 Extracted seeds of _Garcinia_ _cambogia_

A. Seeds with seed coat

B Seeds without seed coat


A
B

Now-a-days, pressure on land has pushed *Kodumpuli* and many other useful plants to the backyard of our agriculture. Further, variation in yield due to repeated seed propagation, the dense shade of foliage and the belief that it is a heavy feeder tend to make farmers regard this crop as a liability. However opportunities are there to create an ideal plant type with short stature, year round fruiting habit and desirable fruit characters like edible pulp and seedlessness which may bring about a radical change in the cultivation of *Kodumpuli* Among them, standardisation of vegetative propagation is in the nearest reach which will offset the ill-effects of repeated seed propagation to some extent. In order to raise the rootstocks for vegetative propagation seeds are of utmost need. The lacuna in seed propagation is the long resting period of seeds before germination. Normally, the seeds take a long period of nine to ten months after sowing, for germination. It will be of great help to the plant propagators, if their long period of rest could be overcome by some viable means. However only little work has been reported so far, in these regards. Hence there exists a need to look after the studies concerning the formulations of vegetative methods of propagation in this crop. Hence the present study was undertaken in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period of 1990-92 with the following objectives.

(i) To study the effect of seed coat and growth regulator treatments on germination of G. *cambogia* seeds.

(ii) To standardise the type and age of rootstock for softwood, epicotyl and double grafting.

(iii) To standardise the days required for the precuring of scion/to study the effect of type and age of scion wood on the success of grafting.

(iv) To study the effect of season on the success of grafting.

(v) To study the anatomy of graft union.

Review of Literature

REVIEW OF LITERATURE

Kodumpuli, Garcinia cambogia, belonging to the family Guttiferae, though an important minor fruit of Kerala's home-steads has not been exploited fully. The dioecious nature of the crop deprives the farmers of its commercial cultivation. *Kodumpuli* being seed propagated, there exists a lot of variation among the seedlings with respect to its yield and quality. Adoption of vegetative propagation is a remedy for these difficulties. Easy, simple and economic vegetative propagation methods can be adopted for the perpetuation of high yielding female trees. This will also avoid the waste incurred towards the maintenance of the male trees till the flowering stage. Unfortunately, very little work has been done in the sexual and asexual methods of propagation, particularly in G. cambogia and generally in the related species and other genera of the family, Guttiferae. This chapter tries to enlighten the attempts made by various scientists in the field of sexual and asexual propagation with special reference to epicotyl and softwood grafting and the factors influencing the success of these two methods of grafting in the close relatives of G. cambogia and the other major tropical fruit crops.

2.1 Sexual propagation

In most of the tropical fruits, though the methods of vegetative propagation have been standardised, seed propagation is also resorted to. Eventhough the seedling plants are not commonly made use of for commercial cultivation, they have a major role to function as rootstocks in vegetative propagation.

Mangosteen (Garcinia mangostana), a close relative of *Kodumpuli* is a seed propagated crop. Ironically, mangosteen has no true seed. It is parthenogenetic in nature and the plants raised from seeds are exactly like the mother tree (Singh et al., 1963 and Dassanayake and Perera, 1988). According to Gonzalez and Anoos (1951) fresh mangosteen seeds had a germination rate of 85 per cent and the average germination period was 19.5 days. They also observed that only 50 per cent of the freshly gathered seeds packed in moist sphagnum moss in tightly closed containers were viable after two months. Of unpacked seeds, or seeds packed in ground charcoal, only 22 per cent were viable after 15 days. Winters and Rodriguez (1953) reported that mangosteen seeds stored for one week, either dry or moist at 50°F failed to germinate. Storage at room temperature in moist charcoal dust gave the highest percentage of germination but was only slightly better than storage in moist peat moss. Both the treatments preserved viability for seven to eight weeks. Seeds stored in the fruits showed delayed germination on sowing. The viability of air dried seeds was lost after four weeks. Seeds stored in the desiccator over calcium chloride for even one week failed to germinate. Shanmugavelu *et al*. (1987) stated that mangosteen seeds gave only 70 per cent germination when sown within five days of extraction. Seeds free of pulp recorded 20 per cent increase in germination over those sown with the pulp intact.

Singh (1951) reported that mango (*Mangifera indica*) stones usually take 30 days for germination. Simao (1960) noticed 36 per cent germination for mango stones of two varieties studied. Giri (1966) observed that the percentage germination of mango seeds extracted from fruits with a soft pulp was significantly higher (76 per cent) than that of seeds from firm fruits (54 per cent).

In seed germination studies of cashew, (*Anacardium occidentale*) Rao *et al*. (1957) found that viability of cashew nuts remained over 90 per cent for 7 months and reduced to zero in 14 months. Time of germination was 13 to 14 days for the first eight months increasing upto 22 days for aged seeds. Pushpalatha *et al*. (1991a) observed that there was no difference in the germination pattern between seeds sown in polythene bags and in the field directly. In both the cases seeds took 15 days for germination.

Guava (*Psidium guajava*) is propagated mostly by vegetative methods. For raising rootstocks, seed propagation is followed. Normally, fully matured fresh seeds are used for sowing. Kumar et al. (1991) obtained 62 per cent germination in guava seeds and it took 25 to 30 days for completion of germination.

Raman (1956) studied seed germination of several types of jack fruit (Artocarpus heterophyllus) and concluded that germination percentage after one month of sowing ranged from 57 to 95. Sinha and Sinha (1968) recorded 50 per cent germination in jack fruit seeds.

Kannan (1971) observed a very wide variation in the number of days taken for germination of nutmeg seeds and it ranged from 27 to 100 days. Stray cases of germination was noticed even after 150 days. Studies on seed viability showed that seeds stored in polythene bags or moss remained viable for 15 days and it took about 60 to 120 days for germination (Philip, 1974). Nair et al. (1977) found that germination took place in 60 to 90 days. Ilyas (1978) opined that maximum seed germination was 45 to 90 days and germination would be as high as 98 per cent if seeds were sown immediately after extraction. According to Mathew (1979) nutmeg seeds showed 65 per cent germination when sown during the month of June and the number of days taken for germination was 55.63.

Sriram (1977) reported 52 per cent germination upto 58 days of sowing in clove (Syzygium aromaticum) seeds.

According to Ilyas (1978) germination of cinnamon (*Cinnamomum zeylanicum*) seeds started in about 20 days of sowing.

2.1.1 Factors affecting seed germination

2.1.1.1 Effect of seed coat on seed germination

The effect of removal of seed coat on germination was studied in mango by Simão (1960). According to him germination was enhanced and germination percentage was increased by dehusking treatment. He obtained 77, 52 and 36 per cent germination with husked stones, stones with the husk cut lightly at the stalk and unhusked stones respectively. Subramanya and Reddy (1989) also obtained early germination of mango stones by the removal of seed coat before sowing. The use of seeds with cracked seed coat also resulted in early germination. The final germination percentage was also considerably increased by these treatments compared to the intact seeds.

According to Ilyas (1978), in clove, dehusked seeds started germination on 16 days after sowing and by the 46th day 88 per cent of them germinated whereas unhusked seeds germinated 27 days after sowing and by the 58th day only 48 to 52 per cent of them germinated.

2.1.1.2 Effect of gibberellic acid on seed germination

The stimulatory effect of applied gibberellic acid on germination of seeds has been widely accepted (Leopold, 1979; Hartmann and Kester, 1989).

In cashew, Shanmugavelu (1985) recommended seed treatment with GA_3 for 48 h at 100 to 500 ppm concentration to enhance germination upto 100 per cent. The treatment also increased the root and shoot growth of seedlings.

In guava, pre-sowing treatment with GA_3 100 ppm improved seed germination to 60 per cent whereas seeds soaked in water recorded 55 per cent and dry seeds recorded 46 per cent germination respectively (Kumar *et al.*, 1991).

Farooqui *et al.* (1971) reported that GA at 25 and 50 ppm concentration enhanced germination and improved germination percentage of sapota (*Achras sapota*) seeds.

Duarte *et al.* (1974) noticed that when cherimoya (*Annona cherimolia*) seeds were treated with GA at 10,000 ppm concentration, germination percentage was significantly increased. If treated with 1000 ppm GA it increased seedling growth.

In nutmeg, seed treatment with GA was found to improve seed germination. Mathew (1979) obtained 75 per cent germination when the seeds were soaked for 24 h in 200 ppm GA.

2.2 Asexual propagation

In mangosteen, one of the most popular members of the family, Guttiferae, considerable attention has been bestowed in the field of vegetative propagation at different parts of the world. Numerous experiments have been conducted to develop stronger, more rapidly growing small mangosteen trees and to reduce the time for fruit production. The methods like cutting, layering, budding and grafting have been reported to be failure or with little success. No method has yet been found that has any real advantage over seed propagation (Anon, 1954, 1956; Shanmugavelu et al., 1987).

Trials conducted at District Agricultural Farm, Thaliparamba revealed that cuttings of mangosteen remain alive for nearly 8 months in beds and stray cuttings do produce one or two weak roots which however fail to survive (Naik, 1948). Hayes (1957) opined that propagation of mangosteen through cutting is fairly successful. Singh et al. (1963) conducted trials on propagation using cuttings at Kallar and Burliar Fruit Research Station and reported that propagation of mangosteen through rooting of its own shoots is feasible, but needs confirmation on a commercial scale.

Layering is not a feasible method of propagation in mangosteen (Naik, 1948; Krishnamurthy and Rao, 1962). Gonzalez and Anoos (1951) also observed that marcotting trials in mangosteen invariably failed.

Naik (1944) opined that budding in mangosteen was less encouraging as the bud take was poor and even after showing signs of union with rootstock they required long time to sprout. But budding was found to be a feasible method of propagation in Manila (Singh, 1986).

Among the various grafting methods, inarching and side grafting have been studied widely. Here also, variable results have been reported by different workers. Naik (1944) proved that side grafting mangosteen on the same seedling rootstock was easy and capable of producing almost cent per cent success. However, the successful side grafts uniformly failed to make any appreciable growth in orchards and eventually died. According to Naik (1948) inarching in mangosteen gave 60 per cent success. Gonzalez and Anoos (1951) noted that grafting of mangosteen with *Garcinia kydia* and *G. morella* rootstocks gave only 10 to 12 per cent success. Thayer (1961) also got some success with *G. tinctoria* and *G. spicata* rootstocks. Recently, softwood grafting by wedge method on mangosteen seedling rootstocks of two to four years age gave 90 per cent success as reported by Dassanayake and Perera (1988).

Kokam (*Garcinia indica*) is a popular spice crop in the coastal parts of Maharashtra and Karnataka used mainly for the extraction of kokam butter which is consumed as an edible fat.

As in the case of *G. cambogia*, in kokam also, the dioecious nature of the crop is a major limitation of its systematic cultivation. Oscar (1983) suggested that this problem could be replaced by maintaining the appropriate ratio of male and female plants by propagation through softwood grafting. He obtained 86 per cent success in this method. Hadangar *et al.* (1987) reported *in situ* softwood grafting as a simple and easily adoptable method for kokam propagation with a maximum success of 90 per cent. Hadangar *et al.* (1991) also showed that softwood grafting could be performed in October for getting the best results in Maharashtra.

Mammey apple (*Mammea americana*), another member of the family Guttiferae, is a native of Tropical America and West Indies. The commercial part of this tree is its fruit, though not popular like mangosteen. In a trial to find out one successful vegetative propagation in mammey apple, Krochmal (1970) found that wedge grafting on the same seedling rootstocks was successful. In another study conducted by Arriaga and Maldonaldo (1976), it was concluded that the best results were obtained with side grafting on nine months old rootstocks (55.7 per cent take) followed by patch budding (35.9 per cent take) while tip grafting was unsuccessful.

2.2.1 Effect of type of rootstocks on the success of grafting

In vegetative propagation methods like budding and grafting, the rootstocks play an important role in the graft or bud union. Only compatible rootstocks form successful union. Incompatible union may survive for some years but they eventually fail showing off the signs of incompatibility (Hartmann and Kester, 1989). So selection of rootstocks in budding and grafting studies has got utmost importance.

Popenoe (1920) described the rootstock trials for mangosteen carried out in Centeral America, Malaya etc. According to him, though mangosteen unites with about 20 species of the genus Garcinia, only a few could be recommended as promising stock plants. Among the two other genera of the same family tried, Calophyllum calaba and C. inophyllum formed imperfect union while one to three years old Platonia insignis seedlings were found to be very promising rootstocks. According to Naik (1948) also C. inophyllum is an incompatible rootstock for mangosteen. He also opined that inarching mangosteen on G. tinctoria and G. speciosa had given 60 per cent success. The grafts on G. tinctoria rootstocks aged more than four years appeared to be the most promising ones. In a rootstock trial conducted by Gonzalez and Anoos (1951) it was proved that mangosteen did not unite with rootstocks of Calophyllum spp., Cratoxylon spp. or Rheedia edulis. Among the 13 species of the genus Garcinia tested, G. kydia and G. morella though showed compatibility, the percentage of union was 10 and 12 respectively. However, Thayer (1961) showed that mangosteen could be successfully grafted on G. spicata, G. tinctoria, Rheedia aristata and Clusia rosea.

Dassanayake and Perera (1987) got 90 per cent success in mangosteen grafting when the same species was used as rootstocks. In the case of mammey apple and kokam also, when the same species were employed as rootstocks, the best results were obtained (Arriaga and Maldonaldo, 1976; Hadangar et al., 1991).

In a study conducted by Richards (1943) in sapota to find out the best rootstocks for budding and grafting techniques, it was revealed that sapota seedlings themselves were the best ones. Bassia longifolia was also found to be compatible while Mimusops hexandra proved to be an incompatible rootstock. However, the slow growth of sapota seedlings is a limiting factor to use it as a rootstock. So another study was conducted by Gonzalez and Fabella (1952) which disclosed that Palaquim foxworthy, P. merrillii, P. philippense and Madhuca betis showed high degree of compatibility with the sapota scion. Trials conducted in Kerala by Nambiar (1954) in the Agricultural Research Station, Thaliparamba revealed that sapota grafted on Mimusops hexandra had made considerably more growth than trees grafted on sapota seedlings themselves. Grafts on Bassia longifolia made growth intermediate between these two combinations, but casualties were more and graft union showed pronounced distortion. Attempts to graft sapota to Mimusops elengi invariably failed. Kulwal et al. (1985) reported that Calocarpum sapota and Manilkara hexandra could be successfully used as rootstocks for sapota. Bhuva et al. (1990) showed that when M. hexandra was used as rootstocks for sapota, a maximum of 90 per cent survival was obtained with inarched grafts.

Jack, when propagated on the same species and on Artocarpus hirsuta rootstocks by inarching, the growth on the latter was poor. The graft union distorted and many of the grafts died within two years of planting (Kannan and Nair, 1960).

Khan and Rao (1953) studied the effects of various rootstocks on the vegetative propagation of custard apple (Annona squamosa). They proved that Annona reticulata could be more efficiently employed as rootstocks for custard apple than custard apple rootstocks. Eventhough both the rootstocks gave cent per cent take, the former showed better stock and scion girth, height and yield. A. muricata and A. palustris proved to be incompatible rootstocks. According to Iglesiaz and Sanchez (1985) A. muricata proved to be the best rootstock for side grafting and patch budding of the same scion. The percentage take was recorded as 47.5 and 82.5 respectively.

Sundararaj and Varadarajan (1956) reported that when nutmeg scions were grafted on *Myristica malabarica* and *M. beddomii* rootstocks 60 per cent success was obtained. Flach (1966) and Rasalam (1978) claimed cent per cent success in approach grafting on seedlings of cultivated and wild species of nutmeg. In clove, for vegetative propagation works, *Euginea cordata* and *Psidium guajava* were found to be promising rootstocks (Sriram, 1977).

2.2.2 Effect of age of rootstock on success of grafting

2.2.2.1 Epicotyl grafting

Epicotyl grafting was suggested first for the vegetative propagation of fruit trees by Verma (1941). He described it as a novel method of mango graft. Later in many crops it was recommended as an easy and economic method for vegetative propagation. Gunjate and Limaye (1977) reported 84 per cent success with immature, four to seven days old rootstocks in stone grafting of mango under Konkan conditions. According to Dhakal (1979), less than two weeks old seedlings were more suitable for stone grafting in mango. He obtained 60 and 50 per cent success on one and two weeks old seedlings respectively. Dengale (1980) also stated that one week old seedlings were the best for stone grafting in mango which accounted 73.3 per cent success. Singh and Sreevastava (1981) tried stone grafting using two to ten days old seedlings and obtained the highest percentage of success (85 per cent) with five days old rootstocks followed by four days old rootstocks (80 per cent). Gunjate <u>et</u> <u>al</u>. (1982) found that less than two weeks old seedlings with coppery red colour were the best for stone grafting. He obtained the highest percentage of success with one week old rootstock (60 per cent) followed by two weeks old ones (58 per cent). Desai and Patil (1984) revealed that seven days old seedlings were the best rootstocks for epicotyl grafting in mango under green house conditions which gave 70 per cent success. Dhungana (1984) standardised the age of rootstocks for epicotyl grafting in mango under Kerala conditions. He stated that the highest survival was obtained with five days old stocks. He also observed that there was a negative correlation between the age of stocks and survival of grafts. The survival rate was noted as 61.33, 50.00 and 32.00 per cent when the age of rootstocks were 5, 10 and 15 days respectively. Chakrabarthy and Sadhu (1984) stated that regardless of the age of the scion, five days old rootstocks gave more success which decreased with an increase in age. Patil and Patil (1985) found that initial sprouting in epicotyl grafting was more in the case of six days old stocks and seven days defoliation but height and number of leaves of the plant were the highest in four days old stock. Devadhas and Pappiah (1988) found that grafting mango on seven days old rootstocks gave the highest success which was accounted as 75 per cent in

Bangalora and 40 per cent in Neelum. Gupta et al. (1988) also found that when the age of rootstock was ten days, the grafts yielded 50 to 55 per cent success under Jammu conditions. Among the various methods, splice grafting gave maximum success followed by side grafting (46 per cent) and veneer grafting (40 per cent).

In cashew, Bhandary et al. (1974) recommended that epicotyl grafting could be successfully done on 21 days old cashew seedlings. Harmekar (1980) reported that four to eight weeks old seedlings were suitable for stone grafting in cashew Nagabhushanam (1982) suggested the use of 15 days old rootstocks for stone grafting. Sawke (1983) reported that about ten days old cashew seedlings were the best for epicotyl grafting. Shylaja (1984) proved that apparently there was no difference in the percentage success of stone grafts prepared from ten days and five days old rootstocks. According to Konkar and Das (1985) five to seven days old rootstocks were the best for epicotyl grafting in cashew. A modified method of epicotyl grafting had been standardised by Sheshadri and Rao (1985) in cashew. They recommended that instead of normal beheading of the stock plant, if only the top of the plant was removed retaining two leaves the presence of leaves alone augmented the percentage success of the grafts.

2.2.2.2 Softwood grafting

According to Dassanayake and Perera (1988) there was more than 90 per cent success in softwood grafting of mangosteen when 2 to 2½ year old mangosteen rootstocks were used. But the success was only 34 per cent with three to four years old rootstocks. This showed that the age of rootstock played the pivotal role in deciding the successful establishment of graft.

Hadangar *et al.* (1987) stated that for softwood grafting in kokam, once the rootstock attained a graftable size (which took about 22 weeks) its age or presence of leaves did not influence the success of grafting. This method was found to give a maximum of 90 per cent success.

Prof. R.S. Amin was the first scientist to try softwood grafting in mango at Anand (Gujarat) with great success. Amin (1978a) described *in situ* softwood grafting in mango as a new method of propagation. He stated that the method could be adopted on seedlings of one or more than one year's age. He obtained cent per cent success in this method. Patil *et al.* (1983) found that seedling at four leaf stage was the best for softwood grafting in mango. Singh *et al.* (1984) reported a mean success of 70 per cent by softwood grafting in mango when one year old seedlings were used as rootstocks. Ghandhoke and Joshi (1987) reported flush grafting method for mango propagation in which they used 30 to 40 days old rootstocks. Success percentage was reported to be 90. Reddy and Melanta (1988) observed that in *in situ* softwood grafting the highest success was obtained with seven months old mango rootstock (90 per cent) followed by eight months old rootstock (80 per cent). Softwood grafting in container grown plants showed that three months old rootstocks recorded the highest graft take (58 per cent) followed by six months old rootstocks (55 per cent). Panicker and Desai (1989) proved that softwood grafting could be carried out at any growth flush from the rootstock provided that it was coppery red in colour.

Konkar and Das (1985) conducted vegetative propagation studies on cashew in Orissa and found that 15 to 60 days old seedlings could be used as rootstocks for softwood grafting. Success was achieved only when the rootstock was green and succulent with a fresh cycle of growth (Nagabhushanam, 1985). In cashew, softwood grafting was carried out on one month old, *in situ* and container grown plants by Pushpalatha *et al*. (1991a). The final percentage of success was assessed as 83.7 in *in situ* grafting and 85 per cent in polybag grafting. Pushpalatha *et al*. (1991b), in another trial, concluded that for attaining maximum success in softwood grafting, the ideal age of rootstock should be 28 days.

2.2.2.3 Double grafting

Nagawekar *et al.* (1984) conducted studies on the various factors affecting survival of mango stone grafts. He found that instead of using one rootstock, two rootstocks at epicotyl stage could be employed for a single scion. The percentage success assessed in this case was 79 while with a single rootstock it was 56.6 per cent.

Subramanya and Reddy (1989) also reported about double grafting in mango. They recommended that when two seedlings at epicotyl stage (six days after emergence) was used as rootstock for a single scion, percentage of survival and further growth was higher than single rootstock for a single scion.

2.2.3 Effect of type of scion wood and time of defoliation on the success of grafting

2.2.3.1 Epicotyl grafting

Bhan *et al.* (1969) conducted studies on epicotyl grafting of mango and recommended that semi matured terminal shoots should be used as scion. Gunjate and Limaye (1977) obtained equal success in stone grafting in mango with and without prior defoliation of scion shoots. Dhakal(1979) found that scion shoots of more than two months age were the most suitable for stone grafting in mango while prior defoliation of scion shoot proved to be of no beneficial effect. Maiti and Biswas (1980) studied the effect of defoliated and undefoliated scion shoot on graft take and observed that the defoliated scion shoots produced higher percentage of successful grafts than the undefoliated shoots. They also revealed that three to four months old scion material gave 50 to 60 per cent success. Singh and Sreevastava (1981) reported that defoliation, ten days prior to grafting, gave the highest success and the least success was with the scions defoliated five days prior to grafting. Scion shoots must be more than two months old whereas precured or non precured scion shoot produced no appreciable result according to Gunjate _et al._ (1982). Patil _et al._ (1983) disclosed that the number of days required for sprouting decreased significantly with the increase in scion defoliation period. Minimum days for sprouting (14.39) were required in the treatment of defoliation prior to grafting and maximum days (17.7) were required in defoliation five days prior to grafting. Patil _et al._ (1984) revealed that among the three defoliation periods tested (three, five and seven days prior to grafting) the best was five days defoliation prior to grafting in mango. According to Dhungana (1984) four months old scion defoliated ten days prior to grafting gave maximum percentage of success in epicotyl grafting of mango. According to Chakrabarthy and Sadhu (1984) one month old scion shoots gave the highest success rates of 53.3 to 55.0 per cent compared with only

13.3 per cent with six months old scion shoots. Devadhas and Pappiah (1988) also opined that precured scion shoots were superior to non precured scion shoots in epicotyl grafting.

Bhandary *et al*. (1974) found that scions with and without defoliation produced almost the same success in cashew. Nagabhushanam (1982) suggested the use of mature scion wood with pointed apical dormant bud for successful epicotyl grafting. Shylaja (1984) conducted studies on epicotyl grafting in cashew and observed that scion shoots defoliated ten days before grafting gave a maximum success of 82.7 per cent.

2.2.3.2 Softwood grafting

Popenoe (1920) reported that in mangosteen seven months old scion could be used in grafting with *G. tinctoria* rootstocks to get effective union. Hadangar *et al*. (1987, 1991) reported that for softwood grafting in kokam, the terminal greenish-brown twigs of five to six months old, 0.5 to 0.6 cm thick and 10 to 12 cm in length could be used.

Amin (1978b) reported that cent per cent success was obtained in *in situ* softwood grafting in mango by wedge method and the scion defoliated ten days prior to grafting operation. Singh *et al*. (1984) obtained a mean success of 70 per cent by softwood grafting in mango using four to five months old scion shoots. Reddy (1987) showed that scions pre-conditioned for ten days gave the maximum success of graft followed by scions pre-conditioned for five days and zero days. Panicker and Desai (1989) obtained scion sprouting and survival after three months of grafting as 72 per cent and 70 per cent respectively when mango scions were taken from 25 years old mother tree. Sreevastava et al. (1989) recommended 2 to 3 cm long cut on the scion stick for effective graft union in softwood grafting in mango.

Pushpalatha et al. (1991 b) concluded that for attaining maximum success in softwood grafting, seven days precuring of the scions before grafting was necessary. The ideal length of scion was between 10 and 12.5 cm.

2.2.3.3 Double grafting

Nagawekar et al. (1984) disclosed that there was no significant difference between terminal or subterminal position of the scion shoot to be used in double grafting. The survival (60.6 per cent to 63.0 per cent) and subsequent growth were very similar in both the cases.

2.2.4 Effect of season on the success of grafting

2.2.4.1 Epicotyl grafting

According to Maiti and Biswas (1980) when epicotyl grafting was done in mango during June-July with three to four months old defoliated scion shoots, the percentage of success varied from 50 to 96 per cent. Dengale (1980) and Gunjate et al. (1982) recommended the period from June to September to be the best time for epicotyl grafting in mango under Konkan conditions. According to Chakrabarthy and Sandhu (1984) grafting success was more or less uniform in June, July and August when epicotyl grafting was done in mango. Desai and Patil (1984) found that when stone grafting was done at 15 days interval between 1st July to 15th September, grafting done on 1st July gave the highest success (70 per cent). The percentage survival of stone grafts made in June and July was the highest. A study by Dhungana (1984) revealed that the percentage of success was the highest (69.33 per cent) when stone grafting in mango was done during August and was the lowest during May (20.6 per cent) in Kerala. Sreevastava (1985) suggested that stone grafting should be done during the last week of June in order to get a high percentage success of 95 when the mean temperature and humidity were 33.5°C and 88 per cent respectively. Gupta et al. (1988) showed that stone grafting carried out from mid August to mid September on ten days old rootstocks gave 50 to 55 per cent success. Devadhas and Pappiah (1988) also found that the percentage success was higher when epicotyl grafting was performed during August to November in mango.

Under Konkan conditions Harmekar (1980) conducted epicotyl grafting in cashew and found that the highest success was obtained during June followed by March and April and the rainy season appeared to be unsuitable. Nagabhushanam (1982) reported a maximum success of 30 per cent during the month of July. Nagabhushanam and Mohan (1982) also obtained a success of 30 per cent in stone grafting in July followed by stone grafting in August. The success gradually declined from 15 per cent in September to 5 per cent in November. They observed that high humidity and heavy precipitation which occurred during June, July and August months had a beneficial effect on the success of epicotyl grafting in cashew. According to Sawke (1983), February to May is the optimum period for epicotyl grafting in cashew under Konkan conditions and there was no success during monsoon. Sawke (1984) observed that the period from February to May was congenial for grafting of cashew in which success ranged from 60 to 74 per cent. Konkar and Das (1985) reported a success of 65 to 80 per cent during April to July and 73 to 100 per cent during October to February. According to Jose (1989) June was the best month for conducting epicotyl grafting in jack under Kerala conditions.

2.2.4.2 Softwood grafting

In kokam, Handangar et al. (1987) proved that October grafting exhibited maximum survival (86 per cent) and was on par with the success in June. Amin (1978a) from Anand, recommended *in situ* softwood grafting in mango to be successful during March to September. Singh and Sreevastava (1980) reported that the best results in mango softwood grafting (84 per cent) was obtained during July. Patel and Amin (1981) pointed out that grafting between the third week of May and the third week of August resulted in 95 to 100 per cent take. Success ranged from 85 to 97 per cent between February and May but after third week in September it decreased considerably. Singh and Sreevastava (1982) worked out various factors influencing softwood grafting in mango and emphasized the effect of season on the success of grafts. They reported that August was the best time for softwood grafting (90 per cent success) followed by September (70 per cent success). According to Singh et al. (1984) grafting in June gave the best results with 100 per cent success. Sreevastava (1985) also confirmed this finding. Tayde et al. (1988), in their studies under Akola conditions, obtained 70 to 100 per cent success in softwood grafting in mango when conducted during July to September.

Sawke et al. (1985), in a three years trial in softwood grafting of cashew, observed that the highest mean success was obtained in August (83.66 per cent) and April (83 per cent) and the lowest (22.23 per cent) in December. Kumar and Khan (1988) tried in situ softwood grafting in cashew and the success percentage was reported to be 40 during March, 50 during April and 70 during May. Swamy et al. (1990) found that the success in softwood grafting in cashew was positively correlated with monthly minimum temperature, monthly mean relative humidity and number of rainy days per month. Monsoon season was found to be the best period for commercial multiplication as the percentage success was quite high (above 60 per cent) during this period as compared to the other months. The investigation made by Sarada et al. (1991) revealed that August, September and January months were suitable for softwood grafting in cashew.

2.2.4.3 Double grafting

According to Subramanya and Reddy (1989) the ideal period for double grafting in mango was July and first fortnight of August under Bangalore conditions.

2.2.5 Effect of growth regulators on the success of grafting

Kannan and Rao (1964) proved that GA at 1000 ppm concentration at the time of approach grafting as well as pre-treatment of stock and scion resulted in earlier separation of grafts (45 days) as compared to control (75 days) in mango. There was good callus formation after 15 days of the treatment. Narwadkar and Anserwadekar (1985) found that in epicotyl grafting of mango, when scions were treated with IAA and GA prior to grafting only IAA was found to be favourable on graft take. They concluded that among the different concentration of IAA viz., 20, 500, 750 and 1000 ppm, ultimate success of graft increased linearly upto 750 ppm and slightly decreased at 1000 ppm. There was an increase in the number of leaves and total leaf area per plant. Ratan et al. (1987) reported that in mango epicotyl grafting, when scion materials were treated with IAA or GA at 100 or 250 ppm and grafted on rootstocks of different heights, the highest sprouting and survival was obtained with 8 cm long scions treated with IAA 100 ppm and grafted on 6 to 8 cm high rootstocks. Devadhas and Pappiah (1988) supported these findings. They revealed that in epicotyl grafting of mango, nutritional and auxin status was greater in the compatible rootstock – scion combination compared to the incompatible ones. Sreevastava et al. (1989) found that in mango grafting the effect of plant growth regulators was negligible. Subramanya and Reddy (1989), while investigating the effect of various chemicals in double grafting of mango, revealed that the treatment of scions with chemicals and growth regulator solutions augmented the graft take. Mathad et al. (1991) concluded that the growth regulators viz., GA and kinetin had an adverse effect on graft take. They revealed that the untreated grafts recorded the highest percentage of success (87.5) compared to treated ones. The treatment, GA in combination with kinetin showed adverse effect on the initiation of new growth, girth, number of leaves and leaf area.

Sheshadri and Rao (1986) compared the effects of NAA as pre-treating chemical for scion on the success of softwood grafting in cashew. It was found that rootstock mortality was the highest (100 per cent) when 60 days old seedlings were grafted with untreated scions.

Subronto and Hutomo (1987) made a comparative evaluation of application of growth regulators on cocoa bud grafting and revealed that the growth regulators viz., GA, IBA etc. did not have any significant effect on the scion bud length, number of leaves and bud diameter but it had a highly significant positive effect on the percentage of bud burst especially IBA at 100 ppm.

2.2.6 Anatomical studies of graft union

Juliano (1941), in his studies about the callus development at the point of graft union of cleft grafts, revealed that the first step was the formation of callus in the gap through the activity of parenchyma of both bark and pith. A cambial bridge formed in that region joined the cambial ends of both stock and scion. Initiation of callus tissue began from the stock but the total contribution of callus by stock and scion was almost equal. According to Buchloh (1960) the lignification of cells were mainly responsible for the formation of strong graft union in pear-quince grafts.

Wilson and Wilson (1961) opined that when young stems were wounded or grafted the cambium was interrupted and new vascular cambia tend to regenerate in the callus proliferating from the wounded surfaces. The amount of callus formation varied among varieties and was influenced by climatic conditions during the previous growing season.

Shimoya et al. (1970) conducted anatomical studies of mango wedge grafts and reported the presence of fungal mycelium at the graft union which appeared to facilitate graft union.

According to Esau (1972) secondary growth and cambial activity were involved in proper graft union. Breakdown products of dead cells formed a necrotic layer on the surface of stock and scion, the callus tissue filled the space between stock and scion and later differentiated to cambial cells and then to vascular tissues. Hartmann (1974) also supported these views. Fahn (1982) opined that the important function of the cambium was to form callus in the wound portion. He also stated that the union of stock and scion was not only through cambia but through wood rays which proliferated and took part in the graft union.

2.2.6.1 Anatomical stages of graft union

Many scientists have worked out the anatomical stages of graft union in various crops.

Chakrabarthy and Sadhu (1985) worked out the different stages in epicotyl grafts of mango. According to them the stages in the graft union were, (1) callusing stage - 10 to 30 days after grafting when live cells form a mass of callus tissues, (2) callus bridge stage - 30 to 60 days after grafting when cambial continuity between rootstock and scion was established, (3) healed union stage - 60 to 120 days after grafting when vascular tissues were differentiated and complete union between stock and scion took place.

According to Ahmed (1966) in inarching experiments of guava stock-scion union was peripheral after 45 days, but complete after 75 days.

Galkina (1979) investigated the different stages in the bench grafts of apple. The successive stages of graft union microscopically examined were (1) union of callus of both components, (2) callus cell differentiation and formation of new secondary cambium and (3) appearance of conducting tissues followed by complete union.

2.2.6.2 Anatomical reasons for graft failure or graft incompatibility

According to Robert (1949) the important factors determining the graft take was not the nature of the union, but the genetically determined incompatibility which resulted in the interaction between stock and scion. Auramov and Jokovic (1961) and Ciz (1969) opined that incompatibility could be diagnosed through anatomical studies after, two to three months of grafting. According to Makhmet et al. (1980), the most common reason for graft incompatibility on woody plants were physiological, anatomical and chemical. Studies were conducted with grafts between 22 species of rootstocks and 26 species of scions which included fruits, nuts and ornamental plants. The results indicated that it might be possible to use an anatomical method for diagnosing compatibility between the graft components when new, untried rootstocks and scions were introduced into cultivation.

Luthra and Sharma (1964) showed that excessive growth of parenchymatous tissues between stock and scion and distortion of xylem elements blocked the conducting vessels and inhibited the movement of water from stock to scion in mango grafts. According to Hartmann (1974) whenever an abnormal positioning of cambium of stock and scion occurred, a proper union did not take place. He also stated that the main causes of poor results of the grafting operation were incomplete callus formation at the graft union and improper cultural methods. Sinsor (1982) revealed that in incomplete stock-scion combinations of apple, the xylem and phloem within the graft union were greatly reduced. Breakage and/or failure within the graft union of certain stock-scion combinations was associated with abnormal ray development. Skene et al. (1983) suggested that infilling of callus and improper development of cambium in between the stock and scion was one of the reasons for graft failure in certain apple varieties viz., Cox's Orange Pippin. Jose (1989) attributed excessive callus growth at the graft union to one of the reasons for graft failure in jack.

Materials and Methods

MATERIALS AND METHODS

Garcinia cambogia, known in vernacular as *Kodumpuli*, is a seed propagated fruit crop. The wide variation due to seed propagation and dioecious nature of the trees set back its cultivation. Practically, very little work has been done to standardise the vegetative propagation methods in this crop. Hence the present study was undertaken to standardise the vegetative propagation methods. The study was conducted in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Trichur, Kerala from February, 1990 to July, 1992. Trichur is under high rainfall tropical region having warm humid climate throughout the year with less fluctuations in daily temperature (Appendix I). The altitude of the place is 22.25 m above main sea level at 10° 32' N latitude and 76° 16' E longitude.

The details of the investigation are given in this chapter.

The various phases of the investigation were the following:

(i) To study the effect of seed coat and gibberellic acid on germination of *Kodumpuli* (G. cambogia) seeds.

(ii) To standardise the type and age of rootstocks for epicotyl, softwood and double grafting.

(iii) To study the effect of the type and age of scion wood on the success of grafting.

(iv) To study the effect of season on the success of grafting.

(v) To study the effect of growth regulators on the success of grafting.

(vi) To study the anatomy of graft union.

3.1 Effect of seed coat and gibberellic acid on germination of G. cambogia seeds

Seeds were collected from different parts of the district. In order to conduct germination test, viable seeds were selected by floating method. Germination test was conducted using seeds with and without the seed coat. The selected seeds were subjected to various growth regulator treatments. The growth regulator used in this study was GA (gibberellic acid) at 100, 300 and 500 ppm concentration with 6 h, 12 h, 18 h and 24 h as soaking periods. After soaking, the seeds were sown in the raised nursery beds. Twenty five seeds were kept under each treatment. The details of the treatments are given below:

Treatments

M_1 T_1 C_1	with seed coat	- 6 h soaking	- 200 ppm	GA
M_1 T_1 C_2	with seed coat	- 6 h soaking	- 300 ppm	GA
M_1 T_1 C_3	with seed coat	- 6 h soaking	- 500 ppm	GA
M_1 T_2 C_1	with seed coat	- 12 h soaking	- 200 ppm	GA
M_1 T_2 C_2	with seed coat	- 12 h soaking	- 300 ppm	GA
M_1 T_2 C_3	with seed coat	- 12 h soaking	- 500 ppm	GA
M_1 T_3 C_1	with seed coat	- 18 h soaking	- 200 ppm	GA
M_1 T_3 C_2	with seed coat	- 18 h soaking	- 300 ppm	GA
M_1 T_3 C_3	with seed coat	- 18 h soaking	- 500 ppm	GA
M_1 T_4 C_1	with seed coat	- 24 h soaking	- 200 ppm	GA
M_1 T_4 C_2	with seed coat	- 24 h soaking	- 300 ppm	GA
M_1 T_4 C_3	with seed coat	- 24 h soaking	- 500 ppm	GA
Control - 1	with seed coat	- no GA treatment		
M_2 T_1 C_1	without seed coat	- 6 h soaking	- 200 ppm	GA
M_2 T_1 C_2	without seed coat	- 6 h soaking	- 300 ppm	GA
M_2 T_1 C_3	without seed coat	- 6 h soaking	- 500 ppm	GA
M_2 T_2 C_1	without seed coat	- 12 h soaking	- 200 ppm	GA
M_2 T_2 C_2	without seed coat	- 12 h soaking	- 300 ppm	GA
M_2 T_2 C_3	without seed coat	- 12 h soaking	- 500 ppm	GA
M_2 T_3 C_1	without seed coat	- 18 h soaking	- 200 ppm	GA
M_2 T_3 C_2	without seed coat	- 18 h soaking	- 300 ppm	GA
M_2 T_3 C_3	without seed coat	- 18 h soaking	- 500 ppm	GA
M_2 T_4 C_1	without seed coat	- 24 h soaking	- 200 ppm	GA
M_2 T_4 C_2	without seed coat	- 24 h soaking	- 300 ppm	GA

$M_2 T_4 C_3$ without seed coat - 24 h soaking - 500 ppm GA

Control - 2 without seed coat - no GA treatment

Total number of treatments : 26

Experimental design : Factorial CRD

3.1.1 Observations

Time taken for maximum germination and germination count at weekly intervals were recorded upto 8 weeks after the beginning of germination. The concordant values for germination percentage recorded at successive weeks were considered as the maximum percentage of germination.

3.2 Standardisation of the type and age of rootstocks for epicotyl, softwood and double grafting

Two species of the family Guttiferae, viz., Garcinia cambogia (*Kodumpuli*) and Garcinia tinctoria (*Rajapuli*) were used as rootstocks. In the case where *Rajapuli* seedlings were used as rootstocks, the age groups selected were 10, 15 and 20 days for epicotyl grafting and two, three and four months for softwood grafting. *Kodumpuli* seedlings did not attain sufficient height and girth at these age groups and epicotyl grafting was not done using this rootstock. Softwood grafting was done using 18 months old *Kodumpuli* seedlings. In double grafting each scion stick was grafted on two rootstocks. The details of combinations of rootstocks used are depicted in 3.2.5.

3.2.1 Raising of seedlings for rootstocks

Seeds of G. cambogia and G. tinctoria were sown in polythene bags filled with FYM, sand and soil in the ratio of 1:1:1. The polythene bags were placed under shade and watered regularly.

3.2.2 Selection and preparation of scion sticks

Healthy, disease free, 6 to 8 cm long, about nine months old brown wood with a portion of green wood of new flush having an apical plumpy bud, from selected mother trees were used for epicotyl, softwood and double grafting.

3.2.3 Methods of grafting

3.2.3.1 Epicotyl grafting

The rootstocks were decapitated 5 to 6 cm above the soil level. A vertical slit of about 2 to 3 cm was given at the centre of the epicotyl. The lower portion of the selected scion was prepared to form a wedge at the base by giving two slanting cuts on opposite sides. The wedge shaped scion was inserted in the vertical slit of the epicotyl. The grafted portion was wrapped tightly with a polythene tape so that a close contact between the two components was ensured (Plates 5 to 8).

Plate 5   A rootstock of <u>Garcinia tinctoria</u>

Plate 6   Vertical slit made on the decapitated stock

Plate 7 The scion inserted in the vertical slit on the stock

Plate 8 The graft joint after securing with a polythene tape


3.2.3.2 Softwood grafting

Wedge method of grafting was followed for softwood grafting also. Grafting was done 12 to 15 cm above the soil level. If possible, a pair of leaves were retained on the rootstock.

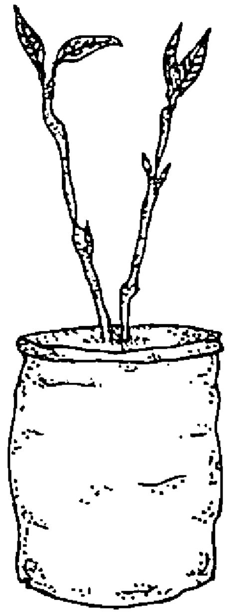
3.2.3.3 Double grafting

Each double graft was made on two rootstocks. For double grafting, two seedlings were grown in the same polythene bag. After decapitating both the seedlings at a height of about 5 to 7 cm from the ground level, a slanting cut was made on the inner side of each of the stock so that a wedge shaped cut was obtained when the two stocks were brought together. The prepared scion as in the case of the other two methods was inserted between these cuts. Two rootstocks and scion were then tied together with a polythene tape (Fig.1).

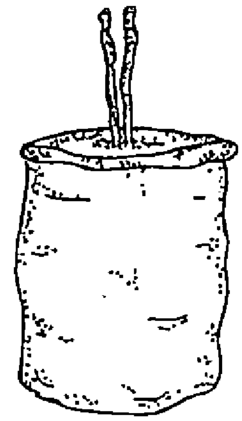
3.2.4 After care of the grafts

The grafts were kept in a mist chamber providing intermittent mist. The sprouts produced from the rootstocks were removed periodically and the grafts were watered regularly. Bordeaux mixture 1 per cent and Ekalux 2 ml l^{-1} were sprayed in every fortnight.

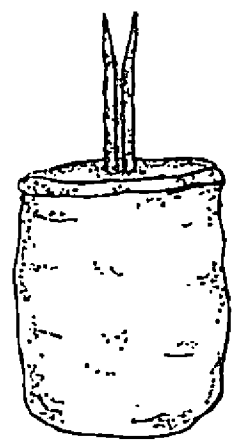
Fig.1 Different steps in double grafting



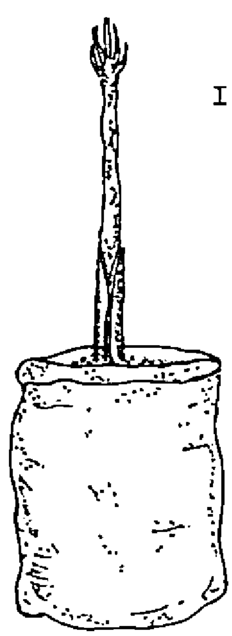
I. Rootstocks ready for double grafting.



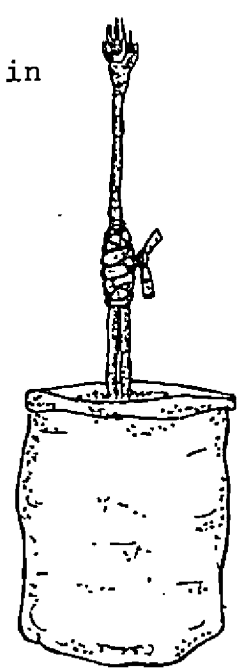
II. Decapitated rootstock



III. Wedge shaped cut made in between the rootstocks



IV. Insertion of the scion in the wedge shaped cut



V. The graft joint after securing with a polythene tape

3.2.5 Treatment details

$M_1A_1R_1$	Epicotyl grafting	- 10 days old - *Rajapuli*
$M_1A_2R_1$	Epicotyl grafting	- 15 days old - *Rajapuli*
$M_1A_3R_1$	Epicotyl grafting	- 20 days old - *Rajapuli*
$M_2A_4R_1$	Softwood grafting	- 2 months old - *Rajapuli*
$M_2A_5R_1$	Softwood grafting	- 3 months old - *Rajapuli*
$M_2A_6R_1$	Softwood grafting	- 4 months old - *Rajapuli*
$M_2A_8R_2$	Softwood grafting	- 18 months old - *Kodumpuli*
$M_3A_1R_1$	Double grafting	- 10 days old - Two seedlings of *Rajapuli*
$M_3A_2R_1$	Double grafting	- 15 days old - Two seedlings of *Rajapuli*
$M_3A_3R_1$	Double grafting	- 20 days old - Two seedlings of *Rajapuli*
$M_3A_7R_2$	Double grafting	- 12 months old - Two seedlings of *Kodumpuli*
M_3A_1R	Double grafting	- 10 days old *Rajapuli* and 12 months old *Kodumpuli*
M_3A_2R	Double grafting	- 15 days old *Rajapuli* and 12 months old *Kodumpuli*
M_3A_3R	Double grafting	- 20 days old *Rajapuli* and 12 months old *Kodumpuli*

Total number of treatments : 14

Experimental design : CRD

3.2.6 Observations

3.2.6.1 Percentage of initial and final success

The scions that remained green whether sprouted or unsprouted, 30 days and 60 days after grafting were counted for calculating the percentage of initial success. Scions which survived after 90 days were noted for calculating the percentage of final success.

3.2.6.2 Extension growth of the scion

The extension growth of scion was measured in centimetres from the graft union at fortnightly intervals.

3.2.6.3 Girth of the scion

The girth of the scion was measured in centimetres at a fixed point at one centimetre above the graft union at fortnightly intervals.

3.2.6.4 Number of leaves of the scion

The number of leaves developed on the scion was recorded at fortnightly intervals.

3.3 Effect of type and age of the scion wood on the success of grafting

For this experiment, three types of scion wood were used. Sixty grafts were made under each treatment. The treatments were the following.

T_1 - New flush with a plumpy apical bud (completely green in colour and three months old).

T_2 - Past season shoot with no new sprout (brown in colour and six months old).

T_3 - Past season shoot with a new sprout and a plumpy apical bud (basally brown, green at the top and nine months old).

Total number of treatments : 3

Softwood grafting was done on 18 months old *G. cambogia* seedlings with the types of scion materials mentioned above. Observations were taken on the extension, girth and number of leaves of the scion, at fortnightly intervals.

3.4 Effect of season on the success of grafting

Softwood grafting was done in May, June, July, October, November and December months on 18 months old *G. cambogia* seedlings. Hundred grafts were made under each treatment and the grafted plants were maintained in a mist chamber.

Treatments

T_1 - May grafting

T_2 - June grafting

T_3 - July grafting

T_4 - October grafting

T_5 - November grafting

T_6 - December grafting

Observations on the number of grafts remained green after 30, 60 and 90 days of grafting were recorded.

3.5 Effect of growth regulators on the success of grafting

The grafted plants were sprayed with GA and IBA each at 100, 250 and 500 ppm concentration, immediately after grafting. The same growth regulators each at 500, 750 and 1000 ppm concentration were used for dipping the detached scion wood. Base of the prepared scion sticks were dipped in these solutions for one minute and softwood grafting was performed on 18 months old _G. cambogia_ seedlings. Sixty grafts were made under each treatment. The details of the treatments are given below.

T_1 - GA 500 ppm

T_2 - GA 750 ppm

T_3 - GA 1000 ppm

T_4 - IBA 500 ppm

T_5 - IBA 750 ppm

T_6 - IBA 1000 ppm

T_7 - Control (no dipping)

Total number of treatments : 7

Experimental design : CRD

Observations were taken as in the experiment cited in 3.3.

3.6 Anatomical studies of graft union

Samples for anatomical studies were collected from the grafts made using the following rootstocks.

1. Epicotyl grafting on G. tinctoria
2. Softwood grafting on G. tinctoria
3. Softwood drafting on G. cambogia
4. Double grafting on two seedlings of G. tinctoria
5. Double grafting on G. tinctoria and G. cambogia
6. Double grafting on two seedlings of G. cambogia

Samples were collected as per the procedure given below.

Representative samples after collection were processed as follows.

3.6.1 Processing

FAA (850 ml of 70 per cent alcohol + 100 ml of 40 per cent formaldehyde + 50 ml of glacial acetic acid) solution was used for fixing and preservation of samples. Specimens were kept in FAA solution for a minimum period of 72 h and then transferred and stored in 70 per cent alcohol until the sections were made. Before sectioning, the samples were removed from alcohol using sterilized forceps and washed in running water for 30 minutes and later with glass distilled water. Uniform thin section of 30 µm (micron) thickness was taken using "Reichert sliding" microtome as per standard microtomy suggested for hardwoods (Cutler, 1978). For cleaning and staining the sections, the schedule suggested by Johanson (1940) which is outlined below was followed.

Sections were serially passed through,

70 per cent alcoholic safranin (5 to 10 minutes),
80 per cent alcohol (2 minutes),
90 per cent alcohol (2 minutes),
95 per cent alcohol (1 minute),
absolute alcohol (1 minute),
pure xylene (1 minute)

and mounted on slides with DPX mountant.

3.6.2 Microscopic examination

The slides were examined carefully through Carl Zeiss binocular research microscope fitted with the objective of magnification ranging from 3.2 x to 100 x and 10 x eyepiece.

3.6.3 Photomicroscopy

Photomicrographs of selected specimens were taken using a photomicrography system (Leitz Dialux 20 EB. Germany) and ORWO film of 100 ASA.

3.7 Statistical analysis

The observations on number of days taken for germination and germination percentage under different treatments and the effect of treatments on the qualitative characters like, extension growth, girth and number of leaves of the scion were statistically analysed using the analysis of variance technique laid out in completely randomised design (Snedecor and Cochran, 1967).

The differences among the treatments with regard to the number of sprouted grafts and survival of grafts were tested using the chi-square statistic (Panse and Sukhatme, 1968).

Two sample case student's t-test (Snedecor and Cochran, 1967) was used to analyse the effect of types of rootstock and scionwood on height and girth of the scion and the number of leaves produced on the scion.

The differences among the treatments with regard to the extension growth of scion was analysed as a non-orthogonal data. The analysis of the number of leaves produced at fortnightly interval was done using Friedman two way analysis of variance described by Siegal (1979).

Results

RESULTS

The results of the experiments described in Chapter II are given in the following order.

4.1 Effect of seed coat and GA on germination of *Garcinia cambogia* seeds

The data on the effect of seed coat and GA on seed germination of *G. cambogia* seeds are given in Tables 1 to 9 and analysis of variance in Appendix II.

4.1.1 Effect of seed coat and GA on time taken for germination and percentage of germination

The data on time taken for 50 per cent germination, maximum germination and the final percentage of germination under different treatments are presented in Table 1. In order to compare the treatments based on the maximum percentage of germination after eight weeks from the beginning of germination, chi-square test was performed.

The seeds without seed coat (M_2) recorded faster germination compared to the seeds with seed coat. Seeds with seed coat and without seed coat started germination 29 weeks and one week respectively, after sowing. In general, seeds without seed coat treated with GA recorded 50 per cent germination after two weeks of sowing, except the control

Table 1. Effect of seed coat and GA on time taken for germination and percentage of germination

Treatments	Number of weeks taken for 50 per cent germination	Number of weeks taken for maximum germination	Maximum percentage of germination after 8 weeks from the beginning of germination
$M_1T_1C_1$	35	36	61.333[a]
$M_1T_1C_2$	34	36	60.000[a]
$M_1T_1C_3$	34	36	70.667[ab]
$M_1T_2C_1$	34	36	65.333[a]
$M_1T_2C_2$	32	36	73.333[ab]
$M_1T_2C_3$	31	36	84.000[ab]
$M_1T_3C_1$	34	36	61.333[a]
$M_1T_3C_2$	31	36	82.667[ab]
$M_1T_3C_3$	32	36	76.000[ab]
$M_1T_4C_1$	32	36	77.333[ab]
$M_1T_4C_2$	34	35	60.000[a]
$M_1T_4C_3$	33	36	69.333[ab]
Control-1	36	36	48.000[a]
$M_2T_1C_1$	2	5	84.000[ab]
$M_2T_1C_2$	2	4	84.000[ab]
$M_2T_1C_3$	2	5	78.667[ab]
$M_2T_2C_1$	2	5	85.333[ab]
$M_2T_2C_2$	2	4	85.333[ab]
$M_2T_2C_3$	1	5	90.667[b]
$M_2T_3C_1$	2	5	88.000[b]
$M_2T_3C_2$	1	3	80.000[ab]
$M_2T_3C_3$	1	5	93.333[b]
$M_2T_4C_1$	2	5	89.333[b]
$M_2T_4C_2$	2	5	80.000[ab]
$M_2T_4C_3$	2	5	81.333[ab]
Control-2	4	5	74.667[ab]

M_1 - with seed coat; M_2 - without seed coat; T_1 - 6 h soaking; T_2 - 12 h soaking; T_3 - 18 h soaking; T_4 - 24 h soaking; C_1 - 200 ppm GA; C_2 - 300 ppm GA; C_3 - 500 ppm GA

Control-1 - with seed coat - no GA - no soaking

Control-2 - without seed coat - no GA - no soaking

X^2 - analysis was done

which took about four weeks for the same. The treatments, $M_2T_2C_3$ (without seed coat - 12 h soaking - 500 ppm GA), $M_2T_3C_2$ (without seed coat - 18 h soaking - 300 ppm GA) and $M_2T_3C_3$ (without seed coat - 18 h soaking - 500 ppm GA) registered the shortest period of one week for attaining 50 per cent germination. All the seeds with seed coat (M_1) required more than 30 weeks for attaining 50 per cent germination. Within M_1, the treatments, $M_1T_2C_3$ (with seed coat - 12 h soaking - 500 ppm GA) and $M_1T_3C_2$ (with seed coat - 18 h soaking - 300 ppm GA) recorded the shortest time span of 31 weeks for attaining 50 per cent germination while the control treatment took the longest time (36 weeks).

When the time required for maximum germination was studied, within M_2, $M_2T_3C_2$ recorded the shortest period of three weeks and $M_2T_2C_2$ and $M_2T_1C_2$ required a period of four weeks from the beginning of germination. All other treatments within M_2, required five weeks to attain maximum germination. Within M_1, all the treatments, except $M_1T_4C_2$, required 36 weeks for attaining maximum germination while $M_1T_4C_2$ required only 35 weeks.

When the final germination percentage after eight weeks from the beginning of germination was considered, seeds without seed coat recorded higher values compared to seeds with seed coat. The final germination percentage of seeds with seed coat ranged from 48.00 to 84.00 per cent while that of seeds without seed coat ranged from 74.667 to 93.333 per cent. Among the seeds without seed coat, $M_2T_3C_3$ recorded the highest percentage of germination (93.333) followed by $M_2T_2C_3$ (90.667). The minimum percentage of final germination within M_2 (74.667) was noticed in the control treatment. Within M_1, the highest percentage of germination was 84.00 in $M_1T_2C_3$ closely followed by 82.667 in $M_1T_3C_2$. Similar to M_2, in M_1 also, the minimum percentage of germination was noticed in the case of control treatment (48.00).

4.1.2 Main effect of seed coat on percentage of seed germination

Data on the main effect of seed coat on seed germination are presented in Table 2. It could be observed that the removal of seed coat influenced the germination percentage significantly. Throughout the period of study, seeds without seed coat recorded higher values for germination compared to seeds with seed coat. The final germination percentage after the eighth week was 70.111 and 85.00 respectively for seeds with and without seed coat.

4.1.3 Effect of GA on percentage of seed germination

4.1.3.1 Main effect of different periods of soaking

The study on the main effect of soaking on seed

Table 2. Main effect of seed coat on seed germination at weekly intervals

Treatments	Germination percentage at weekly intervals							
	1	2	3	4	5	6	7	8
M_1	26.889[a]	38.222[a]	46.278[a]	47.500[a]	57.500[a]	62.556[a]	70.111[a]	70.111[a]
M_2	42.556[b]	60.611[b]	79.000[b]	82.333[b]	85.000[b]	85.000[b]	85.000[b]	85.000[b]
CD(0.05)	2.720*	3.016*	4.552*	4.098*	4.915*	5.299*	5.071*	5.071*

M_1 - with seed coat M_2 - without seed coat

* - Significant at 5 per cent level

germination (Table 3) showed that there was significant difference among the soaking periods (6 h, 12 h, 18 h and 24 h) with respect to the percentage of seed germination, throughout the period of study. In the first week, all the treatments were on par, but were significantly superior to the control (18.00 per cent). From the second week to the end of eighth week, T_2 (12 h soaking) gave the highest percentage of germination as 53.667, 67.778, 68.444, 75.333, 76.889, 80.667 and 80.667 respectively. During all these weeks, the control recorded the lowest values for germination percentage which were computed as 28.667, 38.667, 48.667, 57.334, 59.334, 61.334 and 61.334 respectively.

4.1.3.2 Main effect of different concentrations of GA

The data presented in Table 4 showed that there was significant difference in seed germination between different concentrations of GA and the control, in all the weeks studied. The concentrations of GA (200 ppm , 300 ppm and 500 ppm) were proved to be on par, except in the 2nd, 3rd and 4th weeks, as far as the seed germination was concerned. In these weeks, C_3 (500 ppm GA) was significantly superior to other treatments and yielded 55.667 per cent, 65.917 per cent and 68.250 per cent germination respectively. In all the weeks from 1st to 8th, the control recorded the least values for germination percentage (18.00, 28.667, 38.667, 48.667, 57.334, 59.334, 61.334 and 61.334 respectively).

Table 3. Main effect of different soaking periods on seed germination at weekly intervals

Treatments	Germination percentage at weekly intervals							
	1	2	3	4	5	6	7	8
T_1	29.444^{b}	42.222^{b}	55.778^{b}	58.000^{b}	65.111^{b}	67.111^{b}	73.111^{b}	73.111^{b}
T_2	38.667^{b}	53.667^{c}	67.778^{c}	68.444^{c}	75.333^{c}	76.889^{c}	80.667^{c}	80.667^{c}
T_3	38.778^{b}	53.556^{c}	66.778^{c}	67.667^{c}	73.222^{c}	76.667^{c}	80.222^{c}	80.222^{c}
T_4	32.000^{b}	48.222^{bc}	60.222^{b}	65.550^{c}	71.333^{bc}	74.444^{bc}	76.222^{bc}	76.222^{bc}
Control	17.999^{a}	28.667^{a}	38.667^{a}	48.667^{a}	57.334^{a}	59.334^{a}	61.334^{a}	61.334^{a}
CD (0.05)	9.797*	6.304*	6.047*	5.796*	7.000*	7.494*	7.180*	7.180*

T_1 - 6 h soaking; T_2 - 12 h soaking; T_3 - 18 h soaking; T_4 - 24 h soaking

Control - No soaking

* Significant at 5 per cent level

Table 4. Main effect of different concentrations of GA on seed germination at weekly intervals

Treatments	Germination percentage at weekly intervals							
	1	2	3	4	5	6	7	8
C_1	31.000^{b}	45.833^{b}	60.500^{b}	62.500^{b}	69.500^{b}	71.667^{b}	76.500^{b}	76.500^{b}
C_2	33.750^{b}	46.750^{b}	61.250^{bc}	64.000^{bc}	70.833^{b}	73.000^{b}	76.667^{b}	76.667^{b}
C_3	39.417^{b}	55.667^{c}	65.917^{c}	68.250^{c}	73.417^{b}	76.667^{b}	80.000^{b}	80.000^{b}
Control	17.999^{a}	28.667^{a}	38.667^{a}	48.667^{a}	57.334^{a}	59.334^{a}	61.334^{a}	61.334^{a}
CD (0.05)	12.441*	7.904*	5.344*	5.019*	6.020*	6.490*	6.210*	6.210*

C_1 - GA 200 ppm; C_2 - GA 300 ppm; C_3 - GA 500 ppm; Control - No GA

* Significant at 5 per cent level

4.1.4 Interaction effect of various factors on percentage of seed germination

4.1.4.1. Interaction effect of seed coat and different periods of soaking

It is evident from Table 5 that the combined effect of seed coat and period of soaking was significant only in the fourth and fifth weeks of germination. In both the weeks, M_2T_2 (without seed coat - 12 h soaking) and M_2T_3 (without seed coat - 18 h soaking) recorded the highest percentage of germination while M_1T_1 (with seed coat - 6 h soaking) recorded the lowest percentage of germination. The highest and lowest germination percentage in the fourth week were 84.889 and 35.111 respectively while those in the fifth week were 87.111 and 48.00 respectively.

4.1.4.2 Interaction effect of seed coat and different concentrations of GA

The interaction effect of seed coat and different concentrations of GA was significant only in 3rd, 4th and 5th weeks (Table 6). In these weeks, the highest germination percentage of 80.00, 84.00 and 87.667 respectively were noticed in M_2C_1 (without seed coat - 200 ppm GA). The lowest values in these three weeks were 41.00, 41.00 and 52.333 respectively in M_1C_1 (with seed coat - 200 ppm GA).

Table 5. Interaction effect of seed coat and different periods of soaking on seed germination at weekly intervals

Treatments	Germination percentage at weekly intervals							
	1	2	3	4	5	6	7	8
M_1T_1	19.556	23.889	35.111	35.111^{a}	48.000^{a}	52.000	64.000	64.000
M_1T_2	33.333	43.556	52.000	52.000^{b}	63.556^{b}	66.667	74.222	74.222
M_1T_3	29.778	42.222	50.444	50.444^{b}	59.333^{b}	66.222	73.333	73.333
M_1T_4	24.889	32.222	47.556	52.444^{b}	59.111^{b}	65.333	68.889	68.889
M_2T_1	39.333	55.555	76.444	80.889^{c}	82.222^{c}	82.222	82.222	82.222
M_2T_2	44.000	63.778	83.556	84.889^{c}	87.111^{c}	87.111	87.111	87.111
M_2T_3	47.778	64.889	83.111	84.889^{c}	87.111^{c}	87.111	87.111	87.111
M_2T_4	39.111	58.222	72.889	78.667^{c}	86.556^{c}	83.556	83.556	83.556
CD (0.05)	NS	NS	NS	8.150*	9.781*	NS	NS	NS

M_1 - with seed coat; T_1 - 6 h soaking; T_3 - 18 h soaking;

M_2 - without seed coat; T_2 - 12 h soaking; T_4 - 24 h soaking

* Significant at 5 per cent level

Table 6. Interaction effect of seed coat and different concentrations of GA on seed germination at weekly intervals

Treatments	Germination percentage at weekly intervals							
	1	2	3	4	5	6	7	8
M_1C_1	23.667	34.000	41.000[a]	41.000[a]	52.333[a]	56.667	66.333	66.333
M_1C_2	25.000	34.333	45.667[ab]	48.000[ab]	59.333[a]	63.667	69.000	69.000
M_1C_3	32.000	46.333	52.167[b]	53.500[b]	60.8333[a]	67.333	75.000	75.000
M_2C_1	38.333	57.667	80.000[c]	84.000[c]	86.667[b]	86.667	86.667	86.667
M_2C_2	42.500	59.167	76.834[c]	80.000[c]	82.334[b]	82.334	82.334	82.334
M_2C_3	46.833	65.000	79.667[c]	83.000[c]	86.000[b]	86.000	86.000	86.000
CD (0.05)	NS	NS	7.557*	7.090*	8.514*	NS	NS	NS

M_1 - with seed coat; C_1 - 200 ppm GA; C_3 - 500 ppm GA;

M_2 - without seed coat; C_2 - 300 ppm GA

* Significant at 5 per cent level

4.1.4.3 Interaction effect of different periods of soaking and concentrations of GA

Data on the combined effect of different periods of soaking and concentrations of GA on seed germination are compiled in Table 7. It was evident that the interaction effect was significant in 2nd, 3rd, 4th and 5th weeks. In 2nd and 5th weeks, T_2C_3 (12 h soaking - 500 ppm GA) recorded the maximum germination percentage of 66.667 and 81.333 respectively while in the 3rd and 4th weeks T_3C_3 (18 h soaking 500 ppm GA) recorded the highest germination percentage (76.667). The lowest germination in the 3rd, 4th and 5th weeks was recorded in T_1C_1 (6 h soaking - 200 ppm GA) as 51.333, 56.00 and 63.333 per cent respectively. In the 2nd week, the lowest germination of 37.333 per cent was noticed in T_1C_2 (6 h soaking - 300 ppm GA).

4.1.4.4 Interaction effect of seed coat, different concentrations and soaking periods of GA

The data given in Table 8 indicated that the interaction effect was significant only in the 1st week. In this week, the highest germination percentage was computed as 53.333 in $M_2T_2C_3$ (without seed coat - 12 h soaking - 500 ppm GA) and $M_2T_3C_3$ (without seed coat - 18 h soaking - 500 ppm GA). The lowest germination percentage of 12.00 was noticed in $M_1T_1C_2$ (with seed coat - 6 h soaking - 300 ppm GA). During the other weeks, none of the treatments showed significant difference.

Table 7. Interaction effect of different periods of soaking and concentrations of GA on seed germination at weekly intervals

Treatments	Germination percentage at weekly intervals							
	1	2	3	4	5	6	7	8
T_1C_1	28.000	41.333^{ab}	51.333^{a}	56.000^{a}	63.333^{a}	64.667	72.667	72.667
T_1C_2	26.000	37.333^{a}	58.000^{ab}	58.000^{a}	68.000^{abc}	70.667	72.000	72.000
T_1C_3	34.333	48.000^{abcd}	58.000^{ab}	60.000^{ab}	64.000^{ab}	66.000	74.667	74.667
T_2C_1	31.333	44.000^{abc}	60.667^{abc}	61.333^{ab}	70.000^{abcd}	72.000	75.333	75.333
T_2C_2	35.333	50.333^{bcd}	68.667^{bcde}	69.333^{bc}	74.667^{abcd}	76.000	79.333	79.333
T_2C_3	49.333	66.667^{e}	74.000^{de}	74.667^{c}	81.333^{d}	82.667	87.333	87.333
T_3C_1	28.667	44.667^{abc}	59.333^{ab}	60.667^{ab}	68.667^{abc}	71.333	74.667	74.667
T_3C_2	46.333	59.333^{de}	64.333^{bcd}	65.667^{abc}	70.333^{abcd}	76.667	78.000	78.000
T_3C_3	41.333	56.667^{de}	76.667^{e}	76.667^{c}	80.667^{cd}	82.000	88.000	88.000
T_4C_1	36.000	53.333^{cd}	70.667^{cde}	72.000^{bc}	76.000^{bcd}	78.667	83.333	83.333
T_4C_2	27.333	40.000^{ab}	52.000^{a}	60.000^{ab}	66.667^{ab}	70.000	70.000	70.000
T_4C_3	32.667	51.333^{bcd}	58.000^{ab}	64.667^{abc}	71.333^{abcd}	74.667	75.333	75.333
CD (0.05)	NS	11.142*	10.682*	10.039*	12.040*	NS	NS	NS

T_1 - 6 h soaking; T_1 - 12 h soaking; T_3 - 18 ha soaking; T_4 - 24 h soaking

C_1 - 200 ppm GA; C_2 - 300 ppm GA; C_3 - 500 ppm GA

* Significant at 5 per cent level

Table 8. Interaction effect of seed coat, different concentrations and soaking periods of GA on seed germination at weekly intervals

Treatments	Germination percentage at weekly intervals							
	1	2	3	4	5	6	7	8
$M_1T_1C_1$	18.667[abc]	26.667	29.333	29.333	42.667	45.333	61.333	61.333
$M_1T_1C_2$	12.000[a]	20.000	32.000	32.000	52.000	57.333	60.000	60.000
$M_1T_1C_3$	28.000[cde]	40.000	44.000	44.000	49.333	53.333	70.667	70.667
$M_1T_2C_1$	24.000[bc]	34.667	40.000	40.000	54.667	58.667	65.333	65.333
$M_1T_2C_2$	30.667[cdef]	41.333	53.333	53.333	64.000	66.667	73.333	73.333
$M_1T_2C_3$	45.333[hij]	54.667	62.667	62.667	72.000	74.667	84.000	84.000
$M_1T_3C_1$	17.333[abc]	30.667	37.333	37.333	49.333	54.667	61.333	61.333
$M_1T_3C_2$	42.667[ghij]	52.000	60.000	60.000	68.000	70.667	82.667	82.667
$M_1T_3C_3$	29.333[cdef]	44.000	54.000	54.000	60.667	73.333	76.000	76.000
$M_1T_4C_1$	34.667[cdefg]	44.000	57.333	57.333	62.667	68.000	77.333	77.333
$M_1T_4C_2$	14.667[ab]	24.000	37.333	46.667	53.333	60.000	60.000	60.000
$M_1T_4C_3$	25.333[bc]	46.667	48.000	53.333	61.333	68.000	69.333	69.333
$M_2T_1C_1$	37.333[defgh]	56.000	73.333	82.667	84.000	84.000	84.000	84.000
$M_2T_1C_2$	40.000[efghi]	54.667	82.000	84.000	84.000	84.000	84.000	84.000
$M_2T_1C_3$	40.667[efghi]	56.000	72.000	76.000	78.667	78.667	78.667	78.667
$M_2T_2C_1$	38.667[efgh]	53.333	81.333	82.333	85.333	85.333	85.333	85.333
$M_2T_2C_2$	40.000[efghi]	59.333	84.000	85.333	85.333	85.333	85.333	85.333
$M_2T_2C_3$	53.333[j]	78.667	85.333	86.667	90.667	90.667	90.667	90.667
$M_2T_3C_1$	40.000[efghi]	58.667	81.333	84.000	88.000	88.000	88.000	88.000
$M_2T_3C_2$	50.000[ij]	66.667	74.667	77.333	80.000	80.000	80.000	80.000
$M_2T_3C_3$	53.333[j]	69.333	93.333	93.333	93.333	93.333	93.333	93.333
$M_2T_4C_1$	37.333[defgh]	62.667	84.000	86.667	89.333	89.333	89.333	89.333
$M_2T_4C_2$	40.000[efghi]	56.000	66.667	73.333	80.000	80.000	80.000	80.000
$M_2T_4C_3$	40.000[efghi]	56.000	68.000	76.000	81.333	81.333	81.333	81.333
CD (0.05)	11.600*	NS	NS	NS	NS	NS	NS	NS

M_1 - with seed coat; M_2 - without seed coat; T_1 - 6 h soaking; T_2 - 12 h soaking; T_3 - 18 h soaking; T_4 - 24 h soaking; C_1 - 200 ppm GA; C_2 - 300 ppm GA; C_3 - 500 ppm GA

* Significant at 5 per cent level

Table 9. Effect of different treatments on seed germination over controls at weekly intervals

Treatments	Germination percentage at weekly intervals							
	1	2	3	4	5	6	7	8
Control-1 vs. the rest of M_1	17.556	20.889	19.661	14.167	17.500	18.556	22.111	22.111
Control-2 vs. the rest of M_2	15.889	20.611	28.333	18.333	10.333	10.333	10.333	10.333
CD (0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Control-1 - with seed coat - no GA - no soaking

Control-2 - without seed coat - no GA - no soaking

M_1 - with seed coat

M_2 - without seed coat

4.1.4.5 Effect of different treatments over controls

The data showing the superiority of interaction of seed coat and soaking treatment with GA over controls are tabulated in Table 9. It could be read from the data that the various GA treatments were superior to the corresponding control treatments, throughout the period of study. When control-1 (with seed coat - no GA treatment) was compared with various GA treatments with seed coat it was found that the superiority of treatments over the control increased upto the end of the 2nd week, thereafter decreased upto the end of the 4th week, again increased and remained steady after the end of the 7th week. The superiority of GA treatments over control-2 (without seed coat - no GA treatment) increased upto the end of the 3rd week, then decreased in the 4th week, and remained steady after the 5th week.

4.2 Standardisation of type and age of rootstock for epicotyl, softwood and double grafting

The type and age of rootstock are known to have a pronounced influence on the success and growth of grafted plants in several tropical fruit crops.

4.2.1 Standardisation of the type of rootstock

In the present study, rootstocks belonging to two species of the family Guttiferae, viz., Garcinia tinctoria and

G. cambogia were tried. The initial and final percentage of success of grafts using these rootstocks following various vegetative propagation methods were recorded. The data were computed using chi-square statistic.

4.2.1.1 Epicotyl grafting

Among the two rootstocks tried, G. cambogia did not attain sufficient height and girth at the prescribed age for epicotyl grafting. Hence epicotyl grafting was done only on G. tinctoria rootstocks.

4.2.1.2 Softwood grafting

The data on the effect of types of rootstock on initial (30 and 60 days after grafting) and final (90 days after grafting) success are presented in Table 10. Initial success of grafts was not influenced by the type of rootstock in softwood grafting while the final success after 90 days of grafting was significantly influenced by the type of rootstock. The final success of grafts after 90 days was high (60.00 per cent) when G. cambogia was used as rootstock. When G. tinctoria was used, the success was computed as 40.00 per cent.

Effect of type of rootstock on extension of growth, girth and number of leaves of the scion was compared using two sample case t-test and are tabulated in Tables 11 to 13. It

Table 10. Effect of different types of rootsock on the success of softwood grafting

Treatments	Number of grafts made	Initial success				Final success	
		30 DAG		60 DAG		90 DAG	
		Number	Percentage	Number	Percentage	Number	Percentage
R_1	120	66^a	55.00	53.00^a	44.16	48.00^a	40.00
R_2	120	78^a	65.00	75.00^a	62.50	72.00^b	60.00

R_1 - G. tinctoria DAG - Days after grafting

R_2 - G. cambogia

X^2 - analysis was done

Table 11. Effect of different types of rootstock on the extension growth of scion in cm at fortnightly intervals in softwood grafting

Treatments	Extension growth at fortnightly intervals										Mean
	1	2	3	4	5	6	7	8	9	10	
R_1	1.010	1.020	1.057	1.087	1.133	1.157	1.180	1.213	1.253	1.287	1.140[a]
R_2	1.030	2.370	6.200	9.000	11.300	13.510	15.560	17.250	17.940	19.300	11.346[b]

R_1 - *G. tinctoria*; R_2 - *G. cambogia*

Two sample case t-test was done

Table 12. Effect of different types of rootstock on the girth of scion in cm at fortnightly intervals in softwood grafting

Treatments	Girth at fortnightly intervals										Mean
	1	2	3	4	5	6	7	8	9	10	
R_1	1.067	1.067	1.067	1.077	1.110	1.123	1.137	1.160	1.170	1.180	1.116[a]
R_2	1.280	1.290	1.330	1.360	1.450	1.491	1.520	1.570	1.580	1.630	1.450[b]

R_1 - *G. tinctoria*; R_2 - *G. cambogia*

Two sample case t-test was done

Table 13. Effect of different types of rootstock on the number of leaves of scion at fortnightly intervals in softwood grafting

Treatments	Number of leaves at fortnightly intervals										Mean
	1	2	3	4	5	6	7	8	9	10	
R_1	1.970	1.970	1.960	1.800	1.830	1.700	1.730	1.730	1.700	1.700	1.809[a]
R_2	2.000	2.000	2.600	4.100	4.600	6.300	6.600	7.200	7.200	7.800	5.040[b]

R_1 - *G. tinctoria*; R_2 - *G. cambogia*

Two sample case t-test was done

was evident from the data that R_2 (softwood grafting on G. cambogia was significantly superior to that on G. tinctoria (R_1). The extension growth, girth and number of leaves of the scion on G. cambogia, taken as the average of ten fortnights after grafting were 11.346 cm, 1.450 cm and 5.040 while the corresponding values of the scion on G. tinctoria were 1.140 cm, 1.116 cm and 1.809 respectively.

4.2.1.3 Double grafting

The data on the effect of type of rootstock combinations on the success of double grafting are presented in Table 14. Similar to softwood grafting, in double grafting also, success after 30 days of grafting was not significantly different among the three kinds of combination tried, but after 60 days, M_3R_2 (double grafting using two seedlings of G. cambogia) was significantly superior (55.00 per cent) to the other two combinations while these two were on par. When the final success after 90 days was compared, all the combinations were found to be statistically different from each other. M_3R_2 recorded the highest success percentage (52.50) followed by M_3R_{1} (double grafting using one seedling each of G. cambogia and G. tinctoria) which gave 25.00 per cent success. M_3R_1 (double grafting on two seedlings of G. tinctoria) proved to be the least successful (17.50 per cent success).

Table 14. Effect of different rootstock combinations on the success of double grafting

Treatments	Number of grafts made	Initial success				Final success	
		30 DAG		60 DAG		90 DAG	
		Number	Percentage	Number	Percentage	Number	Percentage
M_3R_1	120	61[a]	50.83	35[a]	29.17	21[a]	17.50
M_3R	120	58[a]	48.33	37[a]	30.83	30[b]	25.00
M_3R_2	120	72[a]	60.00	66[b]	55.00	63[c]	52.50

M_3 - Double grafting

R_1 - G. tinctoria + G. tinctoria; DAG - Days after grafting

R_2 - G. cambogia + G. cambogia

R - G. tinctoria + G. cambogia

x^2 - analysis was done

4.2.2 Standardisation of age of rootstock

The different age groups selected for G. tinctoria rootstocks were 10, 15 and 20 days for epicotyl grafting and two, three and four months for softwood grafting whereas it was 18 months for G. cambogia for softwood grafting. Double grafting was done using two rootstocks for each scion. The details of age groups of rootstocks are given in Chapter II. In order to compute the initial and final percentage of success of grafts chi-square test was adopted.

4.2.2.1 Epicotyl grafting

The data on the initial and final success of epicotyl grafting on G. tinctoria (Table 15) showed that the three age groups of rootstock viz., 10, 15 and 20 days after the emergence of seedlings were statistically homogeneous after 30 days of grafting while after 60 and 90 days the treatments differed significantly. Epicotyl grafting on 20 days old G. tinctoria rootstocks (A_3R_1) recorded the highest percentage of success (80.00 per cent) followed by 15 days old rootstocks (A_2R_1 - 57.50 per cent). Epicotyl grafting on 10 days old G. tinctoria recorded the least percentage of success (A_1R_1 - 52.50 per cent). When the percentage of success after 90 days was computed, the same treatment, A_3R_1 accounted the highest success (75.00 per cent) followed by A_2R_1 (57.50 per cent) and A_1R_1 (50.00 per cent).

Table 15. Effect of age of rootstock on the success of epicotyl grafting

Treatments	Number of grafts made	Initial success				Final success	
		30 DAG		60 DAG		90 DAG	
		Number	Percentage	Number	Percentage	Number	Percentage
A_1R_1	120	72[a]	60.00	63[a]	52.50	60[a]	50.00
A_2R_1	120	75[a]	62.50	69[a]	57.50	69[b]	57.50
A_3R_1	120	96[a]	80.00	93[b]	80.00	90[c]	75.00

A_1 - 10 days R_1 - *G. tinctoria*

A_2 - 15 days   DAG - Days after grafting

A_3 - 20 days

X^2 - analysis was done

4.2.2.2 Softwood grafting

The data pertaining to the effect of age of rootstock on the initial and final success of softwood grafting are presented in Table 16. The results indicated that the different age groups of rootstock influenced the graft success only after 90 days of grafting. At this stage, softwood grafting on 18 months old G. cambogia rootstocks yielded the highest percentage of success followed by softwood grafting on two months, three months and four months old G. tinctoria rootstocks. The percentage of success accounted in these cases were 60.00, 52.00, 38.00 and 30.00 per cent respectively.

4.2.2.3 Double grafting

The results computed on the effect of age of rootstocks on the initial and final success of grafting are shown in Table 17. On comparison of treatments, it was observed that $M_3A_3R_1$ (double grafting using two, 20 days old seedlings of G. tinctoria) yielded the maximum percentage of success after 30 days of grafting (82.50 per cent). The maximum success after 60 days was observed in $M_3A_7R_2$ (55.00 per cent) followed by $M_3A_3R_1$. After 90 days also $M_3A_7R_2$ yielded the maximum success of 52.50 per cent. $M_3A_1R_1$ (double grafting on two seedlings of 10 days old G. tinctoria) recorded the least percentage of success after 30, 60 and 90

Table 16. Effect of age of rootstock on the success of softwood grafting

Treatments	Number of grafts made	Initial success				Final success	
		30 DAG		60 DAG		90 DAG	
		Number	Percentage	Number	Percentage	Number	Percentage
A_4R_1	120	75[a]	62.50	66[a]	55.00	62[c]	52.00
A_5R_1	120	66[a]	55.00	51[a]	42.50	45[b]	38.00
A_6R_1	120	57[a]	47.50	42[a]	35.00	36[a]	30.00
A_8R_2	120	78[a]	65.00	75[a]	62.50	72[d]	60.00

A_4 - 2 months R_1 - *G. tinctoria*

A_5 - 3 months R_2 - *G. cambogia*

A_6 - 4 months DAG - Days after graftig

A_8 - 18 months

X^2 - analysis was done

Table 17. Effect of age of rootstock combinations on the success of double grafting

Treatments	Number of grafts made	Initial success				Final success	
		30 DAG		60 DAG		90 DAG	
		Number	Percentage	Number	Percentage	Number	Percentage
$M_3A_1R_1$	120	27^{a}	22.50	15^{a}	12.50	0^{a}	0.00
$M_3A_2R_1$	120	57^{b}	47.50	33^{bc}	27.50	24^{b}	20.00
$M_3A_3R_1$	120	99^{d}	82.50	57^{c}	47.50	39^{c}	32.50
M_3A_1R	120	54^{b}	45.00	45^{c}	37.50	21^{b}	30.00
M_3A_2R	120	60^{b}	50.00	36^{bc}	30.00	30^{c}	25.00
M_3A_3R	120	60^{b}	50.00	30^{b}	25.00	24^{b}	20.00
$M_3A_7R_2$	120	72^{c}	60.00	66^{d}	55.00	63^{d}	52.50

M_3 - Double grafting

A_1 - 10 days

A_2 - 15 days

A_3 - 20 days

A_7 - 12 months

R_1 - G. tinctoria + G. tinctoria

R_2 - G. cambogia + G. cambogia

R - G. cambogia + G. tinctoria

DAG - Days after grafting

X^2 - analysis was done

days of grafting which was accounted as 22.50, 12.50 and 0.00 respectively.

4.2.3 Standardisation of type of rootstock and method of grafting

The grafted plants at different stages of growth are illustrated in Plates 9 to 14. The data on the success percentage, extension growth, girth and number of leaves of the grafts in different treatments using two types of rootstocks and following three methods of grafting are tabulated in Tables 18, 19, 20 and 21 respectively. In order to compare the treatments based on initial and final success percentage of grafts chi-square test was conducted. Analysis of variance was done (Appendix III) to compare the treatments on the basis of extension growth, girth and number of leaves of the scion which were taken as the average of ten fortnights after grafting.

The results obtained (Table 18) indicated that there was significant difference between the treatments regarding the success of grafts after 60 and 90 days of grafting when different rootstocks were used and different methods were followed, while all the treatments seemed to be homogeneous after 30 days of grafting. A maximum percentage of success after 60 days was found to be associated with M_1R_1 (epicotyl grafting on *G. tinctoria*) and M_2R_2 (softwood grafting on

Plate 9 Epicotyl grafts on *Garcinia tinctoria*

(2, 3 and 4 months after grafting)

Plate 10 Softwood grafts on *Garcinia tinctoria*

(2, 3 and 4 months after grafting)


EPICOTYL GRAFTING ON G.tinctoria


SOFT WOOD GRAFTING ON G.tinctoria

Plate 11 Softwood grafts on *Garcinia cambogia* (3, 4 and 5 months after grafting)

Plate 12 Double grafts on *Garcinia tinctoria* + *Garcinia tinctoria* (2, 3 and 4 months after grafting)


A
B
C


DOUBLE GRAFTING ON G. tinctoria + G. tinctoria

Plate 13 Double grafts on *Garcinia tinctoria* + *Garcinia cambogia* (2, 3 and 4 months after grafting)

Plate 14 Double grafts on *Garcinia cambogia* + *Garcinia cambogia* (2, 3 and 4 months after grafting)


DOUBLE GRAFTING ON G. lanceolata + G. cambogia

Table 18. Interaction effect of different types of rootstock and methods of grafting on the success of grafts

Treatments	Number of grafts made	Initial success				Final success	
		30 DAG		60 DAG		90 DAG	
		Number	Percentage	Number	Percentage	Number	Percentage
M_1R_1	120	81[a]	67.50	75[c]	62.50	74[c]	61.67
M_2R_1	120	66[a]	55.00	53[b]	44.16	48[b]	39.72
M_2R_2	120	78[a]	65.00	75[c]	62.50	72[c]	60.00
M_3R_1	120	61[a]	50.83	35[a]	29.17	21[a]	17.50
M_3R	120	60[a]	50.00	33[a]	27.50	27[a]	22.50
M_3R_2	120	72[a]	60.00	66[c]	55.00	63[c]	52.50

M_1 - Epicotyl grafting

M_2 - Softwood grafting

M_3 - Double grafting

DAG - Days after grafting

X^2 - analysis was done

R_1 - *G. tictoria*

R_2 - *G. cambogia*

R - *G. tinctoria* + *G. cambogia*

G. cambogia) which was accounted as 62.50. At this stage, M_3R_2 (double grafting on two seedlings of G. cambogia) was found to be on par with M_1R_1 and M_2R_2 which gave 55.00 per cent success. After 90 days also, M_1R_1 was found to be on par with M_2R_2 and M_3R_2. These three treatments recorded 61.67, 60.00 and 52.50 per cent success respectively after 90 days. The treatment, M_3R (double grafting on G. tinctoria and G. cambogia) recorded the lowest percentage of success after 60 days of grafting while M_3R_1 (double grafting on two seedlings of G. tinctoria) yielded the lowest percentage of success (17.50) after 90 days of grafting. Since this treatment did not put forth any new growth, it was deleted from further studies.

The statistical analysis of Table 19 revealed that the different treatments with respect to the type of rootstock and method of grafting differed significantly considering the extension growth of the scion. It seemed that the maximum extension growth of 11.346 cm was associated with M_2R_2 followed by M_3R_2 which recorded 8.105 cm. The least extension growth of 1.140 cm was recorded in M_2R_1 (softwood grafting on G. tinctoria) and it was on par with the rest of the two treatments viz., M_2R_1 and M_3R. The treatment, M_2R_2 recorded the highest value for girth of scion (1.450 cm) while the lowest value was foůnd in M_1R_1 (0.887 cm) and it was on par with M_2R_1 and M_3R as revealed from Table 20. It was

Table 19. Interaction effect of different types of rootstock and methods of grafting on the extension growth of scion in cm at fortnightly intervals

Treatments	Extension growth at fortnightly intervals										Mean
	1	2	3	4	5	6	7	8	9	10	
M_1R_1	0.816	0.907	1.003	1.080	1.217	1.283	1.427	1.463	1.500	1.516	1.221^{a}
M_2R_1	1.010	1.020	1.057	1.087	1.133	1.157	1.180	1.213	1.253	1.287	1.140^{a}
M_2R_2	1.030	2.370	6.200	9.000	11.300	13.510	15.560	17.250	17.940	19.300	11.346^{c}
M_3R_2	1.160	2.250	4.250	6.850	8.450	10.660	10.660	11.600	12.400	12.770	8.105^{b}
M_3R	1.075	1.085	1.300	1.435	1.555	1.705	1.940	2.045	2.240	2.425	1.681^{a}
CD (0.05)											3.065*

M_1 - Epicotyl grafting; M_2 - Softwood grafting; M_3 - Double grafting

R_1 - G. tinctoria; R_2 - G. cambogia; R - G. tinctoria + G. cambogia

* Significant at 5 per cent level

Table 20. Interaction effect of different types of rootstock and methods of grafting on the girth of scion in cm at fortnightly intervals

Treatments	Girth at fortnightly intervals										Mean
	1	2	3	4	5	6	7	8	9	10	
M_1R_1	0.733	0.757	0.780	0.800	0.877	0.910	0.923	0.977	0.990	1.027	0.877[a]
M_2R_1	1.067	1.067	1.067	1.077	1.110	1.123	1.137	1.160	1.170	1.180	1.116[bc]
M_2R_2	1.280	1.290	1.330	1.360	1.450	1.491	1.520	1.570	1.580	1.630	1.450[d]
M_3R_2	1.020	1.020	1.060	1.140	1.180	1.240	1.330	1.420	1.530	1.610	1.255[c]
M_3R	0.895	0.895	0.905	0.940	0.990	1.005	1.015	1.070	1.085	1.095	0.990[ab]
CD (0.05)											0.149*

M_1 - Epicotyl grafting; M_2 - Softwood grafting; M_3 - Double grafting

R_1 - *G. tinctoria*; R_2 - *G. cambogia*; R - *G. tinctoria* + *G. cambogia*

* Significant at 5 per cent level

evident that the treatments, M_3R_2 and M_2R_2 recorded higher values for the number of leaves (Table 21). On an average, M_3R_2 and M_2R_2 produced 5.470 and 5.080 leaves respectively. The minimum number of leaves was found in M_2R_1 (1.800) while it was on par with M_1R_1 and M_3R.

4.2.4 Interaction effect of type and age of rootstock and method of grafting on growth parameters

The influence of type and age of rootstock and method of grafting on the various growth parameters of the grafts, viz., extension growth, girth and number of leaves were studied and compared at fortnightly interval upto the 10th fortnight after grafting, adopting the principles of analysis of variance (Appendix IV, V and VI). The data are presented in Tables 22, 23 and 24 respectively.

4.2.4.1 Extension growth of scion

Observations on the extension growth of scion for various treatments are presented in Table 22. The table showed that there was significant difference between the treatments throughout the period of study. In all the fortnights studied, except the first, $M_2A_8R_2$ (softwood grafting on 18 months old G. cambogia) recorded the maximum values for the extension growth of scion. The values were 2.370 cm, 6.20 cm, 9.00 cm, 11.30 cm, 13.510 cm, 15.560 cm,

Table 21. Interaction effect of different types of rootstock and methods of grafting on number of leaves of scion at fortnightly intervals

Treatments	Number of leaves at fortnightly intervals										Mean
	1	2	3	4	5	6	7	8	9	10	
M_1R_1	1.330	1.700	2.130	2.470	3.100	3.200	3.170	3.170	3.130	3.100	2.650[a]
M_2R_1	1.970	1.970	1.930	1.800	1.830	1.700	1.730	1.730	1.700	1.700	1.806[a]
M_2R_2	2.000	2.000	3.000	4.100	4.600	6.300	6.600	7.200	7.200	7.800	5.080[b]
M_3R_2	2.500	2.700	3.200	3.400	4.800	6.000	6.600	7.500	8.300	9.700	5.470[b]
M_3R	2.000	2.150	2.150	3.750	2.800	3.100	3.300	3.550	3.800	3.850	2.945[a]
CD (0.05)											1.344*

M_1 - Epicotyl grafting; M_2 - Softwood grafting; M_3 - Double grafting

R_1 - _G_. _tinctoria_; R_2 - _G_. _cambogia_; R_3 - _G_. _tinctoria_ + _G_. _cambogia_

* Significant at 5 per cent level

Table 22. Interaction effect of different types and age of rootstock and methods of grafting on the extension growth of scion in cm, at fortnightly intervals

Treatments	Extension growth at fortnightly intervals									
	1	2	3	4	5	6	7	8	9	10
$M_1A_1R_1$	0.740^{a}	0.830^{a}	0.880^{a}	0.970^{a}	1.120^{a}	1.200^{a}	1.370^{a}	1.390^{a}	1.420^{a}	1.450^{a}
$M_1A_2R_1$	0.760^{a}	0.860^{a}	1.000^{a}	1.070^{a}	1.280^{a}	1.350^{a}	1.440^{a}	1.450^{a}	1.490^{a}	1.500^{a}
$M_1A_3R_1$	0.950^{b}	1.010^{a}	1.130^{a}	1.200^{a}	1.250^{a}	1.300^{a}	1.470^{a}	1.550^{a}	1.590^{a}	1.600^{a}
$M_2A_4R_1$	0.940^{b}	0.940^{a}	0.950^{a}	0.950^{a}	1.000^{a}	1.010^{a}	1.020^{a}	1.060^{a}	1.070^{a}	1.080^{a}
$M_2A_5R_1$	1.040^{bc}	1.040^{a}	1.100^{a}	1.100^{a}	1.140^{a}	1.170^{a}	1.200^{a}	1.230^{a}	1.290^{a}	1.340^{a}
$M_2A_6R_1$	1.050^{bc}	1.050^{a}	1.120^{a}	1.210^{a}	1.260^{a}	1.290^{a}	1.320^{a}	1.350^{a}	1.400^{a}	1.440^{a}
$M_2A_8R_2$	1.030^{bc}	2.370^{b}	6.200^{c}	9.000^{c}	11.300^{c}	13.510^{c}	15.560^{c}	17.250^{c}	17.940^{c}	19.300^{c}
$M_3A_7R_2$	1.160^{c}	2.250^{b}	4.250^{b}	6.850^{b}	8.450^{b}	10.660^{b}	10.660^{b}	11.600^{b}	12.400^{b}	12.770^{b}
M_3A_2R	1.090^{bc}	1.110^{a}	1.400^{a}	1.570^{a}	1.750^{a}	1.930^{a}	2.180^{a}	2.390^{a}	2.640^{a}	2.870^{a}
M_3A_3R	1.060^{bc}	1.060^{a}	1.200^{a}	1.300^{a}	1.360^{a}	1.480^{a}	1.700^{a}	1.700^{a}	1.840^{a}	1.980^{a}
CD (0.05)	0.160*	0.400*	0.870*	1.290*	1.410*	1.590*	1.760*	1.860*	2.000*	2.120*

M_1 - Epicotyl grafting; M_2 - Softwood grafting; M_3 - Double grafting

A_1 - 10 days; A_2 - 15 days; A_3 - 20 days; A_4 - 2 months; A_5 - 3 months; A_6 - 4 months

A_7 - 12 months; A_8 - 18 months; R_1 - G. tinctoria; R_2 - G. cambogia; R - G. tinctoria + G. cambogia

* Significant at 5 per cent level

17.250 cm, 17.940 cm and 19.30 cm respectively at the end of 2nd to 10th fortnights. In the 1st fortnight, $M_3A_7R_2$ (double grafting on two, 12 months old G. cambogia) recorded the maximum extension growth of scion which was measured as 1.160 cm. In the 1st, 2nd and 3rd fortnights $M_1A_1R_1$ (epicotyl grafting on ten days old G. tinctoria) yielded the lowest values for extension growth as 0.740 cm, 0.830 cm and 0.880 cm respectively. Thereafter, upto the 10th fortnight $M_2A_4R_1$ (softwood grafting on 2 months old G. tinctoria) recorded the lowest values (0.950 cm, 1.00 cm, 1.010 cm, 1.020 cm, 1.060 cm, 1.070 cm and 1.080 cm respectively). An overall comparison of the treatments at different fortnights revealed the superiority of $M_2A_8R_2$ and $M_3A_7R_2$ in all the fortnights while the rest of the treatments were on par, for the extension of the scion. $M_2A_8R_2$ showed the maximum extension growth of 19.30 cm followed by $M_3A_7R_2$ (12.770 cm) while the rest of the treatments showed a difference of only less than 2 cm between the first and last fortnights studied.

4.2.4.2 Girth of scion

It was apparent from Table 23 that the treatments under study differed significantly from each other from 1st to 10th fortnights after grafting. The maximum values for girth of scion were measured in $M_2A_8R_2$ in all the fortnights considered. The values were 1.280 cm, 1.290 cm, 1.330 cm,

Table 23. Interaction effect of different types and age of rootstock and methods of grafting on the girth of scion in cm, at fortnightly intervals

Treatments	Girth at fortnightly intervals									
	1	2	3	4	5	6	7	8	9	10
$M_1A_1R_1$	0.680^{a}	0.680^{a}	0.740^{a}	0.780^{ab}	0.870^{ab}	0.910^{ab}	0.940^{ab}	1.000^{ab}	1.020^{a}	1.060^{a}
$M_1A_2R_1$	0.690^{a}	0.750^{ab}	0.750^{a}	0.760^{a}	0.790^{a}	0.850^{a}	0.860^{a}	0.930^{a}	0.950^{a}	0.990^{a}
$M_1A_3R_1$	0.830^{b}	0.840^{b}	0.850^{ab}	0.860^{ab}	0.970^{b}	0.970^{ab}	0.970^{ab}	1.000^{ab}	1.000^{a}	1.030^{a}
$M_2A_4R_1$	1.140^{d}	1.140^{d}	1.140^{e}	1.140^{c}	1.160^{c}	1.160^{cd}	1.170^{d}	1.180^{bc}	1.180^{bc}	1.190^{bc}
$M_2A_5R_1$	0.970^{c}	0.970^{c}	0.970^{cd}	0.970^{b}	1.020^{bc}	1.040^{bc}	1.050^{bc}	1.090^{bc}	1.100^{ab}	1.110^{ab}
$M_2A_6R_1$	1.090^{cd}	1.090^{d}	1.090^{de}	1.120^{c}	1.150^{c}	1.170^{cd}	1.190^{d}	1.210^{c}	1.230^{c}	1.240^{bc}
$M_2A_8R_2$	1.280^{e}	1.290^{e}	1.330^{f}	1.360^{d}	1.450^{e}	1.491^{e}	1.520^{f}	1.570^{d}	1.580^{d}	1.630^{d}
$M_3A_7R_2$	1.020^{cd}	1.020^{cd}	1.060^{de}	1.140^{c}	1.180^{cd}	1.240^{d}	1.330^{e}	1.420^{d}	1.530^{d}	1.610^{d}
M_3A_2R	0.880^{bc}	0.880^{bc}	0.900^{bc}	0.910^{b}	0.970^{b}	1.000^{b}	1.000^{b}	1.060^{ab}	1.070^{ab}	1.090^{a}
M_3A_3R	0.910^{bc}	0.910^{bc}	0.910^{c}	0.970^{c}	1.010^{b}	1.010^{bc}	1.030^{b}	1.080^{ab}	1.100^{ab}	1.110^{ab}
CD (0.05)	0.125*	0.127*	0.131*	0.133*	0.133*	0.136*	0.139*	0.152*	0.150*	0.158*

M_1 - Epicotyl grafting; M_2 - Softwood grafting; M_3 - Double grafting

A_1 - 10 days; A_2 - 15 days; A_3 - 20 days; A_4 - 2 months; A_5 - 3 months; A_6 - 4 months

A_7 - 12 months; A_8 - 18 months; R_1 - G. tinctoria; R_2 - G. cambogia; R - G. tinctoria + G. cambogia

* Significant at 5 per cent level

1.360 cm, 1.450 cm, 1.491 cm, 1.520 cm, 1.570 cm, 1.580 cm and 1.630 cm respectively from 1st to 10th fortnights. Except in the 1st three fortnights, $M_3A_7R_2$ recorded the second maximum values. In the first three fortnights, $M_1A_1R_1$ (epicotyl grafting using ten days old G. tinctoria rootstock) showed the lowest values for girth of scion while in the rest of the fortnights $M_1A_2R_1$ (epicotyl grafting using 15 days old G. tinctoria rootstock) yielded the lowest values. An overall comparison of the treatments showed the superiority of $M_2A_8R_2$ in all the fortnights which was on par with $M_3A_7R_2$ in 4th, 8th, 9th and 10th fortnights, for the girth of scion.

4.2.4.3 Number of leaves

The data recorded in Table 24 revealed that the treatments differedsignificantly in all the fortnights as in the case of extension growth and girth of scion. $M_3A_7R_2$ and $M_2A_8R_2$ showed apparent superiority with respect to the number of leaves produced on the scion. In all the fortnights, except in the 4th and 6th, $M_3A_7R_2$ produced maximum number of leaves compared to the other treatments. The number of leaves corresponding to $M_3A_7R_2$ from 1st to 10th fortnights were 2.50, 2.70, 3.20, 3.40, 4.80, 6.00, 6.60, 7.50, 8.30 and 9.70 respectively. In the 4th and 6th fortnights, $M_2A_8R_2$ slightly surpassed $M_3A_7R_2$ in which case the number of leaves recorded were 4.10 and 6.30 respectively. Upto the 4th fortnight, $M_1A_1R_1$ recorded the least number of leaves (0.90, 1.20, 1.40

Table 24. Interaction effect of different types and age of rootstock and methods of grafting on the number of leaves of scion at fortnightly intervals

Treatments	Number of leaves at fortnightly intervals									
	1	2	3	4	5	6	7	8	9	10
$M_1A_1R_1$	0.900^{a}	1.200^{a}	1.400^{a}	1.500^{a}	2.800^{ab}	2.800^{bcd}	3.400^{c}	3.400^{bc}	3.200^{cd}	3.200^{bcd}
$M_1A_2R_1$	1.400^{ab}	2.200^{bc}	2.500^{bc}	2.700^{bc}	2.900^{ab}	3.000^{bcd}	3.000^{bc}	2.900^{bcd}	2.900^{bc}	3.000^{bc}
$M_1A_3R_1$	1.700^{bc}	1.700^{ab}	2.500^{bc}	3.200^{cd}	3.600^{bc}	3.800^{d}	3.500^{c}	3.200^{bcd}	3.300^{cd}	3.100^{bcd}
$M_2A_4R_1$	2.200^{cd}	2.200^{bc}	2.200^{ab}	1.800^{ab}	1.600^{a}	1.300^{a}	1.300^{a}	0.900^{a}	0.800^{a}	0.800^{a}
$M_2A_5R_1$	1.900^{bcd}	1.900^{b}	1.900^{ab}	1.900^{ab}	2.200^{a}	2.100^{abc}	2.200^{abc}	2.400^{bc}	2.400^{bc}	2.400^{bc}
$M_2A_6R_1$	1.800^{bc}	1.800^{ab}	1.700^{ab}	1.700^{ab}	1.700^{a}	1.700^{ab}	1.700^{ab}	1.900^{ab}	1.900^{abc}	1.900^{ab}
$M_2A_8R_2$	2.000^{bcd}	2.000^{b}	2.600^{bc}	4.100^{d}	4.600^{c}	6.300^{e}	6.600^{d}	7.200^{e}	7.200^{e}	7.800^{e}
$M_3A_7R_2$	2.500^{c}	2.700^{c}	3.200^{c}	3.400^{cd}	4.800^{c}	6.000^{e}	6.600^{d}	7.500^{e}	8.300^{e}	9.700^{f}
M_3A_2R	2.000^{bcd}	2.000^{b}	2.000^{ab}	2.800^{bc}	2.800^{ab}	3.300^{cd}	3.500^{c}	3.900^{d}	4.300^{d}	4.400^{d}
M_3A_3R	2.000^{bcd}	2.300^{bc}	2.300^{abc}	2.700^{bc}	2.800^{ab}	2.900^{bcd}	3.100^{bc}	3.200^{bcd}	3.300^{cd}	3.300^{cd}
CD (0.05)	0.570*	0.630*	0.920*	1.170*	1.290*	1.410*	1.490*	1.440*	1.350*	1.300*

M_1 - Epicotyl grafting; M_2 - Softgrafting; M_3 - Double grafting

A_1 - 10 days; A_2 - 15 days; A_3 - 20 days; A_4 - 2 months; A_5 - 3 months; A_6 - 4 months

A_7 - 12 months; A_8 - 18 months; R_1 - G. tinctoria; R_2 - G. cambogia; R - G. tinctoria + G. cambogia

* Significant at 5 per cent level

and 1.50 respectively). Thereafter $M_2A_4R_1$ registered the lowest number of leaves (1.60, 1.30, 1.30, 0.90, 0.80 and 0.80 respectively). An overall comparison revealed that $M_3A_7R_2$ produced maximum number of leaves except in the 4th and 6th fortnights and in the 1st, 3rd, 5th, 6th, 7th, 8th and 9th fortnights it was on par with $M_3A_8R_2$.

4.3 Effect of type and age of scion wood on the success of grafting

Type and age of scion wood had got a direct influence on the success of grafting. In the present study, three types of scion wood (Plate 15) viz., new flush shoot with a plumy apical bud (completely green in colour and three months old), past season shoot with no new sprout (completely brown in colour and six months old) and past season shoot with a new sprout and a plumpy apical bud (basally brown, green at the top and nine months old) were used to know their effect on graft take. Among them, six months old scion material did not produce any new growth on the graft even after five months of grafting. The initial and final success could be computed observing the colour of the grafted scion. It remained green even after the prescribed periods (30, 60 and 90 days after grafting). Therefore, comparison of growth parameters like extension growth, girth and number of leaves of the scion was not possible in these grafts. Chi-square statistic was adopted to compute the initial and final percentage of success

Plate 15 Different types of scion wood used for grafting

A - nine months old

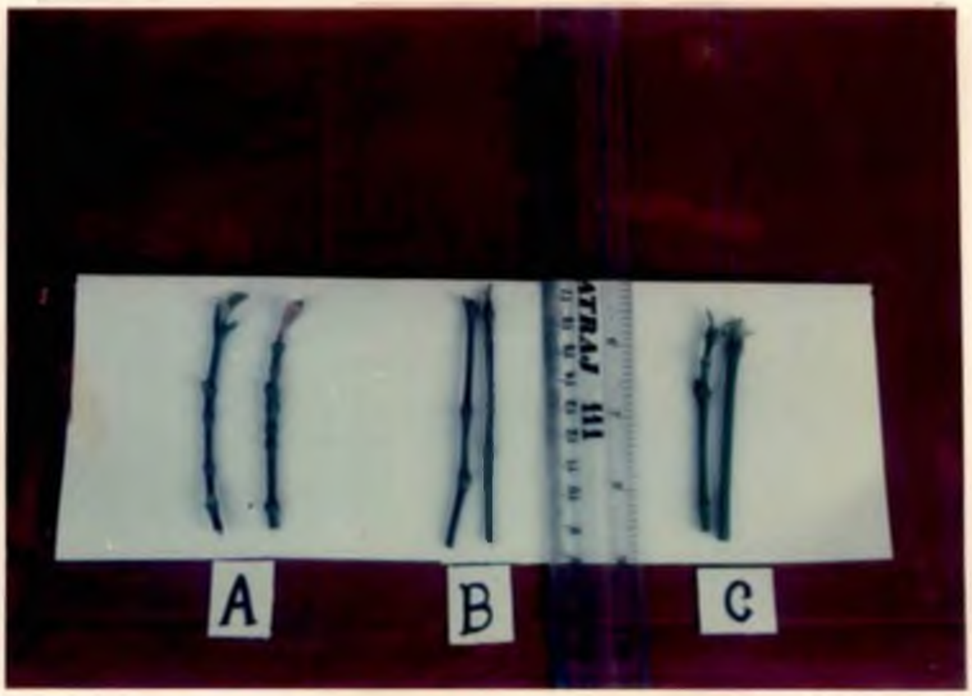
B - six months old

C - three months old

Plate 16 Grafts prepared using different types of scion wood (5 months after grafting)

A - Using three months old scion wood

B - Using nine months old scion wood


A
B
C


A
B

of grafts while the principles of two sample case t-test were followed ,to compare the treatments (T_1 and T_3), on the basis of growth parameters. The grafts prepared using these two types of scion wood are illustrated in Plate 16.

Table 25 gives an account of the initial and final success of grafts and it was seen that there was significant difference between the treatments in this respect. T_3 (nine months old scion wood) recorded the highest percentage of initial and final success of grafts as 80.00, 75.00 and 70.00 after 30, 60 and 90 days of grafting, however it was on par with T_1 (three months old scion wood).

The data pertaining to the comparison of treatments with respect to extension growth, girth and number of leaves of the scion are presented in Tables 26 to 28. The studies revealed that the two treatments were statistically different and T_3 gave higher values for extension growth of scion compared to T_1 (Table 26). Extension growth of scion from the 1st to 10th fortnights, in T_3 were 1.180 cm, 2.250 cm, 4.90 cm, 5.580 cm, 9.310 cm, 10.420 cm, 11.780 cm, 13.40 cm, 14.620 cm and 15.420 cm respectively. When the girth of scion was considered, the treatments were similar to each other (Table 27). The treatments differed significantly with regard to the number of leaves, in all the fortnights except the first and second ones (Table 28). Here also, T_3 recorded more number of leaves compared to T_1. The average number of leaves

Table 25. Effect of type and age of scion wood on the success of grafting

Treatments	Number of grafts made	Initial success				Final success	
		30 DAG		60 DAG		90 DAG	
		Number	Percentage	Number	Percentage	Number	Percentage
T_1	60	45^{b}	75.00	39^{b}	65.00	30^{b}	50.00
T_2	60	6^{a}	10.00	3^{a}	5.00	3^{a}	5.00
T_3	60	48^{b}	80.00	45^{b}	75.00	42^{b}	70.00

T_1 - Three months old

T_2 - Six months old

T_3 - Nine months old

X^2 - analysis was done

DAG - Days after grafting

Table 26. Effect of type and age of scion wood on the extension growth of scion in cm, at fortnightly intervals

Treatments	Extension growth at fortnightly intervals									
	1	2	3	4	5	6	7	8	9	10
T_1	0.870[a]	1.100[a]	1.650[a]	2.120[a]	4.160[a]	6.400[a]	7.380[a]	9.100[a]	9.990[a]	10.496[a]
T_3	1.180[b]	2.250[b]	4.900[b]	5.580[b]	9.310[b]	10.420[b]	11.780[b]	13.400[b]	14.620[b]	15.420[b]

T_1 - Three months old; T_3 - Nine months old

Two sample case t-test was done

Table 27. Effect of type and age of scion wood on the girth of scion in cm, at fortnightly intervals

Treatments	Girth at fortnightly intervals									
	1	2	3	4	5	6	7	8	9	10
T_1	0.950[a]	0.960[a]	0.980[a]	1.050[a]	1.090[a]	1.110[a]	1.190[a]	1.210[a]	1.250[a]	1.250[a]
T_3	0.930[a]	0.940[a]	0.970[a]	1.030[a]	1.080[a]	1.150[a]	1.200[a]	1.270[a]	1.350[a]	1.410[a]

T_1 - Three months old; T_3 - Nine months old

sample case t-test was done

Table 28. Effect of type and age of scion wood on the number of leaves of scion at fortnightly intervals

Treatments	Number of leaves at fortnightly intervals									
	1	2	3	4	5	6	7	8	9	10
T_1	2.000[a]	2.000[a]	2.100[a]	2.200[a]	3.300[a]	4.000[a]	4.300[a]	5.200[a]	5.600[a]	6.300[a]
T_3	2.000[a]	2.000[a]	3.300[b]	3.900[b]	5.300[b]	5.900[b]	7.400[b]	7.800[b]	9.300[b]	10.000[b]

T_1 - Three months old; T_3 - Nine months old

Two sample case t-test was done

computed in T_3 from 3rd to 10th fortnights were 3.30, 3.90, 5.30, 5.90, 7.40, 7.80, 9.30 and 10.00 respectively.

It is concluded from the observations that nine months old scion material was more suitable for softwood grafting in G. cambogia compared to three months old or six months old scion materials, both in the case of percentage of success of grafts and the growth parameters.

4.4 Effect of season on the success of grafting

In order to find out the best season for softwood grafting on G. cambogia and to improve the success percentage, grafting operation was conducted during six months viz., May, June, July, October, November and December. The data showing the effect of season on the initial (30 and 60 days after grafting) and final (90 days after grafting) success are tabulated in Table 29. Chi-square test was adopted to compare the treatments with respect to the success percentage of grafts.

On comparison, it was observed that the treatments differed significantly when the initial and final success of grafts were considered. Grafting operation during May, June and July yielded more success percentage compared to October, November or December grafting, after 30, 60 and 90 days of grafting. Among the six treatments, T_2 (June grafting)

Table 29. Effect of season on the success of grafting

Treatments	Number of grafts made	Initial success				Final success	
		30 DAG		60 DAG		90 DAG	
		Number	Percentage	Number	Percentage	Number	Percentage
T_1	100	88^c	88.00	80^c	80.00	75^c	75.00
T_2	100	92^c	92.00	87^c	87.00	84^c	84.00
T_3	100	90^c	90.00	85^c	85.00	80^c	80.00
T_4	100	60^b	60.00	56^b	56.00	56^b	56.00
T_5	100	52^{ab}	52.00	37^a	37.00	28^a	28.00
T_6	100	43^a	43.00	32^a	32.00	12^a	12.00

T_1 - May grafting T_3 - July grafting T_5 - November grafting

T_2 - June grarfting T_4 - October grafting T_6 - December grafting

X^2 - analysis was done

registered the highest success of 92.00 per cent, 87.00 per cent and 84.00 per cent respectively after 30, 60 and 90 days of grafting while T_6 (December grafting) recorded the lowest success as 43.00 per cent, 32.00 per cent and 12.00 per cent respectively at these stages.

4.5 Effect of growth regulators on the success of grafting

When IBA and GA each at 100, 250 and 500 ppm were sprayed on grafted plants immediately after grafting, it was observed that growth regulators had practically no effect on the graft take as well as further growth of the grafts. The same growth regulators each at 500, 750 and 1000 ppm were used for dipping the scion before grafting. The treatments were compared through chi-square test to find out the initial and final percentage of success. Analysis of variance was done to compare the treatments with respect to the growth parameters like extension growth, girth and number of leaves of the grafts at fortnightly intervals (Appendices VII, VIII and IX).

The observations on initial and final success of grafts are tabulated in Table 30. It was confirmed that there was significant difference between the treatments as far as the initial and final success of grafts after 30, 60 and 90 days of grafting were considered. T_1 (GA 500 ppm) gave the highest percentage of success after 30 and 60 days of grafting which were computed as 62.00 and 60.00 respectively.

Table 30. Effect of growth regulators on the success of grafting

Treatments	Number of grafts made	Initial success				Final success	
		30 DAG		60 DAG		90 DAG	
		Number	Percentage	Number	Percentage	Number	Percentage
T_1	60	37^{c}	62.00	36^{d}	60.00	34^{d}	56.67
T_2	60	32^{c}	54.00	25^{c}	42.00	22^{c}	36.67
T_3	60	15^{b}	25.00	7^{a}	11.67	5^{a}	8.33
T_4	60	19^{b}	32.00	17^{b}	28.33	14^{b}	23.33
T_5	60	10^{a}	16.67	7^{a}	11.67	4^{a}	6.67
T_6	60	10^{a}	16.67	2^{a}	3.33	0^{a}	0.00
T_7	60	36^{c}	60.00	34^{d}	56.67	34^{d}	56.67

T_1 - GA 500 ppm
T_2 - GA 750 ppm
T_3 - GA 1000 ppm
T_4 - IBA 500 ppm
T_5 - IBA 750 ppm
T_6 - IBA 1000 ppm
T_7 - Control
DAG - Days after grafting
X^2 - analysis was done

After 90 days, T_1 and T_7 (control) recorded the highest percentage of success (56.67). The lowest success of 16.67 per cent was recorded in T_5 (IBA 750 ppm) and T_6 (IBA 1000 ppm) after 30 days of grafting while after 60 and 90 days T_6 recorded the least percentage of success (2.33 and 0.00 per cent respectively).

The comparison of the treatments with reference to the extension growth, girth and number of leaves of the scion are depicted in Tables 31, 32 and 33 respectively. In these tables, only six treatments could be compared because the grafts survived in T_6 were too low in number to be compared statistically.

The data taken on the extension growth of scion indicated that the treatments differed significantly in all the fortnights from the 1st to the 10th (Table 31). It was found that T_7 was superior to the other treatments in the first three fortnights. The extension growth registered in T_7 during these fortnights were 1.030 cm, 2.370 cm and 6.20 cm respectively. From the 4th fortnight onwards, T_1 recorded the highest values for extension growth which were measured as 9.840 cm, 11.350 cm, 14.950 cm, 17.750 cm, 19.820 cm, 20.070 cm and 22.220 cm respectively. Eventhough, T_1 registered higher values for extension growth compared to all

Table 31. Effect of growth regulators on the extension growth of scion in cm, at fortnightly intervals

Treatments	Extension growth at fortnightly intervals									
	1	2	3	4	5	6	7	8	9	10
T_1	1.000^{bc}	2.180^{b}	5.890^{b}	9.840^{b}	11.350^{b}	14.950^{b}	17.750^{b}	19.820^{b}	20.070^{c}	22.220^{b}
T_2	0.967^{ab}	0.967^{a}	1.267^{a}	2.267^{a}	2.567^{a}	6.567^{a}	8.100^{a}	11.667^{a}	12.867^{b}	13.433^{a}
T_3	0.833^{a}	0.867^{a}	1.067^{a}	2.007^{a}	2.337^{a}	4.773^{a}	6.000^{a}	7.467^{a}	8.800^{a}	9.267^{a}
T_4	0.920^{ab}	1.350^{a}	1.550^{a}	2.170^{a}	2.870^{a}	4.833^{a}	7.150^{a}	8.340^{a}	10.840^{ab}	11.090^{a}
T_5	0.814^{a}	1.100^{a}	1.206^{a}	2.880^{a}	2.880^{a}	4.357^{a}	5.500^{a}	6.929^{a}	7.071^{a}	8.143^{a}
T_7	1.030^{bc}	2.370^{b}	6.200^{b}	9.000^{b}	11.300^{b}	13.510^{b}	15.560^{b}	17.250^{b}	17.940^{c}	19.300^{b}

T_1 - GA 500 ppm T_2 - BA 750 ppm T_3 - GA 1000 ppm

T_4 - IBA 500 ppm T_5 - IBA 750 ppm T_7 - Control other treatments, T_7 was found to be on par with T_1 throughout the period of study.

The results obtained showed the superiority of T_7 on girth of scion over the other treatments, throughout the period, except the last two fortnights (Table 32). The values for girth of scion corresponding to T_7 in these fortnights were 1.280 cm, 1.290 cm, 1.330 cm, 1.360 cm, 1.450 cm, 1.470 cm, 1.520 cm, 1.570 cm, 1.580 cm and 1.630 cm respectively. All the treatments, except T_7, were statistically similar to each other, in these fortnights as far as the girth of scion was concerned. During the last two fortnights, all the treatments including T_7 were statistically homogeneous.

When the treatments were compared with respect to the number of leaves produced on the scion (Table 33) it was found that the treatments differed significantly except in the first two fortnights. From the third fortnight to the end of tenth fortnight, T_1 (GA 500 ppm) produced the maximum number of leaves which were accounted as 3.70, 4.60, 6.90, 8.00, 8.70, 9.20, 9.20 and 9.40 respectively. However, T_1 did not prove its significant superiority over T_7 except, in the seventh fortnight.

The analysis was also performed through two way classification (Appendix IX) with unequal number of

Table 32. Effect of growth regulators on the girth of scion growth in cm, at fortnightly intervals

Treatments	Girth at fortnightly intervals									
	1	2	3	4	5	6	7	8	9	10
T_1	1.090[a]	1.160[b]	1.160[a]	1.210	1.240[a]	1.270[a]	1.280[a]	1.330[a]	1.350	1.370
T_2	0.957[a]	1.000[a]	1.057[a]	1.086[a]	1.129[a]	1.157[a]	1.124[a]	1.271[a]	1.357	1.400
T_3	1.000[a]	1.000[a]	1.067[a]	1.067[a]	1.133[a]	1.167[a]	1.267[a]	1.300[a]	1.333	1.400
T_4	1.020[a]	1.040[ab]	1.090[a]	1.130[a]	1.200[a]	1.250[a]	1.290[a]	1.360[a]	1.430	1.500
T_5	1.000[a]	1.000[a]	1.000[a]	1.167[a]	1.167[a]	1.200[a]	1.300[a]	1.333[a]	1.400	1.467
T_7	1.280[b]	1.290[b]	1.330[b]	1.360[b]	1.450[b]	1.470[b]	1.520[b]	1.570[b]	1.580	1.630
									NS	NS

T_1 - GA 500 ppm T_2 - GA 750 ppm T_3 - GA 1000 pppm

T_4 - IBA 500 ppm T_5 - IBA 750 ppm T_7 - Control

Table 33. Effect of growth regulators on the number of leaves of scion at fortnightly intervals

Treatments	Number of leaves at fortnightly intervals									
	1	2	3	4	5	6	7	8	9	10
T_1	2.100	2.400	3.700[b]	4.600[b]	6.900[c]	8.000[b]	8.700[b]	9.200[b]	9.200[b]	9.400[b]
T_2	2.000	2.143	3.057[b]	3.571[a]	4.286[a]	5.286[a]	5.571[a]	6.000[a]	6.571[a]	7.143[a]
T_3	2.000	2.000	2.000[a]	3.000[a]	3.000[a]	3.667[a]	5.000[a]	6.000[a]	6.667[a]	7.333[a]
T_4	2.000	2.000	2.200[a]	2.500[a]	3.700[a]	4.800[a]	5.600[a]	6.800[a]	7.000[a]	7.100[a]
T_5	2.000	2.000	2.000[a]	2.000[a]	3.000[a]	3.000[a]	5.667[a]	6.333[a]	7.000[a]	7.333[a]
T_7	2.000	2.000	3.000[b]	4.100[b]	4.600[b]	6.300[b]	6.600[a]	7.200[ab]	7.200[ab]	7.700[ab]
	NS	NS								

T_1 – GA 500 ppm; T_2 – GA 750 ppm; T_3 – GA 1000 ppm; T_4 – IBA 500 ppm;
T_4 – IBA 750 ppm; T_7 – Control

observations in different treatments. It was evident from the analysis that the treatments differed significantly in their effect on the extension growth of scion. It was also found that the increment in extension growth differed significantly from fortnight to fortnight and maximum increase in extension growth was observed from 4th to 8th fortnights. When the different treatments were ranked on the basis of leaves produced it was also found that the different levels of growth regulators differed significantly from each other. The treatment T_1, produced the maximum number of leaves followed by T_7. Here also, the maximum number of leaves were produced from 4th to 8th fortnights (Appendix X).

4.6 Anatomical studies

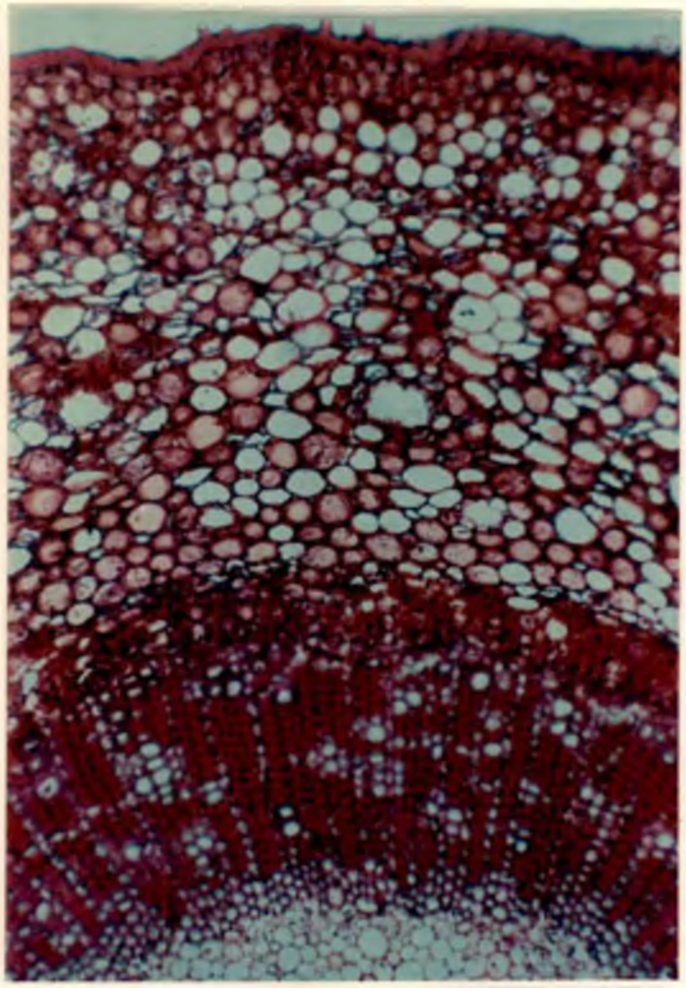
Anatomical studies were conducted to understand the characteristic features of graft union in various methods of grafting and to arrive at the reasons for graft failure.

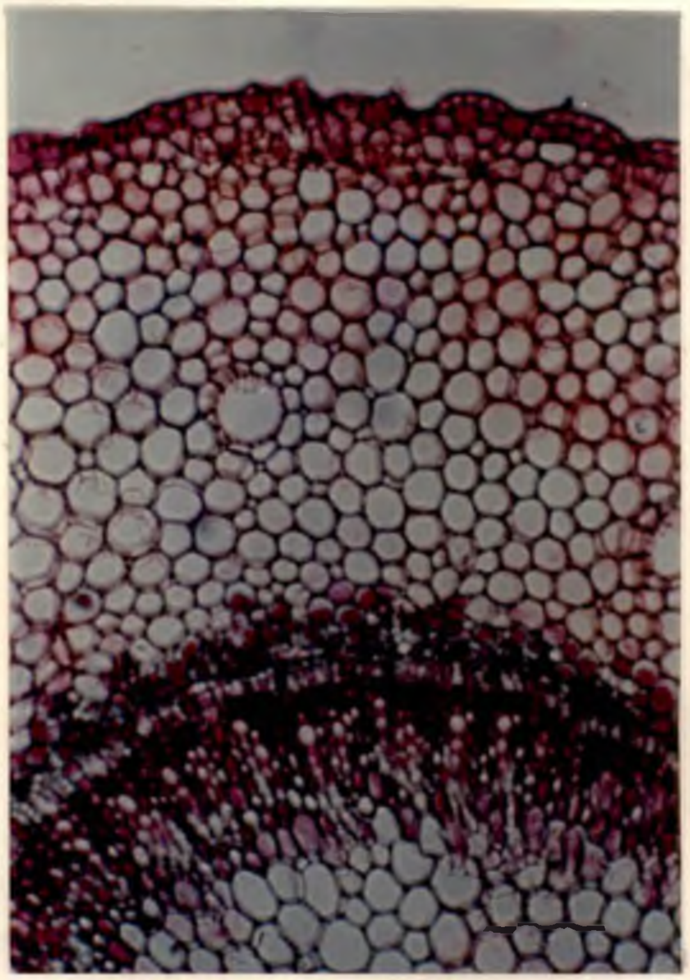
4.6.1 General anatomy of the stem

In *G. tinctoria* (Plate 17) and *G. cambogia* (Plate 18) the outermost layer of cells was the epidermis. These cells were rectangular in shape. A few unicellular epidermal hairs projecting from the epidermis were also seen. Below the epidermis, there were two to three layers of collenchyma which consisted of cells with thick non-lignified walls, thickened at the corners. The cortex consisted of 15 to 20 layers of

Plate 17 Cross-section of *Garcinia tinctoria* stem

Plate 18 Cross-section of *Garcinia cambogia* stem





thin walled parenchymatous cells found to be underlying the collenchyma. In the cortex tissue, three to four layers of laticiferous cells were found in _G. tinctoria_ while in _G. cambogia_, one or two layers of laticifers were seen. Laticifers are cells or series of fused cells containing a fluid called latex and forming system that permeate various tissues of the plant body. In addition to the laticifers, some gummy exudates were also found in the cells of cortex of _G. tinctoria_. The gummy exudates usually consist of phenols and natural dyes. The cells with gummy exudates were found to be deeply stained in the section of _G. tinctoria_ stem. In _G. cambogia_ such gummy exudates were almost absent so that the cells in the cortex appeared to be uniformly stained. In _G. tinctoria_ numerous starch granules and raphides containing calcium crystals were also found to be scattered in the cortex tissue. In _G. cambogia_ such starch grains and raphides were absent in the cortex tissue. Below the cortex, a single layer of endodermis made of parenchyma cells of rectangular shape was seen in _G. tinctoria_ whereas such a distinct endodermis was absent in _G. cambogia_. In the stem structure of _G. tinctoria_ and _G. cambogia_, secondary xylem and phloem were absent upto the softwood stage. Xylem mainly consisted of xylem parenchyma and vessels which were arranged radially from the pitch. Phloem was mainly made up of sieve tubes and fibres. Starch granules were found to be associated with phloem tissue in both the plants. Extending from the pitch and below the cortex, there were radially arranged parenchyma cells called xylem rays. The central tissue, pith, consisted of large thin walled parenchymatous cells.

4.6.2 Anatomy of graft union

In the case of epicotyl grafting using *G. tinctoria* as rootstock (Plate 19), thick callus formation was found only from the stock portion while the scion (*G. cambogia*) did not produce any callus tissue. The damaged cells of the scion at the cut surface turned brown and formed a necrotic layer which persisted at the graft union even after 90 days of grafting. Similar to epicotyl grafting, callus production was noticed only from the stock portion i.e. from *G. tinctoria* in softwood grafting. Here the number of layers of callus cells found in the union was lesser than the epicotyl grafts (Plate 20).

When softwood grafts on *G. cambogia* were studied, it was observed that callus was formed from both the sides viz., stock and scion and the callus was not very thick, unlike the grafts on *G. tinctoria* rootstock (Plate 21).

In double grafts on two seedlings of *G. tinctoria* (Plate 22) the anatomical studies revealed that callus proliferation from the stock portion was very intensive while the scion portion produced no callus at all. When the double grafts on *G. tinctoria* and *G. cambogia* (Plate 23) were studied, it was found that active callus proliferation occurred

Plate 19 Cross-section of epicotyl graft on *Garcinia tinctoria*

SC - Scion

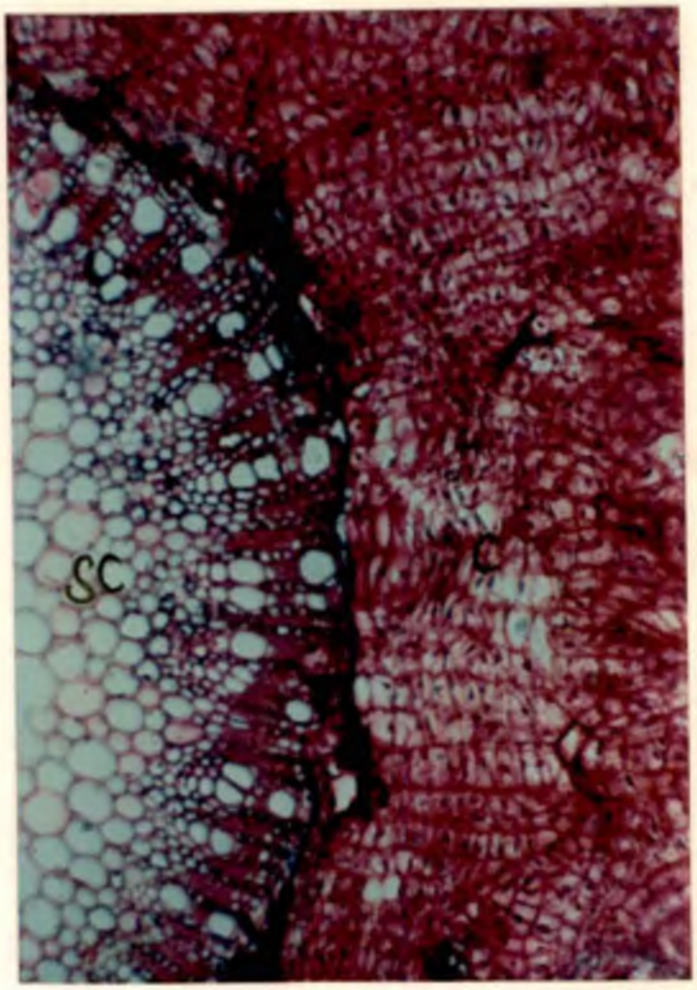
C - Callus

Plate 20 Cross-section of softwood graft on *Garcinia tinctoria*

ST - Stock

SC - Scion

C - Callus


SC
C

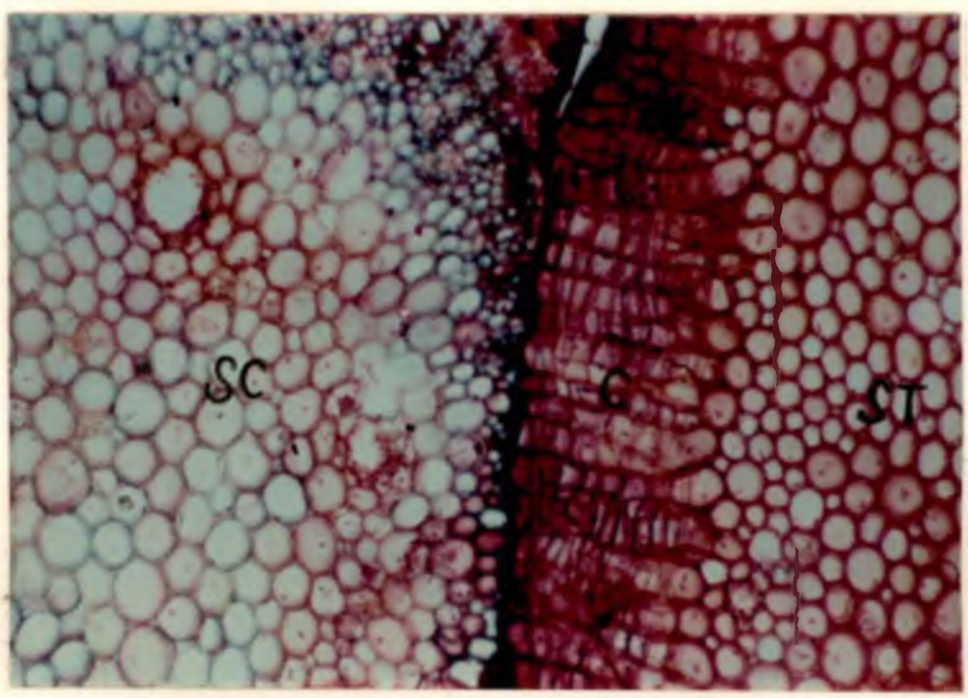

SC
C
ST

Plate 21 Cross-section of softwood graft on *Garcinia cambogia*

SC - Scion

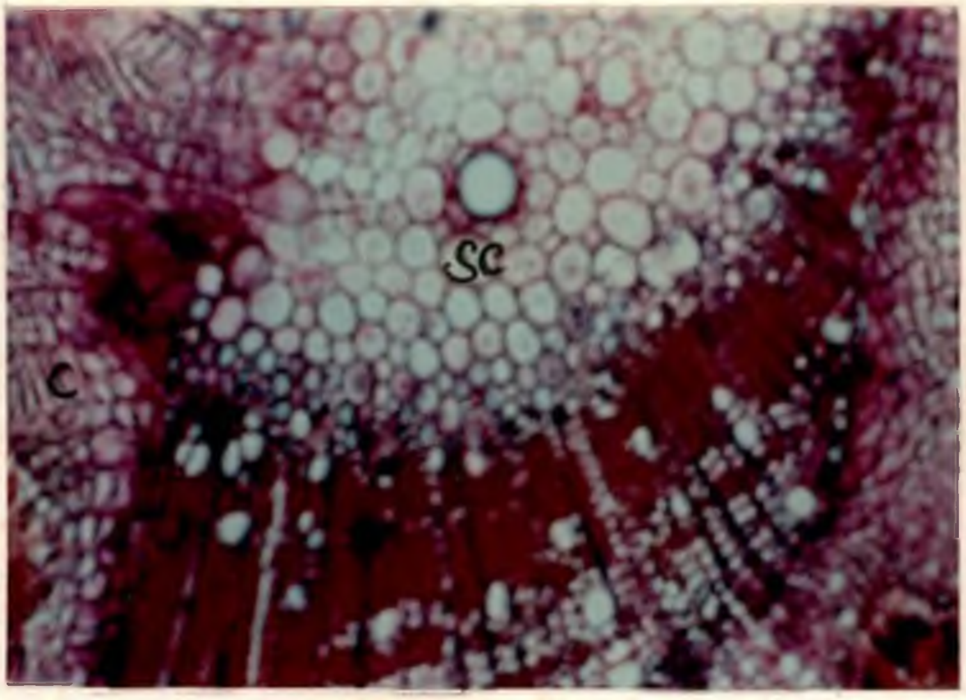
C - Callus

Plate 22 Cross-section of double graft on *Garcinia tinctoria* + *Garcinia tinctoria*

ST - Stock

SC - Scion

C - Callus


SC
C

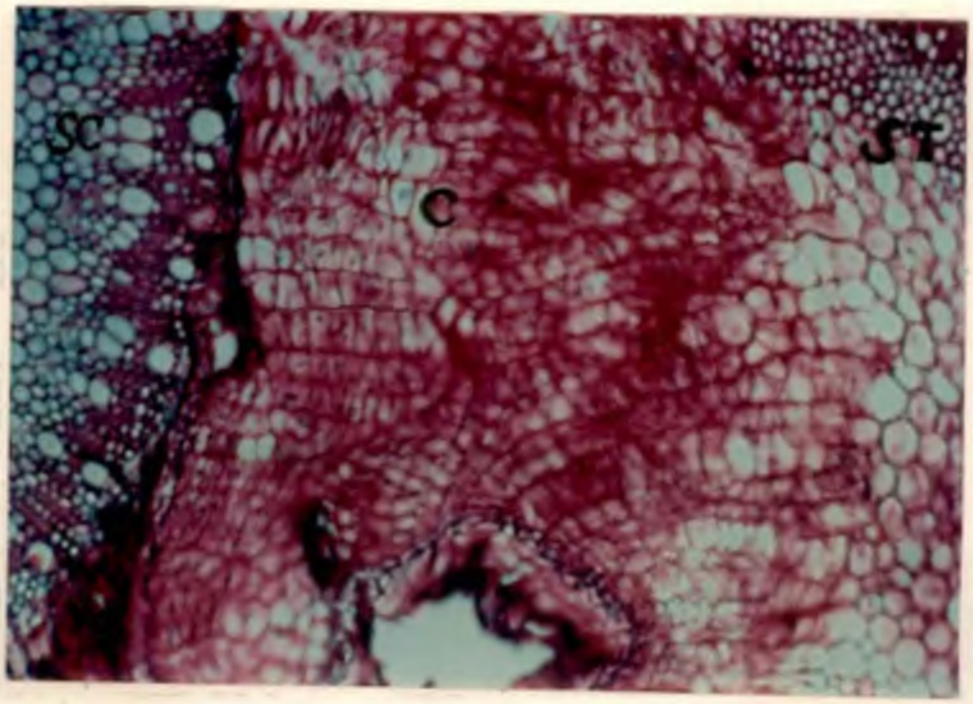

SC
ST
C

Plate 23 Cross-section of double graft on _Garcinia tinctoria_ + _Garcinia cambogia_

ST - Stock

SC - Scion

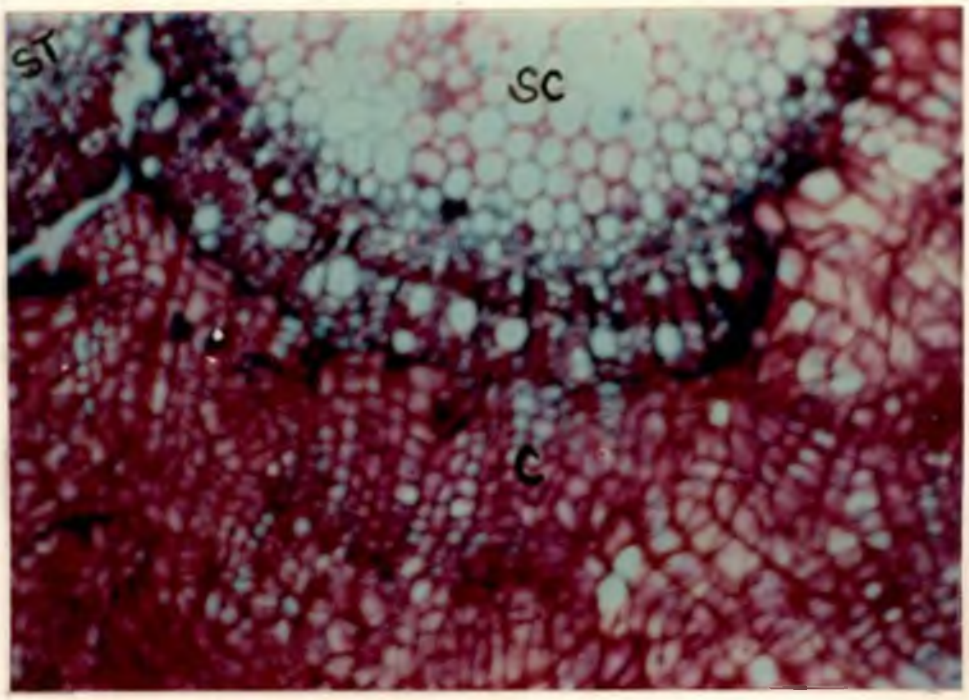
C - Callus

Plate 24 Cross-section of double graft on _Garcinia cambogia_ + _Garcinia cambogia_

ST - Stock

SC - Scion

C - Callus


ST
SC
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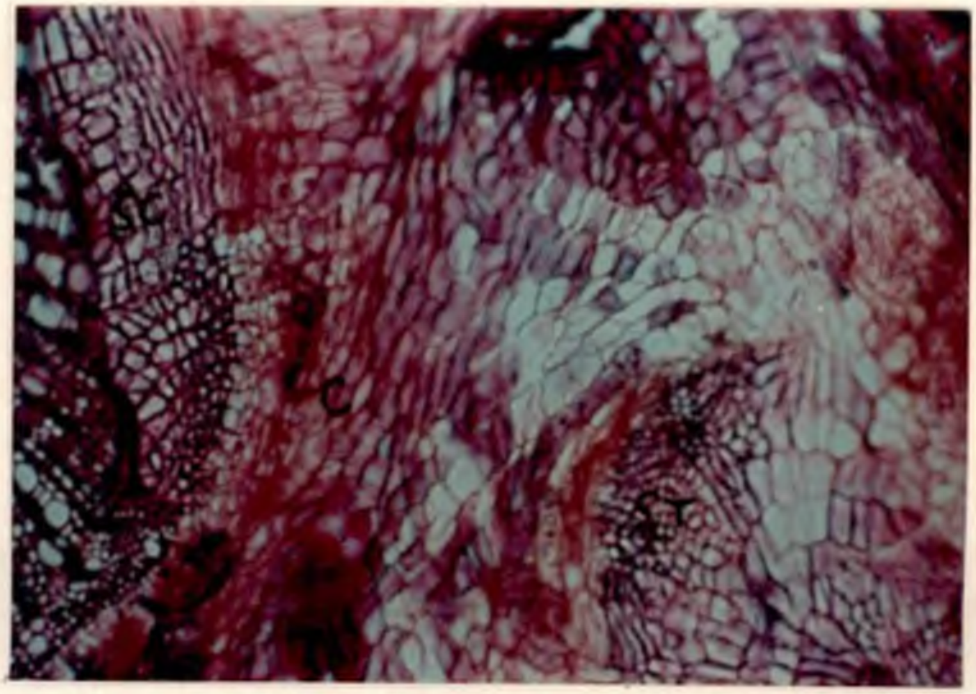

SC
C

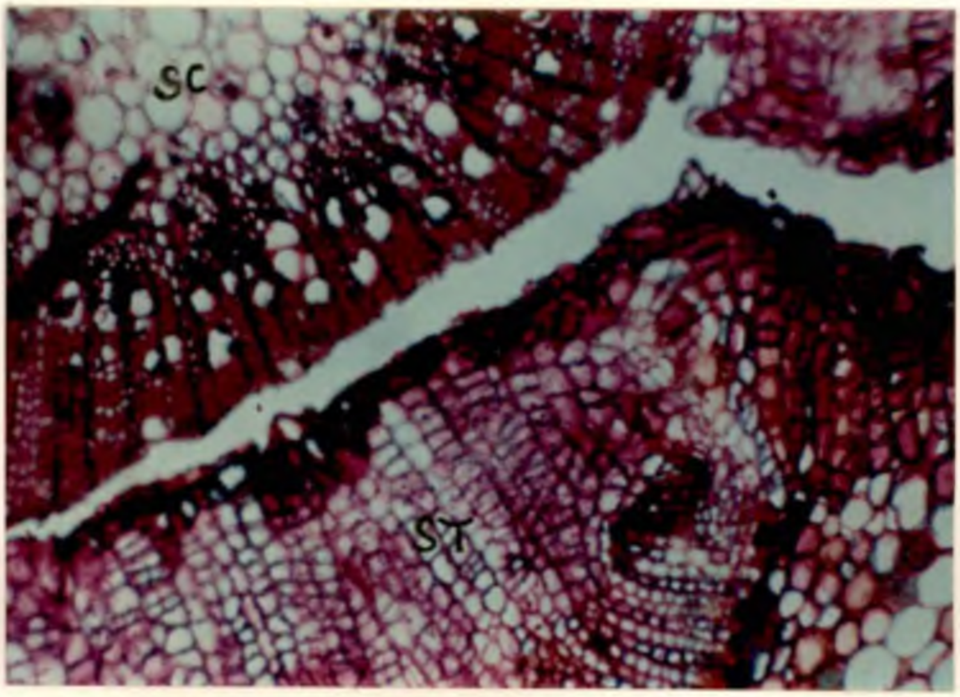
Plate 25 Absence of callus production between stock and scion

ST - Stock

SC - Scion

Plate 26 Excessive callus production between stock and scion

C - Callus


SC
ST

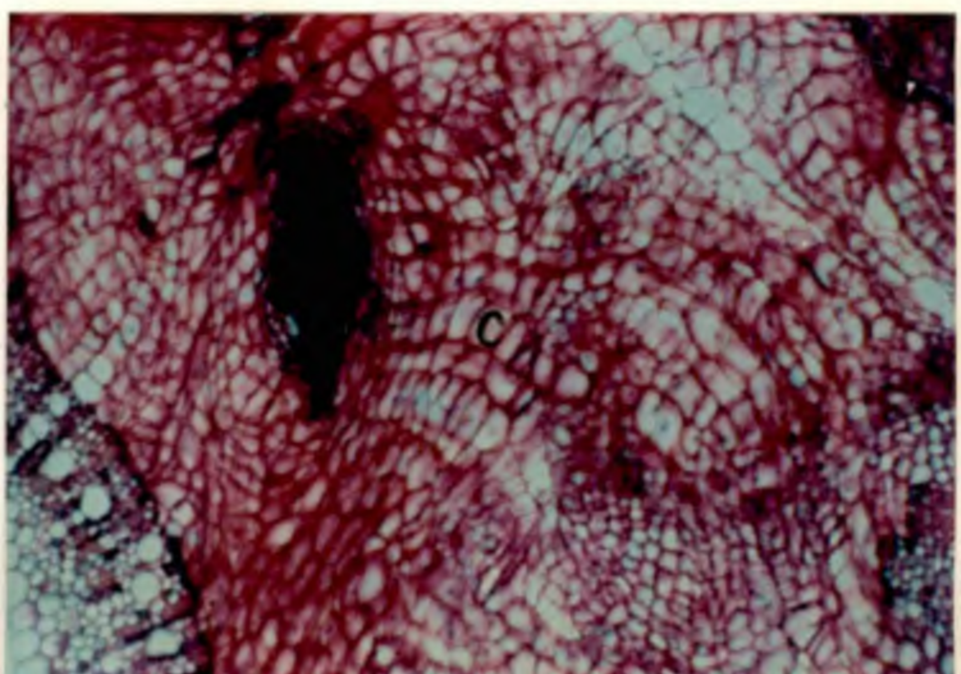

C

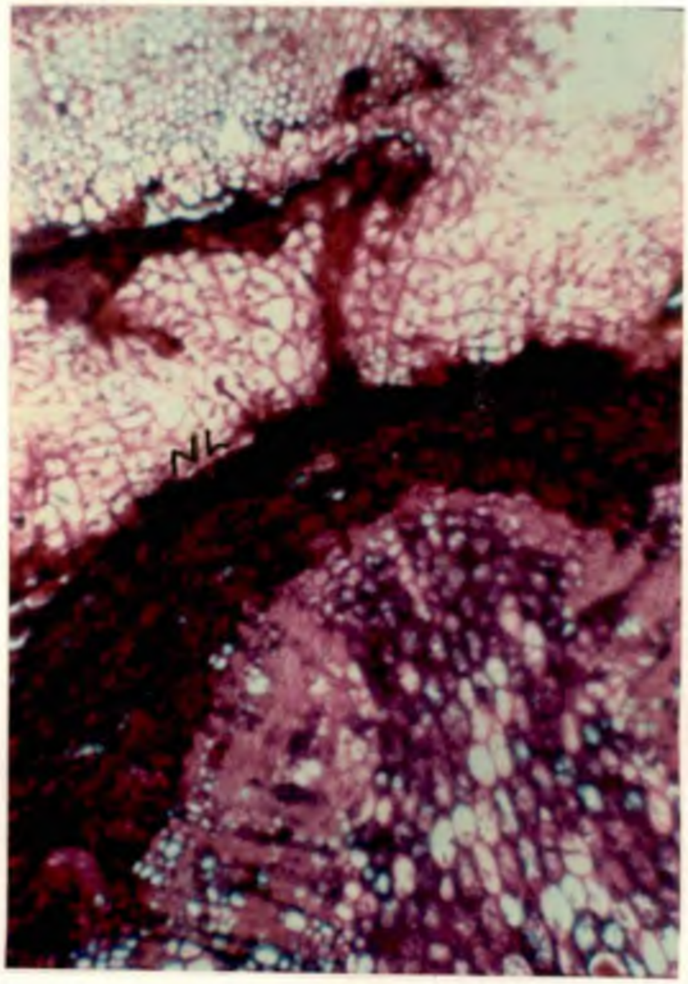
Plate 27 Degenerated phloem of the scion

DP - Degenerated phloem

Plate 28 Formation of a thick necrotic layer between stock and scion

NL - Necrotic layer


DP


NL

from the stock side while the contribution of scion towards callus proliferation was nil or very litte. On the other hand, when grafts were made on two seedlings of G. cambogia (Plate 24) and sections of the grafts were examined it was confirmed that callus proliferation occurred both from scion and stock and was about equal from both the stock and scion.

4.6.3 Reasons for graft failure

Examination of dried up grafts and grafts showing poor growth rate disclosed a wide gap between the stock and scion (Plate 25) owing to the absence of callus production between the stock and scion. Excessive callus production in between the stock and scion with no proper cambial bridge formation (Plate 26) was found to be another reason for graft failure. In some grafts, the formation of a thick necrotic layer at the graft union (Plate 27) was observed. The anatomical studies showed the phloem degeneration of the scion (Plate 28) at the graft union which was also assumed to be one of the reasons for graft failure.

Discussion

DISCUSSION

In Garcinia cambogia (*Kodumpuli*), an important minor fruit of Kerala's homesteads, research on propagation has not made any headway. Generally, it is propagated by seeds obtained from mature ripe fruits. Because of the disadvantages of sexual propagation like wide variation in fruit type and sex of the plant among the seedling progenies and long resting period and seasonal availability of seeds, the seed propagation of G. cambogia can not be solely relied upon. Therefore, a systematic study on a suitable propagation technique in this crop has become a deepfelt need.

In some of the related species of *Kodumpuli* viz., mangosteen (G. mangostana), kokam (G. cambogia) etc. encouraging findings have been reported in the field of vegetative propagation. Taking into account these promising results in these close relatives of *Kodumpuli*, the present series of studies were undertaken on its methods of propagation with special emphasis on epicotyl and softwood grafting in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara. These studies are the first of its kind, though some isolated attempts have been made at the District Agricultural Farm, Thaliparamba and R.A.R.S., Kumarakom (personal communication).

In the present study, two species of the family, Guttiferae, viz., G. cambogia and G. tinctoria (*Rajapuli*) were tried as rootstocks. Both the plants flower during the summer season (March-April) and fruits ripen and seeds become available during the rainy season (June-July). Normally, the seeds of G. cambogia take a long period of about seven months for germination. Removal of seed coat hastens germination of seeds in many of the tropical crops. Stimulatory effect of growth regulators like GA on germination of seeds has also been widely accepted (Hartmann and Kester, 1989). The results of the present study concerned with various factors involved in seed germination and vegetative propagation methods like epicotyl, softwood and double grafting of G. cambogia are discussed hereunder.

5.1 Effect of seed coat and GA on germination of G. cambogia seeds

It was observed that the seeds from which seed coat was removed recorded higher and faster germination compared to seeds with intact seed coat. The difference in the time taken for starting the germination between these two groups was about 28 weeks. On an average, seeds without seed coat took one to four weeks for attaining 50 per cent germination while seeds with intact seed coat required 31 to 36 weeks for the same, after sowing. From the beginning of germination, seeds without seed coat completed germination within five weeks while the seeds with seed coat took seven weeks for the completion of germination. These facts led to the conclusion that in the case of seeds with seed coat, germination was delayed as well as staggered compared to seeds without seed coat. When the final germination percentage in different treatments including two controls was studied, it was found that the seeds without seed coat recorded comparatively higher values. Simao (1960) and Subramanya and Reddy (1989) also found that germination was enhanced and germination percentage was improved in mango stones by dehusking. Ilyas (1978) showed that dehusked clove seeds started germination 16 days after sowing while the normal seeds germinated only after 27 days. Germination percentage was also increased in this case. From the present study, it could be revealed that the reason for the delayed germination and lower percentage of germination of seeds in this crop might be due to the presence of mechanically hard seed coat. Therefore, the beneficial effect of removal of seed coat on seed germination might be due to the removal of mechanically hard seed coat itself or the toxic metabolites present on the seed coat as reported by Hartmann and Kester, 1989.

Studies carried out to know the effect of different concentrations of GA on germination revealed that though the treatments found to differ significantly from control, all the concentrations of GA tried (200 ppm, 300 ppm and 500 ppm) were on par, except in the 2nd, 3rd and 4th weeks. In these weeks, GA 500 ppm showed significantly higher percentage of germination. The treatments of seeds with GA at any concentration significantly improved the germination percentage over the control. Different soaking periods also showed significant results on seed germination over the control. Among the different soaking periods 12 h soaking was found to be superior to others. However 18 h soaking was on par with 12 h soaking. In many tropical fruits like jack, cherimoya, nutmeg, cashew and guava, it has been found that GA treatment could enhance and improve seed germination (Farooqui et al., 1971; Duarte et al., 1974; Mathew, 1979; Shanmugavelu, 1985; Kumar et al., 1991). The study on the action of GA on seed germination indicated that GA accelerated the enzyme reaction which bring about the break down of starch and it is the first step of germination (Hartmann and Kester, 1989). The soaking treatment also could leach out the toxic metabolites from the seeds (Basu et al., 1975). Perhaps these might be the possible reasons in the present study also, for getting an early and higher germination percentage.

In order to obtain an overall comparison, the interaction effect of various factors were analysed. When the interaction of three factors, viz., seed coat, soaking periods and concentrations of GA was considered it was clear that the interaction effect was significant only at the first week. In order to attain the maximum germination within one week (53.333) seed coat removal and seed soaking with 500 ppm GA for 12 h or 18 h could be adopted. However, to prevent wastage of time, a combination of seed coat removal and seed soaking with 500 ppm GA for 12 h could be practised. In spite of the hmogenity of treatments after the first week, seed coat removal and soaking with 500 ppm GA for 12 h and 18 h gave higher percentage of germination (90.667 and 93.333 respectively) compared to all other treatments. The similarity in the effect of treatments on the basis of percentage of germination after the first week of germination indicated that the three factor interaction hastened the germination compared to the individual effect of the factors.

5.2 Vegetative propagation

G. cambogia finds a place in most of the homesteads in Kerala. The popular method of propagation now existing is by seeds obtained from mature ripe fruits. But the seedlings exhibit heterogenity in tree characters and manifest a long pre-bearing period. Unlike many other fruit plants, seed propagation in this plant has an added disadvantage of existence of dioecious plants among the seedlings progenies.

Standardisation of an easy, simple and economic method of vegetative propagation will not only expedite the perpetuation of high yielding female trees but also elude the waste incurred towards the maintenance of male trees till the flowering stage. Practically, very little work has been done to standardise the vegetative propagation methods in this crop. Hence the present study was taken up to find out the feasibility of vegetative procreation methods (like epicotyl, softwood and double grafting) in *Kodumpuli* under Kerala conditions.

The two recent and propitious methods viz., epicotyl and softwood grafting techniques which were reputed to be highly successful in tropical fruits like mango and jack (Ratan, 1985; Radhamony, 1987; Jose, 1989) were studied in this crop. In addition, success of double grafting engaging two rootstocks was also studied. It is well known that success of grafting is greatly influenced by type of rootstock, age of rootstock, type of scion and the season of grafting irrespective of the method of grafting. Therefore, work was initiated in this direction and promising results have been obtained.

5.2.1 Type of rootstock

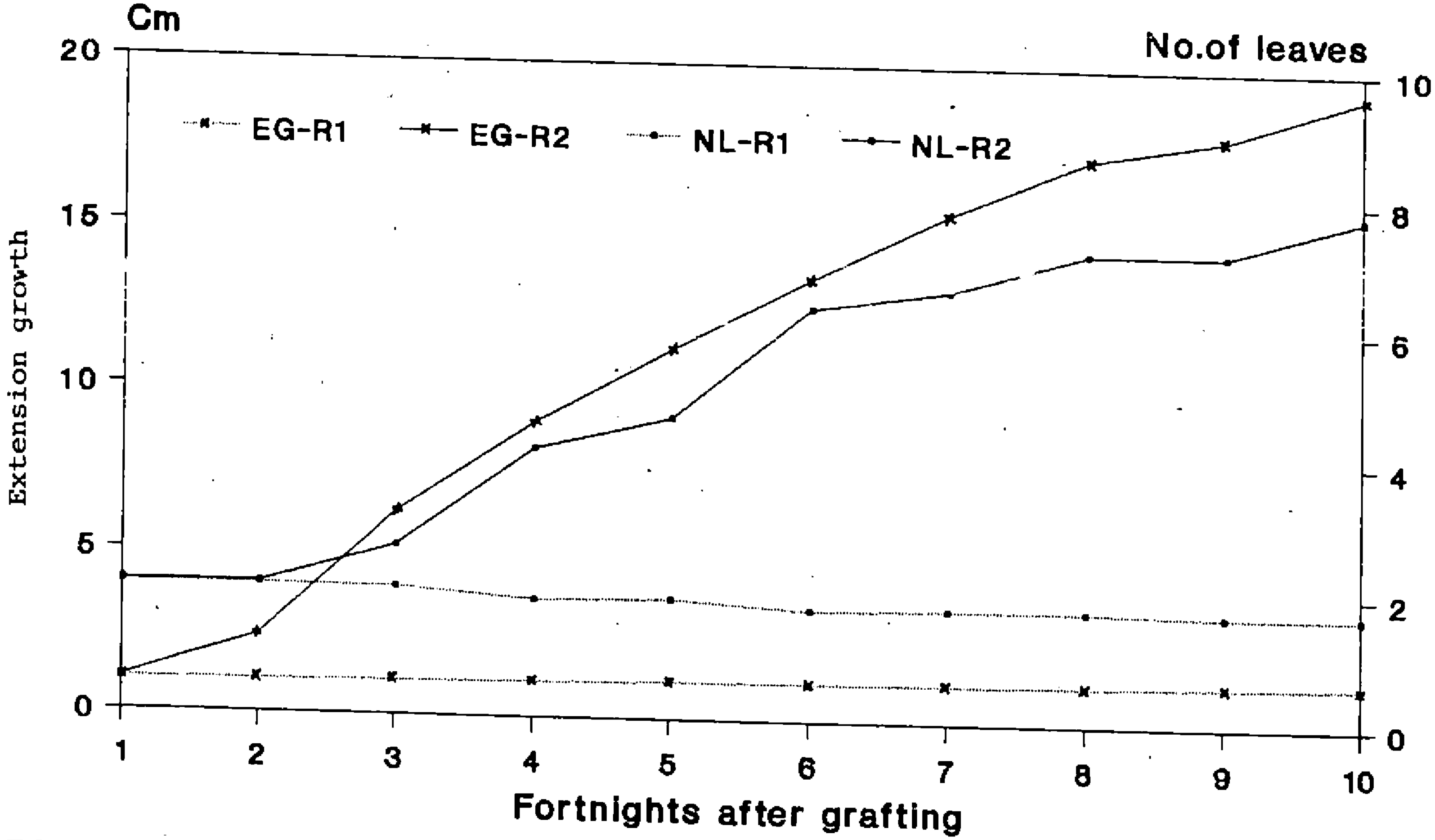
In the present study, two species of the family, Guttiferae, viz., G. cambogia and G. tinctoria were used as rootstocks. But at the epicotyl stage (10 to 20 days after germination) G. cambogia seedlings attained a height of only 4 to 6 cm and a girth of 0.4 to 0.6 cm which made it impossible to perform epicotyl grafting. Therefore, for the assessment of rootstocks, softwood and double grafting were considered. Even in the case of softwood grafting, owing to the inherent slow growth of the seedlings of G. cambogia at the initial stage, it could be performed only on seedlings having at least 18 months age, whereas in G. tinctoria softwood grafting could be started from two months onwards. It was observed from the present study that in softwood grafting, G. cambogia rootstocks contributed higher percentage of success compared to G. tinctoria rootstocks. Also, when the growth parameters like extension growth, girth and number of leaves of the scion were compared, the superiority of G. cambogia over G. tinctoria as rootstock was conspicuous. In the case of extension growth of scion, a significant difference of 18 cm was shown by the grafts on G. cambogia rootstocks. A notable increase in the extension growth was noticed between the 2nd to 8th fortnights and thereafter the rate was slightly retarded, whereas the grafts prepared on G. tinctoria rootstocks showed an increase of only 0.30 cm during the interval of ten fortnights. The increase in girth of scion during ten fortnights was not very conspicuous. A difference of about 0.40 cm was recorded in grafts on G. cambogia whereas it was only 0.10 cm in those on

G. tinctoria. Number of leaves produced by the grafts on G. cambogia was significantly higher. Scions grafted on G. tinctoria rootstock retained the initial number of leaves till the third fortnight and thereafter abcission was noticed. At the same time those on G. cambogia, picked up growth and produced about six new leaves during a span of ten fortnights (Fig.2).

In the case of double grafting also superiority of G. cambogia rootstock was confirmed. During the initial stage, all the three combinations of rootstocks gave statistically similar results in double grafts. When the survival percentage was computed after 90 days of grafting, superiority of G. cambogia rootstocks was evident. Double grafts prepared by using two rootstocks of G. cambogia gave about 52.50 per cent success while it was only 17.50 and 25.00 per cent respectively in the case of grafts on G. tinctoria rootstocks and G. cambogia + G. tinctoria rootstocks.

Compatibility is one of the crucial factors in grafting which ultimately affect the success and further growth of the grafted plants (Popenoe, 1920). From this study, it was evident that when same species was used as rootstock the chance of getting a better graft union and a further vigorous growth was greater. This was found true in

Fig.2 Effect of different types of rootstock on the extension growth and number of leaves of the scion



EG-Extension growth; NL-No.of Leaves
R1-*G.tinctoria*;R2-*G.cambogia*

the relative species of G. cambogia viz., mammey apple, mangosteen and kokam (Krochmal, 1970; Dassanayake and Perera, 1988; Hadangar et al., 1987, 1991).

5.2.2 Age of rootstock

When epicotyl grafting was performed on G. tinctoria at three age groups, viz., 10, 15 and 20 days it was observed that the different age groups did not show any significant difference during the initial stage. Grafts made on 20 days old G. tinctoria rootstocks showed significantly higher percentage of survival after 90 days compared to the other age groups. The study showed a positive relation between the age of rootstock and percentage of survival of grafts. This was in confirmity with the findings of stone grafting in mango by Singh and Sreevastava (1981).

When softwood grafting was done on G. tinctoria (2, 3 and 4 months old rootstocks) and G. cambogia (18 months old rootstocks) the final success ranged from 30.00 to 60.00 per cent. Here also, the different age groups of rootstocks did not show any significant change during the initial stage. But, after 90 days, softwood grafts on G. cambogia rootstocks showed 60.00 per cent survival which was significantly superior to the other three age groups of G. tinctoria. Among the different age groups in G. tinctoria, softwood grafts on two months old rootstock rendered higher percentage of success. A decreasing trend was noticed in the final success percentage with an increase in the age of rootstock. Similar results were obtained in mangosteen (Dassanayake and Perera, 1988) and mango (Reddy and Melanta, 1988) softwood grafts.

The studies on the age of different rootstock combinations on the success of double grafting revealed the superiority of two seedlings of 12 months old G. cambogia both after 60 and 90 days of grafting. When two seedlings of G. tinctoria were used as rootstocks an age of 20 days gave superior results than the rest of the age groups, while the combination of one seedling each of G. tinctoria and G. cambogia was used, ten days old G. tinctoria seedlings with 12 months old G. cambogia seedlings recorded higher percentage of success. Nagawekar et al. (1984) and Subramanya and Reddy (1989) also discussed the possibility of double grafting in mango.

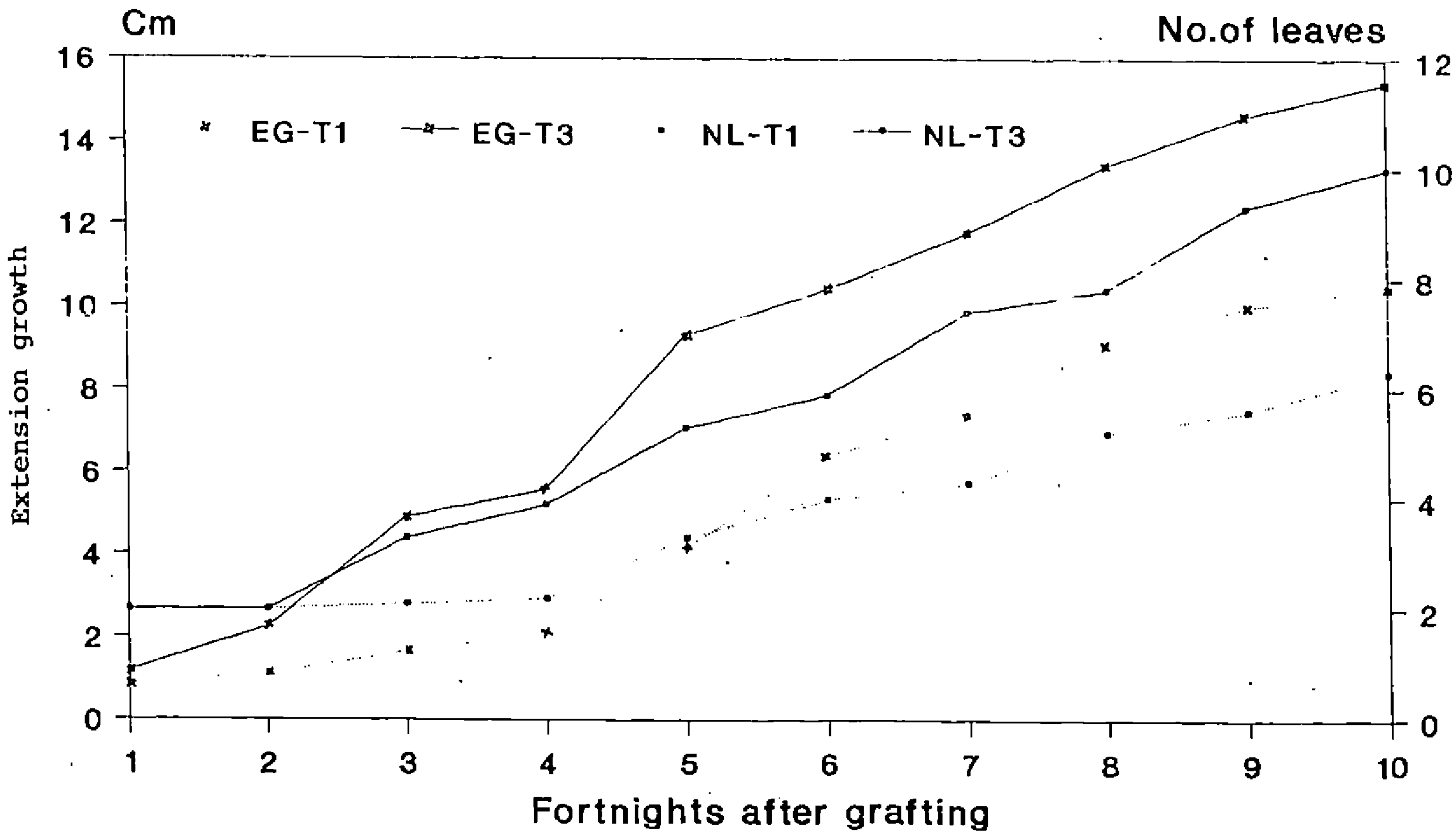
The influence of age of rootstock on the growth rate of epicotyl, softwood and double grafts could be studied from comparison of growth parameters. It was evident from this comparison that epicotyl or softwood grafting on G. tinctoria did not favour extension growth, girth or number of leaves of the grafts desirably, while softwood grafting on 18 months old G. cambogia gave satisfactory results. When double grafting was carried out on two seedlings of 10, 15 and 20 days old rootstocks of G. tinctoria none of the grafts put forth any new growth. When it was performed on one seedling each of G. cambogia and G. tinctoria of three age groups (10, 15 and 20 days old G. tinctoria along with 12 months old G. cambogia in each case), the extension growth and girth of scion were less than 3.00 cm and 1.20 cm respectively and number of leaves produced on the scion was less than five, after ten fortnights of grafting. When double grafting was done on two seedlings of 12 months old G. cambogia, the extension growth, girth and number of leaves of the scion were more than 12.00 cm, 1.60 cm and 9.00 respectively (Tables 22 to 24). Thus, softwood grafting on 18 months old G. cambogia rootstocks or double grafting on 12 months old G. cambogia rootstocks were proved to be superior.

An overall comparison of different methods of grafting employing different types of rootstock revealed that epicotyl grafting on G. tinctoria rootstock yielded the maximum success percentage (Table 18). The percentage of success of softwood grafts on G. cambogia rootstock was on par with epicotyl grafting on G. tinctoria. As in the case of production of significantly higher number of grafts, G. cambogia rootstocks influenced remarkably on the growth of the scion. This was clearly evident from the studies on the growth parameters of softwood grafting using this (18 months old) rootstock. Here the scion produced an extension growth of 19.30 cm, a girth of 1.630 cm and 7.80 leaves. This extension growth of the scion was significantly superior to any other method or age and type of rootstock while the girth and number of leaves were on par with those of double grafts using 12 months old seedlings of the same rootstock. Though the present studies showed the equality in the percentage survival of grafts between epicotyl grafts using G. tinctoria rootstock and softwood grafts employing 18 months old G. cambogia rootstock, the growth rate of the former was very poor and it showed more or less a static growth when the various growth parameters were studied. The negative influence of G. tinctoria rootstocks and the synergistic effect of G. cambogia rootstocks on growth rate of grafts were evident in double grafting also. Double grafts on G. tinctoria seedlings and combinations of G. tinctoria and G. cambogia rootstocks recorded relatively slower growth rate while those on two seedlings of G. cambogia rootstocks showed an extension growth of 12.770 cm, a girth of 1.60 cm and produced 9.70 leaves within ten fortnights.

5.2.3 Type and age of scion wood

In G. cambogia, because of its growth habit, three types of scion materials were available. They were new flush shoot (completely green in colour and about three months old), past season shoot (completely brown in colour and about six months old) and past season shoot with a new sprout and a plumpy apical bud (basally brown, green at the top and about nine months old). These three scion materials when employed for softwood grafting revealed the superiority of nine months old scions on the percentage of success of grafts. Three months old scion materials were also on par, but the former one recorded 20 per cent more take than the latter while six months old scions could produce negligibly lesser take. The superiority of T_3 (nine months old scion) was also evident from the growth rate of scion. Over a period of ten fortnights, T_3 recorded an extension growth of about 15 cm whereas it was only 10 cm in the case of T_1 (three months old scion). Girth of scion did not differ much between the two treatments during these fortnights. But in the case of production of leaves, a remarkable difference was noticed between the two scion wood. Compared to three months old scion wood, leaf production was almost double in the case of nine months old scion wood during a span of five months (Fig.3). The graft using three months old scion wood picked up growth only after the fourth fortnight while those using nine months old wood showed a faster growth rate from the second fortnight onwards. The superiority of nine months old scion wood might be due to the fact that, such type of scion wood contains a good amount of reserve food and plant hormones owing to the presence of brown wood and actively growing

Fig.3 Effect of different types of scion wood on the extension growth and number of leaves of the scion



EG-Extension growth; NL-No.of Leaves
T1-*3 months old; T3-9 months* old

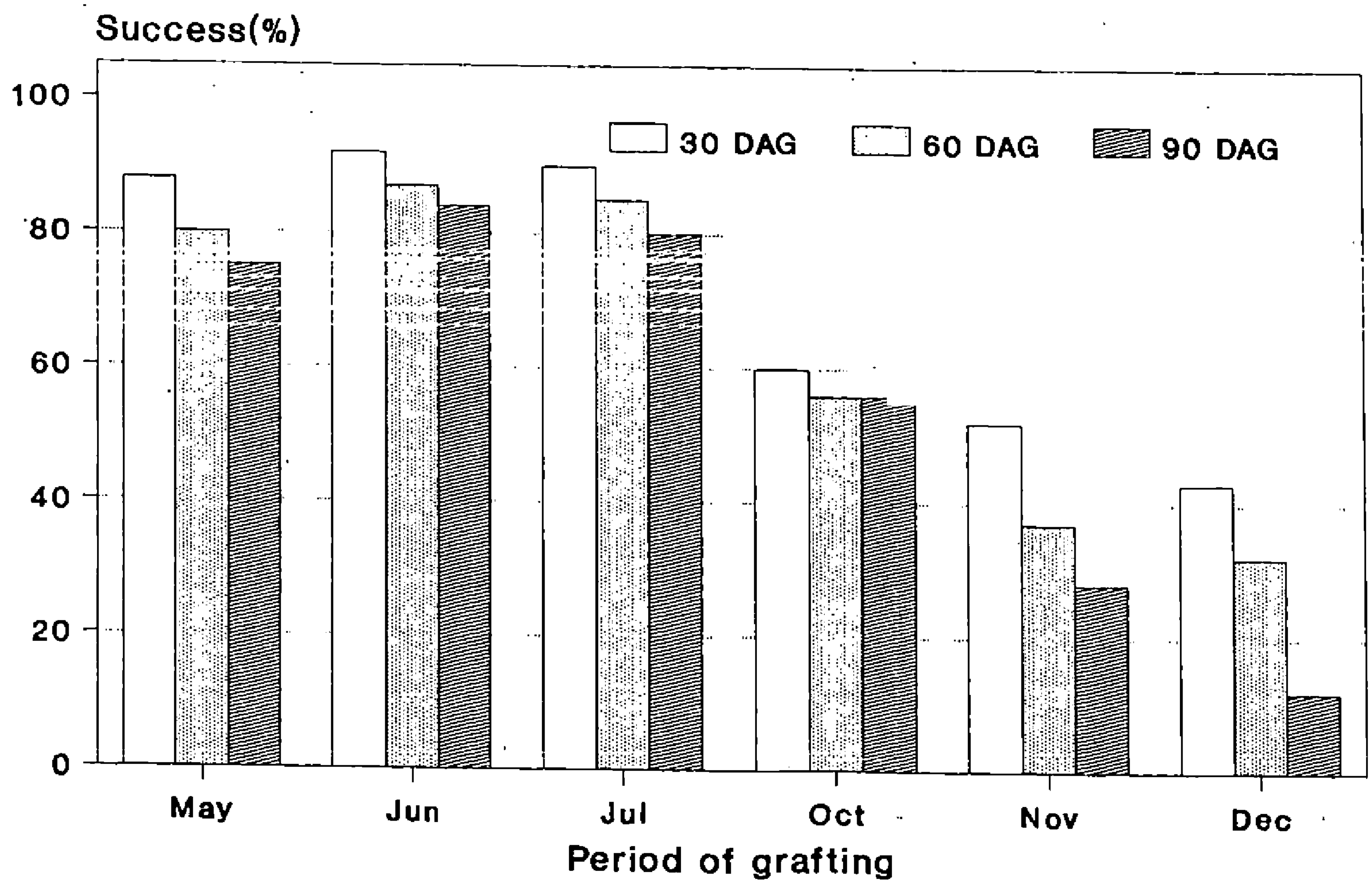
leaves or buds. In three months old wood, eventhough there was actively growing leaves and buds, the amount of food reserve might be comparatively less which might have attributed to its slower growth. In the case of six months old wood, the plant hormones which are necessary to activate the reserve food and thereby growth might be very less in quantity because of the absence of well developed leaves and buds. This might be the reason for lower success percentage and growth rate of grafts using this type of scion. In mangosteen Popenoe (1920) reported that seven months old scion could be used in grafting on G. tinctoria to get effective union. In softwood grafting of kokam, Hadangar et al. (1987, 1991) observed that terminal, greenish brown, five to six months old twigs were successful. These findings clearly indicate the influence of age of scion wood on the graft take.

5.2.4 Effect of season on the success of grafting

Results of the experiment to find out the best method of grafting and type and age of rootstocks, showed the superiority of softwood grafting by using 18 months old G. cambogia roostocks not only in the percentage of success but also in the growth parameters of grafts. Experiments conducted in this department on the tropical fruit crops like mango and jack (Dhungana, 1984; Jose, 1989) and elsewhere revealed that season has got pronounced influence on the success of grafting. Hence the study on the effect of season on softwood grafts using G. cambogia rootstock find relevance.

The data showed that season of grafting had a significant influence in determining the grafting success. The monsoon season was proved to be better than the dry and cold season. June grafting gave the highest percentage of success after 30, 60 and 90 days of grafting (92.00, 87.00 and 84.00 respectively), while December grafting gave the lowest success (43.00, 32.00 and 12.00 respectively) at these stages (Fig.4). Under Vellanikkara conditions, the rainfall and relative humidity were high (993.10 mm and 88.00 per cent respectively) and mean daily temperature was comparatively low (26.8°C) during the month of June, 1991 while low rainfall (0.20 mm) and relative humidity (64.00 per cent) were experienced during December (Appendix I). High rainfall often results in high relative humidity and low temperature. Hartmann and Kester (1989) opined that high humidity was a major factor to enhance the callus growth and graft union. The results of the present study is also in confirmity with this opinion. The results of this study led to the conclusion that June is the best month for softwood grafting in G. cambogia. Harmekar (1980) showed that for epicotyl grafting in jack the maximum success of 95 per cent was obtained in the

Fig.4 Effect of season on success of grafting



DAG - Days after grafting

month of June. According to Gunjate *et al*. (1982) success ranging from 62.20 to 64.70 per cent was obtained from June to September which was reduced in October (55.60 per cent) and November (35.50 per cent). When epicotyl grafting was done in mango during June-July, the percentage of successful grafts varied from 50 to 96 per cent (Maiti and Biswas, 1980). The success percentage of softwood grafts when done in mid-June was 100 per cent, however in mid-July the success was much lower (76.6 per cent) as compared to mid-June (Singh, *et al*., 1984). According to Jose (1989) the month of June was the most suitable for both epicotyl (61.67 per cent) and softwood grafting (5.00 per cent) in jack under Kerala conditions.

5.2.5 Effect of growth regulators on the success of grafting

The studies using growth regulators were conducted to suggest improvements upon softwood grafting of *G. cambogia*. Initially, a preliminary trial was conducted to know the effect of GA and IBA on the graft take in which they were sprayed on grafted plants immediately after grafting, each at 100, 250 and 500 ppm concentration. It was observed from this trial that the growth regulator sprays had no remarkable influence on the graft take compared to control. Hence in the present study, GA and IBA were tried, each at 500, 750 and 1000 ppm concentration for scion dipping before grafting. The study revealed that the maximum final percentage of success of grafts (56.67) was the same for both the control and the plants treated with 500 ppm GA (Table 30). On considering the extension growth of scion,. it led to the conclusion that scions dipped in 500 ppm GA measured the maximum extension growth, after five months of grafting despite, this treatment was on par with the control. After five months of grafting, the scions treated with 500 ppm GA and those not treated with any growth regulator registered an extension growth of 22.22 cm and 19.30 cm respectively. When the girth of scion was considered, no treatment could be recommended for increasing the girth of grafts. After five months of grafting, all the treatments including control were found to be on par with each other. When the number of leaves of the scion was taken as a basis for evaluation of the treatments, GA 500 ppm was found to give higher values similar to the case of extension growth. Here also, the treatment was found to be on par with the control. After five months of grafting, the treatments, GA 500 ppm and control, registered 9.40 and 7.80 leaves, respectively.

Thus, the present studies indicated that the growth regulator treatments had no beneficial effect on the graft take as well as the growth of the grafts. Among the growth regulator treatments, GA 500 ppm had almost similar effects to the control while the other treatments had only adverse effect on the grafts. When the concentration of GA and IBA increased from 500 to 1000 ppm, the intensity of undesirable effects with respect to the percentage success, extension growth, girth and number of leaves of the grafts also increased. It can not, however, be ruled out that the growth regulator will not influence the graft take. Perhaps, the chemicals at the concentrations tried might not be at the optimum level to influence the graft beneficially. Hence detailed studies are required to draw any conclusion. Ratan (1985) opined that IAA or GA at 100 or 250 ppm had no influence on the growth of the grafts. Sreevastava et al. (1989) observed that the effect of plant growth regulators in mango grafting was negligible. Mathad et al. (1991) opined that GA had an adverse effect on mango grafts. They also found that untreated grafts recorded the highest percentage of success compared to the treated ones.

5.2.6 Anatomical studies

Compatibility is one of the important factors which determine the success of grafting. Even if compatible stock and scion were used the graft failure may occur due to many reasons. Anatomical studies can establish some possible explanations in this regard. Mechanism of healing of the graft union not only depends, to a large extent, on the activities of the cambium and vascular tissues but also on the quantity, structure and origin of the callus tissue. Moreover, some of the cells present in the cortex tissue will hasten the formation of a smooth union (Fahn, 1982).

In the stem structure of G. tinctoria, a number of cells with gummy exudates were found. The gummy exudates in the plant parts usually consisted of phenols and natural dyes and the phenols of one species were found to have deleterious effects on the cells of another incompatible species (Esau, 1972). In the grafts made on G. tinctoria the latex contained in the laticifers might have acted additively to this effect. So, in the grafts on G. tinctoria rootstocks, these phenols and latex might be the two reasons for little or no callus production from the scion. In the cortex of G. tinctoria stem, numerous starch grains which form the reserve food were also seen. The presence of these starch grains, found in abundance, clearly explains the thick callus formed at the graft union from the stock side when G. tinctoria was used as rootstock.

The stem anatomy of G. cambogia revealed that the cortical cells were almost free of gummy exudates. So the problem of phenols was not met with in the grafts prepared on G. cambogia rootstock. Even if the content of laticifers had some undesirable effect on the graft union, it was not severe because of the compatibility of the same species. This might be the reason for the grafts made on G. cambogia rootstocks produced callus from both the components, i.e., scion and stock (Plate 21). However this callus was not so thick compared to the grafts on G. tinctoria rootstock because the starch grains found in G. cambogia which were confined to the phloem were lesser in number. When the epicotyl grafts and softwood grafts on G. tinctoria were compared the softwood grafts were found to produce lesser quantity of callus. This might be due to the fact that the epicotyl region, being tender, might be in the actively growing stage and hence respond faster to wounding.

The investigation on the reasons for graft failure arrived at the conclusion that graft failure could be resulted from four general anatomical reasons. In some cases, failure was due to the lack of callus formation even after several days of grafting resulting in a wide gap between the stock and scion (Plate 25). This was in confirmity with the findings of Ratan (1985), Radhamony (1987) and Jose (1989). It might have also been caused by the excessive callus formation at the grafted portion as revealed from the present study (Plate 26). The excessive callus proliferation occurred from G. tinctoria rootstock might have indirectly provided a compressive effect to the phloem sieve tubes and xylem trachieds at the graft union and ultimately led to the phloem degeneration of scion (Plate 27) which is attributed as the third reason for graft failure. Luthra and Sharma (1946) also observed excessive undifferentiated callus or other irregular growth at the union of the incompatible combinations of stock and scion. Hartmann and Kester (1989) attributed the degeneration of xylem and phloem of the scion owing to the incompatibility of components as one of the reasons for graft failure. Another possible reason for the graft failure is the formation of a thick necrotic layer at the wounded surface of stock and scion (Plate 28). This necrotic layer might have prevented the cambial bridge formation which further hindered the formation of vascular continuity between the stock and scion. Jose (1989) also found that formation of a thick necrotic layer at the cut surface of stock and scion as one of the reasons for graft failure.

Summary

SUMMARY

An investigation was carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period of 1990-92 to standardise the epicotyl and softwood grafting in Garcinia cambogia. The following experiments were undertaken during the course of investigation.

(i) Effect of seed coat and growth regulator treatment on germination of G. cambogia seeds.

(ii) Standardisation of type and age of rootstock for epicotyl, softwood and double grafting.

(iii) Effect of type and age of scion wood on the success of grafting.

(iv) Effect of season on the success of grafting.

(v) Effect of growth regulators on the success of grafting.

(vi) Study of the anatomy of graft union.

The salient findings are listed below.

1. There was marked variation in the time required for germination between the seeds with and without seed coat. In order to obtain a higher percentage of seed germination in

this crop, either the seed coat could be removed or seed treatment with GA could be given. For getting an early and higher germination seed coat removal could be better adopted than any growth regulator treatment. For further enhancement of germination, the seeds could be treated with 500 ppm GA for 12 h. This treatment gave a germination percentage of 90.667 within five weeks after sowing.

2. Trials on the vegetative propagation methods like epicotyl, softwood and double grafting revealed that epicotyl grafting (on 10, 15 and 20 days old rootstocks) and softwood grafting (on 2, 3 and 4 months old rootstocks) could not be done using G. cambogia rootstock because the rootstocks were too small in size to perform grafting at these stages. When softwood grafting was done on 18 months old G. cambogia rootstocks a remarkably higher percentage of success was obtained after 90 days of grafting. The treatment also proved its superiority when the extension growth, girth and number of leaves of scion were considered. This treatment was followed by double grafting on two seedlings of G. cambogia (12 months old) with respect to the superiority in the extension growth and girth of scion. When the percentage of success was taken into consideration, epicotyl grafting on G. tinctoria (20 days old) rootstocks gave a higher percentage of success (75.00). Still this treatment could notl be recommended as a method for vegetative propagation in G. cambogia because of the poor growth rate of the grafts. Apart from the softwood and double

grafts on *G. cambogia* all other grafts registered a slow growth to be adopted as an economic method.

3. The study to find out the best type and age of scion wood revealed that past season shoot with a new sprout and a plumpy apical bud (basally brown, green at the top and about nine months old) proved to be the best as far as the percentage of success, extension growth, girth and number of leaves of the scion were concerned. This type of scion wood recorded 70.00 per cent success. Among the other scion materials six months old wood produced no new growth at all while three months old wood produced comparably better results.

4. The investigation to find out the best season for softwood grafting on *G. cambogia* led to the conclusion that June is the best month followed by July, May, October, November and December. The success of grafts registered in June was 84.00 per cent followed by 80.00 per cent in July and 75.00 per cent in May. During the dry and cold months like October, November and December the percentage of success was in the order of 56.00, 28.00 and 12.00 per cent respectively.

5. The studies with growth regulators like IBA and GA, each at 500, 750 and 1000 ppm indicated that none of the treatments had any beneficial effect on the graft take or the growth of the grafts compared to control.

6. The anatomical studies helped to draw the conclusion that the antagonistic effect of G. tinctoria seedlings as rootstock for G. cambogia might be due to the presence of gummy exudates and laticifers present in the stem structure. The investigation also attributed the general anatomical reasons for graft failure. They were (1) absence of callus production between the stock and scion which resulted in a wide gap, (2) excessive callus production but no proper formation of union because of lack of differentiation into cambium, (3) degeneration of phloem of the scion and (4) formation of a thick necrotic layer between the stock and the scion.

In nutshell, for getting a higher and earlier germination in this crop, the seed coat could be removed and seeds could be treated with 500 ppm GA for 12 h. Softwood grafting using 18 months old G. cambogia and double grafting using two seedlings of 12 months old G. cambogia could be adopted as the most suitable methods of vegetative propagation. Among the different types of scion material, nine months old wood was found to give the best results. Grafting operation when done in June gave higher percentage of success compared to the operation during the other months. G. tinctoria rootstocks were found to be incompatible for the epicotyl, softwood or double grafting in G. cambogia. The anatomical reasons for graft failure were also discussed.

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* Originals not seen

Appendices

Appendix-I

Monthly weather data during the course of investigation

Months	Mean temperature (°C)		Mean R.H. (%)		Rainfall (mm)	
	1991	1992	1991	1992	1991	1992
January	27.90	26.50	57.00	53.00	3.90	0.00
February	28.80	28. 20	51.00	65.00	0.00	0.00
March	30.70	29.90	66.00	61.00	1.80	0.00
April	30.10	30.35	68.00	65.00	83.80	48.60
May	30.30	29.30	70.00	73.00	56.10	90.60
June	26.80	26.90	88.00	84.00	993.10	979.80
July	26.00		86.00		975.60	
August	25.90		87.00		533.30	
September	27.60		78.00		61.50	
October	27.10		82.00		281.70	
November	27.30		75.00		191.30	
December	26.60		64.00		0.20	

Appendix-II

Analysis of variance for the interaction effect of seed coat, periods of soaking and concentrations of GA on seed germination at weekly intervals

Source	df	Mean squares at weekly intervals							
		1	2	3	4	5	6	7	8
Methods	1	4418.00*	9022.72*	19273.39*	21840.50*	13612.50*	9067.56*	3990.22*	3990.22*
Period of soaking	3	403.63*	503.28*	578.72*	409.54*	349.54*	377.48*	229.93*	229.93*
Concentration of GA	2	442.06*	708.17*	82.72*	105.50*	58.50*	80.89*	33.56*	33.56*
Method x period of soaking	3	74.15 NS	43.17 NS	195.00 NS	296.80*	105.24*	127.11 NS	24.59 NS	24.59 NS
Method x concentration of GA	2	15.17 NS	64.39 NS	432.95*	465.50*	240.50*	323.56 NS	254.89 NS	254.89 NS
Period of soaking x concentration of GA	6	273.04 NS	321.06*	450.72*	270.09*	186.26*	145.48 NS	253.70 NS	253.70 NS
Method x period of soaking x concentration of GA	6	138.20*	119.95 NS	48.05 NS	34.24 NS	15.91 NS	33.78 NS	55.48 NS	55.48 NS
Control vs. treatment	1	1849.09 NS	14372.56 NS	3775.07 NS	2402.85 NS	2274.33 NS	2766.12 NS	2168.53 NS	2168.53 NS
Error	52	33.64	90.00	90.00	80.36	119.44	137.03	122.67	122.67

* Significant at 5 per cent level

Appendix-III

Analysis of variance for the interaction effect of different types of rootstock and methods of grafting on the extension growth, girth and number of leaves of scion over ten fortnights

Source	df	Mean squares over ten fortnights		
		Extension growth	Girth	Number of leaves
Treatment	4	224.163*	0.372*	23.600*
Error	45	12.228	0.029	2.350

* Significant at 5 per cent level

Appendix-IV

Analysis of variance for the interaction effect of different types and age of rootstock and methods of grafting on the extension growth of scion at fortnightly intervals

Source	df	Mean squares at fortnightly intervals									
		1	2	3	4	5	6	7	8	9	10
Treatments	9	0.189*	3.166*	32.602*	83.941*	136.568*	210.306*	255.481*	315.296*	346.560*	393.542*
Error	90	0.032	0.206	0.985	2.188	2.595	3.265	4.058	4.601	5.207	5.768

* Significant at 5 per cent level

Appendix-V

Analysis of variance for the interaction effect of different types and age of rootstock and methods of grafting on the girth of scion at fortnightly intervals

Source	df	Mean squares at fortnightly intervals									
		1	2	3	4	5	6	7	8	9	10
Treatments	9	0.368*	0.342*	0.339*	0.354*	0.349*	0.351*	0.399*	0.404*	0.467*	0.528*
Error	90	0.020	0.021	0.022	0.022	0.022	0.023	0.024	0.028	0.028	0.030

* Significant at 5 per cent level

Appendix-VI

Analysis of variance for the interaction effect of different types and age of rootstock and methods of grafting on the number of leaves of scion at fortnightly intervals

Source	df	Mean squares at fortnightly intervals									
		1	2	3	4	5	6	7	8	9	10
Treatments	9	1.938*	1.600*	2.623*	7.173*	11.751*	28.899*	32.667*	42.232*	52.160*	69.933*
Error	90	0.422	0.484	1.090	1.842	2.202	2.770	3.232	3.086	2.642	2.373

* Significant at 5 per cent level

Appendix-VII

Analysis of variance for the effect of growth regulators on the extension growth of scion at fortnightly intervals

Source	df	Mean squares at fortnightly intervals									
		1	2	3	4	5	6	7	8	9	10
Treatments	5	0.025*	2.124*	28.806*	57.933*	71.721*	95.709*	93.984*	107.534*	108.006*	129.508*
Error	37	0.014	0.412	3.363	6.581	8.870	10.888	13.975	15.922	16.578	18.783

* Significant at 5 per cent level

Appendix-VIII

Analysis of variance for the effect of growth regulators on the girth of scion at fortnightly intervals

Source	df	Mean squares at fortnightly intervals									
		1	2	3	4	5	6	7	8	9	10
Treatments	5	0.116*	0.111*	0.102*	0.090*	0.118*	0.107*	0.094*	0.100*	0.071 NS	0.083 NS
Error	37	0.023	0.022	0.023	0.027	0.030	0.032	0.039	0.040	0.040	0.052

* Significant at 5 per cent level

Appendix-IX

Analysis of variance for the effect of growth regulators on the number of leaves of scion at fortnightly intervals

Source	df	Mean squares at fortnightly intervals									
		1	2	3	4	5	6	7	8	9	10
Treatments	5	0.015 NS	0.232 NS	3.191 *	6.637 *	15.388 *	19.800 *	14.293 *	14.462 *	15.074 *	13.257 *
Error	37	0.024	0.142	0.772	1.771	2.671	3.613	5.116	5.080	4.954	4.938

* Significant at 5 per cent level

Appendix-X

Friedman two way analysis of variance for the effect of growth regulators on the extension growth of scion at fortnightly intervals

Source	df	Mean squares
Fortnights	8	11.267*
Treatments adjusted	5	66.958*
Treatments x fortnights	40	1.057
Error	333	0.763

Appendix-XI

Friedman ranks for the effect of growth regulators on the number of leaves of the scion at fortnightly intervals

Treatments	Ranks at different fortnights								
	2	3	4	5	6	7	8	9	10
GA 500 ppm	3	8	5	9	7	4	6	2	1
GA 750 ppm	1	7	7	7	9	2	3	4.5	4.5
GA 1000 ppm	2	2	7.5	2	5	9	7.5	5	5
IBA 500 ppm	1	3.5	5	7.5	9	6	7.5	3.5	2
IBA 750 ppm	2.5	2.5	2.5	7	2.5	8.5	8.5	6	5
Control	1	7	8	6	5	9	3	3	3

STANDARDISATION OF SOFTWOOD AND EPICOTYL GRAFTING IN *Garcinia cambogia* Desr.

By

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ABSTRACT OF A THESIS

Submitted in partial fulfilment of the
requirement for the degree

Master of Science in Horticulture

Faculty of Agriculture
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ABSTRACT

The investigations on standardisation of softwood and epicotyl grafting in *Garcinia cambogia* was carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara, Trichur during the period, 1990-92.

The studies revealed that seed coat removal or seed treatment with growth regulators increased the final percentage of seed germination compared to control though there was no significant difference between the treatments. Seed coat removal could enhance the seed germination remarkably. After the beginning of germination seeds with intact seed coat completed germination within seven weeks while those seeds without seed coat required only five weeks for the same. In order to obtain an early and higher germination, seed coat removal along with seed soaking with 500 ppm GA for 12 h could be adopted. This treatment registered 90.667 per cent germination.

Softwood grafting on 18 months old *G. cambogia* rootstock was found to be the best method of vegetative propagation compared to epicotyl grafting (using *G. tinctoria* rootstocks) and double grafting (using different combinations