

**STUDIES ON CROSS GRAFT COMPATIBILITY AND
ASSESSING FIELD PERFORMANCE OF INTER-
SPECIFIC GRAFTS IN *Garcinia* SPECIES**

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ASSESSING FIELD PERFORMANCE OF INTER-
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in

PLANTATION TECHNOLOGY

By

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CERTIFICATE

This is to certify that the thesis entitled "STUDIES ON CROSS GRAFT COMPATIBILITY AND ASSESSING FIELD PERFORMANCE OF INTER-SPECIFIC GRAFTS IN *Garcinia* SPECIES" submitted by Ms. PREETI RAMADAS NAIK bearing I.D number PGS13FOR6283 for the degree of MASTER OF SCIENCE (FORESTRY) in PLANTATION TECHNOLOGY to the University of Agricultural Sciences, Dharwad is a record of work carried out by her during the period of her study in this university, under my guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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1. INTRODUCTION

Garcinia species are becoming popular now a days because of their medicinal and nutritive properties and they have assumed great significance in recent times ever since the finding that hydroxyl citric acid present in these plants can control obesity in man (Maheshwari *et al.*, 2014). Several species of *Garcinia* have been in traditional usage either as spice, source of camboge (colour), as fruit for medicinal purposes in various parts of the world. The genus *Garcinia*, belonging to the family Clusiaceae (syn: Guttiferae), includes species found in the tropical forest of Asia and Africa. Out of the 35 species found in India, 17 are endemic among which seven are endemic to the Western Ghats region (Gunaga *et al.*, 2010). Kokum or *Garcinia indica* (Choisy), Kodampuli or *G. gummi-gutta* (L) Rob Small, Arishina andi or *G. morella*, Dyavanigi or *G. xanthochymus* and mangosteen or *G. mangostana* (L) are the important species used commercially in our country and are mostly of seedling origin and thrive almost in a semi-wild state except the mangosteen, which is always cultivated being an introduced species (Anon, 1956).

Due to the utility with respect to medicinal and nutritive value of the fruits, the demand for the fruits is increasing in India and abroad rapidly (Sara, 1998). *Garcinia* fruit from natural forests are extracted in large scale as an important Non Wood Forest Product in parts of Uttara Kannada district of Karnataka, Kerala and Maharastra. A few farmers have started commercial cultivation of *Garcinia*. Even then, demand far outstrips the supply. It has been reported that Japan imports nearly 50-60 tons of kokum seeds every year for confectionery purpose (Sirodkar, 2003).

However the main problem associated with the *Garcinia* is mainly it's a dioecious nature and monoembryonic seeds which, when planted, will not reproduce true to type and seed viability is also very less. Grafting on its own rootstock or other species is the best way to propagate good types. There exists a great scope to grow grafted elite varieties in the homestead areas as well as in orchard to increase the

production. The vegetative method is desirable because it enables to retain the characteristics of the mother plant, to get flower and fruit earlier, to remain initially relatively smaller with the benefit of accommodating more plants per unit area and to give the owners earlier and much higher economic returns. This has in turn been used to improve the *Garcinia* varieties to dwarf, reduce maturity time and produce bigger fruits through grafting. Grafting refers to various techniques of inserting a section of the stem with leaf buds (scion) into the rootstock. It is the most preferred method for improving and propagating *Garcinia* species. Almost all methods of grafting can be adopted for *Garcinia* but two popular methods used are cleft graft and whip and tongue graft. Successful grafting in the above species is already reported (Magar and Joshi, 2001; Sara, 1998; Jill, 1976) though long term performance of these grafts is not assessed. Effect of grafting of one *Garcinia* species on other related species is however not comprehensively assessed.

In kokum, butter is extracted from seed. Hence, not abundantly seeds are available for rootstock purpose is a real constraint. If other lesser utilized wild species can be used successfully, it will be a great boost to kokum cultivation by saving the seeds for butter production. Since trees are very large, reducing canopy size is also important for easy harvesting. Slow growth of mangosteen is a serious problem limiting its commercial exploitation. The long prebearing period of 7 to 20 years for this species is also a deterrent for large-scale adoption (George *et al.*, 1994)

In spite of improved method of grafting, farmers have experienced graft failures especially at the nursery level. Normally, grafting does not register 100 per cent success due to number of factors, like the choice of scion wood, light intensity, alignment of cambia of stock and scion, time of grafting, temperature under which grafts are grown and scion desiccation after grafting contribute the largest percentage of grafting success (Crasweller, 2005; Barnet and Kindle, 2000).

Anatomical studies have shown that the difficulty in grafting may be due to a marked difference in cellular activity between stock and scion, manifested as a delay in or failure of stock and scion to produce wound parenchyma, especially in the scion (Gyambo, 2000). This research is hence focused on determining individual performance of selected species of *Garcinia* scions to grafting with great emphasis on union wound healing and establishment on a different desirable rootstock.

In the recent years, simple methods of propagation like grafting have not yielded satisfactory results at village/farmers level. The effect of different scion-rootstock combinations on graft wound healing is not known. Because of this, many grafts have failed at the nursery stage and some farmers are unaware of which species are most compatible with the rootstocks. Successful cross species grafts could be utilized to expand the cultivation to non-conventional areas.

There is no information related to the assessment of inter-specific graft compatibility and field performance of inter-specific grafts in *Garcinia* species. With this background, the present study has been conducted with the following objectives.

1. To assess the inter-specific graft compatibility among five important species of *Garcinia*.
2. To assess the survival and field performance of these inter-specific grafts.

2. REVIEW OF LITERATURE

For commercialization of any plant species, a standard protocol of vegetative techniques is very essential. In this chapter literature pertaining to various objectives considered for the study viz., inter-specific grafting and field performance of inter-specific grafts along with importance of *Garcinia* species. Since the information on *Garcinia* is scanty, the studies related to other tree species are also reviewed.

2.1 Uses of *Garcinia* species

Garcinia is the source for a natural diet ingredient hydroxycitric acid. HCA, (1,2-dihydroxypropane-1,2,3-tricarboxylic acid) which is an anti obesity compound present in the fruit rind and leaves of *Garcinia* and is known to inhibit lipid and fatty acid synthesis in living systems (Lewis and Neelakantan, 1965; Subhash Chandran, 1996). The pulp of *G. gummi-gutta* and *G. indica* fruits are traditionally used by the people of high rainfall tracts of Karnataka and Kerala in culinary preparations as flavoring agent and the seeds are also a rich source of an edible fat commercially known as “Kokum butter”. It is nutritive, demulcent, astringent and emollient. It is suitable for ointments, suppositories and other pharmaceutical purposes. It is used for location to ulceration and fissures of lips, hands etc. The cake left after extraction of oil is used as manure (Anon, 1956). Fruit rinds of *G. indica* are used in the preparation of a popular beverage known as kokum consumed during summer. Since both the species of *Garcinia* possess curative properties especially towards stomach and heart ailments, the local healers use them in folk medicine (Hegde *et al.*, 2010).

Over 40 per cent of the indigenous communities in Uttara Kannada district of Karnataka, who traditionally gather NTFP, are solely engaged in the collection of fruits of *G. gummi-gutta* and it is estimated that each such household earns an average of Rs. 35,000/- (about 770\$) in one year solely from such collections (Hegde *et al.*, 2010). Thus *Garcinia* resources are extremely important as a source of livelihood in

the Central Western Ghats. The mangosteen, commonly known as 'Mangkhut' in Thailand, is a medium sized tree with 7-12 m height. The pericarp of mangosteen contains five polyoxygenated xanthenes, including mangostin 4, β -mangostin, nor-mangostin and gartanin (Mahabusarakam *et al.*, 1987). These compounds are used in medicines and, to a certain extent, as anti-bacterial agents (Mahabusarakam *et al.*, 1983).

A derivative of mangosteen has been found to be a central nervous system depressant and it may also cause a rise in blood pressure. Many of the xanthenes are found in the fruit pericarp, and particularly mangosteen, have significant anti-inflammatory properties at doses of 50 mg/kg; anti-ulcer activity has also been demonstrated. The xanthone content in the pericarp and the number of compounds synthesized increases as fruit-ripening proceeds. The fruit pericarp is also used in Thai medicine for healing skin infections and for the relief of diarrhea (Yaacob and Tindall, 1995). Mangosteen twigs are used as chew sticks in Ghana. The fruit rind contains 7 to 14 per cent catechin tannin and rosin, and is used for tanning leather in China. It also yields a black dye. A root decoction is taken to regulate menstruation. A bark extract called "amibiasine", has been marketed for the treatment of amoebic dysentery (Morton, 1987). Fruits of *G. morella* can be preserved by slicing into thin pieces and then drying under sun. It can also be made into pickles. Bodos use unripe fruit as vegetable. Dried up fruit slices are valued as a traditional remedy for dysentery. *G. xanthochymus* contain high levels of secondary compounds called xanthenes that are reported to possess antibacterial and anti-malarial properties (Chanmahasathien *et al.*, 2003) and also used in watercolors and as a yellow fabric dye.

2.2 Grafting and Inter-specific graft compatibility in different plant species

Grafting has been used from the earliest times and is still used on a large scale to preserve and multiply desired genotypes. It is a basic tool for horticulturist and has

been used widely in forestry for clonal propagation of species, which are difficult to root through cuttings or other asexual method. Grafting has the advantage of well-established rootstock, and that of early flowering and fruit set. Success of grafting depends on the selection of proper rootstock and scion, their union, type of grafting and the season of grafting.

Anon (1956) and Jill (1976) suggested that *G. tinctoria* and *G. hombroniana* are suitable rootstock for *G. mangostana* but Mathew *et al.*, (2005) suggested that *G. tinctoria*, *G. gummi-gutta* and *G. cowa* are not suitable as rootstock for *G. mangostana*.

Aiyadurai (1966) conducted inarching in eight species of *Myristica*. *Myristica fragrance* was successful on eight species of *Myristica* namely, *M. malabarica*, *M. beddomei*, *M. attenuate* Wall, *M. contorta* Ward., *M. fragrance* and *M. laurifolia* Bedd.

Chapman (1967) reported that approach grafting of all spices (*Pimenta dioica*) gave 90 per cent success on its own root stock and approach grafting in related species like *Syzygium jambalana* or *S. aromaticum* was not successful.

Canistel (*Pouteria campechiana* (HBK) Baehni), a close relative of Mamey sapote (*Calocarpum sapota* (Jacq.) Merr) in the Sapotaceae, is well adapted to the calcareous soil. Ogden and Campbell (1980) conducted inter-specific grafting experiment using mamey sapote as a scion and canistel as a rootstock. The result showed that mamey sapote has been veener and approach grafted successfully to two year old canistel rootstock and there was no apparent delayed incompatibility.

Megini *et al.* (1988) have reported higher success of cleft grafting on two year old rootstock than one year old root stock of *Castanea sativa*.

Vijayakumar *et al.* (1991) concluded that green wood cleft grafting was a quick and easy method of vegetative propagation of jackfruit compared to other methods.

Haldankar *et al.* (1992) have reported the success of soft wood grafting in *Garcinia indica*. There was successful union between the nature scion of 5-6 months old and more than 5 months old rootstock. The grafts carried out in the month of October showed highest sprouting (93%) and survival (86%).

Nutmeg tree is usually dioecious, that is male and female flowers are produced on separate trees. The main handicap facing the nutmeg cultivation is the segregation of the plants into male and female, which can be identified only after flowering. It is a slow growing species and flowers only about 6-7 years after planting. Generally 50 per cent of plants raised turn out to be females and hence it will be a great loss to the farmers, who have to spend a lot of time, labour and money to realize 50 per cent of trees as unproductive. To overcome this problem, Krishnamoorthy and Rema (1992) conducted grafting techniques in nutmeg popularly called, "epicotyls grafting" has been developed at the IISR, Calicut. The epicotyls grafts produced using wild species (*Myristica beddomei* or *M. malabarica*) or cultivated species (*M. fragrans*) as the root stock but the percentage of success achieved is high by using *M. fragrans* as the rootstock.

Anon (1993) conducted grafting compatibility studies of mangosteen (*Garcinia mangostana* L.) on three *Garcinia* species namely *Garcinia atroviridis*, *Garcinia praniana* and *Garcinia hombroniana*. Various degrees of incompatibility were observed for the three species studied. Total incompatibility was observed for *Garcinia atroviridis* and *Garcinia praniana* when used as rootstocks for mangosteen. As for *Garcinia hombroniana*, partial compatibility with *Garcinia mangostana* was observed. Cleft grafting is the technique used for these studies. Various degrees of incompatibility were also observed in reciprocal grafts for the above three species. Studies also showed that grafting on their own rootstocks for these four *Garcinia* species have no incompatibility problem.

George *et al.* (1994) tried grafting of *G. gambogia* to different age of *G. tinctoria* rootstocks. The graft success increased with increasing age of the rootstocks. The highest number of successful grafts (66%) was produced using three month old rootstocks.

Azad (2000) compared veneer, cleft, splice and epicotyl grafting throughout the year in Bangladesh to determine the optimum method and the best time of the year for high success. He obtained 80 per cent success with veneer in April and 70-73 per cent success with cleft and splice grafting when tried in November.

Cashew and mango belong to the family Anacardiaceae. Both are important commercial crops in the world market. Environmental growth conditions for both crops seem to be similar however, cashew seems more tolerant in drier areas than mango due to its extensive rooting system. Both crops are commercially propagated by grafting, although seedling plants are still in plantations. Grafting mango on cashew rootstock seems laudable for increased mango production in drier areas which are very unsuitable for mango. Therefore Asante (2001) conducted compatibility study on cashew-mango graft combinations. Studies were conducted on the early stages of graft union formation between cashew (rootstock) and mango (scion) using light microscopy and macroscopy examinations. He observed that resin secreted as the initial wound response a few minutes after wounding, and this contributed to the cohesion of the rootstock and scion. Callus was formed in all tissues damaged, beginning in the cortex areas of the graft partner. At 30 days, the periderm had formed across the union edges. Wound edges had sealed, and the cambial linkage between the stock and scion had been restored.

Sapota (*Manilkara zapota*), a crop of tropical region, needs warm (10-38 °C) and humid (70% relative humidity) climate where it flowers and fruit throughout the year. However if taken to subtropics or to places of higher elevation like in Punjab and Haryana, it gives only one crop from summer flowering in April and May. Under

moisture stress also, it produce one crop only. To overcome this problem Meeran and Rajeshwari (2001) carried out grafting technique like inarching using *Manilkara hexandra* (called kirni or rayan in India) as a rootstock which is moisture stress resistant. Sapota on rayan roots is the best combination in respect of plant vigour, productivity and longevity. Softwood grafting using rayan as rootstock and sapota as scion also gave the 93 per cent success in situ. It showed an economically viable, faster, efficient and best technique.

To standardize the grafting method in *Kopak*, a macro propagation work with six different grafting methods were executed by Rajendran (2001). Among the six methods, cleft grafting showed 100 per cent success with mean shoot length of 59.66 cm, which was followed by whip and tongue grafting with 93.33 percent success.

Ratha Krishnan (2001) studies the six grafting methods in *Simarouba glauca* along with seasonal effects. In the study, he identified cleft grafting as the most successful method for the union of the union of root stock and scion which was at par with whip and tongue grafting, with the success per cent of 78.92 and 76.75 respectively.

Prathibhan *et al.* (2003) have reported the success of cleft grafting in *Simarouba glauca*. The maximum success in grafting was recorded during October - November (75.5%) followed by June- July (75%) and August - September.

Islam *et al.* (2004) conducted the grafting experiment in mango. He identified the highest per cent survival of grafted mango plant produced by modified cleft grafting, which might be due to the long cambial layer connection and the easiness of wrapping of graft union hindering the entrance of the rain water.

Gouda (2005) has reported that out of three different vegetative propagation techniques tried, only grafting was successful. Among four different types of grafting tried cleft grafting was found to be better with maximum survival per cent (92.5) after three months of grafting.

Kokum showed the compatibility with the other species of *Garcinia* such as *G. gummi-gutta* and *G. cowa*. In the study conducted by Mathew *et al.* (2005), there was 48-58 per cent survival in grafts with *G. gummi-gutta*, *G. cowa* when *G. indica* was used as rootstock. In the same study *G. hombroniana* also gave very good success as a rootstock (80%) when *G. Gummi-gutta* used as scion and the graft take on *G. cowa* was poor (24%) and no successful union could be obtained between *G. tinctoria* and *G. gummi-gutta*.

Mishra (2005) stated that there are some cases in which given interspecies graft are successful but the reciprocal combination is not. He also stated that Marianna plum (*Prunus cerasifera* X *P. munsoniana*) on peech (*Prunus persica*) makes an excellent graft combination, but graft of the peech on Marianna plum either soon die or fail to develop normally. Although many varieties of Japanese plum (*Prunus salicina*) can be successfully grafted on the European plum (*P. domestica*), graft of most varieties of the European plum on the Japanese plum are unsuccessful.

Campbell (2007) has reported success of interspecies grafting in mango species. Nine *Mangifera* species have been grafted on *Mangifera indica* 'Turpentine' seedlings, which are adapted to the edaphic conditions of South Florida, USA. *Mangifera caesia*/*M. indica* grafts were not successful, with death occurring within 3 days of grafting. Often the rootstocks also died within a few weeks of grafting. *M. foetida* /*M. indica* grafts were also unsuccessful, although the scions survived for up to 3 weeks. *M. pajang* /*M. indica* grafts had a low percentage of success, but successful grafts have grown well for more than 2 years. *M. casturi*, *M. griffithii*, *M. laurina*, *M. odorata*, *M. pentandra* and *M. zeylanica* grafted on *M. indica* had a high percentage of success.

Breadfruit (*Artocarpus altilis*) is popular in Sri Lanka and it is believed to have been introduced in the 14th century during the Portuguese era. Since it is seedless. A successful propagation method was conducted by Medagoda *et al.* (2007)

to assess the success of cleft grafting using three seedling age classes (30, 45 and 60 d) of breadnut (*Artocarpus camansi*) as root stock and *Artocarpus altilis* (Breadfruit) as scion. Randomized Complete Block design was used with 60 plants per treatment with three replications. The success rate of grafting was 83 per cent and significant ($p=0.05$) when seedlings were grafted at 45 d. The grafted plants were ready for field planting in 3 months and fruiting commenced 2½-3 years after planting. The trees have low branching habits, were early bearing and the average yield of first harvest was 10 fruits.

Kureel *et al.* (2009) have reported the 60-70 per cent of success of softwood grafting in six month old Mahua seedlings.

Hedge *et al.* (2010) conducted grafting in both *Garcinia indica* and *Garcinia gummi-gutta* species. They used both species as a root stock as well as scion. They have recorded the 70-80 per cent of graft success in interspecies.

Manjunatha *et al.* (2010) conducted grafting experiment in *Garcinia indica* seedlings. They used *G. indica* both as root stock and scion. Four types of grafting were tried in the month of May, namely cleft grafting, whip grafting, whip and tongue grafting and epicotyls grafting. For first 3 types of grafting rootstock of 8 month old *G. indica* was taken whereas for epicotyls grafting one month old *G. indica* seedlings were selected. Present season sprouts of about 5-8 cm length were selected as a scion from female trees. Two month after grafting *G. indica* showed significant increase in survival per cent, number of sprouts and number of leaves. The maximum survival per cent (92.5) was observed in cleft grafting and this was on par with whip grafting (87.5) and whip and tongue grafting (82.5). Lowest survival per cent was observed in epicotyls grafting (47.5). Number of sprouts per graft and number of leaves per grafts were maximum in cleft grafting (5.07 and 12.02). The lowest number of sprouts and number of leaves per graft (2.97 and 5.81) were observed in epicotyls grafting. The cleft grafting showed 70 per cent increase in number of sprouts per graft over epicotyls grafting.

Solomon Jr *et al.* (2010) conducted grafting experiment using breadfruit on chataigne rootstock. Cultivars of breadfruit scion ('Local Yellow', 'Local White' and 'Macca') were used. Six weeks after grafting, the percentage survival of 'Local Yellow', 'Local White' and 'Macca' breadfruit cultivars grafted on chataigne rootstock were 80 per cent, 97 per cent and 83 per cent respectively. The results suggest that genetic, physiological and environmental factors influence the success of grafting.

Guava is usually propagated from seed and the species is highly cross pollinated in nature, if propagated through seed, exhibits a great variation due to inevitable heterozygosity. Establishment of orchard through seedlings is not recommended at the present time; most of these seedlings will not be like the parental type in yield, taste and fruit flesh colour. Moreover, seed propagated plants come into bearing much later than vegetatively propagated plants. So Abbas *et al.* (2013) conducted an experiment to standardize the technologies for producing true-to-type plants of guava in short period of time by different propagation methods *i.e.* T-budding, T-grafting. Maximum success percentage (59.26) was achieved in plants budded by T-grafting and minimum was recorded in T-budding (22.58%).

Mohamad Cholid *et al.* (2014) conducted grafting experiment in Physic Nut (*Jatropha curcas*. L). They reported that the assessment on cleft grafting treatment showed that high grafting success percentage than that of whip grafting. The higher grafting success percentage on cleft grafting would be due to the stable linkage position provided and the graft union surface between root stock and scion provided was wider than that of the other grafting method.

Garcinia kola (Heckel) is one of the indigenous fruit trees that have great economic potential for poverty alleviation because of its contribution to food security, medicinal value and its economic multiplier effects. Most tropical forest fruit trees have the problem of long gestation; hence modern farmers are not ready to wait for a

long period of time, so Yakuba *et al.* (2014) conducted a trial on the grafting and budding of *G. kola*. They used Modified Cleft Grafting (MCG) and chip budding. The higher success was recorded in grafting (85%) and low in budding (25%).

Thomus, a farmer from idukki, kerala is known for developing “Pepper Thekken”, a high yield variety of pepper which gives a yield of more than 1000 pepper balls in one pepper branch. He developed the Pepper Thekken variety by grafting the pepper plants obtained from the forest on the root stick of *Pepper Colubrinum*, a disease tolerant wild pepper from Brazil. Pepper Thekken is a highly balanced spike resistant to quick wilt disease.

2.3 Evaluation of survival and field performance of inter-specific grafts in different tree species

Anon (1961) conducted field experiment in sapota on rayan root stock. He compared the performance of inarched and softwood grafting after six years of field planting. The result of six year observation clearly indicated that softwood grafts obtained the maximum height (296 cm) than inarched (244 cm). The softwood grafts recorded 14-39 per cent more height than inarched ones 6 years of age. He also observed that 80 per cent of softwood graft trees and 66 per cent of inarched trees were in bearing.

Davidson (1973) conducted top-cleft grafting in *Eucalyptus deglupta* on *Eucalyptus grandis*. Of some 2500 top-cleft grafts were made, only six have survived in the field.

Burgess (1974) reported that in 100 grafts made from 20 selected trees of *Eucalyptus grandis*, initial take was high at 93 per cent, but subsequent field performance was very poor. He also reported that mortality in the field was last assessed at 70 per cent and only one fully compatible union remained.

Senarathe *et al.* (1981) carried out grafting trails in one year old seedling of *Madhuka latifolia* in the field. They record 87 percent success after 45 days in both whip and cleft grafting.

Meeran and Rajeshwari (2001) have reported that Softwood grafting using *Manikara zapota* on *Manikara hexandra* (kirni or rayan variety) as rootstock give 93 per cent success in field.

Patel *et al.* (2010) studied comparative performance of inarching and softwood grafted plants (*C. reticulata* Blanco) in field condition after 10 years of planting. The result revealed that plant spread and height up to 12, 48 and 96 months was significantly higher in approach grafting. Yield was also higher in 10 years old plant by 66 per cent in approach grafting.

Ives *et al.* (2012) conducted graft compatibility experiment using Scotch Bonnet as scion and three salt-tolerant *Solanum* species *Solanum melongena* cv Black Beauty, *Solanum lycopersicum* cv Akash and *Solanum nigrum* cv bitter gumma were used as rootstocks. The results showed that the highest graft survival percentage (100%) was obtained in the Scotch Bonnet/Black Beauty heterografts and the lowest (16%) was obtained in the Scotch Bonnet/bitter gumma heterografts. Therefore, heterografts of Black Beauty and Scotch Bonnet exhibited graft compatibility, while Akash and bitter gumma rootstocks are graft incompatible with Scotch Bonnet scions. This suggests that Scotch Bonnet can be cultivated under saline growing condition.

3. MATERIAL AND METHODS

Under the present investigation entitled “Studies on cross graft compatibility and assessing field performance of inter-specific grafts in *Garcinia* species” two experiments were carried out. The first experiment was on inter-specific graft compatibility of *Garcinia* species at College of Forestry, Sirsi and second was experimental field performance of these inter-specific grafts carried out at ARS, Malagi during 2014-15. The detailed experimental procedure for both experiment are furnished below.

3.1 Experiment – 1: Inter-specific graft compatibility among five important species of *Garcinia*

3.1.1 Experiment site

This study was carried out at the College of Forestry Sirsi (14° 26' N latitude, 74° 50' E longitudes) of Uttara Kannada district of Karnataka, located in hilly zone (zone-9) of Karnataka state.

3.1.2 Sources of Root stock collection

Five different species of *Garcinia* were selected for this experiment viz., *Garcinia indica*, *Garcinia gummi-gutta*, *Garcinia xanthochymus*, *Garcinia morella* and *Garcinia mangostana*. Rootstock of *Garcinia indica* and *Garcinia gummi-gutta* were collected from Karnataka forest department Bellangi nursery, Katgal range Honnavar. *Garcinia xanthochymus* from Forest department Yerakkanabail nursery, Yallapur and *Garcinia mangostana* collected from College of Horticulture, Sirsi.

3.1.3 Experiments

Under this experiment, due to the efficiency and greater cambial contact provided by cleft grafting method, it was tried in the month of June. Rootstock of two and half year old *Garcinia* species was selected from different sources. Present season

sprouts of about 8-15cm length were selected as a scion from female trees (Plate 1). The procedure followed for cleft grafting are mentioned in the following section.

3.1.4 Cleft grafting

In this method of grafting, the main stem of the stock was first cut off and then a vertical split of 5-7 cm long was given down the center of the stem to be grafted. The scion of 10-17 cm long was prepared by cutting the end in the shape of wedge of about 5 cm in length. Then the scion was inserted into rootstock and tightly tied and wrapped with polythene grafting tape (Plate 2).

3.1.5 Treatment details

Total sixteen different interspecies grafting was conducted in this experiment. In each treatment forty eight grafts with three replications were tried. The details of treatments are furnished below.

Treatments	Rootstock	Scion
T 1	<i>Garcinia indcia</i>	<i>Garcinia gummi-gutta</i>
T 2	<i>Garcinia indica</i>	<i>Garcinia xanthochymus</i>
T 3	<i>Garcinia indica</i>	<i>Garcinia morella</i>
T 4	<i>Garcinia indica</i>	<i>Garcinia mangostana</i>
T 5	<i>Garcinia gummi-gutta</i>	<i>Garcinia indica</i>
T 6	<i>Garcinia gummi-gutta</i>	<i>Garcinia xanthochymus</i>
T 7	<i>Garcinia gummi-gutta</i>	<i>Garcinia morella</i>
T 8	<i>Garcinia gummi-gutta</i>	<i>Garcinia mangostana</i>
T 9	<i>Garcinia xanthochymus</i>	<i>Garcinia gummi-gutta</i>
T 10	<i>Garcinia xanthochymus</i>	<i>Garcinia indica</i>
T 11	<i>Garcinia xanthochymus</i>	<i>Garcinia morella</i>
T 12	<i>Garcinia xanthochymus</i>	<i>Garcinia mangostana</i>
T 13	<i>Garcinia mangostana</i>	<i>Garcinia indica</i>
T 14	<i>Garcinia mangostana</i>	<i>Garcinia morella</i>
T 15	<i>Garcinia mangostana</i>	<i>Garcinia gummi-gutta</i>
T 16	<i>Garcinia mangostana</i>	<i>Garcinia xanthochymus</i>

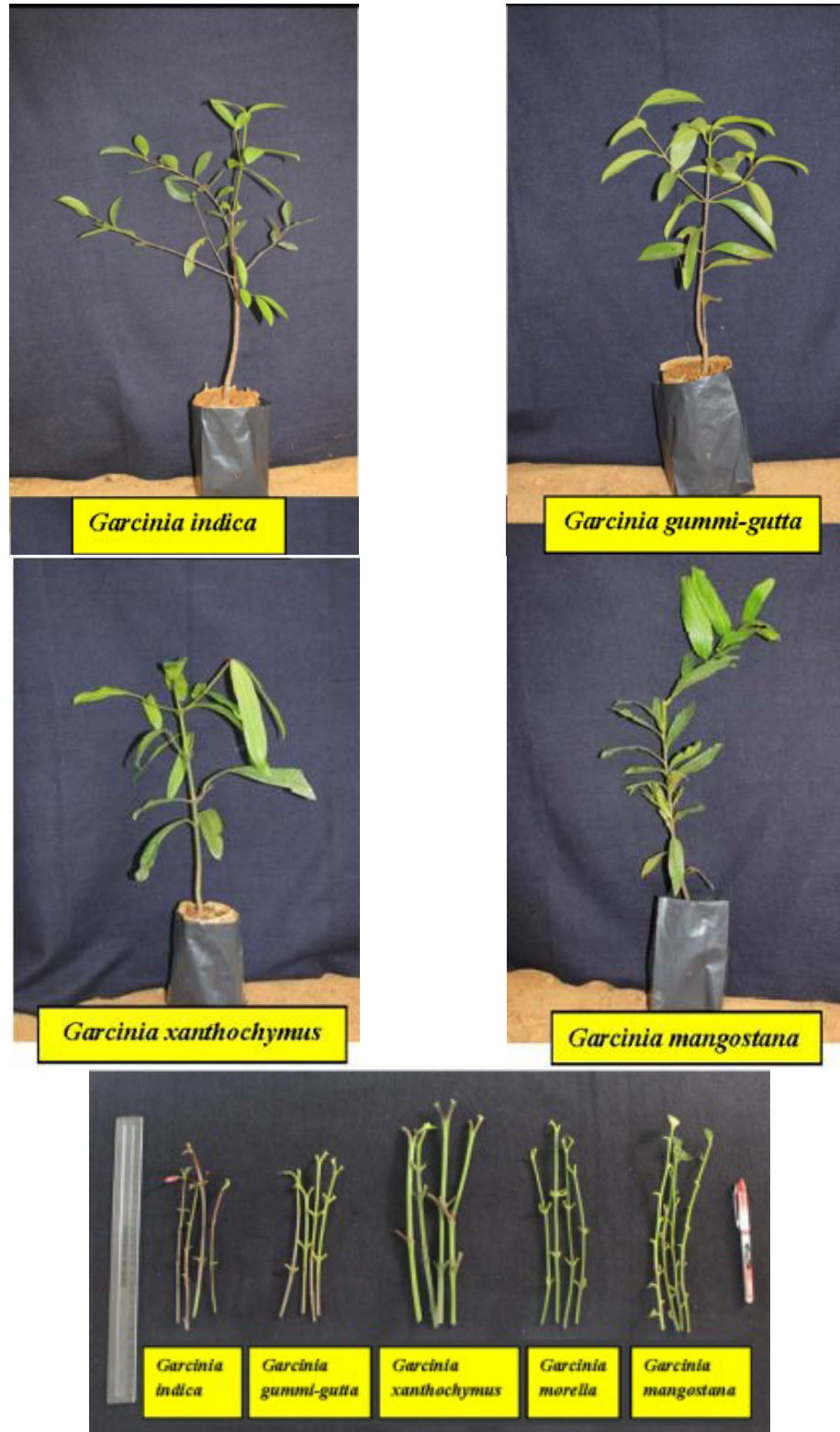
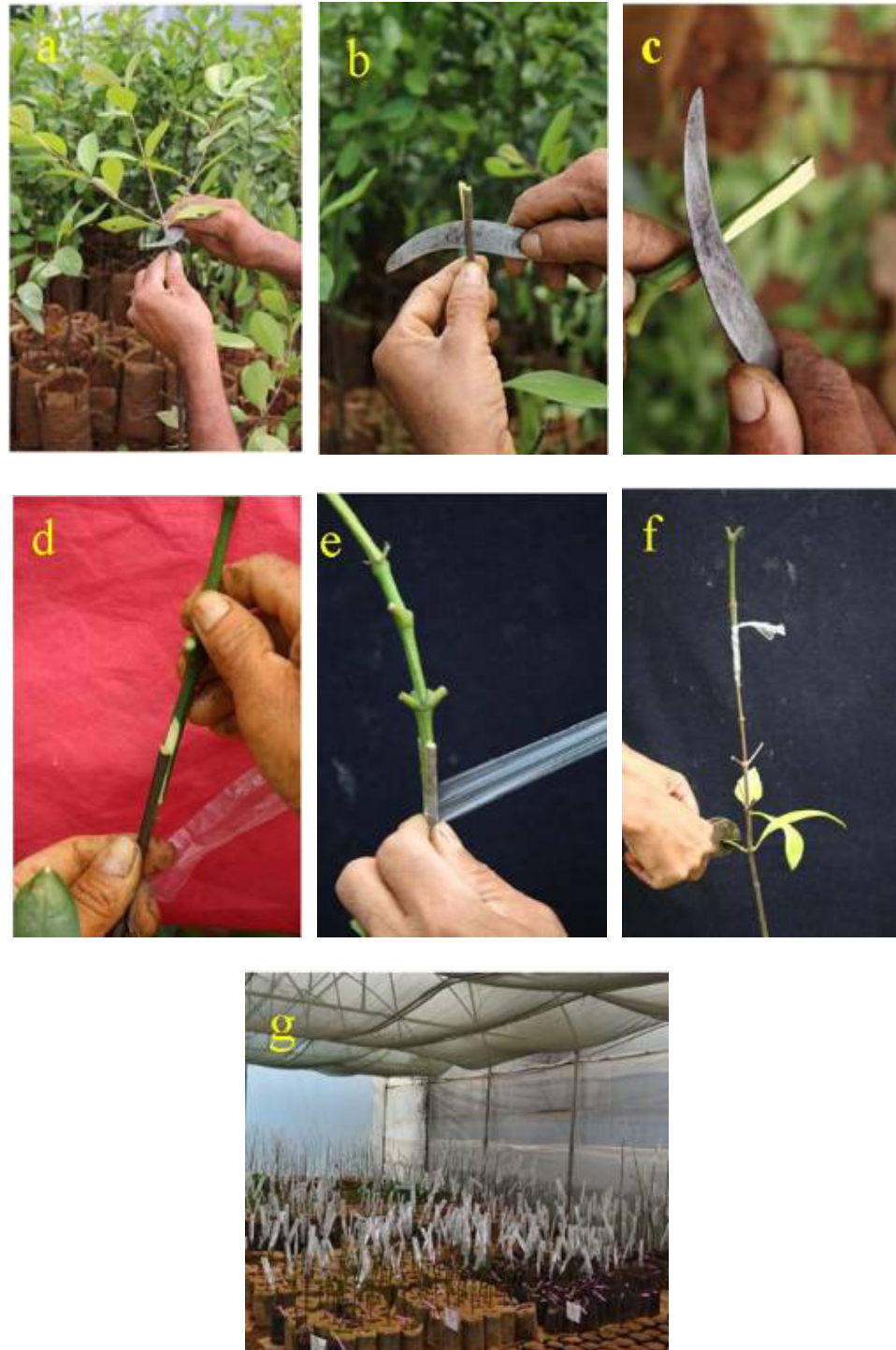


Plate1. Rootstock and scion of different species of garcinia used for interspecific grafting



a-The shoot is cut off at a right angle leaving a smooth and flat surface stub; **b**-Vertical cut is made down the middle of the stub to make V-shaped opening for the scion; **c**-Scion is cut into a gently sloping wedge about 2 cm long; **d**-The scion is inserted into the opening in the rootstock; **e**-The completed graft was then wrapped with polythene grafting tape; **f**- Sprouts growth below the graft was removed; **g**- Grafted plants was covered with clear plastic and placed under polyhouse

Plate 2. Cleft grafting technique adopted for the experiment

3.1.6 Post-graft care

A sprouts growth below the graft was removed. The scion showed sprout formation between 10 and 14 days after grafting. When this happened, the plastic bag was removed but not the grafting tape. The tape was left on the graft until the sapling has flushed twice from the scion and the graft union is fully healed (Simons, 1987).

3.1.7 Hardening

To avoid transplant shock at the time of field planting, saplings were hardened by exposing in full sunlight for one month prior to field planting. Irrigation was reduced to once in three days.

3.1.8 Design and Layout

The experiment was laid out in Completely Randomized Design (CRD).

3.1.9 Data collection

Number of grafts sprouted/dried was taken on weekly basis. In each replication, five grafts were randomly selected + tagged and number of sprouts per graft of these plants was taken on fifteen days interval. Two and half months after grafting observations on length of longest sprout, diameter of longest sprout, number of expanded leaves of longest sprout and total number of expanded leaves was taken in these five randomly selected grafts at fifteen days interval. All these observations were taken up to three months. Lastly the number of grafts survived was conducted at four months after grafting and was expressed in percentage using the formula given below

$$\text{Grafting survival per cent} = \frac{\text{Number of grafts survived}}{\text{Total number of grafted plants}} \times 100$$

3.2 Experiment – 2: The survival and field performance of these inter-specific grafts in *Garcinia* species

3.2.1 Experiment site

This study was carried out at the Agriculture Research Station (ARS) Malagi, Taluk Mundagod in Uttar Kannada district which is situated at 14^o 43' N latitude, 75^o 00' E longitudes. The research station is located in Zone 9 (Hilly Zone) of Karnataka state.

3.2.2 Climatic conditions

The meteorological data viz., average rainfall for the past 12 years (December 2002 – May 2013), rainfall month wise from December 2014 – May 2015, average maximum and minimum temperature for the past 12 years (December 2002 – May 2013) and maximum and minimum temperature during the experiment period (December 2014 – May 2015) was recorded from Hydro Meteorological Station, Malagi which is presented in Table 1 and depicted in Figure 1, 2 and 3. The mean rainfall of 12 years for the month of December 2002 – May 2013 at ARS Malagi was 127.75 mm and highest rainfall was recorded in the month of April (73.36 mm) and minimum was recorded in the month of December (0.93 mm), whereas during the study period (2014-15) total rainfall recorded was 268.2 mm which shows increase of 109.94 per cent rainfall over mean value of last 12 years (2002 – 2013); whereas maximum rainfall (during experiment period) was recorded in the month of May (128.8 mm) and minimum rainfall in the month of March (17.8 mm). No rainfall (0 mm) was recorded in January and February.

The average maximum temperature range was 29°C to 38.6°C for past 12 years (December 2002 – May 2013). During experiment period, April was the hottest month (33.8°C) and February month recorded lowest (29°C) for maximum temperature, whereas minimum temperature range was 14°C to 20°C for past 12 years

Table 1: Meteorological data for the December 2014 to May 2015 and mean of last 12 years (2002-2013) at Agriculture Research Station, Malagi

Months	Rainfall (mm)		Temperature (°C)			
			Maximum		Minimum	
	Mean	2014-15	Mean	2014-15	Mean	2014-15
	(2002-13)		(2002-13)		(2002-13)	
December	0.93	94.6	29.9	27.2	20	20.7
January	5.49	0.00	30.1	29	17.4	18
February	4.33	0.00	29	28.9	14.5	16.4
March	10.36	17.8	31.3	29.9	14	15.7
April	73.36	27.0	33.5	33.8	14.4	17.5
May	33.28	128.8	38.6	32.8	17.8	20.9
Total	127.75	268.2	192.4	181.6	98.1	109.2

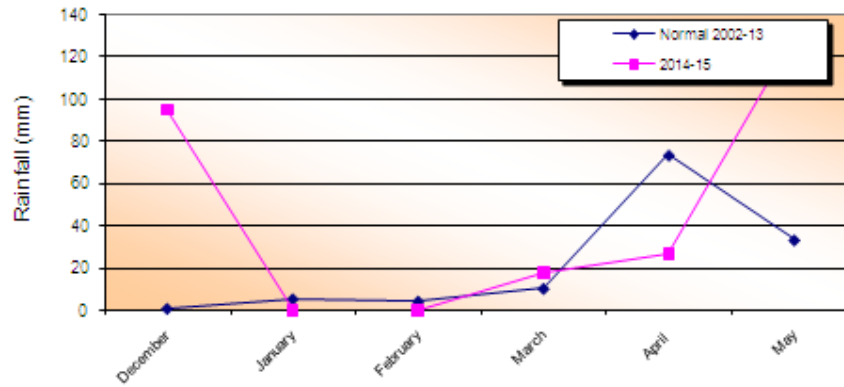


Fig. 1: Rainfall distribution for the period from December 2014 to May 2015 and mean of last 12 years (December 2002- May 2013)

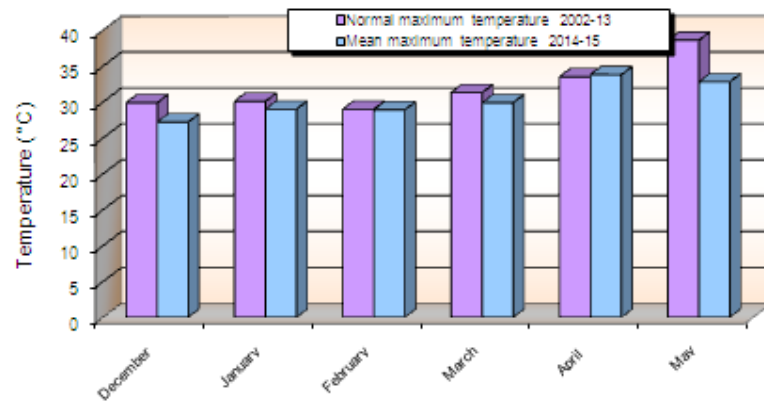


Fig. 2: Mean temperature (Maximum) for the period from December 2014 to May 2015 and mean of last 12 years (December 2002- May 2013)

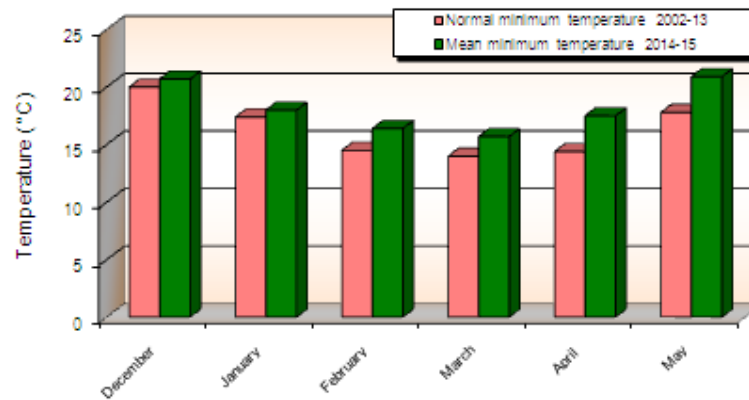


Fig. 3: Mean temperature (Minimum) for the period from December 2014 to May 2015 and mean of last 12 years (December 2002- May 2013)

(December 2002 – May 2013). During experiment period, March as lowest (15.7°C) and May recorded highest minimum temperature (20.9°C).

3.2.3 Planting of inter-specific grafts for field evaluation

Based on the result (success of compatibility) of first experiment, saplings of 12 inter specific grafts were planted at 2m×2m spacing with the following treatment details.

3.2.4 Treatments

Treatments	Rootstock	Scion
T 1	<i>Garcinia indica</i>	<i>Garcinia gummi-gutta</i>
T 4	<i>Garcinia indica</i>	<i>Garcinia mangostana</i>
T 5	<i>Garcinia gummi-gutta</i>	<i>Garcinia indica</i>
T 8	<i>Garcinia gummi-gutta</i>	<i>Garcinia mangostana</i>
T 9	<i>Garcinia xanthochymus</i>	<i>Garcinia gummi-gutta</i>
T 10	<i>Garcinia xanthochymus</i>	<i>Garcinia indica</i>
T 11	<i>Garcinia xanthochymus</i>	<i>Garcinia morella</i>
T 12	<i>Garcinia xanthochymus</i>	<i>Garcinia mangostana</i>
T 13	<i>Garcinia mangostana</i>	<i>Garcinia indica</i>
T 14	<i>Garcinia mangostana</i>	<i>Garcinia morella</i>
T 15	<i>Garcinia mangostana</i>	<i>Garcinia gummi-gutta</i>
T 16	<i>Garcinia mangostana</i>	<i>Garcinia xanthochymus</i>

3.2.5 Design and Layout

The experiment was laid out in Randomized Complete Block Design (RCBD). In each treatment three plants were planted and the treatments replicated thrice. The layout of the experimental treatments is given below.

Block 1	T1	T4	T5	T8	T9	T10	T11	T12	T13	T14	T15	T16
Block 2	T4	T13	T9	T14	T15	T12	T4	T8	T5	T10	T11	T1
Block 3	T5	T9	T10	T13	T16	T8	T5	T1	T12	T11	T4	T14

3.2.6 After care of the grafting

Weeding was done regularly to keep field weed free. Watering was done daily using drip irrigation except during rainy days. Sun scorching was observed on leaves and no major insect pest and disease were noticed during the study period.

3.2.7 Data collection

Observation on above ground growth parameters was recorded for five months at one month interval and survival per cent was taken at the end of the experiment (after 150 days of planting).

3.2.7.1 Plant height (cm)

The height of the grafts was measured from the collar diameter to the growing tip, using measuring tape and was expressed in centimeters.

3.2.7.2 Collar diameter (mm)

Collar diameter was measured at the collar region of the grafts using digital caliper and was expressed in millimeters.

3.2.7.3 Number of leaves

The number of fully opened leaves was counted in each grafts and average was computed as the number of leaves per graft.

3.2.7.4 Leaf area per plant (cm²)

Leaf area is important in the study of physiological processes of plants as well as in assessment of plant growth and development. The leaf area per plant was calculated by measuring the leaf of each plant in each treatment using plastic ruler; thus total of nine leaves (leaf area) was recorded per treatment in three replications and recorded in sq.cm. It was calculated using length, breadth and leaf area factor ($L \times B \times K$). The leaf area factor (K) was calculated by non destructive method of leaf area estimation *i.e.*, Graph method and Dry weight method by developing a regression

equation. From this method developed the leaf area factor for 2 ½ year old five different species of *Garcinia*. They are 0.85 for *Garcinia india* leaf, 0.91 for *Garcinia gummi-gutta* leaf, 0.88 for *Garcinia morella* leaf, 0.91 for *Garcinia xanthochymus* leaf and 0.79 for *Garcinia mangostana* leaf. Several workers had worked on different crops to find out leaf area in non-destructive methods Kobayshi (1988) developed regression equation for guava (*Psidium quajaya*). Shinde *et al.* (1988) developed equation for sugar cane, *Schorum officinarum* L crop.

3.2.7.5 Increment percentage (%)

Increment percentage was calculated to show the increase in the various parameters such as plant height and collar diameter over initial value and was expressed in percentage (%). It was obtained by mathematical formula as:-

$$\text{Increment per cent} = \frac{(\text{Final value} - \text{Initial value})}{\text{Initial value}} \times 100$$

3.2.7.6 Survival percentage (%)

The number of grafts survived was counted after 150 days of planting in the field and was expressed in percentage.

3.3 Data Processing and analysis

The data obtained from the experiment were analyzed statistically. The level of significance used was $p=0.05$. The mean, standard error ($SEM \pm$) and CD at 5% probability was calculated using M-STAT C program.

4. EXPERIMENTAL RESULTS

The results of the grafting experiment conducted at College of Forestry, Sirsi and the field performance assessed at Agricultural Research Station, Malagi during 2014-15 are presented in this chapter.

4.1 Inter-specific graft compatibility among five important species of *Garcinia*

Grafting technique like cleft grafting was tried in different *Garcinia* species which showed significant increase in survival percent, number of sprouts, longest sprout, diameter of longest sprout, number of leaves of longest sprout and total number of leaves.

4.1.1 Survival per cent (%)

There was a significant difference in the survival percent of various combinations of *Garcinia* species after four months of grafting. Survival percent was maximum (100 %) in T11 (*G. xanthochymus* rootstock and *G. morella* scion) and this was on par with T5 consisting *G. gummi-gutta* rootstock and *G. indica* scion (96.00 %), T10 consisting of *G. xanthochymus* rootstock and *G. indica* scion (95.80 %), T1 consisting of *G. indica* rootstock and *G. gummi-gutta* scion (90.2 %). Lowest survival per cent (2.00 %) was observed in T7 (*G. gummi-gutta* rootstock and *G. morella* scion). No survival was recorded in T3 consisting *G. indica* rootstock and *G. morella* scion (Table 2 and Figure 4). Pictorial representation of early stage development of inter-specific grafting of *Garcinia* (4 MAG) depicted in Plate 3.

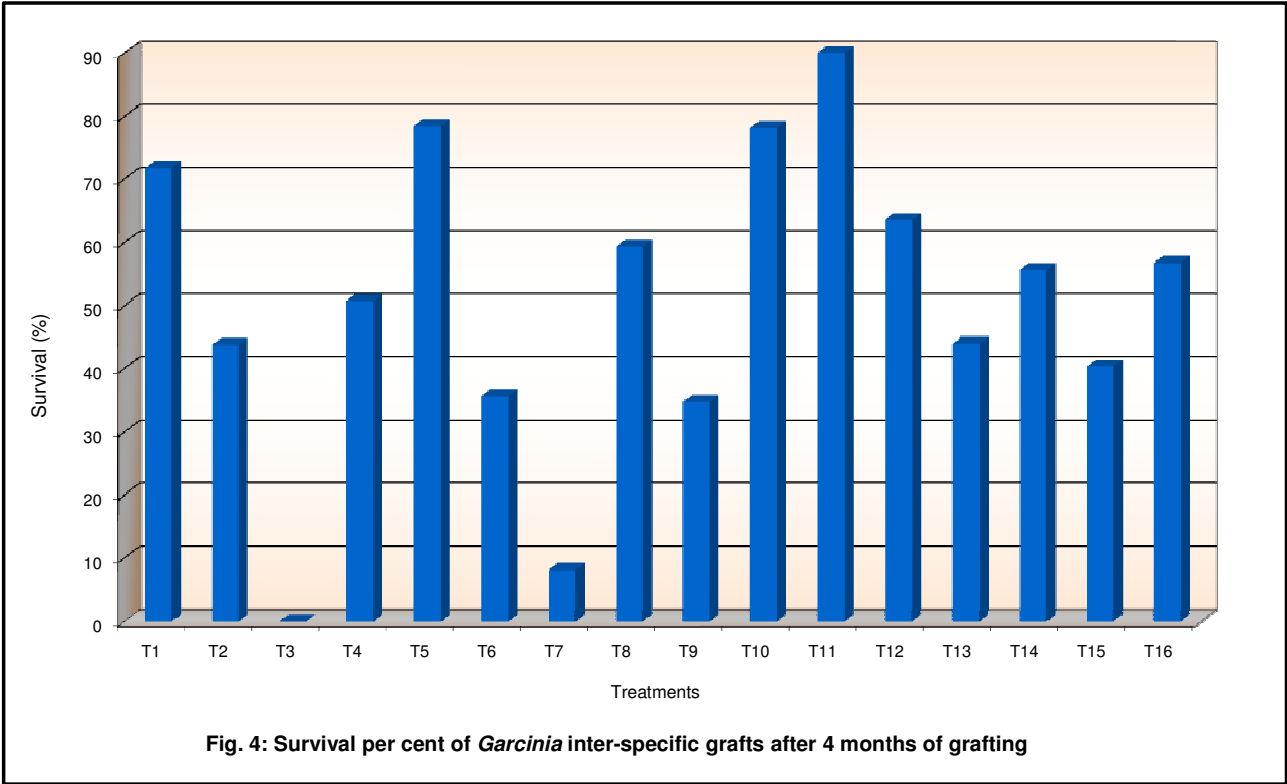
4.1.2 Number of sprouts per graft

The number of sprouts per graft showed significant differences among treatments. In each treatment fifteen grafts were randomly selected and labeled. Sprouts per graft was recorded after 15 days of grafting up to 90 day at 15 days interval depicted in the Table 3 and Figure 5.

Table 2: Survival per cent of *Garcinia* inter-specific grafts after 4 months of grafting

	Treatments (Rootstock X Scion)	Survival (%)
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	90.2 (71.76)
T2	<i>G. indica</i> X <i>G. xanthochymus</i>	48.03 (43.85)
T3	<i>G. indica</i> X <i>G. morella</i>	0.00
T4	<i>G. indica</i> X <i>G. mangostana</i>	60.04 (50.77)
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	96 (78.46)
T6	<i>G. gummi-gutta</i> X <i>G. xanthochymus</i>	34 (35.67)
T7	<i>G. gummi-gutta</i> X <i>G. morella</i>	2 (8.13)
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	74 (59.34)
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	32.5 (34.76)
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	95.8 (78.17)
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	100 (90.00)
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	80.1 (63.51)
T13	<i>G. mangostana</i> X <i>G. indica</i>	48.2 (43.97)
T14	<i>G. mangostana</i> X <i>G. morella</i>	68.3 (55.73)
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	41.9 (40.34)
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	70.0 (56.79)
	Mean	58.82
	SEm±	6.43
	CD@5%	18.53 (25.48)

Figures in parentheses are arcsin – transformed values



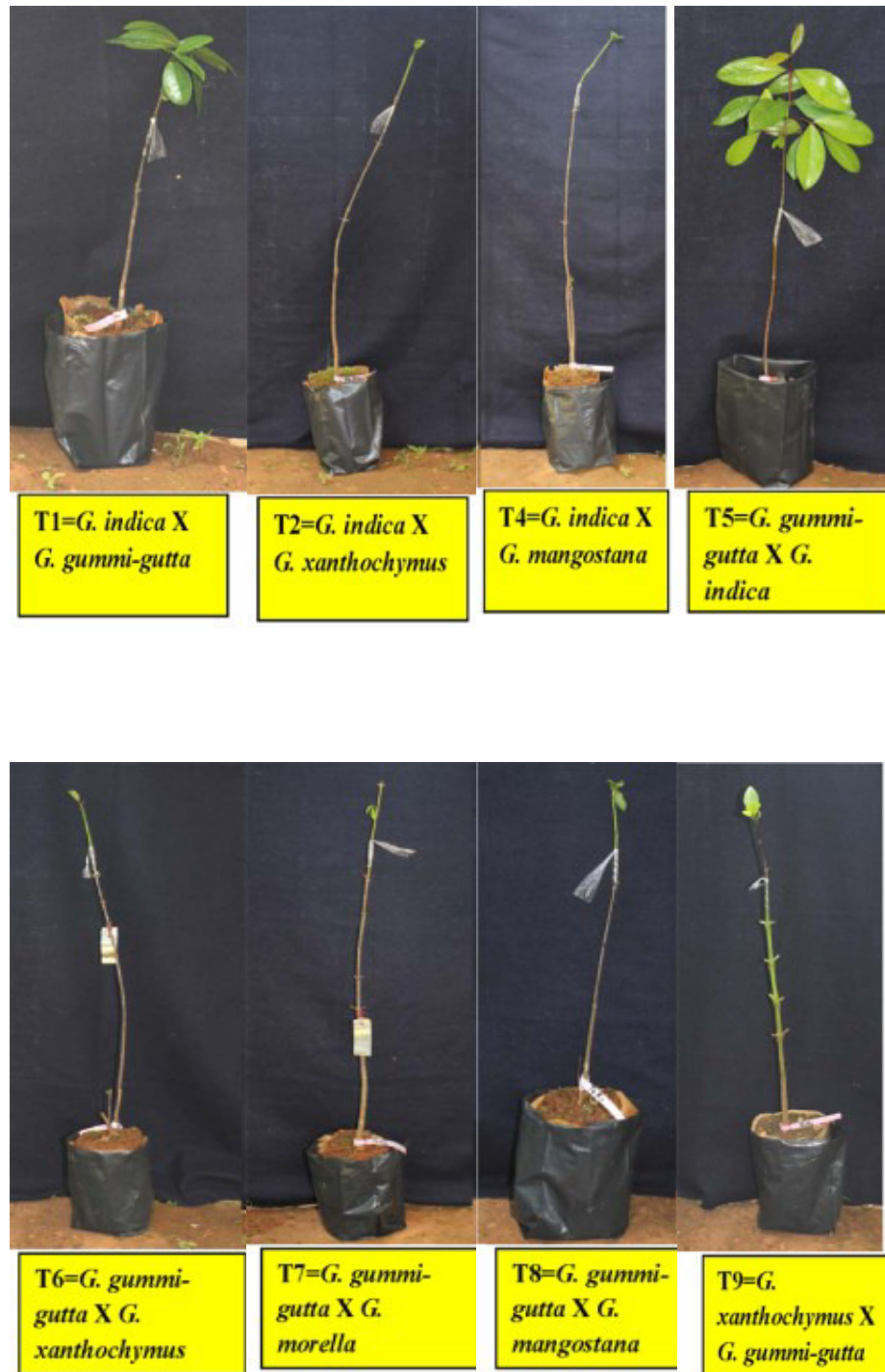


Plate 3. Early stage of development of inter-specific grafting of garcinia (4 MAG)

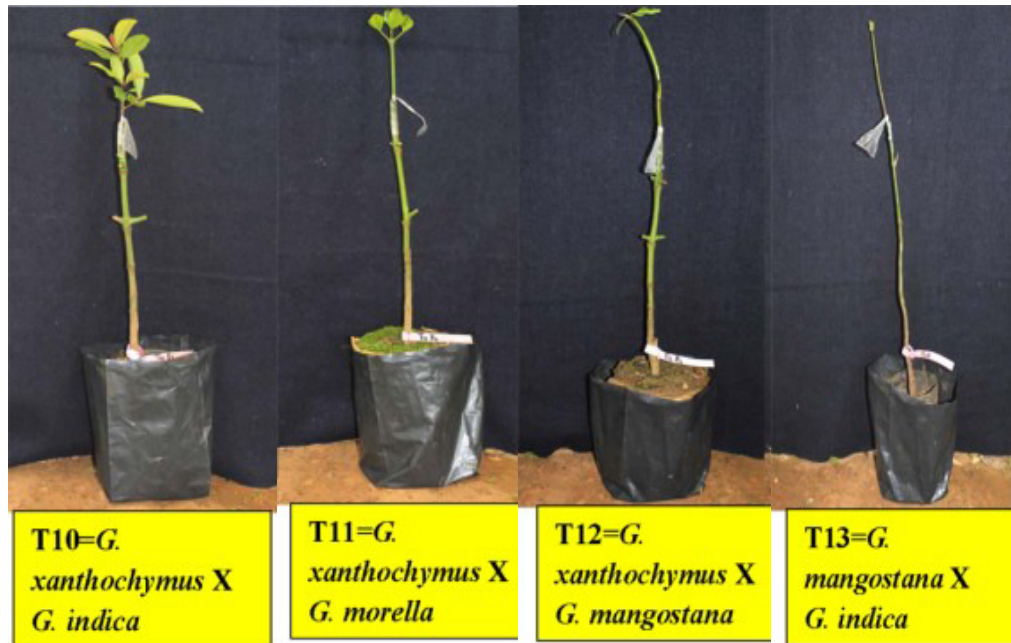
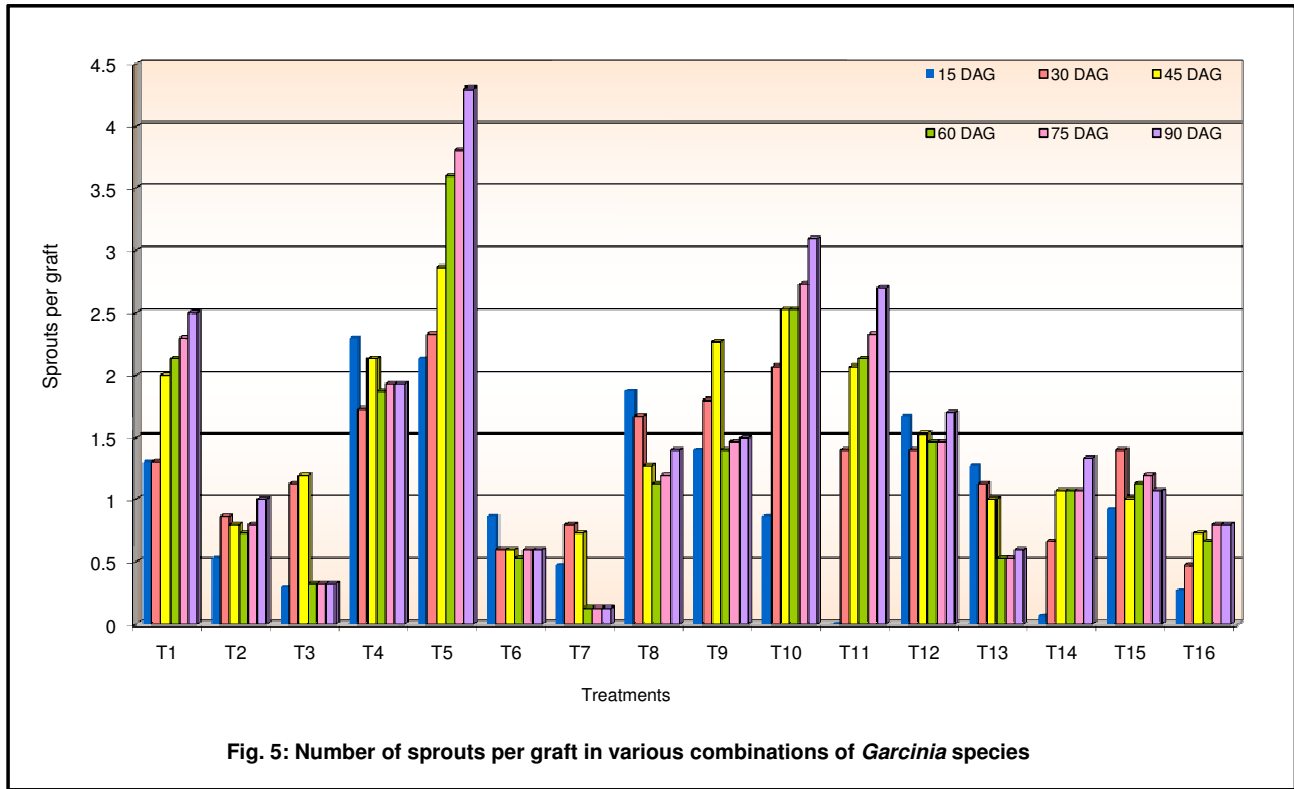


Plate 3. Contd....

Table 3: Number of sprouts per graft in various combinations of *Garcinia* species

Treatments (Rootstock X Scion)		15 DAG	30 DAG	45 DAG	60 DAG	75 DAG	90 DAG
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	1.30	1.30	2.00	2.13	2.30	2.50
T2	<i>G. indica</i> X <i>G. xanthochymus</i>	0.53	0.87	0.80	0.73	0.80	1.00
T3	<i>G. indica</i> X <i>G. morella</i>	0.30	1.13	1.20	0.33	0.33	0.33
T4	<i>G. indica</i> X <i>G. mangostana</i>	2.30	1.73	2.13	1.87	1.93	1.93
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	2.13	2.33	2.87	3.60	3.80	4.30
T6	<i>G. gummi-gutta</i> X <i>G. xanthochymus</i>	0.87	0.60	0.60	0.53	0.60	0.60
T7	<i>G. gummi-gutta</i> X <i>G. morella</i>	0.47	0.80	0.73	0.13	0.13	0.13
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	1.87	1.67	1.27	1.13	1.20	1.40
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	1.40	1.80	2.27	1.40	1.47	1.50
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	0.87	2.07	2.53	2.53	2.73	3.10
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	0.00	1.40	2.07	2.13	2.33	2.70
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	1.67	1.40	1.53	1.47	1.47	1.70
T13	<i>G. mangostana</i> X <i>G. indica</i>	1.27	1.13	1.00	0.53	0.53	0.60
T14	<i>G. mangostana</i> X <i>G. morella</i>	0.07	0.67	1.07	1.07	1.07	1.33
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	0.93	1.40	1.00	1.13	1.20	1.07
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	0.27	0.47	0.73	0.67	0.80	0.80
Mean		1.02	1.30	1.49	1.34	1.42	1.56
SEm±		0.17	0.17	0.24	0.31	0.27	0.34
CD@5%		0.48	0.50	0.69	0.90	0.85	0.98

DAG: Day After Grafting



T4 (*G. indica* rootstock and *G. mangostana* scion) showed the highest number of sprouts (2.3) per graft at 15 DAG. This was on par with T5 consisting of *G. gummi-gutta* rootstock and *G. indica* scion (2.13) and T8 consisting of *G. gummi-gutta* rootstock and *G. mangostana* scion (1.87). However lowest sprouts per graft was recorded in T14 consisting of *G. mangostana* rootstock and *G. morella* scion (0.07) and no sprouts was found in T11 (*G. xanthochymus* rootstock and *G. morella* scion). But 30 DAG T5 showed highest sprouts (2.33) and least sprouts per graft were shown by T16 consisting of *G. mangostana* rootstock and *G. xanthochymus* scion (0.47). At 45 DAG also only T5 (*G. gummi-gutta* rootstock and *G. indica* scion) showed the highest sprouts per graft (2.87) which was on par with T10 consisting *G. xanthochymus* rootstock and *G. indica* scion (2.53) and T9 with *G. xanthochymus* rootstock and *G. gummi-gutta* scion (2.27). However lowest was recorded in T6 with *G. gummi-gutta* rootstock and *G. xanthochymus* scion (0.60). At the time of 60 DAG upto 90 day, T5 (*G. gummi-gutta* rootstock and *G. indica* scion) only showed the highest sprouts per graft (3.6, 3.8 and 4.3 respectively) and least (0.13) was found in T7 (*G. gummi-gutta* rootstock and *G. morella* scion).

4.1.3 Number of grafts sprouted at the end of 1st to 14th week

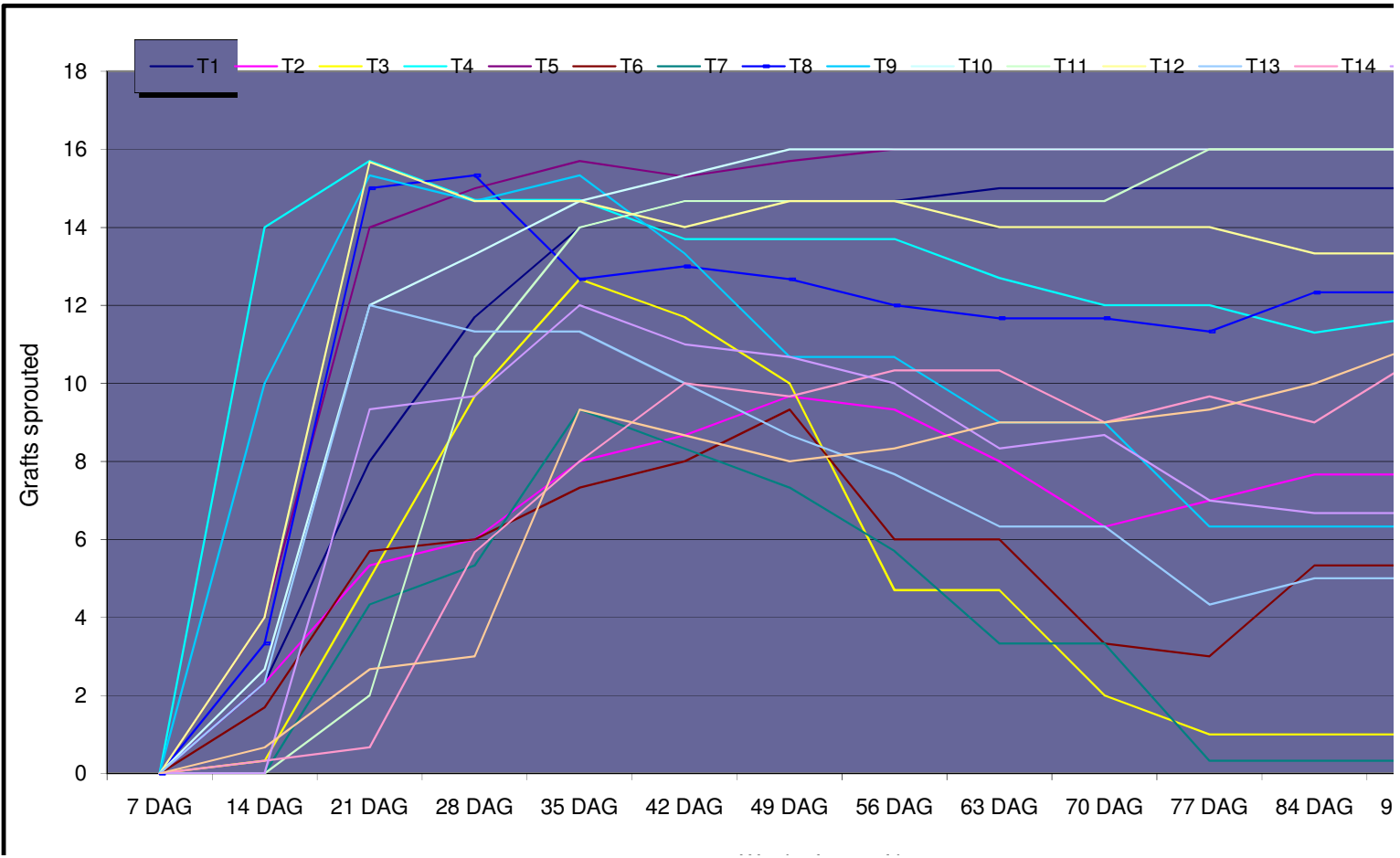
At the end of 1st week up to 14th week, the number of grafts sprouted was counted in each treatment. The data on graft sprouted per week are presented in Table 4 and Figure 6.

At the end of first week after grafting there was no significant difference on graft sprout per treatment. From the second week onwards (2WAG) the sprouts per graft showed significant increase. Only in second week, maximum grafts sprouted (14.00) were observed in T4 (*G. indica* rootstock and *G. mangostana* scion) followed by T9 (*G. xanthochymus* rootstock and *G. gummi-gutta* scion) of 10.00 but no sprouts was observed in T11 (*G. xanthochymus* rootstock and *G. morella* scion) till 2nd week. Same trend continued up to 21 DAG. But at the end of 14th week (98 DAG)

Table 4: Number of grafts with sprouts across time in various inter-specific grafts of *Garcinia*

Treatments	7 DAG	14 DAG	21 DAG	28 DAG	35 DAG	42 DAG	49 DAG	56 DAG	63 DAG	70 DAG	77 DAG	84 DAG	91 DAG	98 DAG
T1	0.00	2.33	8.00	11.7	14.00	14.67	14.67	14.67	15.00	15.00	15.00	15.00	15.00	15.00
T2	0.00	2.33	5.33	6.00	8.00	8.67	9.67	9.33	8.00	6.33	7.00	7.67	7.67	8.00
T3	0.00	0.33	5.00	9.67	12.67	11.70	10.00	4.70	4.70	2.00	1.00	1.00	1.00	1.00
T4	0.00	14.00	15.70	14.70	14.70	13.70	13.70	13.70	12.70	12.00	12.00	11.30	11.70	10.00
T5	0.00	4.00	14.00	15.00	15.70	15.30	15.70	16.00	16.00	16.00	16.00	16.00	16.00	16.00
T6	0.00	1.70	5.70	6.00	7.33	8.00	9.33	6.00	6.00	3.33	3.00	5.33	5.33	5.60
T7	0.00	0.00	4.33	5.33	9.33	8.33	7.33	5.70	3.33	3.33	0.33	0.33	0.33	0.33
T8	0.00	3.33	15.00	15.33	12.67	13.00	12.67	12.00	11.67	11.67	11.33	12.33	12.33	12.33
T9	0.00	10.00	15.33	14.67	15.33	13.33	10.67	10.67	9.00	9.00	6.33	6.33	6.33	6.33
T10	0.00	2.67	12.00	13.3	14.67	15.33	16.00	16.00	16.00	16.00	16.00	16.00	16.00	16.00
T11	0.00	0.00	2.00	10.67	14.00	14.67	14.67	14.67	14.67	14.67	16.00	16.00	16.00	16.00
T12	0.00	4.00	15.67	14.67	14.67	14.00	14.67	14.67	14.00	14.00	14.00	13.33	13.33	13.33
T13	0.00	2.33	12.00	11.33	11.33	10.00	8.67	7.67	6.33	6.33	4.33	5.00	5.00	8.00
T14	0.00	0.33	0.67	5.67	8.00	10.00	9.67	10.33	10.33	9.00	9.67	9.00	10.67	11.33
T15	0.00	0.00	9.33	9.67	12.00	11.00	10.67	10.00	8.33	8.67	7.00	6.67	6.67	7.00
T16	0.00	0.67	2.67	3.00	9.33	8.67	8.00	8.33	9.00	9.00	9.33	10.00	11.00	11.66
Mean	0.00	3.00	8.92	10.42	12.11	11.90	11.63	10.90	10.32	9.77	9.27	9.46	9.65	9.87
SEm±	0.00	1.02	1.50	1.35	1.10	1.16	1.11	1.26	1.19	0.99	1.39	1.32	1.19	1.12
CD@5%	NS	2.95	4.36	3.918	3.1	3.37	3.21	3.65	3.46	2.87	4.05	3.84	3.47	3.24

DAG: Day After Grafting; NS: Non Significant



maximum sprouts (16.00) were recorded in T5 (*G. gummi-gutta* rootstock and *G. indica* scion), T10 (*G. xanthochymus* rootstock and *G. indica* scion), T11 (*G. xanthochymus* rootstock and *G. morella* scion) this was on par with T1 consisting *G. indica* rootstock and *G. gummi-gutta* scion (15.00) and T12 consisting *G. xanthochymus* rootstock and *G. mangostana* scion (13.33). Whereas, minimum sprouts was recorded in T7 consisting *G. gummi-gutta* rootstock and *G. morella* scion (0.33) and T3 consisting *G. indica* rootstock and *G. morella* scion (1.00). This result showed that both *G. indica* and *G. gummi-gutta* rootstock were incompatible with *G. morella* scion. Pictorial representation of inter-specific grafts of *Garcinia* species at 21 day after grafting (DAG) depicted in Plate 4.

4.1.4 Length of longest sprout in randomly selected grafts (cm)

In each treatment fifteen grafts were randomly selected and observation taken on these grafts at 45 day after grafting in 15 days interval up to 90 days, showed significant difference in the length of sprout due to compatibility of rootstock and scion presented in the Table 5 and Figure 7.

The sprout length at 45, 60, 75 and 90 days after grafting varied significantly due to the compatibility of rootstock and scion. The treatment with *G. indica* rootstock and *G. gummi-gutta* scion (T1) showed longer sprout length at 45 days after grafting (4.34 cm), and at 60 days after grafting (7.53 cm) and the shortest length was observed in T9 constituting *G. xanthochymus* rootstock and *G. gummi-gutta* scion (0.04 cm and 0.06 cm, respectively for 45 and 60 days after grafting).

This pattern was similar at 75 and 90 days after grafting. The treatment with *G. indica* rootstock and *G. gummi-gutta* scion (T1) showed significantly longer sprout length (9.43 cm and 11.92 cm respectively). This was on par with treatment constituting of *G. gummi-gutta* rootstock and *G. indica* scion (9.19 cm and 10.95 cm respectively). However, the shortest sprout length (0.07 cm) recorded in both T7 (*G.*

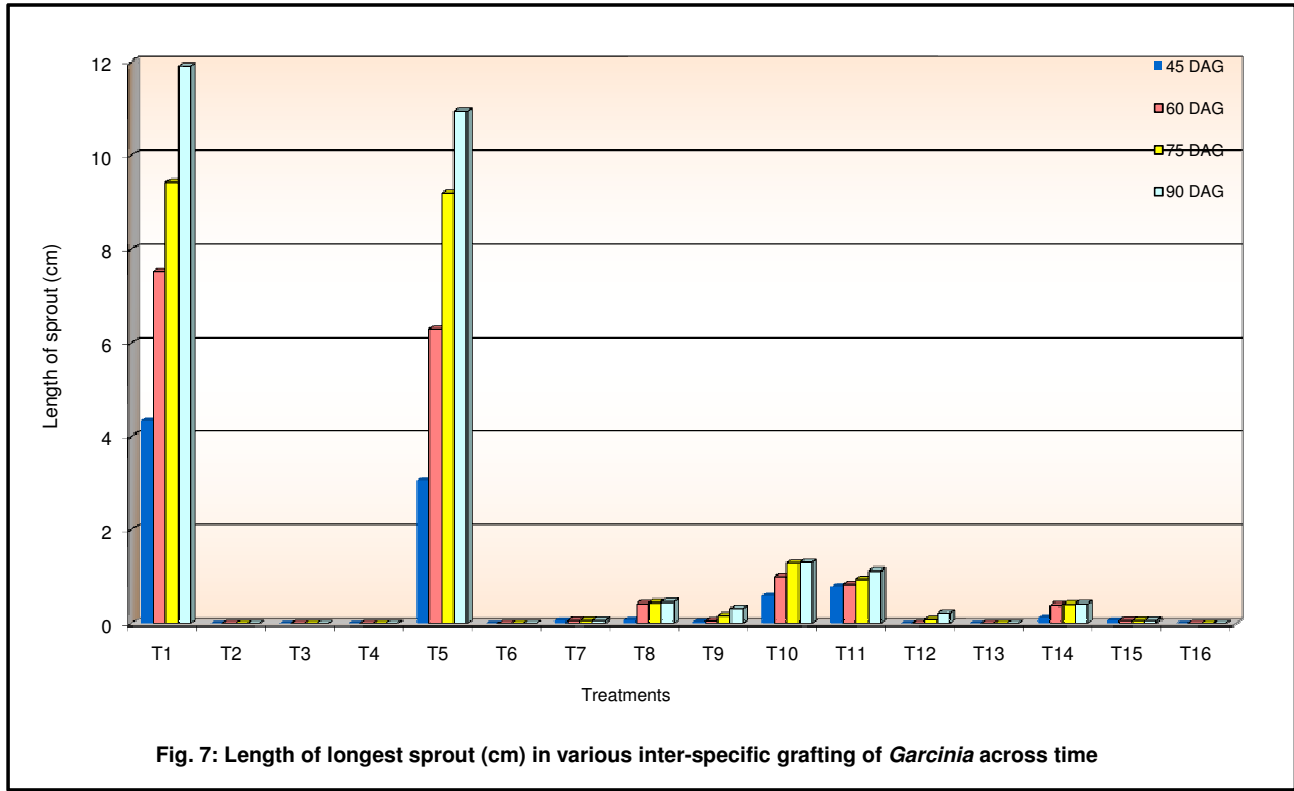


Plate 4. Sprouts of inter-specific grafts of *Garcinia* species at 21 day after grafting (DAG)

Table 5: Length of longest sprout (cm) in various inter-specific grafting of *Garcinia* across time

Treatments (Rootstock X Scion)		45 DAG	60 DAG	75 DAG	90 DAG
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	4.34	7.53	9.43	11.92
T2	<i>G. indica</i> X <i>G. xanthochymus</i>	0.00	0.00	0.00	0.00
T3	<i>G. indica</i> X <i>G. morella</i>	0.00	0.00	0.00	0.00
T4	<i>G. indica</i> X <i>G. mangostana</i>	0.00	0.00	0.00	0.00
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	3.07	6.29	9.19	10.95
T6	<i>G. gummi-gutta</i> X <i>G. xanthochymus</i>	0.00	0.00	0.00	0.00
T7	<i>G. gummi-gutta</i> X <i>G. morella</i>	0.07	0.07	0.07	0.07
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	0.08	0.43	0.45	0.47
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	0.04	0.06	0.17	0.33
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	0.59	1.01	1.29	1.31
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	0.79	0.84	0.95	1.13
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	0.00	0.00	0.09	0.23
T13	<i>G. mangostana</i> X <i>G. indica</i>	0.00	0.00	0.00	0.00
T14	<i>G. mangostana</i> X <i>G. morella</i>	0.13	0.40	0.42	0.43
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	0.07	0.07	0.07	0.07
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	0.00	0.00	0.00	0.00
Mean		1.02	1.85	2.21	2.69
SEm±		0.26	0.42	0.28	0.33
CD@5%		0.76	1.21	0.80	0.97

DAG: Day After Grafting



gummi-gutta rootstock and *G. morella* scion) and T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion).

4.1.5 Diameter of longest sprout (mm)

The diameter of longest sprout was recorded in T1 (*G. indica* rootstock and *G. gummi-gutta* scion) which was significantly higher (1.98 mm, 2.53 mm, 2.77 mm, 3.76 mm) in 45, 60, 75, 90 days respectively. This was on par with T5 constituting *G. gummi-gutta* rootstock and *G. indica* scion (1.66 mm, 2.05 mm, 2.27 mm, 3.06 mm at 45, 60, 75 90 days respectively). However, the minimum diameter was recorded in T7 (*G. gummi-gutta* rootstock and *G. morella* scion) in both 45th and 60 days. After 75 and 90 days of grafting with T7 (*G. gummi-gutta* rootstock and *G. morella* scion), T8 (*G. gummi-gutta* rootstock and *G. mangostana* scion), T12 (*G. xanthochymus* rootstock and *G. mangostana* scion), T14 (*G. mangostana* rootstock and *G. morella* scion) and T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion) also showed lowest diameter except T8 (*G. gummi-gutta* rootstock and *G. mangostana* scion) after 90 days of grafting. (Table 6 and Figure 8)

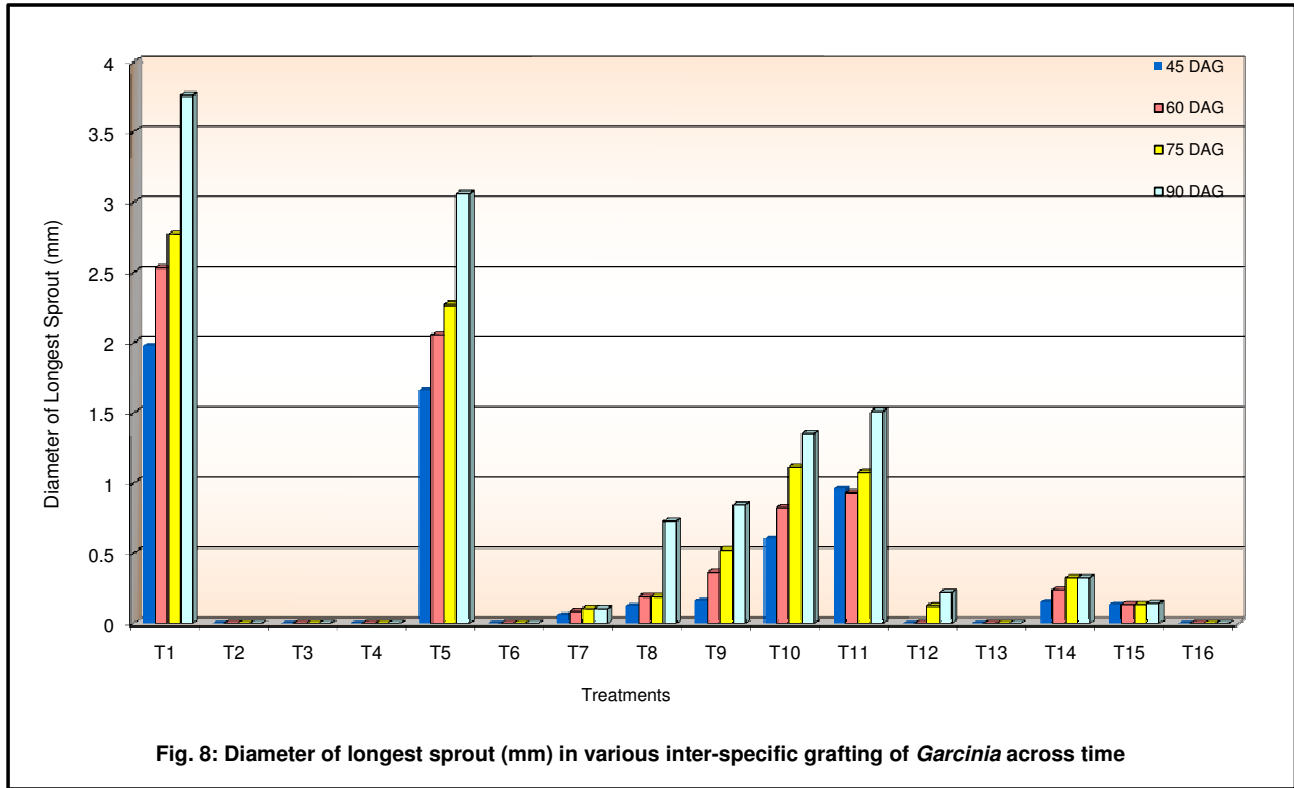
4.1.6 Number of leaves on longest sprout

The number of leaves on longest sprout at 45, 60, 75 and 90 days after grafting varied significantly. The treatment with *G. indica* rootstock and *G. gummi-gutta* scion (T1) showed maximum number of leaves 3.67, 5.07, 6.53, and 7.13 at 45, 60, 75, and for 90 days respectively which was on par with T5 (*G. gummi-gutta* rootstock and *G. indica* scion). The minimum number of leaves on longest sprout was recorded in T7 (*G. gummi-gutta* rootstock and *G. morella* scion), T12 (*G. xanthochymus* rootstock and *G. mangostana* scion), T14 (*G. mangostana* rootstock and *G. morella* scion) and T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion). In T7 the average number of leaves on longest sprout (0.13) was same at 45, 60, 75 days, and after 90 days of planting the leaf number per graft increased to 0.20. In T9 the leaves sprout was same

Table 6: Diameter of longest sprout (mm) in various inter-specific grafting of *Garcinia* across time

Treatments (Rootstock X Scion)		45 DAG	60 DAG	75 DAG	90 DAG
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	1.98	2.53	2.77	3.76
T2	<i>G. indica</i> X <i>G. xanthochymus</i>	0.00	0.00	0.00	0.00
T3	<i>G. indica</i> X <i>G. morella</i>	0.00	0.00	0.00	0.00
T4	<i>G. indica</i> X <i>G. mangostana</i>	0.00	0.00	0.00	0.00
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	1.66	2.05	2.27	3.06
T6	<i>G. gummi-gutta</i> X <i>G. xanthochymus</i>	0.00	0.00	0.00	0.00
T7	<i>G. gummi-gutta</i> X <i>G. morella</i>	0.05	0.08	0.10	0.10
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	0.12	0.19	0.19	0.73
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	0.16	0.36	0.52	0.84
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	0.60	0.82	1.11	1.35
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	0.96	0.93	1.07	1.51
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	0.00	0.00	0.12	0.22
T13	<i>G. mangostana</i> X <i>G. indica</i>	0.00	0.00	0.00	0.00
T14	<i>G. mangostana</i> X <i>G. morella</i>	0.15	0.24	0.32	0.32
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	0.13	0.13	0.13	0.14
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	0.00	0.00	0.00	0.00
Mean		0.65	0.81	0.91	1.20
SEm±		0.13	0.12	0.17	0.21
CD@5%		0.38	0.35	0.48	0.61

DAG: Day After Grafting



(0.13) at 45 and 60 days after grafting but it increased to 0.27 at 75 day and 0.67 at 90 day. But in T14 (*G. mangostana* rootstock and *G. morella* scion) the number of leaves on longest sprout was 0.13 at 45 day. It increased to 0.27 and remained same at 60, 75 and 90 day. The T15 showed bad performance in number of leaves on longest sprout (0.13) which was remained same for all recorded days (Table 7 and Figure 9).

4.1.7 Total number of leaves per graft

The highest number of leaves per graft (7.07, 11.33 and 13.93) was recorded in T1 (*G. indica* rootstock and *G. gummi-gutta* scion) at 45, 60 and 75 day this was on par with T5 (*G. gummi-gutta* rootstock and *G. indica* scion) of 6.80, 10.53 and 12.73 respectively. However after 90 days, the highest number of leaves was observed in T5 (15.13) which were on par with T1 (13.93). Lowest number of leaves (0.27) per graft was observed in T2 (*G. indica* rootstock and *G. xanthochymus* scion) at 45 day which remained same for 60 and 75 day. But after 60 days lowest leaves (0.13) found in both T6 (*G. gummi-gutta* rootstock and *G. xanthochymus* scion) and T7 (*G. gummi-gutta* rootstock and *G. morella* scion). After 75 day again lowest leaves (0.27) recorded in T2 (*G. indica* rootstock and *G. xanthochymus* scion). At last after 90 days lowest performance (0.8) was found in T6 (*G. gummi-gutta* rootstock and *G. xanthochymus* scion), T7 (*G. gummi-gutta* rootstock and *G. morella* scion) and T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion) depicted in the Table 8 and Figure 10.

4.2 Survival and field performance of these inter-specific grafts

After three month of growth under poly house, hardening was done for one and half month before planting. The survived grafts were planted in the Agricultural Research Station, Malagi to know the survival and field performance of these *Garcinia* inter-specific grafts. Total 12 treatments were planted in the field based on the result of experiment one. The results of the various growth attributes of grafts are furnished below.

Table 7: Number of leaves on longest sprout in various inter-specific grafting of *Garcinia* across time

Treatments (Rootstock X Scion)		45 DAG	60 DAG	75 DAG	90 DAG
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	3.67	5.07	6.53	7.13
T2	<i>G. indica</i> X <i>G. xanthochymus</i>	0.00	0.00	0.00	0.00
T3	<i>G. indica</i> X <i>G. morella</i>	0.00	0.00	0.00	0.00
T4	<i>G. indica</i> X <i>G. mangostana</i>	0.00	0.00	0.00	0.00
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	3.07	4.07	5.07	5.80
T6	<i>G. gummi-gutta</i> X <i>G. xanthochymus</i>	0.00	0.00	0.00	0.00
T7	<i>G. gummi-gutta</i> X <i>G. morella</i>	0.13	0.13	0.13	0.20
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	0.00	0.13	0.13	0.67
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	0.13	0.13	0.27	0.67
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	0.67	1.20	1.60	1.87
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	0.80	0.93	1.07	1.20
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	0.00	0.00	0.20	0.33
T13	<i>G. mangostana</i> X <i>G. indica</i>	0.00	0.00	0.00	0.00
T14	<i>G. mangostana</i> X <i>G. morella</i>	0.13	0.27	0.27	0.27
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	0.13	0.13	0.13	0.13
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	0.00	0.00	0.00	0.00
Mean		1.09	1.34	1.54	1.83
SEm±		0.24	0.18	0.36	0.34
CD@5%		0.70	0.53	1.04	0.98

DAG: Day After Grafting

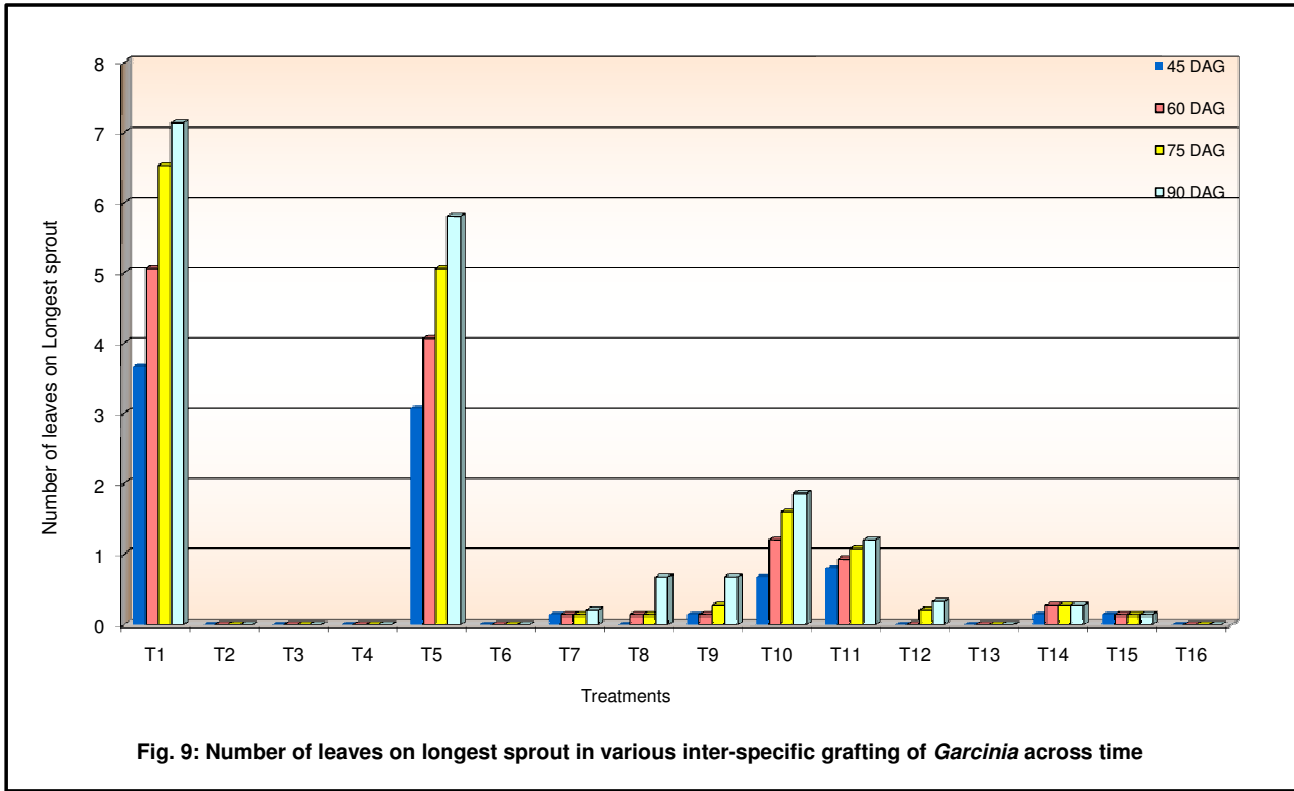
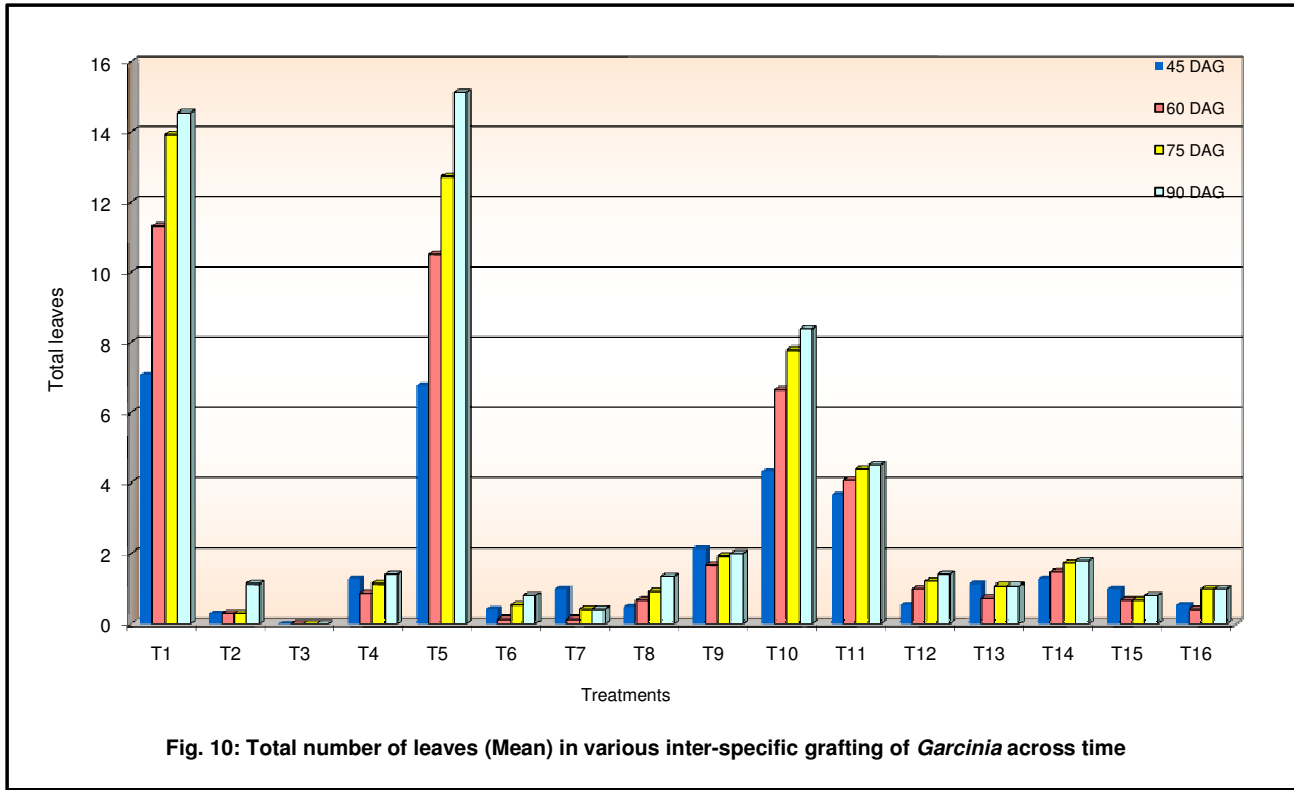


Table 8: Total number of leaves in various inter-specific grafting of *Garcinia* across time

Treatments (Rootstock X Scion)		45 DAG	60 DAG	75 DAG	90 DAG
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	7.07	11.33	13.93	14.56
T2	<i>G. indica</i> X <i>G. xanthochymus</i>	0.27	0.27	0.27	1.13
T3	<i>G. indica</i> X <i>G. morella</i>	0.00	0.00	0.00	0.00
T4	<i>G. indica</i> X <i>G. mangostana</i>	1.27	0.87	1.13	1.40
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	6.80	10.53	12.73	15.13
T6	<i>G. gummi-gutta</i> X <i>G. xanthochymus</i>	0.40	0.13	0.53	0.80
T7	<i>G. gummi-gutta</i> X <i>G. morella</i>	1.00	0.13	0.40	0.40
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	0.47	0.67	0.93	1.33
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	2.13	1.67	1.93	2.00
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	4.33	6.67	7.80	8.40
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	3.67	4.07	4.40	4.53
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	0.53	1.00	1.20	1.40
T13	<i>G. mangostana</i> X <i>G. indica</i>	1.13	0.73	1.07	1.07
T14	<i>G. mangostana</i> X <i>G. morella</i>	1.27	1.47	1.73	1.80
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	1.00	0.67	0.67	0.80
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	0.53	0.40	1.00	1.00
Mean		2.12	2.70	3.31	3.71
SEm±		0.38	0.49	0.59	0.68
CD@5%		1.10	1.41	1.71	1.98

DAG: Day After Grafting



4.2.1 Survival per cent (%)

The survival per cent recorded after five months of planting. Significant difference was observed in all the treatments. Survival per cent was maximum (100 %) in T1 (*G. indica* rootstock and *G. gummi-gutta* scion), T5 (*G. gummi-gutta* rootstock and *G. indica* scion), T10 (*G. xanthochymus* rootstock and *G. indica* scion), T11 (*G. xanthochymus* rootstock and *G. morella* scion) presented in Table 9 and Figure 11. However least survival per cent (11%) was found in T8 (*G. gummi-gutta* rootstock and *G. mangostana* scion). None of the grafts survived in T12 (*G. xanthochymus* rootstock and *G. mangostana* scion), T13 (*G. mangostana* rootstock and *G. indica* scion), T14 (*G. mangostana* rootstock and *G. morella* scion), T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion) and T16 (*G. mangostana* rootstock and *G. xanthochymus* scion). Pictorial representation of growth of inter-specific grafts of *Garcinia* under the field condition was depicted in the Plate 5.

4.2.2 Plant height (cm)

Data on plant height at the field experiment of various inter-specific grafts are presented in Table 10 and Figure 12.

There was no significance difference in plant height in the field performance of *Garcinia* grafts initially as well as 1MAP; in the subsequent month, T5 (*G. gummi-gutta* rootstock and *G. indica* scion) recorded maximum plant height of 59.00, 62.00, 69.00, 74.00 cm after 2, 3, 4 and 5 months after planting (MAP) respectively; which showed an increase of 37.04 per cent (Table 14) over the initial height of 54.00 cm; this was on par with T1 (*G. indica* rootstock and *G. gummi-gutta* scion) recorded plant height of 57.00, 60.00, 65.00, 72.00 cm respectively after 2, 3, 4, and 5 months after planting (MAP); which showed an increase of 35.85 per cent (Table 14) over the initial height of 53.00 cm. Whereas T9 (*G. xanthochymus* rootstock and *G. gummi-gutta* scion) showed minimum plant height of 50.00, 52.00, 55.00, 58.00 cm

Table 9: Survival per cent of various inter-specific grafts in *Garcinia* species after 5 months of field planting

Treatments (Rootstock X Scion)		Survival (%)
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	100(90.00)
T4	<i>G. indica</i> X <i>G. mangostana</i>	22(27.97)
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	100(90.00)
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	11(19.37)
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	66(54.33)
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	100(90.00)
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	100(90.00)
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	0.00
T13	<i>G. mangostana</i> X <i>G. indica</i>	0.00
T14	<i>G. mangostana</i> X <i>G. morella</i>	0.00
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	0.00
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	0.00
Mean		41.58
SEm±		2.37
CD@5%		6.91 (15.23)

Figures in parentheses are arcsin – transformed values

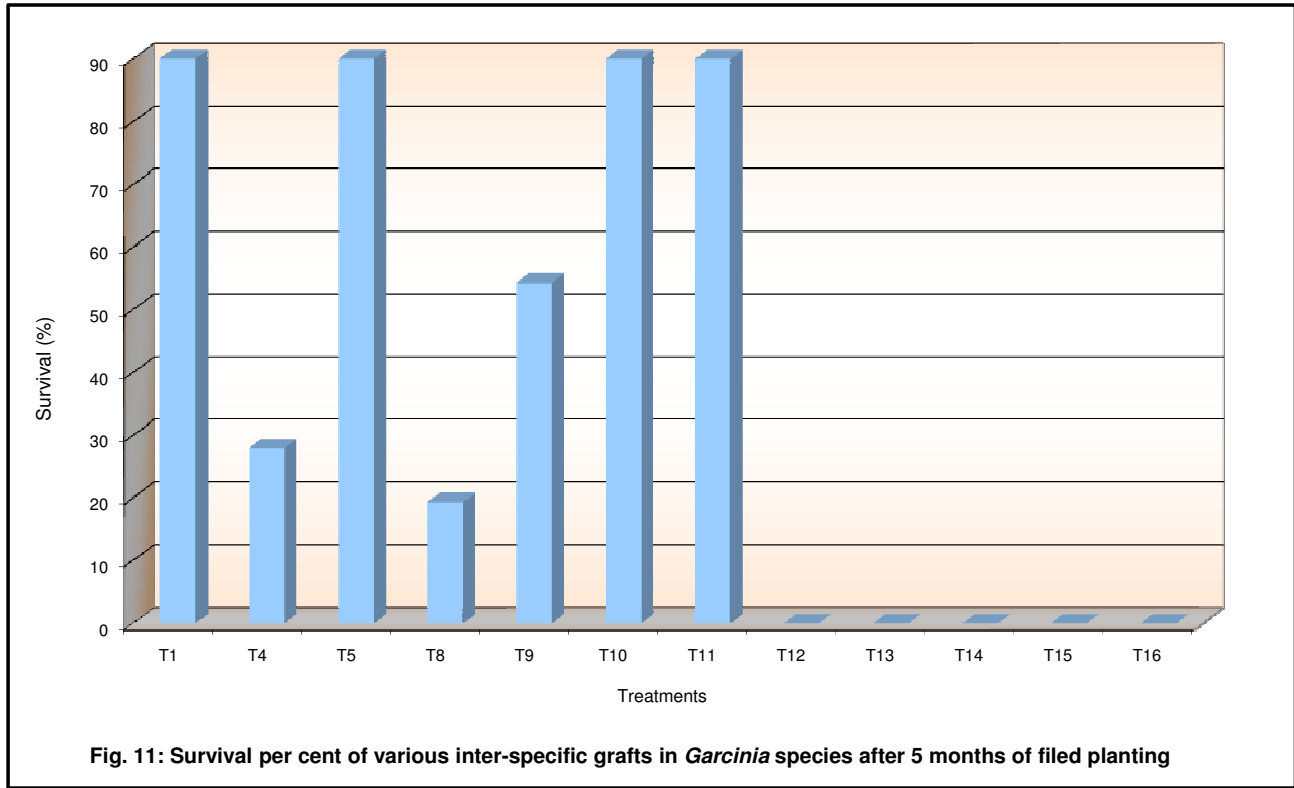


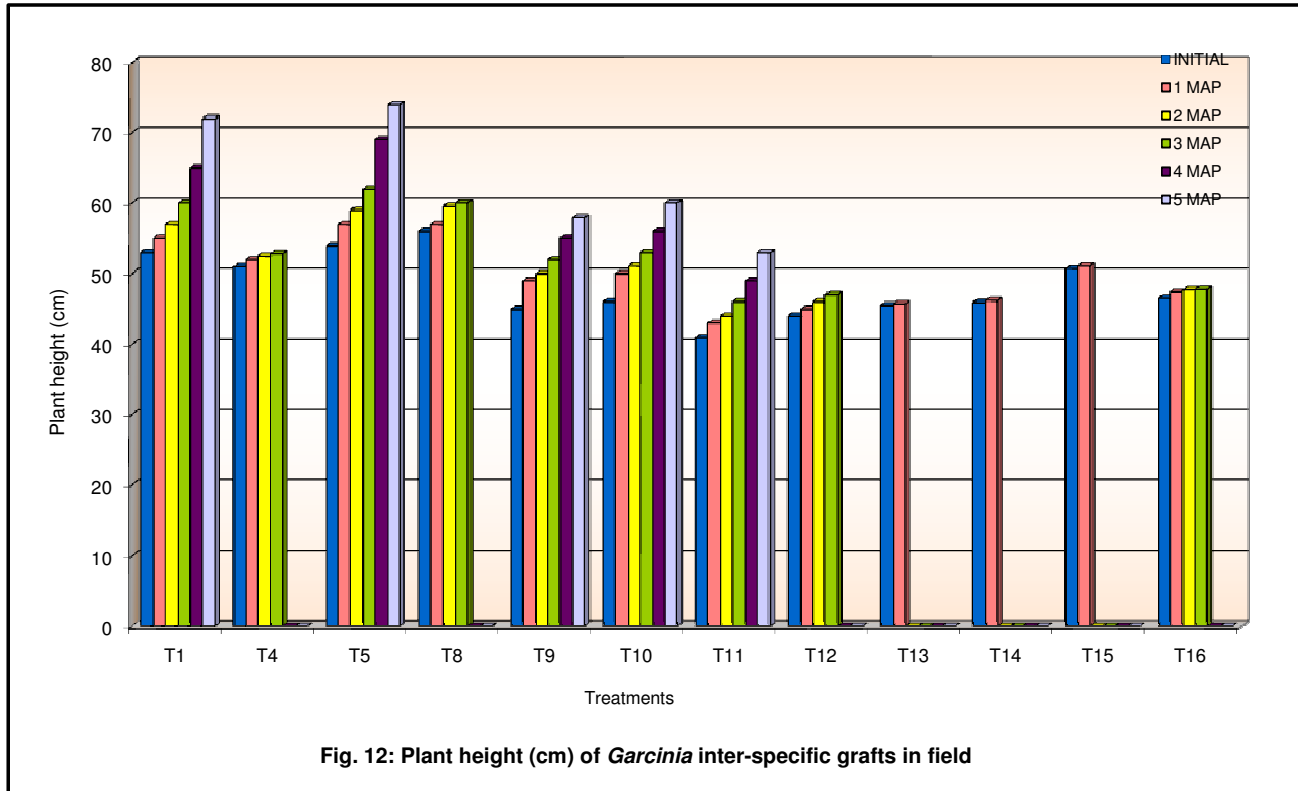


Plate 5. Growth of interspecific grafts of garcinia under field condition

Table 10: Plant height (cm) of *Garcinia* inter-specific grafts in field

Treatments (Rootstock X Scion)		INITIAL	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	53.00	55.00	57.00	60.00	65.00	72.00
T4	<i>G. indica</i> X <i>G. mangostana</i>	51.00	52.00	52.50	52.85	0.00	0.00
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	54.00	57.00	59.00	62.00	69.00	74.00
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	56.00	57.00	59.55	60.00	0.00	0.00
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	45.00	49.00	50.00	52.00	55.00	58.00
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	46.00	50.00	51.08	53.00	56.00	60.00
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	41.00	43.00	44.00	46.00	49.00	53.00
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	44.00	45.00	46.00	47.00	0.00	0.00
T13	<i>G. mangostana</i> X <i>G. indica</i>	45.50	45.70	0.00	0.00	0.00	0.00
T14	<i>G. mangostana</i> X <i>G. morella</i>	45.90	46.20	0.00	0.00	0.00	0.00
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	50.70	51.10	0.00	0.00	0.00	0.00
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	46.50	47.40	47.75	47.80	0.00	0.00
Mean		48.27	49.63	38.73	40.05	28.91	26.41
SEm±		3.46	3.35	9.31	9.52	5.98	3.36
CD@5%		NS	NS	27.17	27.78	17.46	9.81

MAP: Month After Planting; NS: Non significant



respectively after 2, 3, 4 and 5 MAP, which showed an increase of 28.88 per cent (Table 14) over the initial height of 45.00 cm. None of the grafts were survived in T4 (*G. indica* rootstock and *G. mangostana* scion), T8 (*G. gummi-gutta* rootstock and *G. mangostana* scion), T12 (*G. xanthochymus* rootstock and *G. mangostana* scion), T13 (*G. mangostana* rootstock and *G. indica* scion), T14 (*G. mangostana* rootstock and *G. morella* scion), T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion) and T16 (*G. mangostana* rootstock and *G. xanthochymus* scion) combinations after five months of planting.

4.2.3 Collar diameter (mm)

Data on collar diameter at the field experiment of various inter-specific grafts are presented in Table 11 and Figure 13.

Initial and one month after planting (MAP) readings were did not differ significantly and maximum collar diameter was recorded in T4 (*G. indica* rootstock and *G. mangostana* scion) of 10.46 and 10.98 mm respectively. Minimum was recorded in T8 (*G. gummi-gutta* rootstock and *G. mangostana* scion) of 8.12 and 8.29 mm respectively for initial and 1MAP. None of the grafts were survived in T4 and T8 combinations 4 MAP.

Maximum collar diameter was observed in T1 (*G. indica* rootstock and *G. gummi-gutta* scion) of 10.96, 11.85, 12.83 and 13.75 mm respectively for 2, 3, 4 and 5 MAP; which showed an increase of 49.23 per cent (Table 14) over initial collar diameter of 9.16 mm. Whereas minimum was recorded in T10 (*G. xanthochymus* rootstock and *G. indica* scion) of 9.11, 9.24, 9.68 and 10.27 mm for 2, 3, 4 and 5 MAP; which showed an increase of 19.00 per cent (Table 14).

4.2.4 Total number of leaves

Data on plant height at the field experiment of various inter-specific grafts are presented in Table 12 and Figure 14.

Table 11: Collar diameter (mm) of *Garcinia* inter-specific grafts in field

Treatments (Rootstock X Scion)		INITIAL	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	9.16	10.67	10.96	11.85	12.83	13.75
T4	<i>G. indica</i> X <i>G. mangostana</i>	10.46	10.98	11.19	11.36	0.00	0.00
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	10.23	10.68	11.30	11.99	12.64	13.67
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	8.12	8.29	8.71	8.75	0.00	0.00
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	8.40	8.96	9.96	10.30	10.93	11.56
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	8.63	8.93	9.11	9.24	9.68	10.27
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	8.73	9.24	9.57	10.51	11.55	12.61
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	8.86	9.28	9.88	10.10	11.14	0.00
T13	<i>G. mangostana</i> X <i>G. indica</i>	8.96	9.16	0.00	0.00	0.00	0.00
T14	<i>G. mangostana</i> X <i>G. morella</i>	8.56	8.69	0.00	0.00	0.00	0.00
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	8.52	8.65	0.00	0.00	0.00	0.00
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	8.15	8.34	8.54	8.55	0.00	0.00
Mean		8.89	9.32	7.44	7.72	5.73	5.15
SEm±		0.81	0.81	1.63	1.65	0.38	0.37
CD@5%		NS	NS	4.76	4.82	1.10	1.07

MAP: Month After Planting; NS: Non significant

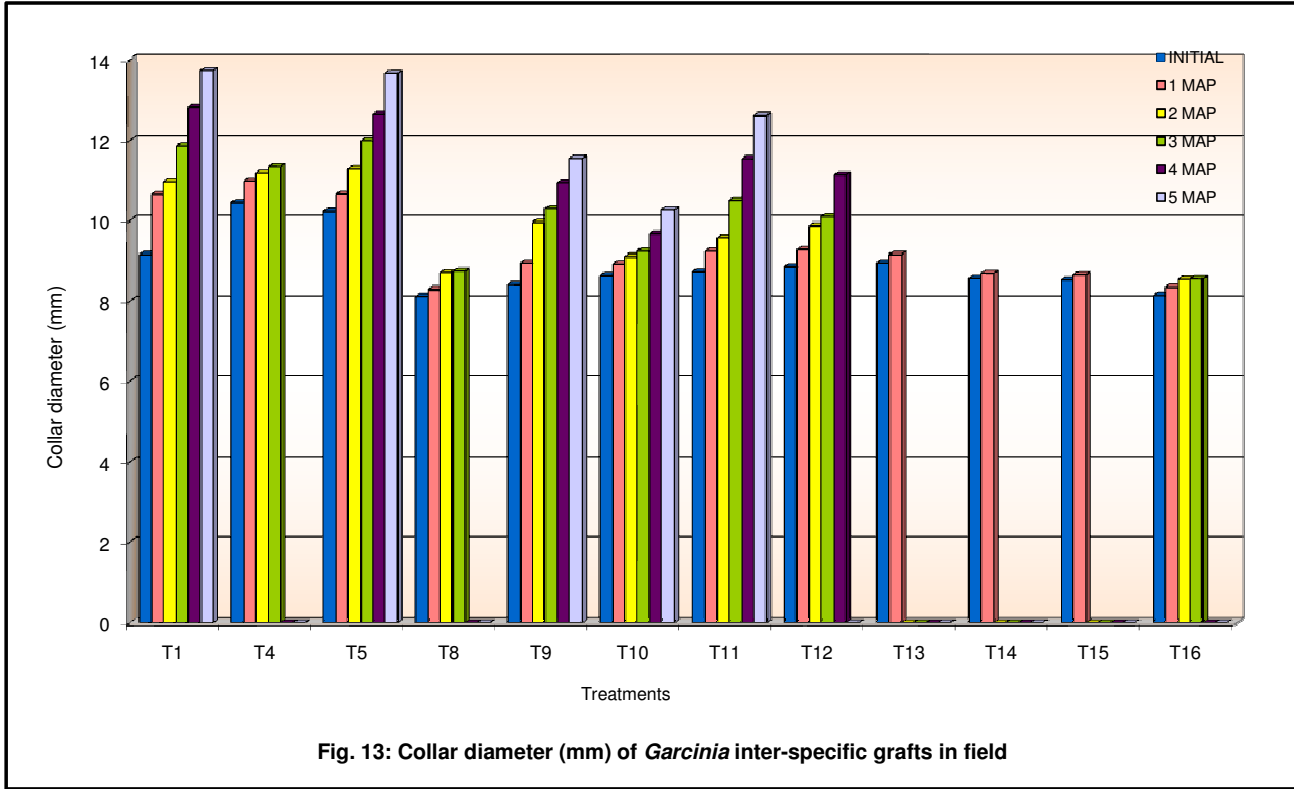
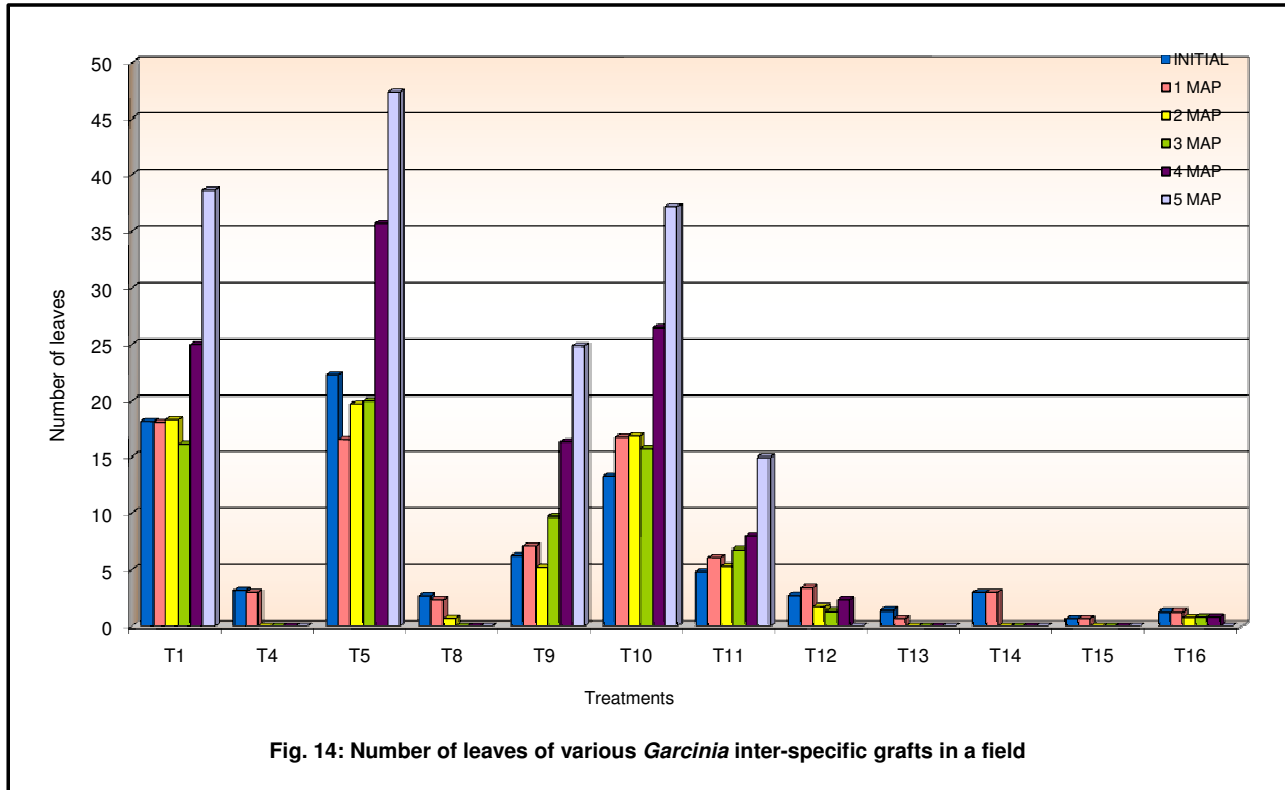


Table 12: Number of leaves of various *Garcinia* inter-specific grafts in field

Treatments (Rootstock X Scion)		INITIAL	1 MAP	2 MAP	3 MAP	4 MAP	5 MAP
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	18.10	18.00	18.3	16.11	24.98	38.69
T4	<i>G. indica</i> X <i>G. mangostana</i>	3.20	3.00	0.0	0.00	0.00	0.00
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	22.32	16.56	19.7	20.00	35.72	47.40
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	2.67	2.33	0.7	0.00	0.00	0.00
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	6.27	7.06	5.2	9.67	16.33	24.85
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	13.29	16.78	16.9	15.72	26.44	37.15
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	4.79	6.11	5.3	6.78	7.98	14.97
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	2.70	3.44	1.7	1.33	2.33	0.00
T13	<i>G. mangostana</i> X <i>G. indica</i>	1.40	0.67	0.0	0.00	0.00	0.00
T14	<i>G. mangostana</i> X <i>G. morella</i>	3.00	3.00	0.0	0.00	0.00	0.00
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	0.67	0.67	0.0	0.00	0.00	0.00
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	1.28	1.28	0.8	0.83	0.83	0.00
Mean		6.64	6.57	5.71	5.87	9.55	13.59
SEm±		2.18	1.36	1.02	2.29	3.30	4.17
CD@5%		6.36	3.96	2.97	6.68	9.64	12.16

MAP: Month After Planting; NS: Non significant



There was a significant difference in the number of leaves initially as well as in subsequent months. Initially the number of leaves were maximum at 6.64 (mean value of initial reading) but the number of leaves decreased in the 1 and 2 MAP to 6.57 and 5.71 (mean values of months), respectively. At the end of final readings (5 MAP) there was an increase in the number of leaves over initial and among the treatments.

Maximum number of leaves was recorded in T5 (*G. gummi-gutta* rootstock and *G. indica* scion) of 47.40 at 5 MAP which was on par with T1 (*G. indica* rootstock and *G. gummi-gutta* scion) of 38.69 and T10 (*G. xanthochymus* rootstock and *G. indica* scion) of 37.15. However, minimum number of leaves was recorded in T11 (*G. xanthochymus* rootstock and *G. morella* scion) of 14.97.

4.2.5 Leaf area per plant (sq. cm)

The data on leaf area per plant recorded is presented in the Table 13 and Figure 15.

There was a significant difference in leaf area initially and also 5MAP because the species were different and the leaf shapes were almost dissimilar so the leaf area readings were showed significant difference. In initial reading the maximum leaf area (30.20 sq. cm) was recorded in T1 (*G. indica* rootstock and *G. gummi-gutta* scion) and minimum leaf area (0.60 sq. cm) recorded in T13 (*G. mangostana* rootstock and *G. indica* scion). 5 MAP also the T1 only showed the maximum leaf area (48.54 sq. cm) but minimum leaf area (4.71 sq. cm) was recorded in T9 (*G. xanthochymus* rootstock and *G. gummi-gutta* scion).

4.2.6 Increment Percentage (%)

Increment percentage shows the increase in the quantitative growth parameters over the initial observations, the details of which are given in Table 14 and Figure 16.

Table 13: Leaf area (sq. cm) of various *Garcinia* inter-specific grafts in a field

Treatments (Rootstock X Scion)		INITIAL	5 MAP
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	30.20	48.54
T4	<i>G. indica</i> X <i>G. mangostana</i>	2.72	0.00
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	19.77	28.29
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	2.46	0.00
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	4.18	4.71
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	5.27	11.39
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	5.23	5.91
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	2.72	0.00
T13	<i>G. mangostana</i> X <i>G. indica</i>	0.60	0.00
T14	<i>G. mangostana</i> X <i>G. morella</i>	2.40	0.00
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	2.01	0.00
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	4.05	0.00
Mean		6.80	8.24
SEm±		1.47	1.22
CD@5%		4.30	3.55

MAP: Month After Planting

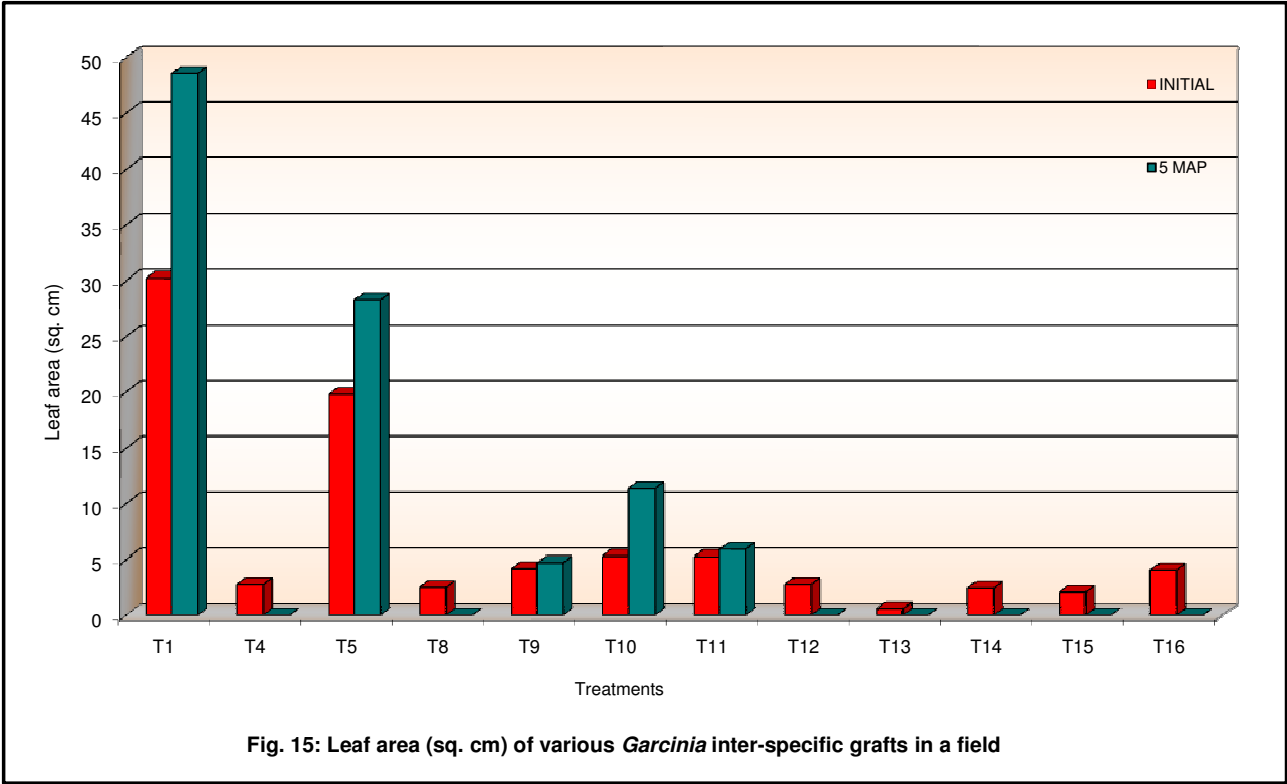
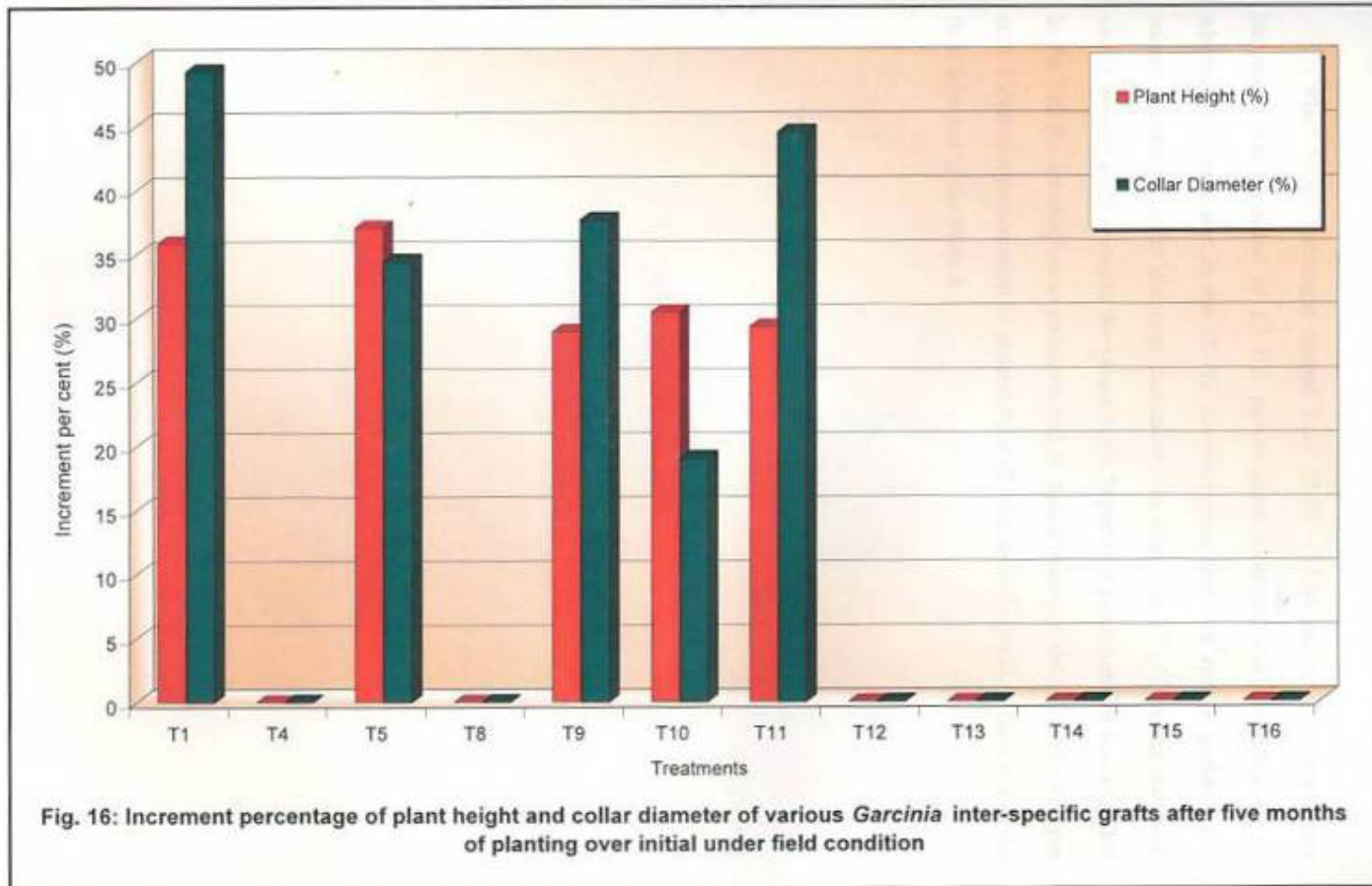


Table 14: Increment percentage of plant height and collar diameter of various *Garcinia* inter-specific grafts after five months of planting over initial under field condition

Treatments (Rootstock X Scion)		Plant Height (%)	Collar Diameter (%)
T1	<i>G. indica</i> X <i>G. gummi-gutta</i>	35.85	49.23
T4	<i>G. indica</i> X <i>G. mangostana</i>	0.00	0.00
T5	<i>G. gummi-gutta</i> X <i>G. indica</i>	37.04	34.40
T8	<i>G. gummi-gutta</i> X <i>G. mangostana</i>	0.00	0.00
T9	<i>G. xanthochymus</i> X <i>G. gummi-gutta</i>	28.88	37.61
T10	<i>G. xanthochymus</i> X <i>G. indica</i>	30.43	19.00
T11	<i>G. xanthochymus</i> X <i>G. morella</i>	29.27	44.44
T12	<i>G. xanthochymus</i> X <i>G. mangostana</i>	0.00	0.00
T13	<i>G. mangostana</i> X <i>G. indica</i>	0.00	0.00
T14	<i>G. mangostana</i> X <i>G. morella</i>	0.00	0.00
T15	<i>G. mangostana</i> X <i>G. gummi-gutta</i>	0.00	0.00
T16	<i>G. mangostana</i> X <i>G. xanthochymus</i>	0.00	0.00



Plant height increment ranged from 28.88 - 37.04 per cent and maximum increment was recorded in T5 (*G. gummi-gutta* rootstock and *G. indica* scion) whereas minimum was in the T9 (*G. xanthochymus* rootstock and *G. gummi-gutta* scion). Maximum collar diameter increment was observed T1 (*G. indica* rootstock and *G. gummi-gutta* scion) to the values of 49.23 per cent and minimum was recorded in the T10 (*G. xanthochymus* rootstock and *G. indica* scion) of the value of 19.00 per cent. Pictorial representation of general view of inter-specific grafts of *Garcinia* in the field depicted in the Plate 6.



Plate 6. General view of performance of inter-specific grafts of Garcinia in the field

5. DISCUSSION

Interest and activities concerning Non-Wood Forest products (NWFPs) have been renewed worldwide during the last two decades after it has been shown by several workers that NWFP yielding species generate fairly large volumes of revenue and strengthen the livelihood of people than the timber yielding species (Yadav and Dugaya, 2013). Currently NWFPs have been viewed to be the most environment-friendly forest resources that could improve the livelihood of people.

In recent years some important species of *Garcinia* are receiving major attention due to their medicinal and industrial uses. However presently, lack of standardized nursery techniques and vegetative propagation techniques hinders such attempts. The dioecious nature of the plant and none of the standard sex distinguishing characters in early stage of growth being known has made the task of identifying the female plant at seedling stage difficult. Hence successful vegetative propagation method is important. Grafting is the art of connecting two pieces of living plant tissue together so that they will unite and subsequently grow and develop as one composite plant. Many fruit and nut trees have been propagated by grafting. Cleft grafting is one of the easiest and quickest methods which were adopted in the present study. Graft compatibility/incompatibility in fruit trees is one of the greatest obstacles in rootstock breeding. In general, it is believed that grafting compatibility increased with the closeness of taxonomic relationship (Roberts, 1949).

However, there are many exceptions to this rule (Andrew and Marquez, 1993; Hartmann *et al.*, 1997). The distinction between a compatible and incompatible graft union is not always clear-cut. An incompatible graft is not synonymous with an unsuccessful graft. This incompatibility could be the result of genetical, physiological or anatomical aspects (Hartmann *et al.*, 1997). Graft incompatibility might be due to the absence of differentiation of callus tissues into new phloem tissues or necrosis of the cells in the site of scion as reported by Moore (1983). These phenomena can cause

a miss-joining between rootstock and scion, leading to lack of lignifications of cells in the site of scion. Sometimes because of immediate or delayed incompatibility also failure of graft union takes place as observed to the black-line condition of English walnut grafted on Black walnut, appeared only after twenty or more years of satisfactory performance. Most incompatibilities of orchards trees, however, were apparent at an early age (Westwood *et al.*, 1971). Graft compatibility occurs when the isozyme band pattern between scion and rootstock is similar. Their exist great scope to grow grafted elite trees in homestead or in orchard to get flower and fruit earlier, to remain initially relatively smaller with the benefit of more plant accumulation per unit area. It is difficult to carry out a uniform experiment on grafting compatibility, because the success of grafting is affected by the art and craftsmanship in grafting.

Recently *Garcinia* species are being adopted into agroforestry system because of their increase economic importance. Inter-specific plants have good potentialities to diversify the plantation. An inter-specific grafting yields valuable fruits and comes up in drier condition also. For *e.g.* *G. gummi-gutta* is highly valued but needs very moist conditions and not tolerant to drier condition. But the rootstock of *G. indica* is resistant to drought (Kureel *et al.*, 2009). Grafting *G. gummi-gutta* scion on *G. indica* rootstock can easily come up on drier region. The studies have revealed the success of kokum grafting by using *G. gummi-gutta*, and species like *G. cowa*, *G. hombroniana* can be adapted to marshy or wet soil and can tolerate inundation of water (Lim, 2012). To induce adaptability to such soil conditions also grafting can be helpful. The rootstock selection should aim at providing drought resistant, disease resistance which will help to establish different *Garcinia* plantation at rainfed areas (Mathew *et al.*, 2005). Keeping these points in mind attempt was made to assess cross graft compatibility/incompatibility in five species of *Garcinia* through inter-specific grafting in early stage and in field using cleft grafting method. The discussion relating to this study is presented below.

5.1 Study on inter-specific graft compatibility among five important species of *Garcinia*

The survival per cent in five species of *Garcinia* varied significantly. It is because of compatibility and incompatibility of different *Garcinia* species. It does not include failure of the graft due to poor technique, non-optimal environment, or disease introduced as a result of grafting. Compatibility is defined as a sufficient close genetic (taxonomic) relationship between stock and scion for a successful graft union to form, assuming that all other factors (technique, temperature, etc) are satisfactory. Incompatibility is a failure (immediate or delayed) of graft union to form due to insufficiently close genetic relationship between the stock and scion. In the present study the highest graft survival per cent was observed in treatment with *G. indica* rootstock and *G. gummi-gutta* scion (T1), *G. gummi-gutta* rootstock and *G. indica* scion (T5), *G. xanthochymus* rootstock and *G. indica* scion (T10) and *G. xanthochymus* rootstock and *G. morella* scion (T11). Similar findings was recorded by Hegde *et al.* (2010) that *G. indica* on *G. gummi-gutta* rootstock and their reciprocal showed 70-80 per cent success. But in present study lowest survival per cent (2 %) was observed in T7 (*G. gummi-gutta* rootstock and *G. morella* scion). No survival was recorded in T3 (*G. indica* rootstock and *G. morella* scion). Compatibility among species within a genus varies considerably with different type of plants. These results are also in conformity with the findings of the Mudge *et al.* (2009) who reported that nearly all inter-specific grafts of different citrus species are compatible. For eg. Sweet orange (*Citrus sinensis*) on rough lemon (*C. Jambhiri*). Toxopeus (1936), attributed the incompatibility in citrus between sweet orange (*Citrus sinensis*) and sour orange (*Citrus aurantium*) to substance produced by the scion was toxic to the stock. Whereas only some, but by no means all, stone fruit species (genus *Prunus*) are compatible eg. almond (*Prunus amygdalus*) on peach (*P. persica*) is compatible, whereas almond on apricot (*P. armeniaca*) is not. Andrew and Marquez (1993) define

incompatibility as graft union failure due to “cellular physiological intolerance” caused by “metabolic, developmental and/or anatomical differences, between stock and scion”.

Inter-specific compatibility may or may not exhibit reciprocity; *i.e.* the union is used as scion. This is true for most compatible stock /scion combinations, but in a few cases the compatibility is not reciprocal. In the present study 100 per cent graft union was shown by *G. xanthochymus* rootstock and *G. indica* scion (T10) but not in *G. indica* rootstock and *G. xanthochymus* scion (T2). It might be due to the grafted scion with bud do not develop because of the yellow resinous latex, released by the *G. xanthochymus* scion when the cortex is cut opened to receive the bud (Patil and Murthy, 2010). The same result was observed in different species for example ‘Myrobalan B’ plum (*Prunus cersifera*) [scion] / ‘Hales Early’ peach (*P. persica*) [stock] is compatible, but the reciprocal combinations, ‘Hales Early’ peach [scion] / ‘Myrobalan’ plum [stock] is not (Mudge *et al.*, 2009). According to Herrero (1951), graft incompatibility may be due to any of the following factors: differences in seasonal periods of growth and vegetative vigour, biochemical differences, mechanical blockade at the union, interface different rates of callusing, and precipitin reaction.

In the present study there was a significant difference in number of sprouts per graft across various combinations. T4 (*G. indica* rootstock and *G. mangostana* scion) showed the highest number of sprouts (2.3) per graft at 15 DAG. It might be due to the dormant bud was less in *G. mangostana* as compared to all other species and the scion sprouted prolifically compatible with all rootstock of *Garcinia* as a scion. 90 DAG T5 (*G. gummi-gutta* rootstock and *G. indica* scion) showed the highest number of sprouts per graft. Similar result was recorded by Gouda (2005) conducted experiment in *G. indica*. The cleft grafting showed the highest number of sprouts per graft both rootstock and scion of the same species. Least sprouts (0.13) was found in

T7 (*G. gummi-gutta* rootstock and *G. morella* scion) this might be due to the scion of *G. morella* consists more dormant bud and thickness of the scion was also less so, this treatments showed the late and least sprouts per graft.

At the end of the green house period maximum number of graft sprouted were recorded in T5 (*G. gummi-gutta* rootstock and *G. indica* scion), T10 (*G. xanthochymus* rootstock and *G. indica* scion), T11 (*G. xanthochymus* rootstock and *G. morella* scion), whereas, minimum sprouts were recorded in T7 (*G. gummi-gutta* rootstock and *G. morella* scion) of 0.33 and T3 (*G. indica* rootstock and *G. morella* scion) of 1.00. This result showed the both *G. indica* and *G. gummi-gutta* rootstock were incompatible with *G. morella* scion may be due to the young nature and lesser thickness of scion. Smaller the area at the joining rootstock and scion thus ultimately reduces the survival per cent. The similar result was recorded by Sundararaj and Varadarajan (1956), in Nutmeg using approach grafting. 35-80 per cent sprouting was observed when nutmeg on rootstocks of *M. fragrans*, *M. malabarica* and *M. Beddomei*. Those on *M. beddomei* and *M. malabarica* developed into low spreading trees. The trial on approach grafting at KAU registered about 95 per cent sprouting success in myristica species (Anon, 2001) while, at HRS, Kanyakumari revealed 82.2 per cent success of sprouting (Thangaselvabai *et al.*, 2010). Haldankar *et al.* (1999) reported that the approach grafts can be prepared throughout the year and maximum percentage of graft success was recorded on *M. malabarica*, (30-100%), and in *M. fragrans* it was 40-90 per cent.

Length of longest sprout and diameter of longest sprout in randomly selected grafts was recorded maximum in T1 (*G. indica* rootstock and *G. gummi-gutta* scion) and minimum length recorded in T7. However, minimum diameter was recorded in T7 (*G. gummi-gutta* rootstock and *G. morella* scion) and T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion). The effect might be due to the environment, rootstock, disbudding growth *etc.*, on grafting. Nauriyal *et al.* (1958) also attributed incompatibility in citrus to environmental factors.

Leaf acts as a major organ in synthesis of carbon and nitrogen by various pathways. It is the most important and major factor in knowing the net assimilation rate, growth rate which are required in growth analysis. In the present study T1 (*G. indica* rootstock and *G. gummi-gutta* scion) and the reciprocal combination T5 (*G. gummi-gutta* rootstock and *G. indica* scion) showed the maximum number of leaves. Mathew *et al.* (2005) have reported in kokum, seedlings of its own worked very well as rootstock. The success rate was up to 86 per cent probably because of the low vigour of scion. However, its take on *G. gummi-gutta* was also equally good, and have proved the growth of kokum was also satisfactory on this species. The minimum number of leaves was found in T6 (*G. gummi-gutta* rootstock and *G. xanthochymus* scion), T7 (*G. gummi-gutta* rootstock and *G. morella* scion) and T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion) of 0.8. Herrero (1951) observed that growth can be affected by incompatibility in the reduction of shoot elongation of the scion and of the radial growth of the stock and scion.

5.2 Survival and field performance of inter-specific grafts

The ultimate success of grafts and later growth of clones is subject to wide variation. Many unions are not viable for long and a form of graft incompatibility is often displayed which leads to death after a few months. Most individual seedling stocks were not able to form a satisfactory union with particular scions and the deaths occur mainly from lack of growth in the stock. Otherwise the stock remained the same size throughout the period while the scion made normal diameter growth.

Effect of climatic parameters on growth of *Garcinia* grafts in field

The meteorological data of Malagi range during the field performance showed that the mean rainfall (December 2002 - May 2013) of 12 years was 127.75 mm and the rainfall over the experiment period was 268.2 mm thus there was increase rainfall of 140.45 mm over the 12 years average rainfall value; with maximum rainfall in the

month of May (128.8 mm) and minimum rainfall in the month of March (17.8 mm). No rainfall (0 mm) was recorded in January and February. The highest monthly maximum temperature over experiment period, was recorded in the month of April (33.8°C) and lowest in the month of February (29°C) whereas highest and lowest monthly minimum temperature over experiment period, was recorded in May (20.9°C) and March (15.7°C) respectively.

In the present experiment after the determination of graft union in *Garcinia* inter-species the field performance also evaluated to understand the compatibility or incompatibility percentage. There was a significant difference in survival per cent in field among 12 treatments. 100 per cent survival per cent was observed in T1 (*G. indica* rootstock and *G. gummi-gutta* scion), T5 (*G. gummi-gutta* rootstock and *G. indica* scion), T10 (*G. xanthochymus* rootstock *G. indica* scion) and T11 (*G. xanthochymus* rootstock and *G. morella* scion). T1 and their reciprocal (T5) showed best compatibility and survivability both in nursery as well as field condition because they are phylogenetically more related. Anusha Bhat (2015) has used the three gene regions to study the phylogenetic relation among the species of *Garcinia* and has observed a close relationship between *G. indica* and *G. gummi-gutta*. Least survival per cent was found in T8 (*G. gummi-gutta* rootstock and *G. mangostana* scion) of 11 per cent and T4 (*G. indica* rootstock and *G. gummi-gutta* scion) of 22 per cent. No grafts were survived in T12 (*G. xanthochymus* rootstock and *G. mangostana* scion), T13 (*G. mangostana* rootstock and *G. indica* scion), T14 (*G. mangostana* rootstock and *G. morella* scion), T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion) and T16 (*G. mangostana* rootstock and *G. xanthochymus* scion). These results showing that both the rootstock and scion of *G. mangostana* was not compatible with most species of *Garcinia*. The incompatibility of *G. mangostana* was similar to that described in experiment one. Up to 2-3 months the mangosteen grafts showed the survival with slow growth later on it showed the delayed incompatibility. No survival

was observed in last 5MAP. This might be due to the immaturities of scion, lack of reserved food material and lack of amount of nutrient supply to the growing shoot. These results are in line with the findings of Mohamad Bin Osam and Abd Rahmon Milon (2006). They used *G. kydia* and *G. venulosa* as a rootstock for *G. mangostana* scion and recorded 10 per cent success for *G. kydia* and 12 per cent for *G. venulosa* rootstock. Jill (1976), Fairechild (1915), Galang (1955) and Ochse *et al.* (1961) reported that *G. tinctoria* (Syn. *G. xanthochymus*), *G. lateriflora*, *G. hombronaina* and *G. livingstonei* have shown fairly successful result as rootstock for *G. mangostana* but the present study doesn't warrant it. Though a good union is possible, subsequent growth was so poor that the effort was not worth pursuing. These results are also in conformity with the findings of the Mathew *et al.* (2005) who reported that for *G. mangostana* its own seedlings are best rootstock for good graft take. But the scion of *G. mangostana* on *G. gummi-gutta*, *G. cowa* and *G. tinctoria* (Syn. *G. xanthochymus*) died within one year of planting. Those on *G. hombronaina* remained alive for more than three years but without any further growth. This was surprising because *G. hombronaina* is considered as one of the parent in the evolutionary origin of mangosteen and closely resemble it. According to Richards (1990), mangosteen is a polyploid that arose from a natural hybridization between *G. hombroniana* and *G. malaccensis*. As already reported by Jill (1976), growth of mangosteen grafts even on its own seedlings was very slow. *G. speciosa* may be a potential rootstock for *G. mangostana* according to research at the Princes of Songkla University, Thailand. But there was no information to indicate that earlier or superior production can be achieved from grafted plants.

In the present study the initial period and after 1MAP the grafts didn't show any significance difference in both plant height and collar diameter. The observation on plant height, collar diameter, number of leaves and leaf area directly associated with compatibility of graft partners (Herrero, 1951). T5 (*G. gummi-gutta* rootstock

and *G. indica* scion) recorded maximum plant height among all treatments whereas T9 (*G. xanthochymus* rootstock and *G. gummi-gutta* scion) showed minimum plant height. But the maximum collar diameter was recorded in T1 (*G. indica* rootstock and *G. gummi-gutta* scion) and minimum was recorded in T10 (*G. xanthochymus* rootstock and *G. indica* scion). The results suggest that genetic, physiological and environmental factors influence the success of grafting. T4 (*G. indica* rootstock and *G. mangostana* scion), T8 (*G. gummi-gutta* rootstock and *G. mangostana* scion), T12 (*G. xanthochymus* rootstock and *G. mangostana* scion), T13 (*G. mangostana* rootstock and *G. indica* scion), T14 (*G. mangostana* rootstock and *G. morella* scion), T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion) and T16 (*G. mangostana* rootstock and *G. xanthochymus* scion) are graft combinations of *G. mangostana* died after 4MAP. During study period up to the month of March there was a negligible increase in height, diameter, number of leaves and leaf area. And in April all these combinations are dried that might be due to the maximum temperature recorded in April month during study period. Schmid and Feucht (1981) also gave the similar reason that unfavourable environmental condition, unfavourable soil condition, nutritional deficiencies, pest and disease attack and histological incompatibility resulting in poor joint ability in grafts. Herrero (1951) reported that growth of the grafts can be affected by incompatibility in the reduction of shoot elongation of the scion and of the radial growth of the stock and scion.

Maximum number of leaves was recorded in T5 (*G. gummi-gutta* rootstock and *G. indica* scion) followed by T1 (*G. indica* rootstock and *G. gummi-gutta* scion) but still T1 showed larger leaf area due to the larger leaf size than the *G. indica* leaves. It might be due to early bud breaking and leaf opening and minimum leaf area might be due to late bud breaking and secondary sprouting. Sufficient number of leaves found initially, in the treatment consisting *G. mangostana* either as a rootstock/scion, resulted in leaf fall in the subsequent months. On the other hand even

though the mangosteen belongs to same genus it couldn't be integrated successfully in the study period. The similar study was recorded by Garner (1976), almond and apricot both in the same genus but they are incompatible. The complexity of the situation is further illustrated by the fact that the "Beauty" variety of Japanese plum (*Prunus salicina*) makes a good union when grafted on the almond, but another variety of *P. Saliciana* "Santa Rosa" cannot be successfully grafted on the almond. Poerwanto (2000) in his study reported that *G. mangostana* takes 2-3 years to grow as a rootstock. The slow growth rate of the mangosteen tree is due to the absence of root hairs and poor branching of the root system, there by restricting water absorption and nutrient uptake. To increase the root system of mangosteen and enhance growth he developed the nurse crop plant techniques. It means giving an additional nurse stock plant to the mangosteen seedlings, provides the tree with a double root system. Nurse stock plants of *G. dulcis* and *G. fructicosa* on non-grafted seedlings enhanced seedlings as much as twice compared to seedlings without nurse stock plant. Other experiments using mangosteen as the nurse stock plant of three type of mangosteen seedlings (non grafted, grafted with juvenile scion, grafted with mature scion) showed that seedlings with a nurse stock plant, especially non-grafted plants and those grafted with juvenile scion, grew better than seedlings without a nurse stock plant. The growth of non-grafted seedlings was better than grafted seedlings. Seedlings grafted with mature scion showed the poorest growth.

However, the finding of this research does not mean that farmers trying to propagate *Garcinia* through grafting should abandon the incompatible scions-rootstock combinations. They should rather aim at increasing survival at the nursery stage through manipulating the genotype-environment interaction. Since farmers have less control on the genotype, they should focus on providing the best environment for seedling survival; adequate water for the seedlings, using sharp knives in cutting, optimum humidity.

Practical utility of this study

1. Recently *Garcinia* species are performing better in agroforestry systems and there is a need to provide quality planting material. Hence this study helps in production of quality planting stock.
2. *G. indica* on the rootstock of *G. gummi-gutta* and its reciprocal, scion of *G. gummi-gutta* on *G. xanthochymus* as well as *G. morella* scion on *G. xanthochymus* showed 100 per cent compatibility and survivability. Further, scion of *G. gummi-gutta* on *G. xanthochymus* rootstock also showed fairly good compatibility hence these combinations could be practically adopted.
3. These inter-specific grafts developed have good potentialities to diversify *Garcinia* plantation as well as earn quick economic returns.
4. Since *Garcinia indica* is a drought resistant species and *Garcinia gummi-gutta* drought sensitive. In the present study *Garcinia gummi-gutta* scion showed 100 per cent survivability on *Garcinia indica* rootstock in nursery as well as field condition. This combination can be easily used to drier region.

Future line of work

1. There is a need for the assessment of growth and yield behaviour of the inter-specific grafts on a long-term basis.
2. Further studies can be conducted on other *Garcinia* species to know the performance of scion- rootstock compatibility, since only five *Garcinia* species were used in this experiment.
3. Other vegetative methods can be tried for less compatible cultivars (rootstocks and scions).
4. In the present experiment *Garcinia morella* was not used as rootstock due to non availability of rootstock so further studies can be made to test rootstock compatibility *G. morella*.
5. The grafting experiment was confined only to monsoon season, hence the study can also be conducted during other season to know the seasonal effect on grafting.
6. In this study, two and half year old root stocks were used. Further study can be made by using small age rootstock.

6. SUMMARY AND CONCLUSION

Study on assessing the compatibility or incompatibility of much different stock/scion combination across a wide range of species, genera and families in *Garcinia* is useful not only horticulturally but also to our understanding of physiological nature of compatibility. *Garcinia* as such is the aristocrat among the tropical fruit species and has been in huge demand in national and international market and for restocking in degraded forests, fallow lands and as in agroforestry. The present experiment aims to address the needs of the use of compatibility and field trial for maximization of early fruit yield and development of plants, various treatment with various combinations of rootstock and scion were applied in two and half year old *Garcinia* plants. Furthermore the objectives are recapitulated below, before the outcome of the objectives which are summarized thereafter.

1. To assess the inter-specific graft compatibility among five important species of *Garcinia*
2. The survival and field performance of these Inter-specific grafts in *Garcinia* species.

The results obtained are:-

- 1) Among all the treatments maximum survival per cent (100 %) was recorded in T11 (*G. xanthochymus* rootstock and *G. morella* scion) at the end of the subsequent months and minimum survival per cent (2.00) was recorded in T7 (*G. gummi-gutta* rootstock and *G. morella* scion). No survival was recorded in T3 (*G. indica* rootstock and *G. morella* scion) in nursery stage.
- 2) Maximum number of sprouts per graft (4.3) was recorded in the T5 (*G. gummi-gutta* rootstock and *G. indica* scion) and least (0.13) was found in T7 (*G. gummi-gutta* rootstock and *G. morella* scion).
- 3) At the end of the 1st week of grafting up to 14th week (98 DAG) the number of grafts sprouted was recorded maximum (16.00) in T5 (*G. gummi-gutta*

rootstock and *G. indica* scion), T10 (*G. xanthochymus* rootstock and *G. indica* scion), T11 (*G. xanthochymus* rootstock and *G. morella* scion). Whereas, minimum sprouts were recorded in T7 with *G. gummi-gutta* rootstock and *G. morella* scion (0.33) and T3 with *G. indica* rootstock and *G. morella* scion (1.00).

- 4) The length of longest sprout, diameter of longest sprout and the number of leaves of longest sprout in randomly selected grafts was maximum at 75 and 90 DAG. The treatment with *G. indica* rootstock and *G. gummi-gutta* scion (T1) showed significantly longer sprouting (11.92 cm), diameter (3.76 mm) and number of leaves (7.13). However, the lowest sprout length (0.07 cm), diameter (0.10 mm and 0.14 mm) and number of leaves of longest sprout (0.20 and 0.13) recorded in both T7 (*G. gummi-gutta* rootstock and *G. morella* scion) and T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion) respectively.
- 5) The total number of leaves in a graft was recorded maximum (15.13) in T5 (*G. gummi-gutta* rootstock and *G. indica* scion). However, the minimum number of leaves (0.8) was recorded in T6 (*G. gummi-gutta* rootstock and *G. xanthochymus* scion), T7 (*G. gummi-gutta* rootstock and *G. morella* scion) and T15 (*G. mangostana* rootstock and *G. gummi-gutta* scion).
- 6) In a field trial of these *Garcinia* inter-species, grafts maximum survival percentage (100 %) among all treatments was recorded in T1 (*G. indica* rootstock and *G. gummi-gutta* scion), T5 (*G. gummi-gutta* rootstock and *G. indica* scion), T10 (*G. xanthochymus* rootstock and *G. indica* scion), T11 (*G. xanthochymus* rootstock and *G. morella* scion) and least survival per cent was found in T8 (*G. gummi-gutta* rootstock and *G. mangostana* scion).
- 7) Among all the treatments higher plant height (72.00 cm) was recorded in T5 (*G. gummi-gutta* rootstock and *G. indica* scion) and maximum collar diameter

(13.75 mm) was recorded in T1 (*G. indica* rootstock and *G. gummi-gutta* scion). However, minimum plant height (58.00 cm) was recorded in T9 (*G. xanthochymus* rootstock and *G. gummi-gutta* scion) and minimum collar diameter (10.27 mm) was recorded in T10 (*G. xanthochymus* rootstock and *G. indica* scion) at the end of the 5MAP.

- 8) The total number of leaves and leaf area per graft in the field trial was recorded maximum in T5 (*G. gummi-gutta* rootstock and *G. indica* scion) of 47.40 and T1 (*G. indica* rootstock and *G. gummi-gutta* scion) of 48.54 sq. cm at 5MAP respectively. However, minimum number of leaves and leaf area was recorded in T11 (*G. xanthochymus* rootstock and *G. morella* scion) of 14.97 and T9 (*G. xanthochymus* rootstock and *G. gummi-gutta* scion) of 4.71 sq. cm.
- 9) Maximum increment for plant height and collar diameter over initial value was recorded in the T5 (*G. gummi-gutta* rootstock and *G. indica* scion) and T1 (*G. indica* rootstock and *G. gummi-gutta* scion) *i.e.*, 37.04 per cent and 49.23 per cent respectively. Lowest height increment and collar diameter increment was recorded in T9 (*G. xanthochymus* rootstock and *G. gummi-gutta* scion) and T10 (*G. xanthochymus* rootstock and *G. indica* scion) *i.e.*, 28.88 per cent and 19.00 per cent respectively.

Graft success and wound healing of *Garcinia* under nursery and field conditions greatly depends on the species used. Significant differences observed on number of sprouts, plant height increase, collar diameter increase and percentage survival. The high survival was due to quick wound response by the necrotic layer cells in callus formation. From the five species used in the experiment, T1 (*G. indica* rootstock and *G. gummi-gutta* scion), T5 (*G. gummi-gutta* rootstock and *G. indica* scion), T10 (*G. xanthochymus* rootstock and *G. indica* scion) and T11 (*G. xanthochymus* rootstock and *G. morella* scion) proved to be best compatible among all grafts.

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STUDIES ON CROSS GRAFT COMPATIBILITY AND ASSESSING FIELD PERFORMANCE OF INTER-SPECIFIC GRAFTS IN *Garcinia* SPECIES

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ABSTRACT

The demand of *Garcinia* species is increasing in India and overseas due to its higher medicinal and nutritive value. However main problem associated with propagation by seeds is long generation and variability in seed progenies, which can be overcome by grafting method. In spite of all these improved method grafting does not register 100 per cent success due to number of factors, like choice of scion wood, light intensity, alignment of cambium of stock and scion, time of grafting, temperature under which grafts are grown and scion desiccation after grafting contribute the largest percentage of grafting success. This research is hence focused on determining individual performance of selected species of *Garcinia* scion to grafting with great emphasis on union wound healing and establishment on a different desirable rootstock. Hence two experiments were carried out. First experiment was on inter-specific grafts compatibility of *Garcinia* species and second experiment was on field performance of these inter-specific grafts. Five different species of *Garcinia* were selected viz., *Garcinia indica*, *Garcinia gummi-gutta*, *Garcinia morella*, *Garcinia xanthochymus* and *Garcinia mangostana* and cleft grafting method was tried. Graft success and wound healing of *Garcinia* under nursery and field condition greatly depends on the species used. Significant difference was observed with number of sprouts, plant height, collar diameter increase and percentage survival. The high survival was due to quick wound response by the necrotic layer cells in callus formation. From the five species used, *Garcinia indica* rootstock and *Garcinia gummi-gutta* scion, *Garcinia gummi-gutta* rootstock and *Garcinia indica* scion, *Garcinia xanthochymus* rootstock and *Garcinia indica* scion and *Garcinia xanthochymus* rootstock and *Garcinia morella* scion proved to be best compatible among all grafts.