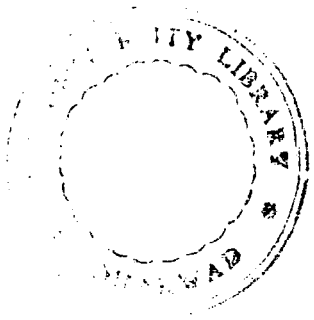
STUDIES ON WEDGE GRAFTING IN TAMARIND (*Tamarindus indica* L.)



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STUDIES ON WEDGE GRAFTING IN TAMARIND (*Tamarindus indica* L.)

Thesis submitted to the
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in

Horticulture

By

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CERTIFICATE

This is to certify that the thesis entitled "**STUDIES ON WEDGE GRAFTING IN TAMARIND (*Tamarindus indica* L.)**" submitted by **Mr. V. SATHISH KUMAR,** for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **Horticulture** to the University of Agricultural Sciences, Dharwad is a record of research work done by him during the period of his 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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SEPTEMBER, 2001

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V. Sathish Kumar

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CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDIX

Introduction

I. INTRODUCTION

Tamarind is a monotypic genus tree, represented by *Tamarindus indica* L. popularly known as 'Indian Date'. The name tamarind was derived from the Arabic word "Tamar-ul-Hind" meaning 'Date of India'. This belongs to the family Leguminosae and sub family Caesalpinioideae with a somatic chromosome number of 2n=24 (Purseglove, 1981).

Tamarind is a hardy tree which grows well under warm climatic conditions of tropics and subtropics. It is drought tolerant and found growing in sandy soils. Further, it also performs well in deep soils and tolerates poor or rocky terrain. In view of its ability to withstand heavy winds, it is preferred as a windbreak also.

Tamarind is cultivated throughout the tropics and has become naturalised at many places. It is indigenous to tropical Africa and Southern India. However, Stephenson and Churchill (1931) opined that tamarind is native to Egypt and Arabia. Dry Savannas of tropical Africa is also considered to be its native and is believed to have been introduced into Asia during ancient times by Arab traders. But the botanical and common names suggest its association with India (Anon., 1979).

Tamarind tree is useful in many ways. The fruit pulp of tamarind is the important commercial product, which is slightly sweetish and more acidic in nature and is widely used as spice in the

preparation of curries, chutnies, sauce, soups and certain beverages besides its use in Ayurvedic medicines. Pulp of tamarind is a rich source of vitamins and important minerals and also contains more of calcium than any other fruit. Hence it has a potential commercial future for the preparation of soft drinks, jams and confectioneries. Pulp contains reducing sugars (25-45%) and organic acids (8-18%), predominantly tartaric acid. The pulp is also a rich source of carbohydrates and vitamins (Duke, 1981; Purseglove, 1981; Ishola *et al.*, 1990). The kernal contains a polysaccharide (Jellose) having a very good sizing properties. Hence, it is used in paper sizing, colour printing in textiles. tanning of leather, dressing of home made baskets and as a glue for wood. The bark is used as a tonic and astringent and is said to be useful in curing paralysis. The seeds are used as raw material for the preparation of sizing powder for textiles. The seeds are also used in the manufacture of live stock feeds. From the seeds, pectin is extracted which is used for jelling of fruit juices and for stabilizing processed foods.

Tamarind is a tall evergreen tree and reaches upto a height of 33m and girth of 2m. The seedling tree begins to bear fruits at the age of 8-12 years and some times continues to be productive even after 100 years of age. On an average, a good full-grown tree yields 150-500 kg of fruits per season and fruit weight varies from 15 to 30 g (Duke, 1981).

Tamarind is a highly cross-pollinated crop and hence wide variability is common in this species. Selection could improve the quality, yield and earliness of fruiting (Geetha, 1995, Saideswararao,

1995). According to Paulus (1975) tamarind is grown from self sown seeds or by sowing seeds of unknown parentage. Hence, they exhibit wide range of heterozygosity for growth, yielding capacity, quantity, quality, size and shape of fruits etc.

The systematic vegetative propagation for mass production of plants is pre-requisite in crops like tamarind, as the vegetatively propagated fruit trees are true-to-type, and they come to bearing early (Hartmann *et al.*, 1993).Approach grafting was tried successfully in tamarind (Swaminathan and Ravindran, 1989). Though it gives fairly a higher percentage of success, it is cumbersome, time and labour consuming process and can only be done on seedlings or rootstocks of more than one year old. Hence, there is a need to standardize a suitable detached scion method of grafting.

Thus, with a view of standardizing vegetative propagation in tamarind, different experiments were conducted at Golden Jubilee Block of Department of Horticulture, University of Agricultural Sciences, Dharwad, with the following objectives.

1. To evaluate the different tamarind provenances for their growth and development for using them as rootstocks

2. To standardise the age and size of rootstocks required for top wedge grafting for maximum success

3. To standardise the season or period of top wedge grafting under propagation structures

Review of Literature

II. REVIEW OF LITERATURE

Vegetative propagation of fruit crops is gaining importance in horticulture as it enables the faster multiplication and maintenance of true-to-type plants.

In recent years, many of the horticulturally important plant species, which are difficult-to-root are made to root easily by using growth regulators, bottom heat and by encouraging rooting with mist chamber facilities. Air layering, grafting and budding are still followed where rooting of cuttings is difficult.

In many parts of the tropics numerous valuable fruit species are represented primarily by seedlings and are often of poor quality. Tamarind in general is mostly propagated from seeds. Thus existing plants are highly heterozygous and exhibit high degree of variation. Hence, there is a need for multiplying tamarind by vegetative means, for getting uniform plants.

According to Paulus (1975), tamarind is mostly grown from self sown seeds or by sowing seeds of unknown parentage, which has resulted in a wide variation among the seedling progenies. Thimmaraju *et al.* (1978) reported that *Tamarindus indica* L. is a protogynous, entamophilous and highly cross pollinated crop. Inspite of its economic importance, very little work has been done in tamarind so far. For its improvement as a tree fruit crop, selection of existing trees and further multiplication by vegetative means is required. Hence to obtain the true-to-type plants with high yielding and good quality fruits, a study on

propagation was taken up. Since the research work on vegetative propagation on tamarind is very meager the relevant studies on propagation of other (tropical) fruit crops by topwedge (softwood) grafting in relation to, seasonal influence, age of rootstock, girth of rootstock on graft success, etc., in India and elsewhere in the world are briefly reviewed under the following headings.

2.1 Propagation of fruit crops by softwood grafting

2.2 Studies on evaluation and selection of varieties as rootstock

2.3 Effect of age of rootstock on success of grafting

2.4 Influence of season of grafting on graft success

2.5 Influence of girth of rootstock on success of grafting

2.1 Propagation of fruit crops by softwood grafting

Amin (1974) was the first Indian who coined the term 'Softwood grafting' in vegetative propagation of mango. He tried this technique and succeeded in establishing *in situ* mango orchards in arid zones of Gujarat state. Park *et al.* (1974) conducted studies on greenwood grafting in apple and reported that covering the grafted part with polythene paper resulted in good survival and further, vigorous growth was noticed when the scions were collected from the basal part of the shoot.

Grafting procedure followed for softwood grafting consists of grafting rootstocks *in- situ* or on rootstocks raised in polythene bags for a year or more and grafting them with scion selected from developing

terminal shoots. The scion should be of same thickness as that of terminal portion of the decapitated stock. Excellent results were obtained when terminal growth of rootstock was bronze in colour (Amin, 1978 a).

Amin (1978b) worked on softwood *in situ* grafting of mango. He recorded only 67.65 per cent graft survival when all the leaves on stock were removed immediately after grafting. But cent per cent success was recorded when all the leaves were retained on stock after grafting. Leaves retained on the stock after grafting enhanced the secondary growth of survived grafts.

Sixty six to hundred per cent graft take was obtained when softwood scions of the pear were grafted on to softwood shoots of pear rootstocks raised from seedlings (Turovskaya, 1980). Gaur (1984) evaluated different methods of grafting and found that softwood grafting was the best method with highest success (75-80%) compared to inarching, veneer grafting and stone grafting in mango.

Vegetative propagation trials by softwood grafting carried out at Bubaneswar and Bapatla showed that softwood grafting was one of the most promising methods that could be adopted for large scale multiplication of cashew (Rao, 1985).

Purushotham and Narasimharao (1990) in their studies on propagation of tamarind by veneer and softwood grafting reported higher graft success in softwood grafting (68%) compared to veneer grafting (49%) at 120 days after grafting. They also recorded higher sprout

number in softwood grafting (3.22) compared to veneer grafting (3.00). However, the average sprout length was higher (16.69 vs 15.95 cm) in veneer grafting.

Minijose and Valsalakumari (1991) working on standardization of grafting techniques in jack, reported that grafts kept under mist conditions showed better survival percentage than those kept in the open field.

2.2 Studies on evaluation and selection of varieties as rootstock

It is a known fact that the rootstock shows marked effects on the growth and subsequent bearing habit and quality of fruits in most of the fruit crops. Hence, it is imperative to select a suitable root-stock. As a first attempt at nursery stage, it is essential to obtain maximum success with grafting technique used. Therefore, screening and selection of varieties or types or provenances is essential to identify best rootstocks which has maximum percentage of germination, uniform growth and other characters required for better grafting. The research work on screening of rootstocks has been done to some extent in citrus and mango. Indiscriminate use of rootstocks in mango has resulted in low productivity and poor fruit quality (Singh, 1963).

Bakshi (1963) studied the suitability of rootstocks of grafted, seedling parents and polyembryonic varieties of mango and noted germination per cent, which ranged between 43.72 per cent and 86.2 per cent in grafted trees. The lowest was in Ram Gola (43.75%) followed by Alphonso (55%). In seedling parents, germination ranged between 75

and 80 per cent, whereas in polyembryonic varieties, it ranged between 0 and 54 per cent. Highest was with Movandan. Seedlings from stones of grafted varieties made good growth in general except, Ram Gola and Alphanso. The height of seedlings ranged between 68.8 cm and 103.3 cm. The seedlings of seed parents recorded height of 88.5 to 104.6 cm. Measurable differences in vigour and germination capacity were noticed within seed parents.

Ahmad (1964) carried out veneer grafting in mango using 9 and 12 month old rootstocks of cultivars Langra, Dashehari and Samar Bahisht on four different dates during spring and autumn. Samar Bahisht was found to be the most successful rootstock.

Inarching of Bennet Alphanso and Baneshan on the polyembryonic rootstocks, Chandrakaran and Bappakai was more successful than on monoembryonic rootstock, Puliyan (George and Nair, 1969). Gowder and Irulappan (1971) conducted a trial using different rootstocks (polyembryonic and monoembryonic) with variety Neelum and suggested the use of Bappakai as best rootstock for Neelum. Singh and Singh (1976) suggested the use of Mylepalium and Vellaikolamban as best rootstocks for all purposes for Dashehari.

Singh and Srivastava (1980) reported 84 per cent success with inarching and softwood grafting when Dashehari was grafted on Bappakai. Similarly, Srivastava *et al.* (1980) studied germination and growth pattern in some polyembryonic mangoes to be used as rootstocks. They noticed the highest (75.93%) germination in Olour and

lowest in Nekkare (40.57%). Bappakai and Movandan showed vigorous growth than other varieties. Seedlings in all the varieties were ready for grafting within a year.

Srivastava and Singh (1981) conducted series of experiments to find out the suitability of different rootstocks with a single scion as well as different stock-scion combinations. Kalapady as rootstock recorded highest success (90%) followed by Nekkare (85%) when veneer grafted with Dashehari scion as against 70 per cent with Dashehari itself as rootstock.

Srinivasamurthy (1984) evaluated the growth potential of two different types of ber *viz.,* umran and local type for raising as rootstocks and concluded that the growth rate of umran was more fast than local type. He attributed this difference to varying seed size in these two types. Corbineau *et al.* (1987) reported that the poly embryonic cultivars of mango with bigger embryos showed rapid germination and seedling growth enabling earlier grafting with good success.

Ponnuswami *et al.* (1988) studied the performance of twelve cultivars in Sapota (as possible sources of seedling rootstocks) for seed germination and seedling vigour index. He observed highest germination in cv. PKM (58%), followed by Oval and Cricket ball (50%) and the lowest in Dwarapudi (26%). Cricket ball seedlings had highest rating for vigour and this is considered to have good rootstock potential.

Eight scion cultivars of mango were stone grafted on to local cultivar in the first week of August. Graft-take ranged from 56 per cent

(Langra) to 93 per cent (Totapuri), but survival rate of sprouted grafts after 180 days was only 14 per cent (Dashehari) to 50 per cent (Musharad). The mortality rate was highest with in the first 60 days and was thought to be due to periods of inadequate humidity (Kulwal and Tayde, 1989). Pushpalatha *et al.* (1989) did some screening of cashew types to select ideal rootstock in cashew at Madakkathara (Kerala). They observed that Anakkayam-1 and BLA-273-1 were the best rootstock varieties followed by BLA-39-4. The type H-3-17 was found inferior to others in all respects. Preliminary studies conducted at Shantigodu (Karnataka) indicated that VTH-539 was best rootstock (80% success), followed by VTH-11, 12 and 174 for softwood grafting in cashew nut (Anon., 1989).

At Vriddhachalam (Tamil Nadu), total 26 types of cashew were screened and M26/2 showed comparatively higher values for growth parameters. The same type recorded the highest scion take of 75 and 68 per cent on 30 and 60 day old rootstock, respectively (Anon., 1989).

2.3 Effect of age of rootstock on success of grafting

Softwood grafting is generally done on the newly emerged or emerging bronze coloured terminal shoots. Naturally, the height of grafting increases with an increase in the age of rootstock which is not considered to be a good graft.

Torrez (1949 and 1960) tried splice grafting on three to nine month old rootstocks in mango and reported a high degree of success

irrespective of the age of rootstocks. On the contrary, Ahmad (1964) reported that a month old seedling was better than 12 month old seedling in veneer grafting of mango. Araque (1968) tried rootstocks of different age in veneer grafting of cashew nut and recorded highest success (80%) on six month old seedlings in containers.

Jagirdar and Bhatti (1968) studied the effect of age of rootstock on success of veneer grafting in mango and reported that the age of rootstocks (3 to 9 months) did not affect the rate of success, but the per cent graft take increased by the use of mature scion wood compared to immature scion wood.

Parente and Maciel (1973) used three, six and nine month old seedlings of cashew nut and obtained best results with six month old rootstock with an average of 25 per cent success, the highest being 70 per cent in one batch. Ferraz *et al.* (1974) obtained the best results (11%) with four month old seedlings and the worst with two month old seedlings (4%) in a comparative trial using two, four, six and eight month old seedlings in cashew nut.

Amin (1974) tried wedge grafting in mango and reported 98.5 per cent success on one year old seedlings raised in nursery. Singh and Srivastava (1979) studied effect of age of rootstocks (6, 12, 18 and 24 months) on the success of veneer grafting in mango. They noted higher success (70%) on 12 month old rootstocks in nursery.

Nagabushanam and Rao (1978) obtained 35-96 per cent graft take in cashew with six month old rootstocks compared to 20-49

per cent graft take with 15-20 month old seedlings. Muniswami (1979) tried veneer grafting in cashew nut under mist chamber and recorded 90 per cent success on 4-5 month old seedlings. Harnekar (1980) reported 44 per cent success with the use of 4 and 8 week old seedlings in wedge grafting in cashew nut under Dapoli conditions.

Singh and Srivastava (1979a) in their studies on veneer grafting in mango obtained 80 per cent success with 12 month old rootstocks and 6 month old scions, when 6, 12, 18 and 24 month old rootstocks were used. Same workers during 1982 tried softwood grafting in mango on three different flushes from top i.e., top current flush, second flush from top and third flush from top with the object to minimize height of grafting. They reported the highest success (87%) in top flush in all the three grafting seasons followed by third flush (73.33%). Hence it is clear from this, that grafting was possible on a healthy young seedling at a desired height with good success.

Results of a trial on veneer grafting in cashew carried out at Vengurla (Maharashtra) have shown that amongst three to eight month old rootstocks, the highest success (80%) was observed with rootstock of six months during the month of September (Anon., 1982).

Haldankar *et al.* (1987) reported that once the rootstocks attained a graftable size in Kokam (*Garcinia indica* L.), which takes about 22 weeks, further increase in age did not influence the percentage of success significantly. The percentage of success ranged between 70 and

78 per cent, and the highest success (78%) was noted with 26 week old rootstock in softwood grafting.

Reddy and Melanta (1988) working at University of Agricultural Sciences, Bangalore, tried 3, 4, 5 and 6 month old rootstock for softwood grafting in mango. They recorded 68 per cent success with three month old rootstock, while 40 per cent was noticed in 4, 5 and 6 month old rootstock raised in containers. In the *in situ* trial the highest success (90%) was obtained with 7 month old rootstocks and the lowest (25%) with 3 month old rootstocks under Bangalore conditions.

Kulwal *et al.* (1988) recommended the use of about 12 to 15 month old rootstock of rayan for softwood grafting in sapota. Rayan was found to be very slow growing in nature and attained graftable stage only after ten months. They reported 52 to 90 per cent success during July to October and the highest success (90%) was observed on 12-15 month old rootstocks in the month of August under Akola conditions.

Bajpai *et al.* (1989) in their studies on the effect of age of rootstock on veneer grafting of mango obtained higher per cent of sprouting, survival and more scion growth with lower leaves on two year old rootstocks than with one or three year old rootstocks. Gowda and Gowda (1989) in their studies on propagation of champaka by softwood wedge grafting at University of Agricultural Sciences, Bangalore, reported success rate of 65-70 per cent when 6-8 month old of seedlings were grafted at a height of 25-30 cm above the ground level.

Jayaramagowda and Melanta (1989) tried rootstock of different age (2, 3, 4, 5, 6, 7 and 8 months) for whip grafting in cashew nut and recorded the highest success (60%) on 4 month old seedlings under Bangalore conditions. Experiments conducted at various cashew nut research stations in India, suggested the use of younger seedlings for softwood grafting. At Vengurla, rootstocks of different age (1, 2, 3, 4, 5 and 6 months were tried and the highest success (84.63%) was observed on three month old seedlings closely followed by two month old (81.85%). Similarly at Jhargram, rootstocks of four different ages were tried and the highest percentage of success (59%) was noticed on two month old rootstock (Anon, 1989).

Waghmare (1990) studied the effect of age of rootstocks (6, 9, 12 and 15 months) of rayan on softwood grafting in sapota and recorded maximum success (59%) on 15 month old rootstock closely followed by 12 month old rootstock (56%).

Satisha *et al.* (1997) in their studies at University of Agricultural Sciences, Bangalore on effect of age of rootstock on success of softwood grafting in tamarind recorded maximum success rate of 76 per cent on six month old rootstock followed by nine month old rootstock (75%). The minimum rate of success (13%) was recorded on 18 month old at 30 days after grafting. However, they recorded highest graft take on nine month and six month old rootstocks with 72 and 69 per cent respectively. Graft take was lowest (11%) on 18 month old rootstock at 60 days after grafting.

2.4 Influence of season of grafting on graft success

Veneer, epicotyl and softwood grafting are generally practiced in different parts of the country depending upon agro climatic conditions.

Success of mango veneer grafting was not affected by scion length (2.5 to 10 cm) but subsequent growth was better with longer scions. Ninety per cent successful grafts were obtained when the scions from non-flowered shoots were used but only seventy per cent successful grafts were obtained when scion shoots were obtained from flowered shoots (Majumdar *et al.,* 1972).

Amin (1978a) tried softwood grafting in cashew during 1975-76 with 71.4 per cent success during August under Anand conditions. He also tried softwood grafting in fruits like aonla (*Emblica officinalis* L.), guava (*Psidium guasjava* L.), jack fruit (*Artocarpus heterophyllus* L.), phalsa (*Grewia asiatica.L*) and sapota (*Manilkara achras* (Mill.) Forseberg) and obtained success of 73.3, 70.7, 33.3, 100.0 and 91.6 per cent, respectively in the month of August at Anand.

Nagabushanam and Rao (1978) found, July month as the best month for veneer grafting in cashew. They reported 85-96 per cent successful graft union during July month. Rao and Nagabushanam (1978) observed positive correlation between the number of rainy days and relative humidity on the percentage of graft take in a study carried out for two years in veneer grafted cashew.

Amin (1979) studied the softwood grafting in mango and found that the period from March to September was very much congenial in drier parts of Gujarat. Dasarathi (1979) obtained 70 per cent success with *in situ* veneer grafting of cashew during July to September months.

There are many factors which influence the healing of graft union. Weather conditions, especially the temperature and humidity play an important role in success of grafting (Hartmann and Kester, 1979).

Kolekar (1979), while working on vegetative propagation of jack fruit recorded maximum success of 80 per cent during February through softwood grafting followed by October (60%). Nagawade *et al.* (1979) reported the success of 34.56 and 29.76 per cent in the month of July and August, respectively under extreme dry conditions of Rahuri (Maharashtra) in mango. Singh and Srivastava (1979b) achieved 92 per cent success when mango was veneer grafted between July and August.

Harnekar (1980) studied softwood grafting in cashew and obtained 56 and 44 per cent success in May and June, respectively under Dapoli conditions. Same worker (1980) tried softwood grafting in Jack fruit and obtained the highest success (41.66%) in May. According to him rainy season was not congenial. Maiti and Biswas (1980) reported that the period of June-July was congenial in mango with the success of 50-96 per cent salable grafts.

Singh and Srivastava (1980) tried double grafting by employing inarching, veneer and softwood grafting during March, July

and September in mango. The results revealed that the highest success (84%) was recorded in July for inarch–softwood grafting and was better as maximum number of double grafted plants could be prepared within three months.

Hulamani and Gowda (1981) reported better success (64.33%) in green wood wedge grafting during the month of February and March irrespective of varieties of mango under Bangalore conditions.

At Bapatla, the success of veneer grafting in cashew ranged from 30 to 77 per cent and 37 to 71 per cent during 1978-79 and 1979-80, respectively. The best months were found to be February and September in the respective years (Nambiar, 1981).

Patel and Amin (1981a) reported that softwood grafting in mango on *in situ* raised seedlings could be done from February to September, recording more than 70 per cent success. Further they could obtain more than 85 per cent success when grafting was carried out between April and August. The spring and summer grafts produced more vegetative growth. The period from October to January was not found favourable in Western parts of India. Further, investigations to know the best period for softwood grafting in mango was done by Patel and Amin (1981b) and reported that between May and August is the best period for softwood grafting with 95-100 per cent success from February to May, the success rate ranged from 77-97 per cent. After third week of September, there was considerable reduction in success rate of graft

union. They also reported that the growth of grafts were not influenced by age of rootstocks but influenced by season of grafting.

Gunjate *et al.* (1982) working at KKV, Dapoli achieved 55.0 to 64.9 per cent success during the period from June to October in mango. The success with splice, modified wedge and wedge was 69.0, 65.0 and 60.3 per cent, respectively and was better than veneer method (50%). Nagabhushanam and Mohan (1982) tried epicotyl grafting in cashew with a success of 30 per cent in July. They tried cleft and whip techniques of grafting also, but no significant difference was observed.

Singh and Srivastava (1982) studied the factors contributing to the success of *in situ* softwood grafting. Grafting success was highest in the month of August (90%) compared to July (67%) and September (70%). Height at which the grafting was done on the young seedling had no effect on the final success. Softwood grafting gave better success compared to veneer grafting.

Khalil *et al.* (1983) reported May to September period as the best time for veneer grafting of Guava, when the success rate was as high as 82-92 per cent. Nagabhushanam (1983) concluded from two years trial that epicotyl grafting in cashew can be successfully done on 15 day old seedlings during June to November by adopting cleft grafting. The grafting success was highest (60-68%) between June and August and declined in November (45-47%) under South Kanara conditions in Karnataka.

Epicotyl grafting trails conducted during 1980-82 at Vengurla (Maharashtra) revealed that this method can be commercially exploited under Konkan (Coastal) conditions. February to May was the congenial period with 62.4 to 67.7 per cent success on 10 day old seedlings (Sawke, 1983). The trials conducted at Bubaneswar from 1980 to 1982 on vegetative propagation of cashew recorded success rate ranging from 10 to 76 per cent. During the year, 1980, the maximum success rate recorded was 76 per cent in the month of June, followed by July (59%) and October (56%). During 1981, the success rate varied from 10 to 85 per cent with a maximum success of 85 per cent during October followed by 50 per cent during July and 40 per cent during June. At Vengurla, better graft union with a maximum success rate of 94 per cent was obtained in April, followed by 92 and 83 per cent success during February and March (Anon, 1983, 1983a).

Aravindakshan *et al.* (1984) observed 57.7, 62.3 and 69.0 per cent success on ten day old seedlings during March, April and May, respectively in cashew under Kerala conditions. Desai and Patil (1984) carried out stone grafting in mango during the period from July to September. They observed 70 per cent success in glass house, while it was only 40 per cent under open in the month of July. Haldankar (1985) reported October as the best month with a success of 80 per cent in Kokam under Dapoli conditions.

Singh *et al.* (1984) reported that softwood grafting was the most successful method of grafting during June month where the success rate was as high as 100 per cent.

Konhar and Das (1985) studied the softwood grafting in cashew throughout the year under Bhubaneswar conditions (Orissa) and found that this technique was very much useful with a success ranging between 43 and 100 per cent during April-February. The highest success of 90 and 100 per cent was recorded during the months of January and February, respectively. They also tried epicotyl grafting and found this method successful almost through out the year on 5 to 7 day old seedlings with 56 to 100 per cent graft take, except march during which, scion sticks were not available. Krishnamurthy *et al.* (1985) reported a success of 39-75 per cent in softwood grafting during the period from February to May in cashew at Ullal. Maximum success obtained was 75 per cent in the month of April. They also reported a success ranging between 72 and 80 per cent during February to May by epicotyl grafting. Mishra (1985) studied softwood grafting in Pecan nut (*Carya illinoensis* (Wang) R. Koch.), a new introduction in India and recorded a very high success of 90 per cent in August followed by 80.7 per cent in July.

Panicker (1986) observed 54 to 82 per cent final survival in a trial carried out on mango softwood grafting for 12 months at Dapoli. The maximum success (82%) was in July followed by May (72%) and November (70%). Sawke *et al.* (1986) reported that softwood grafting was most successful in cashew, throughout the year except December

and January, which coincides with the cold period. The mean graft success of consecutive three years ranged between 71.33 and 83.66 per cent during February to November under warm climate of Konkan region of Maharashtra. The lowest success of 22.33 per cent was observed in the month of December.

According to Desai (1987), the soft wood grafting in jackfruit recorded the highest success (69.33%) in April followed by May (56.0%) under Dapoli conditions. Shankara (1987) tried green wood wedge grafting in mango, during February and March at fortnightly interval and observed the highest graft take (44.66%) during the second fortnight of March followed by first fortnight of March (27.33%) under Dharwad (Karnataka) conditions. He also tried epicotyl grafting during the months of June-July and obtained maximum success (42.26%) in first fortnight of July followed by second fortnight of June (34.33%).

Gupta *et al.* (1988) reported that stone grafting in mango was most successful from mid August to mid September with 50-55 per cent success on 10 day old rootstocks under subtropical conditions of Jammu. The success with splice (57%) followed by side grafting (64%) was better than wedge and saddle (27 and 24%) grafting respectively. Hegde (1988) tried modified epicotyl grafting in cashew and noted 50 to 75 per cent success during June to November on one month old seedlings.

Kulwal *et al.* (1988) opined that September was the best month with 80 per cent success followed by October and November

(50%) in sapota under the semi arid conditions of Akola (Maharashtra). Kumar and Khan (1988), while working on *in situ* softwood grafting in cashew recorded mean success of 42.5 to 60.0 per cent on 12 month old rootstock during March – May, when both day and night temperatures were higher. The success rate was 55 per cent during April and 42.5 per cent during March.

Nalwadi *et al.* (1988) obtained 40 per cent success when 8-10 month old seedlings of *Michelia champaka* L. were grafted with previously defoliated scions in early August, under Dharwad conditions. Upadhyay and Prasad (1988), while studying the effect of time of veneer grafting in mango reported highest success rate of 85 per cent in the month of June, followed by July, August and September, with a success rate of 80% in each month. The lowest success rates were obtained between November and February (18 to 25%).

Bankar (1989) in his studies on vegetative propagation in annonas reported 84 and 86 per cent success rate with veneer grafting in cultivars like Balanagar and Pond-apple respectively. Dhunaga *et al*, (1989) recorded the highest rate of graft take (68.63%) in the month of August and the lowest rate of success during the month of May (20.60%) in mango stone grafting. The highest survival rate was (49.50%) when the scions were defoliated ten days prior to grafting.

Gowda and Gowda (1989) in their studies on propagation of champaka by softwood wedge grafting reported success rate of 65-70 per cent when 6-8 month old of seedlings were grafted at a height of 25-30

cm above the ground level. Gunjate (1989) working on stone grafting of mango recorded highest survival per cent (72-80%) in the warm humid months of June and July. The age of rootstock did not affect the success significantly. Hegde *et al* (1989) reported 28.88 to 38.88 per cent success with epicotyl grafting during January to February and 14.44 to 19.77 per cent during the period from August to October under Dharwad (interior Karnataka) conditions.

Ismail and Rao (1989) in their studies on time and method of propagation for mango cv. Banaganapally reported highest success in the month of August followed by September by veneer grafting, poorest results in other months. Jayaramagowda and Melanta (1989) tried whip and wedge grafting on 4-6 month old rootstocks of cashew and recorded 60 and 30 per cent success in whip and wedge grafting, respectively in the month of April under Banglore conditions.

Kar *et al.* (1989) recorded 100 per cent success in pomegranate when top working was done with side veneer grafting on first and 15th July. Kulwal and Tayde (1989) studied mango propagation by softwood grafting with one year old seedling rootstock. The range of graft union success varied from 70 to 90 per cent. Highest per cent success (100%) was recorded in varieties like Pairi, Pundal and Panchadarakalsa. August and September months were suitable for softwood grafting under Akola conditions.

Kumar *et al.* (1989) in their studies on softwood grafting of cashew in ARS, Ullal, reported success rate ranging from 39.5 to 86.0

per cent with maximum success during the month of May (86%) followed by April (77.5%). They also reported that this method can be adopted from March to May under humid and warm conditions of coastal Karnataka for higher percentage of success. Srivastava (1989) observed that humidity and temperature were the main limiting factors for the success of mango propagation by softwood grafting. Ninety five per cent success was recorded when grafting was done during the last week of June. During this month the mean temperature was 33.5°C and humidity was 82 per cent.

Pushpalatha *et al.* (1989) obtained 100 per cent success through softwood grafting of cashew seedlings of about 30 days with scion variety Anakkayam-1 in the month of March under Madakkathara (Kerala) conditions. The best period of grafting for cashew was June-October under west coast (Dakshina Kannada) conditions which gave an average success of more than 70 per cent during 1986-88. Whereas at other places *viz.,* Bapatla, Bhubaneswar, Jhargram, Madakkathara, Vengurla, the success was towards higher side during post monsoon period, except December – January (Anon, 1989).

Bhuva *et al.* (1990) in their studies on influence of environment on success of sapota propagation reported highest mean survival percentage (90%) for grafts made in February followed by January (86.55%). Negative and significant relationships were observed between the mean number of grafts survived and the minimum temperature, relative humidity (RH) and rainfall. Kulkarni (1990) tried

softwood grafting in custard apple and noted highest success (63.55%) in March on six month old rootstock. Madalageri *et al.* (1990) reported that the percentage of success was higher in Sapota during the first half of the year till July, there after it was poor. Maximum success (82%) was recorded in July followed by May (67.3%). The least success (34.0%) was recorded in September at Dharwad.

Swamy *et al.* (1990) in their correlation studies on success of softwood grafting of cashew with weather parameters, reported that monsoon season (June-October) was the ideal period for commercial production of grafts. The success rate ranged from 54 to 85 per cent. During other months the success rate was poor (10 to 12%) due to unfavourable weather conditions and non-availability of suitable scion sticks. Waghmare (1990) reported higher success of 59 to 76 per cent in sapota during August-September followed by May (50 to 55%) with a rapid scion growth under warm and humid climate at Dapoli.

Vigourly growing scion sticks of cashew were wedge grafted to the selected rootstocks during September–October, December-January, March-April and June-July. In the June–July grafting, 23.3 per cent of scions sprouted, while 3.3 per cent sprouted from the September-October grafting and complete failure was observed in the December-January and March-April graftings (Gowda and Melanta, 1991).

Lenka *et al.* (1991) while studying rejuvenation of cashew nut plants through top working observed that softwood grafting in August produced the highest success rate with an average of 81.80

per cent compared with 72.59 per cent in July and 66.52 per cent in September.

Minijose and Valsalakumari (1991) in their studies on standardisation of grafting technique in jack reported that grafts kept under mist conditions showed better survival percentage than those kept in the open field. They reported that the percentage of sprouting and survival of softwood grafts performed in June differed significantly from other months, though the percentage of success was very poor. Maximum sprouting was in the month of June on two month old rootstocks, which was only 7.22 per cent. Sarada *et al.* (1991) in their studies on softwood grafting in cashew reported significant differences among different months of grafting and with two types of scion shoots. A success rate of 65.43 per cent was recorded in the month of August, followed by 60.63 and 55.63 per cent in September and January. Height of the grafts and number of leaves produced was also highest in grafts prepared during the months of August, September and July, while it was lowest during December.

Mango cultivars Alphonso, Pairi,Neelum, Totapuri and Mallika, was wedge grafted on to one year old rootstock seedlings of local type at three fortnightly intervals during February-March. Highest percentage sprouting (88.66%) and percentage graft take (44.66%) were obtained with grafting done during the second fortnight of March. Very less number of days for graft union formation was taken when the

grafting was done during the first fortnight of March (32.6 days) (Shankara *et al.,* 1991).

Sandhu (1992) in their studies on standardization of grafting techniques in sapota reported better graft success with 2-year old rootstocks than 1 or 3 year old rootstocks, when grafted at a height of 20 cm above ground level. They observed September-November as the best time for grafting.

Mango cultivars Langra and Dashehari were veneer grafted onto one year old healthy, uniform rootstock on the 15th of March, April, May, June and July. Highest sprouting success (82.5%) was obtained with grafting in July in both cultivars while April recorded least success. (Singh *et al.,* 1992).

Pugalendhi *et al.* (1992) in their studies on rejuvenation of old cashew trees by top working observed highest per cent graft success with softwood grafting carriedout during June-September. Lenka *et al.* (1993) in their studies on softwood grafting in cashew nut under Orissa conditions for three years reported significant difference of graft success in different months of grafting. Average monthly (for all 3 years) success ranged from 21.7 per cent in December to 72.3 per cent in August. Graft success was positively correlated with minimum temperature and afternoon relative humidity. It was concluded that softwood grafting would be commercially viable from April to October.

Kumar and Mitra (1994) in their studies on standardization of time and propagation techniques in mango cv. Himsagar, found better

success rate for all techniques of grafting between June and August and then declined dramatically.

Softwood grafting of Sapodilla cv. Kalipatti was performed on 15th day of every month from January to December, 1999. The highest graft take (63.33%) was obtained for grafting done in May, which also resulted in the most scion shoot and leaf growth. In contrast, very low graft take (0-6.67%) was reported in September-February grafting (Pampanna *et al.,* 1994). *In-situ* softwood grafting in cashew was most successful during July, August and September (71.66, 70.00 and 81.66%, respectively). These months coincided with the rainy season. Grafting was least successful during November (26.66%) (Kadam *et al.*, 1995).

In mango highest average graft success (50.33%) was achieved with grafts made in the first fortnight of August, followed by those made in second fortnight of July. Graft success which is lower in 1989-90 than in other two seasons, possibly due to lower humidity and higher temperatures (Basavaraja, 1996).

Mango cv. Amrapali was propagated by softwood grafting from July 1991 to June 1992 at 15 day interval. Highest rate of success (86%) was obtained with July grafting, closely followed by August, September and April. Longest sprouts were also recorded with July grafting (27.34 cm) (Sanjay *et al.,* 1996).

Shinde *et al.* (1996) in their studies on softwood grafting in tamarind reported higher graft success (70.00%) in April (before

flowering) followed by March (58.40%), when elite type tamarind cv. Sel-263 was grafted on to one year old rootstock seedlings of a local type of tamarind. They also reported the failure of grafts made during January-February or June-December under Aurangabad conditions.

Singh and Suryanarayana (1996) carried out softwood grafting during June-October using one and two month old local mango seedlings as rootstocks cv. Bangenapalli as scion. They reported highest rate of graft success (87%), tallest grafted plants (17.1 cm) and highest number of leaves (7.0) after 60 days on one month old rootstocks in August.

Graft union formation in mango cultivars TommyAtkins and Keitt used reciprocally as scion and rootstock was studied using light microscopy. The initial wound response was resin secretion which contributed mainly to the initial adhesion of the graft partners. Early callus formation occurred mainly from the rootstock with cells produced in definite rows, often in fan like array. Parenchyma cells in the cortex, pith, xylem and phloemrays were all involved in callus formation. The establishment of the combial bridge between the stock and scion was followed by the formation of a protective layer, the periderm across the callus edges (Asante and Barnett, 1997). Brahmachari *et al.* (1997) in their studies on seasonal effect on success of veneer grafting in mango cv. Amrapali reported maximum (91.13%) sprouting in July grafting. The greatest average sprout length was recorded for June grafting and survival after 180 days for August grafting.

Geetha *et al.* (1997) in their studies on the influence of polyembryonic rootstocks on the success and survival of softwood grafts on mango observed grafting success dependence on the speed of graft union formation. Grafting success was highest (96.67%) in Movandon and Chandrakaran grafted with cv. Neelum during June and survival was highest (76.67%) in Puliyan grafted with Banginapally during August.

Asante and Barnett (1998) studied the effect of temperature on graft union formation in mango using light microscopy cv. TommyAtkins and Haden were used reciprocally as stock and scion. Graft union was favoured at temperatures of 24°C and 28°C, but grafts failed to develop at 15 and 20°C. At 38°C unions formed 20 days after grafting, but further exposure to this temperature caused tissue injury and death of callus cells.

Yang and Chen (1998) in their studies on grafting methods for mango and their technical features reported that the rootstocks which are too weak or too thick are not suitable for grafting, and scions that are too tender or too old are also not suitable.

Bharad *et al.* (1999) in their studies on seasonal variation in success of softwood grafting of tamarind reported significant influence of season on days taken to sprout, percentage of bud break, percentage of bud survival and percentage of graft success. They reported March and April were the better months for grafting under Akola conditions.

Veneer grafting of mango cv. Amrapali was carried out during January-March and again during July-August, 1994-95. It was found that the time taken to bud break was greater when grafting was done in January (55 days) as compared to July-August (26 days). Percentage of success was greater, 78.8 per cent when it was done in July – August compared with 75 per cent in January-March. However, over all rate of growth was greater in winter grafted plants (Nayak and Sen, 2000).

Pampanna and Sulikeri (2000), reported that the initial and final graft take was highest with May grafting (both 60%) followed by April (both 43.3%) in their studies on use of invigorated rootstock for softwood grafting of sapota. The maximum success was ascribed to the prevailing favorable conditions like higher maximum temperature (36.6°C), the higher minimum temperature (20.9°C) and optimum humidity (65%) resulting in increased cell activity and better union of the stock and scion.

2.5 Influence of girth of rootstock on success of grafting

Lefebvre (1971) recorded a very high success (95%) in tip grafting with three month old cashew seedling of 5 mm stem diameter.

Phadnis (1971) stated that veneer grafting in cashew was advantageous on seedlings not older than five months in age. The ideal rootstock was measuring 50 cm height and 0.4 to 0.5 cm in girth. Veneer grafting was most successful in early part of rainy season.

Singh and Srivastava (1979a) tried different diameter of stock and scion and reported that the more success could be obtained by using stock and scion of nearly equal thickness. However, the success increased with thickness of scion from 23.4 per cent to 44.44 per cent by using 5 to 10 mm thick scion in veneer grafting of mango. The thinner stock of five mm with five mm scion recorded less success (28.8%) when compared with 10 mm stock 10 mm scion diameter (57.0%).

Hussain *et al.* (1989) in their studies on determination of suitable rootstock for some elite mango cultivars taken three grades of rootstock girth 0.41-0.95 cm (I), 0.96-1.20 cm (II) and 1.21-1.88 cm (III). They reported increased grafting success with increasing girth of the rootstock. Grade III rootstocks gave 83.23 per cent success compared with 48.39 per cent with grade II and 14.65 per cent with grade I.

Material and Methods

III. MATERIAL AND METHODS

Studies on standardization of top wedge grafting technique in tamarind (*Tamarindus indica* L.) were conducted at the Golden Jubilee Block, Department of Horticulture, University of Agricultural Sciences, Dharwad. The place is situated in transitional tract of Karnataka at 76°-07' east longitude and 15°-26' north latitude, at an altitude of 667 m above mean sea level. The average annual rainfall of the area is about 800 mm which is fairly distributed from April to October. The average maximum temperature goes upto 36°C in the month of April and the minimum temperature reaches 13°C in the month of December-January. The relative humidity fluctuates between 50 and 87 per cent. The meteorological data as recorded at the Meteorological observatory, Main Research Station, Dharwad for the years 2000, 2001 and average of last 50 years are presented in Appendix I. The experiment was conducted during the period from February 2000 to May 2001. It was conducted under different propagation structures like mist house, green house and shade house.

3.1 General conditions of propagation structures

3.1.1 Mist house

A mist house of dimension 18 x 6 mt was used for the purpose of study. The frequency of misting was 6-7 min for 30 seconds. The relative humidity ranged between 85 to 95 per cent and the temperature between 35 to 40°C.

3.1.2 Green house

The green house of dimension of 27 x 9 mt was used for the purpose of study. It has fan and pad cooling system. The relative humidity inside the green house ranged between 80-90 per cent and the temperature between 25-27°C.

3.1.3 Shade house

A shade house of dimension 18 x 24 mt was erected with a height of 2.4 mt. This is of HDPE green shade net type. It screens 75 per cent sunlight and allowing only 25 per cent sunlight. So, relatively low temperatures with high humidity was maintained in comparison with the out side environment.

3.2 preparatory operations

3.2.1 Collection of Seeds

Seeds from the healthy vigorous trees, free from pest and diseases were collected from different parts of North Karnataka and stored in gunny bags for the purpose of raising rootstocks seedlings.

3.2.2 Raising of rootstocks in polythene bags

Polythene bags of 400 gauge thickness and size of 20 x 10 cm were used for raising rootstocks. Potting mixture containing red earth, farmyard manure (FYM) and coir dust in 1:1:1 v/v proportion was used. Selected healthy, large sized seeds were sown flat on the medium

at a shallow depth. They were kept in the mist house. The seeds took 15 to 20 days to germinate.

3.2.3 Maintenance of seedlings or rootstocks

The seedlings in the polythene bags were watered regularly. General prophylactic sprays were given periodically to control disease and pests. Regular hand weeding was done whenever weeds appeared in the polythene bags. The study consisted of five experiments.

3.3 EXPERIMENT-I: EVALUATION OF DIFFERENT TAMARIND PROVENANCES FOR THEIR GROWTH

The experiment was conducted during the period from March 2000 to August 2000.

3.3.1 Treatments

The treatments included eight provenances as listed below:

1. Bailhongal – Hosur (P_1)
2. Bailhongal – Murgod (P_2)
3. Mudhol (P_3)
4. Dharwad (P_4)
5. Murgod – Yergatti (P_5)
6. Garag – Dharwad (P_6)
7. Bailhongal – Bagevadi (P_7)
8. Tadas (P_8)

Design	:	Randomised Block Design (RBD).
Replications	:	Three
Number of seedlings per treatment	:	100

3.3.2 Observations recorded

1. Percentage of germination at the end of 40 days. Number of seeds germinated were counted and calibrated in per cent.
2. Time taken for 50% germination.
3. Height of the stock plant (cm) at monthly interval
4. Girth of the stem (cm) at monthly interval

3.4 EXPERIMENT II: EVALUATION OF DIFFERENT PROVENANCES FOR THEIR GRAFT SUCCESS

The experiment was conducted on the seedlings of different provenances. They were evaluated for the graft success and growth.

3.4.1 Maintenance and selection of rootstocks

Initially raised seedlings of eight different provenances served as rootstocks. Uniformly vigorous seedlings or rootstocks were selected for grafting.

3.4.2 Collection of scion

The scions were collected from the Dharwad Tamarind Selection-1 (DTS-1), a selection released from UAS, Dharwad, in the

morning hours (8:00 to 9:00 a.m.) on the day of grafting, and defoliated with sharp secateur. The scions so prepared were further used for grafting on the same day.

3.4.3 Method of grafting and maintenance

Top wedge grafting method was followed in the study. For this, the top growth of the rootstock was decapitated with a sharp knife or secateur. Then a longitudinal cut of 5 cm length was given from the terminally pruned rootstock. A scion shoot of about same thickness was selected.

The length of the scion was about 8 to 10 cm. The basal end of the scion was given two gentle sloping cuts of about 5 cm on opposite sides by removing the bark and a little wood, giving a wedge shape. Care was taken to retain some bark on the remaining two sides. The wedge shaped scion thus prepared was inserted in to the 'V' shaped slit of the stock and secured firmly with 150 gauge thickness white transparent polythene strip of 1.5 cm width and 30 to 45 cm length. This kept the stock and scion in firm contact. The scions were covered with small transparent tubular bag to prevent water entering the grafted portion and also to avoid desiccation of the scions by creating humidity in the microclimate near and above the graft union region.

The grafted plants were transferred immediately to the mist chamber and maintained there for 30 days. Then they were shifted to shade house (Plate 1).

Plate 1. Grafts kept in the mist chamber

3.4.4 Observations recorded

1. Percentage of graft success at 30, 45, 60 and 90 days after grafting. Number of successful grafts were counted and calibrated in per cent
2. Number of sprouts on scion per graft at 45, 60 and 90 days after grafting. Number of sprouts per graft were counted and average was calculated.
3. Length of the sprouts per graft at 45, 60 and 90 days after grafting. Length of each sprout was measured and average was calculated.

Design	:	Randomised Block Design (RBD).
Replications	:	Three
Number of grafts per treatment	:	100
Method of grafting	:	Top wedge grafting

3.5 EXPERIMENT - III: EFFECT OF AGE OF ROOTSTOCKS ON SUCCESS OF TOP WEDGE GRAFTING

This experiment was conducted on the rootstocks of different age maintained in the polythene bags. The grafting was done during second fortnight of January with only one variety i.e. (DTS-1) as scion.

3.5.1 Treatments

The treatments included seven age group seedlings as follows.

1. 4 months old (T_1)
2. 5 months old (T_2)
3. 6 months old (T_3)
4. 7 months old (T_4)
5. 8 months old (T_5)
6. 9 months old (T_6)
7. 10 months old (T_7)

Design	:	Randomised Block Design (RBD)
Replications	:	Three
Number of grafts per treatment	:	100
Method of grafting	:	Top wedge grafting

3.5.2 Maintenance and selection of rootstocks

For this experiment the seeds were sown in poly bags during the first week of every month from March to September, so that seedlings of different age groups were available at one time for grafting i.e. during February. Vigorously grown uniform rootstock seedlings were selected for grafting.

3.5.3 Collection of scion

Scions from the clone DTS-1 were collected in the same manner as described in the Experiment–II.

3.5.4 Method of grafting

Grafting was done as described in Experiment–II.

3.5.5 Observations recorded

1. Percentage of graft success at 30, 45, 60 and 90 days after grafting. Number of successful grafts were counted and calibrated in per cent.

2. Number of sprouts on scion per graft at 30, 45, 60 and 90 days after grafting. Number of sprouts per graft were counted and average was calculated.

3. Length of the sprouts on scion per graft at 30, 45, 60 and 90 days after grafting. Length of each sprout was measured and average was calculated.

3.6 EXPERIMENT–IV: STANDARDISATION OF SEASON OF TOP WEDGE GRAFTING

The experiment was conducted on the rootstocks of similar age maintained in the polythene bags. Rootstocks were grafted in the first fortnight of every month.

3.6.1 Treatments

The treatments included seven different months of grafting as follows.

1. August (T_1)
2. September (T_2)
3. October (T_3)
4. November (T_4)
5. December (T_5)
6. January (T_6)
7. February (T_7)

Design	:	Randomised Block Design (RBD).
Replications	:	Three
Number of grafts per treatment	:	100
Method of grafting	:	Top wedge grafting

3.6.2 Maintenance of rootstock

For this experiment five months old seedlings were used as stock. Hence, staggered sowing of the seeds was done to get stock of same age in every month

3.6.3 Collection of Scion

Scion material was collected in the same way as mentioned in Experiment – II.

3.6.4 Method of grafting

Grafting was done as described in Experiment – II.

3.6.5 Observations recorded

1. Percentage of graft success at 30, 45, 60 and 90 days after grafting. Number of successful grafts were counted and calibrated in per cent.

2. Number of sprouts on scion per graft at 30, 45, 60 and 90 days after grafting. Number of sprouts per graft were counted and average was calculated.

3. Length of the sprouts per graft at 30, 45, 60 and 90 days after grafting. Length of each sprout was measured and average was calculated.

3.7 EXPERIMENT-V: EFFECT OF GIRTH OF ROOTSTOCK ON SUCCESS OF TOP WEDGE GRAFTING

This experiment was conducted on the rootstocks which have attained the prescribed girth. The grafting was done in the second fortnight of February.

3.7.1 Treatments

The treatments included three different girth of rootstock as follows.

1 0.4 - 0.6 (cm) (T_1)

2 0.6 - 0.8 (cm) (T_2)

3 0.8 – 1.0 (cm) (T_3)

Design	: Randomised Block Design (RBD)
Replications	: Seven
Number of grafts per treatment	: 50
Method of grafting	: Top wedge grafting

3.7.2 Maintenance and selection of rootstocks

For this experiment, seeds were sown in polythene bags. The rootstocks growing vigorously were used which have attained the desired girth (0.4-0.6, 0.6-0.8, 0.8-1.0 cm) and grafted.

3.7.3 Collection of Scion

Scion material was collected in the same way as described in Experiment – II.

3.7.4 Method of grafting

Grafting was done as described in Experiment–II.

3.7.5 Observations recorded

1. Percentage of graft success at 30, 45, 60 and 90 days after grafting. Number of successful grafts were counted and calibrated in per cent.

2. Number of sprouts on scion per graft at 30, 45, 60 and 90 days after grafting. Number of sprouts per graft were counted and average was calculated.

3. Length of the sprouts per graft at 30, 45, 60 and 90 days after grafting. Length of each sprout was measured and average was calculated.

3.8 Statistical analysis

The data were statistically analysed as per the method outlined by Panse and Sukhatme (1967) and Sundararaj *et al.* (1972). The level of significance used in F test was P=0.05. Critical difference (CD) values were calculated at 5 per cent probability levels wherever 'F' test was signicant.

The data taken in percentage were transformed into angular transformation value and transformed data was used for statistical analysis (Snedecor and Cochran, 1967 and Fisher and Yates, 1963).

Experimental Results

IV. EXPERIMENTAL RESULTS

The studies were conducted to standardize the propagation technique of tamarind by top wedge grafting and to evaluate seedlings of different provenances for utilizing them as rootstocks. The results of the experiments are presented in this chapter.

4.1 Evaluation of seedlings of different provenances for their growth and vigour

This experiment was carried out to identify an ideal rootstock for softwood grafting. The experiment consisted of eight provenances each constituting a treatment. Performance of provenances was assessed by germination per cent, time taken for 50 per cent germination and seedling vigour.

4.1.1 Germination

The provenances differed significantly for the per cent germination and period taken for 50 per cent germination (Table 1).

Maximum germination per cent (93.50%) was recorded in P_8 followed by P_1 (86%) and P_4 (84.50%) while minimum germination per cent (65.5%) was recorded in P_3. Minimum period (15 days) for 50 per cent germination was observed in the provenances P_4 and P_8, which were on par with P_1 (16 days) and P_6 (16.33 days), while maximum period (20 days) was taken by P_3 followed by P_7 (18 days).

Table 1. Per cent germination and time taken for 50% germination in different provenances in tamarind

Provenance	Per cent germination	Time taken for 50% germination (days)
P_1	86.00	16.00
P_2	75.00	17.00
P_3	65.50	20.00
P_4	84.50	15.00
P_5	74.50	17.66
P_6	81.50	16.33
P_7	66.00	18.00
P_8	93.50	15.00
Mean	78.31	16.87
S.Em±	0.69	0.62
CD at 5%	2.12	1.89

4.1.2 Vigour of seedlings of different provenances

The growth parameters like height and girth at collar region were influenced significantly due to different provenances. At 30 days after germination the maximum height was recorded in P_4 (15.46 cm) followed by P_7 (14.8 cm) (Table 2).

Similar trend was observed at 60 DAG. However, at 90 days it was in P_7 where maximum height (42.53 cm) was recorded followed by P_4. Same trend continued even at 180 days after germination. All other provenances exhibited steady growth (Table 2).

At 30 days after germination the highest girth of 0.19 cm was recorded in P_4, P_5 and P_7, while at 60 days P_7 recorded maximum seedling girth (0.32 cm) followed by P_4 and P_5 with 0.30 cm. At all the stages of observation. P_7 recorded higher girth than all other provenances, while other provenances retained steady graftable size after 120 days after germination (Table 3).

4.1.3 Evaluation of seedlings of different provenances for graft success

The various provenances which were studied varied significantly in their vigour and produced differential success for graft success.

4.1.4 Availability of graftable seedlings

The provenances differed significantly in the percentage of seedlings available for grafting. Highest percentage of graftable seedlings

Table 2. Height (cm) of seedlings of different provenances in tamarind

Provenance	Height (cm)					
	30 DAG	60 DAG	90 DAG	120 DAG	150 DAG	180 DAG
P_1	14.51	26.25	30.63	35.74	37.86	42.63
P_2	14.38	25.29	32.80	34.94	36.83	41.46
P_3	13.67	23.86	29.91	30.48	31.33	31.83
P_4	15.46	29.28	37.75	39.77	41.38	45.16
P_5	13.83	25.00	33.43	37.43	39.93	42.50
P_6	14.19	24.11	31.80	35.36	36.66	39.26
P_7	14.80	27.61	38.50	42.53	45.86	48.46
P_8	13.23	25.34	30.30	35.13	37.36	41.33
Mean	14.26	25.84	33.14	36.42	38.40	41.58
S.Em±	0.24	0.24	0.67	0.38	0.30	0.60
CD at 5%	0.74	0.75	2.06	1.17	0.92	1.83

DAG : Days after germination

Table 3. Girth (cm) of seedlings of different provenances in tamarind

Provenance	Girth (cm)					
	30 DAG	60 DAG	90 DAG	120 DAG	150 DAG	180 DAG
P_1	0.18	0.28	0.31	0.35	0.39	0.43
P_2	0.17	0.29	0.33	0.36	0.39	0.44
P_3	0.18	0.28	0.31	0.34	0.38	0.43
P_4	0.19	0.30	0.35	0.38	0.41	0.46
P_5	0.19	0.30	0.34	0.39	0.41	0.48
P_6	0.18	0.29	0.34	0.40	0.43	0.49
P_7	0.19	0.32	0.37	0.41	0.46	0.51
P_8	0.17	0.25	0.31	0.35	0.42	0.44
Mean	0.18	0.29	0.33	0.37	0.41	0.46
S.Em±	0.005	0.006	0.006	0.005	0.003	0.005
CD at 5%	0.01	0.01	0.01	0.01	0.01	0.01

DAG : Days after germination

(93%) were obtained in the P_8, followed by P_1 (83.49%), P_4 (82.0%) and P_6 (80.5%), which differed significantly among themselves. The lowest percentage of graftable seedlings (64%) were found in P_7 (Table 4).

4.1.5 Evaluation of different provenances as rootstocks on success of top wedge grafting

It would be clearly seen from the data presented in Table 4 that the percentage of graft success was significantly influenced by the different provenances at 30, 45, 60 and 90 DAG.

Higher graft success was recorded after 30 days in all the treatments, followed by a sharp decline of success after 45 days and then a stable success of graft take at 60, 90 DAG (Fig 1).

The data (Table 4) indicates that after 30 days, the highest success of 95.01 per cent was recorded in P_8 followed by P_1 (88.0%), P_3 (86.0%) with significance. The lowest success was recorded in P_5 (68.0%).

After 45 days, the graft take was the highest (40.01%) in P_1 followed by P_4 and P_3 with 36.74 and 33.0 per cent success, respectively, which are significantly superior over other treatments. The lowest graft success was recorded on P_7 (9%).

After 60 days, 39.03 per cent successful grafts were obtained with P_1 which was on par with P_4 (35.73%) and P_3 (31.99%). P_8 which recorded the highest successful grafts after 30 days, had recorded as low as 22.07 per cent success. However, after 60 days the lowest per cent of success (6.98%) was observed in P_7.

Table 4. Influence of different provenances as root stocks on percentage of graft success in tamarind

Provenances	Availability of graftable seedlings (%)	Graft success (%)			
		30 DAG	45 DAG	60 DAG	90 DAG
P_1	83.49 (65.98)	88.00 (69.67)	40.01 (39.20)	39.03 (39.61)	39.03 (38.61)
P_2	74.00 (59.32)	76.97 (61.31)	30.98 (33.81)	30.00 (33.21)	28.99 (32.55)
P_3	65.49 (53.99)	86.00 (67.99)	33.00 (35.03)	31.99 (34.42)	34.93 (36.17)
P_4	82.00 (64.85)	75.50 (60.31)	36.74 (37.28)	35.73 (36.68)	33.68 (35.43)
P_5	75.00 (59.98)	68.00 (55.53)	17.97 (25.05)	17.02 (24.30)	17.02 (24.30)
P_6	80.50 (63.79)	69.01 (56.16)	22.99 (28.63)	22.99 (28.63)	22.99 (28.63)
P_7	64.00 (53.09)	72.01 (58.03)	9.00 (17.39)	6.98 (15.20)	6.00 (14.10)
P_8	93.00 (74.64)	95.01 (77.16)	27.98 (31.90)	23.08 (28.47)	22.07 (27.81)
Mean	77.18 (61.95)	78.81 (63.27)	27.33 (31.04)	25.85 (29.94)	25.59 (29.70)
S.Em±	0.24	0.65	0.43	1.24	1.39
CD at 5%	0.74	1.97	1.31	3.76	4.22

DAG : Days after grafting
Figures in the parentheses are arc sine values

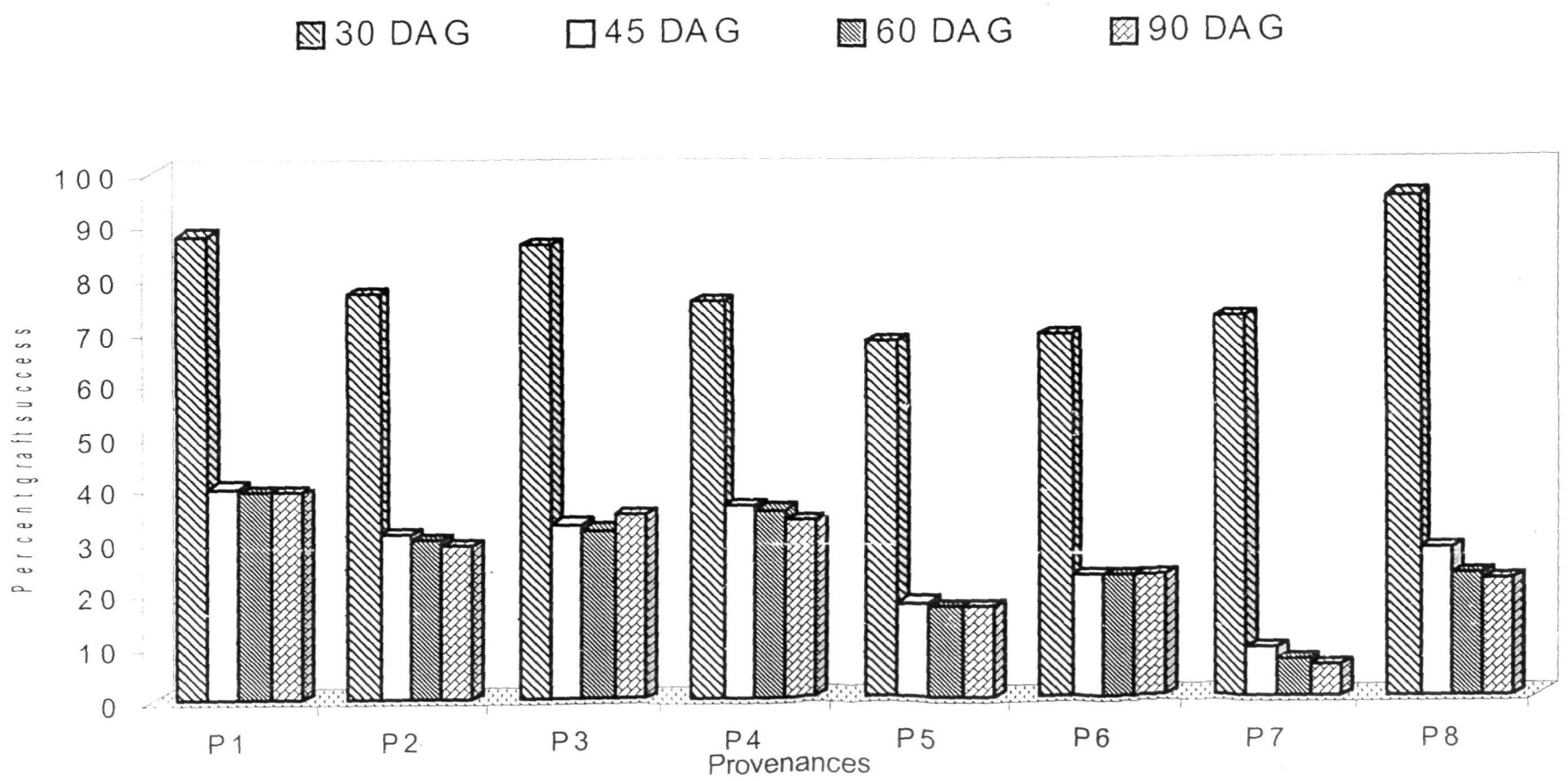

Fig. 1. Influence of different provenances of tamarind on graft success

After 90 days the maximum survival was recorded in P_1 (39.03%), which was on par with P_3, P_4 (34.93 and 33.68%, respectively). Minimum survival of 6 per cent was recorded in P_7, while provenance P_5, P_6 andP_8 were on par with each other (Table 4).

4.1.6 Influence of seedlings of tamarind provenances as rootstock on number of sprouts

The number of sprouts on scion were recorded at 45, 60 and 90 days after grafting and the data is presented in Table 5.

Average number of sprouts per graft differed significantly at 45th day while differences were not significant at 60th and 90th day.

After 45 days maximum number of sprouts (3.78) were observed in P_7 which was on par with P_2, P_6 and P_1. The minimum number (2.91) of sprouts were recorded in P_3.

4.1.7 Influence of seedlings of provenances as rootstock on sprout length

Average sprout length were recorded at 45, 60 and 90 days after grafting (Table 6).

Sprout lengths recorded at 45, 60 days after grafting were non significant with all the provenances. However, the sprout lengths recorded after 90 days were significant in different provenances. Longest sprouts (9.82 cm) were recorded in P_7. The shortest sprout length (4.17 cm) was recorded in P_3 while all other provenances were on par with each other (Table 6).

Table 5. Influence of different provenances as root stocks on average number of sprouts in tamarind

Provenance	Average number of sprouts		
	45 DAG	60 DAG	90 DAG
P_1	3.36	3.33	3.41
P_2	3.71	3.73	3.61
P_3	2.91	2.74	2.70
P_4	3.14	3.02	3.11
P_5	3.11	3.04	3.05
P_6	3.43	3.27	3.19
P_7	3.78	3.83	3.33
P_8	3.17	3.02	3.51
Mean	3.32	3.25	3.24
S.Em±	0.18	0.26	0.23
CD at 5%	0.55	NS	NS

DAG : Days after grafting

Table 6. Influence of different provenances as root stocks on average sprout length (cm) in tamarind

Provenance	Average sprout length (cm)		
	45 DAG	60 DAG	90 DAG
P_1	2.58	3.52	4.35
P_2	2.59	3.30	4.64
P_3	2.15	3.06	4.17
P_4	2.71	3.79	5.38
P_5	3.56	5.69	6.45
P_6	3.34	5.12	5.83
P_7	2.93	5.79	9.82
P_8	2.79	4.77	5.75
Mean	2.83	4.38	5.80
S.Em±	0.32	0.71	0.70
CD at 5%	NS	NS	2.13

DAG : Days after grafting

4.2 Influence of age of rootstock on growth and success of top wedge grafts

The diameter, height of the rootstock seedlings at grafting and per cent of graft success are presented in Table 7.

4.2.1 Height

From the data, it can be seen that the height of the seedlings of different age groups differed significantly (Table 7). The height of the different age group seedlings varied from 20.24 cm in 6 month old rootstock (T_3) to 48.90 cm in 10 month old seedling (T_7) at the time of grafting. Maximum height of 48.9 cm was recorded in T_7 followed by T_6 (44.97 cm). All other treatments were found to be on par with each other.

4.2.2 Diameter

From the data it can be seen that there is significant difference among the different age groups in attainment of certain girth. The diameter of the different age seedling varied from 0.24 cm (T_2) in 5 month old rootstock to 0.56 cm (T_7) in 10 month old. Maximum girth (0.56 cm) was noticed in T_7 followed by T_6 (0.52 cm), while minimum girth (0.24 cm) was recorded in T_2 (Table 7).

4.2.3 Graft success

The percentage of success recorded after 30 days was considerably influenced due to rootstock age. On perusal of Table 7, it is evident that the sprouting of the grafts ranged between 61.11 per cent in 5 month old rootstock to 84.99 per cent in 10 month old rootstock.

Table 7. Influence of age of root stock on graft success (%) in tamarind

Age of the root stock (months)	Period of growth of seedling	Growth parameters of stocks at the grafting time		Graft success (%)			
		Height (cm)	Diameter (cm)	30 DAG	45 DAG	60 DAG	90 DAG
T_1 (4 month)	September - December	22.29	0.31	81.54 (64.58)	47.18 (43.39)	44.56 (41.82)	44.56 (41.82)
T_2 (5 month)	August - December	20.85	0.24	61.11 (51.41)	38.88 (38.51)	35.18 (36.33)	33.33 (35.24)
T_3 (6 month)	July - December	20.24	0.29	74.03 (59.34)	38.02 (37.99)	34.99 (36.20)	34.01 (35.61)
T_4 (7 month)	June - December	21.15	0.32	80.00 (63.43)	55.00 (47.91)	45.00 (42.09)	45.00 (42.09)
T_5 (8 month)	May - December	23.39	0.36	75.98 (60.62)	56.00 (48.51)	51.96 (46.16)	51.96 (46.16)
T_6 (9 month)	April - December	44.97	0.52	80.00 (63.42)	44.32 (40.76)	39.27 (37.79)	38.26 (37.22)
T_7 (10 month)	March - December	48.90	0.56	84.99 (67.15)	25.01 (37.72)	24.03 (29.38)	24.03 (29.38)
Mean		28.83	0.37	76.81 (61.42)	43.49 (42.11)	39.28 (38.54)	38.73 (38.22)
S.Em±		1.09	0.008	0.71	5.50	4.55	4.41
CD at 5%		3.36	0.02	2.20	NS	NS	NS

DAG : Days after grafting
Figures in parentheses indicate arc sine transformed value

Highest percentage (84.99%) of graft success was recorded in T_7 followed by T_1, T_4, T_6 with 81.54, 80.0 and 80.0, respectively.

The observations recorded on 45, 60 and 90 days after grafting showed a decline in success rate when compared to 30th day. This decline in success was steep at 45 days generally. It can be seen from the data that the percentage of success after 45, 60 and 90 days was not statistically significant. However, higher per cent success (51.96%) was recorded with seedlings aged 8 month (T_5), while minimum (24.03%) was recorded with 10 month old rootstock as against its highest success after 30 days.

4.2.4 Influence of rootstock age on average number of sprouts

The data on average number of sprouts per graft present on scion at 30, 45, 60 and 90 days after grafting are presented in Table 8. On pursual of the Table 8, it is evident that the average number of sprouts produced in different aged rootstocks differed significantly only after 45 days, while no significant difference was observed at 30, 60 and 90 DAG.

At 45 days, maximum number of sprouts (3.85) were recorded in 10 month old rootstock followed by 4 month old (3.50) and 8 month old (3.33) rootstocks which are on par with each other. Minimum number of sprouts (2.76) were recorded in 7 month old rootstocks. However, maximum number of sprouts (3.85) were continued to be maintained in 10 month old rootstock, while the minimum number of sprouts (3.01) were recorded in 7 month old rootstocks at 90 DAG.

Table 8. Influence of age of root stock on average number of sprouts in tamarind

Age of the root stock (months)	Average number of sprouts			
	30 DAG	**45 DAG**	**60 DAG**	**90 DAG**
T_1 (4 month)	3.33	3.50	3.38	3.61
T_2 (5 month)	2.94	3.06	2.91	3.05
T_3 (6 month)	3.06	3.05	3.09	3.44
T_4 (7 month)	3.12	2.76	2.82	3.01
T_5 (8 month)	3.64	3.33	3.54	3.54
T_6 (9 month)	2.96	2.93	3.07	3.22
T_7 (10 month)	3.61	3.85	3.80	3.85
Mean	3.24	3.21	3.23	3.39
S.Em±	0.19	0.18	0.25	0.27
CD at 5%	NS	0.56	NS	NS

DAG : Days after grafting

4.2.5 Influence of age of rootstock on sprout length

Average sprout length were recorded at 30, 45, 60 and 90 days after grafting (Table 9).

The average sprout length recorded at 30, 45, 60 and 90 DAG were found significant with respect to different age groups. After 30 days the highest sprout length (2.85 cm) was recorded in 10 month old (T_7) rootstock group, which was significantly higher than all other rootstock age groups. The lowest sprout length (0.99 cm) was recorded in 5 month (T_2) old rootstock group. Ten month old rootstock continued to have grafts with longer sprouts at 45, 60 and 90 days, followed by 9 month old (T_6) rootstock, 5 month old rootstock (T_2) continued to record the lowest sprout length at all the times of observation (Table 9).

4.3 Influence of season on the per cent success of graft and their subsequent growth

From the data presented in Tables 10, 11 and 12, it can be seen that the percentage of graft success and subsequent growth parameters were significantly affected by grafting time.

4.3.1 Influence on percentage graft success

The data recorded at 30,45, 60 and 90 DAG clearly revealed the significant influence of season on percentage graft success (Table 10; Fig 2).

The percentage success noted after 30 days varied from 24.98 in grafts prepared during September to 92.49 per cent in grafts prepared during February. The highest percentage of success (92.49%)

Table 9. Influence of age of root stock on average sprout length (cm) in tamarind

Age of the root stock (months)	Average sprout length (cm)			
	30 DAG	45 DAG	60 DAG	90 DAG
T_1 (4 month)	1.05	1.56	1.80	2.86
T_2 (5 month)	0.99	1.27	1.40	2.10
T_3 (6 month)	1.04	2.02	2.21	3.10
T_4 (7 month)	1.10	1.54	1.67	2.10
T_5 (8 month)	1.27	1.77	1.92	3.04
T_6 (9 month)	1.65	3.96	5.15	6.41
T_7 (10 month)	2.85	5.46	6.37	7.08
Mean	1.42	2.51	2.93	3.81
S.Em±	0.19	0.32	0.29	0.43
CD at 5%	0.61	1.00	0.91	1.35

DAG : Days after grafting

Table 10. Influence of season on success of grafting (%) in tamarind

Treatments	Meteorological observations			Growth parameters of stock at the time of grafting		Graft success (%)			
	Relative humidity (%)	Temperature (°C)		Height (cm)	Diameter (cm)	30 DAG	45 DAG	60 DAG	90 DAG
		Minimum	Maximum						
T_1 August	84	20.2	27.2	43.78	0.49	32.02 (34.43)	32.02 (34.43)	33.98 (35.62)	33.00 (35.03)
T_2 September	83	20.3	29.0	39.30	0.41	24.98 (29.95)	23.02 (28.62)	22.01 (27.93)	22.01 (27.93)
T_3 October	83	20.1	29.4	38.57	0.38	30.00 (33.21)	25.01 (29.97)	20.05 (26.38)	20.05 (26.38)
T_4 November	72	16.9	30.4	35.50	0.33	29.76 (33.01)	29.76 (33.01)	27.38 (31.51)	26.19 (30.75)
T_5 December	64	13.4	29.2	20.50	0.26	36.00 (36.83)	19.04 (25.73)	13.04 (20.93)	12.03 (20.16)
T_6 January	66	14.9	29.8	24.42	0.33	58.57 (49.91)	52.84 (46.60)	48.47 (44.10)	48.16 (44.17)
T_7 February	59	16.7	34.0	24.21	0.29	92.49 (74.03)	57.47 (49.26)	43.73 (41.37)	38.79 (38.48)
Mean				32.32	0.35	43.40 (41.62)	34.16 (35.37)	29.81 (32.55)	28.67 (31.84)
S.Em ±				1.61	0.01	0.57	1.14	1.60	1.64
CD at 5%				4.97	0.03	1.77	3.54	4.94	5.06

DAG : Days after grafting
Figures in parentheses indicate arc sine transformed values

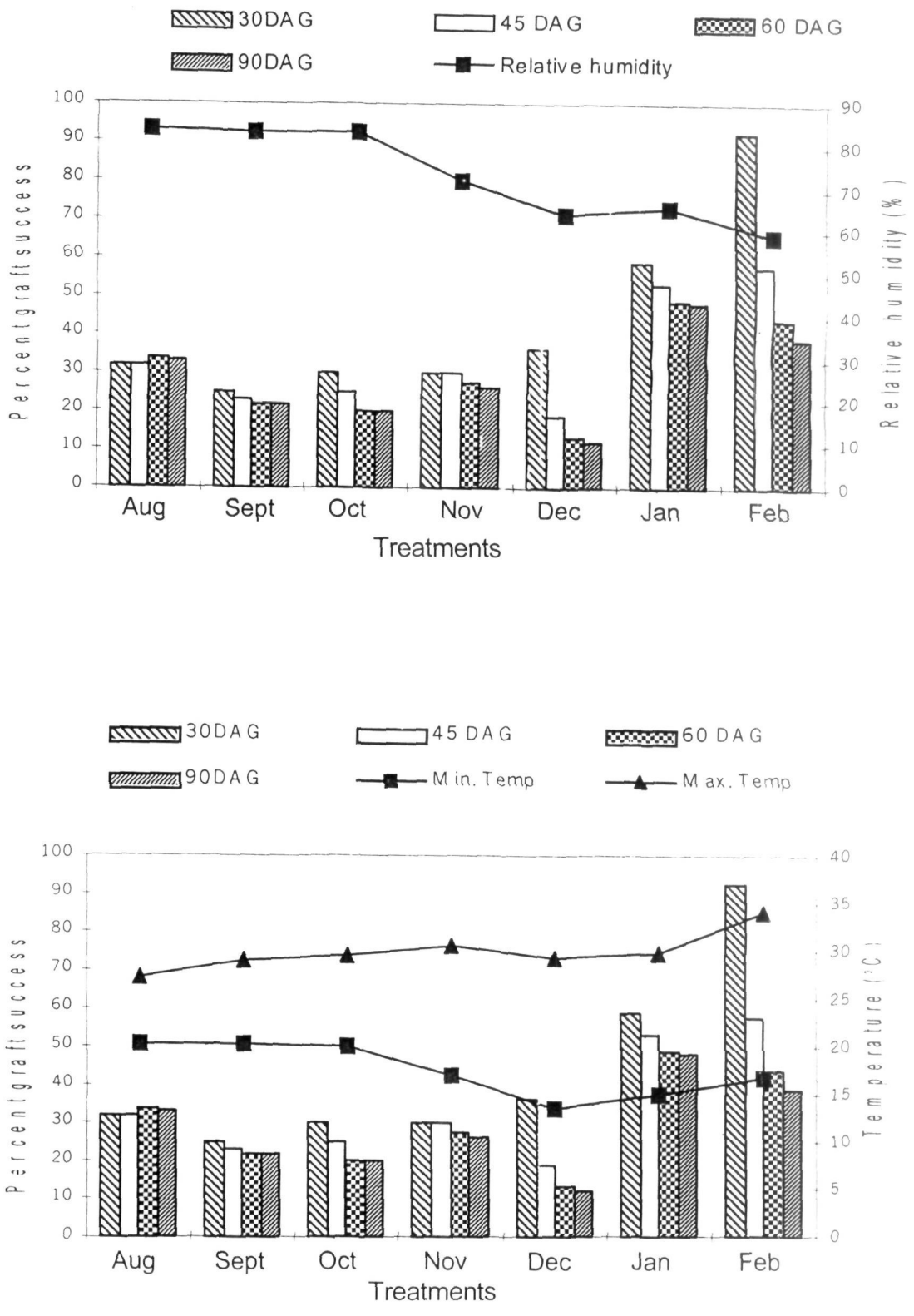

Fig. 2. Influence of relative humidity (%) and temperature (°C)on graft success in tamarind

was recorded in the grafts prepared in the month of February followed by January (58.57%). The lowest percentage of success (24.98%) was recorded in the grafts made during September.

After 45 days, graft survival was significantly influenced by the time of grafting. Highest survival of grafts were recorded among the grafts prepared in the month of February (57.47%) followed by January (52.84%). Lowest success of grafts (19.04%) was recorded in the December prepared grafts followed by September (23.02%) grafts.

After 60 days, maximum percentage of success (48.47%) was recorded in January grafting followed by February (43.73%), while minimum per cent of success (13.04%) was recorded in grafts prepared during December.

After 90 days, the highest survival percentage of 48.61 was recorded in January grafts, lowest of 12.03 per cent was recorded in December grafts.

4.3.2 Influence of grafting season on average number of sprouts

It is evident from the data that the sprout numbers were significantly influenced by the time of grafting at all the stages of observation (Table 11).

The average number of sprouts observed at 30 DAG varied from 3.08 in the grafts of February to 5.13 in the grafts of October. Highest number of sprouts (5.13) were recorded in the grafts prepared during October, followed by December (4.61), September (4.54), November (4.46) and August (4.28) which are on par with each other.

Table 11. Influence of season on average number of sprouts in tamarind

Treatment	Average number of sprouts			
	30 DAG	**45 DAG**	**60 DAG**	**90 DAG**
T_1 August	4.28	3.79	3.62	3.54
T_2 September	4.54	4.20	4.19	4.19
T_3 October	5.13	5.14	4.69	4.62
T_4 November	4.46	3.91	3.33	3.05
T_5 December	4.61	4.15	2.91	3.02
T_6 January	3.91	3.22	3.33	3.56
T_7 February	3.08	2.75	2.69	3.22
Mean	4.29	3.88	3.54	3.60
S.Em ±	0.24	0.21	0.28	0.21
CD at 5%	0.75	0.67	0.86	0.65

DAG : Days after grafting

After 45 days, maximum number of sprouts (5.14) were recorded in the grafts prepared during October and a decrease in average number of sprouts was observed in the grafts prepared in all other months at 45 DAG. This trend continued even 60 DAG (Table 11).

October prepared grafts continued to retain the highest number of sprouts after 60 and 90 days, while lowest number of sprouts (2.69) were recorded in February at 60 DAG, which improved after 90 DAG. Highest number of sprouts (4.62) were recorded in grafts prepared during October at 90 DAG, while the lowest number of sprouts were recorded in the grafts prepared during December. The average sprout number recorded after 90 days were found statistically on par in the grafts prepared in August (3.54), September (4.19) and January (3.56).

4.3.3 Influence of season on sprout length

Perusal of the data (Table 12) revealed that there was a significant influence of time of grafting on length of sprout attained. After 30 days of grafting, there was a significant influence of month during which the grafting was done on the sprout length recorded. Sprout length recorded varied from 0.81 cm in the grafts of December to 3.72 cm in the grafts of August. Longest sprouts were observed in the grafts prepared during August (3.72 cm) followed by September (3.38 cm).

After 45 and 60 days of grafting, similar trend was observed with highest sprout length (4.43 and 5.06 cm) in the grafts prepared in August while lowest sprout length (1.37 and 2.15 cm) was recorded in the grafts prepared in December. After 90 days of grafting also

Table 12. Influence of season on average sprout length (cm) in tamarind

Treatment	Average sprout length (cm)			
	30 DAG	**45 DAG**	**60 DAG**	**90 DAG**
T_1 August	3.72	4.43	5.06	6.12
T_2 September	3.38	4.03	4.59	5.43
T_3 October	1.29	2.02	2.16	2.35
T_4 November	1.03	1.33	2.47	2.67
T_5 December	0.81	1.37	2.15	2.53
T_6 January	1.77	2.60	2.88	4.21
T_7 February	1.26	2.28	3.09	3.73
Mean	1.90	2.58	3.20	3.86
S.Em ±	0.09	0.25	0.40	0.55
CD at 5%	0.28	0.78	1.24	1.69

DAG : Days after grafting

significant difference in sprout length was observed. Maximum sprout length (6.12 cm) was recorded in August followed by September (5.43 cm) and January (4.21 cm), while the minimum sprout length (2.35 cm) was recorded in the grafts prepared in October.

4.4 Influence of girth on percentage success and subsequent growth parameters

The perusal of the Tables 13, 14 and 15, revealed that the girth of the rootstock has insignificant influence on the percentage of success and growth parameters.

4.4.1 Influence on graft success

The perusal of the Table 13, revealed that the diameter of rootstock had no significant effect on percentage of success at 30, 45, 60 and 90 days after grafting. However, numerically highest percentage (86.22%) of success was recorded in rootstock of diameter 0.4-0.6 cm, followed by the rootstocks of diameter 0.8-1.0 cm, while in the rootstocks of diameter of 0.6-0.8 cm lowest percentage of success. Similar trend was observed at 45, 60 and 90 days after grafting.

After 90 days maximum graft success (34.69%) was recorded with the rootstock diameter of 0.4-0.6 cm, and the minimum graft success (20.63%) was recorded with the diameter (0.6-0.8 cm) of the rootstock. Generally there was a sudden decline in graft success in all the treatments at 45 DAG as compared to 30 days after grafting.

Table 13. Influence of girth or diameter of root stock on success of grafting (%) in tamarind

Girth of the stock at grafting time (cm)	Graft success (%)			
	30 DAG	45 DAG	60 DAG	90 DAG
T_1 (0.4-0.6)	86.22 (68.21)	36.73 (36.84)	36.73 (36.84)	34.69 (35.62)
T_2 (0.6-0.8)	84.72 (67.16)	20.63 (26.80)	20.63 (26.80)	20.63 (26.80)
T_3 (0.8-1.0)	85.00 (70.01)	28.57 (31.99)	28.57 (31.99)	25.71 (28.19)
Mean	85.31 (68.46)	28.64 (31.88)	28.64 (31.88)	27.01 (30.20)
S.Em±	2.73	2.61	2.61	3.46
CD at 5%	NS	NS	NS	NS

DAG : Days after grafting
Figures in parentheses arc sine transformed values

Table 14. Influence of girth of root stock on average sprout number in tamarind

Girth of the stock at grafting time (cm)	Average sprout number			
	30 DAG	45 DAG	60 DAG	90 DAG
T_1 (0.4-0.6)	3.73	3.91	3.70	3.68
T_2 (0.6-0.8)	3.77	4.00	4.35	4.35
T_3 (0.8-1.0)	4.05	4.50	4.64	3.85
Mean	3.85	4.14	4.23	3.95
S.Em±	0.15	0.32	0.28	0.42
CD at 5%	NS	NS	NS	NS

DAG : Days after grafting

Table 15. Influence of girth of root stock on average sprout length (cm) in tamarind

Girth of the stock at grafting time (cm)	Average sprout length			
	30 DAG	45 DAG	60 DAG	90 DAG
T_1 (0.4-0.6)	1.24	3.04	3.85	4.20
T_2 (0.6-0.8)	1.13	2.89	3.41	4.72
T_3 (0.8-1.0)	1.57	4.29	4.84	5.95
Mean	1.31	3.41	4.03	4.96
S.Em±	0.21	0.72	0.79	0.91
CD at 5%	NS	NS	NS	NS

DAG : Days after grafting

4.4.2 Influence on sprout number

Perusal of data in the table 14, revealed that the average number of sprouts produced were statistically non significant in all the rootstock diameters (treatments). However, maximum number of sprouts were recorded in stock with diameter of 0.8-1.0 cm, while minimum number of sprouts were recorded in the rootstocks of 0.4-0.6 cm after 30, 45 and 60 days. The maximum number of (4.05, 4.50 and 4.64) sprouts were recorded in T_3 at 30, 45 and 60 DAG. While minimum number of (3.73, 3.91, 3.70 and 3.68) sprouts were recorded in T_1 (0.4-0.6 cm) at 30, 45, 60 and 90 DAG. After 90 days of grafting, the maximum number of sprouts (4.35) were recorded with the stock diameter (T_2) of 0.6-0.8 cm.

4.4.3 Influence on sprout length

The Table 15 revealed that the rootstock girth has no significant influence on the sprout length recorded. However, highest sprout length (1.57, 4.29, 4.84 and 5.95 cm) was recorded with the stock diameter of 0.8-1.0 cm at 30, 45, 60 and 90 DAG. Lowest sprout length (1.13, 2.89 and 3.41 cm) was recorded with the stock diameter of 0.6-0.8 cm (T_2) at 30, 45 and 60 DAG. After 90 days of grafting the lowest sprout length (4.20 cm) was recorded in the rootstock diameter (T_1) of 0.4-0.6 cm while the highest sprout length was observed in T_3 (0.8-1.0 cm).

Discussion

V. DISCUSSION

Vegetative propagation method would be the important step which would be taken up for the improvement in the production and multiplication of perennial and cross pollinated crops like tamarind.

Seed propagation is very common and rarely vegetative propagation methods such as, approach grafting and air layering are found with different degrees of success in tamarind (Swaminathan and Ravindran, 1989). Though such grafting methods are available, there is a need for improvement in the raising of grafts on container grown rootstocks. Grafts prepared on young seedlings will be easy to manage, maintain and transfer to main field (Sawke, 1992).

The advantage of vegetative propagation in producing clonal planting material is well known. But not much work has been carried out in crops like tamarind. In perennial crops like mango, cashew, sapota, softwood grafting techniques have been popularized with different success (Dhunaga *et al.*, 1989; Sawke, 1992; Pampanna *et al.*, 1994). Recently a thrust is given to tamarind commercial propagation to meet the demands of agro-forestry systems for which tamarind is one of the popular crop.

The present studies were conducted to find out an ideal provenance as rootstock source, optimum age and size of rootstock for grafting and the influence of season of grafting and their influence on the growth of the grafts.

5.1.1 Evaluation of provenances as rootstock source

It appears from the published literature that the research efforts in screening and selection of an ideal rootstock in tamarind have not yet been taken up. The work in this respect is about four decades old in mango, but still commercially important mango cultivars are mostly grafted on indiscriminate seedling rootstocks. It is well established that rootstock plays a very important role in influencing the growth and productivity pattern, also affects the disease resistance, salt tolerance, adaptation to particular soil and climate and tolerance to adverse weather conditions. Rootstock is also an important pre-requisite for raising the orchards with desired uniformity (Bakshi, 1963; Jauhari *et al.*, 1972; Singh and Singh, 1976).

The studies revealed that there was lot of variability existing in different provenances for the response of the seedlings of different provenances for their germination and vigour (Table 1, 2 and 3).

Among different provenances highest germination per cent was observed in P_8 followed by P_1 and P_4. Minimum period for fifty per cent germination was observed in the provenances P_4 and P_8. Bakshi (1963) found significant difference in germination among the progenies of seedling and polyembryonic varieties of mango. This variation in germination may be due to the variation in physical barrier by seed coat for germination as reported by Sawke (1992) in cashew nut.

The study revealed that there was significant differences among the seedlings of the provenances for their growth and vigour.

Eventhough P_7 has taken more number of days for fifty per cent germination, it put forth better growth interms of height and diameter than all other provenances. This may be attributed to better nourishment in the initial stages through reserve food material in the cotyledons at the disposal of embryo until the seedling has developed active root as well as shoot system. While other provenances produced steady growth (Table 2 and 3 & Plate 2).

5.1.2 Evaluation of seedlings of different provenances for graft success

The present investigation revealed that there was significant difference among the provenances for the per cent availability of graftable seedlings and their subsequent graft success and growth (Table 4, 5 and 6 & Plate 3.).

Production of highest per cent of graftable seedlings were found in P_8 followed by P_1 and P_4, while lowest per cent of graftable seedlings were found in P_7. Among the seedlings of eight provenances studied for graft success P_1 has shown its superiority followed by P_3 and P_4 at 90 days after grafting, although the initial success was higher in P_8 at 30 DAG. Even though P_7 recorded for higher vigour (Table 2 and 3) there was least graft success in this provenance. This may be due to physiological over activeness. Hartmann *et al.* (1997) reported that when rootstocks are physiologically over active or under active they are likely to be unsuccessful in graft take. While Yang and Chen (1998) reported that too weak or too thick stocks are not suitable for graft success.

LEGEND

P_1	Bailhongal – Hosur
P_2	Bailhongal – Murgod
P_3	Mudhol
P_4	Dharwad
P_5	Murgod – Yergatti
P_6	Garag – Dharwad
P_7	Bailhongal – Bagevadi
P_8	Tadas

Plate 2. Growth of seedlings of P_7 provenance at the time of grafting

Plate 3. Successful grafts obtained by using different tamarind provenances as rootstocks

Top wedge grafting is done on linearly growing fresh terminal shoot of the rootstock. Naturally, the height of grafting may thus exerts an influence on the success and subsequent growth of scion portion. Besides, grafting at greater height makes the grafts very lanky which is not rated as a good graft (Singh and Srivastava, 1982). This may be one of the reason for the failure of P_7 for graft success. The study also revealed that there was a steep decline in graft success after 45 days in all the provenances inspite of high initial success. Similar findings were reported by Kulwal and Tayde (1989) in mango. The variaton in graft success may be due to the genetic differences among the provenances as rootstock source. However, the grafts of different provenances have not shown much differences in their growth habit, but P_7 produced longest lanky sprouts which are not desirable as reported by Singh and Srivastava (1982) in mango. However, the performance of different scion varieties on these rootstocks need further investigation.

The differential response of various provenances in respect of seed germination, seedling growth and reaction to grafting observed in this study may be attributed to differences in the inherent genetical traits of the seedlings of provenances expressed in terms of seedling vigour (Teotia and Maurya, 1970), antatomical structures (Soule, 1971; Tiwari and Rajput, 1972 and Hoque and Hussain, 1974), callus formation (Hartmann and Kester, 1979), differential nutrient absorption and translocation, etc. All these factors might have cumulative effect.

5.2 Influence of age and girth of rootstock on graft success

The studies revealed that the graftable seedlings attained differential height and diameter. With the advancement of age naturally the growth parameters of the seedling increases. Interestingly in the present studies the higher seedling height and diameter were recorded in T_7 (10 month), T_6 (9 month) and T5 (8 month) followed by T_1 (4 month). Comparitively better growth of 4 month old seedling may be due to the favourable environmental conditions during which it was grown (Table 7 & Plate 4) and other factors. Top wedge grafting is done on linearly growing fresh terminal shoot of the rootstock. The height of grafting may thus exerts an influence on the success and subsequent growth of scion portion. Besides, grafting at greater height makes the grafts were lanky which is not considered as a good graft (Singh and Srivastava, 1982). Hence, it is considered worthwhile to perform grafting at lower height. The rootstock age had significant influence on initial graft success at 30 DAG, while it was found non significant at all other stages of observation (Table 7 & Plate 5). Highest graft success was observed in 10 month old rootstock followed by 4 month old rootstock at 30 DAG, while it was non significant at 45, 60 and 90 days after grafting. However, numerically higher graft success was observed in eight and seven months old rootstocks followed by 4 months old rootstock. It may be due to the physiological maturity of rootstock which plays an important role in the success and growth of grafts as reported by several workers in different crops (Lefebvre, 1971; Parente and Maciel, 1973; Muniswami, 1979; Reddy and Melanta, 1988; Jayaramagowda and Melanta, 1989). They

LEGEND

A-10 month old

B-9 month old

C-8 month old

D-7 month old

E-6 month old

F-5 month old

G-4 month old

Plate 4. Growth of seedlings of different age at the time of grafting

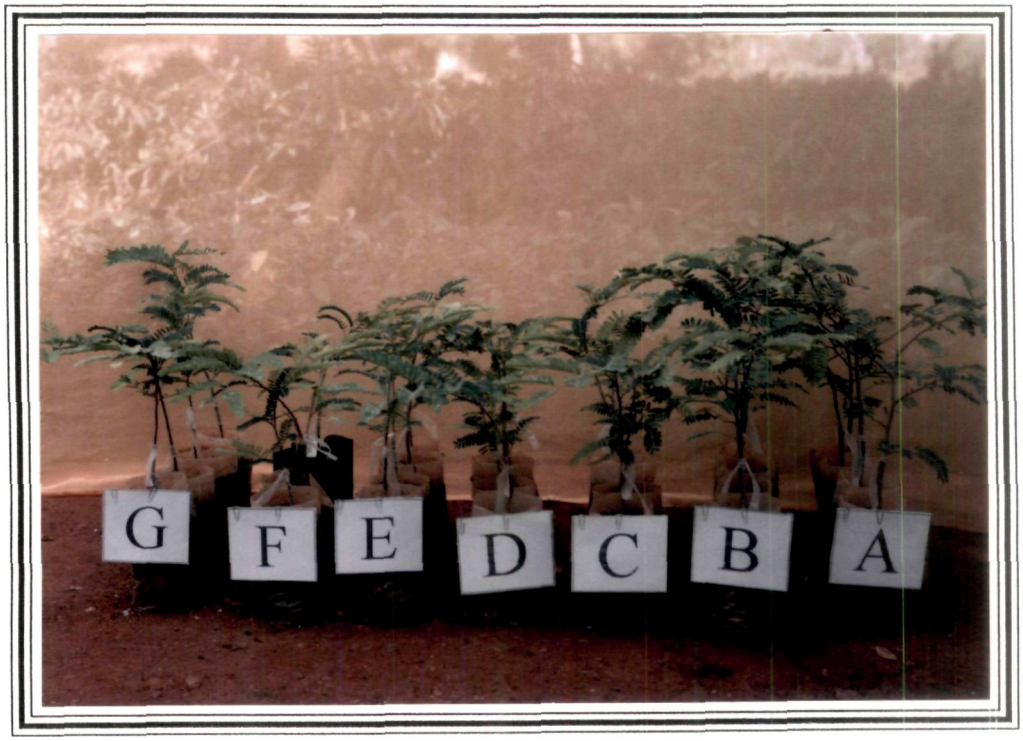

Plate 5. Successful grafts of rootstocks of different age in tamarind

opined that the younger rootstocks give more success in softwood grafting than older ones.

According to Hartmann and Kester (1979) the age of the rootstock has a relationship with the regenerating ability of plant part which is found to be higher in younger rootstocks and this is because of higher activity of meristematic cells resulting in faster callus formation and quick healing of graft union.

It was evident from the present investigation that the rootstocks with appropriate vigour and physiological maturity succeeded well after 90 days of grafting, which was noticed in comparatively younger rootstocks like 8, 7 and 4 month old than the 10 month old rootstock. Haldankar *et al* (1987) reported that once the rootstock attained a graftable size in Kokam, which takes 22 weeks, further increase in age did not influence the per cent of success significantly. Use of rootstock at younger age is bound to reduce the cost of graft in nursery and will be short statured, prone to less damage in transport as well as better survival on transplanting. Satisha *et al.* (1997) reported lowest graft success in 9 month and above old rootstock in tamarind. Similar results were obtained by Reddy and Melanta (1988) in mango, Gowda and Gowda (1989) in champaka. The present studies also revealed that the average number of sprouts produced differed significantly only at 45 DAG with different age rootstocks, while they were non significant at all the other stages of observation. The average sprout length recorded was highest in 10 month old rootstock followed

by 9 month old rootstock, while all other age rootstocks were found on par with each other (Table 8 and 9).

Other investigations to know the influence of rootstock girth on graft success and growth exclusively revealed that there is no significant influence of girth of the rootstock on graft success and development (Table 13, 14 and 15). However, it is the attainment of the graftable size, which is important for the graft success. Similar views were expressed by Haldanker *et al* (1987) while working on Kokam. In the present study also, the different girth (0.4-0.6 cm, 0.6-0.8 cm and 0.8-1.0 cm) of the rootstock has no significance influence on the graft success and subsequent growth (Table 13, 14 and 15 & Plate **6**). However, the higher success was observed with 0.4- 0.6 cm girth group. By this it can be concluded that the girth of the rootstocks of girth 0.35 – 0.55 cm was sufficient to get higher graft success.

5.3 Influence of season on the per cent graft success and growth

Season of grafting plays a paramount role among different factors involved in topwedge grafting success. If the season is not conducive, the favourable effects of other factors are likely to be nullified, resulting in lower success. The success of grafting is solely dependent upon the weather conditions and thus vary from region to region within a season. The seasonal influence could be ascribed to the influence of prevailing temperature and humidity. The present investigation revealed that there was a significance influence of season of grafting on success and growth. Bharad *et al.* (1999) under Akola conditions in tamarind

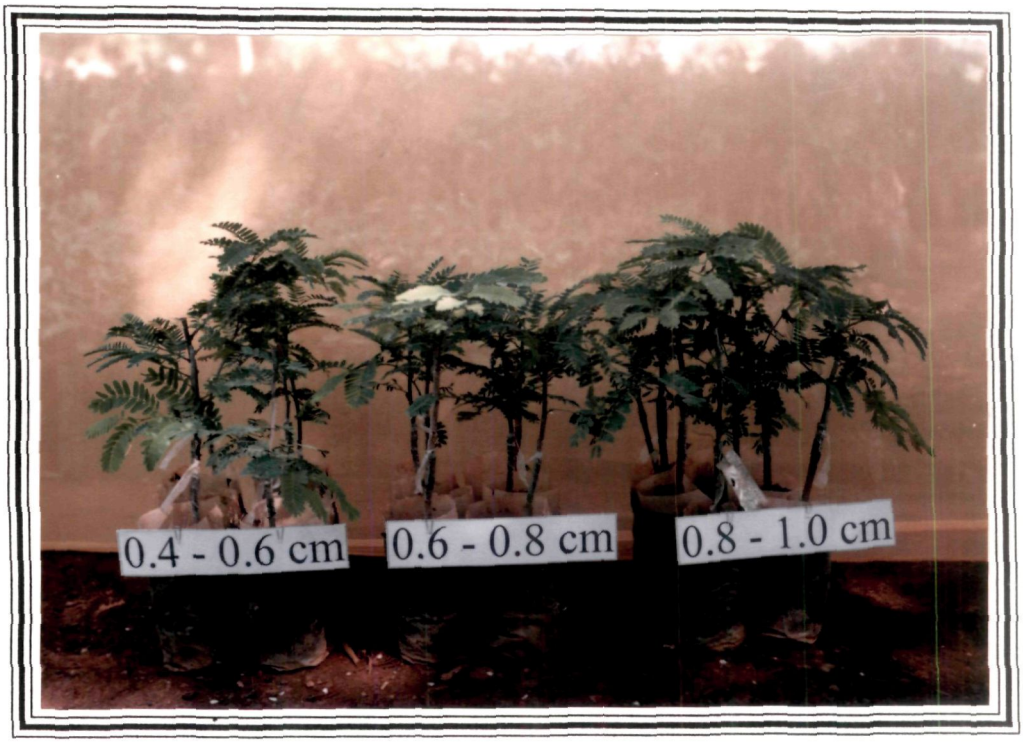

Plate 6. Successful grafts of rootstocks of different girth in tamarind

found the significance influence of season on days taken to sprout, per cent of bud break, per centage of bud survival and per centage of graft success. The present studies revealed that the relative humidity (RH) ranged from 59 per cent in February to 84 per cent in August. It was observed that the relative humidity gradually declined during the period of experiment (Table 10) i.e., from August to February. The minimum mean temperature was recorded in the month of December, while in other months there was not much fluctuation in mean minimum and maximum temperatures. The grafting success was fair enough in each month of grafting initially at 30 DAG. It was maximum in the grafts prepared during February followed by January, while the final success was highest in January grafts followed by February at 90 DAG. The lowest graft success was recorded in the grafts prepared during December. It may be due to the lowest mean minimum temperature recorded at that time of grafting. Shinde *et al.* (1996) reported higher graft success in March and April with softwood grafting in tamarind, while a complete failure of grafts made during January-February or June-December in Aurangabad conditions. On the contrary, in the present investigation it was observed a fair degree of success for each month in which grafting was tried. It may be due to the high relative humidity coupled with high temperature that prevailed during initial stages of graft union as the grafts were kept under mist house conditions. Similar observations were also made by Sawke (1992) in cashew nut at Nanora due to favorable conditions. Asante and Barnett (1998) stressed the effect of temperature on graft union formation in

mango. Graft union was favoured at temperatures of 24°C and 28°C, but grafts failed to develop at 15 and 20°C. At 38°C unions formed 20 DAG, but further exposure to this temperature caused tissue injury and death of callus cells.

In the present investigation the highest success in the month of January and February are due to the prevailing favorable conditions like higher maximum temperature (34°C), the higher minimum temperature (16.7°C) and optimum humidity (60-65%) resulting in increased cell activity and better union of the stock and scion. Similar observations were made by Pampanna and Sulikeri (2000) in sapota under Dharwad conditions (Fig 2 & Plate 7).

Hartmann *et al.* (1997) opined that certain environmental conditions during and following grafting must be met for callus tissue to develop and to form a graft union. Out door grafting operation need to take place at the time of year, when such favourable environmental conditions are expected and when plant tissue specially cambium are in naturally active state. The cambium of graft partners and parenchyma cells comprising important callus tissue are thin walled and tender with no provision for resisting desiccation.

The environmental conditions during and following grafting for mist containarised graft can of course been readily controlled, there by permitting greater reliability of grafting over a long period of time, when compared to out door grafting operation (Hartmann *et al.*, 1997). Madalageri *et al.* (1990) reported least success in the month of

LEGEND

T1 August

T2 September

T3 October

T4 November

T5 December

T6 January

T7 February

Plate 7. Established grafts prepared in different months

September in sapota at Dharwad. However, in the present studies the initial least success was recorded in September grafted plants while the final success at 90 DAG was found least in December grafted seedlings (Table 10). Significant differences among the treatments were observed for the sprout number and length (Table 11 and 12). The differences may be due to the active growth period of mother trees with higher level of nutrients in scion shoots. Poor success during December may be attributed to the reduced rates of division of cambial cells, their differentiation and consequent development in healing of stock scion union due to decrease in the synthesis of endogenous auxins and mobilization of reserved food material caused by reduced activity of hydrolyzing enzymes. Abrupt change in climate during day and night, which may, inturn, retard the activity of cambial cells and formation of new callus tissue, necessary for union of stock and scion.

Future line of work

1. Further investigations should be carried out to standardize the top wedge grafting method under different agro climatic conditions.
2. Other elite tamarind selections may be tried as rootstock source.
3. The grafting technique should also be standardized under outdoor conditions for graft success.
4. Nutritional and hormonal influences can be studied for increasing graft success and development.

Summary

VI. SUMMARY

In view of the established superiority of vegetatively propagated planting material over the use of seedlings, especially in heterozygous perennial crops like tamarind, propagation studies in tamarind (*Tamarindus indica* L.) were carried at Golden Jublee Block, Department of Horticulture, University of Agricultural Sciences, Dharwad (Karnataka) during 2000-2001. Experiments were carried out to find out appropriate rootstock source out of different provenances, the ideal rootstock age, girth and season of grafting to obtain maximum graft success and development.

A brief account of the findings has been summarized as below.

1. Among different provenances studied P_8 (Tadas) followed by P_1 (Bilhongal - Hosur) and P_4 (Garag - Dharwad) has recorded maximum germination per cent, while P_8 and P_4 had taken minimum period (15 days) for fifty per cent germination. P_8 has given highest per cent of graftable seedlings among all the provenances.

2. Among different provenances P_8 recorded highest graft success (95.01%) followed by P_1 and P_3 (Bailhongal–Murgod) at 30 days after grafting, while it was Bailhongal–Hosur (39.03%) and Bailhongal–Murgod (34.93%) recorded higher graft success at 90 days after grafting. P_7 (Dharwad) put forth good vegetative growth on the graft. In all the experiments conducted, it was observed that

there was a decline in graft success after 45 days from the highest success at 30 days.

3. Rootstock age was found to be non-significant with graft success at all the stages of observation except 30 DAG. However numerically highest graft success (51.96%) was observed in 8 month old rootstock, followed by 7 month (45%) and 4 month (44.56%) old rootstocks. At 90 days after grafting significantly longer sprouts (7.08 cm) were recorded in 10 month old rootstock followed by 9 month old (6.41 cm) rootstock while all other age groups were found on par with each other.

4. Season of grafting has profound influence on grafting success. Relative humidity ranged from 59 per cent to 84 per cent during the period of experiment, while the minimum and maximum temperatures recorded were (13.4 to 20.3°C) and (27.2 to 34.0°C) respectively. Fairly high per cent (48.61%) of graft success was recorded in January grafted seedlings followed by February (38.79%) at 90 days. However, it was reverse at 30 days after grafting with February grafted seedlings recording as high as 92.49 per cent followed by 58.57 per cent in case of January. Least success of 12.03 per cent was recorded in December. The higher sprout number and sprout length were found in the grafts of August and September.

5. Rootstock grith was found to had no influence on graft success and development. However, it is the attainment of the graftable size

which is important for the graft success. Numerically highest graft success was noticed with the 0.4-0.6 cm girth group which is 34.69 per cent.

After reviewing the all experimental result obtained it can be concluded that for the Dharwad tamarind selection-1 (DTS-1) the provenances Bailhongal - Hosur (P_1), Bailhongal - Murgod (P_3) and Garag - Dharwad (P_4) were found suitable. The age and girth were not of much importance but it is the attainment of graftable girth (0.35 - 0.55 cm), which can be attained earliest. January - February months were found to be congenial for more graft success.

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* Original not seen

Appendix

Appendix I. Meteorological data recorded at the Main Research Station, University of Agricultural Sciences, Dharwad , for the years 2000-2001 and the average of 50 years (1950-99)

Month	Temperature °C						Relative humidity (%)			Rainfall (mm)		
	2000		2001		1950-99							
	Min	Max	Min	Max	Min	Max	2000	20001	1950-99	2000	2001	1950-99
January	NA	NA	14.9	29.9	14.11	29.19	NA	66	63	NA	0.00	0.10
February	15.7	32.1	16.7	34.0	15.96	34.67	69	59	52	0.09	0.00	0.00
March	19.1	35.1	19.5	35.3	18.80	35.17	31	61	57	0.09	0.00	7.46
April	21.3	37.2	22.0	36.8	21.39	37.11	77	72	73	44.1	52.1	47.83
May	21.1	33.8	21.5	34.8	21.46	36.64	82	75	67	45.4	23.2	85.43
June	21.2	29.0	NA	NA	21.20	29.47	80	NA	82	51.7	NA	114.33
July	20.4	26.8	NA	NA	20.97	27.05	85	NA	88	125.4	NA	153.72
August	20.2	27.2	NA	NA	20.65	27.12	84	NA	87	50.1	NA	99.70
September	20.3	29.0	NA	NA	20.18	28.74	83	NA	83	117.0	NA	104.43
October	20.1	29.4	NA	NA	19.25	30.13	83	NA	77	83.0	NA	136.34
November	16.9	30.4	NA	NA	15.38	29.38	72	NA	69	0.0	NA	34.44
December	13.4	29.2	NA	NA	13.43	29.16	64	NA	65	3.0	NA	5.85

NA- Not applicable

STUDIES ON WEDGE GRAFTING IN TAMARIND (*Tamarindus indica* L.)

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ABSTRACT

In view of the established superiority of vegetatively propagated planting material over the use of seedlings, especially in heterozygous perennial crops like tamarind, studies on wedge grafting in tamarind (*Tamaridus indica* L.) were carried out.

Among different provenances studied for their growth and graftability, P_8 (Tadas) followed by P_1 (Bailhongal-Hosur) and P_4 (Garag-Dharwad) recorded maximum germination per cent, while P_8 and P_4 has taken minimum period (15 days) for fifty per cent germination. P_8 has given highest per cent of graftable seedlings among all the provenances. Further, P_8 recorded highest graft success (95.01%) followed by P_1 and P_3 (Bailhongal-Murgod) 30 days after grafting, while it was P_1 (39.03%) and P_3 (34.93%) which recorded higher graft success 90 days after grafting. However, P_7 (Dharwad) put forth good vegetative growth on the graft.

The age of the rootstock was found to have no significant effect on graft success at all the stages of observation except 30 DAG. However, numerically highest graft success (51.96%) was observed with 8 month old rootstocks, followed by 7 months (45%) and 4 months (44.56%) old rootstocks. With regard to sprout length, 90 days after grafting significantly longer sprouts (7.08 cm) were recorded in 10 month old rootstock followed by 9 months old rootstock, while all other age groups were found on par with each other. Rootstock girth was also found to have no influence on graft success and development. However, highest graft success was noticed with the 0.4-0.6 cm girth group.

It was interesting note that the season of grafting had the profound influence on grafting success. Grafting done during February recorded as high as 92.49 per cent success followed by 58.57 per cent in case of January 30 DAG. However, 90 DAG fairly higher per cent (48.61%) of graft success was recorded in January grafted stocks than February (38.79%). Incidentally least success of only 12.03 per cent was recorded in December grafting.