VARIETAL RESPONSES OF SCION TO STONE GRAFTING IN MANGO FOR COMMERCIAL PROPAGATION

By

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THESIS

submitted in partial fulfilment of
the requirement for the degree

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DECLARATION

I hereby declare that this thesis entitled "Varietal responses of scion to stone grafting in mango for commercial propagation" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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To my parents

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Introduction

INTRODUCTION

Mango "The king of fruits" occupies a predominent place among the fruit crops grown in India. The varietal wealth of mango in India is very great and Kerala has its distinction of producing earliest mangoes in the country. Since mango is highly heterozygous due to cross pollination, multiplication of selected desirable varieties could be possible only through vegetative methods of propagation. Among several methods of vegetative propagation the most commonly adopted methods are inarching, veneer grafting and stone grafting. However, the only method commercially adopted in Kerala is inarching. But this technique possesses serious difficulties especially when mother trees selected for scion shoots are scattered or spread in distant locations. Moreover, this is time consuming, laborious and expensive.

The work initiated in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from May 1982 to June 1985 had revealed that there exist great possibilities of adopting stone grafting on a commercial scale in our state. The effect

of season, procuring of scion, age of stock and scion, length of scion, covering the grafts with polythene bags and application of fungicides against dieback disease were studied (Dhungana, 1984 and Retan, 1985). Some anatomical studies were also carried out to find out the various stages of graft union. But in the earlier studies only one variety Neelum was made use of as scion material. Thus in mango there existed a need for further studies to find out the response of varieties to stone grafting before recommending this method for commercial rapid multiplication of true to type progenies. Hence the present series of studies were carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from May 1985 to December 1986 with the following objectives.

1. To find out the response of selected six varieties of mango viz., Mulgoa, Priur, Bangarapally, Mundappa, Banglore and Alphonso for stone grafting.

2. To standardise the length of scion for stone grafting.

3. Detailed anatomical studies of graft union of all the above selected varieties to find out the different steges of graft union and the possible reasons for stock scion incompatibility.

Review of Literature

REVIEW OF LITERATURE

The research during the last decades have completely revolutionised the method and technique of mango propagation. The commercial method of mango propagation in India is still inarching despite its various drawbacks involving several expensive operations. Moreover, it is laborious and time consuming. "Stone grafting or Epicotyl grafting" the recently developed new technique has manifold advantages over the traditional method of propagation.

As early as 1933, Traub and Auchter made use of sprouted mango stones for grafting in Florida. Actively growing mango seedlings of 2 to 3 weeks old were used as rootstocks for inarching in mango (Singh, 1951). These works led to the development of a new simple and economic method of propagation in mango viz., stone grafting at the State Horticultural Research Station, Krishna Nagar, West Bengal (Bhan et al., 1969). Thus it created a lot of interest among other research workers in India and abroad who had tried this technique with varying degrees of success (Majumdar and Rathore, 1970; Bedoes and Prasad, 1975; Patel and Amin, 1976; Gunjate and Limaye,

1976; Singh and Srivastava, 1981 and Thomas, 1981). However, only very recently this technique was employed for the commercial production of Alphonso mango grafts in the Konkan region of Maharashtra (Gunjate et al., 1982).

The literature on some of the factors affecting success in different grafting methods was reviewed and arranged under the following heads.

2.1 Effect of season on graft take

2.1.1 Stone grafting

In Gujarat Agricultural University, Anand, Patel and Amin (1976) found that success in stone grafting was directly related with humidity and minimum temperature within the range of 23.15°C to 25.87°C. Dhakal (1979) obtained a grafting success of 55 to 65 per cent during June to September. Mandal (1979) reported 60 to 90 per cent success during July to October for stone grafting in mango under Bihar conditions, while Upadhaya and Gupta (1979) observed a success of 80 to 85 per cent when stone grafting was done from July to August under Basti conditions. Studies conducted by Dengale (1980) under Konkan conditions recorded a maximum success of 61 to 70 per cent for stone grafting in mango during June to September. The beneficial

effect of June-July season for stone grafting in mango was observed by Maiti and Biswas (1980) when they got a success of 96 per cent under West Bengal conditions. However, Nagawekar (1981) did not observe any significant difference in sprouting of mango grafts done during the months of June, July or August. The significant effect of season on the sprouting and survival of stone grafts were also studied by Gunjate et al. (1982) and Kotecha (1982).

Studies conducted by Dhungana (1984) revealed that stone grafting could be best done during the month of August under Kerala conditions. He obtained maximum success of 69.33 per cent during August when grafting was done using the variety Neelum as scion shoot. Desai and Patil (1994) conducted stone grafting in mango inside a glass house and observed highest success in the month of July as there was prevalence of more temperature (41°C) and humidity (83 per cent) inside the glass house. Reddy and Kohli (1985) in their attempts to standardise the method of stone grafting in mango under Bangalore condition observed that high humidity and temperature were associated with a better success in stone grafting. They obtained a success of 95 per cent for the variety Totapuri, when grafting was done inside the mist chamber.

In cashew, Harmekar (1980) found March-April as the ideal season for stone grafting under Konkan conditions while Nagabhushanam and Mohan (1982) from Cashew Seed Farm, Shantigodu, Karnataka reported rainy season as the best time for stone grafting. They stated that high humidity and heavy precipitation during June, July and August months had beneficial effect on graft union. Trials conducted at Cashew Research Station, Madakkathara, Kerala revealed March to May as the most congenial season for stone grafting in cashew.

2.1.2 Veneer grafting

Ahmed (1964) reported that veneer grafting in mango could be best done during the spring rather than the autumn. Mukherjee and Majumdar (1964) observed a success of 76 to 96 per cent in all the varieties of mango tried except Langra during the months of March to July under Delhi conditions. A gradual decrease in graft take was noticed from September onwards. Sukla (1964) obtained a success of 80, 60 and 30 per cent respectively during the months of August, September and March for veneer grafting in mango, cv. Kesar under Gujarat conditions. Bhambota et al. (1971) obtained 96 per cent success for veneer grafting in mango during July, and 83 per cent success

during August under Saharanpur conditions (Prasad et al., 1973). Gunjate et al. (1976) obtained 76 to 84 per cent success for veneer grafting in mango during the period from March to May but the grafts prepared during the month of May failed to produce sufficient growth so as to plant them in the field during the monsoon season of the same year. Therefore, March to April was considered as the optimum season for grafting. Ram and Bist (1982) in their experiments on veneer grafting in mango cv. Deshehari observed 100 per cent take when grafting was done in June, July and August. Singh et al. (1983) also stressed the significant effect of season on veneer grafting in mango. They obtained a maximum success of 75 to 92 per cent during rainy season of May to June while success was only 16 to 20 per cent during November-December.

In cashew, Phadnis et al. (1974) obtained a maximum success of 60 per cent during July for veneer grafting and the percentage of success was gradually reduced to 53.3, 13.3 and 6.7 per cent respectively during the months of June, August and September. Rao and Nambiar (1977) reported that in East Coast of Kerala June to September was the best season for veneer grafting in cashew when they obtained a success of 50 to 96 per cent. Rao and Nagabhushanam (1977) found monsoon season as the

most suitable for veneer grafting in cashew under Karnataka conditions. They obtained 85 to 96 per cent take during July. Dhandar (1978) noticed 36 per cent success during November to March and 96 per cent during rainy season of June-July. Trials conducted at Cashew Research Station, Madakkathara revealed a success of 56 per cent during June to September (Damodaran et al., 1979).

2.1.3 Inarching

The success in inarching is also found to be highly influenced by weather conditions. Under South Indian conditions the best time for inarching was found to be from February to July (Naik, 1941). Talukdar and Ahmed (1965) reported that inarching in mango during mid August was most ideal compared to mid September. Giri (1966) also observed the superiority of August compared to other seasons for inarching in mango. Singh et al. (1963) found monsoon period as the best time for inarching in mango under Lucknow conditions.

In cashew, Rao and Rao (1957) obtained a success of 40 to 75 per cent for inarching during January to May. Rao (1965) reported 52 to 96 per cent success for inarching in cashew during the period from July to December when seven months old seedlings were used as stocks.

2.1.4 Side grafting

In Punjab the most ideal season for side grafting in mango was found to be during March-April or June to October (Kanwar and Bajwa, 1974). Under Lucknow conditions Singh et al. (1983) obtained maximum success of 76 to 80 per cent during August followed by 76 per cent in July. November and December proved unsuitable for carrying out side grafting when the success was only 8 to 12 per cent.

Rao et al. (1957) successfully tried side grafting in cashew during the months of February to May with 70 per cent success. Nagabhushanam (1965) observed June, July and October as most ideal months for side grafting in cashew. Valsalakumari et al. (1985) observed May-June and September-October as most ideal season for side grafting in cashew under Vellanikkara condition.

2.2 Effect of age of rootstock on graft take

2.2.1 Stone grafting

Majumder and Rathore (1979) developed successful stone grafts by grafting on young germinating mango stones. Gunjate et al. (1976) recommended the use of 4 to 7 days old germinating mango stones as root stocks for stone grafting in mango. Stone grafting in mango using one week

old seedlings resulted in maximum graft take (73.3 per cent) and subsequent growth of the grafted plant. Singh and Srivastava (1981) observed 4 to 5 days old seedlings as the most ideal for stone grafting. Gunjate et al. (1982) conducted trials with stocks of different ages and observed that stocks of less than two weeks old and coppery red in colour were most suitable as rootstocks. Dhungana (1984) standardised the age of rootstock for stone grafting in mango under Vellanikkara conditions and obtained 58 per cent success when grafting was done on 5 days old seedlings. The age of rootstock was negatively related with survival rate. The survival rate decreased from 50 to 82 per cent when the age of stock increased from 5 to 15 days. Reddy and Kholi (1985) obtained 95 per cent success when grafting was done on eight days old rootstocks. The initial sprouting of stone grafts was found to be high when 6 days old seedlings were used as rootstocks (Patil and Patil, 1985).

In cashew, studies conducted at Dapoli conditions revealed that 4 to 8 weeks old seedlings could be used successfully for stone grafting (Harmekar, 1980). Nagabhushanam (1982) suggested the use of 10 to 15 days old seedlings as rootstocks for stone grafting.

2.2.2 Veneer grafting

Jagirdar and Bhatti (1968) in their attempts to find out the effect of age of rootstock on the success of veneer grafting in mango observed no significant difference between the stocks of different age groups. One to two year old seedlings were found to be the most ideal as rootstock for veneer grafting in mango (Limaye and Phadnis, 1968; Rajput and Haribabu, 1971; Prasad *et al*., 1973 and Singh and Srivastava, 1979).

In Cashew, Phadnis *et al*. (1974) obtained maximum success (60 per cent) on five months old seedlings. Nambiar (1976) made use of 10 to 15 months old seedlings as rootstocks for veneer grafting in cashew.

2.2.3 Inarching

Burns and Prayag (1921) from Philippines reported that 3 weeks old seedlings were best suited for inarching in mango. Naik (1941) stated that 4½ months old seedlings could be used as rootstocks for inarching. Singh and Singh (1956) found rapid union when 2 to 3 weeks old seedlings were used as rootstocks for grafting. Majhail and Singh (1962) observed the superiority of two months old seedlings for inarching in mango.

2.3.3 Side grafting

Sahani (1982) recommended a height of 15 to 20 cm on the root stocks for side grafting in cashew for obtaining maximum success.

2.4 Effect of thickness of rootstock and scion on graft take

2.4.1 Stone grafting

Rajput and Haribabu (1971) reported that in mango the stock and scion of uniform thickness was most ideal for stone grafting.

2.4.2 Veneer grafting

Singh and Srivastava (1979) stated that stock scion combinations of girth 1.0 - 1.0 cm; 1 - 1.5 cm and 1.5 - 1.5 cm, were most suitable for veneer grafting in mango.

2.4.3 Inarching

Majhail and Singh (1962) used rootstocks of three different girths viz., 8 to 10 mm, 11 to 14 mm and 15 to 17 mm for grafting and observed no significant difference in success between stocks of various thickness. Giri (1966) in his experiments with rootstocks of varying

girth for inarching in mango observed that percentage success was significantly high on seedlings of 1.3 to 1.6 cm girth.

Asceneo and Milheiro (1973) obtained 100 per cent take for splice and cleft grafting of cashew with stock and scion of 3 to 5 mm diameter.

2.5 Effect of age of scion on graft take

2.5.1 Stone grafting

Bhen et al. (1969) used semi mature terminal shoots as scions for stone grafting in mango under Vengurla conditions. But mature defoliated scions of 3 to 4 months old were found to be most ideal for stone grafting in mango under Konkan conditions (Gunjate et al., 1976). Dhakal (1979) in his experiments observed that scion shoots of age more than 2 months were most suitable for stone grafting. The success in grafting was found to have increased with increase in age of scion. Chakraberti and Sadhu (1984) suggested to use 1 month old scion shoots for stone grafting in mango. Nagewekar et al. (1984) obtained a grafting success ranging from 60.6 to 63.00 per cent with the use of terminal and sub terminal shoots as scion in stone grafting of mango. Thungana (1984) under Vellanikkara condition used four months old scion

material for stone grafting in mango when he recorded a success of 61.33 per cent.

In cashew, Nagabhushanam (1992) successfully conducted stone grafting using the terminal shoots of previous seasons growth as scion.

2.5.2 Veneer grafting

Mukherjee and Majumdar (1964) obtained maximum success for veneer grafting in mango (88 per cent) with 3 months old scion shoots and the grafting success was only 12 per cent when scion shoots of age 1½ to 2½ months were used. In veneer grafting of mango success percentage could be considerably increased by the use of mature scion wood as against immature scion (Jagirdar and Bhatti, 1968). Singh and Srivastava (1979) recorded maximum success with 6 months old scions as against scions of 1 to 3 months age. Singh *et al.* (1995) observed that in mango 3 months old scion shoots were most ideal for veneer grafting.

2.6 Effect of length of scion on graft take

2.6.1 Stone grafting

Bhan *et al.* (1969) observed the beneficial effect of using 10 to 12 cm long scions for stone grafting in

mango. Dhakal (1979) did not observe any significant difference in success between scions of varying lengths. Kotecha (1982) obtained maximum sprouting of grafts (75 per cent) with 7.5 cm long scions. Chakrabarti and Sadhu (1984) suggested that for stone grafting in mango 10 cm long scions were most suitable compared to 5 or 15 cm long scions. However, Ratan (1985) observed 8 cm long scions as most ideal for stone grafting in mango and he obtained a graft take of 87.5 per cent under Vellanikkara conditions.

2.6.2 Veneer grafting

Mukherjee and Majumdar (1961) observed that for veneer grafting in mango 6" long scions with enlarged plumpy terminal buds should be taken from terminal shoots. Majumdar *et al.* (1972) in their experiments on veneer grafting with scions of different lengths ranging from 2.5 to 10 cm observed no significant difference in success with regard to length of scion, but the subsequent growth of scions after grafting was more with longer scions. Ram and Bist (1982) observed significant difference in success percentage of veneer grafts with scions of different length. They obtained a success of 20, 80 and 40 per cent respectively with scion shoots of lengths 5 cm, 10 cm and 15 cm.

2.6.3 Side grafting

Kanwar and Bajwa (1974) reported that for side grafting in mango scions of 7.5 cm length were most suitable resulting better graft union.

2.7 Effect of defoliation of scion on graft take

2.7.1 Stone grafting

Defoliated scion shoots always found to result good success in stone grafting of mango (Perssai, 1974 and Maiti and Biswas, 1980). Gunjate and Limaye (1976) observed no significant difference in graft take with and without defoliation treatment of scion shoots. Singh and Srivastava (1981) observed the superiority of scion shoots defoliated 10 days prior to grafting as against other defoliation treatments. Patil *et al.* (1984) obtained maximum success when 10 days prior defoliated scion shoots were stone grafted on 4 days old rootstock. Dhungana (1984) recorded highest percentage of sprouting (78.5 per cent) with 15 days prior defoliated scion shoots and maximum survival of (49.5 per cent) with 10 days prior defoliated scion shoots. However, Gunjate (1985) did not observe any beneficial effect of defoliation of scion shoot on graft take under Konkan conditions.

In cashew, defoliation of scion shoots about a week prior to grafting was found to be beneficial (Nagabhushanam, 1982). Studies conducted at Cashew Research Station, Madakkathara clearly revealed that procuring of scion 10 days prior to stone grafting was highly beneficial resulting a success of 57 to 69 per cent.

2.7.2 Veneer grafting

In veneer grafting of mango only 10 per cent success was obtained when undefoliated scions were used for grafting (Mukherjee and Majumdar, 1964). Gunjate *et al.* (1976) obtained 70 and 63.83 per cent sprouting respectively when defoliated and undefoliated scions were used for veneer grafting under Konkan conditions. Singh and Srivastava (1979) and Singh *et al.* (1984) suggested 10 days prior defoliated scion shoots for veneer grafting in mango under Utter Pradesh conditions. Dhungana (1984) observed no significant difference in sprouting and survival between 10 days and 15 days prior defoliated scion shoots in veneer grafting of mango under Vellanikkara conditions.

2.7.3 Side grafting

Kashyap *et al.* (1972) recorded a graft take of 100 per cent when 10 days procured scions were used for

side grafting in mango. But Kanwar and Bajwa (1974) used undefoliated scions for side grafting in mango when they obtained a survival of 92 per cent.

2.8 Effect of type of scion material on graft take

2.8.1 Stone grafting

Nagewekar (1981) stated that for stone grafting in mango, terminal or subterminal shoots could be used successfully. He obtained 63 per cent success with terminal and 66.6 per cent success with subterminal shoots.

2.8.2 Veneer grafting

Mukherjee and Majumdar (1964) obtained 80 per cent success with subterminal shoots and 96 per cent success with terminal shoots as scion for veneer grafting in mango. Majumdar *et al.* (1972) observed that veneer grafting of mango with scions collected from non flowering shoots resulted in 90 per cent success compared to 70 per cent with scions from flowering shoots.

2.9. Effect of grafting methods on graft take

De la Roche (1953) suggested that splice method could be successfully utilised for stone grafting in mango.

Majumdar and Rathore (1970) tried splice, veneer and wedge grafting on 4, 6, and 8 days old seedlings and obtained respectively 50, 46.6 and 33.3 per cent success. Pinheiro et al. (1970) obtained maximum success of 97 per cent with cleft grafting compared to other methods. Bhambota et al. (1971) observed veneer grafting as most superior method compared to side and cleft grafting in mango. Majumdar et al. (1972) compared splice, saddle and wedge grafting techniques and obtained better success (30 per cent) for splice grafting compared to other methods. Singh and Srivastava (1982) noticed the superiority of soft wood grafting over veneer grafting. Gaur (1984) obtained maximum per cent of success in soft wood grafting as against inarching, veneer grafting, and stone grafting in mango.

In cashew, for large scale multiplication cleft grafting was found to be the best method according to Nagabhushanam (1982). Valsalakumari et al. (1985) compared the success in side, veneer, wedge and patch budding methods in cashew and obtained 75 per cent success in wedge grafting compared to other methods where success was found to be very poor.

2.10 Effect of varieties of stock and scion

2.10.1 Stone grafting

Dhakal (1979) conducted studies to find out the response of selected seven varieties of mango for stone grafting and obtained 86, 85, 70, 66, 65, 64 and 61 per cent success respectively for Kesar, Totapuri, Pairi, Vanraj, Fernandin, Gomankur, and Alphonso varieties when used as scions. Maiti and Biswas (1980) studied the effect of 14 scion varieties on stone grafting in mango. Among the varieties tried Fazli gave the highest percentage of success (96 per cent) followed by Ranipasand (94 per cent), Kohinoor (90 per cent), Safar pasand (88 per cent), Zardaloo (83 per cent), Alphonso (76 per cent), Langra (75 per cent), SamarBahishetChausa (71 per cent), Himsagar (60 per cent), Anuoam (58 per cent), Bombai (50 per cent) and Kishenbhog (29 per cent). Kulwal and Tayde (1985a) conducted studies on stone grafting in mango under Akola conditions using eight scion varieties viz., Dasheheri, Dudhpeda, Jehangir, Langra, Mushared, Pairi, Rajapuri and Totapuri and obtained a success varying from 56 to 93 per cent for different varieties. Another trial using Langra and Pairi as scion material resulted 70 to 100 per cent success initially. However, the

ultimate survival after 180 days of grafting was 14 to 50 per cent. Maximum mortality rate was noticed within first 3 months of grafting.

Studies conducted at Cashew Research Station, Madakkathara, to find out the response of different promising types of cashew to stone grafting revealed maximum success of 81.17, 77.16 and 71.6 per cent respectively for the types BLA 39-4, BLA 139-1, and K 22-1. Another trial on stone grafting where four promising types of cashews were used as rootstocks and scions in all possible combinations revealed no incompatibility among the types grafted. Among the different types used as rootstocks BLA 39-4 and BLA 139-1 appeared to be best.

2.10.2 Veneer grafting

Studies conducted to find out the response of three varieties of mango viz., Langra, Dashehari and SamarBahishetChausa for veneer grafting in mango proved, SamarBahishetChausa as the most successful variety for veneer grafting (Ahmed, 1964). Singh and Srivastava (1979) evaluated the success in propagation of different scion varieties on important rootstocks in mango.

Dashehari when used as scion on Kalamady rootstock resulted in 90 per cent success followed by Nakkare as scion on Kalamady (85 per cent). When different varieties were used as scion on common rootstock, Ratual, Mallika and Chausa, resulted 85, 80 and 35 per cent graft take respectively. Studies conducted by Dhungana (1984) under Vellanikkara conditions also revealed that there was significant difference in response of scion varieties to veneer grafting in mango. Maximum graft take was observed for the variety Bennet Alphonso (46 per cent) while minimum was observed for Banganappally (16.67 per cent). Bajpai et al. (1985) used scions of two varieties, viz., Amrapali and Mallika for veneer grafting in mango on a common rootstock and observed that graft take and growth of scion were more for Amrapali compared to Mallika. Kulkarni et al. (1985) from Fruit Research Station, Sangareddy also reported significant varietal difference in response to veneer grafting in mango.

2.10.3 Inarching

Naik (1941) observed differential response of varieties for inarching in mango. Asadullah and Khan (1960) observed maximum success for inarching in the variety Langra followed by Dashehari and Samar Behishet. But

Talukdar and Ahmad (1965) in their studies on inarching in mango using three varieties viz., Langra, Dashehari, and Samar Bahishet recorded highest success with Samar Bahishet (71 per cent) as scion.

2.10.4 Saddle grafting

Thomas (1981) conducted saddle grafting studies in mango using varieties Mahroka, Peter, and Julie as scion on a local polyembryonic rootstock and obtained maximum success of 95 per cent for varieties Mahroka and Peter and 80 per cent for the variety Julie.

2.10.5 Soft wood grafting

Kulwal and Tayde (1985 b) reported varietal differences in soft wood grafting of mango under Akola conditions. The varieties like Pairi, Kesar and Penchadara Kalsa, showed nearly 100 per cent success while varieties like Neelum, Locat-1, Locat-2, Totapuri and Banganapally, recorded only 72 to 85 per cent success.

2.11 Effect of tying materials on graft take

De la Rocha (1953) used Rubber bands coated with paraffin wax for tying the graft union in mango and obtained

better success. Asadullah and Khan (1960) suggested that for tying the graft unions in approach grafting mud plaster was superior to waxed cotton tape. Mukherjee and Majumdar (1961) recommended the use of 200 to 300 guage alkathene film for tying the graft unions in veneer grafting. Uredya (1976) stated that during rainy season 250 guage alkathene tape should be used for tying mango veneer grafts for effecting better union. Singh and Srivastava (1979) observed that gunny twine was much inferior to white and green polythene tapes for tying the veneer grafts in mango.

2.12 Anatomy of graft union

Walters (1932) observed that mango bud was unique in its method of union with stock plant. Cohesion took place only under the bark not at the sides. The bud was thus found to be carried upward on a cushion of rapidly dividing cambium cells. Juliano (1941) studied the callus development in graft union of cleft grafts and observed that first step in the formation of graft union was the formation of callus cushion in the gap through the activity of the parenchyma of both bark and pith. From this callus a cambial bridge was developed joining the cambial ends of both stock and scion. He observed that

the initiation of callus tissue began from stock but the total contribution of callus by stock and scion was almost equal. Callus development usually initiated first in the bark. Luthra and Sharma (1946) studied the histology of graft unions in mango variety Langra. They observed that excessive growth of parenchymatous tissues (Callus) between stock and scion and distortion of xylem elements blocked the conducting vessels. These factors later inhibited the movement of water from stock to scion. Robert (1949) stated that the important factors determining the graft take was not the nature of the union but the genetically determined interaction between stock and scion. Healing of a graft union could be considered as the healing of wound in fruit crops (Bloch, 1952). Detailed anatomical studies revealed that mango stem consists of an outer cuticle and inner epidermis, cortex, endodermis, pericycle, arched shaped fibre, resin canal, phloem, cambium, xylem, uniseriate medullary rays, biseriate medullary rays and pith cell full of granules (Singh, 1960).

Wilson and Wilson (1961) reported that when young stems were wounded or grafted the cambium was interrupted and new vascular cambia tended to regenerate

in the callus proliferating from the wounded surfaces. The position in which such cambia regenerated varied according to the type of wound. Asgarov and Jokovic (1961) observed that the degree of callus formation varied considerably between varieties and was highly influenced by rootstock and weather conditions prevailed during the previous growing season. Turkovac (1961) observed excessive undifferentiated callus or other irregular growths at the union of incompatible combinations of stock and scion. Ciz (1969) opined that incompatibility could be diagonised through anatomical studies after 2 - 3 months of grafting.

Shimoya et al. (1970) reported the presence of a fungal mycelium in graft union which seemed to facilitate proper graft union. Anatomical studies conducted by Soule (1971) indicated the presence of five important stages in the process of bud union anatomy of mango viz., Stage-1 (4 days) wound periderm development; stage 2 (8 days) - callus proliferation and enlargement from cambium resulting in firm attachment of both stock and scion; stage 3 (12 days) - completion of cambial bridge; stage 4 (36-48 days) differentiation of vascular tissue and complete healing of union and stage 5 (6-8 months) -

formation of several cylinders of new tissues and lateral shifting of the scion to align with the stock.

Esau (1979) conducted studies on graft union and observed that secondary growth and cambial activity were involved in the proper graft union formation. Break down products of dead cells on the surface of stock and scion formed a necrotic layer. Intact cells next to necrotic layers enlarged, divided and formed callus tissue which filled the space left between the stock and scion. Eventually the cambia between stock and scion became continuous across the callus by the differentiation of callus cells into cambial cells which later formed vascular tissues. The callus production was noticed both from phloem ray and immature ray cells.

Fahn (1982) observed that the important function of cambium was to form callus in the wound portion. He further stated that union of stock and scion was not only through cambia but also through wood rays which proliferated and took part in the graft union. Dave and Rao (1982) studied the cambial activity in mango and observed that radial growth of the tree was continuous as cambium was active all the year round. Tangential division in the

cambial zones resulted in differentiation of vascular elements. Climatic factors showed no relationship with cambial activity. Ratan (1985) reported four distinct stages during the process of graft union in the variety Neelum. It was observed that in successful grafts callus proliferation commenced from 5th day onwards and completion of cambial bridge of the stock and scion was attained within 15 days after grafting.

Materials and Methods

MATERIALS AND METHODS

The studies reported in this thesis is in continuation of the earlier works done in the Department of Pomology and Floriculture during the period from May 1982 to June 1985 with the objective of standardising various aspects of stone grafting in mango.

The present studies on stone grafting in mango were carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from May 1985 to December 1986 with the following objectives.

1. To find out the response of selected six varieties of mango viz., Mulgoa, Priur, Banganappally, Mundappa, Banglora and Alphonso for stone grafting.

2. To standardise the length of scion for stone grafting.

3. Anatomical studies of graft union of all the above selected varieties to find out the

different stages of healing process and the possible reasons for stock scion incompatibility.

Experiment No.1

3.1 Studies on the effect of varieties and length of scion on stone grafting

For these studies the following six commercial varieties of mango were made use of as scion.

1. Mulgoa
2. Priur
3. Banganappally
4. Mundappa
5. Banglore
6. Alphonso

Scions of three different lengths viz., 6 cm, 8 cm and 10 cm were prepared from each of the above varieties for grafting. Grafting was done during July-August on stocks raised from a single variety. There were altogether 18 treatment combinations of six scion varieties at three different lengths. Fifty grafts were prepared under each of the treatment combination and the

trial was laid out in completely randomised design. Total number of grafts prepared for the study was 900.

3.1.1 Raising of seedlings for rootstock

Mango stones required for raising the rootstocks were collected from a single variety. Healthy, uniform well developed, plumpy stones were selected and sown in flat position in raised beds of size 2 m x 1 m prepared under partial shade. The stones were sown in lines at a spacing of 2.5 cm x 10 cm. A thin layer of sand was spread evenly on the surface of the nursery bed. In order to avoid the termite attack BHC 10 per cent dust was applied around the seed beds. Sowing was done on 21st May 1985. The beds were always kept at a well moistened condition. Stones started sprouting from 2nd week onwards.

The healthy vigorous seedlings with straight stout epicotyl were removed from the nursery beds five days after sprouting along with the seedstone without causing any injury to the root system. These seedlings were then transplanted in polythene bags of size 20 cm x 15 cm filled with potting mixture consisting of FYM, sand and soil in 2:1:1 ratio. The bagged seedlings were kept under partial shade.

3.1.2 Selection and preparation of scion shoots

Healthy, disease free, uniform mother trees of 10 year old were located in the mango orchard at Instructional Farm, Vellanikkara. Terminal, mature, 3 to 4 months old shoots of 12 to 15 cm long and 1.5 to 2.5 cm thick were selected from the mother trees of all the above mentioned six varieties. Defoliation was done by clipping the leaf portion keeping the petioles intact on the twig. Defoliation was done 10 days ahead of the grafting operation as suggested by Dhungana (1984). Selected scions were cut back at appropriate lengths of 6 cm, 8 cm and 10 cm for doing grafting.

3.1.3 Method of stone grafting

The grafting was done when the seedlings were established in polybags within five to ten days. The cleft method of grafting was adopted. Rootstocks were decapitated 4 to 5 cm above the cotyledons and two slanting cuts about 3 to 5 cm long were made in the centre of the stock with a clean sharp knife.

The basal ends of detached scions from the mother trees were treated with a solution of captan 0.2 per cent

for few minutes before grafting as a prophylatic measure against dieback disease. The scions were then prepared like a wedge giving a slanting cut of 3 to 4 cm on both sides of basal ends with a sharp knife.

The wedge shaped scions were then inserted carefully into the cleft made on the rootstock so as to get a tight fitting of the cambial layers of both stock and scion. The graft joint was than firmly tied with transparent polythene strips of 1.5 cm width, 30 to 40 cm length and 200 guage thickness (Plates I to VII).

3.1.4 After care of the grafts

The grafts were kept under partial shade in a thatched shed. During the course of study subsequent seedlings produced from the polyembryonic seeds were removed. The grafts were watered on alternate days during the course of investigation. A combination of Rogor 2 ml/ litre + Foltaf 3 g /litre was sprayed at fortnightly intervals to control the shoot midge attack and die back disease.

Plate I Prepared rootstock for stone grafting

Plate II Prepared scions of varying lengths for stone grafting

Plate I

Plate II

Plate III Scion inserted into rootstock for stone grafting

Plate IV Graft joint tied with polythene strip

Plate V A sprouted scion after 5 days of grafting

Plate III

Plate IV

Plate V

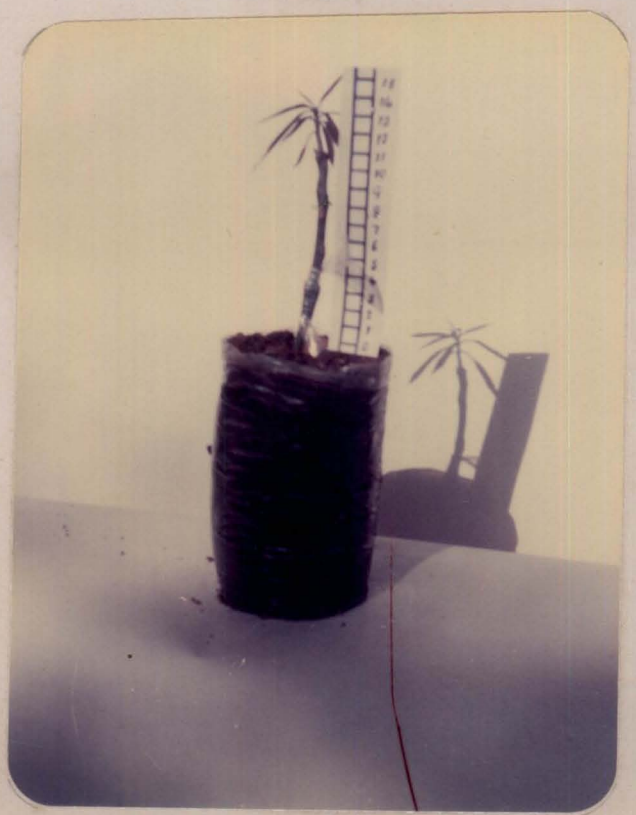


Plate VI Successful stone graft of the variety Priur 6 months after grafting

Plate VII Successful stone graft of the variety Banganappally 6 months after grafting

Plate VI

Plate VII

3.1.5 Observations

3.1.5.1 Percentage of sprouting and survival

The observations on days taken for sprouting of scions after grafting were recorded. The scions that remained green whether sprouted or unsprouted 15 days after grafting were accounted as the initial success. These scions actually sprouted and survived after three months were accounted as final success (Dhungana, 1994 and Raton, 1985).

The following growth parameters were also recorded at fortnightly intervals for a period of four months.

3.1.5.2 Growth of scion

The growth of scion was measured in centimeters from the point where the scion put forth new growth.

3.1.5.3 Number of leaves

The number of leaves produced by the graft was recorded at fortnightly intervals.

3.1.5.4 Girth of stock, scion and new growth

A fixed circular mark was made on the stock and scion at one cm above and below the graft joint. The girth of stock and scion was measured in centimeters at these points at fortnightly intervals.

The girth of new growth was also measured in centimeters at a height of one cm from the point where the scion put forth new growth.

Experiment No.2

3.2 Anatomical studies of graft union

Grafts were prepared separately for anatomical studies by using the scions of three different lengths viz., 6 cm, 8 cm and 10 cm collected from each of the following six varieties.

1. Mulgoa
2. Priur
3. Banganappally
4. Mundappa
5. Bangalora
6. Alphonso

Totally there were 18 treatment combinations. Here also the similar procedure was followed for raising root stocks, selection of scions, scion preparation and grafting operation. Samples were collected for anatomical studies as per the procedure furnished below.

3.2.1 Collection and storage of specimens

Representative samples of graft union from all the treatment combinations were taken for the anatomical studies. Two samples were collected from each treatment combination at intervals of 5 days, 15 days, 45 days and 90 days after grafting. Samples were also taken from those grafts which showed sign of shrinking or drying from 5th day onwards and those grafts which remained green without sprouting even after 60 days. Immediately after collection the samples were processed as follows.

3.2.2 Processing

FAA (850 ml of 70 per cent alcohol + 100 ml 40 per cent formaldehyde + 50 ml glacial acetic acid) solution was used for killing and fixing of the samples. Specimens were kept in FAA solution for a minimum period of 72 hours and were transferred to 70 per cent alcohol.

They were then removed using a sterilised forceps and washed in running water for 30 minutes and later with glass distilled water. Uniform thin sections of 25 /a (micron) thickness were taken using "Reichert Sliding microtome" as per standard microtomy suggested for hardwoods (Cutler, 1978).

The detailed schedules followed for cleaning and staining of sections were as follows (Johanson, 1940).

Sections

↓

1% alcoholic safranin (5-10 minutes)

↓

30% alcohol (2 minutes)

↓

50% alcohol (2 minutes)

↓

70% alcohol (2 minutes)

↓

80% alcohol (2 minutes)

↓

90% alcohol (2 minutes)

↓

Fast green (2 minutes)

↓

95% alcohol (20 seconds)

↓

absolute alcohol (1 minute)

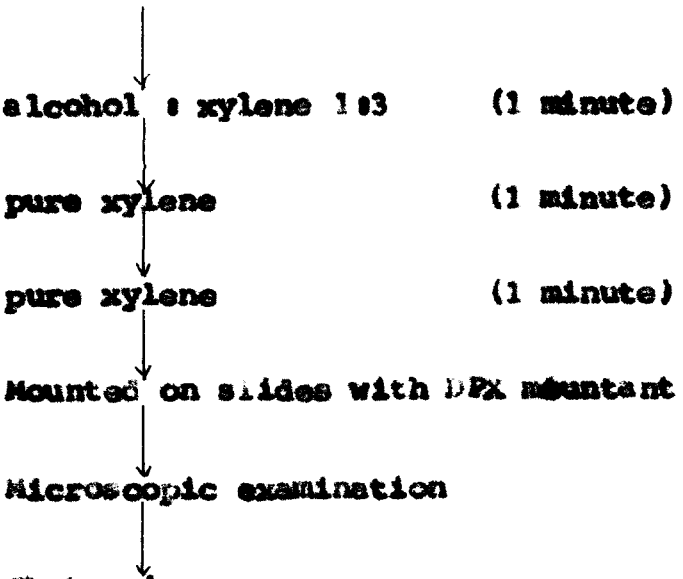
↓

alcohol : xylene 3:1 (1 minute)

↓

alcohol : xylene 1:1 (1 minute)

↓



3.2.4 Microscopic examination

The slides were examined carefully through "Olympus binocular research microscope fitted with objective of magnification ranging from 3.2x to 40x and 10x eye piece.

3.2.5 Photomicrography

Photo micrographs of selected sections were taken using a photo micrography system (Olympus PM-6) ORWO black and white negative film of 125 ASA.

3.3 Statistical analysis

Differences among the treatments with regard to the number of sprouting and survival of grafts were tested

by employing the following chi-square test as described by Panse and Sukhatme (1968).

$$\chi^2 = \frac{1}{n_1 n_2} \quad \frac{(an_2 - \dot{a}n_1)^2}{a + \dot{a}}$$

where χ^2 = Chi-square

a - Number of grafts sprouted or survived for each treatment.

$\dot{a}$ - Number of grafts unsprouted or not survived for each treatment

n_1 - Number of grafts sprouted or survived for all the treatments

n_2 - Number of grafts unsprouted or not survived for all the treatments

The degrees of freedom for chi-square is (K-1) where K is the number of treatments.

Pairwise comparison of treatments were made using chi-square test of independence.

The relevant test criterion is given by

$$\chi^2 = \frac{(ad - bc)^2 n}{(a+b)(a+c)(b+d)(c+d)}$$ with one degree of freedom

where a and c - Number of grafts sprouted or survived in the two treatments.

b and d - Number of grafts unsprouted or not survived in the two treatments.

The observations on the effect of treatments on the quantitative characters viz., growth of scion, number of leaves, girth of rootstock, girth of scion and girth of new growth were analysed statistically using the analysis of variance technique as applied to the factorial experiment in CRD as described by Snedecor and Cochran (1967).

Results

RESULTS

The results of the present series of studies on the standardisation of stone grafting technique in mango are summarised in the following pages.

4.1 Effect of varieties and scion length on sprouting and survival of grafts

The observations on the percentage of sprouting and final survival of stone grafts are presented in Table 1. The results indicated that the length of scion and varieties had profound effect on initial success as well as final survival of grafts. The highest percentage of sprouting (84 per cent) was obtained for the varieties Banganappally with the scion of lengths 8 cm and 10 cm and for Priur with the scion of length 8 cm. The sprouting was very poor (50 per cent) for the variety Alphonso when the scions of lengths 8 cm and 10 cm were used for grafting. It is also clear from the table that the variety Priur recorded maximum survival of 54 per cent with the scion of length 8 cm while survival was the least (12 per cent) for the variety Mulgoa with the scion of length 6 cm.

Table 1. Effect of varieties and scion length on sprouting and survival of grafts

Varieties	Scion length (cm)	No.of grafts prepared	Sprouting		Survival	
			Number	Percentage	Number	Percentage
Mulgoa	6	50	39	78	6	12
	8	50	36	72	11	22
	10	50	32	64	11	22
Priur	6	50	38	76	16	32
	8	50	42	84	27	54
	10	50	36	72	17	34
Banganappally	6	50	31	62	17	34
	8	50	42	84	25	50
	10	50	42	84	24	48
Mundappa	6	50	37	74	15	30
	8	50	37	74	16	32
	10	50	40	80	23	46
Banglora	6	50	41	82	17	34
	8	50	39	78	23	46
	10	50	39	78	19	38
Alphonso	6	50	32	64	12	24
	8	50	29	58	19	38
	10	50	29	58	11	22
Value of Chi-square			33.12*		49.01**	

* Significant at 5% level
** Significant at 1% level

The results of the statistical analysis of the pooled data on the response of varieties of scion on sprouting and survival of grafts presented in Table 2 indicated high significant difference between varieties. The variety Banglora recorded maximum sprouting of 79.33 per cent followed by Priur (77.33 per cent). The sprouting was minimum (60 per cent) for the variety Alphonso. The highest percentage of survival (44 per cent) was obtained for the variety Banganappally which is on par with the variety Priur (40 per cent). The survival was only 18.66 per cent for the variety Mulgoa (Fig.1).

The results of the statistical analysis of the pooled data on the effect of scion length on percentage of sprouting and survival of grafts are presented in Table 3. From the table it is clear that there was no significant difference between scions of various lengths with regard to initial sprouting of stone grafts (Fig.2). However, highest percentage of survival (40.33 per cent) was observed for the scion of length 8 cm and minimum (27.66 per cent) for the scion of length 6 cm (Appendix I - IV).

Table 2. Effect of varieties on sprouting and survival of grafts

Varieties	Number of grafts prepared	Sprouting		Survival	
		Number	Percentage	Number	Percentage
Mulgoa	150	107	71.33	28	18.66
Priur	150	116	77.33	60	40.00
Banganappally	150	115	76.66	66	44.00
Mundappa	150	114	76.00	54	36.00
Banglora	150	119	79.33	59	39.33
Alphonso	150	90	60.00	42	28.00
Value of Chi-square		19.38**		29.20**	

** Significant at 1% level

FIG. 1. EFFECT OF VARIETIES ON SPROUTING AND SURVIVAL OF GRAFTS.

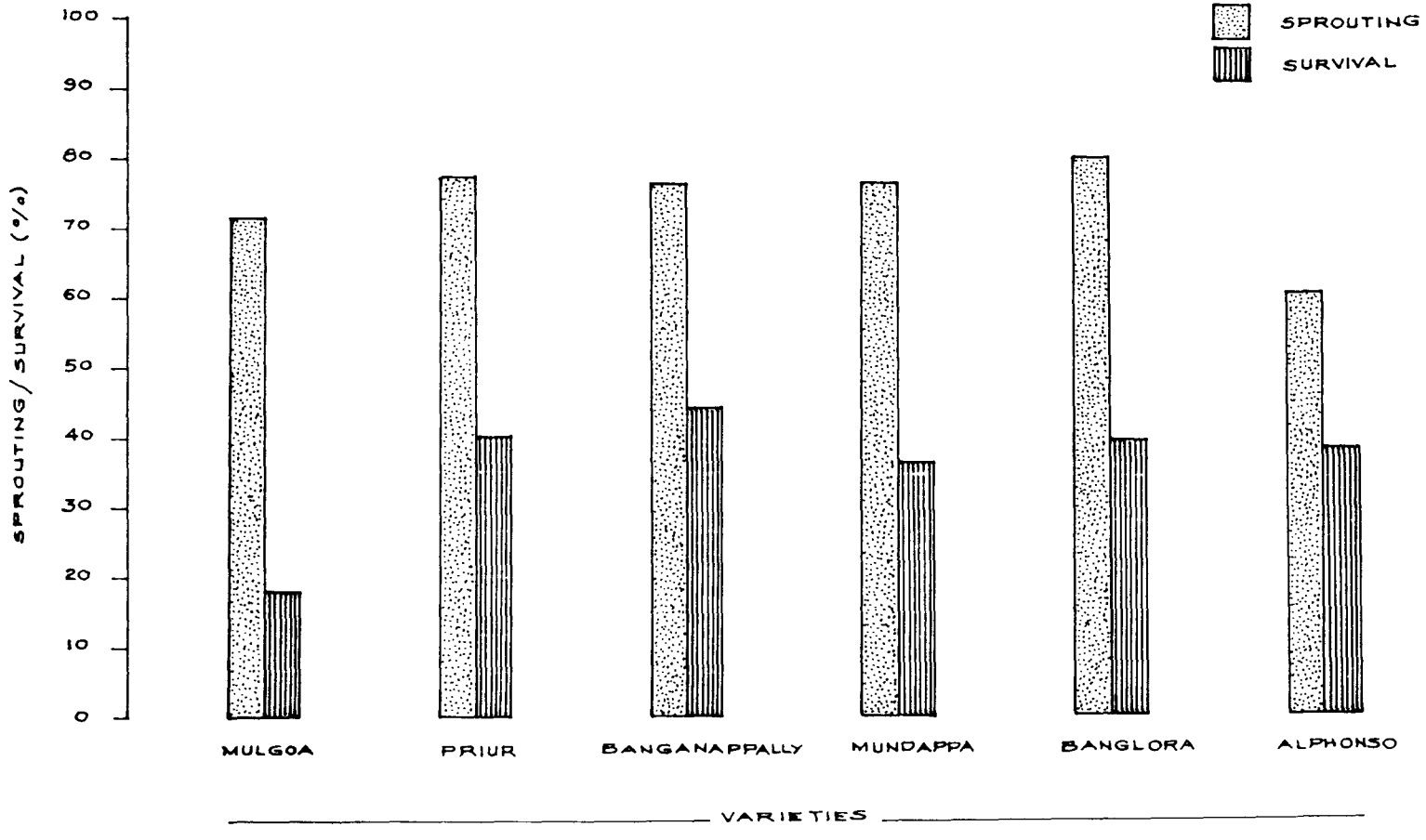


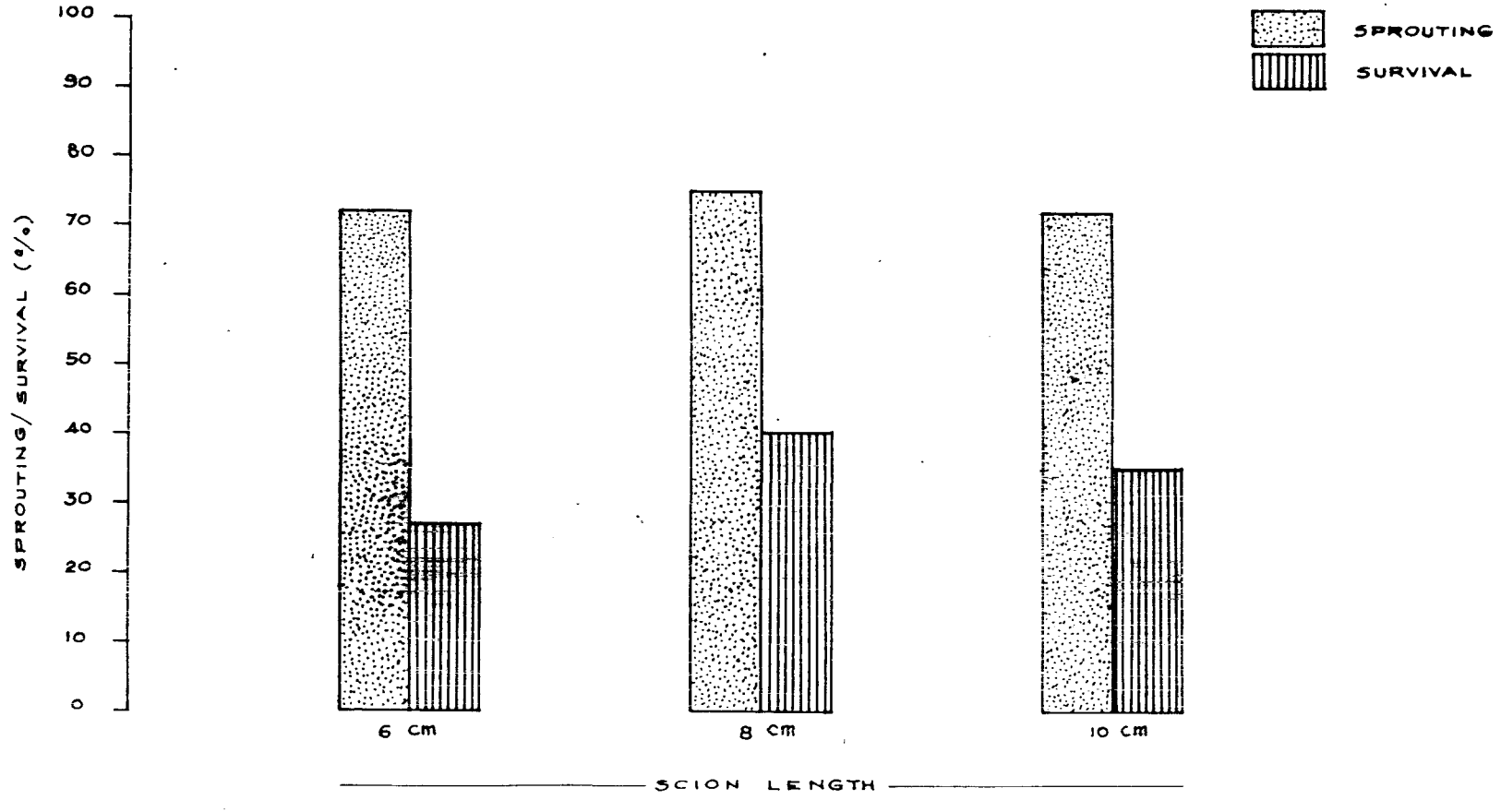
Table 3. Effect of scion length on sprouting and survival of grafts

Scion length (cm)	No.of grafts prepared	Sprouting		Survival	
		Number	Percentage	Number	Percentage
6	300	218	72.66	83	27.66
8	300	225	75.00	121	40.33
10	300	218	72.66	105	35.00
Value of Chi-square		0.56^{NS}		10.76**	

** Significant at 1% level

NS - Not significant

FIG. 2. EFFECT OF SCION LENGTH ON SPROUTING AND SURVIVAL OF GRAFTS.



4.2 Effect of varieties and scion lengths on growth parameters of grafts

4.2.1 Growth of scion

The observations on the extension growth of scion at fortnightly intervels for various treatment combinations are furnished in Table 4. Analysis of variance of the data revealed high significant difference in growth of scion for different varieties throughout the period of study (Fig.3). The variety Mulgoa recorded maximum mean growth of 8.91 cm, 9.3 cm, and 11.61 cm respectively during 2nd, 3rd and 4th fortnights of grafting which was immediately followed by the variety Banganappally. The mean growth of scion was on par between the varieties Mulgoa and Banganappally. From 5th fortnight onwards extension growth was maximum for the variety Banganappally which produced maximum mean growth of 12.34 cm, 15.29 cm, 15.29 cm and 20.53 cm respectively during 5th, 6th, 7th, and 8th fortnights of observation. The least extension growth was recorded by the variety Banglora particularly up to 5th fortnight and there after the variety Mundappa registered the least value with regard to this parameter. There was no significant difference between the scions of lengths 6 cm, 8 cm, and 10 cm with regard to growth of scion (Fig.4).

Table 4. Effect of varieties and scion length on growth of scion at fortnightly intervals

Varieties / Scion length (cm)	2nd Fortnight				3rd Fortnight				4th Fortnight				5th Fortnight			
	Growth of scion (cm)															
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Mulgoa	9.06	8.92	8.74	8.91	9.30	9.18	9.42	9.30	9.40	15.02	10.36	11.61	10.02	15.52	10.50	12.01
Priur	5.44	7.02	6.88	6.45	6.24	8.04	7.90	7.39	7.70	8.50	7.96	8.05	8.00	8.58	8.90	8.49
Banganappally	7.06	6.02	8.10	7.06	9.62	6.70	8.76	8.36	12.70	8.10	8.76	9.85	13.02	11.20	12.80	12.34
Mundappa	7.04	4.36	7.56	6.32	7.04	4.56	8.00	6.53	7.38	4.88	9.52	7.26	7.46	4.98	9.58	7.34
Banglora	3.98	4.62	3.68	4.09	4.58	4.88	4.68	4.71	4.60	5.44	5.22	5.10	8.56	6.30	5.80	6.89
Alphonso	4.98	8.14	4.54	5.89	5.06	8.14	4.66	5.95	6.20	8.50	5.14	6.61	6.30	12.38	5.68	8.12
Mean	6.26	6.51	6.58	6.45	6.97	6.92	7.23	7.04	8.01	8.41	7.82	8.08	8.89	9.83	8.88	9.30

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	2.14	0.76	2.17	0.77	2.49	0.88	2.83	1.01
Length	NS	0.54	NS	0.55	NS	0.62	NS	0.71
Length for any particular variety	NS	1.32	NS	1.32	4.30	1.53	4.89	1.74

NS - Not significant

(Contd.)

Table 4. (Contd.) Effect of varieties and scion length on growth of scion at fortnightly intervals

Varieties / Scion length (cm)	6th Fortnight				7th Fortnight				8th Fortnight			
	Growth of scion (cm)											
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Mulgoa	10.02	16.12	10.50	12.18	11.54	17.30	10.54	13.12	12.12	17.40	10.76	13.43
Priur	9.70	8.60	8.92	9.07	9.70	8.64	8.92	9.08	13.20	11.20	11.76	12.06
Banganappally	15.10	14.30	16.46	15.29	15.10	14.30	16.46	15.29	13.06	20.00	23.52	20.53
Mundappa	7.46	4.98	9.66	7.35	7.96	5.20	9.72	7.63	10.54	7.20	9.86	9.20
Banglora	10.22	9.38	6.60	8.73	11.54	10.64	7.30	9.83	13.14	12.44	8.44	11.34
Alphonso	6.34	15.66	6.42	9.47	6.34	16.68	6.46	9.82	6.34	20.04	6.68	11.01
Mean	9.80	11.51	9.74	10.35	10.36	12.03	9.90	10.79	12.23	14.71	11.84	12.93

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	3.04	1.08	3.22	1.15	3.95	1.40
Length	NS	0.76	NS	0.81	NS	0.99
Length for any particular variety	5.27	1.87	5.61	1.99	6.85	2.42

NS - Not significant

FIG. 3. EFFECT OF VARIETIES ON GROWTH OF SCION AT FORTNIGHTLY INTERVALS.

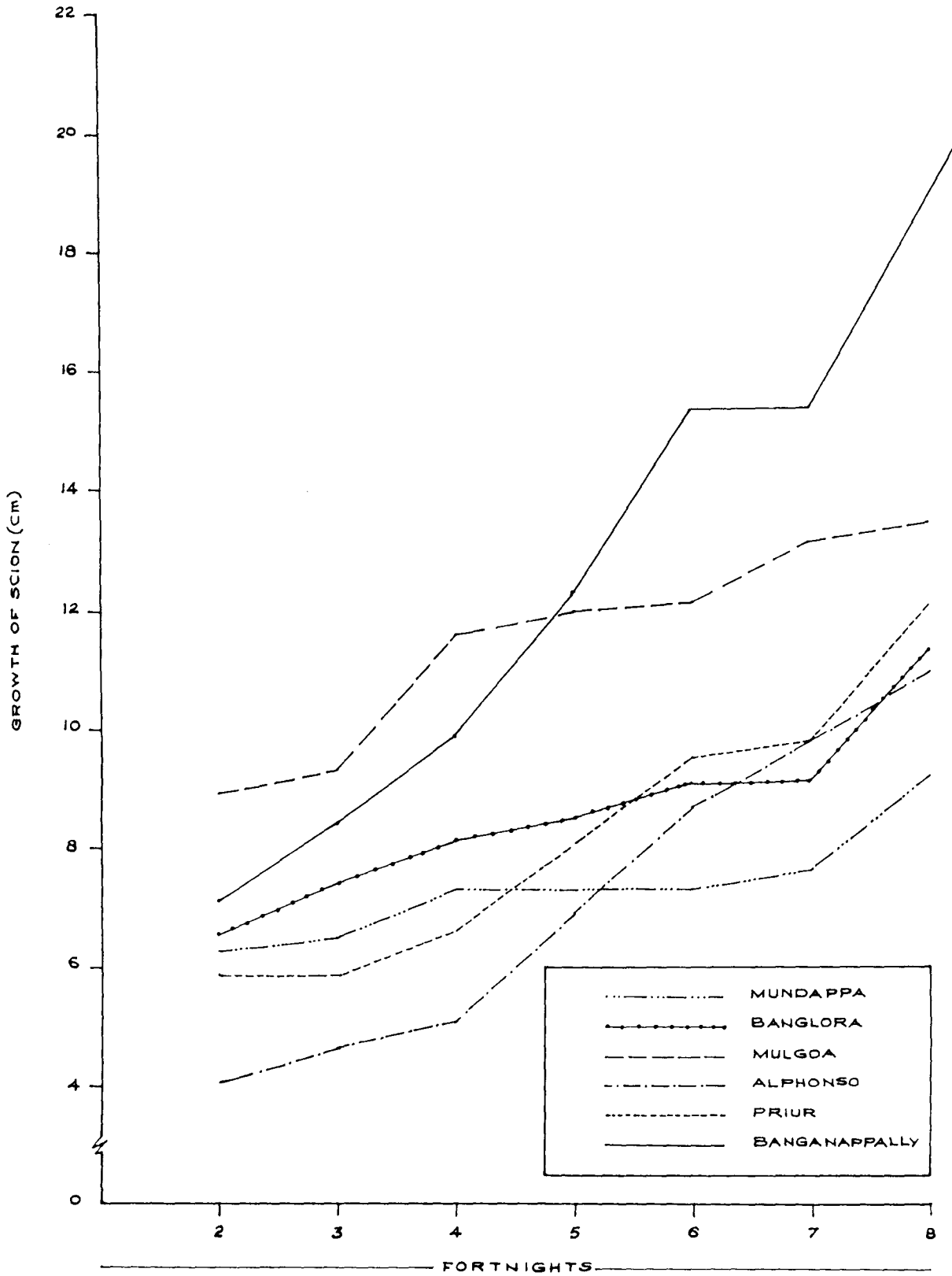
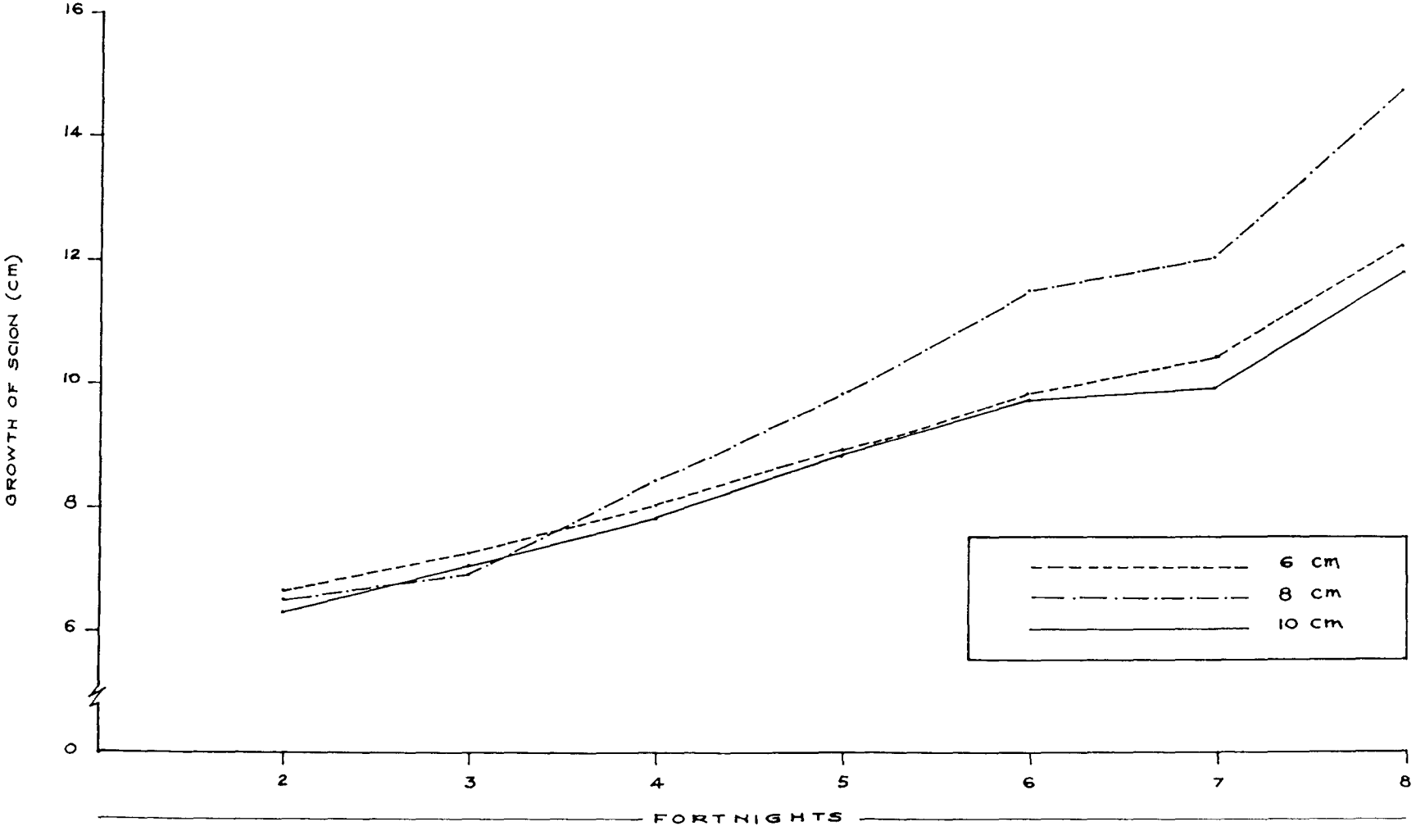


FIG. 4. EFFECT OF SCION LENGTH ON GROWTH OF SCION AT FORTNIGHTLY INTERVALS.



The analysis of the data also showed that the interaction effects were significant from 4th fortnight onwards. During 4th and 5th fortnights the treatment combination of the variety Mulgoa with scion of length 8 cm recorded maximum growth of scion of 15.02 cm and 15.52 cm respectively. For the remaining fortnights the treatment combination of Banganappally with scion of 10 cm length showed maximum mean growth except during 7th fortnight. The treatment combination of Bangalora with scion of length 6 cm recorded the least value, for the 2nd, 3rd and 4th fortnights and there after the variety Mundappa with scion of length 8 cm recorded the least value with regard to this parameter throughout the period of study except during 6th fortnight (Appendix V).

4.2.2 Girth of rootstock

Observations on girth of rootstock for various treatment combinations are presented in Table 5. It is clear from the table that varieties had significant effect on girth of rootstock during the initial stages of growth (Fig.5). The variety Bangalora recorded maximum mean girth of 2.19 cm and 2.37 cm respectively during the 2nd and 3rd fortnights of grafting while the variety Mundappa recorded maximum mean girth of 2.42 cm during 4th fortnight. However,

Table 5. Effect of varieties and scion length on girth of rootstock at fortnightly intervals

Varieties / Scion length (cm)	2nd Fortnight				3rd Fortnight				4th Fortnight				5th Fortnight			
	Girth of rootstock (cm)															
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Mulgoa	2.02	2.14	2.08	2.08	2.06	2.22	2.12	2.13	2.23	2.36	2.24	2.29	2.32	2.38	2.34	2.35
Priur	1.40	1.42	1.24	1.35	1.54	1.50	1.32	1.45	1.94	1.62	1.76	1.77	2.26	2.08	2.26	2.20
Banganappally	1.30	1.64	1.42	1.45	1.56	1.88	1.58	1.67	1.96	2.00	1.96	1.97	2.18	2.56	2.22	2.32
Mundappa	1.86	2.22	2.38	2.15	1.92	2.22	2.42	2.19	2.40	2.26	2.60	2.42	2.40	2.44	2.68	2.51
Banglora	2.12	2.26	2.18	2.19	2.30	2.46	2.36	2.37	2.30	2.46	2.38	2.38	2.38	2.50	2.48	2.45
Alphonso	2.00	2.16	1.72	1.96	2.10	2.32	1.90	2.11	2.16	2.48	2.02	2.22	2.18	2.48	2.14	2.27
Mean	1.78	1.97	1.84	1.86	1.91	2.10	1.95	1.99	2.17	2.20	2.16	2.18	2.29	2.41	2.35	2.35

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	0.23	0.81	0.22	0.08	0.19	0.07	NS	0.08
Length	NS	0.06	NS	0.06	NS	0.05	NS	0.05
Length for any particular variety	NS	0.14	NS	0.14	NS	0.12	NS	0.13

NS - Not significant

(Contd.)

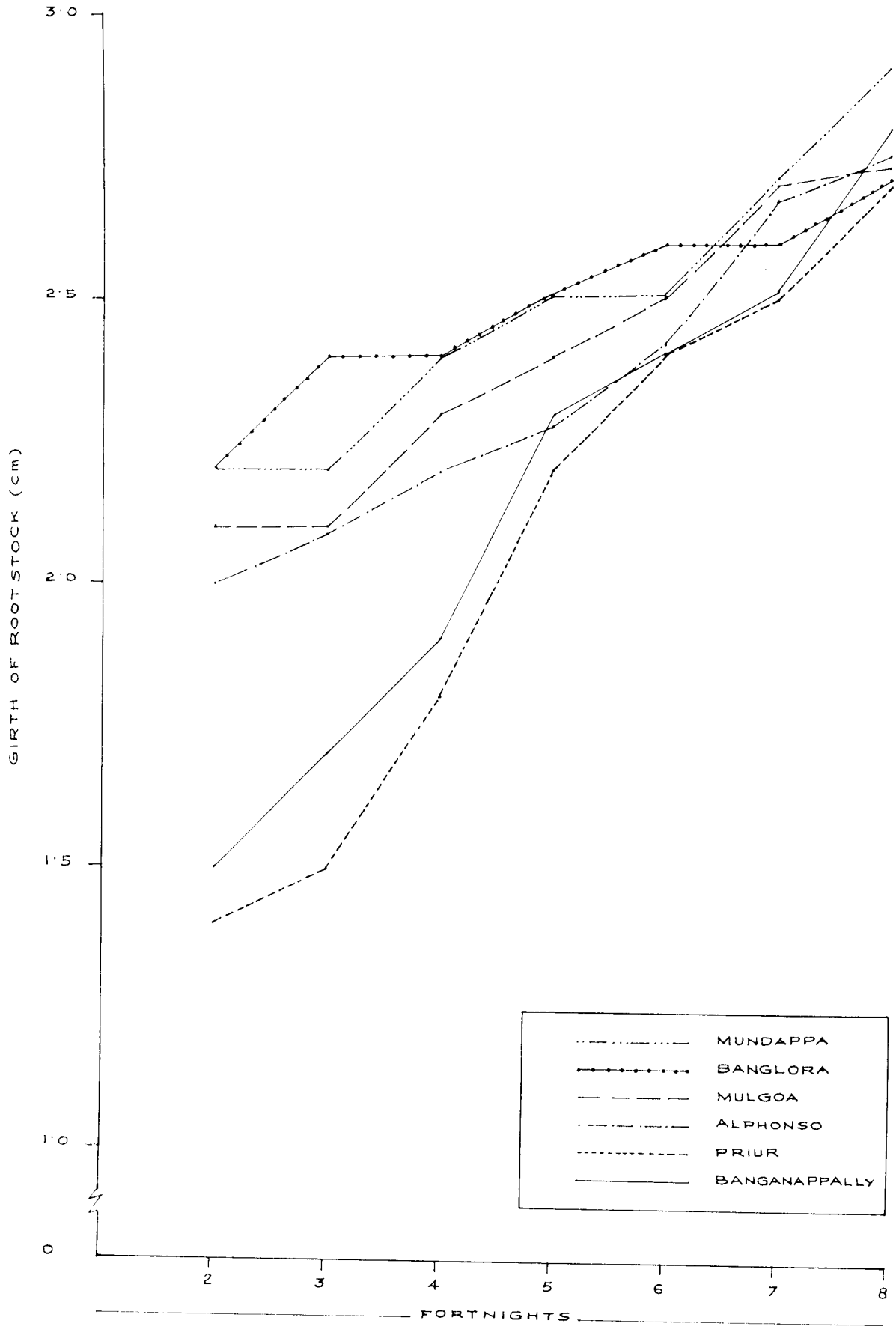
Table 5 (Contd.) Effect of varieties and scion length on girth of rootstock at fortnightly intervals

Varieties / Scion length (cm)	6th Fortnight				7th Fortnight				8th Fortnight			
	Girth of rootstock (cm)											
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Mulgoa	2.42	2.52	2.46	2.47	2.56	2.78	2.60	2.65	2.66	2.82	2.74	2.74
Priur	2.56	2.22	2.26	2.35	2.64	2.32	2.54	2.50	2.70	2.50	2.90	2.70
Banganappally	2.28	2.68	2.30	2.42	2.44	2.72	2.46	2.54	2.72	2.92	2.74	2.79
Mundappa	2.40	2.46	2.74	2.51	2.62	2.62	2.78	2.67	2.70	2.88	[illegible]	2.91
Banglora	2.54	2.66	2.54	2.58	2.64	2.66	2.60	2.63	2.72	2.82		2.76
Alphonso	2.18	2.86	2.28	2.44	2.54	3.02	2.38	2.65	2.60	3.06	2.56	2.74
Mean	2.39	2.57	2.43	2.46	2.57	2.69	2.56	2.61	2.69	2.83	2.81	2.77

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	NS	0.08	NS	0.09	NS	0.09
Length	NS	0.06	NS	0.06	NS	0.07
Length for any particular variety	0.39	0.14	NS	0.17	NS	0.17

NS - Not significant

FIG. 5. EFFECT OF VARIETIES ON GIRTH OF ROOT STOCK AT FORTNIGHTLY INTERVALS.



the observations recorded during 4th fortnight showed no significant difference between the varieties Mulgoa, Bangalora, Mulgoa and Alphonso with regard to girth of stock. Mean girth of rootstock was least for the variety Priur up to 4th fortnight of observation. From 4th fortnight onwards the girth of stock did not differ significantly between the varieties studied (Appendix VI). The length of scion did not influence significantly the girth of rootstock in any of the varieties studied (Fig.6).

The data also showed that during 6th fortnight interaction effect was significant, the maximum (2.86 cm) being noticed for the variety Alphonso with scion of length 8 cm and least (2.15 cm) for the scion of length 6 cm.

4.2.3 Girth of scion

The data on the girth of scion at fortnightly intervals for various treatment combinations are presented in Table 6. Analysis of variance of the data revealed that there was high significant difference in girth of scion between the different varieties throughout the course of study (Fig.7). During 2nd and 3rd fortnight the variety Banglora recorded maximum mean girth of 2.09 cm and 2.23 cm respectively and there after mean girth of scion

FIG. 6. EFFECT OF SCION LENGTH ON GIRTH OF ROOT STOCK AT FORTNIGHTLY INTERVALS.

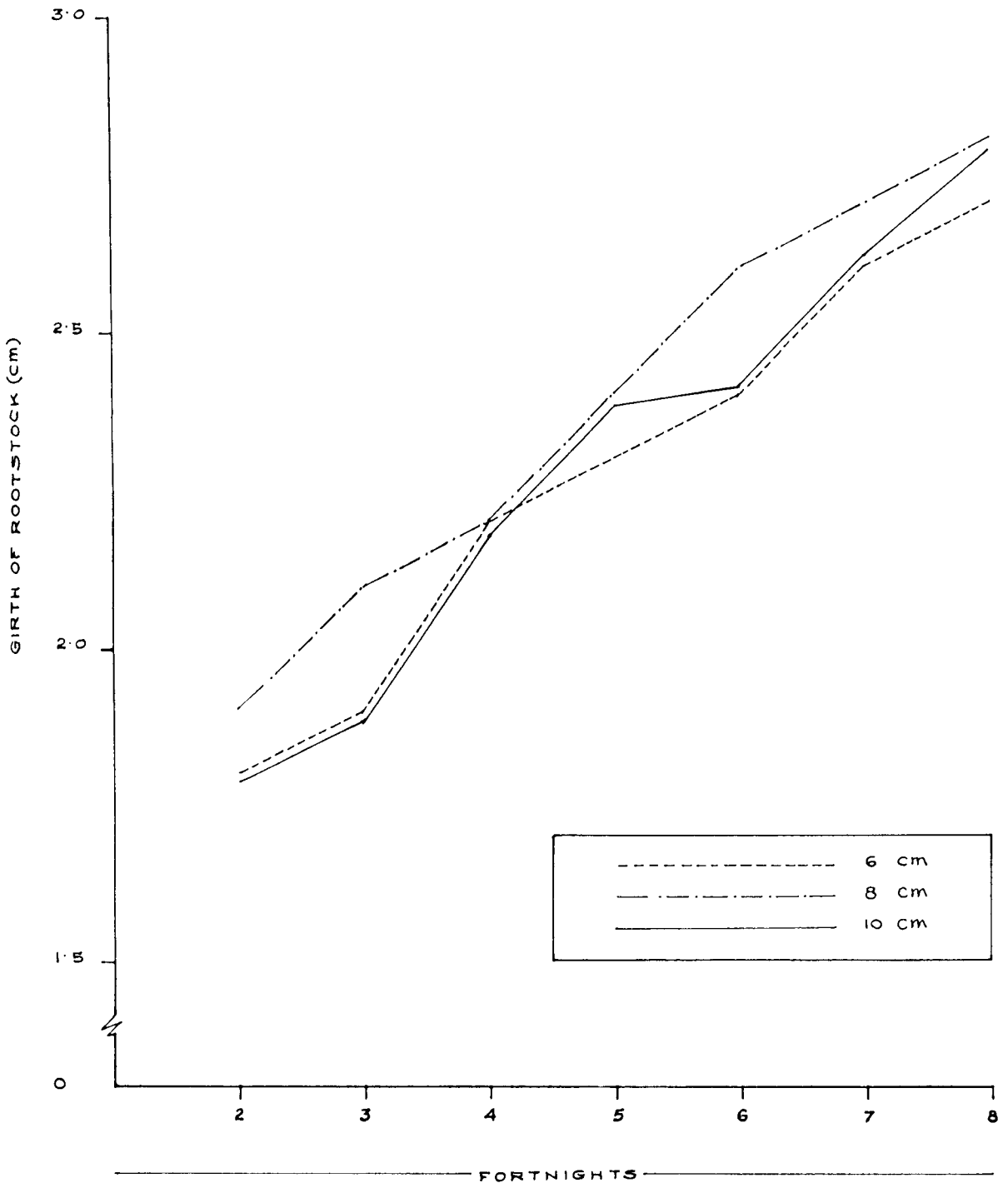


Table 6. Effect of varieties and scion length on [illegible] at fortnightly intervals

Varieties / Scion length (cm)	2nd Fortnight				3rd Fortnight				4th Fortnight				5th Fortnight			
	Girth of scion (cm)															
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Mulgoa	1.86	2.16	2.06	2.03	1.92	2.20	2.10	2.07	2.14	2.34	2.20	2.23	2.20	2.34		2.25
Priur	1.16	1.20	1.06	1.14	1.28	1.38	1.24	1.30	1.62	1.62	1.26	1.50	1.62	1.90		1.79
Banganappally	1.12	1.38	1.18	1.23	1.30	1.58	1.32	1.40	1.66	1.70	1.58	1.65	1.66	1.78	1.66	1.70
Mundappa	1.94	1.74	2.36	2.01	1.98	1.92	2.36	2.09	2.12	2.10	2.58	2.27	2.22	2.26	2.62	2.37
Banglora	1.90	2.24	2.14	2.09	2.06	2.33	2.24	2.23	2.06	2.38	2.24	2.23	2.12	2.42	2.24	2.26
Alphonso	1.96	2.20	1.74	1.97	2.04	2.20	1.84	2.01	2.08	2.32	1.94	2.11	2.10	2.32	2.04	2.11
Mean	1.66	1.82	1.76	1.74	1.76	1.94	1.85	1.85	1.95	2.08	1.97	2.00	1.99	2.13	2.12	2.08

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	0.25	0.09	0.24	0.09	0.22	0.08	0.19	0.07
Length	NS	0.06	NS	0.06	NS	0.05	NS	0.05
Length for any particular variety	NS	0.16	NS	0.15	NS	0.13	NS	0.12

NS - Not significant

(Cont'd.)

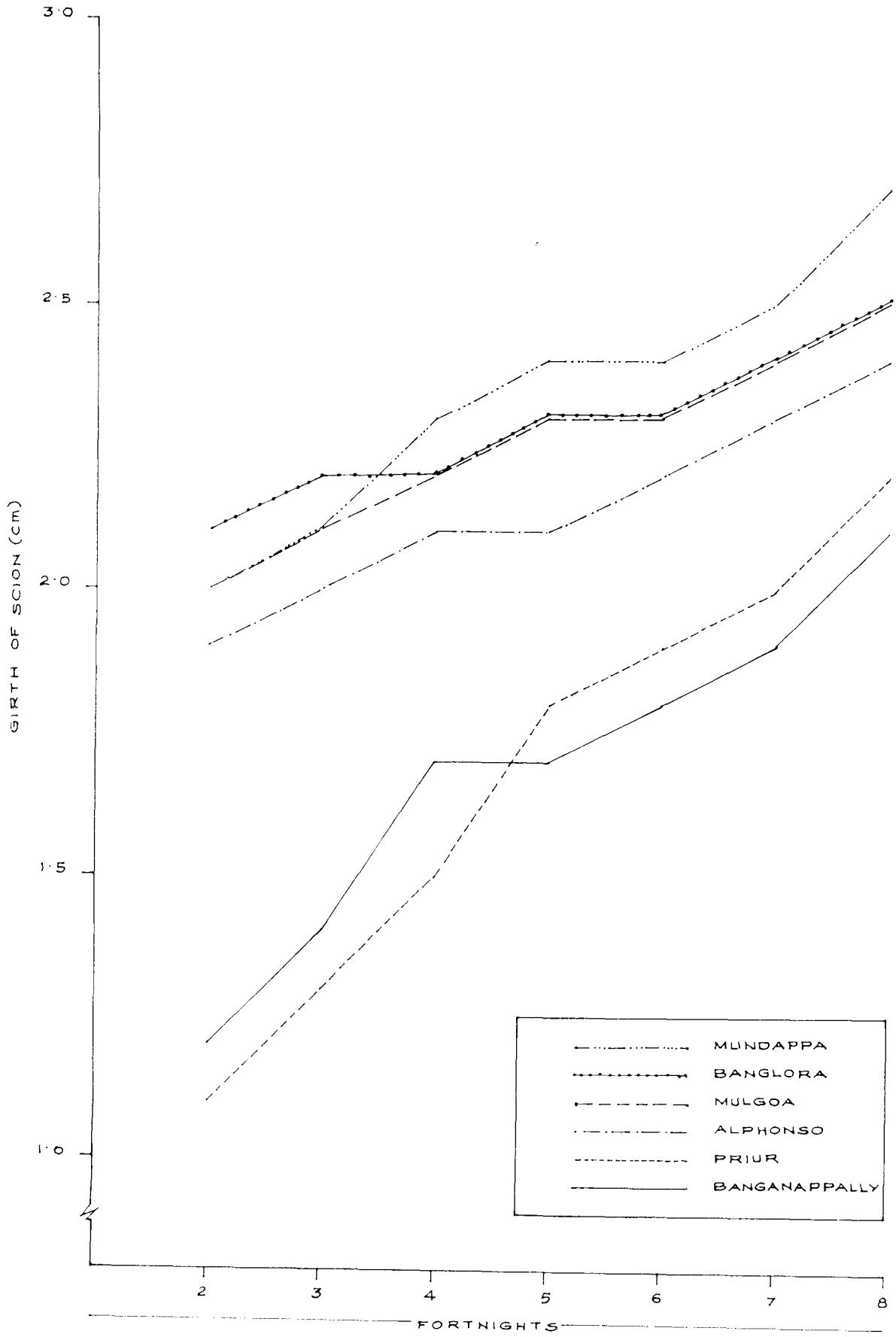
Table 6. (Contd.) Effect of varieties and scion length on girth of scion at fortnightly intervals

Varieties / Scion length (cm)	6th Fortnight				7th Fortnight				8th Fortnight			
	Girth of scion (cm)											
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Mulgoa	2.30	2.34	2.32	2.32	2.38	2.42	2.34	2.38	2.48	2.44	2.44	2.45
Priur	1.98	1.80	2.02	1.93	2.08	1.96	2.08	2.04	2.16	2.16	2.20	2.17
Banganappally	1.86	1.90	1.74	1.83	1.96	1.90	1.74	1.87	2.00	2.26	2.14	2.13
Mundappa	2.23	2.28	2.62	2.38	2.38	2.40	2.64	2.47	2.46	2.64	2.86	2.65
Banglora	2.20	2.50	2.28	2.33	2.24	2.50	2.40	2.38	2.42	2.64	2.52	2.53
Alphonso	2.14	2.48	2.10	2.24	2.28	2.58	2.12	2.33	2.46	2.64	2.18	2.43
Mean	2.12	2.22	2.18	2.17	2.22	2.29	2.22	2.24	2.33	2.46	2.39	2.39

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	0.17	0.06	0.18	0.06	0.21	0.07
Length	NS	0.04	NS	0.05	NS	0.05
Length for any particular variety	0.30	0.11	NS	0.11	NS	0.13

NS - Not significant

FIG. 7. EFFECT OF VARIETIES ON GIRTH OF SCION AT FORTNIGHTLY INTERVALS



was found to be maximum for the variety Mundappa. The minimum girth of scion was noticed for the variety Priur up to 4th fortnight and there after the variety Banganappally showed minimum girth of scion. With regard to girth of scion there was no significant difference between the scion of lengths 6 cm, 8 cm and 10 cm during the entire period of observation (Fig.8).

The interaction effect was not significant during the period of study except during 6th fortnight when the treatment combinations of the variety Mundappa with scion of 10 cm length recorded maximum girth of 2.62 cm while the variety Banganappally with scion of 10 cm length recorded the minimum girth of 1.74 cm (Appendix VII).

4.2.4 Girth of new growth

The observations recorded on girth of new growth are presented in Table 7. From the table it is evident that there is significant difference with regard to girth of new growth for different varieties studied throughout the period of observation. Maximum mean girth of new growth (1.51 cm) was noticed for the variety Mundappa during the 2nd fortnight and there after the variety Alphonso ranked first with regard to this growth parameter. The least girth

FIG. 8. EFFECT OF SCION LENGTH ON GIRTH OF SCION AT FORTNIGHTLY INTERVALS.

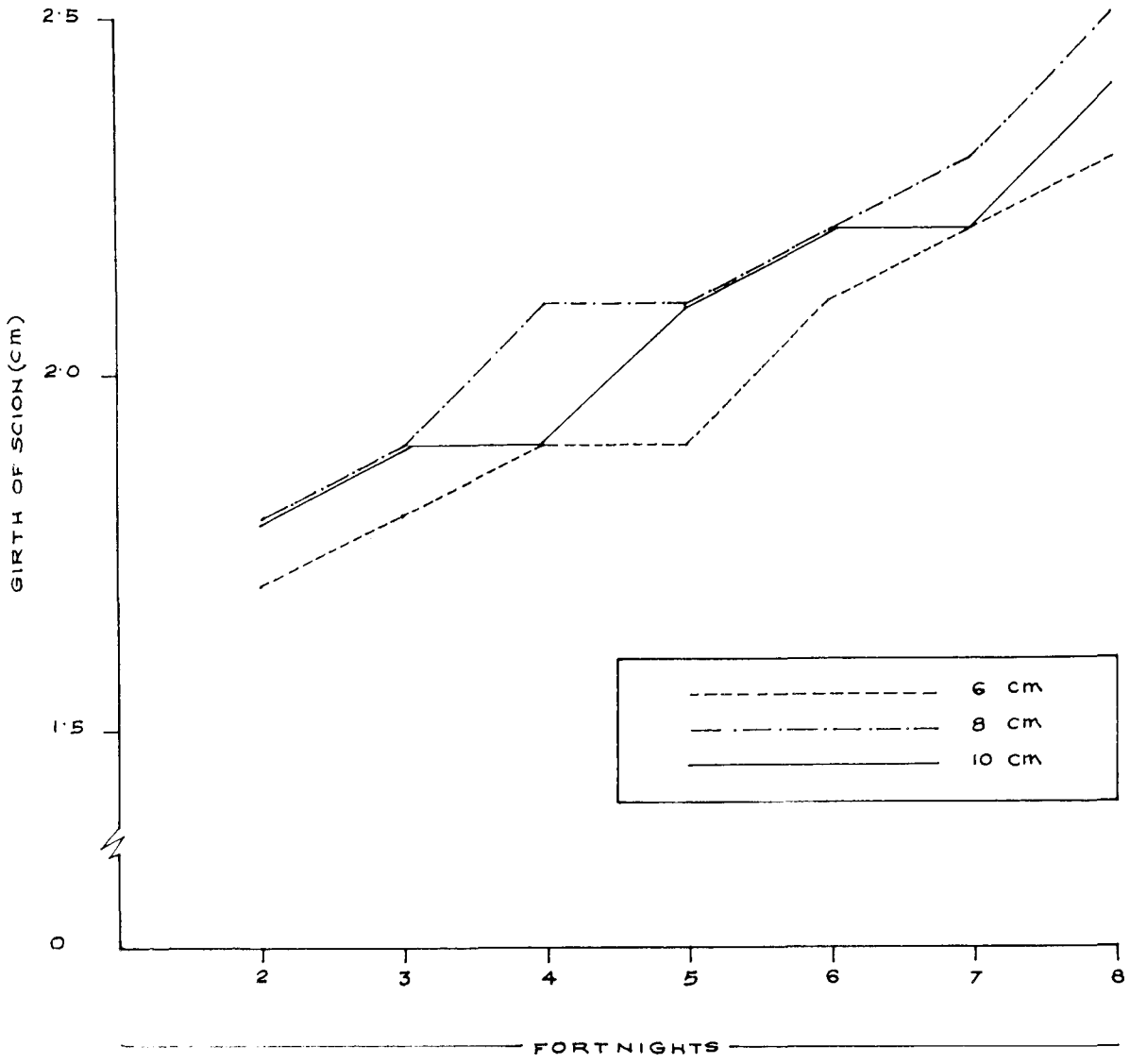


Table 7. Effect of varieties and scion length on girth of new growth at fortnightly intervals

Varieties / Scion length (cm)	2nd Fortnight				3rd Fortnight				4th Fortnight				5th Fortnight			
	Girth of new growth (cm)															
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Mulgoa	1.26	1.64	1.34	1.41	1.32	1.64	1.36	1.44	1.44	1.80	1.56	1.60	1.48	1.86	1.58	1.64
Priur	1.04	1.04	1.00	1.03	1.12	1.30	1.24	1.19	1.22	1.34	1.38	1.31	1.28	1.46	1.38	1.37
Banganappally	1.08	0.98	1.10	1.05	1.26	1.22	1.30	1.26	1.46	1.28	1.36	1.37	1.46	1.40	1.42	1.43
Mundappa	1.54	1.38	1.62	1.51	1.54	1.42	1.64	1.53	1.64	1.46	1.86	1.65	1.68	1.58	1.92	1.73
Banglora	1.46	1.28	1.32	1.35	1.56	1.52	1.54	1.54	1.56	1.66	1.54	1.58	1.66	1.70	1.62	1.66
Alphonso	1.40	1.62	1.40	1.47	1.50	1.78	1.64	1.64	1.54	2.04	1.64	1.75	1.56	2.06	1.66	1.76
Mean	1.30	1.32	1.30	1.31	1.38	1.46	1.45	1.43	1.48	1.60	1.56	1.54	1.52	1.68	1.60	1.76

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	0.24	0.09	0.22	0.08	0.22	0.08	0.08	0.22
Length	NS	0.06	NS	0.05	NS	0.06	NS	0.05
Length for any particular variety	NS	0.15	NS	0.14	NS	0.14	NS	0.13

NS - Not significant

(Contd.)

Table 7.(Contd.) Effect of varieties and scion length on girth of new growth at fortnightly intervals

Varieties / Scion length (cm)	6th Fortnight				7th Fortnight				8th Fortnight			
	Girth of new growth (cm)											
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Mulgoa	1.50	2.02	1.64	1.72	1.54	2.02	1.74	1.77	1.68	2.04	1.84	1.85
Priur	1.46	1.56	1.68	1.57	1.60	1.64	1.78	1.67	1.72	1.74	1.94	1.80
Banganappally	1.68	1.52	1.44	1.55	1.76	1.74	1.62	1.71	1.88	1.88	1.78	1.85
Mundappa	1.74	1.66	1.98	1.79	1.84	1.72	2.00	1.85	1.98	1.92	2.30	2.07
Banglora	1.76	1.78	1.84	1.79	1.94	1.82	1.84	1.87	2.12	2.02	2.00	2.05
Alphonso	1.64	2.12	1.76	1.84	1.88	2.28	1.88	2.01	2.08	2.34	1.92	2.11
Mean	1.63	1.78	1.72	1.71	1.76	1.87	1.81	1.81	1.91	1.99	1.96	1.95

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	0.19	0.07	0.19	0.07	2.49	0.89
Length	NS	0.05	NS	0.04	NS	0.63
Length for any particular variety	0.32	0.12	NS	0.12	NS	1.54

NS - Not significant

was noticed for the variety Priur throughout the period of study except during 6th fortnight when it was on par with the variety Banganappally with regard to this parameter (Fig.9). The girth of new growth was not found to be significantly affected by the scions of lengths 6 cm, 8 cm and 10 cm (Fig.10).

Interaction effect was found to be significant only during 6th fortnight when maximum mean girth (2.12 cm) was observed for variety Alphonso with scion of 8 cm length and minimum (1.44 cm) for the variety Banganapally with scion of length 10 cm (Appendix VIII).

4.2.5 Number of leaves

The significant effect of varieties on number of leaves produced by grafts are clearly evident from the data furnished in Table 3. The mean leaf production was maximum for the variety Banganappally throughout the period of study (Fig.11). During 8th fortnight the variety Banganappally recorded maximum leaf production of 26.4. The variety Bangalora recorded minimum leaf production up to 6th fortnight and this was not significantly different from the varieties Mulgoa, Alphonso and Priur. From 6th fortnight onwards the variety Priur found to produce minimum leaf

FIG. 9. EFFECT OF VARIETIES ON GIRTH OF NEW GROWTH AT FORTNIGHTLY INTERVALS.

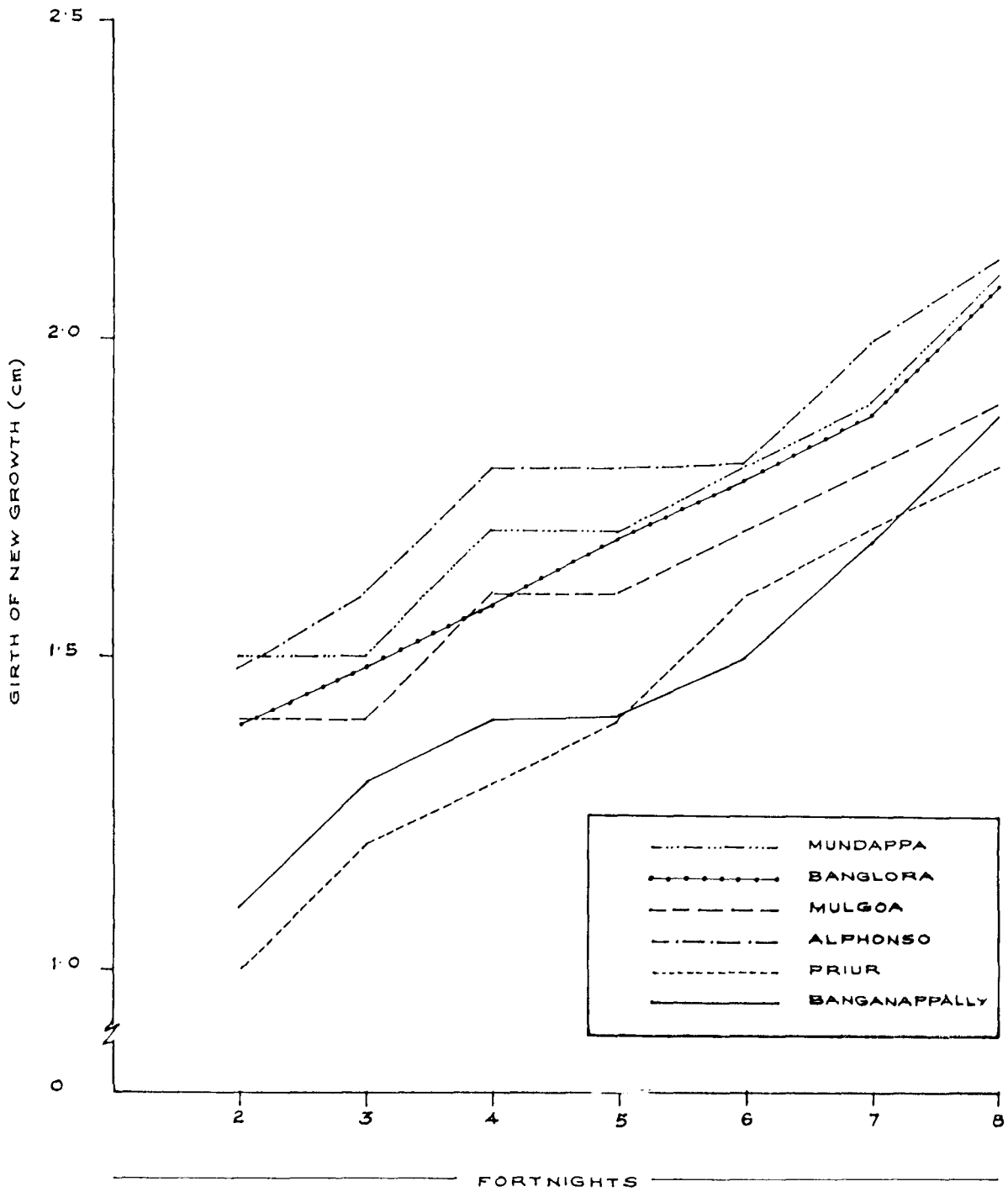


FIG. 10. EFFECT OF SCION LENGTH ON GIRTH OF NEW GROWTH AT FORTNIGHTLY INTERVALS.

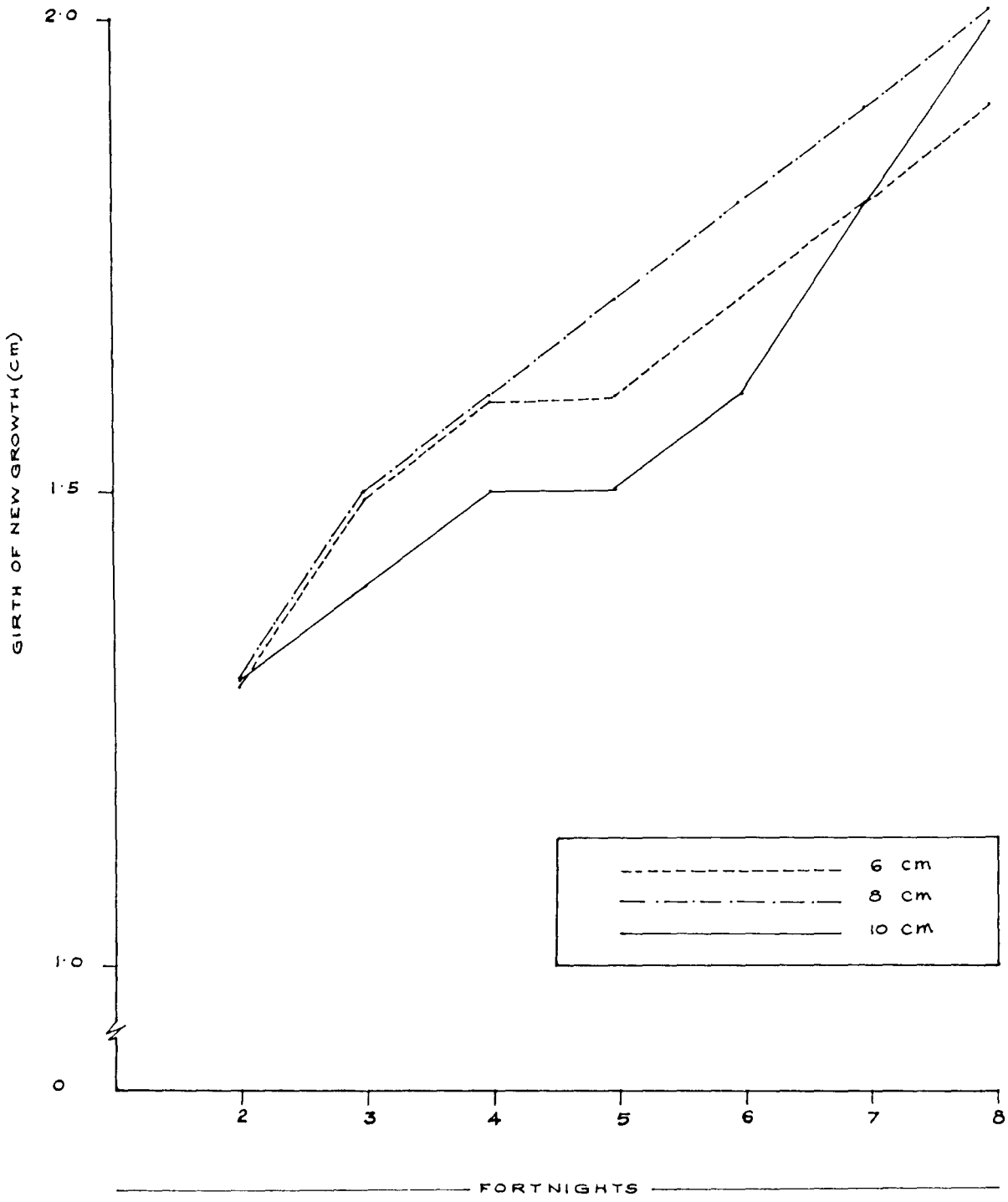


Table 8. Effect of varieties and scion length on number of leaves at fortnightly intervals

Varieties / Scion length (cm)	2nd Fortnight				3rd Fortnight				4th Fortnight				5th Fortnight			
	Number of leaves															
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Bulgoa	8.80	5.80	5.00	6.53	8.60	7.40	5.80	7.27	9.60	10.40	6.60	8.53	9.40	9.80	6.20	8.47
Priur	7.40	8.00	9.20	8.20	7.80	10.40	9.60	9.27	8.80	8.00	9.20	8.67	8.40	8.20	8.80	8.47
Banganappally	13.20	10.40	14.00	12.53	14.00	10.80	13.80	12.87	18.20	11.60	16.80	15.53	17.60	13.20	19.00	16.60
Mundappa	10.00	8.40	9.80	9.40	10.20	8.40	9.80	9.47	9.00	8.40	10.00	9.13	9.00	8.40	10.00	9.13
Banglora	7.20	9.00	3.00	6.40	7.40	6.20	5.20	6.27	7.60	8.00	5.60	7.07	10.20	7.80	5.80	7.93
Alphonso	8.40	8.60	4.60	7.20	7.80	9.60	5.00	7.47	8.20	9.60	5.00	7.60	7.60	14.00	5.80	9.13
Mean	9.17	8.37	7.60	8.38	9.30	8.80	8.20	8.77	10.07	9.33	8.87	9.42	10.37	10.23	9.27	9.96

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	2.49	0.89	2.57	0.91	2.69	0.96	3.26	1.16
Length	NS	0.63	NS	0.64	NS	0.68	N S	0.82
Length for any particular variety	NS	1.54	NS	1.59	NS	1.67	NS	2.01

(Contd.)

NS - Not significant

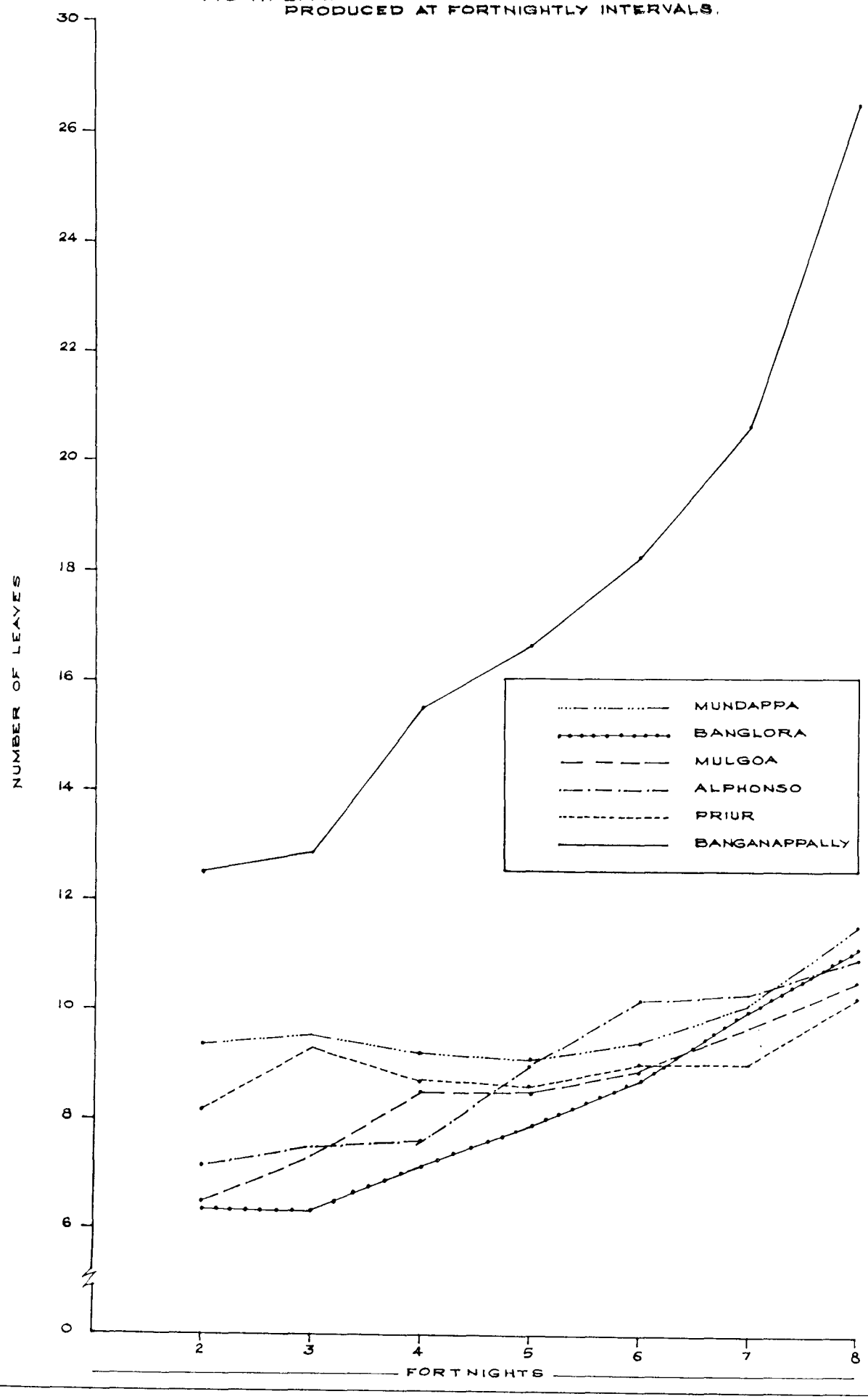
Table 8.(Contd.). Effect of varieties and scion length on number of leaves at fortnightly intervals

Varieties / Scion length (cm)	6th Fortnight				7th Fortnight				8th Fortnight			
	Number of leaves											
	6	8	10	Mean	6	8	10	Mean	6	8	10	Mean
Mulgoa	9.20	10.60	7.00	8.93	11.20	10.80	7.00	9.67	11.20	11.20	9.20	10.53
Priur	9.60	8.20	8.80	8.87	9.00	9.00	9.00	9.00	9.60	10.40	10.60	10.20
Banganappally	18.60	14.40	21.60	18.20	23.80	14.60	23.40	20.60	22.60	26.40	30.20	26.40
Mun	9.20	9.00	10.00	9.40	11.20	9.00	10.00	10.07	13.60	10.80	10.00	11.47
Bang...	9.60	10.20	6.40	8.73	11.20	11.20	7.80	10.07	12.60	11.40	9.20	11.07
Alphonso	7.80	14.80	8.00	10.20	7.80	17.20	5.80	10.27	7.80	19.40	5.80	11.00
Mean	10.67	11.20	10.30	10.72	12.37	11.97	10.50	11.61	12.90	14.93	12.50	13.44

	CD	S.Em ±	CD	S.Em ±	CD	S.Em ±
Varieties	3.27	1.16	3.89	1.38	4.91	1.75
Length	NS	0.82	NS	0.98	NS	1.23
Length for any particular variety	NS	2.01	6.74	2.38	NS	3.02

NS - Not significant

FIG. 11. EFFECT OF VARIETIES ON NUMBER OF LEAVES PRODUCED AT FORTNIGHTLY INTERVALS.



number compared to other varieties. The number of leaves produced in treatments with scions of lengths 6 cm, 8 cm and 10 cm was on par during the course of study (Fig.12).

During 7th fortnight of observation the interaction effect was significant. The treatment combination of variety Bangenapally with scion of lengths 6 cm and 10 cm produced maximum leaf number while the variety Alphonso with scion of 10 cm length produced the minimum leaf number 5.8 (Appendix IX).

4.3 Anatomical studies of the graft union

Anatomical studies were conducted with the objective to find out the steges of graft union formation and the possible reasons for graft failures. The study revealed that the anatomical features and the process of graft union formation were almost quite similar in all the six varieties. The mango stem contains numerous parenchymatous cells in the pith, cluster of vascular bundles, resin canals, xylem parenchyma and fibers, uniseriate and occasionally biseriate vascular rays, numerous tanniferous inclusions, single layer epidermis and a multiple layer cortex with thick walled sclerosed cells. The various steges of development of graft union in different varieties during different periods of observation are illustrated in Plates VIII - XIII.

4.3.1 Formation of graft union

Generally in all the varieties the following four main stages could be distinguished in the formation of stone graft union.

Stage 1 (Precallus - 5 days after grafting). The wounded exposed tissues of stock and scion were found to be brownish when the union was examined 5 days after grafting. Wound periderm was present along with a thick dark brown coating of suberin and resinous contents from several laticiferous canals on external walls of exposed cells. The callus proliferation started from stock side only.

Stage 2 (Callus - 15 days after grafting). Wound periderm on cut surfaces was thicker and darker in colour than in stage 1, and was ruptured in many spots. Callus was proliferated either from stock, or scion or from both components depending upon their activity. Living cells of mainly wood rays in the most recently formed xylem, cambial layers and phloem were involved in the process. Occasionally, cells in the cortex and rarely in the pith also produced callus. Callus from pith involved two types of cells viz., occluded cells and nonoccluded cells. Groups of cells produced by several tissues except those

produced from the pith were so intermingled that their origin could not be distinguished properly. The original cut was easily traced where stock and scion tissues were necrotic or inactive. Callus tissue formed a bridge between the cambium of stock and scion.

Stage 3 (Cambial bridge - 45 days after grafting)

A cambial bridge across the union was well established 45 days after grafting. Cambial layers extended circumferentially straight into the callus on stock side but were strongly arched on scion side. Most of the callus proliferations were originated from stock tissues particularly those adjacent to the cambium. Growth was less active on the scion side in all the varieties and was confined to tissues near the cambium. Differentiation of apperently normal secondary xylem and secondary phloem from cambial layers in the callus was observed in unions examined 45 days after grafting. Wound periderm was not observed at some points and there was a tendency for mixing up of cells between stock and scion.

Stage 4 (Healed union - 90 days after grafting)

The graft union was completed 3 months after insertion of the scion to stock under favourable conditions. Several

continuous cylinders of new tissue between the stock and scion were formed, the wound was properly healed and the graft union was successfully completed. New xylem produced subsequent to grafting was shifted circumferentially in the direction of the scion at a point directly beneath the original wound. Cylinders of xylem produced concurrently were completed and twisted in several location along their perimeter. Cambial layers, phloem, cortex and other tissues lying outside the scion xylem were similarly crumpled and twisted. There was also a thick layer of wound periderm on the surface of the stock on either side in the areas where internal tissues were exerting pressure on the scion. Tissues on the side of the stock opposite to the scion had normal configuration as to direction but layers were much thinner than on the scion side. This unequal growth was the beginning of the final phase of graftage whereby the scion axis was moved laterally to align with the stock axis.

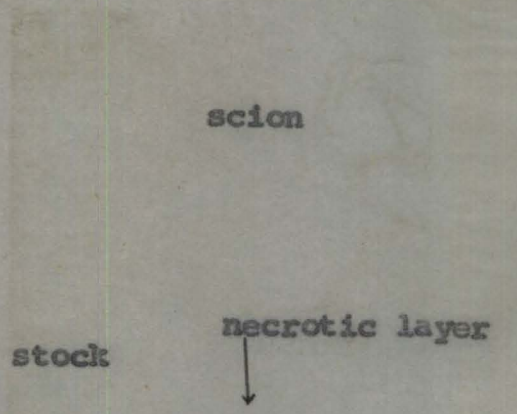
In the present study two types of graft failures were observed, viz., shrinking and drying of scions within 5 to 10 days after grafting, and unsprouted scions remaining green for more than 60 days. Anatomical studies of the first type of graft failure showed no sign of callus

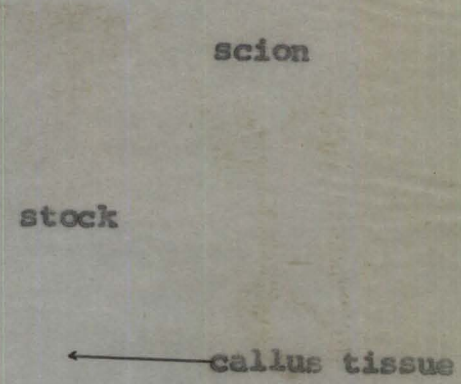
proliferation even after 5 to 10 days of grafting. In such grafts wound periderm was found to be very thick than the successful grafts (Plate XIV) and some of such grafts showed wide gap between stock and scion (Plate XV). The anatomy of second type of graft failure revealed excess production of callus between stock and scion and differentiation was very slow in these cases (Plate XVI). Some of such grafts initiated callus production only from stock side even after 60 days of grafting (Plate XVI).

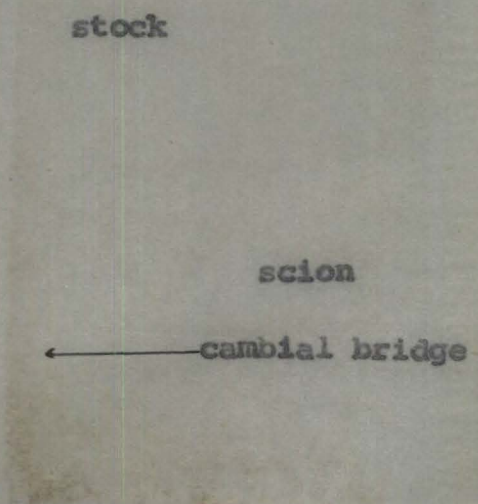
Plate VIII Anatomical stages of the graft union of the variety Pulcea

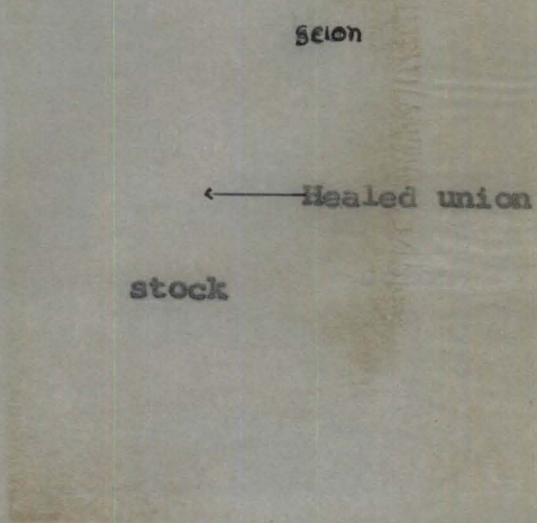
Magnification: 16x10x0.32x2.3 (Stages I & II)

,, : 6.3x10x0.32x2.3 (Stages III & IV)


scion
necrotic layer
stock

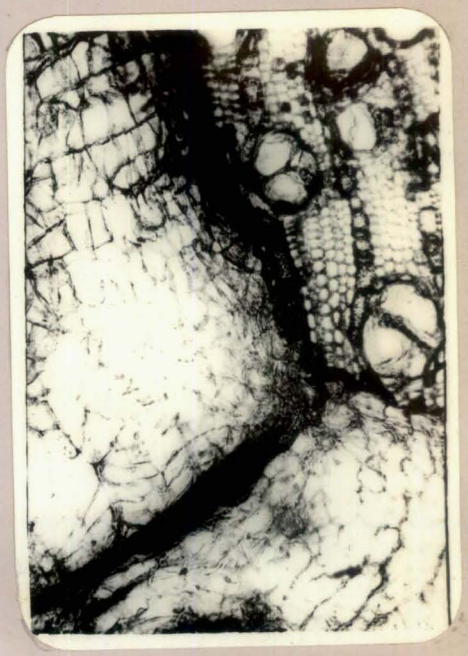

scion
stock
callus tissue


stock
scion
cambial bridge


scion
Healed union
stock

Stage 1 (5 days after grafting)

Stage 2 (15 days after grafting)

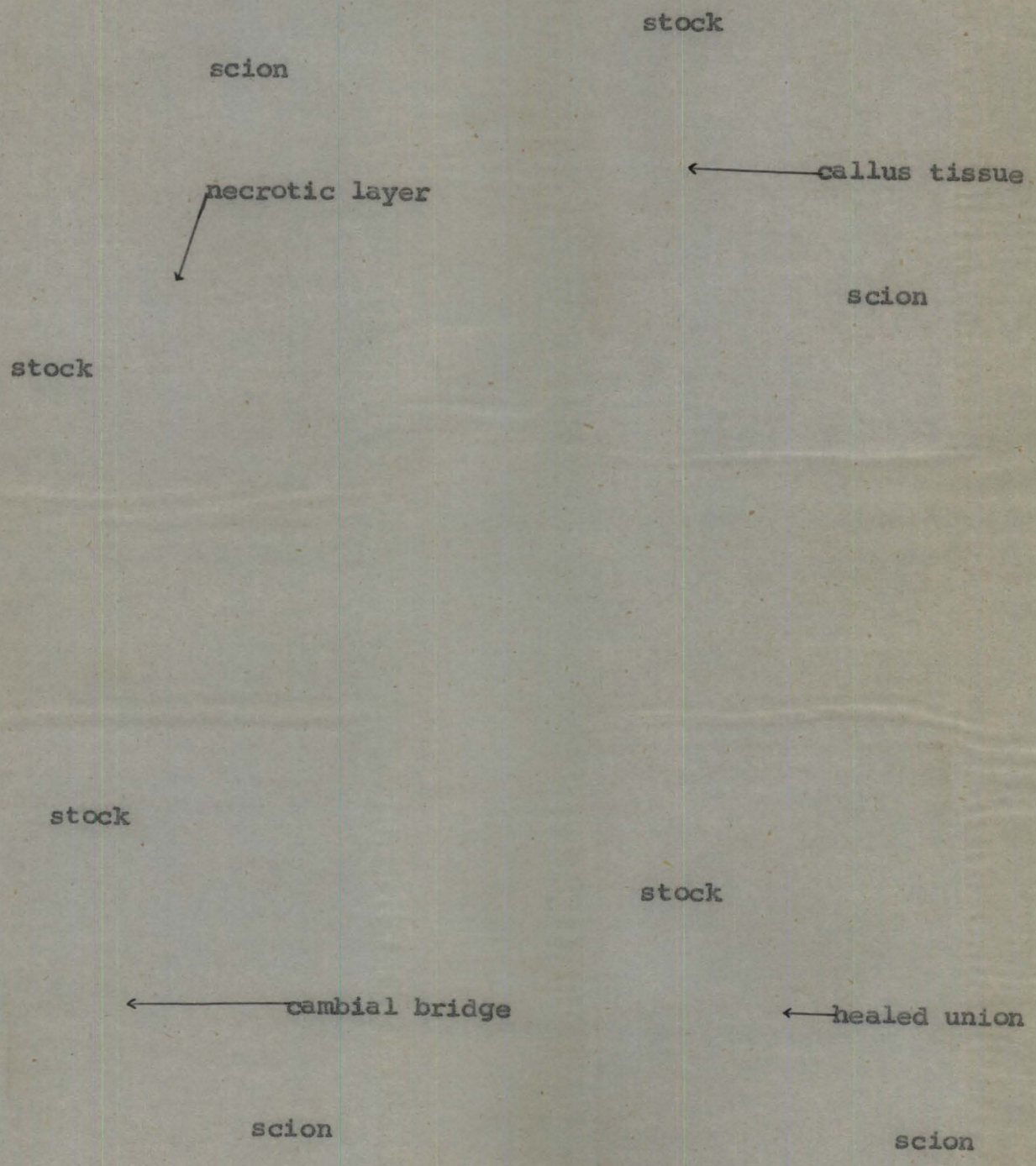


Stage 3 (45 days after grafting)

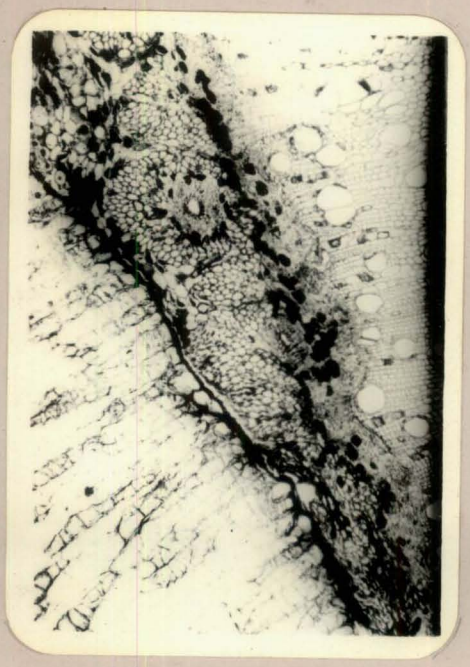
Stage 4 (90 days after grafting)

Plate IX Anatomical stages of the graft union of the variety Priur

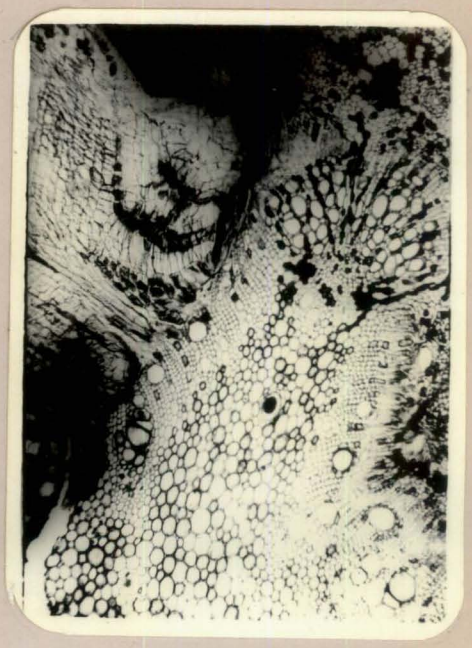
Magnification: 6.3 x 10 x 0.32 x 2.3


stock
scion
callus tissue
necrotic layer
scion
stock
stock
stock
cambial bridge
healed union
scion
scion

Stage 1 (5 days after grafting)



Stage 2 (15 days after grafting)



Stage 3 (45 days after grafting)

Stage 4 (90 days after grafting)

Plate X Anatomical stages of the graft union of the variety Benganappally

Magnification: 6.3 x 10 x 0.32 x 2.3

scion

←necrotic layer

stock

stock

←callus tissue

scion

stock

scion

←combial bridge

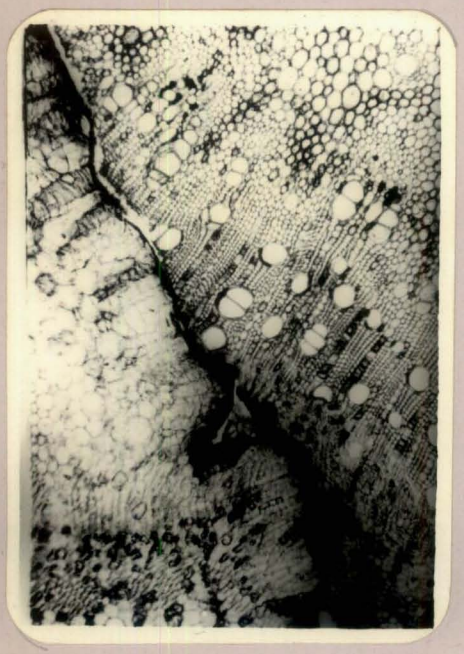
←healed union

←cambium

stock

scion

Stage 1 (5 days after grafting)



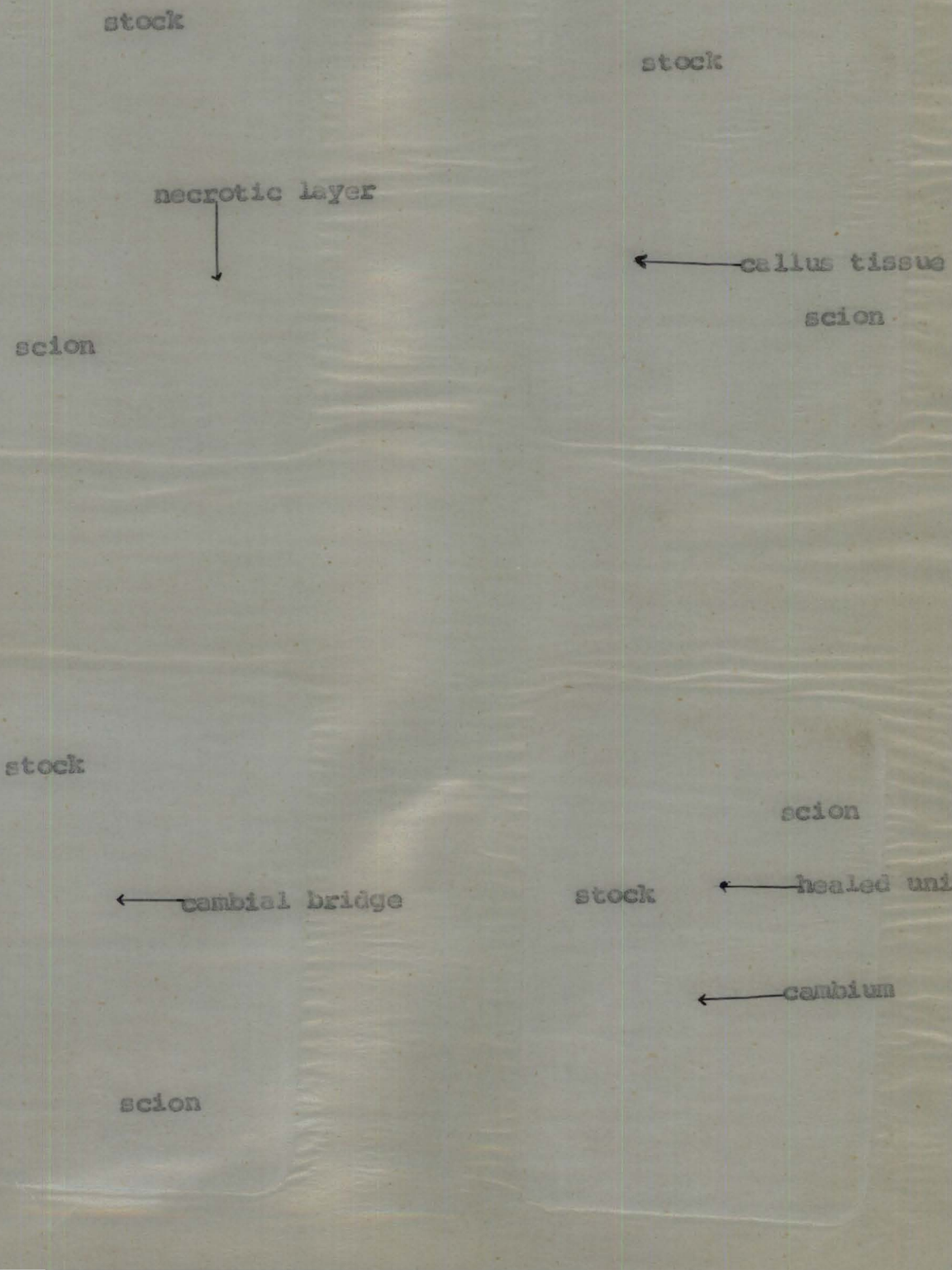
Stage 2 (15 days after grafting)

Stage 3 (45 days after grafting)

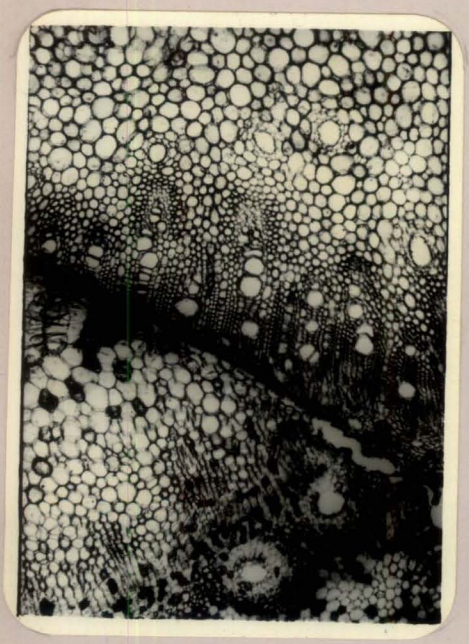
Stage 4 (90 days after grafting)

Plate XI Anatomical stages of the graft union of the variety Mundappa

Magnification: 6.3 x 10 x 0.32 x 2.3


stock
necrotic layer
scion
stock
callus tissue
scion
stock
cambial bridge
scion
scion
stock
healed union
cambium

Stage 1 (5 days after grafting)



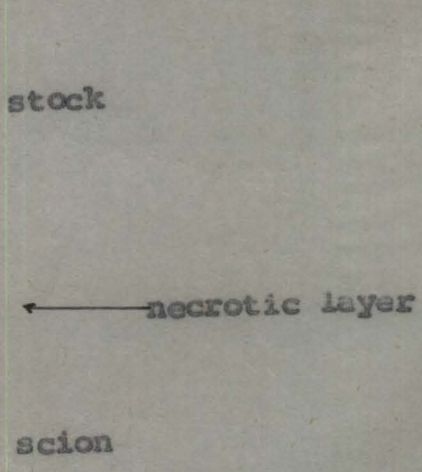
Stage 2 (15 days after grafting)

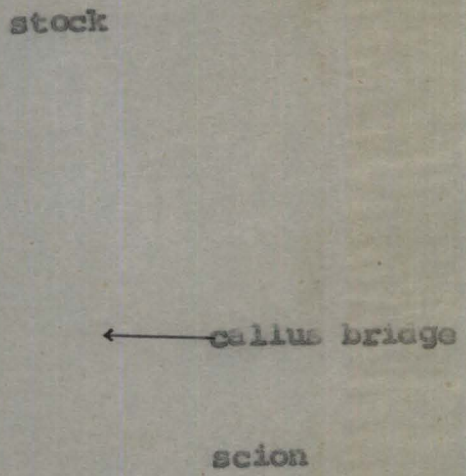
Stage 3 (45 days after grafting)

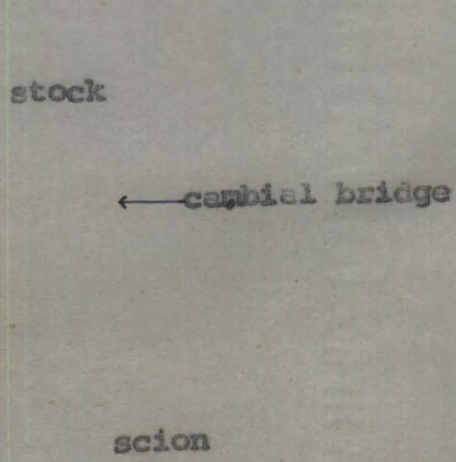
Stage 4 (90 days after grafting)

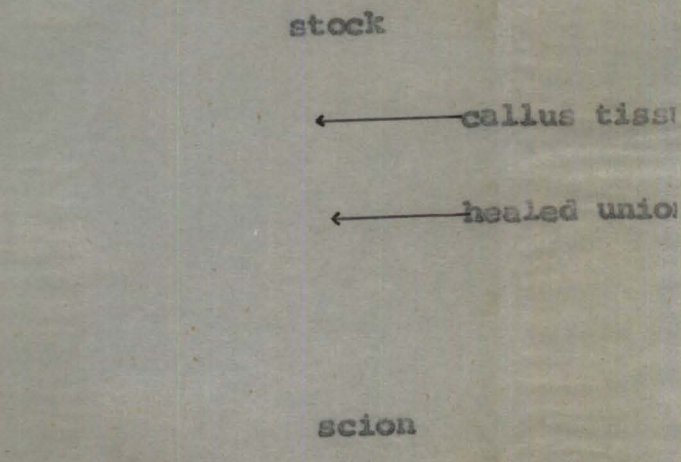
Plate XII Anatomical stages of the graft union of the variety Banglora

Magnification: 6.3 x 10 x 0.32 x 2.3


stock
necrotic layer
scion

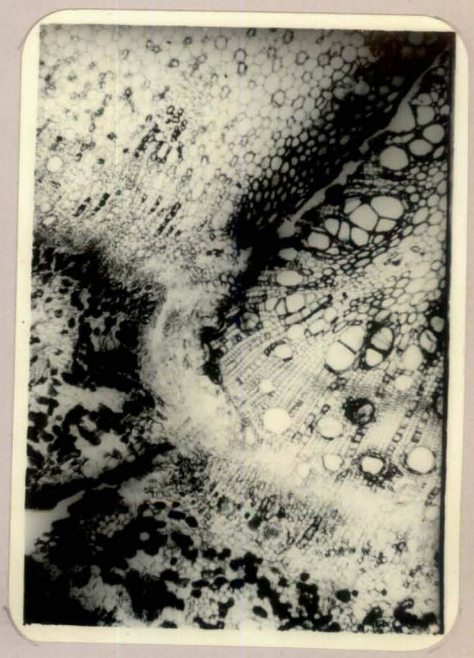

stock
callus bridge
scion


stock
cambial bridge
scion


stock
callus tissu
healed unio
scion

Stage 1 (5 days after grafting)

Stage 2 (15 days after grafting)

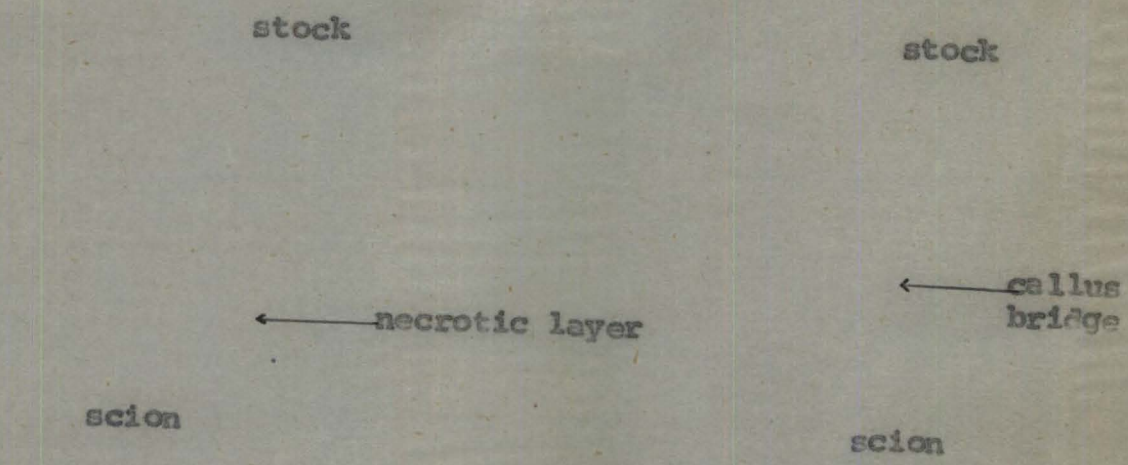


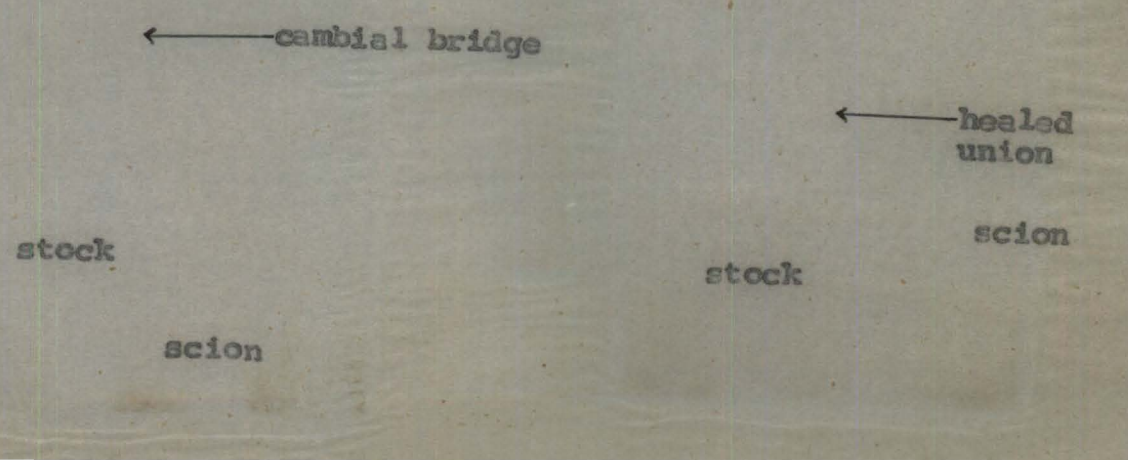
Stage 3 (45 days after grafting)

Stage 4 (90 days after grafting)

Plate XIII Anatomical stages of the graft union of the variety Alphonso

Magnification: 6.3 x 10 x 0.32 x 2.3

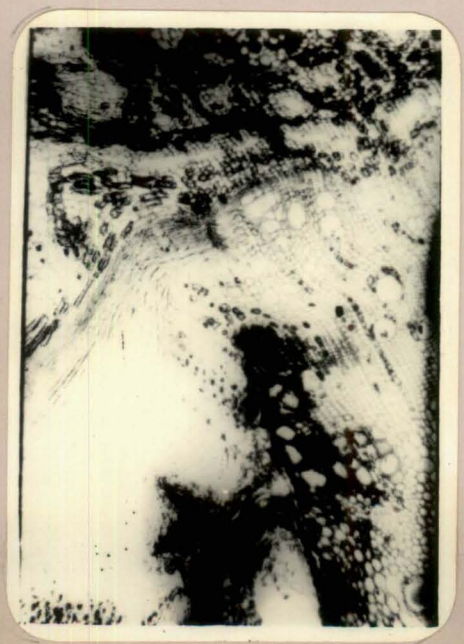

stock
stock
callus bridge
necrotic layer
scion
scion


cambial bridge
healed union
scion
stock
stock
scion

Stage 1 (5 days after grafting)

Stage 2 (15 days after grafting)

Stage 3 (45 days after grafting)



Stage 4 (90 days after grafting)

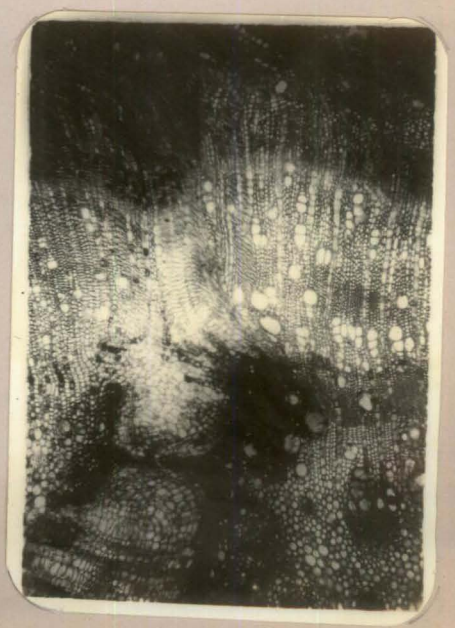


Plate XIV Anatomy of unsuccessful graft showing very thick necrotic layer

Magnification: 6.3 x 10 x 0.32 x 3.4

Plate XV Anatomy of the unsuccessful graft showing wide gap between stock and scion

Magnification: 6.3 x 10 x 6.32 x 3.4

scion

←thick necrotic layer

stock

scion

stock ←wide gap

Plate XIV

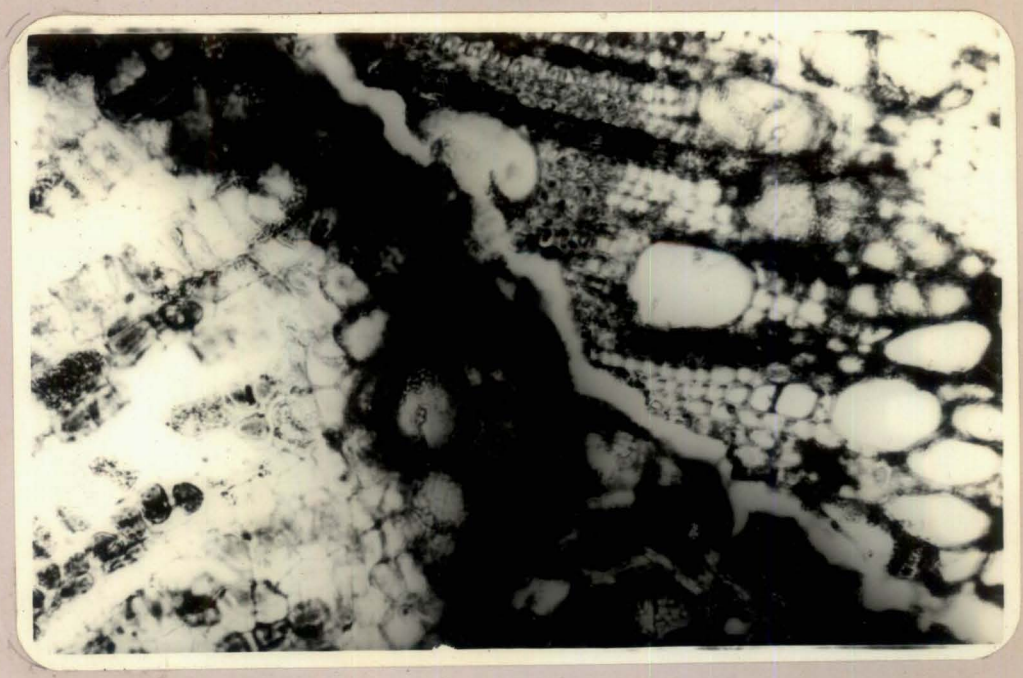


Plate XV

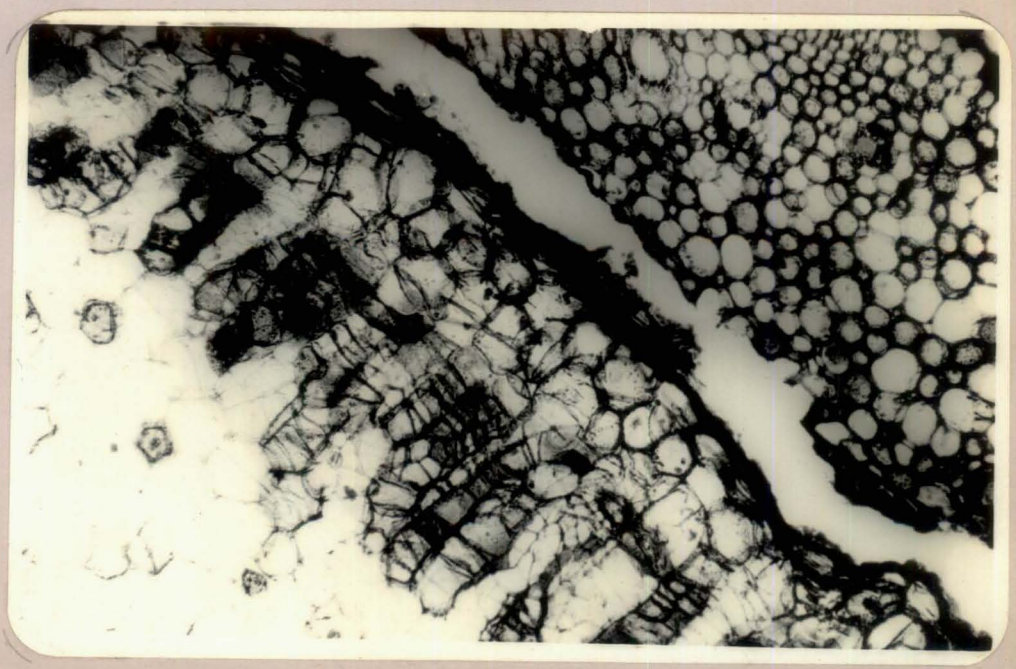
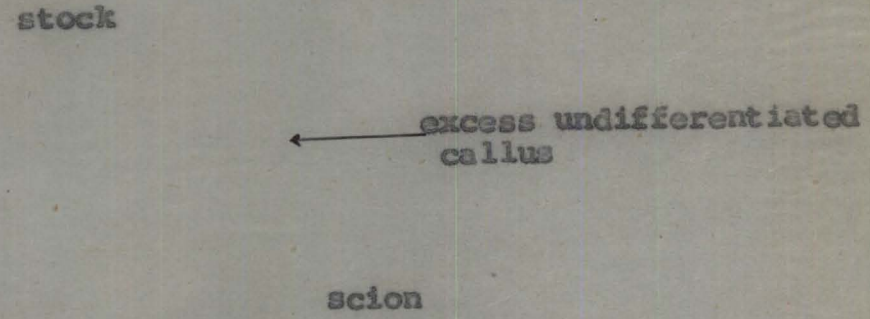


Plate XVI Anatomy of the unsuccessful graft showing excess undifferentiated callus between stock and scion

Magnification: 6.3 x 10 x 0.32 x 3.4

Plate XVII Anatomy of the unsuccessful graft showing callus production only from stock side

Magnification: 6.3 x 10 x 0.32 x 3.4


stock
excess undifferentiated callus
scion

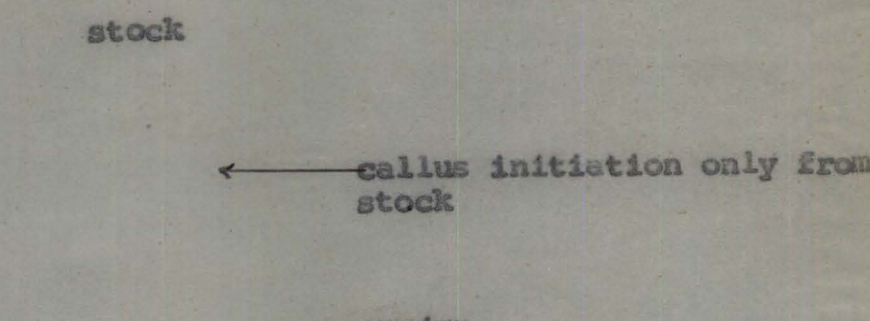

stock
callus initiation only from stock
scion

Plate XVI

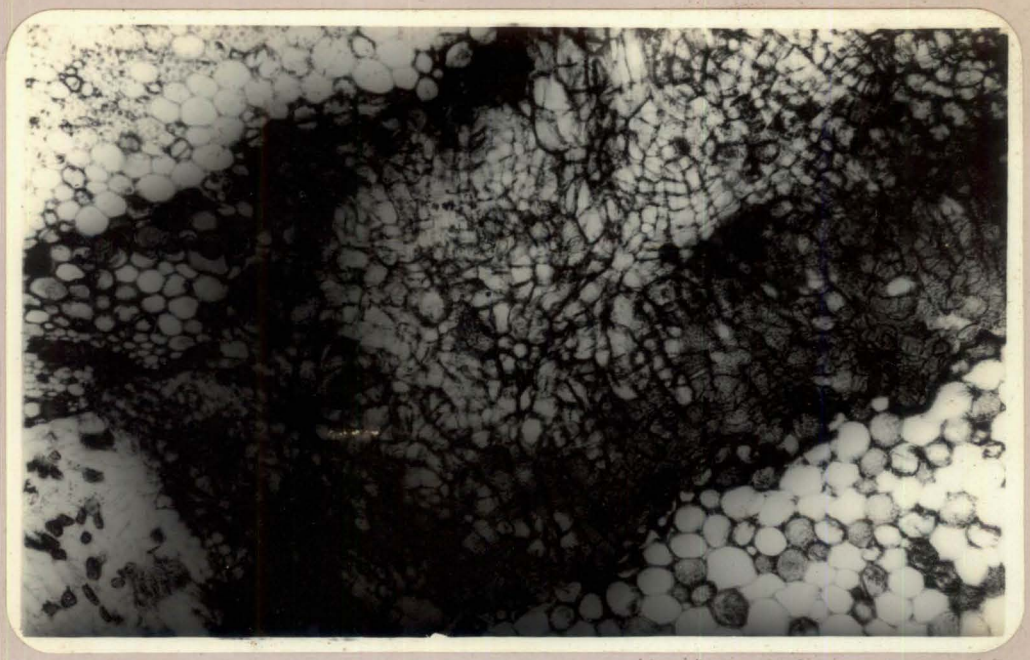
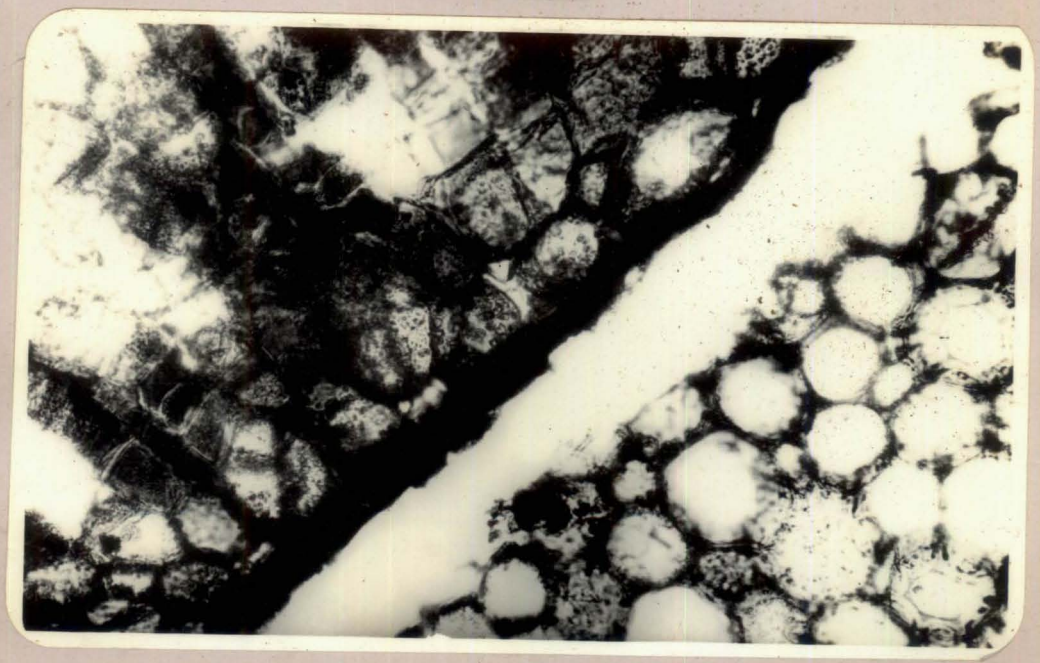


Plate XVII



Discussion

DISCUSSION

The methods of vegetative propagation in mango are known in India since very ancient times as reported by Singh (1960). However, according to Popence (1920) the technique of inarching was first introduced to India by the European missionaries in Goa. Though today this method is in large scale use, this possesses serious difficulties when mother trees located for scion shoots are spread far and wide. Besides, this is expensive and laborious. Hence cheaper and easy methods of producing mango grafts have to be standardised for large scale production of true to type planting materials on a commercial scale. The works initiated in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the years 1982-'85 had given enchanting results and had pointed out the possibility for adopting this technique on a commercial scale in the variety Neelum. In the earlier studies carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara the effect of season, procuring of scion, age of stock and scion, length of scion, covering of grafts with polythene bags and application of fungicides against die-back disease were standardised.

Some anatomical studies were also carried out to find out the various stages of graft union. But, for the earlier studies, only one variety, Neelum was made use of as scion material.

Hence the present series of studies were taken up in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara to find out the response of six varieties of mango viz., Mulgoa, Priur, Banganapally, Mundappa, Banglora and Alphonso for stone grafting. Detailed anatomical studies were also carried out to find out the various stages of graft union in the above six varieties and also the possible reasons for graft failures.

5.1 Effect of varieties and length of scion on sprouting and survival of grafts

The success in any method of grafting greatly depends on the compatibility between stock and scion used. In mango, varietal response to grafting has been clearly demonstrated by many workers (Ahmed, 1964; Mukherjee and Majumdar, 1964; Talukdar and Ahmed, 1965; Jagirdar and Bhatti, 1968; Dhakal, 1979; Maiti and Biswas, 1980, Singh and Srivastava, 1981; Dhungana, 1984; Kulwal and Tayde, 1985 a and Kulkarni *et al*., 1985).

In the present study, scion materials from six different varieties were stone grafted on a common rootstock and the results indicated that the length of scion and the varieties have profound effect on success and survival of grafts. The higher percentage of sprouting (84 per cent) was obtained for the variety Banganapally with scion of length 8 cm and 10 cm and for the variety Priur with scion of length 8 cm. It could also be seen that the variety Priur recorded maximum survival (54 per cent) with the scion of length 8 cm while survival was least (12 per cent) for the variety Mulgoa with scion of length 6 cm.

The varietal difference in response to stone grafting might be due to the variation in the genetic make up which influences the histological and physiological developments within the scion shoots. The differential response of varieties might have some relationship with the growing habit or other genetic factors of the tree. Mukherjee and Majumdar (1964) observed that the success in veneer grafting of mango depends upon the active growing phase of the mother tree. From the results of the present study it would be stated that stone grafting is most suitable for the varieties, Banganapally and Priur.

However, further detailed investigation using large number of varieties and their evaluation based on physiological factors may bring out still more interesting results.

The studies on length of scion for stone grafting clearly showed that initial sprouting was not influenced by length of scion. However, highest percentage of survival (40.33 per cent) was observed for the scion of length 8 cm and minimum (27.66 per cent) for the scion of length 6 cm. The effect of scion length in success of graft take was established by several research workers (Parsai, 1963; Kanwar and Bajwa, 1974; Maiti and Biswas, 1980; and Ram and Bist, 1982). The results obtained in the present study also agrees with the findings of Dhungana (1984) and Ratan (1985) who found that scion of length 8 cm was the best suited for stone grafting compared to scions of other lengths. The superiority of 8 cm long scions could perhaps be attributed to higher reserve food materials in them compared to shorter lengths. In shorter scions exhaustion of food materials would have taken place before the union is completed. Fahmy (1952) observed strong positive correlation between the amount of carbohydrate in scion shoots and graft union in Macadamia and Sapodilla. However, Dhakal (1979) did not observe any

significant difference in success between scions of varying lengths.

5.2 Effect of varieties and length of scion on growth parameters of grafts

In the present study observations on growth of scion showed that the variety Mulgoa recorded maximum mean growth followed by variety Banganapally and that growth of scion was not influenced significantly by different lengths of scion used. But Majumder et al. (1972) in their experiments on veneer grafting in mango using scions of different lengths observed that subsequent growth after grafting was more with longer scions. But according to Ratan (1985) the length of scion appeared to be more concerned with graft union rather than the subsequent growth of grafts.

Observations on girth of rootstock for various treatment combinations revealed that varieties had significant effect on girth of rootstock only during the initial stages of growth and length of scion did not have any influence on this parameter.

In the present study there was high significant difference in girth of scion between different varieties

throughout the course of study. During 2nd and 3rd fortnights the variety Banglora recorded maximum mean girth of 2.19 cm and 2.23 cm respectively and thereafter mean girth of scion was found to be maximum for the variety Mundappa. Amin (1978) also observed differential response with regard to girth of scion in softwood grafting of mango. The genetic make up of the varieties would have some relationship with growing habit of grafted plants. The observations also revealed that with regard to girth of scion there was no significant difference between scion of length 6 cm, 8 cm and 10 cm.

The observations on the number of leaves produced by grafted plants showed that mean leaf production was maximum for the variety Banganapally throughout the period of study which is probably due to the better graft take in this variety compared to other varieties. However, the number of leaves produced in treatments with scion of lengths 6 cm, 8 cm and 10 cm was on par during the course of study. Bhungena (1984) and Retan (1985) also did not observe any significant difference in leaf production with scions of lengths 5 cm, 6 cm and 8 cm in stone grafting of mango using the variety Neelum.

5.3 Anatomical studies of the graft union

Detailed anatomical studies of the graft union of all the varieties revealed four distinct stages in graft union viz., development of pre-callus, callus, cambial bridge and healed union. Juliano (1941) studied the callus development and observed that the first stage in the formation of graft union was the formation of callus cushion in the gap through the activity of parenchymn of both bark and pith. From this callus a cambial bridge was developed joining the cambial ends of both stock and scion. In the present study pre callus formation was noticed after five days of grafting and callus formation after 15 days of grafting. Callus proliferated either from stock or scion or from both components depending upon the activity. The histological studies conducted by Luthra and Sharma (1940) showed that callus development took place both from stock and scion in the variety Langra when used as scion. Occasionally cells in the cortex and rarely in the pith also produced callus. A cambial bridge across the union was well established 45 days after grafting. Cambial layers extended circumferentially straight into the callus on stock side but were strongly arched on scion side as was reported by

Ratan (1985). The growth was less active on the scion side and the degree of callus formation varied between varieties. Auramov and Jokovic (1961) also observed that callus formation differed between the varieties and was highly influenced by rootstock and weather conditions prevailed during previous growing season.

The graft union was found to be completed within three months after insertion of scion to rootstock. Several continuous cylinders of new tissue between stock and scion were found healing the wound and the graft union was completed. New xylem produced subsequent to grafting was shifted circumferentially in the direction of scion at the point directly beneath the original wound as was reported by Chakrabarti and Sadhu (1985). Esau (1970) conducted studies on graft union and observed that secondary growth and cambial activity were involved in the proper graft union formation. The break down products of dead cells on surface of stock and scion formed a necrotic layer. Intact cells next to necrotic layer enlarged, divided and formed callus tissue which filled the space left between stock and scion. Eventually, the cambia between stock and scion became continuous across the callus by the differentiation of callus cells into cambial cells which later formed vascular tissues.

Anatomical studies to find out the possible reasons for graft failure revealed that in cases where there was shrinking and drying of scion within a few days of grafting there was no callus formation even after 5 to 10 days of grafting. It might be due to the formation of very thick necrotic layer in the wounded exposed surfaces of stock and scion. Soule (1971) reported that thick necrotic layers were due to deep crushing of cells during wrapping which contributed for graft failures. Raton (1985) observed no cell differentiation in the cut portions of stock even after 7 days of grafting. Moreover, in such cases thick necrotic layers were also seen to have developed. Some of the unsuccessful grafts showed wide gap between stock and scion. Irregular surfaces of cut portions of stock and scion were also observed in the present study which is in agreement with the reports of Copes (1969) who stated that poorly matched stock and scion resulted in very slow cambial union and delayed bud sprouting. This emphasises the skill and care required for stone grafting operation in mango.

The anatomy of unsuccessful grafts which remained green for more than 60 days showed excess callus proliferation between stock and scion and differentiation

was very slow in such cases. Some of the unsuccessful grafts initiated callus production only from stock side even after 60 days of grafting. Luthra and Sharma (1946) observed excessive growth of Parenchymatous cells between stock and scion and distortion of xylem elements that blocked the conducting vessels which later inhibited the movement of water from stock to scion resulting in graft failures. Turkovac (1962) observed excessive undifferentiated callus or other irregular growths at the union of incompatible combinations of stock and scion. Robert (1949) stated that important factors determining the graft take was not the nature of the graft union but genetically determined interaction between stock and scion. In mango although stock and scion are not biochemically or genetically found apart the possibility of some of these factors interfering the healing process cannot be ruled out. In the present study some of the above factors discussed might have been responsible for the low percentage of graft take in Mulgoa and Alphonso.

Summary

SUMMARY

In the present investigation an attempt has been made to evaluate the response of different varieties of scion with varying lengths for stone grafting based on the results of the earlier works carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara for the standardisation of various aspects of stone grafting techniques in mango. Detailed anatomical studies of the graft union of all the selected varieties were also conducted to find out the various stages of graft union and the possible reasons for graft failure. The salient results are summarised below.

1. The results of the study on the response of varieties and lengths of scion on graft take indicated highest percentage of sprouting (84 per cent) for the variety Banganappally with scion of lengths 8 cm and 10 cm and for the variety Priur with scion of length 8 cm. The sprouting was poor for the variety Alphonso (53 per cent) with scion of lengths 8 cm and 10 cm.

2. The variety Priur recorded maximum survival (54 per cent) with scion of length 8 cm while the variety Mulgoa with scion of length 6 cm recorded minimum survival (12 per cent).

3. The observations on growth parameters revealed that the variety Mulgoa recorded maximum mean growth followed by the variety Banganapally up to 4th fortnight. The least extension growth was recorded by the variety Bangalora up to 5th fortnight and thereafter the variety Mundappa registered the least value with regard to this parameter.

4. The girth of scion was found to be influenced by the varieties throughout the period of observation while the girth of rootstock was influenced by the varieties only during initial stages of growth.

5. With regard to girth of new growth interaction effect was significant only during 6th fortnight of observation when maximum mean girth (2.12 cm) was observed for the variety Alphonso with the scion of length 8 cm and minimum for Banganapally (1.44 cm) with the scion of length 10 cm.

6. The highest and the lowest leaf production was noticed respectively for the varieties Banganappally and Bangalora particularly during the initial stages of grafting.

7. In the present study the growth parameters viz., growth of scion, girth of scion, girth of new growth, girth of rootstock and leaf production were not influenced significantly by varying lengths of scion used.

8. Anatomical studies revealed four distinct stages in the healing process of graft union. The cambial bridge across the union was well established 45 days after grafting. Most of the callus proliferation was originated from stock tissues particularly those adjacent to cambium. The union was completed 3 months after grafting operation. Several continuous cylinders of new tissues between stock and scion were found, the wound was properly healed and the graft union was successfully completed.

9. Anatomical studies to find out the possible reasons for graft failure revealed that in cases where

there was shrinking and drying of scion within a few days of grafting, there was no callus formation even after 5 to 10 days of grafting operation. Very thick necrotic layers were seen developed in the wounded exposed surfaces of stock and scion. Some of the unsuccessful grafts showed wide gap between stock and scion.

10. The unsuccessful grafts which remained green for more than 60 days indicated excess callus proliferation between stock and scion and the differentiation was very slow in such cases. Some of the grafts initiated callus production only from stock side even after 60 days of grafting.

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* Originals not seen

Appendices

APPENDIX - I

Chi-square values for comparisons between pair of varieties and scion length with [illegible] number of sprouting of grafts

rieties/ ngth	V_1L_1	V_1L_2	V_1L_3	V_2L_1	V_2L_2	V_2L_3	V_3L_1	V_3L_2	V_3L_3	V_4L_1	V_4L_2	V_4L_3	V_5L_1	V_5L_2	V_5L_3	V_6L_1	V_6L_2	V_6L_3
L_1	-	0.48	2.37	0.05	0.58	0.48	3.04	0.58	0.58	0.21	0.22	0.06	0.25	-	-	2.37	4.59*	4.59*
L_2	-	-	0.73	2.08	2.09	-	1.13	2.09	2.09	0.05	0.05	0.88	1.41	0.48	0.48	0.73	2.15	2.15
L_3	-	-	-	0.99	5.19*	0.73	0.04	5.19*	5.19*	1.16	1.16	3.17	4.10*	2.37	2.37	-	0.37	0.37
L_1	-	-	-	-	1.00	0.20	2.29	1.00	1.00	0.05	0.05	0.23	0.54	0.05	0.05	1.71	3.66	3.66
L_2	-	-	-	-	-	2.09	6.13*	-	-	1.50	1.50	0.27	0.07	0.65	0.65	5.19*	8.20**	8.20**
L_3	-	-	-	-	-	-	1.13	2.09	2.09	0.05	0.05	0.88	1.41	0.48	0.48	0.73	2.15	2.15
L_1	-	-	-	-	-	-	-	6.13**	6.13**	1.65	1.65	3.93*	4.96*	3.04	3.04	0.04	0.16	0.16
L_2	-	-	-	-	-	-	-	-	-	1.50	1.50	0.27	0.07	0.65	0.65	5.19*	8.20**	8.20**
L_3	-	-	-	-	-	-	-	-	-	1.50	1.50	0.27	0.07	0.65	0.65	5.19*	8.20**	8.20**
L_1	-	-	-	-	-	-	-	-	-	-	-	0.50	0.93	0.21	0.21	1.16	2.85	2.85
L_2	-	-	-	-	-	-	-	-	-	-	-	0.50	0.93	0.21	0.21	1.16	2.85	2.85
L_3	-	-	-	-	-	-	-	-	-	-	-	-	0.06	0.06	0.06	3.17	5.65*	5.65*
L_1	-	-	-	-	-	-	-	-	-	-	-	-	-	0.27	0.27	4.10*	6.85**	6.85**
L_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.37	4.59*	4.59*
L_3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.37	4.59*	4.59*
L_1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.37	0.37
L_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
L_3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

V - Varieties

V_1 = Mulgoa
V_2 = Priur
V_3 = Bangenapally
V_4 = Mundappa
V_5 = Banglora
V_6 = Alphonso

L - Length of scion

L_1 - 6 cm
L_2 - 8 cm
L_3 - 10 cm

* Significant at 5% level
** Significant at 1% level

APPENDIX - II

Chi-square values for comparisons between pair of varieties and scion length with regard to number of survival of grafts

rieties/ ngth	V_1l_1	V_1l_2	V_1l_3	V_2l_1	V_2l_2	V_2l_3	V_3l_1	V_3l_2	V_3l_3	V_4l_1	V_4l_2	V_4l_3	V_5l_1	V_5l_2	V_5l_3	V_6l_1	V_6l_2	V_6l_3
l_1	-	1.77	1.77	5.82*	19.9**	6.83**	6.83**	16.88**	15.42**	4.88*	5.82*	14.03**	6.83**	14.03**	9.01**	2.43	9.01*	1.77
l_2	-	-	-	5.20*	10.86**	1.78	1.78	8.50**	7.40**	0.83	1.20	6.40*	1.78	6.40*	3.04	0.05	3.04	0.00
l_3	-	-	-	1.23	10.86**	1.78	1.78	8.50**	7.40**	0.83	1.20	6.40*	1.78	6.40*	3.04	0.05	3.04	0.00
l_1	-	-	-	-	4.93*	0.04	0.04	3.34	2.60	0.04	0.00	2.05	0.04	2.05	0.39	0.79	0.39	1.20
l_2	-	-	-	-	-	4.05*	4.05*	0.16	0.36	5.91*	4.93*	4.93*	4.05*	0.64	2.57	9.45**	2.57	10.86**
l_3	-	-	-	-	-	-	0.00	2.62	2.02	0.18	0.04	1.50	0.00	1.50	0.17	1.20	0.17	1.78
l_1	-	-	-	-	-	-	-	2.62	2.02	0.18	0.04	1.50	0.00	1.50	0.17	1.20	0.17	1.78
l_2	-	-	-	-	-	-	-	-	0.04	4.16*	3.34	0.16	2.62	0.16	1.46	7.25**	1.46	8.50**
l_3	-	-	-	-	-	-	-	-	-	3.40	2.60	0.04	2.02	0.04	1.01	6.25*	1.01	7.40**
l_1	-	-	-	-	-	-	-	-	-	-	0.04	2.71	0.18	2.71	0.71	0.45	0.71	0.83
l_2	-	-	-	-	-	-	-	-	-	-	-	2.05	0.04	2.05	0.39	0.79	0.39	1.20
l_3	-	-	-	-	-	-	-	-	-	-	-	-	1.50	0.00	0.65	5.30*	0.65	6.40*
l_1	-	-	-	-	-	-	-	-	-	-	-	-	-	1.50	0.17	1.20	0.17	1.78
l_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.65	5.30*	0.65	6.40*
l_3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.29	-	3.04
l_1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.29	0.05
l_2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.04
l_3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Varieties

V_1 - Mulgoa
V_2 - Priur
V_3 - [illegible]
V_4 - Mundappa
V_5 - Banglora
V_6 - Alphonso

L - Length of scion

l_1 = 6 cm
l_2 - 8 cm
l_3 - 10 cm

* Significant at 5% level
** Significant at 1% level

APPENDIX - III

Chi-square values for comparison between pairs of varieties with regard to the sprouting and survival of grafts

		Sprouting						Survival					
		V_1	V_2	V_3	V_4	V_5	V_6	V_1	V_2	V_3	V_4	V_5	V_6
V_1	Mulgoa	-	0.18	0.31	0.48	2.58	13.26**	-	16.47**	22.37**	11.34**	15.55**	3.65
V_2	Priur	-	-	2.83	0.03	1.62	10.40**	-	-	0.49	0.50	0.01	9.50**
V_3	Banganappally	-	-	-	0.02	1.10	9.62**	-	-	-	2.00	0.70	8.33**
V_4	Mundappa	-	-	-	-	1.70	8.88**	-	-	-	-	0.35	2.20
V_5	Banglora	-	-	-	-	-	4.27*	-	-	-	-	-	4.31*
V_6	Alphonso	-	-	-	-	-	-	-	-	-	-	-	-

* Significant at 5% level

** Significant at 1% level

APPENDIX IV

Chi-square values for comparison between pairs of length of scion with regard to sprouting and survival of grafts

Comparison			Chi-square value	
			Sprouting	Survival
6 cm	Vs	8 cm	0.42	10.72**
8 cm	Vs	10 cm	0.42	1.82
6 cm	Vs	10 cm	-	3.74

APPENDIX - V

Analysis of variance for the effect of varieties and scion length on growth of scion at fortnightly intervals

Source	d.f.	Mean squares at fortnightly intervals						
		2	3	4	5	6	7	8
Varieties	5	36.90**	37.53**	82.00**	84.75**	125.14**	119.44**	236.52**
Scion length	2	0.87	9.79	2.63	8.87	30.13	42.33	72.97
Interaction	10	8.73	7.67	23.25*	29.87*	44.93*	55.05**	77.12**
Error	72	8.67	8.93	11.68	15.11	17.51	19.82	29.49
Total	89	-	-	-	-	-	-	-

* Significant at 5% level
** Significant at 1% level

APPENDIX - VI

Analysis of variance for the effect of varieties and scion length on girth of rootstock at fortnightly intervals

Source	d.f.	Mean squares at fortnightly intervals						
		2	3	4	5	6	7	8
Varieties	5	2.02**	1.82**	0.96**	0.18	0.09	0.07	0.08
Scion length	2	0.29	0.29	0.01	0.11	0.27	0.15	0.19
Interaction	10	0.11	0.11	0.12	0.19	0.22*	0.16	0.15
Error	72	0.09	0.94	0.08	0.07	0.10	0.14	0.14
Total	89	-	-	-	-	-	-	-

* Significant at 5% level

** Significant at 1% level

APPENDIX - VII

Analysis of variance for the effect of varieties and scion length on girth of scion at fortnightly intervals

Source	d.f.	Mean squares at fortnightly intervals						
		2	3	4	5	6	7	8
Varieties	5	2.87**	2.34**	1.69**	1.12**	0.79**	0.84	0.62**
Scion length	2	0.20	0.23	0.15	0.20	0.08	0.05	0.13
Interaction	10	0.19	0.11	0.16	0.08	0.12*	1.10	0.30
Error	72	0.12	0.11	0.09	0.07	0.06	0.06	0.08
Total	89	-	-	-	-	-	-	-

* Significant at 5% level

** Significant at 1% level

APPENDIX - VIII

Analysis of variance for the effect of varieties and scion length on girth of new growth at fortnightly intervals

Source	d.f.	Mean squares at fortnightly intervals						
		2	3	4	5	6	7	8
Varieties	5	0.68**	0.47**	0.46**	0.37**	0.23**	0.23**	0.28**
Scion length	2	0.01	0.06	0.11	0.18	0.17	0.09	0.06
Interaction	10	0.08	0.06	0.14	0.11	0.16*	0.13	0.13
Error	72	0.11	0.10	0.09	0.10	0.07	0.07	0.08
Total	89	-	-	-	-	-	-	-

* Significant at 5% level
** Significant at 1% level

APPENDIX - IX

Analysis of variance for the effect of varieties and scion length on the production of number of leaves

Source	d.f.	Mean squares at fortnightly intervals						
		2	3	4	5	6	7	8
Varieties	5	81.14**	83.22**	142.98**	162.07**	205.61**	233.93**	607.16**
Scion length	2	18.41	9.10	10.98	10.81	6.15	28.98	51.08
Interaction	10	20.06	12.62	21.75	35.06	35.97	68.74*	66.30
Error	72	11.78	12.45	13.72	20.13	20.19	28.67	45.68
Total	89	-	-	-	-	-	-	-

* Significant at 5% level

** Significant at 1% level

VARIETAL RESPONSES OF SCION TO STONE GRAFTING IN MANGO FOR COMMERCIAL PROPAGATION

By

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ABSTRACT OF THESIS

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ABSTRACT

The present series of studies were carried out in the Department of Pomology and Floriculture, College of Horticulture, Vellanikkara during the period from May 1985 to December 1986 with the objective of studying the response of varieties of scion shoots with varying lengths for stone grafting in mango. Scion shoots of three different lengths viz., 6 cm, 8 cm and 10 cm collected from six varieties of mango viz., Maigoa, Priur, Banganappally, Mundappa, Bangalora and Alphonso were used for grafting operation. Detailed anatomical studies of graft union of all the selected varieties were also conducted to find out the various stages of graft union and the possible reasons for graft failures.

The results of the experiment on the response of varieties and length of scion indicated highest percentage of sprouting for the variety Banganappally with scion of lengths 8 cm and 10 cm and for Priur with scion of length 8 cm, while sprouting was poor for the variety Alphonso with scion of lengths 8 cm and 10 cm. The variety Priur recorded maximum survival with the scion of length 8 cm

while the variety Mulgoa with the scion of length 6 cm recorded least survival.

The experiment to find out the effect of varieties and length of scion on growth parameters revealed that the variety Mulgoa recorded maximum mean growth followed by the variety Banganappally up to 4th fortnight and that growth of scion was not influenced significantly by different lengths of scion used for grafting. The varieties had significant effect on girth of rootstock only during the initial stages of growth while girth of scion was influenced by varieties throughout the period of observations. With regard to these parameters there was no significant difference between scions of lengths 6 cm, 8 cm and 10 cm. The maximum and minimum leaf production was noticed respectively for the varieties banganappally and Bangalora particularly during initial stages of growth. However, the use of scions with varying lengths did not reveal any significant difference with regard to this parameter.

Anatomical studies of the successful grafts revealed four distinct stages in the healing process of graft union. Cambial bridge across the union was established

45 days after grafting and the union was completed three months after the grafting operation. In the unsuccessful grafts there was no callus formation even after 5 to 10 days of grafting. Very thick necrotic layers were seen to have developed in the wounded exposed surfaces of stock and scion. Irregular cut surfaces, wide gap between stock and scion and slow differentiation of callus were also observed. Moreover, some of the unsuccessful grafts initiated callus production only from stock side.