REFINEMENT OF SOFTWOOD GRAFTING TECHNIQUE IN SAPOTA

(Manilkara zapota* L.*)

By

ARCHANA P.V.

(2019-12-026)

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF AGRICULTURE

PADANNAKKAD, KASARAGOD 671314

KERALA, INDIA

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Refinement of softwood grafting technique in Sapota (*Manilkara zapota* L.)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Place: Padannakkad
Date: 26/7/2022

Archana P.V.
(2019 -12-026)

CERTIFICATE

Certified that this thesis, entitled **"Refinement of softwood grafting technique in Sapota (*Manilkara zapota* L.)"** is a record of research work done independently by Ms. Archana P.V. (2019-12-026) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

26/7/2022

Place: Padannakkad

Date: 26.07.2022

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(Major Advisor, Advisory Committee)
Assistant Professor (Horticulture)
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CERTIFICATE

We, the undersigned members of the advisory committee of Ms. Archana P.V. (2019-12-026) a candidate for the degree of Master of Science in Horticulture with major field in Fruit Science, agree that the thesis entitled **"Refinement of softwood grafting technique in Sapota (*Manilkara zapota* L.)"** may be submitted by Ms. Archana P.V. (2019-12-026), in partial fulfilment of the requirement for the degree.

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ARCHANA P.V.

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LIST OF ABBREVIATIONS AND SYMBOLS USED

et al.	Co- workers/ Co-authors
DAG	Days after grafting
NAA	1-Naphthalene acetic acid
IBA	Indole-3-butyric acid
i.e.	That is
g	Gram
cm	Centimetre
MT	Metric ton
GOK	Government of Kerala
Ha	Hectare
ppm	Parts per million
%	Percent
ml	Milli litre
mg	Milli gram
NARP	National agriculture research project
BA	Benzyl adenine
var	Variety
$c.m^2$	Centimetre square
IBA	Indole 3-butyric acid
°C	Degree celsius
Ki	Kinetin
$ZnSO_4$	Zinc sulphate
viz.	Namely
cv.	Cultivar
WAG	Week after grafting
Dt.	District
BAP	6-Benzyl amino purine

Dedicated to my family

Introduction

1. INTRODUCTION

Sapota is a common fruit of tropical region belonging to family sapotaceae and called in various names as chikku, zapota, sapodilla plum and nose-berry. Origin of sapota is known to be Mexico (Vavilov and Freier, 1951) and then it was spread to different countries like Malaysia, Indonesia, Philippines, Unites states, India and Sri Lanka. Currently, sapota production is found in all tropical countries of the world. In India, the major sapota cultivation is concentrated in states like Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, West Bengal, Uttar Pradesh, Gujarat, Assam, Haryana, and Kerala. In India, total area of sapota cultivation is nearly 80000 ha and production is 979000 MT (GOK, 2020). Humid tropical climate is most suitable for sapota production and diversified soil and climatic conditions are adoptable for its cultivation. Presently, sapota has an increasing demand in our country and beneficial for its sweet, tasty fruits. The major cultivars grown in various states of India are Cricket Ball, Kirti Bharti, Oval, Kalipatti, Long Oval, Pala, DHS-1, DHS-2, CO-1, CO-2, PKM-1, PKM-2, PKM-3 and Baramasi.

Sapota, is an evergreen tree with slow-growing nature which produces flower and fruits terminally on leaf axils. Leaves are elliptic to obovate shape. Fruits are berry type with thin skin and brown colour. Seeds are black in colour with shiny appearance. Delicious fruits of sapota contain the richest source of vitamins like A, B_1 , B_2 , B_6 , C and minerals like phosphorous, calcium, potassium, iron, sodium and magnesium. Unripe sapota fruits have a milky latex secretion called as “gutta percha” or “chuckle” having a higher market value which can be utilised as base material for chewing gum manufactures. Sapota seeds have diuretic and bark has antipyretic properties. Many processed products like jam, marmalade, fruit bar, jelly, flakes and dried fruit powder can be prepared from sapota fruits.

In sapota different propagation methods are there with varied success rate. Propagation of sapota through seeds takes a higher time for establishment showing more heterogeneity. Hence, vegetative propagation is more suitable. Vegetative propagation of sapota is achieved through different methods like budding, air layering, side grafting, veneer grafting, approach grafting and softwood grafting. Commonly approach grafting was practiced for the past many years. But this technique is costly,

time-consuming and tedious hence, can not meet the huge demand of planting material. Recently, softwood grafting in sapota has become familiar among farmers and horticulture sector due to various benefits. It is an easy and cheap method. It provides rapid multiplication of plants with considerable success per cent. Khirni (*Manilkara hexandra)* is used as rootstock commonly for grafting in sapota. Success, survival and subsequent growth of scion shoot and development of successful graft depend on a number of factors *viz*. time of grafting operation, varieties, grafting methods, compatibility of rootstock and scion, age of scion and rootstock and environmental conditions (Hartmann *et al*.,1997).

Even though scope of sapota crop is very demanding, it has less cultivation area compared to other major fruit crops due to the non availability of quality planting material. So, there is a large requirement of production of healthy and quality planting material for various cultivars. This should be carried out as a rapid multiplication technique thorough out the year to satisfy the huge demand. The success per cent of grafts performance may change at various environmental conditions and various cultivars. Precuring treatment gives better success of grafts in sapota (Pampanna and Sulikeri, 2000) and more beneficial for higher success rate along with better overall graft growth (Tanuja and Thippesha, 2017). But it takes time and effort in grafting. There is influence of different environmental conditions on the performance of sapota softwood grafts on invigorated khirni rootstock (Ashutosh *et al*., 2020). Application of cytokinin showed the potential effect on the early graft union and growth parameters like survival per cent of grafts and increase in the success rate of number of days taken for bud sprout incase of grape under polyhouse condition (Sunitha *et al*., 2016). Influence of hormones like cytokinins on graft union of grape cuttings had enhanced callus proliferation (Kose and Guleryuz, 2006). So for overcoming all problems, it is proposed to undertake a trial on the modified aspects of softwood grafting in Sapota. Hence, present study entitled "Refinement of softwood grafting technique in Sapota (*Manilkara zapota* L.)" was undertaken to know the details on this aspects with following objectives.

OBJECTIVES

1) To study the most proper technique for improving success per cent in softwood grafting of sapota cultivars by applying various environmental conditions with various defoliation treatments.

2) To study the effect of cytokinin for improving success of softwood grafting in sapota.

Review of Literature

2. REVIEW OF LITERATURE

Sapota is one of the valuable introductions from Mexico. Sapota has shown a phenomenal growth in the recent years. It has reached the status of a major fruit crop after mango, banana, citrus, apple and guava. Though approach grafting is highly successful in sapota and which was followed for past many years, it is a painstakingly laborious process. A rapid and successful propagation technique is required to meet the huge demand of sapota seedlings throughout the year. So, softwood grafting is practiced. The most commonly used rootstock for sapota is Khirni ((*Manilkara hexandra)*. Various research works have been conducted on different aspects of grafting of sapota in the world. But, research works related to the effect of environmental conditions, cultivars, precuring of scion and cytokinin application on scion on the success of sapota grafts are very few under Kerala conditions. The important literatures available on the present study have been reviewed in this chapter under different titles.

2.1 Vegetative propagation

2.1.1 Vegetative propagation of sapota by different methods

Hussain and Bukhari (1977) described that among six asexual method of propagation of sapota, the highest success percentage was found in veneer grafting (87.5%) followed by side inarching, side grafting, saddle grafting, whip grafting, and tongue grafting.

A study had been conducted by Singh and Bons (2016) to specify the most appropriate propagation methods and time of propagation in sapota under north Indian conditions. Veneer grafting, side grafting, and wedge grafting were the propagation methods carried out during the months of February, March, July and August. Side grafting followed by veneer grafting showed highest average graft survival (68.7%). Maximum graft survival (62.8%) reported on month of July. The earliest sprouting of bud was observed in side grafting. Veneer grafting followed by wedge grafting showed maximum number of days needed for bud sprouting. The maximum graft height was recorded in side grafting.

2.1.2 Vegetative propagation of fruit crops by softwood grafting

According to Desai and Desai (1989), in case of softwood grafting in jackfruit with six months old scion reported highest sprouting and survival of grafts. The scion length of 7.5 cm and 10 cm gave the highest success (58.33%) rate of graft.

Soft wood grafting recorded maximum success per cent than patch budding in aonla. Maximum success per cent in soft wood grafting was noticed during the month of January (86%) and minimum success was observed during April to September (Panchbhai *et al*., 2006).

Prasanth *et al.* (2007) had studied the time of grafting of mango cultivars by softwood method in different mango cultivars. Grafting done during the month of September reported early graft sprouting (24.50 days). Significantly maximum per cent of sprouting (82.50%) and graft take (54.56%) was observed during first fortnight of September. Grafting done on December showed poor performance of grafts with respect to parameters like sprouting and survival.

Kudmulwar *et al*. (2008) claimed optimum period of grafting in softwood grafting of custard apple was between 1st February to 15th march. Highest success per cent (88.87%) was observed on 15th February. February 1st and February 15th showed minimum number of days for sprouting of graft.

According to Patil *et al.* (2008) the study of different rootstock on success of softwood grafting of mango indicated that Alphonso variety grafted on Sindhura showed higher success (77.80%) of graft. Number of leaves (10.15), height of graft sprout (4.41), graft diameter (8.57mm) were recorded highest on Sindhura and Baneshan.

A work done by Selvi *et al.* (2008) showed that softwood grafting can be recommended for fast production of jackfruit seedlings under Tamil Nadu conditions during October. Higher graft success can be obtained if kept under agro shade net condition.

A study on seasonal variation done by Alka *et al.* (2010) on softwood grafting in jamun indicated that, on 15th March and 15th September was best time for softwood grafting in terms of graft survival (67%) for commercial multiplication.

According to Aralikatti *et al.* (2011) a study conducted on softwood grafting in jackfruit revealed that highest graft take, higher number of leaves and higher number of graft sprouts were obtained in seven months old rootstocks followed by nine months old rootstocks. Lesser graft take was found in both younger and older rootstocks.

Ghojage *et al.* (2011) studied the effect of season on softwood grafting in jamun. Different months of grafting indicated variation in graft success and survival. Highest graft success and graft survival were obtained during February (81.66% and 95.97% respectively), while minimum graft success and graft survival were obtained during December (35.00 and 61.90% respectively) in jamun.

Effect of scion maturity and polythene bag cover on softwood grafting of karonda showed that graft with the use of younger scion (2 month old scion) and polythene bag cover resulted in early sprouting (Nimbalkar *et al.*, 2011).

A study of season of softwood grafting in carambola indicated that maximum sprouting (90%) and survival of grafts (87.50%) recorded during the months of June to August at 90 days after grafting (Sonawane *et al.*, 2012).

Roshan *et al.* (2008) showed the influence of age of rootstock and time of softwood grafting on success of grafting in Aonla. Highest grafting success was observed in eight month old rootstock (77%), while minimum grafting success was obtained in ten month old rootstock (68.3%). Soft wood grafting done during the first week of January (77.8%) recorded highest grafting success whereas minimum grafting success was reported from grafts done during the first week of December (66.1%). Eight month old rootstock required significantly fewer days (26.8 days) than the older rootstocks regarding number of days for sprouting.

Sridhar (2014) done a study to find out the better season for success and growth of mango grafts by softwood grafting method. The result showed that maximum graft success was noticed during the month of June (80.56%) followed by

July, August, September and October (78.34%, 65.56%, 71.67%, 53.89% respectively). Minimum graft success was found during the month of November and December (35.02 and 32.23 respectively).

Maheswari and Nivetha (2015) had conducted an investigation on influence of age of the rootstock for the success of softwood grafting in jackfruit. From the experiment it was clear that four months old rootstocks showed highest values for the parameters like graft success, graft survival per cent, plant height, number of leaves, days taken for first and last sprouting, number of sprouts, sprouting per cent, leaf area and girth of stem which was followed by five months old rootstocks.

Softwood grafting of jamun performed during different months gave result as the grafting performed during September proved to be highest graft success (75.24%) and graft survival (71.45%). Maximum height of graft (33.13 cm), highest graft diameter (0.48 cm), minimum number of days (23.28) for sprouting and maximum leaf area (32.45 cm2) were also showed in September . Grafting done during month of February showed better for other growth parameters like number of leaves (9.70), number of sprouts (2.54) and sprout length (3.68 cm) (Chander *et al.*, 2016).

Barathkumar (2017) had done an attempt to find out the influence of rootstocks of different age on softwood grafting in aonla. Three months to twelve months old rootstocks were utilized for grafting. Grafts made from eight months old rootstock had showed highest values for observations like total biomass (91.14), graft success per cent (93.74), graft survival per cent (96.32), shoot length (6.98) and number of leaves (16.82).

Kholia *et al*. (2017) reported the chances of softwood grafting of different varieties of guava with different final survival per cent under semi arid conditions of Akola. During second fortnight of February, maximum final survival of grafts (93.89 %) was observed while, during second fortnight of January (71.67%), minimum survival of grafts was obtained.

Ullah *et al*. (2017) concluded that veneer grafting should be preferred over softwood and epicotyl grafting in order to get better survival and over all sprout growth for commercial propagation of quality plants of mango cv. Amrapali.

Karna and Varu (2018) recorded that maximum level of survival per cent (49.44), success per cent (59.44), plant height (75.23), leaves per graft (12.77), maximum shoot length of scion (13.61) and girth of stock (9.33mm) were found in softwood grafting of mango which was done at a height of 60 cm. Grafting done at 40 cm height on rootstock showed minimum days to shoot emergence and maximum scion girth (8.58mm) of grafts.

Deependra *et al*. (2019) carried out a study to find out the impact of the height of rootstock on the success and growth parameters of grafts in mango. This was done by applying the softwood grafting method in various varieties of scions of mango. Best results for the per cent graft take success, scion shoot length, number of leaves per plant and per cent graft survival were obtained from the rootstock having a height 100 cm. The root stock of 75 cm height in which grafting was done gave the highest value for the scion shoot girth and sprouting time. The rootstock height of 25 cm showed the lowest value for the number of leaves per plant and scion shoot girth. Grafts prepared on the root stock with a height of 50 cm had lowest value for graft success and scion shoot length.

Madala *et al.* (2019) found out that among five types of jackfruit, early emergence of grafts (28.67 days) observed in Gumless type along with highest per cent of sprouting (46.90). Cluster type showed more number of leaves (8.33) and maximum survival per cent (75 %). Maximum shoot length (8.37 cm) observed in early bearing Varikka.

Yadav *et al.* (2019) observed the impact of the age of rootstock on the success and growth parameters of grafts in mango. This was done by the method of softwood grafting in Bombay Green, Langra, Chausa, Amrapali, Dashehari, and Mallika cultivars of mango. Among different ages of the rootstocks, the scion cultivar Langra performed the best for the sprouting time and graft take success per cent. Langra showed maximum scion shoot girth and maximum number of leaves per plant. Graft survival per cent was highest in scion cultivar Chausa and scion shoot length was maximum for Bombay Green. Graft take success per cent, girth of scion shoot and the number of leaves per plant was lowest in Amrapali whereas graft sprouting time, graft survival per cent and scion shoot length was lowest in Mallika. Two months old

rootstock performed best for all the graft success parameters and graft growth parameters. But there was an exception for scion shoot girth. Grafting done on one month old root-stock was found to perform the best for scion shoot girth. Six months old rootstock has lowest performance for all graft success parameters and graft growth parameters.

Naik and Kumar (2020) had done a study on recent developments of mango propagation through various grafting methods which showed that softwood grafting is best for success of graft than other grafting methods in nursery mango seedlings.

2.1.3 Vegetative propagation of sapota by softwood grafting

Pampanna and Sulikeri (2000) had done an attempt to study the impact of growth and season on softwood graft growth of sapota by grafting on invigorated Rayan rootstock. Graft uptake at initial and final stage was highest in grafting during May (both 60%) month followed by April (both 43.33%). Using the Rayan rootstock plants from failed grafts of previous season, softwood grafting of sapota can be done effectively during the month of May for better graft take and survival.

A work done by Tandel and Patel (2009) showed that in softwood grafting of sapota scion stick stored after wrapping in newspaper and sealing in perforated polythene bag had maximum growth of grafts in terms of height, girth and total number of leaves. It also had minimum days for leaf emergence and maximum sprouting of grafts.

Wazarkar *et al.* (2009) conducted a study to know the influence of grafting materials and grafting dates on success of softwood grafting in sapota under middle Gujrat agro climatic conditions. They could find out that among five grafting dates, date 30-7-2017 significantly showed highest number of sprouted grafts (7.33) at 60 days after grafting, maximum increase in scion length (11.49%) and (15.94%) at 30 and 31 to 60 days after grafting, higher number of leaves per scion (4.66) and (7.15) at 30 and 60 days after grafting, lowest number of days to emergence (15.33), highest survival per cent *etc*. Degraded tape as grafting material performed better than polythene strip for the increment in scion length at 30 and 31 to 60 days after grafting,

number of fully opened leaves per scion at 60 days after grafting whereas polythene strip showed maximum increment in length of rootstock at 30 days after grafting.

Maske *et al*. (2009) evaluated the seasonal effect on success of softwood grafting in sapota. They could concluded that for maximum success of softwood grafting in sapota, grafting should be carried out from mid July to mid August. Grafting from 15th November to 15th April showed poor performance of success.

Ghosh *et al* 2010, conducted a study to find out the most suitable time for softwood grafting in Sapota. The results showed that softwood grafting performed on 1st July (72%) followed by 15th August (70%), 5th June (62%) and 15th June (56%) had highest success rate.

Tanuja and Thippesha (2016) had found out that scion diameter had an influence on success of softwood grafting of sapota. Among the four scion wood diameters, highest success was observed in thicker scion (64.60%, 62.00% and 58.00%) at 30, 60, and 90 days after grafting respectively. Scion represented by thicker diameter shoots provided maximum graft survivability per cent (87%).

According Tanuja and Thippesha (2017), best graft growth and maximum success in softwood grafting of sapota is obtained by using younger scions with three to four month maturity. Maximum number of sprouts observed at 30 (1.17), 60 (1.20) and 90 (2.10) days after grafting by using three month old scion. Grafts made with three months old scion showed minimum number of days for sprout initiation (9.80 days). For 50 per cent sprouting and 100 per cent sprouting it took 16.20 and 24.80 days respectively. Maximum number of leaves and leaf area index on 60 (6.16 and 2.07) and 90 (7.10 and 2.47) days after grafting, maximum length and breadth of leaves at 60 (6.70 cm and 3.57 cm) and 90 (7.20 cm and 4.10 cm) days after grafting, maximum height of the graft at 30 (35.66 cm), 60 (36.30 cm) and 90 (37.60 cm) days after grafting, scion girth at 60 (4.70 mm) days after grafting, graft index at 30 (2423.50), 60 (2373.25) and 90 (2029.25) days after grafting, per cent graft success at 30 (50%), 60 (42.50%) and 90 (37.50%) days after grafting and maximum survival per cent (87.00%) was obtained.

A study conducted by Ghritlahare and Anant (2018) among various grafting seasons in sapota, 20th July showed maximum growth of scion (2.64 cm and 4.69 cm) at 60 and 120 days after grafting.

Ashutosh *et al.* (2020) had evaluated that decaping height of invigorated khirni rootstock had an effect on scion length and leaves per graft. Decaping height at 15 cm from ground level indicated clearly maximum length of scion shoot (8.51 cm) at 30 days after grafting. Decaping height at 10 cm from ground level (7.90 cm) showed minimum length of scion. Same type of outcome were noticed at 60, 90, 120, 150 and 180 days after grafting. Leaves per graft also influenced by decaping height of invigorated khirni rootstock. At 30 days after grafting minimum leaves per graft was noticed in decaping height at 10 cm from ground level (1.98) and decaping height at 15 cm from ground level indicated maximum leaves per graft (3.06). Same trend of results were noticed at 60, 90, 120, 150 and 180 days after grafting.

Mithapara and Karetha (2020) showed that June-July is the best season in which least number of days taken for sprout emergence (11.72) was reported in sapota grafts. Maximum survival per cent (56.94%, 58.00%, 55.56% and 55.56%) and highest success rate (56.94%, 59.72%, 59.72% and 59.72%) with minimum mortality (43.06%, 40.28%, 40.28%, and 40.28%) at 30, 60, 90 and 120 days after grafting were noticed in February-March.

2.2 Environmental conditions

2.2.1 Effect of environmental conditions on grafting of fruit crops

Importance of growing condition in graft success of jackfruit was noticed by Selvi *et al*. (2008). The number of days taken to graft union and success of graft were comparatively higher under agro shade net condition followed by mist chamber. Success at minimum level was observed under tree shade condition.

A study of softwood grafting in mandarin showed that grafts under poly house had higher success of graft, early sprouting of graft and growth of scion was found to be better compared to other conditions. Higher success of graft and early graft sprouting were seemed to be best under the open condition compared to net house.

Grafted plants showed better growth performance under net house condition than the open condition (Patel *et al*., 2010).

Significant variation of success of softwood grafting in jamun due to structural conditions revealed that grafts kept under open condition showed maximum survival per cent, highest increase in scion length, length of rootstock, number of grafts sprouted and minimum days for graft sprouting (75.32%) at 90 days after grafting (Shinde *et al.*, 2010).

According to Mulla *et al.* (2011) by considering the environmental condition in softwood grafting of jamun, maximum per cent of graft take (100%) and graft survival per cent showed during months of October, November and December under controlled conditions. Minimum days for sprouting (16.60) produced during January month. Under open conditions, maximum graft success (100%) was reported during the month of November and May. Survival per cent of graft at maximum level (93.33%) was noticed during October, November and May. Highest leaf area (34.8 cm^2) and sprout length (5.34 cm) were observed in May. Higher number of leaves (12.48) was showed in June.

Ragavendra *et al.* (2011) had found out that wood apple can be propagated by method of softwood grafting under poly mist house condition with usage of various aged rootstocks found to be better than grafting under open condition. Rootstock of nine month old under poly mist house condition showed maximum leaf area (8.5 cm^2). It was found that poly mist house condition with ten month old rootstock proved to be best by evaluating the interaction effects of growing condition and rootstock age. It took the lowest number of days for success of graft (19.4). Lower leaf area (4.3 cm^2) was noticed on ten month old rootstocks under open condition. Lower number of leaves (8.5) was observed under open condition on rootstocks of five month old.

Angadi and Rajeshwari (2012) concluded that softwood grafting in jamun could be standardized under poly mist house condition throughout the year. Higher graft success per cent and survival of grafts obtained from eleven to nineteen month old rootstock during April to November respectively.

According to Uchoi *et al.* (2012), a study on softwood grafting in jamun revealed that maximum per cent of graft success (99%) was observed during the month of January by keeping the grafts inside the low cost polyhouse. Maximum number of leaves (12.23) per graft noticed in grafts kept inside the shade net house during January month. Grafts kept under open (natural shade) condition during the month of December reported least number of leaves (5.85). Grafts of jamun kept under shade net house condition during the month of December noted least (70%) success of grafts.

Beera *et al*. (2013) revealed that in wedge grafting of guava there was an impact of grafting time and environment on the success of graft. Graft sprouting at maximum per cent level was noticed in 15th February by grafting under controlled environment (when scion shoot covered with poly tube). Graft sprouting at minimum per cent level was found in 15th January under natural environment condition. Graft mortality per cent was found minimum in 15th March under open field condition.

Anushma *et al*. (2014) had carried out a study to find the effect of various coloured shade nets like red, white, green, black and blue on graft take. From the study it is revealed that graft take and graft growth parameters are significantly influenced by different coloured shade nets. Highest graft success (72.50%) was noticed in grafts which are kept under red coloured shade nets. Grafts kept under blue shade net showed least graft success (47.50%). Higher number of leaves per graft was found in grafts kept under white shade net at 30 days after grafting and 60 days after grafting (5.6 and 8.96 respectively). At 90 days after grafting, grafts under red shade net (12.00) reported highest number of leaves. Grafts under blue shade net (8.22) noted minimum number of leaves.

Sivudu *et al*. (2014) had studied success and survival of mango grafts prepared through veneer grafting by altering structural conditions. The results indicated that among the five structural conditions studied, naturally ventilated polyhouse condition at 90 days after grafting showed best results. It recorded significantly highest increase in survival per cent (67.18%), number of grafts sprouted (71.27%), length of sprout (6.06 cm), number of leaves per graft (17.34), minimum days needed for graft sprouting (12.11 days) and graft height (17.92 cm) at 90 days after grafting. Open

condition at 90 days after grafting showed minimum survival per cent of grafts by veneer grafting.

Chander *et al*. (2016) illustrated that in jamun grafts under mist chamber showed highest graft success (72.51%) and graft survival (67.88%). Minimum survival of graft (64.09%) and minimum success of graft (61.82%) were noticed under open condition.

Wedge grafting of Guava, under polyhouse condition gave better result than open field condition with respect to growth parameters like survival per cent of graft (60.69), sprouting per cent (65.50), number of days taken to graft sprout (13.27), height of graft (23.96), graft take per cent (68.27), girth of graft (1.31) and number of leaves per new shoot (12.46) (Gotur *et al.,* 2017).

Mahesh *et al.* (2017) performed softwood grafting in various mango varieties in both polyhouse and shade net under northern dry zone of Karnataka. From the results it was clear that under polyhouse condition grafts on 15th August (72.60 and 66.00) noticed highest graft survivability (%) at 90 and 120 days after grafting whereas, the lowest graft survivability (%) noted on 30th September (60.30) and on 30th August (54.40) grafted plants at 90 and 120 days after grafting. Highest graft survivability (%) reported in Baneshan (81.00 and 74.13) at 90 and 120 days after grafting whereas, the lowest graft survivability (%) noticed in Khadar (48.00 and 43.60) at 90 and 120 days after grafting under shade net condition.

Manga *et al*. (2017) carried out an experiment which was based on the significant influence of various propagation environment for softwood grafting in guava cv. Sardar. Graft success at maximum level and maximum survival per cent was obtained in mist house eco system (62.00 and 97.40% respectively) followed by shade house (48.00 and 95.00% respectively). Grafts under poly tunnel showed minimum graft success and minimum graft survival per cent (10 and 41.67 %) respectively. Grafts grown under mist house eco system showed maximum number of sprouts (4.62), maximum number of leaves (21.60) and highest length of sprout (6.30 cm).

Wedge grafting of guava by growing the grafts under shade net and polyhouse conditions showed that grafting done during the month of January provided higher graft survival per cent and success rate. Grafts under shade net condition showed maximum per cent of sprouting of grafts (18.57%), minimum number of days taken for 50 per cent of graft sprouting (29.80 days), number of flushes per sprout (2.10) compared to the grafts kept under poly house condition (Vanaja *et al.,* 2017).

Jalal *et al.* (2018) conducted a study to determine the influence of growing environment in propagation of different cultivars of aonla (NA-7 and Francis). The grafting was done by cleft grafting and tongue grafting under polyhouse and open field conditions. Grafts under polyhouse condition reported maximum (0.88 cm) rootstock diameter, minimum time (11.61 days) taken for bud sprout and 100 % graft take. The grafts made under open field condition showed maximum (37.00) number of leaves, maximum scion diameter (0.75) and highest graft survival (80.00%).

Praveenakumar *et al.* (2018) carried out a study to find the influence of environmental condition and seasonal variability of softwood grafting in jamun. The results indicated that optimum temperature for grafting success was in treatment july + low cost polyhouse (29.69ºC) and treatment july + low cost polyhouse with highest relative humidity (98.83%). Highest relative water content observed in the treatment june + open field (91.10 g) and highest chlorophyll content was noticed in the treatment june + low cost polyhouse (46.33µ mol per m^2).

Parmar *et al.* (2019) reported that in case of mulberry, growing conditions affected the success percent of graft survival by softwood grafting method. Among the growing conditions, poly house with poly cap noticed maximum number of fully opened leaves on scion (9.91 and 16.68 per plant). Survival per cent of grafts (63.41 and 61.16) and maximum number of shoots per plant (3.78) at 90 days after grafting was shown by growing condition of poly house with poly cap. Same growing condition recorded maximum increase in scion length (10.98, 28.00 and 48.91 cm) at 30, 60 and 90 days after grafting respectively. Incremental girth of scion (3.82, 6.15 and 6.89 mm) and incremental girth of rootstock (5.13, 6.21 and 8.01 mm, respectively) were also significantly maximum at this condition at 30, 60 and 90 days after grafting respectively.

2.2.2 Effect of environmental conditions on softwood grafting of sapota

A study was conducted by Shankararao (2012) on standardization of period for soft wood grafting of sapota in shade net house, polyhouse and open conditions. It was clear from the study that September month was suitable period for grafting sapota for maximum success and had higher vegetative growth.

Kalalbandi *et al*. (2014) carried out softwood grafting of sapota var. Kalipatti under 50% shadenet house condition using khirni seedling of 18 months old as stock and 15 days prior defoliated scion stick of 8 cm length and 8 mm in diameter. It gave maximum number of leaves per graft (14.44), sprout length (9.48), success per cent of graft (64.66), early bud sprout and graft survival per cent (64.21) which was done in the months of August and September under Marathwada conditions.

A study conducted by Nitish *et al.* (2019) in softwood grafting on invigorated khirni rootstocks of sapota performed under polyhouse and shade net using two different scion length (15 and 10 cm) during different month of grafting (May, June, July and August). The grafts propagated under polyhouse using scion of length 10 cm during the month of July showed maximum number of leaves and early sprout of grafts. The grafts under polyhouse propagated by using scion of length 15cm during the month of July noticed maximum graft height (above the union).

Ashutosh *et al.* (2020) experimented influence of different environmental conditions on performance of sapota softwood grafts on invigorated khirni rootstock. Four different environmental conditions like poly house condition, open condition, partial shade condition and partial shade (tree shade) were considered. Two decaping height of invigorated khirni rootstocks of 10 cm and 15 cm from ground level were evaluated. Maximum scion length(20.20 cm) was noticed in poly tunnel and decaping height at 15 cm from ground level. Minimum scion length (12.16 cm) was observed in open condition and decaping height at 10 cm from ground level.

Mithapara and Karetha (2020) revealed that among different environmental conditions grafts kept at polyhouse recorded minimum number of days needed for sprout emergence (10.34), maximum survival per cent (43.44%), minimum mortality

(59.83%) and highest success rate (44.00%) at 30, 60, 90 and 120 days after grafting compared to open field and net house conditions in sapota.

2.3 Cultivars

2.3.1 Effect of cultivars on grafting of fruit crops

According to Prasanth *et al.* (2007) softwood grafting of mango performed during different time in three mango cultivars showed that Mallika has highest per cent of sprouting (68.90%) and graft take (40.52%) whereas lowest was noticed in Baneshan.

Jagannath *et al*. (2011) conducted a work to find out the effect of various mango cultivars on success of grafting by softwood method. Maldah followed by Amrapali showed maximum survival per cent. Chausa showed minimum success and survival per cent. Maximum number of leaves (14.05) was noticed in Mahmood bahar and minimum (11.93) in Prabhashankar.

Response of different mango varieties on softwood grafting indicated that success per cent of graft was found maximum in Kesar and minimum in Local-4. Minimum days required for sprouting was observed in Dashehari and maximum was found in Rajapuri (Prajapati *et al.,* 2014).

Kholia *et al.* (2017) reported that softwood grafting was done by taking the scion from three different guava cultivars like L-49, Lalit and Shweta. It provided the result as the maximum final graft survival (93.34 %) and maximum per cent of bud sprouting (96.25%) with the scion of cultivar Shweta.

2.3.2 Effect of cultivars on softwood grafting of sapota

Ghosh *et al.* (2010) found out the significant variation in success of softwood grafting among ten sapota cultivars. By evaluating ten cultivars, CO-2 performed more compatibility with khirni rootstock to softwood grafting followed by Cricket Ball and DSH-2. Sapota cultivars like CO-1, DSH-1 and Guthi showed failure in graft take.

2.4 Scion precuring

2.4.1 Effect of scion precuring on grafting of fruit crops

Desai and Desai (1989) found out that defoliation of scion prior to softwood grafting in jackfruit did not show any significant difference in graft growth and success compared to undefoliated condition of scion stick. So it was not required under Konkan conditions for softwood grafting of jackfruit.

Influence of defoliation of scion on the success of grafting of lime showed that scions defoliated 6 days before grafting had highest graft success (90.50%) and graft survivability (89.36%). Scions defoliated on the same day of grafting gave lowest graft success (77.83%) and graft survivability (77.67%) (Nahar *et al.*, 2015)

Mane and Nalage (2017) conducted a study of soft wood grafting in tamarind on defoliation period. Defoliation done on eight days prior to grafting reported maximum growth, survival per cent and sprouting per cent than four days prior to grafting and defoliation done on the day of grafting.

Interaction effect of scion length, polytube capping and defoliation period affected parameters like girth of sprout, length of sprout, total height of graft and number of leaves per grafts *etc*.in case of wedge grafting of mango cv. Dashehari. The result revealed that eight days defoliation duration combined with 21 cm length of scion with polytube capping gave maximum height of graft (59.23 cm), maximum leaves per graft (11.81) and maximum length of sprout (18.31 cm) (Mishra *et al*., 2017)

Chavda *et al.* (2018) put forward a study to find out the influence of defoliation and storage of scion on softwood graft of jamun var. Goma Priyanka. Among different treatments of defoliation and scion storage one day stored scion with defoliated condition showed individual superiority in growth parameters like maximum number of leaves, leaf area and minimum days required for leaf emergence. It can be used in jamun for better growth and graft sprouting through softwood grafting.

Tandel *et al*. (2020) laid out an experiment to find the impact of defoliation and scion storage on survival and sprouting through softwood method of mango var. Sonpari. Among different treatments twelve days prior defoliated scion of mango without any storage treatment, showed better results. It took minimum days to sprouting, maximum sprouting per cent, maximum number of leaves, leaf area, and graft survival per cent.

2.4.2 Effect of scion precuring on softwood grafting of sapota

Pampanna and Sulikeri (2001) reported the effect of precuring treatments on success of sapota variety Kallipatti. The result showed that ten days prior defoliation with fresh scion without storage showed minimum number of days for graft sprout (29.67). Number of leaves of scion (18.25 leaves per graft) and height of scion (17.30cm) were found maximum in ten days prior defoliation combined with fresh scion.

Tanuja and Thippesha (2016) conducted a study to know the effect of precuring of scion in softwood grafting of sapota and it was clear from the study that precuring of scion was more beneficial for higher success rate along with better overall graft growth. Among different days cured scions, ten days cured scions showed minimum days for initiation of sprouting. Ten days cured scions also showed maximum number of sprouts at 30 (1.55), 60 (2.08) and 90 (2.45) days after grafting. Maximum number of leaves and leaf area index at 60 (5.30) (2.13) and 90 (6.55) (2.78) days after grafting and maximum length and breadth of leaves at 60(2.78cm) (3.59cm) and 90 (6.73 cm) (3.79cm) days after grafting also noticed in cured scion of ten days. Parameters like maximum percent graft success at 30 (68.75%), 60 (65.00%) and 90 (62.50%) days after grafting, maximum survival per cent of grafts (84.00%), maximum height of the graft at 30 (36.50 cm), 60 (36.85 cm) and 90 (38.47 cm) days after grafting and maximum girth of scion at 60 (4.74 mm) days after grafting were also recorded when grafting in sapota was performed with ten days cured scion.

An experiment of scion precuring on softwood grafting of sapota done by Ghritlahare and Anant (2018) indicated that among various scion precuring treatments (allowed to remain on the plant with defoliation) growth of scion was maximum (2.61

cm and 4.69 cm) at 60 and 120 days after grafting which was observed in ten days procured scions.

2.5 Role of cytokinin on plant growth

Nieminen *et al.* (2008) studied cytokinin signaling across the cambial zones of two tree species, poplar and birch which indicated that the reduced radial growth associated with less number of cambial cell layers. Thus, a reduced amount of cytokinin signaling is the main basis for the impaired cambial growth. Cambial development is primarily controlled by cytokinins.

2.5.1 Effect of cytokinin application on vegetative propagation of fruit crops

Kumar *et al.* (2017) had done a study on effect of cytokinin on budding and growth of bael. Study revealed that most significant treatment was BA at 50 ppm concentration as foliar spray on rootstocks of bael. The treatment of BA (50 ppm) with rootstocks showed early bud breaking (10.67 days), maximum scion growth initiation (87.50%), maximum bud sprouting per cent (100%), more number of leaves (7.13), maximum diameter of sprouted scion (2.53 mm) and length of sprouted scion (22 cm) 30 days after budding.

2.5.2 Effect of cytokinin application on grafting of fruit crops

Kose and Guleryuz (2006) reported the influence of hormones like cytokinins and auxins on graft union and root formation of grafted cuttings of four different grape vine graft combinations by dipping cut grafted surfaces of both the scion and rootstock. The result of study showed that, treatment of cut surfaces with Ki and BA (250 and 500 mg per litre) enhanced callus proliferation rapidly between rootstock and scion of graft for the 1000 mg per litre concentrations. But, NAA and IBA improved root formation of grafted cuttings at the basal end.

A study was done to determine the effect of the plant growth regulators on graft union of breadfruit. Indole butyric acid (IBA) (100 ppm and 200 ppm) and 6-benzylaminopurine (BAP) (200 ppm) are the treatments applied. This was not positively affected the length of survival of the newly grafted plants while comparing with the control treatment (0 ppm) (Solomon *et al.*, 2013)

The study of Le Khandu Thongdok *et al.* (2016) revealed that dipping of scion stick in BAP 20mg/litre+750mg/litre $ZnSO_4$ was very effective in case of epicotyl grafting of mango for early graft sprouting (8.07) maximum number of graft sprouts (18.00), higher survival per cent of grafts (81.67) and lower mortality (18.33) of CV. Kesar.

Sunitha *et al*. (2016) conducted a study to evaluate the beneficial effect of cytokinins and silver nitrate on graft union of grape cutting (Thompson Seedless var.) on Salt creek under polyhouse condition. The treatments include concentrations of kinetin (150 ppm, 250 ppm and 350 ppm), BAP (150 ppm, 250 ppm and 350 ppm), silver nitrate (50 ppm, 100 ppm and 150 ppm) and control. From the study results indicated that cuttings treated with kinetin at 250 ppm followed by BAP at 250 ppm under polyhouse condition showed potential effect on the early graft union and growth parameters like survival per cent of grafts (63.33), increase in success rate of number of days taken for bud sprout (18.75), stock: scion ratio (0.84).

Sunitha *et al.* (2016) had done the application of cytokinins and silver nitrate on success of graft union of Thompson Seedless grape cuttings on Dogridge under open and poly house conditions. Among the different concentration of chemicals, application of cuttings with kinetin 250 ppm followed by BAP 250 ppm reported potential effect on the early graft union and other growth parameters of grafts grown under polyhouse condition compared to open condition.

Materials and Methods

3. MATERIALS AND METHOD

The present study entitled on "Refinement of softwood grafting technique in sapota (*Manilkara zapota* L.)" was performed during the period from November 2020 to June 2021 at Department of Fruit Science, College of Agriculture Padannakkad, Kasaragod (Dt.). The experiment was carried out with the main objective to find out the best practice for improving the success per cent in softwood grafting of sapota cultivars by applying different environmental conditions and to evaluate the effect of cytokinin for improving success of sapota grafting. The experiment could not start in time during 2020 due to Covid-19 pandemic; hence the study was carried out during offseason period (November 2020 - April 2021) with all required facilities. The details of materials utilised and methods adopted during the investigation are given below.

3.1 Experimental site

The study was done in the instructional farm of College of Agriculture, Padannakkad located in northern part of Kerala at an elevation of 20m above mean sea level, at 12 ^{0} 20 '30 " N latitude and 75 ^{0} 04 '15" E.

3.2 Climatic condition

The College of Agriculture, Padannakkad experiences a humid climate which comes under tropical humid region. It belongs to NARP Northern zone of the state of Kerala and AZ 109th climatic zone of the country**.**

3.3 Experimental material

3.3.1 Polyhouse

Sapota grafts were kept under Polyhouse condition with 510 m² size (200 micron thickness)

3.3.2 Polytunnel

Soon after grafting, plants were transferred to two polytunnels having dimensions of 3m length,0.75m height and 1.06m breadth. These polytunnels were placed inside the polyhouse. It was prepared completely air tight by proper closure of

side parts without the influence of external factors. After one month, depending up on the visibility of sprouts the grafts were shifted outside.

3.3.3 Shade net house

The grafts kept under polytunnel were transferred to a shade net house (60 % shade) with dimension of 4.27m length, 0.55m breadth and 2.24m height after a period of one month.

3.4 Preparatory operations

3.4.1 Selection of rootstock

One year old vigorous khirni seedlings raised in polybags (6 X 8 inches**)** having pencil thickness were selected as rootstocks.

3.4.2 Selection of scion

Healthy mother plants of sapota having high yield and mature vigorous terminal shoot with greenish brown colour and well developed buds of current season growth was used as scion. Scion should be free from pest and disease.

3.4.3 Collection of scion

Scion shoots were collected directly from sapota mother plant during the morning hours on the day of softwood grafting operation. A sharp secateur was used for detaching the scion from mother plant and wrapped in newspaper. Scions were kept in polythene bags and carried to site of grafting. Grafting was performed on the same day of scion collection.

3.4.4 Softwood grafting procedure

Sapota tree of Oval, Pala, and Cricket Ball cultivars were considered as mother tree from which mature and vigorous scion sticks of uniform length (8-10 cm length) were detached on the day of grafting and collected in a container with water to avoid dessication. Rootstock of one to one and a half year old healthy khirni *(Manilkara hexandra* L.) seedlings of uniform growth were used for grafting purpose. Top portion of rootstock seedlings were decapitated. Using a sharp grafting knife the upper part of rootstock was splitted vertically to a length of 4 to 5 cm forming “V” shape. Scion

Plate 1a:Scion preparation

Plate 1b:Rootstock preparation

Plate 1c: Insertion& union of non defoliated scion into stock

Plate 1d: Insertion& union of defoliated scion into stock

Non defoliated graft

Defoliated graft

Plate 1: Procedure of softwood grafting followed in sapota

Plate 2a:Polytunnel structure

Plate 2b:Grafts under polytunnel

Plate 2c:Air tight closed polytunnel

Plate 2d:View of grafts after opening (30 DAG)

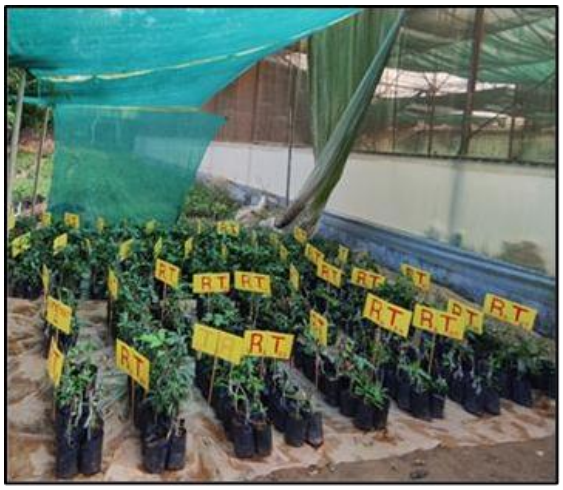


Plate 2e:After transferring to shade condition (180 DAG)

Plate 2:Varoius stages of aftercare operation

shoot having similar thickness of rootstock with 10 days prior defoliation or defoliation on same day of grafting or without defoliation as per treatment were used. A wedge cut of about 4 to 5 cm at lower end of scion was made by removing bark and little wood from two opposite side in such a way that cut end of scion should be of paper thickness. Then scion was inserted properly into the silt of rootstock. After making sure their perfect contact, then it was tied with transparent polythene strip and secured firmly. Observations were taken at monthly interval upto 180 DAG.

3.4.5 Aftercare of grafts

In the first experiment, to compare the variation in success rate of grafts of three cultivars they were placed under open, polyhouse and polytunnel conditions with or without defoliation treatments. Defoliated grafts which were placed under open and polyhouse conditions were covered with polythene tubes for maintaining humidity which was removed after observing new sprout. In the second experiment, cytokinin applied at different concentration grafts without scion defoliation were placed under polytunnel for 1 month period. In both experiments, grafts kept under polytunnels (3m length, 0.75m height and 1.06m breadth) which were covered tightly with transparent polythene sheet. Grafts were placed on a slightly raised soil floor of polytunnel which was irrigated properly before placing the grafts on it. Polytunnel was watered frequently from the outside.

After 1 month of grafting polytunnel was opened gradually by slightly opening the polythene sheet from one corner of polytunnel. Remaining portion was opened in the following days. The grafts were then transferred to outside of polytunnel under shade net condition and provided adequate irrigation. Removal of new growth originating from rootstock portions was done regularly. Weeding and optimum irrigation to all grafts had done regularly. Adequate plant protection measures were taken at proper time when incidence of pest and disease was observed. Nimbecidine (4 to 5ml per litre) at weekly interval was applied to prevent attack of leaf blotch miner.

3.5 Experiment details

In both experiments grafting was performed under open condition and then they were transferred to corresponding environmental conditions (open, polyhouse, polytunnel followed by shade net). Grafts under polytunnel were shifted to shade net after 1 month.

3.5.1 Experiment 1: Role of varieties and environmental conditions on success of sapota grafting

The experiment was performed to find out the influence of varieties and environmental conditions on the success of sapota grafting. This was done by applying various environmental conditions and scion precuring in different sapota cultivars.

Location : College of Agriculture Padannakkad, Kasargod

Design : Factorial CRD experiment

Factors : 3 factors

Replications : 2 (15 grafts each)

3.5.1.1 Treatment details of experiment 1

Selected scions from mother plant of Oval, Pala and Cricket Ball cultivars had undergone defoliation as a part of precuring treatments. Defoliation was carried out on the same day and 10 days prior to grafting. Scions without any defoliation treatment were also used for grafting. After grafting, grafts were placed under various environmental conditions like open, polyhouse and polytunnel (for 1 month period after in shade condition).

Factors

Factor 1- Environmental conditions

C_1 - Softwood grafting under open conditions

C_2 - Softwood grafting under polyhouse conditions

C_3 - Softwood grafting under polytunnel conditions followed by shade net

Factor 2 -Cultivars

V_1 - Cricket Ball

V_2 - Pala

V_3 - Oval

Factor 3 -Scion precuring

S_1 - Defoliation 10 days prior to grafting

S_2 - Defoliation followed by grafting on the same day

S_3 - Without defoliation

Total number of treatment combinations=27

3.5.1.2 Observations recorded

Temperature and humidity of environmental conditions were observed for one month after grafting. Observations like number of leaves per grafts, length of scion shoot (cm), leaf area (cm^2), height of graft (cm), girth of stem graft (cm), length of leaves (cm), breadth of leaves (cm), number of successful grafts were recorded at 30,60, 90, 120 ,150 and 180 DAG. Success percentage (%) was noticed at 90 DAG and survival percentage (%), fresh weight (g) and dry weight (g) were recorded at 180 DAG. Observations were made by taking mean value of successful grafts with uniform growth in each treatment of replication. The parameters recorded were as follows:

3.5.1.2.1 Temperature

Temperature of environmental conditions where the grafts were kept was taken up to 30 DAG in weekly intervals using thermo hygrometer apparatus.

3.5.1.2.2 Humidity

Humidity of environmental conditions where the grafts were kept was taken up to 30 DAG in weekly intervals using thermo hygrometer apparatus.

3.5.1.2.3 Number of leaves per grafts

Number of leaves was observed from selected grafts plants up to 180 DAG monthly intervals.

3.5.1.2.4 Length of scion shoot (cm)

Length of scion shoot was recorded using a centimetre scale from selected grafts plants up to 180 DAG in monthly intervals.

3.5.1.2.5 Height of graft (cm)

Graft height was measured using a centimetre scale up to 180 DAG in monthly intervals.

3.5.1.2.6 Girth of stem graft (cm)

Girth of stem or stem diameter of graft plants were recorded using a thread. Observations continued up to 180 DAG in monthly intervals.

3.5.1.2.7 Length of leaves (cm)

Maximum length was recorded as length of leaf. Length of physiologically matured leaves of grafted plants were measured using a centimetre scale up to 180 DAG in monthly intervals.

3.5.1.2.8 Breadth of leaves (cm)

Middle part of leaf showing maximum breadth were taken. Physiologically matured leaves of grafted plants were recorded using a centimetre scale in monthly intervals up to 180 DAG.

3.5.1.2.9 Leaf area (cm^2)

Leaf area was calculated by linear measurement method. Length (L) and breadth (B) of leaves at maximum multiplied with leaf area constant give the area of leaf. Leaf area constant is a constant (K) which is specific for each crops. Observations are taken up to 180 DAG in monthly intervals.

Leaf area= LX BX K

3.5.1.2.10 Number of successful grafts

Number of successful grafts were noticed periodically at 30,60,90,120,150 and 180 DAG.

3.5.1.2.11 Success percentage (%)

Success percentage of grafts was measured at 90 DAG.

$$\text{Success percentage} = \frac{\text{Total number of successful grafts}}{\text{Total number of grafts}} \times 100$$

3.5.1.2.12 Survival percentage (%)

Survival percentage of grafts was measured at 180 DAG.

$$\text{Survival percentage} = \frac{\text{Total number grafts survived}}{\text{Total number of grafts}} \times 100$$

3.5.1.2.13 Fresh weight (g)

Fresh weight of three randomly selected grafted plants in each treatment were measured in grams with help of digital balance at 180 DAG.

3.5.1.2.14 Dry weight (g)

Dry weight of three randomly selected grafted plants in each treatment were measured in grams with help of digital balance at 180 DAG. This was done by cutting the plants followed by drying in oven at temperature range of 80^0 c for 4-5 days till reaching a constant weight. After this, weight was measured using an electronic balance and average value was calculated.

3.5.2 Experiment 2: Effect of cytokinin for improving success of sapota grafting

The experiment was carried out to study the influence of cytokinin for improving success of softwood grafting in sapota Cricket Ball cultivar. This was done by applying different concentration of cytokinin at different days of application.

Location : College of Agriculture Padannakkad, Kasaragod

Crop : Sapota- Cricket Ball cultivar

Design : Factorial CRD

Replications : 2 (15 grafts each)

3.5.2.1 Treatment details of experiment 2

Factors

Factor 1: Concentration of Cytokinin

P_1 :100 ppm

P_2 :150 ppm

P_3 :200 ppm

P_4 :Control

Factor 2: Days of application

D_1 :0^{th} day prior to grafting (Dipping treatment of cytokinin on scion)

D_2 :5^{th} day prior to grafting (Spraying of cytokinin on scion)

D_3 :10^{th} day prior to grafting (Spraying of cytokinin on scion)

Total number of treatment combinations=12

3.5.2.2 Preparation of solution of plant growth regulator cytokinin

The hormonal solution is prepared by using cytokinin in the form of BAP. Initially 1000 ppm stock solution of BAP was prepared by weighing 1000 mg (1g) BAP with the help of digital balance and dissolving it into 5 ml 0.1 per cent NaOH. The solution were made upto 1litre by adding distilled water. Application of BAP solution in 100 ppm, 150 ppm and 200 ppm was done by making it into 2 litre volume. 100 ppm, 150 ppm and 200 ppm BAP solution of 2 litre volume each is prepared by pipette outing 200ml, 300ml ,400 ml respectively from stock solution and made to 2 litre by adding distilled water.

3.5.2.3 Scion treatment by cytokinin

Application of cytokinin treatment on scion at 100,150 and 200 ppm were done on 10^{th} ,5^{th} and 0^{th} day prior to grafting. Spraying of cytokinin on scion was done on 10^{th} and 5^{th} day prior to grafting and dipping treatment of cytokinin on scion was done on 0^{th} day prior to grafting.

3.5.2.4 Observations recorded

Observations like number of leaves per grafts, length of scion shoot (cm), leaf area (cm^2), height of graft (cm), girth of stem graft (cm), length of leaves (cm), breadth of leaves (cm), number of successful grafts were noticed periodically at 30,60, 90, 120 ,150 and 180 DAG. Success percentage (%) was observed at 90 DAG and survival percentage (%), fresh weight (g) and dry weight (g) were recorded at 180 DAG. For taking observations, mean value of successful grafts with uniform growth in each treatment of replication is considered. Parameters observed under present study were follows:

3.5.2.4.1 Number of leaves per grafts

Number of leaves was observed from selected graft plants up to 180 DAG in monthly intervals.

3.5.2.4.2 Length of scion shoot (cm)

Length of scion shoot was recorded using a centimetre scale from selected graft plants upto 180 DAG in monthly intervals

3.5.2.4.3 Height of graft(cm)

Graft height was measured using a centimetre scale up to 180 DAG in monthly intervals.

3.5.2.4.4 Girth of stem graft (cm)

Girth of stem or stem diameter of graft plants were recorded using a thread. Observations continued upto 180 DAG at monthly intervals.

3.5.2.4.5 Length of leaves (cm)

Middle part of leaf showing maximum length was recorded as length of leaf. Length of physiologically matured leaves of grafted plants were measured using a centimetre scale upto 180 DAG at monthly intervals.

3.5.2.4.6 Breadth of leaves (cm)

Maximum breadth of physiologically matured leaves of grafted plants were recorded using a centimetre scale at monthly intervals up to 180 DAG.

3.5.2.4.7 Leaf area (cm^2)

Leaf area was calculated by linear measurement method. Length (L) and breadth (B) of leaves at maximum were multiplied with leaf area constant provided area of leaf. Leaf area constant is a constant (K) which is specific for each crops. Observations were taken up to 180 DAG in monthly intervals.

Leaf area= LX BX K

3.5.2.4.8 Number of successful grafts

The grafts which were successful were measured up to 180 DAG in monthly intervals.

3.5.2.4.9 Success percentage (%)

Success percentage of grafts was measured at 90 DAG.

$$\text{Success percentage} = \frac{\text{Total number of successful grafts X 100}}{\text{Total number of grafts}}$$

3.5.2.4.10 Survival percentage (%)

Survival percentage of grafts was measured at 180 DAG.

$$\text{Survival percentage} = \frac{\text{Total number of survived grafts X 100}}{\text{Total number of grafts}}$$

3.5.2.4.11 Fresh weight (g)

Fresh weight of three randomly selected grafted plants in each treatment were calculated in grams with help of digital balance at 180 DAG.

3.5.2.4.12 Dry weight (g)

Dry weight of three randomly selected grafted plants in each treatment were observed in grams with help of digital balance at 180 DAG. This was done by cutting the plants followed by drying in oven at temperature range of 80^0c for 4-5 days till reaching a constant weight. After this, weight was measured using an electric balance and average value was calculated.

3.6 Statistical analysis

The observations recorded were subjected to statistical analysis to find the significant differences between the treatments using GRAPE software (prepared by KAU) and OPSTAT software.

Results

4. RESULTS

The present study entitled "Refinement of softwood grafting technique in Sapota (*Manilkara zapota* L.)" was carried out at college of agriculture Padannakkad Kasaragod during 2019-2021. The first experiment included three environmental conditions *viz.* open, polyhouse and polytunnel followed by shade net with three cultivars *viz.* Cricket Ball, Pala and Oval and three scion precuring treatments *viz.* defoliation 10 days prior to grafting, defoliation followed by grafting on the same day and grafting without defoliation. Second experiment comprised of different concentration of cytokinin at 100 ppm, 150 ppm, 200 ppm and control levels with different days of application like 0^{th} day, 5^{th} and 10^{th} day prior to grafting. The results are presented in this chapter.

4.1 Experiment 1

4.1.1 Number of leaves per graft

The data showing number of leaves of graft influenced by environmental conditions, different cultivars and scion precuring treatments from 30 to 180 DAG are given in Table 1. Data indicated significant differences between environmental conditions, different cultivars and scion precuring treatments and among their interactions during the growth stages from 30 DAG to 180 DAG.

4.1.1.1 Effect of Environmental conditions

The observation on number of leaves at 30 DAG revealed that C_3 -polytunnel had higher (5.41) number of leaves followed by C_2-polyhouse (3.51). Least number (1.67) was observed with C_1 (open). The trend was similar at 60, 90, 120, 150 and 180 DAG. At 180 DAG, grafts under C_3 -Polytunnel had 14.79 leaves, whereas graft under open condition had only 8.33 leaves.

4.1.1.2 Effect of cultivars

Among the cultivars, Pala (V_2) had higher (3.61) number of leaves at 30 DAG which was statistically on par with V_1 (3.53). Least number of leaves was observed with variety V_3 Oval which was statistically on par with V_1 Cricket Ball (3.53). Similar trend was observed at 60 DAG. At 90 DAG number of leaves was highest

(5.86) in V_1 -Cricket Ball which was on par with V_2 (5.81). V_3 (Oval) had least (5.79) number of leaves. The differences between the cultivars regarding number of leaves were statistically insignificant at 120 DAG. Cricket Ball (V_1) had higher number of leaves (9.30) followed by both V_3 (9.0) and Pala (9.0) at 150 DAG. At 180 DAG, Cricket Ball (V_1) had higher number of leaves (11.05), followed by V_3 (10.90). Least was observed with V_2 Pala (10.55).

4.1.1.3 Effect of precuring

Among precuring treatments, S_1 defoliation 10 days prior to grafting was found to be better (3.89), followed by S_2 defoliation followed by grafting on the same day (3.53) at 30 DAG. Least number of leaves was seen in S_3 without defoliation. Similar trend was recorded at 60, 90,120, 150 and 180 DAG. Defoliation 10 days prior to grafting (S_1) had 13.69 leaves while in S_3 without defoliation only 5.92 leaves were present on an average at 180 DAG.

4.1.1.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, leaf production differ according the environmental condition in which grafts are kept. The treatment combination, C_3 V_3 (Polytunnel + Oval) showed higher (5.47) number of leaves. The trend was similar up to final growth stages. C_3 V_3 was statistically on par with C_3 V_1 -Polytunnel + Cricket Ball (5.37) and C_3 V_2 -Polytunnel + Pala (5.40) at 30 DAG. Least (1.49) number of leaves was in C_1V_3 Open condition + Pala at 30 DAG. At 180 DAG, C_3 V_3 (Polytunnel + Oval) had the highest (15.3) number of leaves followed by C_3 V_2 - Polytunnel + Pala (14.42). Least was observed with C_1V_3 (7.88).

4.1.1.5 Interaction effect of environmental conditions under which grafts are kept and precuring

The interaction between environmental conditions under which grafts were kept and precuring was found to be significant statistically. The grafts done without defoliation and kept in open condition (C_1S_3) could not survive. They dried off completely. Those grafts without defoliation and kept in poly house condition (C_2S_3)

also dried off. Grafts without defoliation could only survive under poly tunnel condition (C_3S_3). Highest number of leaves was found in C_3S_3 (9.50) at 30 DAG. Lowest (2.38) number of leaves was in grafts kept under poly house with same day defoliation (C_1 S_2). Similar results were observed up to 180 DAG. Number of leaves was highest in C_3S_3 (17.78) and lowest (12.10) number of leaves was in grafts kept under poly house with same day defoliation (C_1 S_2) at final stage of growth.

4.1.1.6 Interaction effect of cultivars and precuring

Varietal response to leaf production of grafts under different precuring treatments differed significantly. Highest leaf production (4.19) was in Pala with defoliation 10 days prior to grafting (V_2S_1) at 30 DAG. This was followed by V_1S_1 Cricket Ball with defoliation 10 days prior to grafting (3.87). Least was in Pala without defoliation (3.05). Similar results were observed at 60 DAG , 90 DAG and 120 DAG. Higher number of leaves (9.36) was observed in Pala with defoliation 10 days prior to grafting (V_2S_1) which was on par with V_3S_1 Oval with defoliation 10 days prior to grafting (9.29) at 120 DAG. Lowest number of leaves (4.24) was recorded in Pala without defoliation (V_2S_3). Highest number of leaves (11.67) was recorded with Cricket Ball with defoliation prior to 10 days of grafting (V_1S_1) which was on par with Oval with defoliation 10 days prior to grafting (11.41) at 150 DAG. V_2S_3 Pala without defoliation (5.00) and V_3S_3 Oval without defoliation had the lowest number of leaves. Similar results were observed at 180 DAG.

4.1.1.7 Interaction effect of environmental conditions, cultivars, scion precuring

The grafts without defoliation of cultivars Cricket Ball, Pala and Oval kept under open condition did not survive after grafting (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3). Also the grafted plants without defoliation of cultivars, Cricket Ball, Pala and Oval kept under poly house condition did not survive after grafting (C_2 V_1 S_3 , C_2 V_2 S_3 and C_2 V_3 S_3). Those grafted plants wherein grafting was done without defoliation could survive only under the polytunnel condition.

Table 1. Effect of environmental conditions, cultivars, scion precuring and their interactions on mean number of leaves

Factors	30 days	60days	90days	120days	150days	180days
Factor C						
C_1	1.67	2.47	3.58	4.81	6.27	8.33
C_2	3.51	4.43	5.29	6.58	8.07	9.38
C_3	5.41	6.91	8.59	10.79	12.95	14.79
C.D(0.05)	0.08	0.05	0.05	0.19	0.08	0.09
SEm (±)	0.02	0.02	0.01	0.06	0.02	0.03
Factor V						
V_1	3.53	4.53	5.86	7.28	9.30	11.05
V_2	3.61	4.66	5.81	7.40	9.00	10.55
V_3	3.45	4.61	5.79	7.51	9.00	10.90
C.D(0.05)	0.08	0.05	0.05	NS	0.08	0.09
SEm (±)	0.02	0.02	0.01	0.06	0.02	0.03
Factor S						
S_1	3.89	5.51	7.11	9.18	11.48	13.69
S_2	3.53	4.66	6.37	8.41	10.60	12.88
S_3	3.16	3.64	3.98	4.59	5.21	5.92
SEm (±)	0.02	0.02	0.01	0.06	0.02	0.03
C.D(0.05)	0.08	0.05	0.05	0.19	0.08	0.09
Factor CXV						
C_1 V_1	1.65	2.42	3.51	4.53	6.35	8.65
C_1 V_2	1.86	2.82	3.86	5.31	6.61	8.47
C_1 V_3	1.49	2.18	3.39	4.58	5.85	7.88
C_2 V_1	3.57	4.37	5.56	6.59	8.22	9.85
C_2 V_2	3.56	4.47	5.14	6.50	7.79	8.77
C_2 V_3	3.40	4.44	5.17	6.65	8.22	9.53
C_3 V_1	5.37	6.82	8.51	6.65	8.22	9.53
C_3 V_2	5.40	6.71	8.45	10.39	12.60	14.42
C_3 V_3	5.47	7.19	8.81	11.29	12.92	15.30
SEm(±)	0.05	0.03	0.03	0.11	0.04	0.05
C.D(0.05)	0.14	0.09	0.09	0.32	0.14	0.15
Factor CXS						
C_1 S_1	2.63	4.02	5.65	7.69	9.79	12.90
C_1 S_2	2.38	3.40	5.11	6.74	9.03	12.10
C_1 S_3	-	-	-	-	-	-
C_2 S_1	5.72	7.50	8.63	10.38	13.08	15.07
C_2 S_2	4.81	5.7	7.24	9.37	11.15	13.09
C_2 S_3	-	-	-	-	-	-
C_3 S_1	3.33	5.00	7.05	9.48	11.58	13.12
C_3 S_2	3.42	4.80	6.77	9.13	11.62	13.46
C_3 S_3	9.50	10.92	11.94	13.78	15.65	17.78
SEm (±)	0.05	0.03	0.03	0.11	0.04	0.05
C.D(0.05)	0.14	0.09	0.09	0.32	0.14	0.15
Factor VXS						
V_1 S_1	3.87	5.07	7.06	8.89	11.67	13.80
V_1 S_2	3.51	4.6	6.28	8.03	10.67	13.00
V_1 S_3	3.21	3.89	4.24	4.90	5.56	6.34
V_2 S_1	4.19	5.96	7.24	9.36	11.37	13.58

Table 1 (contd…)

V_2 S_2	3.59	4.58	6.47	8.60	10.63	12.41
V_2 S_3	3.05	3.46	3.74	4.24	5.00	5.68
V_3 S_1	3.63	5.49	7.03	9.29	11.41	13.71
V_3 S_2	3.50	4.77	6.37	8.60	10.50	13.24
V_3 S_3	3.23	3.56	3.96	4.63	5.09	5.76
SEm (±)	0.05	0.03	0.03	0.11	0.04	0.05
C.D(0.05)	0.14	0.09	0.09	0.32	0.14	0.15
Factor CXVXS						
C_1 V_1 S_1	2.64	3.75	5.17	7.27	9.70	13.04
C_1 V_1 S_2	2.32	3.51	5.36	6.34	9.37	12.91
C_1 V_1 S_3	-	-	-	-	-	-
C_1 V_2 S_1	2.94	4.92	6.18	8.41	10.31	13.39
C_1 V_2 S_2	2.65	3.54	5.40	7.53	9.54	12.02
C_1 V_2 S_3	-	-	-	-	-	-
C_1 V_3 S_1	2.31	3.39	5.60	7.40	9.38	12.27
C_1 V_3 S_2	2.17	3.16	4.57	6.35	8.19	11.38
C_1 V_3 S_3	-	-	-	-	-	-
C_2 V_1 S_1	5.79	7.18	9.38	10.48	13.48	16.03
C_2 V_1 S_2	4.92	5.93	7.31	9.29	11.18	13.53
C_2 V_1 S_3	-	-	-	-	-	-
C_2 V_2 S_1	5.86	7.74	8.18	10.18	12.38	14.21
C_2 V_2 S_2	4.82	5.67	7.24	9.34	10.99	12.12
C_2 V_2 S_3	-	-	-	-	-	-
C_2 V_3 S_1	5.53	7.58	8.33	10.47	13.40	14.98
C_2 V_3 S_2	4.69	5.76	7.18	9.48	11.27	13.62
C_2 V_3 S_3	-	-	-	-	-	-
C_3 V_1 S_1	3.18	4.27	6.64	8.94	11.84	12.33
C_3 V_1 S_2	3.29	4.50	6.17	8.47	11.47	12.57
C_3 V_1 S_3	9.65	11.68	12.72	14.72	16.68	19.03
C_3 V_2 S_1	3.76	5.22	7.36	9.50	11.44	13.14
C_3 V_2 S_2	3.30	4.53	6.77	8.94	11.35	13.09
C_3 V_2 S_3	9.15	10.39	11.22	12.72	15.00	17.04
C_3 V_3 S_1	3.05	5.52	7.16	10.01	11.46	13.88
C_3 V_3 S_2	3.66	5.38	7.37	9.97	12.04	14.73
C_3 V_3 S_3	9.69	10.68	11.89	13.90	15.28	17.28
SEm(±)	0.08	0.05	0.05	0.19	0.08	0.09
C.D(0.05)	0.25	0.17	0.15	0.56	0.24	0.27

C_1- Softwood grafting under open

C_2- Softwood grafting under polyhouse

C_3- Softwood grafting under polytunnel

V_1- Cricket Ball

V_2- Pala

V_3- Oval

S_1- Defoliation 10 days prior to grafting

S_2- Defoliation followed by grafting on the same day

S_3- Without defoliation

Higher number of leaves (9.69) was observed with Cricket Ball grafted without defoliation and kept in poly tunnel condition C_3 V_3 S_3 which was on par with C_3 V_1 S_3 grafted without defoliation of Pala kept under poly tunnel condition (9.65). This was followed by Pala grafted without defoliation and kept under poly tunnel condition (9.15). Lowest number of leaves was seen in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting and kept under open condition (2.17). C_3 V_1 S_3 Pala grafted without defoliation kept under poly tunnel condition had the top number of leaves (11.68) at 60 DAG. This was followed by C_3 V_3 S_3 cricket ball grafted without defoliation and kept in poly tunnel condition (10.68). Lowest number of leaves was seen in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting and kept under open condition (4.57). The trend was similar at 90, 120, 150 and 180 DAG. C_3 V_1 S_3 Pala grafted without defoliation kept under poly tunnel condition had 19.03 leaves on an average at 180 DAG.

4.1.2 Length of scion shoot

There was significant variation of length of scion shoot in terms of environmental conditions, different cultivars and scion precuring treatments from 30 to 180 DAG showed in the Table 2. Data indicated significant differences between environmental conditions, different cultivars and scion precuring treatments and among their interactions during the growth stages from 30 DAG to 180 DAG.

4.1.2.1 Effect of environmental conditions

The observation on length of scion shoot at 30 DAG revealed that C_3 -Polytunnel (9.79) had higher length of scion shoot followed by C_2 (6.60). Least was observed with C_1 -open condition (6.09). The trend was similar at 60, 90, 120, 150 and 180 DAG. Grafts under C_3 -Polytunnel had 19.28 scion length, whereas graft under open condition had only 11.52 scion length at 180 DAG.

Table 2. Effect of environmental conditions, cultivars, scion precuring and their interactions on mean length of scion shoot

Factors	30days	60days	90days	120days	150days	180days
Factor C						
C_1	6.09	6.72	8.26	9.41	10.71	11.52
C_2	6.60	7.43	8.61	9.95	11.21	12.32
C_3	9.79	11.30	13.40	15.23	17.20	19.28
SEm (±)	0.01	0.01	0.03	0.01	0.011	0.033
C.D(0.05)	0.02	0.03	0.09	0.02	0.02	0.09
Factor V						
V_1	7.48	8.62	10.18	11.54	13.06	14.43
V_2	7.58	8.46	10.11	11.72	13.01	14.29
V_3	7.42	8.37	9.98	11.33	13.04	14.40
C.D(0.05)	0.02	0.03	0.09	0.02	0.02	0.09
SEm (±)	0.01	0.01	0.03	0.007	0.008	0.033
Factor S						
S_1	9.64	10.85	12.79	14.90	16.72	18.44
S_2	9.25	10.47	12.39	14.13	16.10	17.71
S_3	3.59	4.14	5.09	5.56	6.30	6.97
C.D(0.05)	0.02	0.03	0.09	0.02	0.02	0.09
SEm (±)	0.010	0.011	0.032	0.007	0.008	0.033
Factor CXV						
C_1 V_1	6.19	6.94	8.59	9.62	10.94	11.58
C_1 V_2	6.09	6.72	8.14	9.63	10.87	11.67
C_1 V_3	6.01	6.50	8.05	8.99	10.33	11.32
C_2 V_1	6.48	7.29	8.59	9.72	10.95	12.34
C_2 V_2	6.84	7.41	8.69	10.20	11.32	12.13
C_2 V_3	6.48	7.60	8.57	9.92	11.34	12.49
C_3 V_1	9.77	11.64	13.37	15.29	17.28	19.37
C_3 V_2	9.81	11.25	13.49	15.32	16.85	19.07
C_3 V_3	9.79	11.00	13.33	15.08	17.46	19.40
SEm(±)	0.018	0.019	0.056	0.012	0.013	0.055
C.D(0.05)	0.05	0.05	0.16	0.03	0.03	0.15
Factor CXS						
C_1 S_1	9.29	10.18	12.63	14.41	16.37	17.35d
C_1 S_2	9.00	9.98	12.16	13.84	15.77	17.22
C_1 S_3	-	-	-	-	-	-
C_2 S_1	10.33	11.46	13.34	15.77	17.47	19.52
C_2 S_2	9.47	10.84	12.51	14.07	16.16	17.45
C_2 S_3	-	-	-	-	-	-
C_3 S_1	9.32	10.90	12.41	14.52	16.31	18.46
C_3 S_2	9.28	10.58	12.49	14.48	16.37	18.45
C_3 S_3	10.77	12.42	15.29	16.68	18.91	20.92
SEm (±)	0.018	0.019	0.056	0.012	0.013	0.055
C.D(0.05)	0.050	0.050	0.162	0.035	0.039	0.158
Factor VXS						
V_1 S_1	9.53	10.99	12.83	14.90	16.65	18.56
V_1 S_2	9.33	10.55	12.54	14.12	16.02	17.62

Table 2 (contd…)

$V_1 S_3$	3.58	4.32	5.17	5.62	6.51	7.12
$V_2 S_1$	9.70	10.88	12.85	14.99	16.58	18.41
$V_2 S_2$	9.44	10.43	12.44	14.59	16.41	17.68
$V_2 S_3$	3.61	4.07	5.03	5.57	6.05	6.78
$V_3 S_1$	9.71	10.67	12.70	14.82	16.92	18.36
$V_3 S_2$	8.99	10.42	12.18	13.69	15.87	17.83
$V_3 S_3$	3.58	4.01	5.07	5.48	6.34	7.01
SEm (±)	0.018	0.019	0.056	0.012	0.013	0.055
C.D(0.05)	0.051	0.056	NS	0.035	0.039	0.158
Factor CXVXS						
$C_1 V_1 S_1$	9.22	10.36	12.84	14.54	16.36	17.47
$C_1 V_1 S_2$	9.35	10.46	12.94	14.33	16.47	17.29
$C_1 V_1 S_3$	-	-	-	-	-	-
$C_1 V_2 S_1$	9.22	10.14	12.33	14.25	16.25	17.46
$C_1 V_2 S_2$	9.05	10.04	12.11	14.66	16.37	17.56
$C_1 V_2 S_3$	-	-	-	-	-	-
$C_1 V_3 S_1$	9.43	10.05	12.73	14.44	16.52	17.13
$C_1 V_3 S_2$	8.60	9.46	11.44	12.54	14.47	16.83
$C_1 V_3 S_3$	-	-	-	-	-	-
$C_2 V_1 S_1$	10.13	11.38	13.34	15.81	17.54	19.88
$C_2 V_1 S_2$	9.31	10.49	12.44	13.35	15.33	17.15
$C_2 V_1 S_3$	-	-	-	-	-	-
$C_2 V_2 S_1$	10.55	11.55	13.61	16.05	17.34	19.24
$C_2 V_2 S_2$	9.98	10.69	12.46	14.55	16.62	17.16
$C_2 V_2 S_3$	-	-	-	-	-	-
$C_2 V_3 S_1$	10.32	11.46	13.08	15.46	17.52	19.44
$C_2 V_3 S_2$	9.13	11.34	12.63	14.32	16.52	18.03
$C_2 V_3 S_3$	-	-	-	-	-	-
$C_3 V_1 S_1$	9.24	11.25	12.32	14.34	16.06	18.33
$C_3 V_1 S_2$	9.33	10.70	12.25	14.67	16.25	18.41
$C_3 V_1 S_3$	10.75	12.98	15.53	16.88	19.54	21.36
$C_3 V_2 S_1$	9.33	10.95	12.61	14.68	16.14	18.53
$C_3 V_2 S_2$	9.29	10.57	12.76	14.55	16.26	18.33
$C_3 V_2 S_3$	10.83	12.23	15.11	16.72	18.15	20.36
$C_3 V_3 S_1$	9.38	10.50	12.31	14.56	16.73	18.52
$C_3 V_3 S_2$	9.24	10.47	12.47	14.23	16.62	18.62
$C_3 V_3 S_3$	10.74	12.04	15.22	16.45	19.04	21.05
SEm(±)	0.030	0.034	0.097	0.021	0.023	0.094
C.D(0.05)	0.08	0.09	0.28	0.06	0.06	0.27

C_1- Softwood grafting under open condition V_1- Cricket Ball

C_2- Softwood grafting under polyhouse V_2- Pala

C_3- Softwood grafting under polytunnel V_3- Oval

S_1- Defoliation 10 days prior to grafting S_3- Without Defoliation

S_2- Defoliation followed by grafting on the same day

4.1.2.2 Effect of precuring

Regarding precuring treatments, at 30 DAG, S_1 defoliation 10 days prior to grafting was found to be better (9.64), followed by S_2 defoliation followed by grafting on the same day. Least scion length was seen in S_3 (3.59) without defoliation. Similar trend was recorded at 60, 90,120, 150 and 180 DAG. At 180 DAG, S_1 defoliation 10 days prior to grafting had 18.44 scion shoot length while in S_3 without defoliation had only 6.97 scion shoot length on an average.

4.1.2.3 Effect of cultivars

Among the cultivars, V_2 Pala had higher length of scion shoot at 30 DAG (7.58). Least (7.42) length of scion shoot was observed with V_3 Oval. Similar trend was observed at 120 DAG. At 60 DAG length of scion shoot was highest in V_1 - Cricket Ball (8.62). V_3 Oval had the least length of scion shoot (8.37). At 90 DAG similar trend was observed. At 150 DAG and 180 DAG V_1-Cricket Ball had the higher length of scion shoot (13.06 and 14.43) followed by V_3 Oval (13.04 and 14.40) and least was in V_2 Pala (13.01 and 14.29).

4.1.2.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, length of scion shoot varied according the environmental condition in which grafts are kept. The treatment combination, C_3 V_2 (Polytunnel + Pala) showed the higher (9.81) length of scion shoot which was statistically on par with C_3 V_1 -Polytunnel + Cricket Ball (9.77) and C_3 V_3 -Polytunnel+ Oval (9.79). Least number of length of scion shoot was in C_1V_3 Open condition + Oval (6.01) at 30 DAG. The trend was similar at 90 DAG and 120 DAG. At 150 DAG and 180 DAG, C_3 V_3 (Polytunnel + Oval) had the highest length of scion shoot (17.46 and 19.40) which was on par with C_3V_1 (Polytunnel + Cricket Ball) where as least was observed with C_1V_3 (10.33 and 11.32).

4.1.2.5 Interaction effect of environmental conditions under which grafts are kept and scion precuring

There was significant variation between interaction of environmental conditions under which grafts are kept and procuring treatments. The grafts done without defoliation and kept in open condition could not survive. They dried off completely. Those grafts without defoliation and kept in polyhouse condition also dried off. Grafts without defoliation could only survive under poly tunnel condition. Highest length of scion shoot was found in C_3S_3- grafts under polytunnel without defoliation (10.77) at 30 DAG. Lowest length of scion shoot was in C_1 S_2 (9.00) grafting done in poly house with same day defoliation. Similar trends of results were observed at 60, 90, 120, 150 and 180 DAG.

4.1.2.6 Interaction effect of cultivars and precuring

Varietal effect to length of scion shoot of grafts under different precuring treatments varied significantly. Highest scion length was in V_3S_1 Oval with defoliation 10 days prior to grafting (9.71) at 30 DAG. Least was in V_1S_3 Cricket Ball without defoliation (3.58) and V_3 S_3 Oval without defoliation (3.58) at 30 DAG. Similar results were observed at 60 DAG and 180 DAG where highest scion length was in V_1 S_1 (10.99 and 18.56) Cricket Ball with defoliation 10 days prior to grafting. There was no significant difference recorded at 90 DAG. Maximum length of scion shoot was observed in V_2S_1 Pala with defoliation 10 days prior to grafting (14.99) at 120 DAG. At 150 DAG, highest length of scion shoot was recorded with V_3S_1 (16.92) Oval with defoliation prior to 10 days of grafting and minimum was in V_2 S_3 (6.05).

4.1.2.7 Interaction effect of environmental conditions, cultivars, scion precuring

The grafts under open condition without scion defoliation of cultivars, Cricket ball, Pala and Oval could not survive (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3). Grafts without scion defoliation of cultivars, Cricket Ball, Pala and Oval which were kept under poly house condition also did not survive(C_2 V_1 S_3 , C_2 V_2 S_3 , and C_2 V_3 S_3). Survival was only under polytunnel condition in which grafting was done without defoliation. At 30 DAG, more length of scion shoot was observed with C_3 V_2 S_3 Pala grafted without defoliation under poly tunnel condition (10.83) which

was on par with C_3 V_1 S_3 (10.75) grafted without defoliation of Cricket Ball kept under poly tunnel condition. Lowest length of scion shoot was seen in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting under open condition (8.60). Cricket Ball grafted without defoliation kept under poly tunnel condition C_3 V_1 S_3 had maximum (12.98) length of scion shoot and minimum was found in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting and kept under open condition (9.46) at 60 DAG. The trend was similar from 90 to 180 DAG.

4.1.3 Leaf area

There was significant variation of leaf area in terms of environmental conditions, different cultivars and scion precuring treatments from 30 to 180 DAG showed in the Table 3.

4.1.3.1 Effect of environmental conditions

The observation on leaf area at 30 DAG revealed that C_3 -Polytunnel (3.48) had higher leaf area followed by C_2 (1.91). Least leaf area was observed with C_1 (open condition) (1.83). The trend was similar at 60, 90, 120, 150 and 180 DAG. At 180 DAG, leaf area of grafts under C_3 -Polytunnel was 26.01, whereas graft under open condition had only 12.59.

4.1.3.2 Effect of cultivars

Regarding the cultivars, V_1-Cricket Ball had maximum leaf area at 30 DAG (2.55) and least leaf area was observed with V_2-Pala (2.30). V_3 -Oval had more leaf area (5.19) which was on par with V_1 - Cricket Ball and V_2 showed minimum (4.74) leaf area at 60 DAG. At 120 DAG, V_2 - Pala (10.76) showed statistically higher leaf area. At 150 DAG, V_3-Oval had highest leaf area (14.22) which was followed by V_2 Pala (13.83). At 180 DAG, V_2 Pala had higher leaf area (18.77), followed by V_3(Oval). Least was observed with V_1 Cricket Ball (17.66).

4.1.3.3 Effect of precuring

Regarding precuring treatments, at 30 DAG, S_1 defoliation 10 days prior to grafting was found to be highest (2.85). Similar trend was recorded at 60,120, 150 and

Table 3. Effect of environmental conditions, cultivars, scion precuring and their interactions on mean leaf area

Factors	30days	60days	90days	120days	150days	180days
Factor C						
C_1	1.83	2.96	4.56	7.19	9.47	12.59
C_2	1.91	4.22	6.20	9.25	12.27	16.17
C_3	3.48	6.95	10.60	15.37	19.84	26.01
SEm (±)	0.010	0.014	0.023	0.03	0.02	0.033
C.D(0.05)	0.02	0.04	0.06	0.08	0.07	0.09
Factor V						
V_1	2.55	4.74	7.19	10.41	13.54	17.66
V_2	2.30	4.67	7.19	10.76	13.83	18.77
V_3	2.37	5.19	7.97	10.64	14.22	18.30
C.D(0.05)	0.02	0.04	0.06	0.08	0.07	0.09
SEm (±)	0.01	0.01	0.023	0.03	0.02	0.03
Factor S						
S_1	2.85	5.71	8.56	12.94	17.31	22.31
S_2	1.69	3.40	4.91	11.83	15.93	21.19
S_3	2.69	5.49	8.66	7.04	8.35	11.24
SEm (±)	0.01	0.01	0.023	0.03	0.02	0.03
C.D(0.05)	0.02	0.04	0.06	0.08	0.07	0.09
Factor CXV						
C_1 V_1	1.57	2.94	4.46	7.33	9.86	11.89
C_1 V_2	1.60	3.07	4.63	7.27	9.31	13.57
C_1 V_3	2.32	4.30	7.03	10.78	13.85	19.15
C_2 V_1	1.93	4.01	6.52	8.62	11.83	15.67
C_2 V_2	1.89	4.17	6.07	9.47	12.44	16.59
C_2 V_3	1.92	4.48	6.03	9.66	12.54	16.25
C_3 V_1	3.63	7.26	10.59	15.27	18.93	25.42
C_3 V_2	3.42	6.79	10.35	15.55	19.73	26.17
C_3 V_3	3.40	6.80	10.85	15.28	20.86	26.46
SEm(±)	0.01	0.02	0.04	0.05	0.04	0.05
C.D(0.05)	0.04	0.07	0.11	0.15	0.13	0.16
Factor CXS						
C_1 S_1	2.48	4.61	7.03	11.17	14.51	18.86
C_1 S_2	2.25	4.29	6.68	10.41	13.91	18.81
C_1 S_3	-	-	-	-	-	-
C_2 S_1	3.21	7.01	10.05	15.12	20.18	26.01
C_2 S_2	2.53	5.65	8.57	12.63	16.65	22.51
C_2 S_3	-	-	-	-	-	-
C_3 S_1	2.85	5.51	8.63	12.52	17.23	22.08
C_3 S_2	2.82	5.93	8.19	12.45	17.24	22.24
C_3 S_3	4.78	9.41	14.98	21.14	25.05	33.72
SEm (±)	0.01	0.02	0.04	0.05	0.04	0.05
C.D(0.05)	0.04	0.07	0.11	0.15	0.13	0.16
Factor VXS						
V_1 S_1	2.89	5.83	8.30	12.31	16.86	21.27

Table 3 (contd…)

V_1 S_2	1.72	3.59	4.90	7.56	9.96	12.88
V_1 S_3	2.51	4.80	8.37	11.36	13.80	18.83
V_2 S_1	2.64	5.53	8.33	12.59	17.13	22.54
V_2 S_2	1.96	3.39	5.25	8.47	10.87	14.78
V_2 S_3	1.49	5.11	7.47	11.23	13.48	18.91
V_3 S_1	3.01	5.77	9.05	13.91	17.92	23.14
V_3 S_2	1.38	3.24	4.71	6.83	19.01	13.29
V_3 S_3	3.24	6.57	10.15	6.93	8.46	25.42
SEm (±)	0.01	0.02	0.04	0.05	0.04	0.05
C.D(0.05)	0.04	0.07	0.11	0.15	0.13	0.16
Factor CXVXS						
C_1 V_1 S_1	2.43	4.46	6.87	11.14	14.78	17.77
C_1 V_1 S_2	2.28	4.38	6.52	10.85	14.79	17.90
C_1 V_1 S_3	-	-	-	-	-	-
C_1 V_2 S_1	1.87	4.38	6.17	10.16	13.23	18.65
C_1 V_2 S_2	2.92	4.83	7.74	11.67	14.72	22.08
C_1 V_2 S_3	-	-	-	-	-	-
C_1 V_3 S_1	3.15	4.98	7.96	12.22	15.53	20.17
C_1 V_3 S_2	1.55	3.66	5.80	8.72	12.23	16.45
C_1 V_3 S_3	-	-	-	-	-	-
C_2 V_1 S_1	3.32	7.08	10.42	14.09	20.32	25.94
C_2 V_1 S_2	2.48	4.95	9.14	11.78	15.18	21.09
C_2 V_1 S_3	-	-	-	-	-	-
C_2 V_2 S_1	3.23	6.63	10.02	15.03	20.43	26.06
C_2 V_2 S_2	2.45	5.89	8.19	13.38	16.9	23.70
C_2 V_2 S_3	-	-	-	-	-	-
C_2 V_3 S_1	3.10	7.32	9.71	16.24	19.78	26.02
C_2 V_3 S_2	2.67	6.13	8.38	12.75	17.85	22.74
C_2 V_3 S_3	-	-	-	-	-	-
C_3 V_1 S_1	2.93	5.95	7.60	11.69	15.49	20.09
C_3 V_1 S_2	2.90	6.39	8.19	11.82	15.08	20.74
C_3 V_1 S_3	5.05	9.45	15.99	22.30	26.22	35.42
C_3 V_2 S_1	2.82	5.58	8.80	12.59	17.75	22.92
C_3 V_2 S_2	2.95	5.34	8.03	13.74	17.89	22.55
C_3 V_2 S_3	4.48	9.45	14.22	20.32	23.54	33.04
C_3 V_3 S_1	2.80	5.01	9.48	13.28	18.46	23.23
C_3 V_3 S_2	2.61	6.06	8.35	11.78	18.74	23.44
C_3 V_3 S_3	4.80	9.34	14.72	20.80	25.38	32.70
SEm(±)	0.02	0.04	0.07	0.12	0.08	0.09
C.D(0.05)	0.08	0.12	0.20	0.26	0.23	0.28

C_1- Softwood grafting under open condition

C_2- Softwood grafting under polyhouse

C_3- Softwood grafting under polytunnel

V_1- Cricket Ball

V_2- Pala

V_3- Oval

S_1- Defoliation 10 days prior to grafting

S_2- Defoliation followed by grafting on the same day

S_3- Without Defoliation

180 DAG. At 180 DAG, S_1 defoliation 10 days prior to grafting had 22.31 cm² leaf area while in S_3 without defoliation had only 11.24 cm² area of leaf on an average.

4.1.3.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, length of scion shoot varied according the environmental condition in which grafts are kept. The treatment combination, C_3 V_1 (Polytunnel + Cricket Ball) showed the higher (3.63) leaf area. Least number of leaf area was in C_1V_1 Open condition + Cricket Ball (1.57) at 30 DAG. The trend was similar at 60 DAG. Considering data at 90 DAG, 150 DAG and 180 DAG, had similar findings where C_3 V_3 (Polytunnel + Oval) had the highest leaf area (10.85, 20.86 and 26.46).

4.1.3.5 Interaction effect of environmental conditions under which grafts are kept and precuring

The interaction between environmental conditions under which grafts are kept and precuring was found to be significant statistically. The grafts done without defoliation and kept in open condition could not survive. Those grafts without defoliation and kept in polyhouse condition also dried off. Grafts without defoliation could only survive under poly tunnel condition. Highest leaf area was observed in C_3S_3 (4.78) and lowest leaf area was in C_1 S_2 (2.25) grafting done in poly house with same day defoliation at 30 DAG. At 60, 90, 120, 150 and 180 DAG similar findings were recorded.

4.1.3.6 Interaction effect of cultivars and precuring

Varietal response to length of scion shoot of grafts under different precuring treatments varied significantly. Highest leaf area was in V_3S_3 Oval without defoliation (3.24) at 30 DAG. Similar findings were observed in 90,120,150 and 180 DAG. Least was in V_2S_3 Pala without defoliation (1.49) at 30 DAG. Highest leaf area was in V_3 S_3 (25.42) Oval without defoliation and lowest was found in V_3 S_2 (13.29) at final stage of growth.

4.1.3.7 Interaction effect of environmental conditions, cultivars, scion precuring

There was no survival of grafts of cultivars, Cricket Ball, Pala and Oval kept under open condition without scion defoliation (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3). The same was observed in grafts without scion defoliation of cultivars, Cricket Ball, Pala and Oval and kept under poly house condition (C_2 V_1 S_3 , C_2 V_2 S_3 and C_2 V_3 S_3). Survival was obtained with grafts without scion defoliation under polytunnel condition. Higher leaf area was observed with C_3 V_1 S_3 Cricket Ball grafted without defoliation and kept in poly tunnel condition (5.05) at 30 DAG. Lowest leaf area was seen in C_1 V_3 S_2 Oval grafted with defoliation on the same day of grafting and kept under open condition (1.55). The trend was similar at 90 to 180 DAG. Leaf area recorded maximum in C_3 V_1 S_3 (35.42) and minimum was in C_1 V_3 S_2 (16.45) at 180 DAG.

4.1.4 Height of graft

There was significant difference of height of graft in terms of environmental conditions, different cultivars and scion precuring treatments from 30 to 180 DAG showed in the Table 4. Data showed significant differences between environmental conditions, different cultivars and scion precuring treatments and among their interactions during the growth stages from 30 DAG to 180 DAG.

4.1.4.1 Effect of environmental conditions

The observation on height of graft at 30 DAG showed that C_3 -Polytunnel (23.84) had higher height of graft followed by C_2 (15.70). Least height of graft was observed with C_1 -open condition (15.53). The trend was similar at 60, 90, 120, 150 and 180 DAG. Grafts under C_3 -Polytunnel recorded 33.47 height of graft, whereas graft under open condition had only 21.17 height of graft at 180 DAG.

4.1.4.2 Effect of cultivars

Regarding the cultivars, V_3-Oval had maximum height of graft at 30 DAG (18.40) and least height of graft was observed with V_1 -Cricket Ball (18.33). V_2 - Pala showed statistically higher value at 60 and 120 DAG. V_1 Cricket Ball had highest height of graft at 150 and 180 DAG. At 180 DAG, V_1 Cricket Ball showed highest

Table 4. Effect of environmental conditions, cultivars, scion precuring and their interactions on mean height of graft

Factors	30days	60days	90days	120days	150days	180days
Factor C						
C_1	15.53	16.67	18.04	18.77	19.97	21.17
C_2	15.70	16.98	18.28	19.37	20.68	21.99
C_3	23.84	25.67	27.73	29.68	31.58	33.47
SEm (±)	0.003	0.003	0.005	0.005	0.003	0.004
C.D(0.05)	0.010	0.009	0.015	0.014	0.010	0.009
Factor V						
V_1	18.33	19.80	21.37	22.57	24.14	25.76
V_2	18.35	19.84	21.37	22.66	24.03	25.37
V_3	18.40	19.68	21.31	22.59	24.07	25.50
C.D(0.05)	0.010	0.009	0.015	0.014	0.010	0.009
SEm (±)	0.003	0.003	0.005	0.005	0.003	0.004
Factor S						
S_1	23.48	25.43	27.44	29.05	30.99	32.76
S_2	23.37	25.09	27.11	28.62	30.31	32.30
S_3	8.23	8.79	9.49	10.16	10.94	11.57
SEm (±)	0.003	0.003	0.005	0.005	0.003	0.004
C.D(0.05)	0.010	0.009	0.015	0.014	0.010	0.009
Factor CXV						
C_1 V_1	15.58	16.64	18.01	18.57	19.87	21.28
C_1 V_2	15.52	16.85	18.21	19.15	19.97	21.09
C_1 V_3	15.51	16.52	17.89	18.60	20.08	21.15
C_2 V_1	15.66	16.99	18.31	19.21	20.59	21.94
C_2 V_2	15.70	16.98	18.18	19.33	20.82	21.82
C_2 V_3	15.76	16.95	18.37	19.58	20.65	22.21
C_3 V_1	23.74	25.75	27.80	29.94	31.96	34.06
C_3 V_2	23.83	25.68	27.71	29.50	31.30	33.20
C_3 V_3	23.94	25.58	27.69	29.59	31.48	33.16
SEm(±)	0.006	0.005	0.009	0.008	0.006	0.005
C.D(0.05)	0.017	0.016	0.025	0.024	0.017	0.015
Factor CXS						
C_1 S_1	23.36	25.32	27.24	28.39	30.31	31.92
C_1 S_2	23.25	24.70	26.88	27.94	29.62	31.60
C_1 S_3	-	-	-	-	-	-
C_2 S_1	23.69	25.61	27.73	29.53	31.40	33.38
C_2 S_2	23.43	25.32	27.13	28.59	30.66	32.59
C_2 S_3	-	-	-	-	-	-
C_3 S_1	23.39	25.36	27.37	29.23	31.26	33.00
C_3 S_2	23.43	25.26	27.33	29.31	30.66	32.71
C_3 S_3	24.69	26.39	28.49	30.49	32.83	34.71
SEm (±)	0.006	0.005	0.009	0.008	0.006	0.005
C.D(0.05)	0.017	0.016	0.025	0.024	0.017	0.015
Factor VXS						
V_1 S_1	23.39	25.39	27.43	28.98	31.03	32.99

Table 4 (contd…)

V_1 S_2	23.34	25.09	27.15	28.37	30.25	32.38
V_1 S_3	8.25	8.90	9.54	10.37	11.4	11.9
V_2 S_1	23.47	25.39	27.46	29.07	30.85	32.34
V_2 S_2	23.36	25.35	27.13	28.87	30.43	32.36
V_2 S_3	8.21	8.77	9.52	10.04	10.81	11.40
V_3 S_1	23.57	25.50	27.45	29.09	31.08	32.96
V_3 S_2	23.42	24.83	27.06	28.61	30.26	32.16
V_3 S_3	8.22	8.72	9.43	10.07	10.88	11.40
SEm (±)	0.006	0.005	0.009	0.008	0.006	0.005
C.D(0.05)	0.017	0.016	0.025	0.024	0.017	0.015
Factor CXVXS						
C_1 V_1 S_1	23.42	25.32	27.42	28.21	30.31	32.33
C_1 V_1 S_2	23.33	24.62	26.62	27.52	29.32	31.52
C_1 V_1 S_3	-	-	-	-	-	-
C_1 V_2 S_1	23.23	25.22	27.24	28.41	29.50	31.12
C_1 V_2 S_2	23.32	25.33	27.41	29.06	30.42	32.16
C_1 V_2 S_3	-	-	-	-	-	-
C_1 V_3 S_1	23.43	25.42	27.06	28.55	31.11	32.32
C_1 V_3 S_2	23.11	24.15	26.61	27.26	29.13	31.13
C_1 V_3 S_3	-	-	-	-	-	-
C_2 V_1 S_1	23.62	25.64	27.61	29.42	31.63	33.40
C_2 V_1 S_2	23.37	25.35	27.32	28.23	30.14	32.41
C_2 V_1 S_3	-	-	-	-	-	-
C_2 V_2 S_1	23.77	25.54	27.82	29.66	31.75	33.31
C_2 V_2 S_2	23.33	25.42	26.74	28.33	30.71	32.14
C_2 V_2 S_3	-	-	-	-	-	-
C_2 V_3 S_1	23.67	25.66	27.76	29.53	30.83	33.42
C_2 V_3 S_2	23.61	25.20	27.35	29.23	31.14	33.23
C_2 V_3 S_3	-	-	-	-	-	-
C_3 V_1 S_1	23.15	25.23	27.27	29.32	31.16	33.26
C_3 V_1 S_2	23.32	25.31	27.53	29.37	31.31	33.22
C_3 V_1 S_3	24.77	26.72	28.62	31.13	33.42	34.75
C_3 V_2 S_1	23.41	25.42	27.32	29.16	31.31	32.60
C_3 V_2 S_2	23.43	25.32	27.24	29.22	30.16	32.79
C_3 V_2 S_3	24.65	26.32	28.56	30.13	32.43	34.22
C_3 V_3 S_1	23.62	25.43	27.53	29.21	31.32	33.14
C_3 V_3 S_2	23.54	25.15	27.24	29.35	30.51	32.11
C_3 V_3 S_3	24.66	26.16	28.31	30.23	32.64	34.22
SEm(±)	0.010	0.009	0.015	0.014	0.010	0.009
C.D(0.05)	0.029	0.028	0.044	0.041	0.030	0.027

C_1- Softwood grafting under open condition

C_2- Softwood grafting under polyhouse

C_3- Softwood grafting under polytunnel

V_1- Cricket Ball

V_2- Pala

V_3- Oval

S_1- Defoliation 10 days prior to grafting

S_2- Defoliation followed by grafting on the same day

S_3- Without Defoliation

height of graft (25.76) followed by V_3 -Oval (25.50). Least was observed with V_2 Pala (25.37).

4.1.4.3 Effect of precuring

Regarding precuring treatments at 30 DAG, S_1 defoliation 10 days prior to grafting was found to be better (23.48) followed by S_2 defoliation followed by grafting on the same day. Least height of graft was seen in S_3 (8.23) without defoliation. Similar trend was recorded at 60, 90,120, 150 and 180 DAG. At 180 DAG, S_1 defoliation 10 days prior to grafting had a graft height of 32.76 while in S_3 without defoliation had only 11.57.

4.1.4.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, height of graft varied according the environmental condition in which grafts are kept. Grafts of Oval kept under polytunnel (C_3 V_3) showed statistically higher value (23.94) and lower value was found in C_1 V_3 (15.51) at 30 DAG. Grafts of Cricket Ball cultivar kept under polytunnel (C_3V_1) had maximum graft height from 60 to 180 DAG. At 180 DAG, C_3 V_1 (Polytunnel + Cricket Ball) had highest graft height (34.06) and lowest was in C_1 V_2 (21.09).

4.1.4.5 Interaction effect of environmental conditions under which grafts are kept and precuring

The interaction between environmental conditions under which grafts are kept and precuring was found to be significant statistically. The non-defoliated grafts which were kept under open condition could not established. The same was observed with those grafts without scion defoliation and kept in polyhouse condition also. The non-defoliated grafts could survive only under poly tunnel condition. Highest height of graft was observed in C_3S_3 (24.69). Lowest height of graft was in C_1 S_2 (23.25) grafting done in poly house with same day defoliation. At 60, 90, 120, 150 and 180 DAG similar findings were recorded. At 180 DAG, superiority was in C_3S_3 (34.71) and lowest was in C_1 S_2 (31.60).

4.1.4.6 Interaction effect of cultivars and precuring

Varietal response to height of graft of grafts under different precuring treatments varied significantly. Highest height of graft was in V_3S_1 Oval with defoliation 10 days prior to grafting (23.57) at 30 DAG. Similar findings were observed in 60, 120 and 150 DAG. Least was in V_2S_3 Pala without defoliation (8.21) at 30 DAG. At 90 DAG, V_2 S_1 Pala with defoliation 10 days prior to grafting (27.46) showed highest graft height and V_3 S_3 Oval Without defoliation (9.43) was the lowest. Treatment combination V_1 S_1 Cricket Ball with scion defoliation 10 days prior to grafting (32.99) had the maximum at 180 DAG,.

4.1.4.7 Interaction effect of environmental conditions, cultivars, scion precuring

Survival was not observed with grafts of cultivars, Cricket Ball, Pala and Oval kept under open condition without scion defoliation (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3). Grafts which were kept under poly house condition without scion defoliation of cultivars also dried off (C_2 V_1 S_3 , C_2 V_2 S_3 and C_2 V_3 S_3). The grafted plants without scion defoliation could become established under the polytunnel condition only. At 30 DAG, more height of graft was observed with C_3 V_1 S_3 Cricket Ball grafted without defoliation and kept in poly tunnel condition (24.77). Lowest height of graft was seen in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting and kept under open condition (23.11). The trend was similar up to180 DAG. At 180 DAG, highest recorded in C_3 V_1 S_3 (34.75) and minimum observed in C_1 V_3 S_2 (31.13).

4.1.5 Girth of stem

There was significant difference of girth of stem in terms of environmental conditions, different cultivars and scion precuring treatments from 30 to 180 DAG showed in the Table 5. Data showed significant differences between environmental conditions, different cultivars and scion precuring treatments and among their interactions during the growth stages from 30 DAG to 180 DAG.

4.1.5.1 Effect of environmental conditions

The observation on girth of stem at 30 DAG revealed that C_3 -Polytunnel (1.31) had higher girth of stem followed by C_2. Least girth of stem was observed with C_1 (open condition) (0.69). The trend was similar at 60, 90, 120, 150 and 180 DAG. At 180 DAG, grafts under C_3 -Polytunnel recorded 2.70 girth of stem, whereas graft under open condition had only 1.61 girth of stem.

4.1.5.2 Effect of cultivars

Regarding the cultivars, V_3-Oval had maximum girth of stem at 30 DAG (1.06) and least girth of stem was observed with V_1-Cricket Ball (0.94). Similar trend was observed up to 180 DAG. V_3-Oval had highest girth of stem (2.31) and V_1 - recorded least girth of stem (2.00) at 30 DAG.

4.1.5.3 Effect of precuring

Regarding precuring treatments at 30 DAG, S_1 defoliation 10 days prior to grafting was found to be better (1.21), followed by S_2 defoliation followed by grafting on the same day. Least height of graft was seen in S_3 (0.61) without defoliation. Similar trend was recorded at 60, 90,120, 150 and 180 DAG. At 180 DAG, S_1 defoliation 10 days prior to grafting had girth of stem 2.59 while in S_3 without defoliation had only 1.27 stem girth on an average.

4.1.5.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, stem girth varied according the environmental condition in which grafts are kept. C_3 V_3 , C_3 V_1 and C_3 V_2 showed statistically higher (1.31) stem girth and lower was found in C_1 V_3 (0.59) at 30 DAG. C_3 V_3 (Polytunnel +Oval) had highest stem girth (1.50) which was on par with C_3V_1 and lowest was in C_1 V_3 (0.77) at 60 DAG. C_3 V_2 (Polytunnel + Pala) recorded maximum (1.72) which was on par with C_3 V_1 (1.69) and minimum (0.93) was found in C_1 V_3 (Open +Oval) at 90 DAG. C_2 V_3 showed highest (2.16) girth of stem at 120 DAG which was statistically on par with C_3 V_1 (2.14) and C_3 V_2

(2.11). C_3 V_1 recorded maximum (2.40) at 150 DAG which was on par with C_3 V_3 (2.37) and C_3 V_2 (2.38). C_3 V_3 had maximum stem girth (2.72) which was on par with C_3 V_1 (2.70) and C_3 V_2 (2.68) at 180 DAG. Least stem girth was observed in C_1 V_3 (1.59).

4.1.5.5 Interaction effect of environmental conditions under which grafts are kept and precuring

The interaction between environmental conditions and precuring treatments was found to be significant statistically. The grafts kept in open condition which were non defoliated could not survive. Same was observed with grafts kept under polyhouse condition also. The establishment of grafts without scion defoliation was found under poly tunnel condition only. Highest stem girth was observed in C_3S_3 (1.40). Lowest stem girth was in C_1 S_2 (1.02) grafting done in poly house with same day defoliation. At 60, 90, 120, 150 and 180 DAG similar findings were recorded. At 180 DAG, highest value was in C_3S_3 (2.98) and lowest was in C_1 S_2 (2.38).

4.1.5.6 Interaction effect of cultivars and precuring

Varietal effect of stem girth of grafts under different precuring treatments varied significantly. At 30 DAG highest stem girth was in V_2S_1 Oval with defoliation 10 days prior to grafting (1.24). Similar findings were observed at 150 DAG (2.33). Least was in V_2S_3 Pala without defoliation (0.46) at 30 DAG. At 90 DAG, V_2 S_1 Pala with defoliation 10 days prior to grafting and V_1S_1 Cricket Ball with defoliation 10 days prior to grafting showed highest (1.64) and V_2 S_3 Pala Without defoliation (0.59) was the lowest. At 120 and 180 DAG, treatment combination V_3S_1 Oval with defoliation 10 days prior to grafting had the maximum (2.05 and 2.60) and V_2 S_3 had the minimum (0.76 and 0.99).

4.1.5.7 Interaction effect of environmental conditions, cultivars, scion precuring

There was no survival in non-defoliated grafts of cultivars, Cricket Ball, Pala and Oval kept under open condition (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3). The grafts kept under poly house condition without scion defoliation of cultivars did not survive after grafting (C_2 V_1 S_3 , C_2 V_2 S_3 and C_2 V_3 S_3). Grafts under the polytunnel condition without scion defoliation only had survival. At 30 DAG, more

Table 5. Effect of environmental conditions, cultivars, scion precuring and their interactions on mean girth of stem (5cm above graft union)

Factors	30days	60days	90days	120days	150days	180days
Factor C						
C_1	0.69	0.83	0.98	1.22	1.49	1.61
C_2	0.98	1.12	1.27	1.64	1.82	2.03
C_3	1.31	1.48	1.69	2.09	2.38	2.70
SEm (±)	0.006	0.006	0.004	0.012	0.006	0.007
C.D(0.05)	0.017	0.017	0.013	0.035	0.017	0.019
Factor V						
V_1	0.94	1.09	1.25	1.56	1.81	2.00
V_2	0.97	1.10	1.27	1.59	1.82	2.03
V_3	1.06	1.24	1.42	1.80	2.05	2.31
C.D(0.05)	0.017	0.017	0.013	0.035	0.017	0.019
SEm (±)	0.006	0.006	0.004	0.012	0.006	0.007
Factor S						
S_1	1.21	1.40	1.62	2.00	2.32	2.59
S_2	1.16	1.35	1.55	1.94	2.26	2.47
S_3	0.61	0.68	0.77	1.00	1.11	1.27
SEm (±)	0.006	0.006	0.004	0.012	0.006	0.007
C.D(0.05)	0.017	0.017	0.013	0.035	0.017	0.019
Factor CXV						
C_1 V_1	0.69	0.84	0.98	1.20	1.49	1.61
C_1 V_2	0.78	0.88	1.03	1.25	1.50	1.63
C_1 V_3	0.59	0.77	0.93	1.20	1.47	1.59
C_2 V_1	0.83	0.95	1.08	1.35	1.55	1.69
C_2 V_2	0.83	0.96	1.08	1.42	1.59	1.79
C_2 V_3	1.30	1.46	1.67	2.16	2.32	2.62
C_3 V_1	1.31	1.49	1.69	2.14	2.40	2.70
C_3 V_2	1.31	1.46	1.72	2.11	2.38	2.68
C_3 V_3	1.31	1.50	1.67	2.03	2.37	2.72
SEm(±)	0.010	0.010	0.008	0.021	0.010	0.012
C.D(0.05)	0.029	0.029	0.022	0.061	0.030	0.034
Factor CXS						
C_1 S_1	1.04	1.25	1.51	1.88	2.24	2.44
C_1 S_2	1.02	1.24	1.44	1.77	2.23	2.38
C_1 S_3	-	-	-	-	-	-
C_2 S_1	1.33	1.52	1.72	2.19	2.42	2.72
C_2 S_2	1.18	1.37	1.56	2.04	2.29	2.54
C_2 S_3	-	-	-	-	-	-
C_3 S_1	1.26	1.42	1.64	1.94	2.31	2.62
C_3 S_2	1.26	1.44	1.66	2.02	2.27	2.49
C_3 S_3	1.40	1.58	1.78	2.32	2.58	2.98
SEm (±)	0.010	0.010	0.008	0.021	0.010	0.012
C.D(0.05)	0.029	0.029	0.022	0.061	0.030	0.034
Factor VXS						
V_1 S_1	1.23	1.42	1.64	1.97	2.32	2.60
V_1 S_2	1.13	1.33	1.51	1.93	2.24	2.39

Table 5(contd…)

V_1 S_3	0.47	0.53	0.60	0.78	0.88	1.01
V_2 S_1	1.24	1.40	1.64	2.00	2.33	2.58
V_2 S_2	1.22	1.38	1.60	2.02	2.29	2.50
V_2 S_3	0.46	0.51	0.59	0.76	0.84	0.99
V_3 S_1	1.16	1.37	1.59	2.05	2.31	2.60
V_3 S_2	1.12	1.35	1.55	1.88	2.25	2.50
V_3 S_3	0.90	0.99	1.13	1.47	1.60	1.82
SEm (±)	0.010	0.010	0.008	0.021	0.010	0.012
C.D(0.05)	0.029	0.029	0.022	0.061	0.030	0.034
Factor CXVXS						
C_1 V_1 S_1	1.11	1.29	1.54	1.85	2.23	2.43
C_1 V_1 S_2	0.97	1.22	1.42	1.75	2.26	2.40
C_1 V_1 S_3	-	-	-	-	-	-
C_1 V_2 S_1	1.12	1.29	1.55	1.84	2.27	2.45
C_1 V_2 S_2	1.23	1.36	1.54	1.92	2.23	2.43
C_1 V_2 S_3	-	-	-	-	-	-
C_1 V_3 S_1	0.89	1.16	1.43	1.96	2.23	2.45
C_1 V_3 S_2	0.88	1.15	1.36	1.66	2.20	2.32
C_1 V_3 S_3	-	-	-	-	-	-
C_2 V_1 S_1	1.33	1.53	1.72	2.10	2.42	2.7
C_2 V_1 S_2	1.16	1.33	1.52	1.95	2.22	2.35
C_2 V_1 S_3	-	-	-	-	-	-
C_2 V_2 S_1	1.33	1.52	1.73	2.23	2.44	2.73
C_2 V_2 S_2	1.16	1.35	1.51	2.05	2.33	2.64
C_2 V_2 S_3	-	-	-	-	-	-
C_2 V_3 S_1	1.33	1.52	1.71	2.25	2.40	2.69
C_2 V_3 S_2	1.24	1.44	1.66	2.13	2.32	2.63
C_2 V_3 S_3	-	-	-	-	-	-
C_3 V_1 S_1	1.25	1.43	1.67	1.95	2.31	2.63
C_3 V_1 S_2	1.27	1.44	1.60	2.10	2.24	2.42
C_3 V_1 S_3	1.42	1.61	1.81	2.36	2.66	3.05
C_3 V_2 S_1	1.27	1.40	1.64	1.93	2.30	2.56
C_3 V_2 S_2	1.27	1.43	1.75	2.11	2.32	2.53
C_3 V_2 S_3	1.38	1.55	1.77	2.30	2.54	2.97
C_3 V_3 S_1	1.27	1.45	1.62	1.94	2.32	2.67
C_3 V_3 S_2	1.26	1.47	1.64	1.85	2.25	2.54
C_3 V_3 S_3	1.40	1.57	1.77	2.31	2.55	2.94
SEm(±)	0.017	0.017	0.013	0.036	0.018	0.020
C.D(0.05)	0.050	0.050	0.038	0.105	0.052	0.058

C_1- Softwood grafting under open condition

C_2-Softwood grafting under polyhouse

C_3-Softwood grafting under polytunnel

V_1- Cricket Ball

V_2- Pala

V_3- Oval

S_2- Defoliation followed by grafting on the same day

S_3-Without defoliation

height of graft was observed with C_3 V_1 S_3 Cricket Ball grafted without defoliation and kept in poly tunnel condition (1.42). Lowest height of graft was seen in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting and kept under open condition (0.88). The trend was similar up to 180 DAG. At 180 DAG, highest recorded in C_3 V_1 S_3 (3.05) and minimum observed in C_1 V_3 S_2 (2.32).

4.1.6 Length of leaves

Variation of height of graft in terms of environmental conditions, different cultivars and scion precuring treatments was significant from 30 to 180 DAG showed in the Table 5. Data indicated significant differences between environmental conditions, different cultivars and scion precuring treatments and among their interactions during the growth stages from 30 DAG to 180 DAG.

4.1.6.1 Effect of environmental conditions

The observation on length of leaves at 30 DAG depicted that C_3 -Polytunnel (3.22) had higher length of leaf followed by C_2. Least length of leaf was observed with C_1 -open condition (1.71). The trend was similar at 60, 90, 120, 150 and 180 DAG. At 180 DAG, grafts under C_3 -polytunnel recorded 9.15 length of leaf, whereas graft under open condition had only 5.01 length of leaf on an average.

4.1.6.2 Effect of cultivars

Regarding the cultivars, V_1- Cricket Ball had higher value of length of leaf at 30 DAG (2.34) and minimum length of leaf was observed with V_3 -Oval (2.25). Similar trend of result was observed at 60 DAG also. V_3-Oval and V_1- Cricket Ball had highest length of leaf (4.00) and V_3 - Pala recorded least length of leaf (4.00) at 90 DAG. At 120 and 180 DAG, V_2 recorded maximum leaf length. V_3 (6.04) was found to be higher and V_1 (5.76) was the lower at 150 DAG.

4.1.6.3 Effect of precuring

Regarding precuring treatments at 30 DAG, S_1 defoliation 10 days prior to grafting was found to be better (2.86), followed by S_2 defoliation followed by grafting on the same day. Least length of leaf was seen in S_3 (1.28) without defoliation. Similar trend was recorded at 60, 90,120, 150 and 180 DAG. At 180 DAG, S_1

defoliation 10 days prior to grafting had 8.34 cm leaf length while in S_3 without defoliation had only 3.65 cm leaf length on an average.

4.1.6.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was found to be statistically significant. Leaf length varied according the environmental condition in which grafts are kept. At 30 DAG, C_3 V_1 showed statistically higher value (3.36) and lower value found in C_1 V_1 (1.72). At 60 DAG, C_3 V_1 (Polytunnel + Cricket Ball) had highest leaf length (4.51) and lowest was in C_1 V_1- Open + Cricket Ball (2.12). At 90 DAG, C_3 V_3 (Polytunnel + Oval) recorded maximum (5.64) and minimum (2.82) was found in C_1V_1 (Open + Cricket Ball). At 120 DAG, C_3V_2- Polytunnel+ Pala showed highest (7.11) leaf length and C_1V_3 recorded minimum (3.87). C_3V_3 (Polytunnel +Oval) recorded maximum (8.36) and lowest was in C_1V_3-Open + Oval (4.59) at 150 DAG. Similar trend was found at 180 DAG.

4.1.6.5 Interaction effect of environmental conditions under which grafts are kept and precuring

There was significant influence due to interaction between environmental conditions under which grafts are kept and precuring treatments. There was no survival in grafts done without scion defoliation and kept in open condition. Those grafts kept in polyhouse condition without scion defoliation also dried off. Survival of grafts was observed under poly tunnel condition without any scion defoliation. At 30 DAG, highest length of leaf was observed in C_3S_3 (3.86) and lowest was in C_1 S_2 (2.56) grafting done in poly house with same day defoliation. At 60, 90, 120, 150 and 180 DAG similar findings were recorded. At 180 DAG, highest was in C_3S_3 (10.95) and lowest was in C_1 S_1 (7.51).

4.1.6.6 Interaction effect of cultivars and precuring

Varietal response to length of leaves of grafts under different precuring treatment differed significantly. At 30 DAG highest leaf length was in V_1S_1 Cricket Ball with defoliation 10 days prior to grafting (2.90) and lowest was in V_2S_3 Pala

Table 6. Effect of environmental conditions, cultivars, scion precuring and their interactions on mean length of leaves

Factors	30days	60days	90days	120days	150days	180days
Factor C						
C_1	1.71	2.14	2.87	3.82	4.50	5.01
C_2	1.92	2.74	3.49	4.35	5.16	5.94
C_3	3.22	4.36	5.59	6.95	8.03	9.15
SEm (±)	0.005	0.007	0.004	0.005	0.006	0.004
C.D(0.05)	0.01	0.02	0.01	0.01	0.017	0.01
Factor V						
V_1	2.34	3.11	4.00	4.99	5.76	6.59
V_2	2.27	3.10	3.95	5.14	5.89	6.80
V_3	2.25	3.04	4.00	4.98	6.04	6.72
C.D(0.05)	0.01	0.02	0.01	0.01	0.017	0.01
SEm (±)	0.005	0.007	0.004	0.005	0.006	0.004
Factor S						
S_1	2.86	3.85	4.92	6.23	7.44	8.34
S_2	2.71	3.68	4.65	5.98	7.15	8.12
S_3	1.28	1.72	2.38	2.91	3.10	3.65
SEm (±)	0.005	0.007	0.004	0.005	0.006	0.004
C.D(0.05)	0.01	0.02	0.01	0.01	0.017	0.01
Factor CXV						
C_1 V_1	1.72	2.12	2.82	3.87	4.59	5.02
C_1 V_2	1.74	2.22	2.91	3.91	4.48	5.17
C_1 V_3	2.45	3.14	4.41	5.58	6.47	7.38
C_2 V_1	1.94	2.69	3.58	4.23	5.12	5.89
C_2 V_2	1.92	2.79	3.42	4.39	5.02	6.05
C_2 V_3	1.90	2.76	3.46	4.41	5.33	5.88
C_3 V_1	3.36	4.51	5.61	6.88	7.56	8.87
C_3 V_2	3.15	4.31	5.51	7.11	8.18	9.17
C_3 V_3	3.16	4.27	5.64	6.84	8.36	9.41
SEm(±)	0.009	0.012	0.007	0.008	0.010	0.006
C.D(0.05)	0.027	0.036	0.019	0.02	0.03	0.018
Factor CXS						
C_1 S_1	2.59	3.26	4.37	5.79	6.83	7.51
C_1 S_2	2.56	3.16	4.25	5.68	6.69	7.53
C_1 S_3	-	-	-	-	-	-
C_2 S_1	3.07	4.33	5.43	6.80	8.14	9.29
C_2 S_2	2.69	3.91	5.04	6.24	7.35	8.54
C_2 S_3	-	-	-	-	-	-
C_3 S_1	2.92	3.97	4.97	6.10	7.37	8.21
C_3 S_2	2.88	3.96	4.66	6.01	7.43	8.29
C_3 S_3	3.86	5.16	7.14	8.73	9.31	10.95
SEm (±)	0.009	0.012	0.007	0.008	0.010	0.006
C.D(0.05)	0.02	0.03	0.019	0.02	0.03	0.01
Factor VXS						
V_1 S_1	2.90	3.88	4.77	6.05	7.30	8.11
V_1 S_2	2.82	2.45	2.99	3.89	4.48	5.11

Table 6(contd…)

V_1 S_3	2.19	2.99	4.25	5.04	5.49	6.56
V_2 S_1	2.86	3.88	4.95	6.31	7.43	8.44
V_2 S_2	1.82	2.38	2.98	4.07	4.82	5.42
V_2 S_3	2.13	3.06	3.91	5.03	5.44	6.53
V_3 S_1	2.82	3.81	5.05	6.34	7.60	8.47
V_3 S_2	1.69	2.29	2.93	3.73	7.43	5.29
V_3 S_3	3.00	4.06	5.53	6.78	7.74	8.88
SEm (±)	0.009	0.012	0.007	0.008	0.010	0.006
C.D(0.05)	0.02	0.03	0.019	0.02	0.03	0.01
Factor CXVXS						
C_1 V_1 S_1	2.52	3.13	4.24	5.76	6.84	7.54
C_1 V_1 S_2	2.66	3.23	4.22	5.84	6.93	7.52
C_1 V_1 S_3	-	-	-	-	-	-
C_1 V_2 S_1	2.63	3.43	4.32	5.96	6.83	7.68
C_1 V_2 S_2	2.61	3.22	4.42	5.77	6.61	7.84
C_1 V_2 S_3	-	-	-	-	-	-
C_1 V_3 S_1	2.64	3.23	4.56	5.66	6.82	7.33
C_1 V_3 S_2	2.40	3.05	4.13	5.44	6.53	7.25
C_1 V_3 S_3	-	-	-	-	-	-
C_2 V_1 S_1	3.15	4.40	5.42	6.54	8.32	9.22
C_2 V_1 S_2	2.67	3.67	5.33	6.16	7.05	8.46
C_2 V_1 S_3	-	-	-	-	-	-
C_2 V_2 S_1	3.10	4.26	5.42	6.73	7.93	9.32
C_2 V_2 S_2	2.65	4.12	4.86	6.45	7.15	8.85
C_2 V_2 S_3	-	-	-	-	-	-
C_2 V_3 S_1	2.96	4.33	5.45	7.13	8.16	9.33
C_2 V_3 S_2	2.76	3.95	4.94	6.12	7.84	8.33
C_2 V_3 S_3	-	-	-	-	-	-
C_3 V_1 S_1	3.05	4.12	4.64	5.85	6.73	7.57
C_3 V_1 S_2	3.12	4.12	4.77	5.85	6.53	7.82
C_3 V_1 S_3	3.91	5.31	7.43	8.96	9.43	11.22
C_3 V_2 S_1	2.85	3.94	5.13	6.24	7.55	8.33
C_3 V_2 S_2	2.86	3.91	4.54	6.45	7.84	8.42
C_3 V_2 S_3	3.74	5.07	6.87	8.66	9.16	10.76
C_3 V_3 S_1	2.88	3.87	5.14	6.22	7.83	8.74
C_3 V_3 S_2	2.67	3.84	4.67	5.74	7.91	8.63
C_3 V_3 S_3	3.93	5.11	7.13	8.57	9.33	10.87
SEm(±)	0.016	0.021	0.011	0.014	0.018	0.011
C.D(0.05)	0.04	0.06	0.03	0.04	0.05	0.03

C_1- Softwood grafting under open condition

C_2- Softwood grafting under polyhouse

C_3- Softwood grafting under polytunnel

S_1- Defoliation 10 days prior to grafting

S_2- Defoliation followed by grafting on the same day

S_3 – Without Defoliation

V_1- Cricket Ball

V_2- Pala

V_3- Oval

without defoliation (1.69). Similar findings were observed at 60 DAG. At 90 to 180 DAG, V_3S_1 Oval with defoliation 10 days prior to grafting. At 180 DAG, V_3S_1 Oval with defoliation 10 days prior to grafting (8.47) showed highest and V_2 S_3 (3.58) had lowest value.

4.1.6.7 Interaction effect of environmental conditions, cultivars, scion precuring

There was no survival observed with grafted plants without defoliation of cultivars, Cricket Ball, Pala and Oval kept under open condition ($C_1V_1S_3$, $C_1V_2S_3$ and $C_1V_3S_3$).Grafted plants which were kept under poly house condition without defoliation of cultivars also failed. At 30 DAG, more length of leaves was observed with C_3 V_3 S_3 Oval grafted without defoliation and kept in poly tunnel condition (3.93) which was on par with C_3 V_1 S_3 (3.91). Lowest leaf length was seen in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting and kept under open condition (2.40). The trend was similar from 90 to 180 DAG.in which highest leaf length found in C_3 V_1 S_3 and minimum observed in C_1 V_3 S_2 . At 180 DAG, maximum leaf length was in C_3 V_1 S_3 (11.22) and lowest was C_1 V_3 S_2 (7.25).

4.1.7 Breadth of leaves

There was significant variation of breadth of leaves in terms of environmental conditions, different cultivars and scion precuring treatments from 30 to 180 DAG showed in the Table 7. Data showed significant differences between environmental conditions, different cultivars and scion precuring treatments and among their interactions during the growth stages from 30 DAG to 180 DAG.

4.1.7.1 Effect of environmental conditions

The observation on leaf breadth at 30 DAG indicated that C_3 -Polytunnel (1.45) had higher length of leaf followed by C_2. Least leaf breadth was observed with C_1 (open condition) (0.83). The trend was similar at 60, 90, 120, 150 and 180 DAG. At 180 DAG, grafts under C_3 -Polytunnel recorded 3.85 breadth of leaves whereas graft under open condition had only 2.28 breadth of leaves on an average.

Table 7. Effect of environmental conditions, cultivars, scion precuring and their interaction on mean breadth of leaves

Factors	30days	60days	90days	120days	150days	180days
Factor C						
C_1	0.83	1.26	1.44	1.71	1.91	2.28
C_2	0.90	1.40	1.62	1.93	2.16	2.48
C_3	1.45	2.15	2.55	2.98	3.35	3.85
SEm (±)	0.004	0.005	0.005	0.006	0.005	0.005
C.D(0.05)	0.01	0.01	0.01	0.01	0.01	0.01
Factor V						
V_1	1.06	1.60	1.87	2.18	2.47	2.81
V_2	1.07	1.58	1.86	2.21	2.48	2.92
V_3	1.07	1.62	1.87	2.24	2.48	2.88
SEm (±)	0.004	0.005	0.005	0.006	0.005	0.005
C.D(0.05)	NS	0.01	NS	0.01	NS	0.01
Factor S						
S_1	1.36	2.01	2.36	2.83	3.17	3.65
S_2	1.27	1.96	2.29	2.70	3.04	3.56
S_3	0.56	0.83	0.95	1.10	1.22	1.40
SEm (±)	0.004	0.005	0.005	0.006	0.005	0.005
C.D(0.05)	0.01	0.01	0.01	0.01	0.01	0.01
Factor CXV						
C_1 V_1	0.83	1.27	1.44	1.73	1.96	2.16
C_1 V_2	0.83	1.26	1.45	1.70	1.90	2.39
C_1 V_3	1.28	1.87	2.17	2.64	2.93	3.57
C_2 V_1	0.90	1.35	1.66	1.85	2.09	2.42
C_2 V_2	0.90	1.36	1.61	1.96	2.25	2.50
C_2 V_3	0.92	1.48	1.58	1.99	2.14	2.52
C_3 V_1	1.45	2.18	2.51	2.97	3.37	3.86
C_3 V_2	1.47	2.12	2.53	2.96	3.28	3.88
C_3 V_3	1.45	2.14	2.60	3.02	3.40	3.82
SEm(±)	0.006	0.009	0.009	0.011	0.008	0.009
C.D(0.05)	0.01	0.02	0.02	0.03	0.02	0.02
Factor CXS						
C_1 S_1	1.31	1.94	2.19	2.64	2.91	3.44
C_1 S_2	1.19	1.85	2.14	2.50	2.84	3.41
C_1 S_3	-	-	-	-	-	-
C_2 S_1	1.43	2.22	2.53	3.04	3.39	3.83
C_2 S_2	1.29	1.98	2.32	2.77	3.10	3.60
C_2 S_3	-	-	-	-	-	-
C_3 S_1	1.33	1.89	2.37	2.81	3.20	3.68
C_3 S_2	1.34	2.05	2.41	2.83	3.17	3.67
C_3 S_3	1.69	2.50	2.87	3.31	3.68	4.21
SEm (±)	0.006	0.009	0.009	0.011	0.008	0.009
C.D(0.05)	0.01	0.02	0.02	0.03	0.02	0.02
V_1 S_1	1.36	2.04	2.36	2.78	3.15	3.57
V_1 S_2	0.81	1.94	1.49	1.77	2.03	2.29
V_1 S_3	1.01	1.43	1.76	2.01	2.25	2.58

Table7(contd…)

V_2 S_1	1.25	1.94	2.28	2.72	3.13	3.64
V_2 S_2	0.98	1.30	1.60	1.89	2.05	2.51
V_2 S_3	0.97	1.50	1.71	3.00	2.25	2.62
V_3 S_1	1.47	2.07	2.45	3.00	3.22	3.74
V_3 S_2	0.74	1.27	1.45	1.66	1.93	2.27
V_3 S_3	1.44	2.16	2.45	2.98	3.32	3.90
SEm (±)	0.006	0.009	0.009	0.011	0.008	0.009
C.D(0.05)	0.01	0.02	0.02	0.03	0.02	0.02
Factor CXVXS						
C_1 V_1 S_1	1.32	1.95	2.22	2.65	2.96	3.23
C_1 V_1 S_2	1.17	1.86	2.11	2.54	2.92	3.26
C_1 V_1 S_3	-	-	-	-	-	-
C_1 V_2 S_1	0.98	1.75	1.96	2.33	2.65	3.32
C_1 V_2 S_2	1.53	2.05	2.40	2.77	3.05	3.86
C_1 V_2 S_3	-	-	-	-	-	-
C_1 V_3 S_1	1.64	2.11	2.39	2.96	3.12	3.77
C_1 V_3 S_2	0.88	1.65	1.92	2.19	2.56	3.11
C_1 V_3 S_3	-	-	-	-	-	-
C_2 V_1 S_1	1.44	2.20	2.63	2.95	3.34	3.85
C_2 V_1 S_2	1.27	1.85	2.35	2.62	2.95	3.41
C_2 V_1 S_3	-	-	-	-	-	-
C_2 V_2 S_1	1.43	2.13	2.53	3.06	3.53	3.83
C_2 V_2 S_2	1.27	1.96	2.31	2.84	3.24	3.67
C_2 V_2 S_3	-	-	-	-	-	-
C_2 V_3 S_1	1.43	2.32	2.44	3.12	3.32	3.82
C_2 V_3 S_2	1.33	2.13	2.32	2.85	3.12	3.74
C_2 V_3 S_3	-	-	-	-	-	-
C_3 V_1 S_1	1.32	1.98	2.24	2.74	3.15	3.63
C_3 V_1 S_2	1.27	2.12	2.35	2.77	3.16	3.63
C_3 V_1 S_3	1.70	2.44	2.95	3.41	3.81	4.32
C_3 V_2 S_1	1.35	1.94	2.35	2.76	3.22	3.77
C_3 V_2 S_2	1.41	1.87	2.42	2.92	3.12	3.67
C_3 V_2 S_3	1.64	2.55	2.83	3.21	3.52	4.20
C_3 V_3 S_1	1.33	1.77	2.53	2.92	3.23	3.64
C_3 V_3 S_2	1.34	2.16	2.45	2.81	3.24	3.72
C_3 V_3 S_3	1.67	2.50	2.83	3.32	3.72	4.12
SEm(±)	0.011	0.015	0.016	0.019	0.015	0.015
C.D(0.05)	0.03	0.04	0.04	0.05	0.04	0.04

C_1- Softwood grafting under open condition

C_2- Softwood grafting under polyhouse

C_3- Softwood grafting under polytunnel

S_1- Defoliation 10 days prior to grafting

S_2- Defoliation followed by grafting on the same day

S_3 – Without Defoliation

V_1- Cricket Ball

V_2- Pala

V_3- Oval

4.1.7.2 Effect of cultivars

Regarding the cultivars, V_3- Oval had maximum breadth of leaves at 30 DAG (1.07). Similar trend was observed up to 150 DAG. Least breadth of leaves was observed with V_1 - Cricket Ball (1.06). Similar trend was observed at 120, 150 and 180 DAG. At 180 DAG, V_2 -Pala recorded maximum (2.92) breadth of leaves and V_1 -Cricket Ball (2.81) was the lowest.

4.1.7.3 Effect of precuring

Related to precuring treatments at 30 DAG, S_1 defoliation 10 days prior to grafting was found to be better (1.36), followed by S_2 defoliation followed by grafting on the same day. Least leaf breadth was seen in S_3 (0.56) without defoliation. Similar trend was recorded at 60, 90,120, 150 and 180 DAG. At 180 DAG, S_1 defoliation 10 days prior to grafting had 3.65 leaf breadth while in S3 without defoliation had only 1.40 leaf breadth on an average.

4.1.7.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, leaf breadth varied according the environmental condition in which grafts are kept. At 30 DAG, C_3 V_2 -Pala under polytunnel showed statistically higher (1.47) and minimum found in C_1 V_1 -Cricket Ball under open condition (0.83). Similar findings were observed at 180 DAG. At 60 DAG, C_3 V_1 (Polytunnel + Cricket Ball) had highest leaf breadth (2.18) and lowest was in C_1 V_2 (1.26). At 90 DAG, C_3 V_3 (Polytunnel + Oval) recorded maximum (2.60) and minimum (1.44) was found in C_1 V_1 (Open + Cricket Ball). At 120 to 150 DAG, C_3 V_3 (Polytunnel +Oval) showed highest leaf breadth. C_3 V_2 (Polytunnel +Pala) recorded maximum (3.88) which was on par (3.86) with C_3 V_1 (Polytunnel+ Cricket Ball) and lowest was in C_1 V_1 (2.16) at 180 DAG.

4.1.7.5 Interaction effect of environmental conditions under which grafts are kept and precuring

The interaction between environmental conditions under which grafts are kept and precuring was found to be significantly varied. The grafts could not survive which were non defoliated and kept in open condition. Those grafts without defoliation and

kept in polyhouse condition also dried off. Grafts without defoliation could only survive under poly tunnel condition. At 30 DAG, highest breadth of leaf was observed in C_3S_3 (1.69) and lowest was in C_1 S_2 (1.19) grafting done in open with same day defoliation. At 60, 90, 120, 150 and 180 DAG similar findings were recorded. At 180 DAG, highest was in C_3S_3 (4.21) and lowest was in C_1 S_2 (3.41).

4.1.7.6 Interaction effect of cultivars and precuring

Varietal response to breadth of leaves of grafts under different precuring treatments differed significantly. At 30 DAG highest leaf breadth was in V_3S_1 Oval with defoliation 10 days prior to grafting (1.47). Similar trend was observed at 90 and 120 DAG. At 150 and 180 DAG, V_3 S_3 Oval without defoliation showed statistically highest (3.74 and 3.90) value.

4.1.7.7 Interaction effect of environmental conditions, cultivars, scion precuring

The non-defoliated grafts of cultivars, Cricket ball, Pala and Oval kept under open condition did not survive after grafting (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3). Grafted plants without defoliation of cultivars, Cricket Ball, Pala and Oval which were kept under polyhouse condition also neither emerged nor established (C_2 V_1 S_3 , C_2 V_2 S_3 , and C_2 V_3 S_3). The survival was seen only in those grafted plants in which grafting was done without defoliation and kept under polytunnel condition. At 30 DAG, higher leaf breadth was observed with C_3 V_1 S_3 Cricket Ball grafted plants without defoliation and kept in poly tunnel condition (1.77). Lowest leaf breadth was seen in C_1 V_3 S_2 Oval grafted with defoliation on same day of grafting and kept under open condition (0.88) at 30 DAG. The trend was similar from 90 to 180 DAG. At 180 DAG, maximum leaf breadth was in C_3 V_1 S_3 (4.32) and lowest was C_1 V_3 S_2 (3.11). C_3 V_2 S_3 (2.55) was the highest and C_1 V_3 S_2 was the lowest (1.65) at 60 DAG.

4.1.8 Number of successful grafts

There was significant variation for number of successful grafts in terms of environmental conditions, different cultivars and scion precuring treatments from 30 to 180 DAG showed in the Table 8. Data showed significant differences between

environmental conditions, different cultivars and scion precuring treatments and among their interactions during the growth stages from 30 DAG to 180 DAG.

4.1.8.1 Effect of environmental conditions

The observation on number of successful grafts at 30 DAG indicated that C_3 - Polytunnel (7.55) had higher number of successful grafts followed by C_2. Least number of successful grafts was observed with C_1 (open condition) (3.50). The trend was similar up to final growth stages. At 180 DAG, grafts under C_3 -Polytunnel recorded 7.00 number of successful grafts whereas graft under open condition had only 3.11 number of successful grafts on an average.

4.1.8.2 Effect of cultivars

Regarding the cultivars s, V_1- Cricket Ball had maximum number of successful grafts at 30 DAG (5.55) which was on par with V_2 (5.16). Least number of successful grafts was observed with V_3- Oval (4.66). Similar trend was observed up to 180 DAG. At 180 DAG, V_1-Cricket Ball recorded maximum (5.22) and V_3 -Oval (4.33) was minimum.

4.1.8.3 Effect of precuring

Regarding precuring treatments at 30 DAG, S_1 defoliation 10 days prior to grafting was found to be better (6.61) followed by S_2 defoliation followed by grafting on the same day. Least number of successful grafts was seen in S_3 (3.88) without defoliation. Similar trend was recorded at 60, 90, 120, 150 and 180 DAG. At 180 DAG, S_1 defoliation 10 days prior to grafting had 6.05 successful grafts while in S_3 without defoliation had only 3.88 successful grafts on an average.

4.1.8.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, scion precuring varied according the environmental condition in which grafts are kept. At 30 DAG, C_3 V_1 (Polytunnel + Cricket Ball) showed higher (8.50) and lower (2.50) found in C_1 V_3 (Open+ Oval).

Table 8. Effect of environmental conditions, cultivars, scion precuring and their interactions on mean number of successful grafts

Factors	30days	60days	90days	120days	150days	180days
Factor C						
C_1	3.50	3.38	3.38	3.22	3.16	3.11
C_2	4.33	4.27	4.22	4.22	4.11	4.11
C_3	7.55	7.22	7.22	7.11	7.05	7.00
SEm (±)	0.16	0.15	0.14	0.15	0.13	0.13
C.D(0.05)	0.46	0.43	0.42	0.45	0.39	0.39
Factor V						
V_1	5.55	5.38	5.38	5.22	5.22	5.22
V_2	5.16	5.05	5.00	4.88	4.72	4.66
V_3	4.66	4.44	4.44	4.44	4.38	4.33
C.D(0.05)	0.46	0.43	0.42	0.45	0.39	0.39
SEm (±)	0.16	0.15	0.14	0.15	0.13	0.13
Factor S						
S_1	6.61	6.44	6.38	6.22	6.16	6.05
S_2	4.88	4.55	4.55	4.44	4.27	4.27
S_3	3.88	3.88	3.88	3.88	3.88	3.88
SEm (±)	0.16	0.15	0.14	0.15	0.13	0.13
C.D(0.05)	0.46	0.43	0.42	0.45	0.39	0.39
Factor CXV						
C_1 V_1	3.83	3.66	3.66	3.33	3.33	3.33
C_1 V_2	4.16	4.00	4.00	3.83	3.83	3.83
C_1 V_3	2.50	2.50	2.50	2.50	2.33	2.16
C_2 V_1	4.33	4.33	4.33	4.33	4.33	4.33
C_2 V_2	4.50	4.50	4.33	4.33	4.00	4.00
C_2 V_3	4.16	4.00	4.00	4.00	4.00	4.00
C_3 V_1	8.50	8.16	8.16	8.00	8.00	8.00
C_3 V_2	6.83	6.66	6.66	6.50	6.33	6.16
C_3 V_3	7.33	6.83	6.83	6.83	6.83	6.83
SEm(±)	0.27	0.26	0.25	0.27	0.23	0.23
C.D(0.05)	0.80	0.75	0.73	0.79	0.68	0.68
Factor CXS						
C_1 S_1	5.50	5.50	5.50	5.16	5.00	4.83
C_1 S_2	5.00	4.66	4.66	4.50	4.50	4.50
C_1 S_3	-	-	-	-	-	-
C_2 S_1	8.66	8.50	8.33	8.33	8.33	8.33
C_2 S_2	4.33	4.33	4.33	4.33	4.00	4.00
C_2 S_3	-	-	-	-	-	-
C_3 S_1	5.66	5.33	5.33	5.16	5.16	5.00
C_3 S_2	5.33	4.66	4.66	4.50	4.33	4.33
C_3 S_3	11.66	11.66	11.66	11.66	11.66	11.50
SEm (±)	0.27	0.26	0.25	0.27	0.23	0.23
C.D(0.05)	0.80	0.75	0.73	0.79	0.68	0.68
Factor VXS						
V_1 S_1	6.66	6.50	6.50	6.16	6.16	6.16

Table 8(contd…)

V_1 S_2	5.33	5.00	5.00	4.83	4.83	4.83
V_1 S_3	4.66	4.66	4.66	4.66	4.66	4.66
V_2 S_1	7.00	7.00	6.83	6.66	6.66	6.50
V_2 S_2	5.00	4.66	4.66	4.50	4.00	4.00
V_2 S_3	3.50	3.50	3.50	3.50	3.50	3.50
V_3 S_1	6.16	5.83	5.83	5.83	5.66	5.50
V_3 S_2	4.33	4.00	4.00	4.00	4.00	4.00
V_3 S_3	3.50	3.50	3.50	3.50	3.50	3.50
SEm (±)	0.27	0.26	0.25	0.27	0.23	0.23
C.D(0.05)	NS	NS	NS	NS	0.68	0.68
Factor CXVXS						
C_1 V_1 S_1	4.50	4.50	4.50	3.50	3.50	3.50
C_1 V_1 S_2	7.00	6.50	6.50	6.50	6.50	6.50
C_1 V_1 S_3	-	-	-	-	-	-
C_1 V_2 S_1	7.50	7.50	7.50	7.50	7.50	7.50
C_1 V_2 S_2	5.00	4.50	4.50	4.00	4.00	4.00
C_1 V_2 S_3	-	-	-	-	-	-
C_1 V_3 S_1	4.50	4.50	4.50	4.50	4.00	3.50
C_1 V_3 S_2	3.00	3.00	3.00	3.00	3.00	3.00
C_1 V_3 S_3	-	-	-	-	-	-
C_2 V_1 S_1	9.00	9.00	9.00	9.00	9.00	9.00
C_2 V_1 S_2	4.00	4.00	4.00	4.00	4.00	4.00
C_2 V_1 S_3	-	-	-	-	-	-
C_2 V_2 S_1	8.50	8.50	8.00	8.00	8.00	8.00
C_2 V_2 S_2	5.00	5.00	5.00	5.00	4.00	4.00
C_2 V_2 S_3	-	-	-	-	-	-
C_2 V_3 S_1	8.50	8.00	8.00	8.00	8.00	8.00
C_2 V_3 S_2	4.00	4.00	4.00	4.00	4.00	4.00
C_2 V_3 S_3	-	-	-	-	-	-
C_3 V_1 S_1	6.50	6.00	6.00	6.00	6.00	6.00
C_3 V_1 S_2	5.00	4.50	4.50	4.00	4.00	4.00
C_3 V_1 S_3	14.00	14.00	11.66	11.66	11.66	11.50
C_3 V_2 S_1	5.00	5.00	5.00	4.50	4.50	4.00
C_3 V_2 S_2	5.00	4.50	4.50	4.50	4.00	4.00
C_3 V_2 S_3	10.50	10.50	10.50	10.50	10.50	10.50
C_3 V_3 S_1	5.50	5.00	5.00	5.00	5.00	5.00
C_3 V_3 S_2	6.00	5.00	5.00	5.00	5.00	5.00
C_3 V_3 S_3	10.50	10.50	10.50	10.50	10.50	10.50
SEm(±)	0.48	0.45	0.44	0.47	0.40	0.40
C.D(0.05)	1.39	1.31	1.28	1.36	1.18	1.18

C_1 - Softwood grafting under open

C_2 - Softwood grafting under polyhouse

C_3 - Softwood grafting under polytunnel

V_1- Cricket Ball

V_2- Pala

V_3- Oval

S_1 - Defoliation 10 days prior to grafting

S_2 - Defoliation followed by grafting on the same day

S_3 - Without Defoliation

Similar findings were observed up to 180 DAG. At 180 DAG, C_3V_1 -Polytunnel+ Cricket Ball had highest (8.00) successful grafts and lowest was in C_1V_3 (2.16).

4.1.8.5 Interaction effect of environmental conditions under which grafts are kept and precuring

The interaction between environmental conditions under which grafts are kept and precuring was found to be significant statistically. The grafts done without defoliation and kept in open condition could not survive Those non defoliated grafts which were kept in polyhouse condition also dried off. The survival was only with the non defoliated grafts which were kept under poly tunnel condition. At 30 DAG, highest number of successful grafts was observed in C_3S_3 (11.66) and lowest was in C_2 S_2 (4.33) grafting done in poly house with same day defoliation. At 60, 90, 120, 150 and 180 DAG similar findings were recorded. At 180 DAG, maximum was in C_3S_3 (11.50) and lowest was in C_2 S_2 (4.00).

4.1.8.6 Interaction effect of cultivars and precuring

Varietal response to number of successful grafts of grafts under different precuring treatments had found to be insignificant from 30 to 120 DAG and significant difference was observed at 150 and 180 DAG. At 150 and 180 DAG, V_2 S_1 Pala with 10 days prior defoliation produced maximum value (6.66 and 6.50) which was on par with V_1 S_1 (6.16). Minimum value (3.50) was showed in V_2 S_3 Pala without defoliation and V_3 S_3 Oval without defoliation at 150 and 180 DAG.

4.1.8.7 Interaction effect of environmental conditions, cultivars, scion precuring

The grafts without scion defoliation of cultivars, (Cricket Ball, Pala, Oval) kept under open (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3) and poly house condition did not survive after grafting (C_2 V_1 S_3 , C_2 V_2 S_3 and C_2 V_3 S_3). Those grafted plants in which grafting was done without defoliation could survive only under polytunnel condition. At 30 DAG, maximum number of successful grafts was observed with C_3 V_1 S_3 Cricket Ball grafted without defoliation and kept in poly tunnel condition (14.00). Lowest number of successful grafts was seen in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting and kept under open condition (3.00) at 30 DAG. The trend was similar up to 180 DAG. At 180 DAG, maximum

number of successful grafts was observed in C_3 V_1 S_3 (11.50) which was on par with $C_3V_2S_3$ and $C_3V_3S_3$ and lowest was C_1 V_3 S_2 (3.00).

4.1.9.1 Success percentage

There was significant variation of success percentage in terms of environmental conditions, different cultivars and scion precuring treatments at 90 DAG as shown in the Table 9.

4.1.9.1.1 Effect of environmental conditions

The observation on success percentage at 90 DAG indicated that C_3 - Polytunnel (48.14) had higher success percentage followed by C_2. Least number of success percentage was observed with C_1 (open condition) (22.59).

4.1.9.1.2 Effect of cultivars

Regarding the cultivars, V_1- Cricket Ball had maximum success percentage at 90 DAG (35.92). Least success percentage was observed with V_3 - Oval (29.63).

4.1.9.1.3 Effect of precuring

Considering the precuring treatments at 90 DAG, S_1 defoliation 10 days prior to grafting was found to be better (42.59) followed by S_2 defoliation followed by grafting on the same day. Least number of successful grafts was seen in S_3 (25.92) without defoliation.

4.1.9.1.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, scion precuring varied according the environmental condition in which grafts are kept. At 90 DAG, C_3 V_1 (Polytunnel + Cricket Ball) showed statistically higher (54.44) and lower (16.66) found in C_1 V_3 (Open + Oval).

4.1.9.1.5 Interaction effect of environmental conditions under which grafts are kept and precuring

The interaction between environmental conditions under which grafts are kept and precuring was found to be significant statistically. The grafts done without defoliation and kept in open condition could not survive. Those grafts without defoliation and kept in polyhouse condition also dried off. Grafts without defoliation could only survive under poly tunnel condition. At 90 DAG, highest success percentage of grafts was observed in C_3S_3 (77.77) and lowest was in $C_2\ S_2$ (28.88) grafting done in poly house with same day defoliation.

4.1.9.1.6 Interaction effect of cultivars and precuring

Varietal response to success percentage of grafts under different precuring treatments had found to be insignificant at 90 DAG.

4.1.9.1.7 Interaction effect of environmental conditions, cultivars, scion precuring

The non-defoliated grafts of cultivars (Cricket Ball, Pala and Oval) kept under open condition ($C_1\ V_1\ S_3$, $C_1\ V_2\ S_3$ and $C_1\ V_3\ S_3$) and polyhouse condition ($C_2\ V_1\ S_3$, $C_2\ V_2\ S_3$ and $C_2\ V_3\ S_3$) did not become successful after grafting. The grafted plants wherein grafting was done without defoliation only had survival under polytunnel condition. At 90 DAG, highest success percentage was observed with $C_3\ V_1S_3$ Cricket Ball grafted without defoliation and kept in poly tunnel condition (77.77) which was on par with $C_3V_2S_3$ and $C_3V_3S_3$. Lowest number of successful grafts was seen in $C_1\ V_3\ S_2$ Oval grafted with defoliation on the day of grafting and kept under open condition (20.00) at 90 DAG.

4.1.9.2 Survival percentage

4.1.9.2.1 Effect of environmental conditions

The observation on survival percentage (Table 9) at 180 DAG indicated that C_3 -Polytunnel (46.66) had higher survival percentage followed by C_2. Least number of survival percentage was observed with C_1 (open condition) (20.74).

4.1.9.2.2 Effect of cultivars

Regarding the cultivars, V_1- Cricket Ball had maximum survival percentage at 180 DAG (34.81). Least survival percentage was observed with V_3 - Oval (28.88).

4.1.9.2.3 Effect of precuring

Regarding precuring treatments at 180 DAG, S_1 defoliation 10 days prior to grafting was found to be better (40.37) followed by S_2 defoliation followed by grafting on the same day. Least number of successful grafts was seen in S_3 (25.92) without defoliation.

4.1.9.2.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, scion precuring varied according the environmental condition in which grafts are kept. At 180 DAG, C_3 V_1 (Polytunnel+Cricket Ball) showed statistically higher (53.33) and lower (14.44) found in C_1 V_3 (Open+Oval).

4.1.9.2.5 Interaction effect of environmental conditions under which grafts are kept and precuring

The interaction between environmental conditions under which grafts are kept and precuring was found to be significant statistically. The grafts done without defoliation and kept in open condition could not survive. Those grafts without defoliation and kept in polyhouse condition also dried off. Grafts without defoliation could only survive under poly tunnel condition. At 180 DAG, highest survival percentage of grafts was observed in C_3S_3 (76.66) and lowest was in C_2 S_2 (26.66) grafting done in poly house with same day defoliation.

4.1.9.2.6 Interaction effect of cultivars and precuring

Varietal response to success percentage of grafts under different precuring treatments had found to be insignificant at 180 DAG.V_2 S_1 Pala with 10 days prior

defoliation showed highest survival percentage (43.33) which was on par with V_1 S_1 (41.11). Lowest survival percentage was found in V_3 S_3 and V_2 S_3 (23.33).

4.1.9.2.7 Interaction effect of environmental conditions, cultivars, scion precuring

The non-defoliated grafts of cultivars, Cricket Ball, Pala and Oval kept under open condition did not survive after grafting (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3). No survival was found in non defoliated grafts of cultivars (Cricket Ball, Pala and Oval) which were kept under polyhouse condition(C_2 V_1 S_3 , C_2 V_2 S_3 and C_2 V_3 S_3). Those grafts wherein grafting was done without defoliation could survive only under the polytunnel condition. At 180 DAG, highest survival percentage was observed with C_3 V_1 S_3 Cricket Ball grafted without defoliation and kept in poly tunnel condition (76.66). Lowest number of survival percentage was seen in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting and kept under open condition (20.00) at 180 DAG.

4.1.9.3 Fresh weight

4.1.9.3.1 Effect of environmental conditions

The observation on fresh weight (Table 9) at 180 DAG indicated that C_3 - Polytunnel (22.11) had higher survival percentage followed by C_2. Least number of fresh weight was observed with C_2 (polyhouse condition) (10.01).

4.1.9.3.2 Effect of cultivars

Regarding the cultivars, V_2- Pala had maximum fresh weight at 180 DAG (15.26). Least fresh weight was observed with V_1 –Cricket Ball (13.88).

4.1.9.3.3 Effect of precuring

Regarding precuring treatments at 180 DAG, S_1 defoliation 10 days prior to grafting was found to be better (17.73) followed by S_2 defoliation followed by grafting on the same day. Fresh weight was less in S_3 (10.69) without defoliation.

Table 9. Effect of environmental conditions, cultivars, scion precuring and their interactions on survival percentage, fresh weight, dry weight (180 DAG) and success percentage (90 DAG)

Factors	Success percentage	Survival percentage	Fresh weight	Dry weight
	90 DAG	180DAG		
Factor C				
C_1	22.59(23.57)	20.74(22.37)	10.01	4.33
C_2	28.14(26.88)	27.40(26.42)	11.04	4.90
C_3	48.14 (44.45)	46.66(43.50)	22.11	10.01
SEm (±)	0.980(0.59)	0.907(1.61)	0.007	0.006
C.D(0.05)	2.84 (1.71)	2.63(0.55)	0.02	0.01
Factor V				
V_1	35.92(33.73)	34.81(32.99)	15.26	6.76
V_2	33.33(31.24)	31.11(30.34)	13.80	6.16
V_3	29.63(29.44)	28.88(28.97)	14.11	6.32
C.D(0.05)	2.84(1.71)	2.63(0.55)	0.02	0.01
SEm (±)	0.980(0.59)	0.907(1.61)	0.007	0.006
Factor S				
S_1	42.59(40.63)	40.37(39.20)	17.73	7.99
S_2	30.37(30.31)	28.51(32.14)	14.75	6.39
S_3	25.92(20.96)	25.92(20.96)	10.69	4.86
SEm (±)	0.980(0.59)	0.907(1.61)	0.007	0.006
C.D(0.05)	2.84(1.71)	2.63(0.55)	0.02	0.01
Factor CXV				
C_1 V_1	24.44 (24.75)	22.22(23.30)	11.46	5.17
C_1 V_2	26.66(26.05)	25.55(25.36)	11.85	5.22
C_1 V_3	16.66(19.91)	14.44(18.46)	9.82	4.33
C_2 V_1	28.88(27.28)	28.88(27.28)	8.09	3.02
C_2 V_2	28.88(27.28)	26.66(26.00)	11.04	5.02
C_2 V_3	26.66(26.00)	26.66(26.00)	10.91	4.95
C_3 V_1	54.44(49.14)	53.33(48.30)	22.87	10.30
C_3 V_2	44.44(41.75)	41.11(39.6)	21.86	10.04
C_3 V_3	45.55(42.45)	45.50(42.4)	21.61	9.68
SEm(±)	1.69	1.57	0.01	0.01
C.D(0.05)	4.92	4.56	0.03	0.03
Factor CXS				
C_1 S_1	36.66 (37.11)	32.22(34.21)	18.10	7.97
C_1 S_2	31.11 (33.61)	30.00(32.91)	15.04	6.75
C_1 S_3	-	-	-	-
C_2 S_1	55.55(48.19)	55.55(48.19)	18.12	8.48
C_2 S_2	28.88(32.44)	26.66(31.09)	11.92	4.50
C_2 S_3	-	-	-	-
C_3 S_1	35.55(36.58)	33.33 (35.19)	16.98	7.53
C_3 S_2	31.11(33.87)	28.88(32.42)	17.29	7.92
C_3 S_3	77.77(62.89)	76.66(61.90)	32.08	14.58
SEm (±)	1.69(1.02)	1.57(0.96)	0.012	0.011
C.D(0.05)	4.92(2.96)	4.56(2.8)	0.036	0.030

Table 9(contd…)

Factor VXS				
V_1 S_1	43.33(41.05)	41.11(39.60)	14.37	6.66
V_1 S_2	33.33(35.11)	32.22(34.36)	14.69	6.14
V_1 S_3	31.11(25.01)	31.11(25.01)	12.35	5.68
V_2 S_1	45.55(42.39)	43.33(41.00)	19.50	8.92
V_2 S_2	31.11 (33.83)	26.66(31.09)	15.83	7.21
V_2 S_3	23.33(18.94)	23.33(18.94)	10.44	4.68
V_3 S_1	38.88(38.45)	36.66(37.00)	19.33	8.39
V_3 S_2	26.66(31.97)	26.66(31.97)	13.73	5.82
V_3 S_3	23.33(18.94)	23.33(18.94)	9.28	4.21
SEm (±)	1.69	1.57(0.96)	0.01	0.01
C.D	NS	4.56(2.8)	0.03	0.03
Factor CXVXS				
C_1 V_1 S_1	30.00(33.17)	23.33(28.82)	16.88	7.43
C_1 V_1 S_2	43.33(41.08)	43.33(41.08)	17.51	8.07
C_1 V_1 S_3	-	-	-	-
C_1 V_2 S_1	50.00(45.00)	50.00(45.00)	17.81	7.62
C_1 V_2 S_2	30.00(33.17)	26.66(31.09)	17.76	8.05
C_1 V_2 S_3	-	-	-	-
C_1 V_3 S_1	30.00(33.17)	23.33(28.82)	19.63	8.86
C_1 V_3 S_2	20.00(26.56)	20.00(26.56)	9.84	4.12
C_1 V_3 S_3	-	-	-	-
C_2 V_1 S_1	60.00(50.76)	60.00(50.76)	11.68	4.93
C_2 V_1 S_2	26.66(31.09)	26.66(31.09)	12.59	4.13
C_2 V_1 S_3	-	-	-	-
C_2 V_2 S_1	53.33(46.91)	53.33(46.91)	22.86	10.71
C_2 V_2 S_2	33.33(35.16)	26.66(31.09)	10.28	4.36
C_2 V_2 S_3	-	-	-	-
C_2 V_3 S_1	53.33(46.91)	53.33(46.91)	19.83	9.81
C_2 V_3 S_2	26.66(31.09)	26.66(31.09)	12.91	5.04
C_2 V_3 S_3	-	-	-	-
C_3 V_1 S_1	40.00(39.23)	40.00(39.23)	14.55	7.63
C_3 V_1 S_2	30.00(33.17)	26.66(31.09)	13.97	6.23
C_3 V_1 S_3	77.77(62.89)	76.66 (61.90)	32.06	15.04
C_3 V_2 S_1	33.33(35.16)	26.66(31.09)	17.84	6.85
C_3 V_2 S_2	30.00(33.17)	26.66(31.09)	19.44	9.22
C_3 V_2 S_3	70.00(56.82)	70.00(56.82)	31.34	14.06
C_3 V_3 S_1	33.33(35.16)	33.33(35.16)	18.54	8.11
C_3 V_3 S_2	33.33(35.16)	33.33(35.16)	18.45	8.31
C_3 V_3 S_3	70.00(56.82)	70.00(56.82)	27.84	12.64
SEm(±)	2.94 (1.77)	2.72(1.67)	0.02	0.01
C.D(0.05)	8.53 (5.13)	7.90(4.85)	0.06	0.05

C_1- Softwood grafting under open condition

C_2- Softwood grafting under polyhouse

C_3- Softwood grafting under polytunnel

V_1- Cricket Ball

V_2- Pala

V_3- Oval

S_1 - Defoliation 10 days prior to grafting

S_2 - Defoliation followed by grafting on the same day

S_3- Without Defoliation

4.1.9.3.4 Interaction effect of environmental conditions under which grafts were kept and cultivars.

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, scion precuring varied according the environmental condition in which grafts are kept. At 180 DAG, C_3 V_2 (Polytunnel+Oval) showed statistically higher value (22.87) and lower value (8.09) found in C_2 V_1 (Polyhouse+Cricket Ball).

4.1.9.3.5 Interaction effect of environmental conditions under which grafts were kept and precuring

The interaction between environmental conditions under which grafts are kept and precuring was found to be significant statistically. The grafts done without defoliation and kept in open condition could not survive. Those grafts without defoliation and kept in polyhouse condition also dried off. Grafts without defoliation could only survive under poly tunnel condition. At 180 DAG, highest fresh weight of grafts was observed in C_3S_3 (32.08) and lowest was in C_2S_2 (11.92) grafting done in poly house with same day defoliation.

4.1.9.3.6 Interaction effect of cultivars and precuring

Varietal response to fresh weight of grafts under different precuring treatments had found to be insignificant at 180 DAG.V_2S_1 Pala with 10 days prior defoliation showed highest fresh weight (19.50). Lowest fresh weight was found in V_3S_3 (9.28).

4.1.9.3.7 Interaction effect of environmental conditions, cultivars, scion precuring

The grafted plants kept under open and polyhouse condition without defoliation of cultivars, (Cricket Ball, Pala and Oval) did not survive after grafting (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3). Those grafted plants wherein grafting was done without defoliation could survive only under the polytunnel condition. At 180 DAG, highest fresh weight was observed with $C_3V_1S_3$ Cricket Ball grafted without defoliation and kept in poly tunnel condition (37.06). Lowest number of fresh weight was seen in C_1 V_3 S_2 Oval grafted with defoliation on the day of grafting and kept under open condition (9.84) at 180 DAG.

4.1.9.4 Dry weight

4.1.9.4.1 Effect of environmental conditions

The observation (Table 9) on dry weight at 180 DAG indicated that C_3 - Polytunnel (10.01) had higher dry weight followed by C_2. Least number of dry weight was observed with C_2 (polyhouse condition) (4.33).

4.1.9.4.2 Effect of cultivars

Regarding the cultivars, V_2- Pala had maximum dry weight at 180 DAG (6.76). Least dry weight was observed with V_1 –Cricket Ball (6.16).

4.1.9.4.3 Effect of precuring

Regarding precuring treatments at 180 DAG, S_1 defoliation 10 days prior to grafting was found to be better (7.99) followed by S_2 defoliation followed by grafting on the same day. Dry weight was less in S_3 (4.86) without defoliation.

4.1.9.4.4 Interaction effect of environmental conditions under which grafts are kept and cultivars

Interaction effect of environmental conditions and different cultivars was statistically significant that in different cultivars, scion precuring varied according the environmental condition in which grafts are kept. At 180 DAG, C_3 V_1 (Polytunnel+Cricket Ball) produced statistically maximum (10.30) and minimum values (3.02) in C_2 V_1 (Polyhouse+Cricket Ball).

4.1.9.4.5 Interaction effect of environmental conditions under which grafts are kept and precuring

The interaction between environmental conditions under which grafts are kept and precuring was found to be significant statistically. The grafts done without defoliation and kept in open and polyhouse condition had dried off. Grafts without defoliation could only survive under poly tunnel condition. At 180 DAG, highest dry weight of grafts was observed in C_3S_3 (14.58) and lowest was in C_2 S_2 (4.50) grafting done in poly house with same day defoliation.

4.1.9.4.6 Interaction effect of cultivars and precuring

Varietal effect of fresh weight of grafts under different precuring treatments had found to be significant at 180 DAG.V_3 S_1 Oval with 10 days prior defoliation showed highest dry weight (8.92). Lowest fresh weight was found in V_3 S_3 (4.21).

4.1.9.4.7 Interaction effect of environmental conditions, cultivars, scion precuring

There was no survival observed in non defoliated grafted plants of cultivars, (Cricket Ball, Pala and Oval) which were kept under open (C_1 V_1 S_3 , C_1 V_2 S_3 and C_1 V_3 S_3) and polyhouse condition (C_2 V_1 S_3 , C_2 V_2 S_3 , and C_2 V_3 S_3). Those grafted plants wherein grafting was done without defoliation could survive only under the polytunnel condition. At 180 DAG, highest dry weight was observed with C_3 V_1 S_3 Cricket Ball grafted without defoliation and kept in poly tunnel condition (17.06). Lowest number of fresh weight was seen in C_2 V_1 S_2 Cricket Ball grafted with defoliation on the day of grafting and kept under polyhouse condition (4.12) at 180 DAG.

4.1.10 Temperature and humidity

From data given in Table 10. indicated that from first week after grafting to 4th week after grafting, humidity was highest at polytunnel conditions (80.45,73.5,82.13 and 79.50 respectively) where grafts showed highest success (48.14) and survival (46.66) per cent. Humidity was lowest at open conditions from first week after grafting to 4th week after grafting (68.12,54.45,56.34 and 62.5). Temperature was more at polyhouse condition from first week after grafting to 4th week after grafting (32.65,32.26,35.05 and 31.85 respectively). Temperature was recorded lower at open conditions compared with other two conditions (32.55,31.2,34.65 and 31.25 respectively) from first week after grafting to 4th week after grafting.

Table 10. Effect of temperature and humidity under different environmental conditions

Conditions	Open		Polyhouse		Polytunnel	
Parameters	Temperature (^{0}c)	Humidity	Temperature (^{0}c)	Humidity	Temperature(^{0}c)	Humidity
1 WAG	32.55	68.12	32.65	73.21	32.6	80.45
2 WAG	31.2	54.45	32.26	66.25	31.9	73.5
3 WAG	34.65	56.34	35.05	65.5	34.88	82.13
4 WAG	31.25	62.5	31.85	69.37	31.5	79.5

Plate 3: Growth of grafts under polytunnel condition at 30 DAG (After opening cladding material)

Plate 4: Grafts under open condition at 30 DAG

Plate 5: Grafts under polyhouse at 30 DAG

Plate 6:New leaves on defoliated graft

Plate 7: New leaves on non defoliated graft at polytunnel conditions

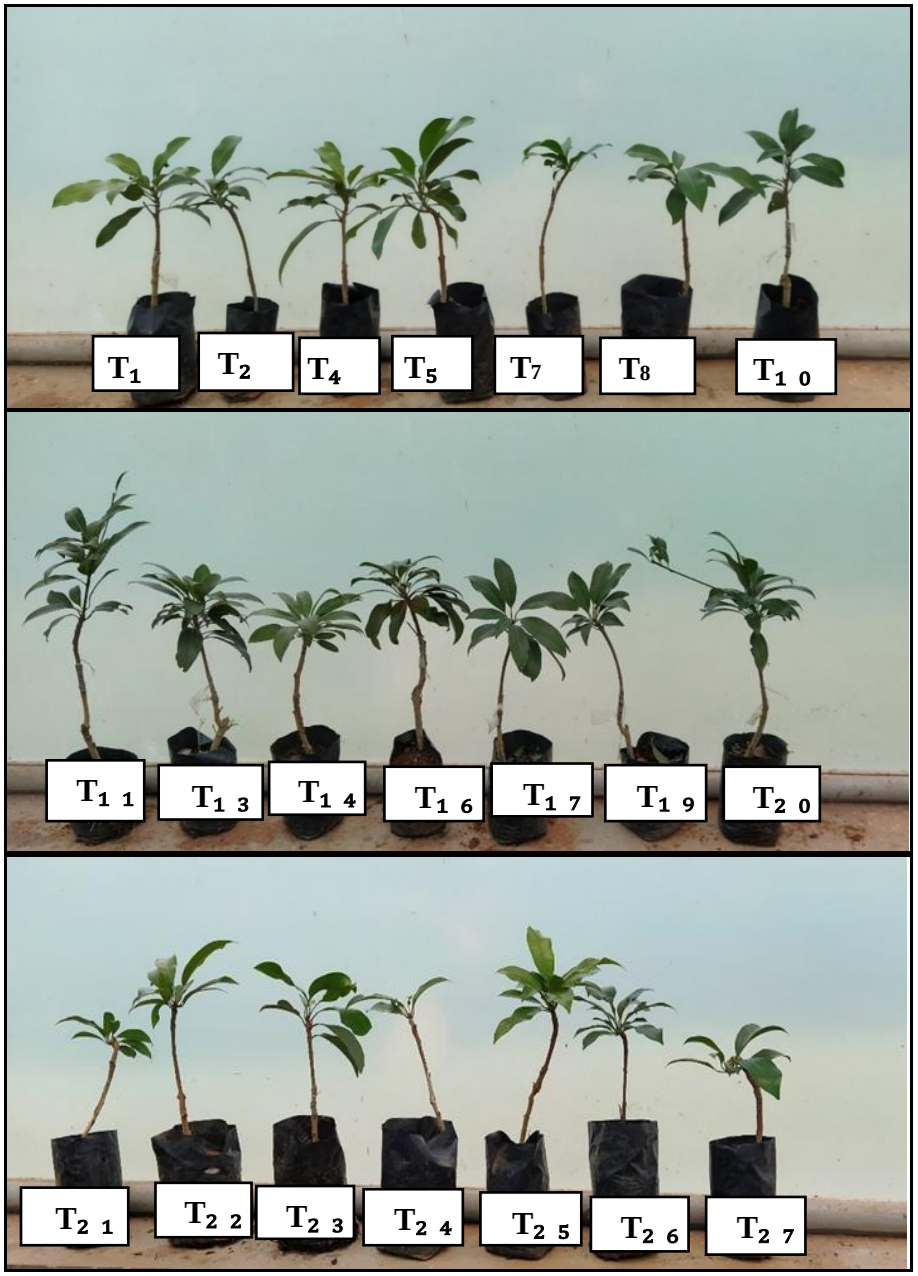
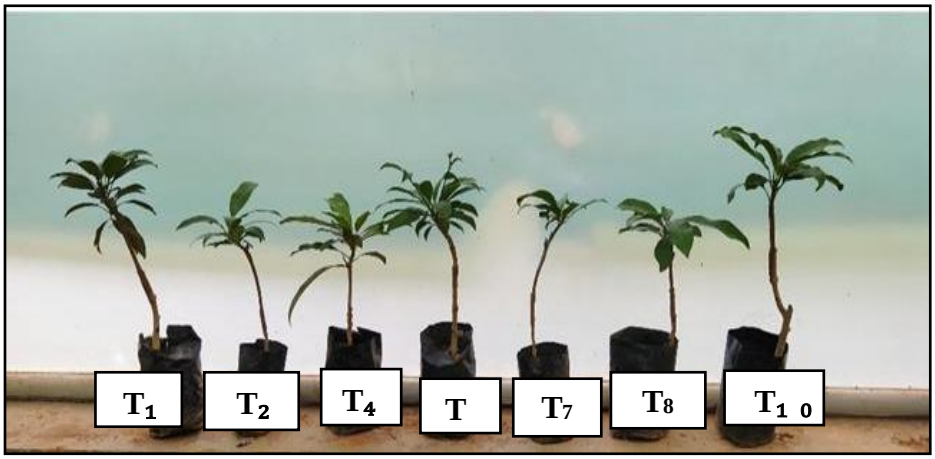


Plate 8: Growth of grafts at 90 DAG

T_1 -C_1 V_1 S_1	T_{11} - C_2 V_1 S_2	T_{21} - C_3 V_1 S_3
T_2 - C_1 V_1 S_2	T_{13} - C_2 V_2 S_1	T_{22} - C_3 V_2 S_1
T_4 - C_1 V_2 S_1	T_{14} - C_2 V_2 S_2	T_{23} - C_3 V_2 S_2
T_5 - C_1 V_2 S_2	T_{16} - C_2 V_3 S_1	T_{24} - C_3 V_2 S_3
T_7 - C_1 V_3 S_1	T_{17} - C_2 V_3 S_2	T_{25} - C_3 V_3 S_1
T_8- C_1 V_3 S_2	T_{19} -C_3 V_1 S_1	T_{26} - C_3 V_3 S_2
T_{10} - C_2 V_1 S_1	T_{20} - C_3 V_1 S_2	T_{27} - C_3 V_3 S_3



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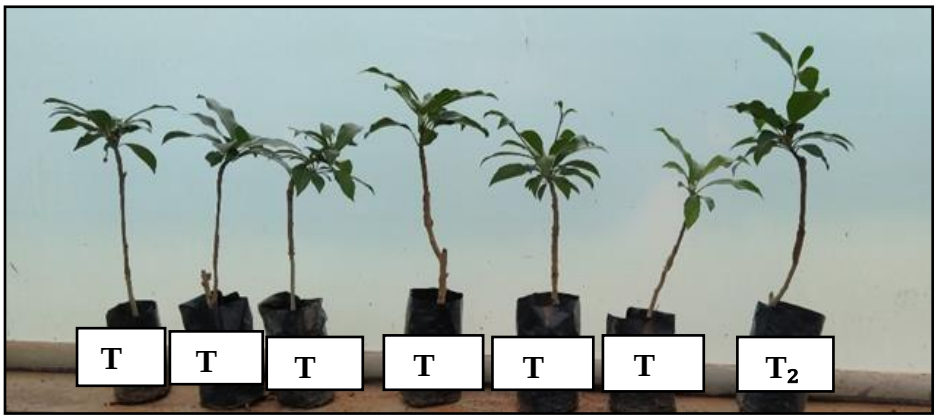
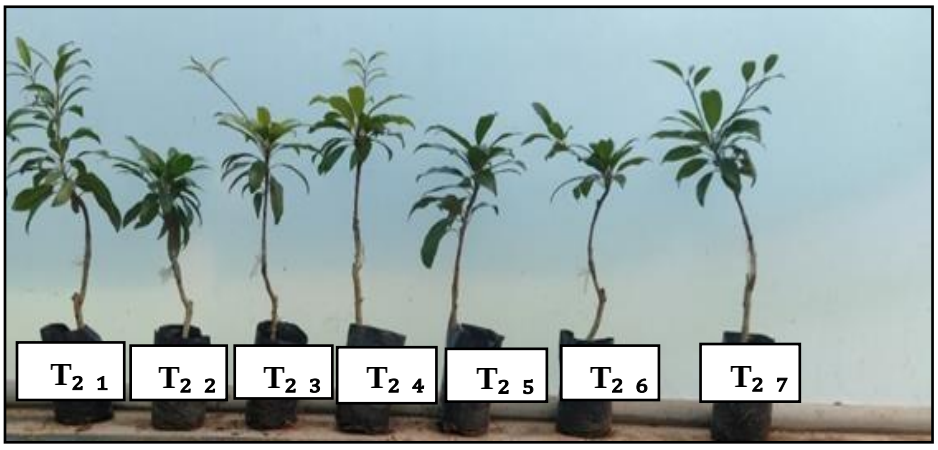


b



c

Plate 9(a,b and c): Growth of grafts at 150 DAG

T_1 -C_1 V_1 S_1	T_{11} - C_2 V_1 S_2	T_{21} - C_3 V_1 S_3
T_2 -C_1 V_1 S_2	T_{13} - C_2 V_2 S_1	T_{22} - C_3 V_2 S_1
T_4 - C_1 V_2 S_1	T_{14} - C_2 V_2 S_2	T_{23} - C_3 V_2 S_2
T_5 - C_1 V_2 S_2	T_{16} - C_2 V_3 S_1	T_{24} - C_3 V_2 S_3
T_7 - C_1 V_3 S_1	T_{17} - C_2 V_3 S_2	T_{25} - C_3 V_3 S_1
T_8- C_1 V_3 S_2	T_{19} -C_3 V_1 S_1	T_{26} - C_3 V_3 S_2
T_{10} - C_2 V_1 S_1	T_{20} - C_3 V_1 S_2	T_{27} - C_3 V_3 S_3

Plate 10:Final establishment of graft growth under polyhouse condition(180 DAG)

Plate 11: Final establishment of graft growth under open condition (180 DAG)

Plate 12: Final establishment of graft growth after shifting to shade condition (180 DAG)

Plate13: Dried up grafts (Non defoliated under open& polyhouse)

4.2 Experiment 2: Effect of cytokinin for improving success of sapota grafting

4.2.1 Number of leaves

The data indicating number of leaves of graft as influenced by concentration of cytokinin and different days of cytokinin application from 30 to 180 DAG showed in Table11. There was a significant difference observed between concentration of cytokinin and different days of cytokinin application and among their interactions also from 30 DAG to 180 DAG.

4.2.1.1 Effect of cytokinin concentration

At 30 DAG maximum number of leaves (12.56) was observed in cytokinin concentration at 200ppm (P_3) which was on par with P_2- concentration of cytokinin at 150ppm (12.55) and P_1-concentration of cytokinin at 100ppm (11.90). Concentration of cytokinin at control (P_4) level showed the least (9.76) leaves number on an average. Similar findings were followed from 90 to 180 DAG. At 60 DAG, (P_2)-concentration of cytokinin at 150ppm had higher number of leaves (14.60) which was on par with P_3- concentration of cytokinin at 200ppm (14.56). Concentration of cytokinin at control (P_4) level showed the least (11.91) number of leaves. At 180 DAG revealed that significantly higher (22.33) number of leaves was shown by concentration of cytokinin at 200 ppm (P_3) and 150 ppm (P_2). Cytokinin at control (P_4) showed minimum (19.93) number of leaves.

4.2.1.2 Effect of days of cytokinin application

Related to days of cytokinin application at 30 DAG, D_1-0^{th} day prior to grafting (12.83) showed maximum number of leaves followed by D_2-5^{th} day prior to grafting (11.81) and D_3-10^{th} day prior to grafting (10.43) and they significantly differed from D_1. There was similarity followed in observation from 90 to 180 DAG. Higher value on number of leaves was found in D_1-0^{th} day prior to grafting (22.62) and D_3-10^{th} day prior to grafting (20.60) was lower at 180 DAG.

4.2.1.3 Effect of cytokinin concentration and days of cytokinin application

Response of cytokinin concentration at different days showed that at 30 DAG, P_3D_1-concentration of cytokinin at 200ppm+0^{th} day prior to grafting recorded

Table 11. Effect of cytokinin concentration, days of application and their interactions on mean number of leaves

Factors	30days	60days	90days	120days	150days	180days
Factor P						
P_1	11.90	13.83	15.93	17.81	19.65	21.55
P_2	12.55	14.60	16.86	18.78	20.60	22.33
P_3	12.56	14.56	17.18	18.86	20.90	22.33
P_4	9.76	11.91	14.61	16.73	18.30	19.93
SEm (±)	0.22	0.57	0.50	0.61	0.44	0.53
C.D(0.05)	0.70	0.18	0.16	0.19	0.146	0.17
Factor D						
D_1	12.83	15.02	17.23	19.18	20.98	22.62
D_2	11.81	13.80	16.21	18.00	19.90	21.38
D_3	10.43	12.40	15.00	16.96	18.70	20.60
SEm (±)	0.19	0.16	0.14	0.17	0.12	0.15
C.D(0.05)	0.60	0.49	0.44	0.53	0.38	0.46
Interaction effects PXD						
P_1 D_1	12.80	14.90	16.65	18.60	20.50	22.50
P_1 D_2	11.90	13.95	16.10	18.00	19.50	21.40
P_1 D_3	11.00	12.65	15.05	16.85	18.95	20.75
P_2 D_1	13.80	15.85	17.60	19.45	21.40	23.10
P_2 D_2	12.15	14.10	15.90	18.00	20.00	21.50
P_2 D_3	11.70	14.00	17.10	18.90	20.40	22.40
P_3 D_1	14.80	16.90	19.80	21.55	23.50	24.30
P_3 D_2	13.15	14.65	16.90	18.50	20.75	22.25
P_3 D_3	9.75	12.15	14.85	16.55	18.45	20.45
P_4 D_1	9.95	12.45	14.90	17.15	18.55	20.60
P_4 D_2	10.05	12.50	15.95	17.50	19.35	20.40
P_4 D_3	9.30	10.80	13.00	15.55	17.00	18.80
SEm (±)	0.39	0.32	0.28	0.34	0.25	0.03
C.D(0.05)	1.21	0.99	0.88	1.06	0.77	0.09

P_1:100 ppm

P_2:150 ppm

P_3: 200 ppm

P_4: Control

D_1:0th day prior to grafting

D_2:5th day prior to grafting

D_3:10th day prior to grafting

maximum (14.80) which was on par with P_2D_1 (13.80). P_4D_3 -concentration of cytokinin at control+10^{th} day prior to grafting (9.30) was minimum which was on par with P_3D_3-concentration of cytokinin at 200ppm+10^{th} day prior to grafting (9.75). At 60 DAG higher (16.90) number of leaves observed with P_3D_1 (concentration of cytokinin at 200ppm +0^{th} day prior to grafting). P_4D_3- concentration of cytokinin at control+10^{th} day prior to grafting (10.80) was the treatment with minimum value. Same trend was followed till 180 DAG. At 180 DAG, interaction effect of P_3D_1 concentration of cytokinin at 200ppm +0^{th} day prior to grafting showed higher number of leaves (24.30) on number of leaves.

4.2.2 Length of scion shoot

Concentration of cytokinin, different days of cytokinin application and their interactions effect had significantly influenced on length of scion shoot from 30 DAG to 180 DAG given in Table 12.

4.2.2.1 Effect of cytokinin concentration

Regarding cytokinin concentration at 30 DAG higher scion shoot length was observed in cytokinin application at 100ppm (P_1) (11.90). Length of scion was minimum at control (P_4) level (8.43). P_3 showed more scion length (13.23) at 60 DAG and minimum was in P_4 (11.66) Similar trend was followed up to 180 DAG.

4.2.2.2 Effect of days of cytokinin application

Response of cytokinin application at different days showed that, D_1-0^{th} day prior to grafting (11.90) had maximum scion length followed by D_3-10^{th} day prior to grafting (11.09) which was on par with D_2-5^{th} day prior to grafting (11.06) at 30 DAG. There was a similar trend followed till 180 DAG. At 180 DAG, D_1-0^{th} day prior to grafting (20.73) had highest scion length followed by D_2-(19.43). D_3-(19.30) had minimum length of scion which was significantly differed from D_1.

Table 12. Effect of cytokinin concentration, days of application and their interactions on mean length of scion shoot

Factors	30days	60days	90days	120days	150days	180days
Factor P						
P_1	11.90	12.33	13.14	14.20	16.71	19.66
P_2	11.33	12.70	13.62	14.67	17.14	19.98
P_3	11.15	13.23	14.39	15.90	18.10	20.73
P_4	8.43	11.66	12.41	13.31	15.24	18.33
SEm (±)	0.05	0.07	0.01	0.03	0.16	0.20
C.D(0.05)	0.17	0.15	0.05	0.11	0.51	0.62
Factor D						
D_1	11.90	13.01	14.03	15.31	17.39	20.73
D_2	11.06	12.22	13.11	14.19	16.51	19.43
D_3	11.09	12.21	13.03	14.05	16.49	19.30
SEm (±)	0.05	0.08	0.01	0.03	0.14	0.17
C.D(0.05)	0.15	0.27	0.05	0.09	0.44	0.54
Interaction effects PXD						
P_1 D_1	11.38	12.89	13.57	14.75	17.14	20.20
P_1 D_2	11.26	12.19	13.06	14..22	16.79	19.54
P_1 D_3	10.81	11.92	12.79	13.63	16.21	19.25
P_2 D_1	11.32	12.76	13.69	14.90	17.18	20.18
P_2 D_2	11.39	12.55	13.66	14.43	16.92	19.37
P_2 D_3	11.27	12.78	13.51	14.68	17.31	20.41
P_3 D_1	12.60	14.65	16.41	18.12	20.19	22.50
P_3 D_2	11.32	12.59	13.26	14.86	17.01	20.29
P_3 D_3	11.78	12.47	13.50	14.72	17.10	19.41
P_4 D_1	10.17	11.75	12.45	13.47	15.08	18.32
P_4 D_2	10.30	11.57	12.46	13.26	15.31	18.52
P_4 D_3	10.20	11.66	12.33	13.19	15.33	18.15
SEm (±)	0.10	0.08	0.03	0.06	0.28	0.35
CD(0.05)	0.31	0.27	0.09	0.19	0.88	1.08

P_1:100 ppm	D_1:0th day prior to grafting
P_2:150 ppm	D_2:5th day prior to grafting
P_3: 200 ppm	D_3:10th day prior to grafting
P_4: Control	

4.2.2.3 Effect of interaction effect of days of cytokinin application and concentration of cytokinin

Regarding the application of cytokinin at different days, length of scion differed statistically. At 30 DAG, P_3D_1- concentration of cytokinin at 200 ppm $+0^{th}$ day prior to grafting (12.60) had maximum length of scion. P_4D_1- concentration of cytokinin at control+0^{th} day prior to grafting had minimum (10.17) length of scion shoot which was on par with P_4D_2-concentration of cytokinin at control +5^{th} day prior to grafting (10.30) and P_4D_3- concentration of cytokinin at control+10^{th} day prior to grafting (10.20). At 60 DAG, among interaction effects P_3D_1- concentration of cytokinin at 200 ppm +0^{th} day prior to grafting was found to be better treatment (14.65) and P_4D_3- concentration of cytokinin at control+10^{th} day prior to grafting (11.66) was interaction treatment with minimum value. Same tendency was observed till 180 DAG.

4.2.3 Leaf area

Leaf area from 30 DAG to 180 DAG was highly influenced by different concentration of cytokinin and days of cytokinin application as an individual treatments and interaction treatments given in the table 13.

4.2.3.1 Effect of cytokinin concentration

Highest area of leaf at 30 DAG observed when cytokinin applied at 200 ppm (P_3) (10.40) and cytokinin at control (P_4) had least (5.42) leaf area. At 60 DAG cytokinin concentration at 200 ppm (P_3) had highest area of leaf (14.79) followed by P_2-concentration of cytokinin at 150 ppm (11.75). Concentration of cytokinin at control (P_4) level was minimum leaf area on an average (7.15). The same trend was followed up to 180 DAG.

4.2.3.2 Effect of days of cytokinin application

Considering application of cytokinin at different days, maximum leaf area was found when cytokinin applied on D_1-same day of grafting (8.67) followed by D_2-5^{th} day prior to grafting (7.77) which was on par with D_3-10^{th} day prior to grafting (7.62) with least value of leaf area at 30 DAG. The trending of result was same

Table 13. Effect of cytokinin concentration, days of application and their interactions on mean leaf area

Factors	30 days	60 days	90 days	120 days	150 days	180 days
Factor P						
P_1	7.66	11.56	14.69	19.30	25.84	30.81
P_2	8.60	11.75	14.68	20.25	26.83	32.56
P_3	10.40	14.79	19.11	24.46	30.59	35.41
P_4	5.42	7.15	10.42	13.31	16.90	23.14
SEm (±)	0.22	0.22	0.24	0.36	0.41	0.66
C.D(0.05)	0.67	0.69	0.74	1.11	1.28	2.04
Factor D						
D_1	8.67	13.05	17.09	23.56	27.93	33.30
D_2	7.77	11.10	14.76	18.53	25.54	31.06
D_3	7.62	9.79	12.33	15.90	21.65	27.07
SEm (±)	0.19	0.19	0.21	0.31	0.36	0.57
C.D(0.05)	0.58	0.60	0.64	0.96	1.11	1.77
Interaction effects PXD						
P_1 D_1	8.22	14.33	18.61	24.02	29.39	33.65
P_1 D_2	8.10	11.27	14.10	19.09	27.11	30.44
P_1 D_3	6.65	9.07	11.36	14.80	21.03	28.33
P_2 D_1	9.01	13.10	16.88	26.34	30.17	32.90
P_2 D_2	8.60	11.48	14.65	18.50	27.26	34.74
P_2 D_3	8.20	10.68	12.52	15.91	23.06	30.04
P_3 D_1	12.50	17.30	22.59	30.12	35.07	41.27
P_3 D_2	9.48	15.31	20.00	23.86	30.67	36.32
P_3 D_3	9.16	11.78	14.74	19.40	26.05	28.66
P_4 D_1	4.89	7.48	10.27	13.75	17.11	25.40
P_4 D_2	4.89	6.36	10.30	12.68	17.12	22.75
P_4 D_3	6.49	7.63	10.70	13.50	16.48	21.27
SEm (±)	0.38	0.39	0.42	0.62	0.72	1.15
C.D(0.05)	1.17	1.21	1.29	1.93	2.22	3.54

P_1:100 ppm
P_2:150 ppm
P_3: 200 ppm
P_4: Control

D_1:0^{th} day prior to grafting
D_2:5^{th} day prior to grafting
D_3:10^{th} day prior to grafting

till 180 DAG. Related to days of cytokinin application, at 180 DAG, D_1-0th day prior to grafting (33.30) had highest value followed by D_2-5th day prior to grafting (31.06) and D_3-10th day prior to grafting (27.07) and they significantly differed from D_1.

4.2.3.3 Effect of days of cytokinin and concentration

Effect of application of cytokinin at various concentration in different days showed that at significantly maximum leaf area was noticed in P_3D_1- concentration of cytokinin at 200 ppm+0^{th} day prior to grafting (12.56) which was higher to all other interaction treatments. Similar observation was followed up to 180 DAG. The minimum leaf area found in P_4D_1- concentration of cytokinin at control+0^{th} day prior to grafting (4.89) and P_4D_2- concentration of cytokinin at control+5^{th} day prior to grafting (4.89).

At 180 DAG, interaction effects P_3D_1- concentration of cytokinin at 200 ppm+0^{th} day prior to grafting (41.27) produced significantly maximum effect on leaf area. P_4D_3-concentration of cytokinin at control+10^{th} day prior to grafting (21.27) was the lower interaction treatment.

4.2.4 Height of graft

It is evident from Table 14. that from 30 DAG to 180 DAG height of graft was significantly varied with concentration of cytokinin and days of cytokinin application individually. Interaction effect of both factors also influenced significantly in case of height of graft from 30 DAG to 180 DAG.

4.2.4.1 Effect of concentration of cytokinin

At 30 DAG graft height was highest when cytokinin applied at 200 ppm (P_3) (24.70) which on par with P_1-concentration of cytokinin at 100 ppm (24.41) and P_2-concentration of cytokinin at 150 ppm (24.41). The least (23.48) value of height of graft stem was obtained when cytokinin was at control (P_4) level. Similar trend was observed at 60,90,120,150,180 DAG. Height of graft at 120 DAG showed that maximum (31.16) value when concentration was at 200ppm (P_3). Concentration of

cytokinin at control (P_4) level recorded minimum (29.50) effect. At 180 DAG cytokinin at 200 ppm (P_3) had the maximum (34.93) graft height which was on par with P_1- concentration of cytokinin at 100ppm (34.75). Height of graft stem was least (33.38) when cytokinin was at control (P_4) level.

4.2.4.2 Effect of days of cytokinin application

Regarding with days of cytokinin application at 30 DAG, D_1-0^{th} day prior to grafting (24.48) had maximum height of graft followed by D_2-5^{th} day prior to grafting and D_3-10^{th} day prior to grafting(24.13). Similar result was observed till 180 DAG. At 60 DAG, D_1-0^{th} day prior to grafting (26.66) noticed as better treatment followed by D_3-10^{th} day prior to grafting (26.33). D_2-5^{th} day prior to grafting (26.28) was lower among individual treatments of days of application of cytokinin which was significantly differed from D_1.

4.2.4.3 Effect of days of cytokinin application and concentration of cytokinin

Regarding the effect of cytokinin application at different days and different concentration indicated that at 30 DAG, significantly highest graft height was observed when cytokinin applied at 200 ppm with same day of grafting- P_3 D_1 (25.20). Similar trend was observed up to 180 DAG. At 30 DAG minimum graft height was obtained when cytokinin applied at control level on same prior to grafting -P_4 D_1 (23.40) and the same condition was observed at 60 DAG also. This was on par with P_4D_3- concentration of cytokinin at control+10^{th} day prior to grafting (23.45) and P_4D_2-concentration of cytokinin at control+5^{th} day prior to grafting (23.60) at 30 DAG. At 90 DAG and 120 DAG, least graft height was observed in P_4D_3- concentration of cytokinin at control+10^{th} day prior to grafting (26.95), (29.25). At 180 DAG, highest graft height was seen when cytokinin applied at 200 ppm with same day of grafting- P_3D_1 (35.70). P_4D_2- concentration of cytokinin at control+5^{th} day prior to grafting (33.30) was minimum recorded interaction which was on par with P_4D_3- concentration of cytokinin at control+10^{th} day prior to grafting (33.35), P_4D_1- concentration of cytokinin at control+0^{th} day prior to grafting (33.50) and P_2D_2-concentration of cytokinin at 150 ppm +5^{th} day prior to grafting (33.65).

Table 14. Effect of cytokinin concentration, days of application and their interactions on mean height of graft

Factors	30days	60days	90days	120days	150days	180days
Factor P						
P_1	24.41	26.73	28.51	31.03	32.75	34.75
P_2	24.41	26.60	28.26	30.86	32.75	34.25
P_3	24.70	26.91	28.56	31.16	33.08	34.93
P_4	23.48	25.46	27.20	29.50	31.38	33.38
SEm (±)	0.06	0.05	0.07	0.07	0.06	0.06
C.D(0.05)	0.21	0.17	0.21	0.24	0.20	0.21
Factor D						
D_1	24.48	26.66	28.38	31.21	32.98	34.81
D_2	24.13	26.28	28.11	30.33	32.22	33.98
D_3	24.13	26.33	27.91	30.37	32.26	34.18
SEm (±)	0.05	0.04	0.06	0.06	0.05	0.05
C.D(0.05)	0.18	0.15	0.18	0.20	0.17	0.18
Interaction effects PXD						
P_1 D_1	24.70	27.00	28.70	31.60	33.50	35.25
P_1 D_2	24.25	26.45	28.45	30.75	32.35	34.60
P_1 D_3	24.30	26.75	28.40	30.75	32.40	34.40
P_2 D_1	24.65	26.70	28.50	31.40	33.20	34.80
P_2 D_2	24.20	26.45	28.15	30.55	32.60	33.65
P_2 D_3	24.40	26.65	28.15	30.65	32.45	34.30
P_3 D_1	25.20	27.65	29.15	32.25	33.80	35.70
P_3 D_2	24.50	26.50	28.40	30.40	32.70	34.40
P_3 D_3	24.40	26.60	28.15	30.85	32.75	34.70
P_4 D_1	23.40	25.30	27.20	29.60	31.45	33.50
P_4 D_2	23.60	25.75	27.45	29.65	31.25	33.30
P_4 D_3	23.45	25.35	26.95	29.25	31.45	33.35
SEm (±)	0.11	0.09	0.12	0.13	0.11	0.11
C.D(0.05)	0.36	0.30	0.37	0.41	0.35	0.36

P_1:100 ppm
P_2:150 ppm
P_3: 200 ppm
P_4: Control

D_1:0th day prior to grafting
D_2:5th day prior to grafting
D_3:10th day prior to grafting

4.2.5 Girth of stem (5 cm above the graft union)

It is evident from the Table 15. that treatments of concentration of cytokinin and days of cytokinin application showed significant variation with girth of stem 5 cm above graft union from 30 DAG to 180 DAG

4.2.5.1 Effect of concentration of cytokinin

The observation on girth of stem graft 5 cm above the graft union at 30 DAG highest (1.31) stem girth was seen at a concentration of 200 ppm (P_3) which was on par with P_1 - concentration of cytokinin at 100 ppm (1.29). Same tendency showed at 90 DAG and 120 DAG also where concentration of 200ppm (P_3) was higher. At 60 DAG significantly higher girth of stem (1.54) was found when concentration of cytokinin at 100 ppm (P_1) was applied which was on par with P_3 (1.50). The same tendency was showed at 150 DAG and 180 DAG. Concentration of cytokinin at control (P_4) showed lesser effect on girth of stem from 30 to 180 DAG. Girth of stem graft 5cm above the graft union at 180 DAG indicated that concentration of cytokinin at 100ppm(P_1) found to be higher (3.10) which was on par with P_3- concentration of cytokinin at 200ppm (3.04). Similar result was obtained upto 180 DAG. D_1-0^{th} day prior to grafting (11.80) had maximum leaf length at 180 DAG followed by D_2-5^{th} day prior to grafting (11.42). Lowest length of leaf was seen in D_3-10^{th} day prior to grafting (10.70).

4.2.5.2 Effect of days of cytokinin application

Regarding cytokinin application at different days, highest stem girth was obtained on D_1-same day of grafting (1.30). This was followed by D_2 -5^{th} day prior to grafting (1.16) which was on par with D_3-10^{th} day prior to grafting (1.14). Same tendency was observed upto 180 DAG. Maximum girth of stem was seen on D_1-0^{th} day prior to grafting (3.06) at 180 DAG. This was followed by D_2-5^{th} day prior to grafting(2.88) which was on par with D_3-10^{th} day prior to grafting(2.82).

Table 15. Effect of cytokinin concentration, days of application and their interactions on mean girth of stem (5cm above graft union)

Factors	30days	60days	90days	120days	150days	180 days
Factor P						
P_1	1.29	1.54	2.28	2.48	2.88	3.10
P_2	1.18	1.44	2.25	2.45	2.73	2.99
P_3	1.31	1.50	2.38	2.58	2.80	3.04
P_4	1.04	1.26	1.63	2.11	2.28	2.55
SEm (±)	0.03	0.01	0.01	0.02	0.03	0.03
C.D(0.05)	0.09	0.04	0.04	0.06	0.09	0.09
Factor D						
D_1	1.30	1.52	2.21	2.54	2.85	3.06
D_2	1.16	1.40	2.09	2.36	2.61	2.88
D_3	1.14	1.38	2.10	2.33	2.56	2.82
SEm (±)	0.02	0.01	0.01	0.01	0.02	0.02
C.D(0.05)	0.08	0.03	0.04	0.05	0.08	0.08
Interaction effects PXD						
P_1 D_1	1.30	1.64	2.43	2.70	3.13	3.26
P_1 D_2	1.33	1.53	2.25	2.40	2.81	3.13
P_1 D_3	1.23	1.44	2.15	2.35	2.69	2.92
P_2 D_1	1.33	1.55	2.30	2.61	2.90	3.15
P_2 D_2	1.10	1.33	2.34	2.51	2.79	3.05
P_2 D_3	1.12	1.45	2.12	2.24	2.50	2.77
P_3 D_1	1.43	1.69	2.52	2.81	3.16	3.38
P_3 D_2	1.24	1.42	2.24	2.41	2.58	2.83
P_3 D_3	1.25	1.39	2.39	2.54	2.67	2.92
P_4 D_1	1.15	1.23	1.62	2.04	2.20	2.47
P_4 D_2	0.99	1.33	1.52	2.12	2.26	2.51
P_4 D_3	0.98	1.23	1.74	2.19	2.38	2.68
SEm (±)	0.05	0.02	0.02	0.03	0.05	0.05
C.D(0.05)	NS	0.07	0.08	0.10	0.16	0.16

P_1:100 ppm

P_2:150 ppm

P_3: 200 ppm

P_4: Control

D_1:0th day prior to grafting

D_2:5th day prior to grafting

D_3:10th day prior to grafting

4.2.5.3 Effect of days of cytokinin application and concentration of cytokinin

At 30 DAG, interaction effects of concentration of cytokinin and days of cytokinin application was found to be non significant on girth of stem graft. At 60 DAG, significantly maximum value of stem girth was obtained when cytokinin at 200 ppm concentration with same day of grafting- P_3 D_1 (1.69) was and on par with P_1D_1- concentration of cytokinin at 100 ppm+0^{th} day prior to grafting (1.64). Similar results was found upto 180 DAG. At 60 DAG, minimum stem girth was obtained in P_4D_3- concentration of cytokinin at control+10^{th} day prior to grafting (1.23) which was on par with P_4D_1- concentration of cytokinin at control+0^{th} day prior to grafting (1.23). At 180 DAG, P_3D_1- concentration of cytokinin at 200 ppm+0^{th} day prior to grafting recorded maximum (3.38) which was on par with P_1D_1- concentration at 100 ppm +0^{th} day prior to grafting (3.26). Stem girth was found to be minimum in P_4D_1- concentration of control +0^{th} day prior to grafting (2.47) which was on par with P_4 D_2 - concentration of control +5^{th} day prior to grafting (2.51).

4.2.6 Length of leaf

Length of leaves had highly differed by concentration of cytokinin and days of cytokinin as individual treatments from 30 DAG to 180 DAG. The interaction effect of both factors on length of leaf was significantly differed from 30 DAG to 150 DAG (Table 16).

4.2.6.1 Effect of concentration of cytokinin

Result on length of leaf at 30 DAG showed that highest leaf length was observed when cytokinin applied at a concentration of 200ppm (P_3) (5.78) which was on par with P_2- concentration of cytokinin at 150ppm (5.63). The results was same upto 180 DAG. Minimum leaf length (4.53) was obtained when cytokinin applied at control (P_4) level. This same trend was seen upto 180 DAG. Length of leaf at 180 DAG indicated that highest (12.06) length of leaf was seen in cytokinin at concentration of 200 ppm(P_3) which was on par with P_2- cytokinin at concentration of 150 ppm(12.01). Cytokinin at control (P_4) level showed lesser (9.80) effect.

Table 16. Effect of cytokinin concentration, days of application and their interactions on mean length of leaves

Factors	30days	60days	90days	120days	150days	180days
Factor P						
P_1	5.06	6.80	7.48	8.50	10.51	11.36
P_2	5.63	6.79	7.50	8.86	10.96	12.01
P_3	5.78	7.15	8.30	9.62	11.37	12.06
P_4	4.53	5.15	6.37	7.31	8.42	9.80
SEm (±)	0.07	0.06	0.07	0.05	0.05	0.11
C.D(0.05)	0.22	0.19	0.21	0.17	0.17	0.36
Factor D						
D_1	5.43	7.13	7.99	9.65	10.81	11.80
D_2	5.24	6.33	7.48	8.26	10.44	11.42
D_3	5.07	5.95	6.77	7.80	9.70	10.70
SEm (±)	0.06	0.05	0.06	0.04	0.04	0.10
C.D(0.05)	0.19	0.16	0.18	0.15	0.14	0.31
Interaction effects PXD						
P_1 D_1	5.21	7.62	8.32	9.48	11.39	11.92
P_1 D_2	5.61	6.66	7.52	8.35	10.65	11.59
P_1 D_3	4.37	6.12	6.62	7.67	9.49	10.57
P_2 D_1	6.21	7.56	8.38	10.61	11.51	12.07
P_2 D_2	5.42	6.61	7.46	8.10	11.12	12.33
P_2 D_3	5.26	6.20	6.66	7.87	10.26	11.64
P_3 D_1	6.16	7.75	9.06	11.26	11.82	12.94
P_3 D_2	5.42	7.31	8.47	9.33	11.46	12.06
P_3 D_3	5.77	6.40	7.39	8.28	10.83	11.19
P_4 D_1	4.17	5.60	6.19	7.27	8.52	10.28
P_4 D_2	4.52	4.76	6.49	7.28	8.52	9.73
P_4 D_3	4.90	5.10	6.43	7.37	8.22	9.40
SEm (±)	0.12	0.11	0.12	0.09	0.09	0.20
C.D(0.05)	0.38	0.33	0.37	0.29	0.29	NS

NS: Non Significant

P_1:100 ppm

P_2:150 ppm

P_3: 200 ppm

P_4: Control

D_1:0th day prior to grafting

D_2:5th day prior to grafting

D_3:10th day prior to grafting

4.2.6.2 Effect of days of cytokinin application

Regarding cytokinin application at different days, length of leaf was highest on D_1-0^{th} day prior to grafting (5.43). This was followed by D_2-5^{th} day prior to grafting (5.24) and D_3-10^{th} day prior to grafting. The same observation was noticed up to 150 DAG. Length of leaf was minimum when application of cytokinin was done at control level on 5^{th} day prior to grafting- P_4 D_2 (4.76) at 60 DAG. At 150 DAG, P_3D_1- found to be the highest (11.82) value on length of leaf. The least effect was observed in P_4D_3- -concentration of cytokinin at control+10^{th} day prior to grafting (8.22). Interaction effects of concentration of cytokinin and days of cytokinin had failed to produce significant effect on length of leaf at 180 DAG.

4.2.6.3 Effect of days of cytokinin application and concentration of cytokinin

Regarding the effect of application of cytokinin at different days, at 30 DAG leaf length was maximum (6.21) when application of cytokinin at 150 ppm with 0^{th} day prior to grafting -P_2D_1 and which was on par with P_3D_1- concentration of cytokinin at 200 ppm+0^{th} day prior to grafting (6.16). P_4D_1- concentration of cytokinin at control +0^{th} day prior to grafting (4.17) was minimum which was on par with P_1D_3- concentration of cytokinin at 100 ppm+10^{th} day prior to grafting (4.37) and P_4D_2- concentration of cytokinin at control+5^{th} day prior to grafting (4.52). At 60 DAG, highest leaf length was observed when cytokinin at 200 ppm applied on same day of grafting -P_3D_1 (7.75).

4.2.7 Breadth of leaf

The data presented in the Table 17. showed that breadth of leaf was varied with concentration of cytokinin and days of cytokinin application. The combination effect of both also influenced breadth of leaf.

4.2.7.1 Effect of concentration of cytokinin

According to observation of breadth of leaf, at 30 DAG data showed that cytokinin at a concentration of 200 ppm (P_3) had maximum (2.45) leaf breadth. This was followed by P_1- concentration of cytokinin at 100 ppm (2.09) which was on par

with P_2- concentration of cytokinin at 150ppm (2.07). Breadth of leaf was least (1.63) when cytokinin at control (P_4) level was applied. The same findings was observed upto 180 DAG. At 180 DAG highest leaf breadth was noticed when concentration of cytokinin at 200 ppm(P_3) (4.00) was given to the graft plant. This was followed by P_1- concentration of cytokinin at 100 ppm (3.71) and P_2- concentration of cytokinin at 150ppm (3.71). Minimum (3.23) leaf breadth was seen in cytokinin at control (P_4) level.

4.2.7.2 Effect of days of cytokinin application

Regarding days of cytokinin application at 30 DAG, breadth of leaf was not significantly differed. Cytokinin application at 60 DAG, D_1-0^{th} day prior to grafting (2.46) showed more leaf breadth followed by D_2-5^{th} day prior to grafting (2.35). D_3-10^{th} day prior to grafting (2.24) produced least breadth of leaf. Similar effect was followed upto 180 DAG. At 180 DAG, cytokinin application at D_1-0^{th} day prior to grafting (3.83) recorded maximum value which was on par with D_2-5^{th} day prior to grafting (3.69). D_3-10^{th} day prior to grafting (3.45) was the treatment with minimum value.

4.2.7.3 Effect of days of cytokinin application and concentration of cytokinin

At 30 DAG, P_3D_1- concentration of cytokinin at 200ppm+0^{th} day prior to grafting had maximum effect (2.79) on breadth of leaf. From 30 to 180 DAG, similar effect of cytokinin application at different days with different concentration was noticed. P_4D_2- concentration of cytokinin at control+5^{th} day prior to grafting (1.48) was interaction with least value on breadth of leaf. At 180 DAG, highest breadth of leaf was obtained in P_3D_1- concentration of cytokinin at 200 ppm+0^{th} day prior to grafting (4.39) which was on par with P_3 D_2 -concentration of cytokinin at 200ppm +5^{th} day prior to grafting (4.12). P_4D_3-concentration of cytokinin at control+10^{th} day prior to grafting was lower (3.10) treatment**.**

Table 17. Effect of cytokinin concentration, days of application and their interactions on mean breadth of leaf

Factors	30days	60days	90days	120days	150days	180days
Factor P						
P_1	2.07	2.30	2.66	3.08	3.35	3.71
P_2	2.09	2.37	2.67	3.10	3.34	3.71
P_3	2.45	2.81	3.12	3.46	3.67	4.00
P_4	1.63	1.90	2.24	2.49	2.75	3.23
SEm (±)	0.04	0.04	0.04	0.04	0.05	0.06
C.D(0.05)	0.13	0.12	0.12	0.14	0.15	0.19
Factor D						
D_1	2.13	2.46	2.87	3.28	3.48	3.83
D_2	2.00	2.35	2.66	3.03	3.31	3.69
D_3	2.05	2.24	2.48	2.78	3.03	3.45
SEm (±)	0.05	0.03	0.03	0.04	0.04	0.05
C.D(0.05)	0.03	0.10	0.10	0.12	0.13	0.17
Interaction effects PXD						
P_1 D_1	2.16	2.57	3.06	3.47	3.53	3.86
P_1 D_2	1.98	2.32	2.57	3.13	3.48	3.59
P_1 D_3	2.07	2.03	2.35	2.64	3.03	3.67
P_2 D_1	1.98	2.37	2.76	3.40	3.59	3.73
P_2 D_2	2.17	2.38	2.69	3.13	3.36	3.86
P_2 D_3	2.13	2.36	2.57	2.77	3.08	3.53
P_3 D_1	2.79	3.06	3.41	3.66	4.06	4.39
P_3 D_2	2.39	2.87	3.23	3.50	3.66	4.12
P_3 D_3	2.17	2.52	2.73	3.21	3.29	3.51
P_4 D_1	1.61	1.83	2.27	2.59	2.75	3.38
P_4 D_2	1.48	1.83	2.17	2.38	2.75	3.20
P_4 D_3	1.81	2.05	2.28	2.51	2.74	3.10
SEm (±)	0.07	0.07	0.07	0.08	0.08	0.11
C.D(0.05)	0.23	0.21	0.21	0.25	0.26	0.34

P_1 -100 ppm	D_1 -0th day prior to grafting
P_2 -150 ppm	D_2 -5th day prior to grafting
P_3 -200 ppm	D_3 -10th day prior to grafting
P_4 -control	

4.2.8 Number of successful grafts

In the Table 18. with regard to number of successful grafts which was observed from 30 DAG to 180 DAG illustrated that cytokinin at different concentration had highly influenced on number of successful grafts. But, interaction effect of concentration of cytokinin and days of application and individual effect of days of application failed to produce significant difference on number of successful grafts from 30 DAG to 180 DAG.

4.2.8.1 Effect of concentration of cytokinin

Number of successful grafts at 30 DAG pointed that cytokinin at concentration of 200 ppm(P_3) recorded the highest value (12.33) which was followed by P_1- concentration of cytokinin at 100 ppm (12.16) and P_2- concentration of cytokinin at 150 ppm (11.83). Treatment at control (P_4) level showed least (10.00) effect on number of successful grafts. There was similar trend of observation on number of successful grafts from 30 DAG to 180 DAG.

At 180 DAG revealed that concentration of cytokinin at 200 ppm(P_3) registered highest (11.66) number of successful grafts which was on par with P_1- concentration of cytokinin at 100 ppm(10.66) and P_2- concentration of cytokinin at 150 ppm (10.50). Control level treatment (P_4) produced minimum (7.83) effect on number of successful grafts.

4.2.8.2 Effect of days of cytokinin application

Individual effect of cytokinin application at different days did not record any significant difference from 30 to 180 DAG.

4.2.8.3 Effect of days of cytokinin application and concentration of cytokinin

Interaction effect of days of cytokinin application and concentration of cytokinin did not record any significant difference from 30 to 180 DAG.

Table 18. Effect of cytokinin concentration, days of application and their interactions on mean number of successful grafts

Factors	30days	60days	90days	120days	150days	180days
Factor P						
P_1	12.16	11.83	11.66	11.66	11.33	10.66
P_2	11.83	11.66	11.50	11.16	10.83	10.50
P_3	12.33	12.33	12.33	11.83	11.66	11.66
P_4	10.00	9.83	9.33	8.66	8.00	7.83
SEm (±)	0.48	0.51	0.4	0.54	0.52	0.68
C.D(0.05)	1.49	1.58	1.51	1.66	1.62	2.10
Factor D						
D_1	11.75	11.62	11.62	11.0	10.62	10.00
D_2	11.00	10.87	10.62	10.5	10.25	10.12
D_3	12.00	11.75	11.37	11.0	10.37	10.25
SEm (±)	0.42	0.44	0.42	0.46	0.45	0.59
C.D(0.05)	NS	NS	NS	NS	NS	NS
Interaction effects PXD						
P_1 D_1	12.0	11.5	11.5	11.5	11.5	10.0
P_1 D_2	11.0	11.0	11.0	11.0	11.0	10.5
P_1 D_3	13.5	13.0	12.5	12.5	11.5	11.5
P_2 D_1	11.0	11.0	11.0	10.0	10.0	9.5
P_2 D_2	12.0	11.5	11.5	11.5	11.0	11.0
P_2 D_3	12.5	12.5	12.0	12.0	11.5	11.0
P_3 D_1	14.5	14.5	14.5	14.0	13.5	13.5
P_3 D_2	11.0	11.0	11.0	10.5	10.5	10.5
P_3 D_3	11.5	11.5	11.5	11.0	10.5	10.5
P_4 D_1	9.5	9.5	9.5	8.5	7.5	7.0
P_4 D_2	10.0	10.0	9.0	9.0	8.5	8.5
P_4 D_3	10.5	10.0	9.5	8.5	8.0	8.0
SEm (±)	0.84	0.89	0.85	0.93	0.91	1.18
C.D(0.05)	NS	NS	NS	NS	NS	NS

NS: Non Significant

P_1:100 ppm

P_2:150 ppm

P_3: 200 ppm

P_4: Control

D_1:0th day prior to grafting

D_2:5th day prior to grafting

D_3:10th day prior to grafting

4.2.9.1 Success percentage

4.2.9.1.1 Effect of cytokinin concentration

In Table 20. success percentage of grafts at 90 DAG revealed that concentration of cytokinin at 200 ppm-P_3 (82.22) showed maximum success percentage which was on par with P_1- concentration of cytokinin at 100 ppm (77.77) and P_2- concentration of cytokinin at 150 ppm(76.66). Minimum success percentage was at control (P_4) level.

4.2.9.1.2 Effect of days of cytokinin application

Days of cytokinin application had no significant difference on success percentage.

4.2.9.1.3 Effect of days of cytokinin application and concentration of cytokinin

Interaction effect of concentration of cytokinin and days of application did not make any significant difference among the results at 90 DAG.

4.2.9.2 Survival percentage

4.2.9.2.1 Effect of cytokinin concentration

Considering survival percentage showed Table 19. which was observed at 180 DAG illustrated that application of cytokinin at 200 ppm -P_3(77.77) had highest survival percentage which was on par with P_1-concentration of cytokinin at 100ppm (71.10) and P_2-concentration of cytokinin at 150 ppm (69.99)

4.2.9.2.2 Effect of days of cytokinin application

Days of cytokinin application had no significant difference on success percentage.

4.2.9.2.3 Effect of days of cytokinin application and concentration of cytokinin

Interaction effect of concentration of cytokinin and days of application did not record any significant difference at 90 DAG.

4.2.9.3 Fresh weight

4.2.9.3.1 Effect of concentration of cytokinin

The data pertaining fresh weight of plants at 180 DAG in Table 19. showed significant difference between concentration of cytokinin. Concentration of cytokinin at 200 ppm (P_3) had maximum (26.43) fresh weight which was on par with P_2-concentration of cytokinin at 150 ppm (26.21). Fresh weight was found least when cytokinin was at control (P_4) (20.89).

4.2.9.3.2 Effect of days of cytokinin application

With regard to days of cytokinin application, D_1-0^{th} day prior to grafting (27.05) had the highest fresh weight followed by D_3-10^{th} day prior to grafting (23.47) and D_2-5^{th} day prior to grafting (23.34).

4.2.9.3.3 Effect of interaction of concentration of cytokinin and days of cytokinin application

Among interaction effects maximum fresh weight was found when concentration of cytokinin at 200ppm with 0^{th} day prior to grafting- P_3D_1 (33.19) and concentration of cytokinin at control with 5^{th} day prior to grafting -P_4D_1 (20.70) showed lesser effect among all other interaction treatments which was on par with P_4D_2- concentration of cytokinin at control+5^{th} day prior to grafting (20.07).

4.2.9.4 Dry weight

4.2.9.4.1 Effect of concentration of cytokinin

In the Table 19. data of dry weight of plants at 180 DAG revealed that there is significant difference between concentration of cytokinin. Among the individual effects of concentration of cytokinin, maximum dry weight was found at 200 ppm (P_3) (11.41) which was on par with P_2-(10.68). Cytokinin at control (P_4) level showed lower (8.96) effect.

4.2.9.4.2 Effect of days of cytokinin application

With related to days of cytokinin application, D_1-0^{th} day prior to grafting (11.26) showed maximum value which was on par with D_2-5^{th} day prior to grafting (9.87) and D_3-10^{th} day prior to grafting (9.93).

4.2.9.4.3 Effect of interaction of concentration of cytokinin and days of cytokinin application

According to interaction effects, dry weight was highest when cytokinin at 200ppm with 0^{th} day prior to grafting -P_3D_1 (16.39) was applied and concentration of cytokinin at control with 5^{th} day prior to grafting -P_4D_2 (8.64) recorded minimum dry weight compared to all other interaction treatments which was on par with P_3D_3-concentration of cytokinin at 200 ppm+0^{th} day prior to grafting (8.66) and P_4D_1-concentration of cytokinin at control+0^{th} day prior to grafting (8.71).

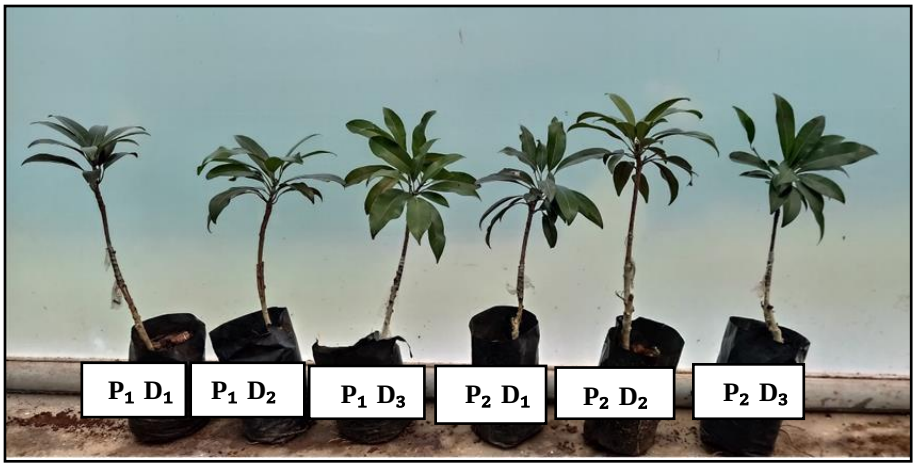
Table1 9. Effect of cytokinin concentration, days of application and their interactions on survival percentage, fresh weight, dry weight (180 DAG) and Success percentage (90 DAG)

Factors	Success percentage	Survival percentage	Fresh weight	Dry weight
	90 DAG	180 DAG		
P_1	77.77(62.24)	71.10(57.94)	24.95	10.36
P_2	76.66(61.32)	69.99(56.96)	26.21	10.68
P_3	82.22(67.59)	77.77 (62.24)	26.43	11.41
P_4	62.21(52.10)	52.21 (46.28)	20.89	8.96
SEm (±)	3.28(2.16)	4.54(2.88)	0.37	0.26
C.D(0.05)	10.12	14.01	1.15	0.83
D_1	77.49(64.00)	66.66 (55.90)	27.05	11.26
D_2	70.83(57.53)	67.49 (55.46)	23.34	9.87
D_3	75.83(60.91)	68.33 (55.95)	23.47	9.93
SEm (±)	2.84	5.57	0.32	0.23
C.D(0.05)	NS	NS	0.99	0.71
P_1 D_1	76.66(61.65)	66.66 (55.83)	31.19	13.39
P_1 D_2	73.33(59.08)	69.99(56.81)	23.36	10.20
P_1 D_3	83.3 (66.00)	76.66 (61.17)	24.76	10.65
P_2 D_1	73.33(59.08)	63.33(52.90)	27.52	11.18
P_2 D_2	76.66 (61.17)	73.33 (59.08)	25.08	9.99
P_2 D_3	79.99 (63.74)	73.33(58.90)	26.02	10.88
P_3 D_1	96.66(82.51)	89.99 (71.80)	28.79	11.77
P_3 D_2	73.33 (59.08)	70.00 (57.10)	24.85	10.65
P_3 D_3	76.66 (61.17)	69.99 (56.81)	21.22	8.66
P_4 D_1	63.33 (52.75)	46.66 (43.08)	20.70	8.71
P_4 D_2	59.99 (50.82)	56.66 (48.83)	20.07	8.64
P_4 D_3	59.99(50.82)	56.66(48.83)	20.07	8.64
SEm (±)	5.69	11.14	0.64	0.46
C.D(0.05)	NS	NS	1.99	1.43

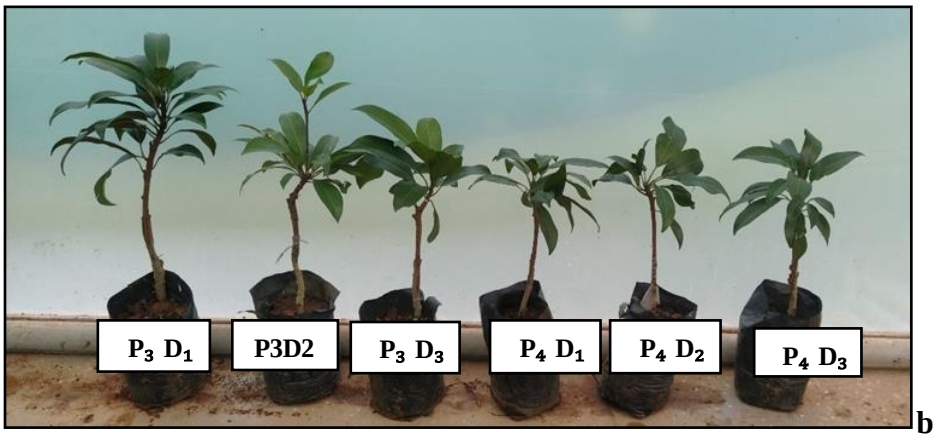
NS: Non Significant

P_1:100 ppm	D_1:0^{th} day prior to grafting
P_2:150 ppm	D_2:5^{th} day prior to grafting
P_3: 200 ppm	D_3:10^{th} day prior to grafting
P_4: Control	

Plate 14: View of grafts after opening of polytunnel at 30 DAG

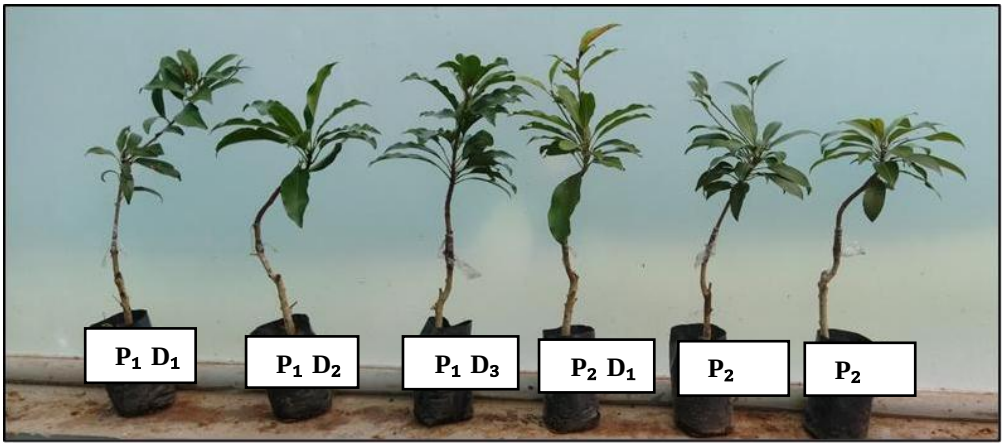


a

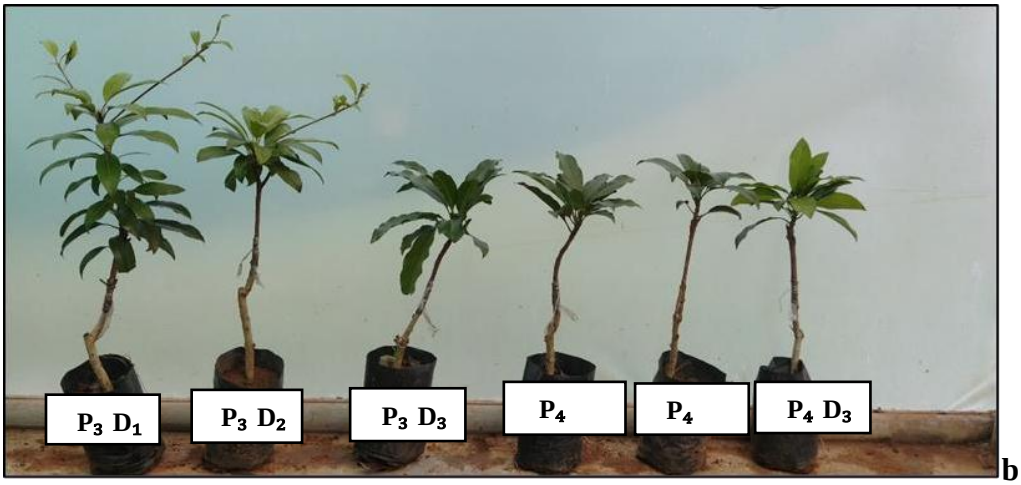


b

Plate 15(a and b): Growth of grafts at 90 DAG



a



b

Plate 16 (a and b): Growth of grafts at 150 DAG

Plate 17 : View of final established growth of grafts at 180 DAG under shade net condition

Discussion

5. DISCUSSION

An investigation entitled as "Refinement of softwood grafting technique in Sapota (*Manilkara zapota* L.)" was carried out at college of Agriculture Padannakkad Kasaragod during 2019-2021The first experiment included three environmental conditions: open, polyhouse and polytunnel with three cultivars *viz*. Cricket Ball, Pala and Oval and three scion precuring treatments *viz.* defoliation 10 days prior to grafting, defoliation followed by grafting on the same day and grafting without defoliation. Second experiment comprised of different concentrations of cytokinin at 100 ppm, 150 ppm, 200 ppm and control levels with different days of application like the 0^{th} day, 5^{th} and 10^{th} day prior to grafting. The salient findings of result are discussed below.

5.1 ROLE OF VARIETIES AND ENVIRONMENTAL CONDITIONS ON THE SUCCESS OF SAPOTA GRAFTING

5.1.1 Environmental conditions

With regard to the individual effect of environmental conditions on graft success up to final growth stage, grafting under C_3-polytunnel provided the best result compared to open and polyhouse conditions for various parameters *viz.* length of scion (19.28), girth of stem (2.70), number of successful grafts (7.00) (Fig.1), success percentage (48.14), survival percentage (46.66) (Fig.1), leaf area (26.01), length of leaf (9.15), breadth of leaf (3.85), number of leaves (14.79), fresh weight (22.11), dry weight (10.01) and height of graft (33.47) during growth intervals. The environmental conditions under polytunnel was responsible for the highest graft success. This was attributed by higher percentage of relative humidity coupled with minimum fluctuation between mean maximum and minimum temperature, which was suitable for enhanced cell activity. These results are coinciding with the findings of Sulikeri *et al.* (1997) and Kalabandi *et al*. (2014). The congenial environment under polytunnel had contributed to fast callusing rate and contact of the cambial layer as early as possible, which resulted in quick graft healing. Thus strong stock scion union was established, which led to the high vegetative growth of sapota grafts (Patel *et al*., 2007). Similar findings were obtained by Ashutosh *et al*. (2020) who reported effect

of different environmental conditions on performance of sapota softwood grafts worked on invigorated Khirni rootstock. Sivudu *et al*. (2014) in mango, Parmar *et al.* (2019) in mulberry, Selvi *et al*. (2008) in jackfruit and Beera *et al*. (2013) in guava observed significant variation due to environmental conditiions

5.1.2 Cultivars

V_1-Cricket Ball indicated higher response with regard to growth parameters like length of scion (at 60,90,150,180 DAG), leaf area (at 30,60 90 DAG), length of leaf (at 30,60,90 DAG), number of successful grafts (5.22), success percentage (35.92), survival percentage (34.81). V_1-Cricket Ball also recorded significantly higher value for fresh weight (15.26), and dry weight (6.76) of grafts. Similar findings were observed by Ghosh *et al*. (2010) on sapota cultivars in which Cricket Ball gave the highest percentage of success (85 to 65%) under Paschim Midnapore, West Bengal condition.

The observations like girth of stem (2.31), length of leaf (at 90,150 DAG) and breadth of leaf except 180 DAG (3.30) were significantly influenced by the individual effect of cultivar V_3-Oval. This might be due to the genetic make of cultivars having the large number of live parenchymatous cells, less content of vessels and more meristematic activity at bud level, which helps in sap flow smoothly and good callus. Various responses of sapota cultivars to success of softwood grafting had been reported by Kulwal *et al.* (1988) and Shirol *et al.* (2005). Sapota cultivars responded significantly to softwood grafting with different degrees of success. This could be due to phenomenon of graft incompatibility which exists between scion and rootstock of sapota cultivars. This might be contributed to woody nature of tissues, differential active flow of sap and sometimes presence of growth enhancing or inhibiting factors at graft union site retarding cambial activity between rootstock and scion. Varietal influence on graft success also had been proved by Prasanth *et al*. (2007), Jagannath *et al*. (2012) and Prajapati *et al*. (2014) in mango.

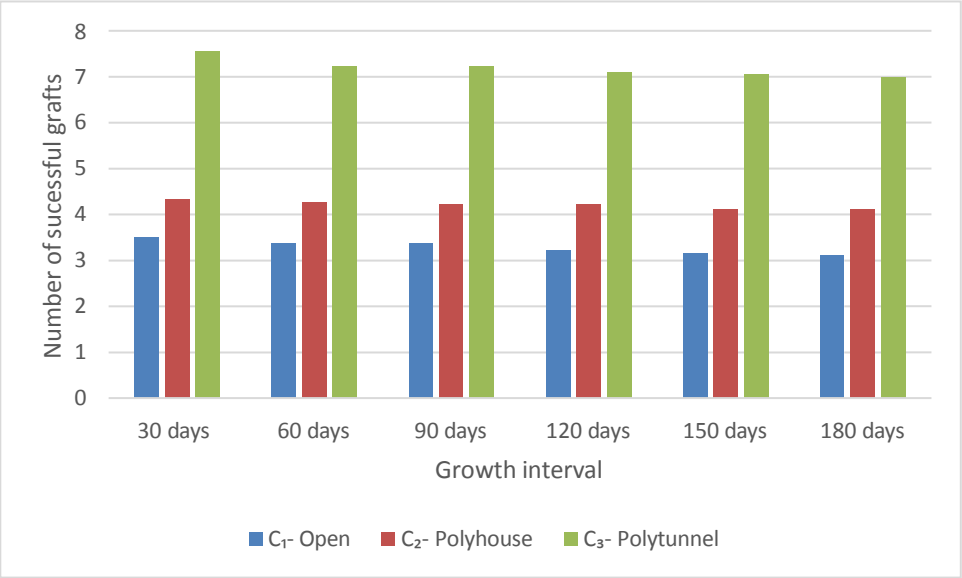


Fig 1. Effect of environmental conditions on number of successful grafts

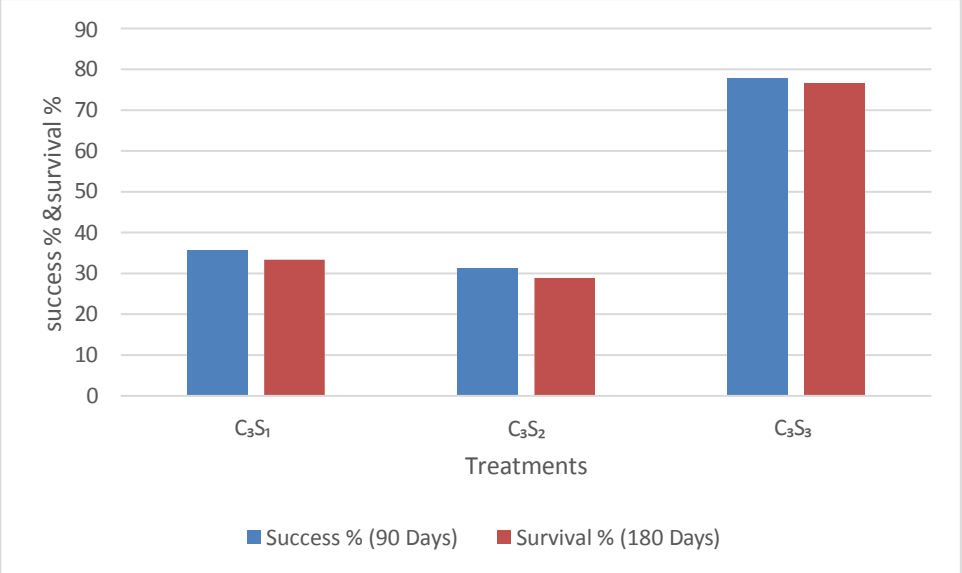


Fig 2. Effect of environmental conditions and scion precuring on success % and survival %

5.1.3 Scion precuring

Regarding the individual effect of scion precuring treatment on success of grafts throughout growth period showed that defoliation 10 days prior to grafting-S_1 had significantly maximum values in characters like number of leaves (13.69), length of scion (18.44), leaf area (22.31), height of graft (32.76), girth of stem (2.59), length of leaf (8.34), breadth of leaf (3.65), fresh weight (17.73), dry weight (7.99), success percentage (42.59) and survival percentage (40.37).

A similar sort of result was obtained by Tanuja and Thippesha (2016). The significant influence on number of leaves with 10 days cured scion might be due to early breaking of bud and ample growing period which might have resulted in more number of leaves per plant. The maximum length and breadth of leaves was produced in grafts of the scion shoots grafted after 10 days of defoliation and minimum length and breadth of leaves were observed in case of cured scion on same day of grafting. Similar results of scion precuring on length and breadth of leaves was proved by Maiti and Biswas (1986) and Sarada *et al.* (1997).

The graft height was significantly highest in case of 10 days cured scion and lowest graft height recorded on cured scion with same day of grafting. The maximum height of grafts could be due to formation of fast and strong graft union, better nutrient uptake and their continual growth. Similar results were obtained in Guava by Patel *et al*. (2007). The effect of precuring of scion was significant on the girth of the graft which might be due to early bud sprouting which provided fast growth. Scion girth was maximum in grafts with pre cured scion than normal scion (Sarada *et al*., 1997). Scions cured for 10 days prior to grafting had the highest per cent of graft success. This might be due to the presence of more carbohydrate and food material in the collected scion and the stored food material was mobilized for new growth which resulted in high meristematic activity of scion. Similar views on higher degree of success with defoliated bud sticks were expressed by Sarada *et al.* (1997). Ram and Bist (1982) reported that in precured scions, the desiccation is less compared to freshly defoliated scion.

5.1.4 Interaction effect of environmental conditions and cultivars

The data regarding interaction effect of environmental conditions and cultivars during growth stages of grafts depicted that C_3 V_3 (Polytunnel+Oval) showed higher value on growth parameters like number of leaves (15.30), leaf area (90,150,180 DAG), length of leaf at 90 DAG, 150 DAG, 180 DAG (9.41) and breadth leaf at 90 DAG, 120 DAG, 150 DAG. C_3V_1(Polytunnel+Cricket Ball) had highest value on height of graft except 30 DAG (34.06), number of successful grafts (8.00), success percentage (54.44), survival percentage (53.33) and dry weight (10.30) of grafts. C_3V_2 (Polytunnel+Pala) had recorded maximum in fresh weight (22.87). This may be due to prevailing congenial climatic condition along with presence of dormant and swollen terminal buds of scion of different sapota cultivars which promoted early sprouting and better graft growth.

5.1.5 Interaction effect of environmental conditions and scion precuring

The interaction effect of environmental conditions and scion precuring treatments during intervals of graft growth C_3S_3 (Polytunnel+Without defoliation) found to be best with respect to all growth parameters like length of scion (20.92), number of successful grafts (11.50), success percentage (77.77) (Fig.2), survival percentage (76.66) (Fig.2), leaf area (33.72), girth of stem (2.98), length of leaf (10.95), breadth of leaf (4.21), number of leaves (17.78) and height of graft (34.71) from 30 DAG to 180 DAG. The reason for this might be due to the formation and accumulation of more food materials in the grafts as well as increased hormonal activities which resulted in fast cell division and better growth of existing cells. Ultimately this results into more vegetative growth of grafts. This was more or less close to the findings of Ashutosh *et al*.2020. This was attributed by prevailing long periods of favourable temperature and relative humidity for survival and growth of grafts under polytunnel conditions. The process of defoliation caused an immediate increase in sucrose level of phloem sap of shoot which helped in movement of solutes toward the apex of the shoots and thereby resulting in initiation of higher meristematic activity at the bud level. This condition helps in better sap flow and good callus formation due to stimulation of cambium division favouring better graft union.

5.1.6 Interaction effect of cultivars and scion precuring

Considering the interaction effect of cultivars and scion precuring treatments during growth period, V_2S_1 (Pala+10 days prior defoliation) registered maximum value on survival percentage (43.33), fresh weight (19.50) and number of leaves (9.36) (30 DAG to 120 DAG). This might be due to the initiation of good cambial activity which might have resulted from defoliation (Hartman *et al*., 1997). Interaction effect of V_3S_1(Oval+10 days prior defoliation) recorded maximum value on dry weight (8.92), height of graft except 90 DAG and180 DAG (31.08).

5.1.7 Interaction effect of environmental conditions, cultivars and scion precuring

The data pertaining combined interaction effect of environmental conditions, cultivars and scion precuring treatments till the final graft growth stage indicated that $C_3V_1S_3$ (Polytunnel+Cricket Ball+Without defoliation) was found to be the best treatment combination on all growth parameters *viz* girth of stem except 30DAG(3.05), leaf area (35.42), length of leaf except 30 DAG (11.22), breadth of leaf except 60 DAG (4.32), number of leaves except 30 DAG, length of scion except 30 DAG and height of graft (34.75), fresh weight (32.06) and dry weight (15.04). Grafts without defoliation resulted more photosynthetic activity and ample growing period which might have attributed better graft success and growth. The condition under polytunnel promoted less rate of transpiration loss, which maintained guard cells in turgid condition and the stomata opened. This might have caused earlier formation and accumulation of carbohydrate, protein and fast completion of physiological process for the development of rapid growth between the rootstock and scion (Baghel *et al*., 2000).

$C_1V_3S_2$(Open+Oval+Same day defoliation) showed minimum values related to most of the growth parameters like length of scion (16.83), girth of stem (2.32), number of successful grafts (3.00) , success percentage (20.00) , survival percentage (20.00), leaf area (16.45) (Fig.3), length of leaf (7.25), breadth of leaf (3.11), number of leaves(except 120DAG) and height of graft (31.13).

$C_1V_1S_3$(Open+Cricket Ball+Without defoliation),$C_1V_2S_3$(Open+Pala+Without defoliation),$C_1V_3S_3$(Open+Oval+Without defoliation),$C_2V_1S_3$(Polyhouse+Cricket Ball+Withoutdefoliation),$C_2V_2S_3$(Polyhouse+Pala+Withoutdefoliation)and$C_2V_2S_3$(Pol yhouse+Pala+Without defoliation) are failed which resulted in dried up grafts.

Grafts without defoliation did not survive under open and polytunnel conditions. It could be due to failure to unite sometimes in adverse weather conditions as the experiment had been done in offseason. This might be attributed to absence of callus production resulted in a huge gap between the scion and rootstock which led to failure of grafts (Jose and Valsalakumari,1991). Grafts with defoliated scion and without defoliated scion could survive under polytunnel condition (followed by shade net condition). But, survival per cent varied. Grafts under polytunnel condition (followed by shade net) without defoliated scion had highest survival per cent (77.77%). As this experiment had conducted off season this modified method of grafting found to be the best compared to others which can be recommended as an ideal method in off season. Successful production of vigorous grafts at commercial scale within a short period of time (by shortening the graft cycle) can be done through this refined method of grafting.

5.1.8 Temperature and humidity

From data given in Table 10. showed that humidity was highest under polytunnel conditions from one week after grafting to 4th week after grafting (80.45,73.5.82.13 and 79.50 respectively). Temperature was more at polyhouse condition from one week after grafting to 4th week after grafting (32.65,32.26,35.05 and 31.85 respectively). The higher graft success under polytunnel conditions might be attributed by higher percentage of relative humidity coupled with minimum fluctuation between mean maximum and minimum temperature which was congenial for increased cell activity. These results are coinciding with the findings of Sulikeri *et al.* (1997) and Kalabandi *et al*. (2014) in which appropriate weather factors promoted graft success.

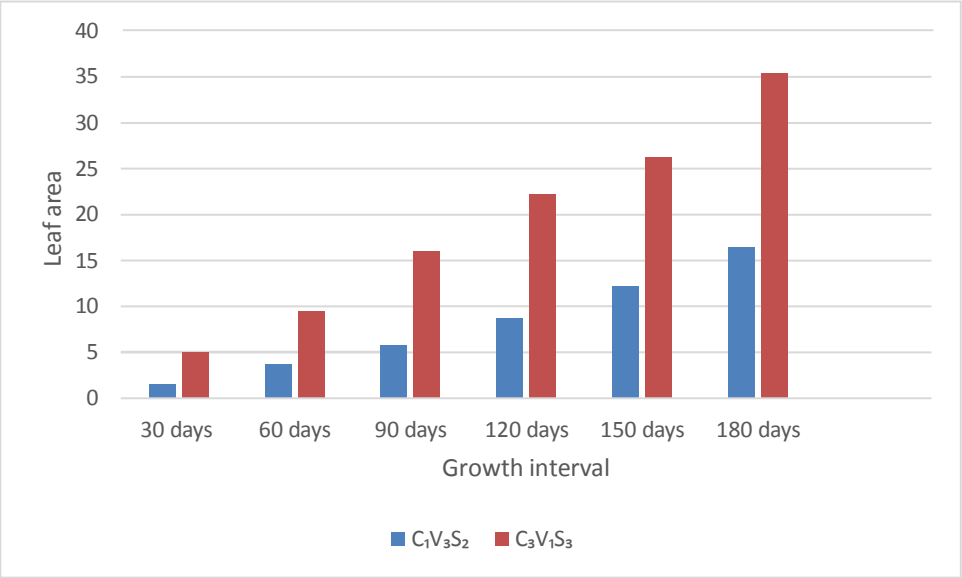


Fig 3. Effect of superior and inferior interactions (3 factor) on leaf area

In conclusion, grafting of Cricket Ball without defoliation of scion kept under polytunnel condition ($T_{2\ 1}$ -C_3 V_1 S_3) favoured as best treatment intems of girth of stem except 30 DAG (3.05), leaf area (35.42), length of leaf except 30 DAG (11.22), breadth of leaf except 60 DAG (4.32), number of leaves except 30 DAG, length of scion except 30 DAG and height of graft (34.75),fresh weight (32.06) and dry weight (15.04). Varietal effect on graft success revealed that cricket Ball had best performance. Grafts under C_3-polytunnel found to be better in growth parameters compared to open and polyhouse conditions. Among scion precuring treatments, defoliation 10 days prior to grafting-S_1 provided highest percentage of graft success. For further future studies, as an ideal approach off season production of graft seedlings through modified grafting method and application of this technique for other fruit crops like mango can also be promoted.

5.2 EFFECT OF CYTOKININ FOR IMPROVING THE SUCCESS OF SAPOTA GRAFTING

5.2.1 Number of leaves

There was a significant difference between concentration of cytokinin and different days of cytokinin application and among their interactions from 30 to 180 DAG (Fig.4) related to number of leaves of grafts. Concentration of cytokinin at 200ppm (P_3) found to be higher (22.33) till the final stage of growth (180 DAG) except at 60 DAG. Dumanoglu *et al*. (2014) reported that endogenous growth regulators have found to play critical role in grafting. Cytokinins are N6-substituted aminopurines that will start proliferation of cell in many plant cells (Cary *et al*., 1995). Mature plant cells generally do not divide in the plant, but it can be done by plant hormones application. The union of stock and scion takes place as a result of formation of callus on two components. With regard to individual effect of days of cytokinin application, D_1- 0^{th} day prior to grafting treatment showed highest value on number of leaves from initial stage to 180 DAG (22.62). Among interaction effects, P_3D_1-cytokinin at 200ppm + 0^{th} day prior to grafting showed maximum number of leaves (24.30) to all other interaction treatments up to final stage of growth (180 DAG). P_4D_3 (18.80) which is the combination of control treatment and 10^{th} day prior

to grafting showed minimum value of interaction among all treatments till final stage of growth (180 DAG).

5.2.2 Length of scion shoot

The data indicated that concentration of cytokinin and different days of cytokinin application and their interactions effect had showed significant variation on length of scion shoot from 30 DAG to 180 DAG. Regarding cytokinin concentration at 180 DAG, maximum scion shoot length was observed in cytokinin application at 200ppm (P_1) (20.73). Length of scion was minimum at control (P_4) level (18.33) Related of cytokinin application at different days, D_1-0^{th} day prior to grafting (20.73) had highest scion length followed by D_2-(19.43) at 180 DAG. D_3 (19.30) had minimum length of scion which was significantly differed from D_1. In case of interaction treatments, P_3D_1 had more scion length from 30 to 180 DAG (22.50). Influence of length of scion shoot by cytokinin might be due to the result of application of cytokinin which was noticed to enhance rapid growth of scion shoot. Because physiologically cytokinin increases development of lateral bud and decrease apical dominance. Besides this, cytokinin promote protein levels and increase DNA, RNA in plant tissue which contribute to growth of shoot tip. These findings were in conformation with results of Fox (1968); Srivastava (1968) ; Audus (1972). According to Meier *et al.* (2012) exogenous application of cytokinin promotes formation of bud on scions after successful graft union which coincides with the obtained result of current study.

5.2.3 Leaf area

The data of leaf area from 30 DAG to 180 DAG was highly influenced by different concentration of cytokinin and days of cytokinin application as an individual treatments and interaction treatments. The individual effect of concentration cytokinin on leaf area showed that higher (35.41) value was obtained when concentration of 200ppm (P_3) was applied to the scion from initial to final growth stage of grafts (Fig.5). Regarding the days of cytokinin application, D_1- 0^{th} day prior to grafting treatment showed maximum (33.30) value as an individual effect on leaf area through out the graft growth stages. Effect of interaction treatments on leaf area indicated that

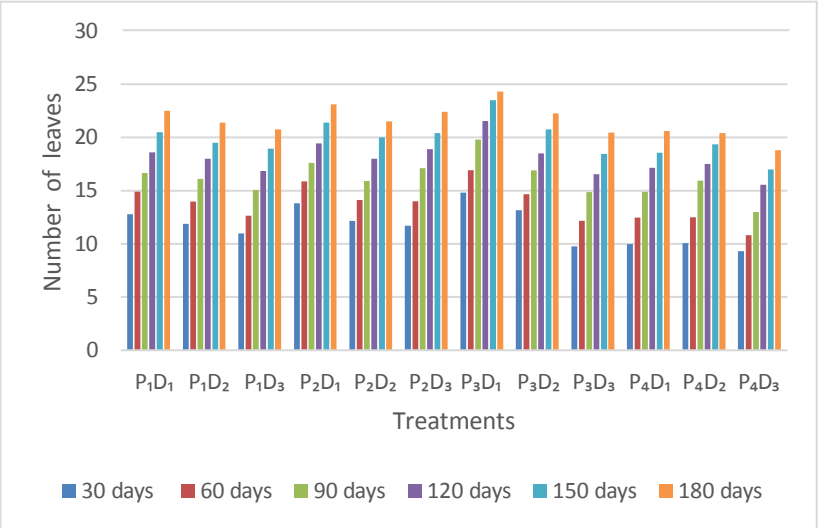


Fig 4. Effect of interactions of concentration of cytokinin and days of application on number of leaves

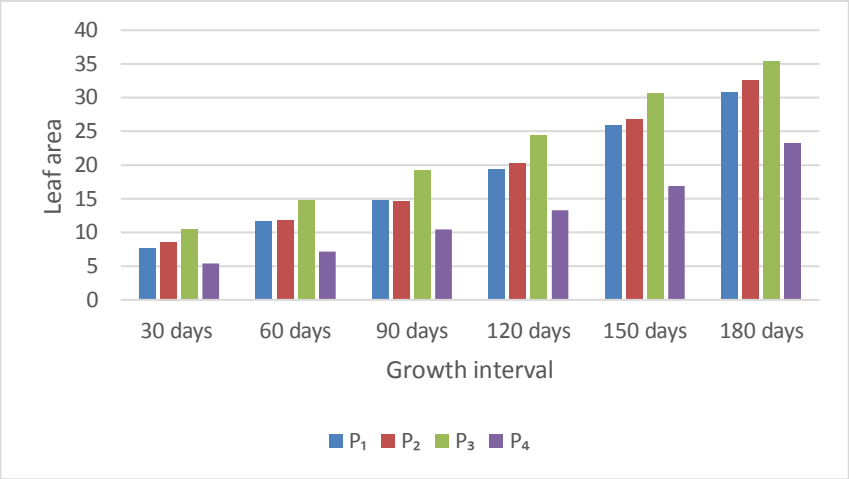


Fig 5. Effect of concentration of cytokinin on leaf area

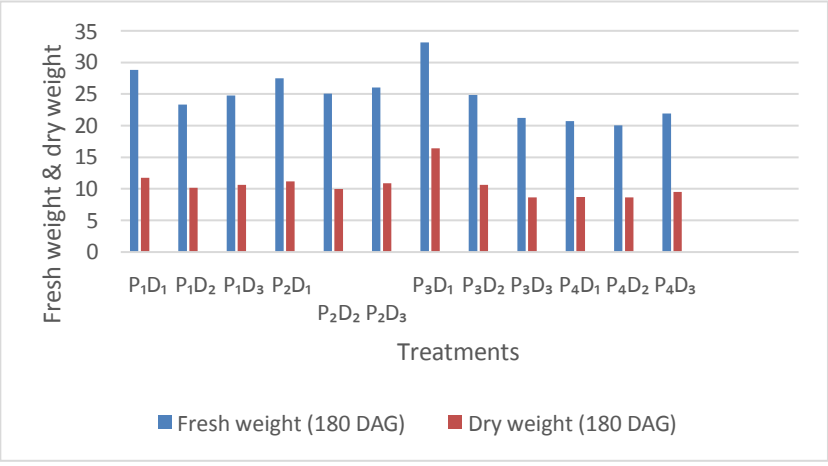


Fig 6. Effect of interactions of concentration of cytokinin and days of application on fresh weight and dry weight

cytokinin at 200ppm with 0^{th} day prior to grafting (P_3D_1) observed as better (41.27) treatment among all other interaction treatments up to 180 DAG. This might be due to the rapid cell division and cell elongation which could be attributed by the application of cytokinin. This was in conformation with findings of Murashige and Skoog(1962); Salisbury and Ross (1992).

5.2.4 Height of graft

It is evident that from 30 DAG to 180 DAG height of graft showed significant variation with concentration of cytokinin and days of cytokinin application individually. Interaction effect of both factors also affected significantly in case of height of graft from 30 DAG to 180 DAG. Height of graft was obtained maximum (34.93) when concentration of 200 ppm (P_3) was applied to the scion till 180 DAG. Through out the growth intervals individual effect of days of cytokinin application, indicated that D_1- 0^{th} day prior to grafting treatment had the higher (34.81) value. Regarding interaction treatments on height of graft data, cytokinin at 200 ppm + 0^{th} day prior to grafting (P_3D_1) was noticed as better (35.70) treatment among all other interaction treatments up to 180 DAG. The significant effect could be due to application of cytokinin with grafts promoted fast graft growth and maximum success rate which might be due to increased callus formation, fast regeneration of phloem, and enhanced nutrient transport to the scions from soil via stocks. This findings were supported by the findings of Autio *et al.*(2014).

5.2.5 Girth of stem (5 cm graft above graft union)

Significant variation in girth of terms of individual effect of concentrations of cytokinin and days of cytokinin application from 30 DAG to 180 DAG. Application of cytokinin at a concentration of 200ppm (P_3) applied to the scion was found to be the more at 30, 90 and 120 DAG. Cytokinin at a concentration of 100ppm (P_1) noticed as better at 60, 150,180 DAG. Considering individual effect of days of cytokinin application, D_1- 0^{th} day prior to grafting treatment was the better treatment (3.06) on girth of stem through out the graft growth intervals. According to interaction

treatments on girth of stem, data indicated that the better (3.38) treatment was the combination of cytokinin at 200 ppm + 0^{th} day prior to grafting (P_3D_1) up to 180 DAG except 30 DAG. This influence might be due to the critical role of cytokinin in the growth of vascular cell during the primary as well as secondary development of vascular bundles. Moreover, the growth and development of cambium tissue was regulated by cytokinin (Nieminen *et al.,* 2008).

5.2.6 Length of leaves

The data pertaining length of leaf had showed variation by individual effect of the concentration of cytokinin and days of cytokinin treatments from 30 DAG to 180 DAG. Interaction effect of both factors had influenced on length of leaf from 30 DAG to 150 DAG. Length of leaves produced maximum (12.06) when application of cytokinin was at a concentration of 200 ppm (P_3) till 180 DAG. Individual effect of days of cytokinin application, illustrated that D_1- 0^{th} day prior to grafting treatment had the maximum (11.80) value on length of leaves. Related to interaction treatments cytokinin at 200 ppm+0^{th} day prior to grafting (P_3D_1) pointed as better (11.82) treatment among all other interaction treatments up to 150 DAG. There was no significant variation among interaction effects at 180 DAG.

5.2.7 Breadth of leaves

The data presented in the Table 17. showed that breadth of leaf was varied with concentration of cytokinin and days of cytokinin application. The combination effect of both also influenced breadth of leaf. Breadth of leaves was maximum (4.00) when application of cytokinin was done at a concentration of 200ppm (P_3) from 30 DAG to 180 DAG. Individual effect of days of cytokinin application, through out the growth intervals (except 30 DAG at which non significance was found) indicated that D_1 - 0^{th} day prior to grafting treatment was found as better (3.83) treatment. D_3 was the inferior treatment. Data regarding interaction treatments on breadth of leaves pointed that combined effect of cytokinin at 200ppm + 0^{th} day prior to grafting (P_3D_1) found to be the better (4.39) treatment among all other interaction treatments up to 180 DAG.

1.1.3 Number of successful grafts

The results on number of sucesful grafts fom 30 to 180 DAG(table 18) reorded significant difference between oncentration of cytokinin. With regard to number of suessful grafts results indicated that from 30 to 180 DAG cytokinin at different concentration had highly influenced on number of successful grafts .

As an individual treatment P_3-(11.66) had the higher effect on number of successful grafts from 30 DAG to 180 DAG. This could be due to the fact that callus makes a pathway for movement of water until formation of vascular connections between the scion and rootstock. Application of cytokinin (Kinetin and BAP) enhanced callus formation which showed success of grafts reported by Hartmann *et al*. (1997). But, interaction effect of concentration of cytokinin and days of application and individual effect of days of application failed to produce significant difference on number of successful grafts from 30 DAG to 180 DAG.

1.1.4 Success percentage

Success percentage of grafts at 90 DAG revealed that concentration of cytokinin at 200 ppm -P_3 (82.22) had higher value which was on par with P_1- (77.77) and P_2-(76.66). The effect of cytokinin (kinetin -250 ppm and BAP -250 ppm

) promoted graft take and showed significant variations in grape which was reported by Kose and Guleryuz (2006) ; Sunitha *et al*. (2016). Here, treatment at control (P_4) level produced minimum (62.21) effect on success percentage. These findings have close conformity with the present study. Days of application and interaction effect of concentration of cytokinin and days of application did not make any significant difference among the results.

1.1.5 Survival percentage

Considering survival percentage which was observed at 180 DAG illustrated that concentration of cytokinin at 200 ppm -P_3 (77.77) showed higher value which was on par with P_1-(71.10) and P_2-(69.99). Concentration of cytokinin at control (P_4) level showed less (52.21) effect on survival percentage. Interaction effect of concentration of cytokinin and days of application and individual effect of days of application did not record any significant difference on survival percentage.

1.1.6 Fresh weight and dry weight

The observation on both fresh weight and dry weight depicted that concentration of cytokinin at 200 ppm (P_3) registered the maximum (26.43 and 11.41 respectively) which was on par with P_2- cytokinin at 150 ppm (26.21 and 10.68 respectively) during similar growth intervals. With regard to days of cytokinin application, D_1-0^{th} day prior to grafting (27.05 and 11.26 respectively) showed highest value which was on par with D_2-5^{th} day prior to grafting (23.34 and 9.87 respectively) and D_3- 10^{th} day prior to grafting (23.47 and 9.93 respectively). Among interaction effects in case of fresh weight and dry weight, P_3D_1- cytokinin at 200 ppm + 0^{th} day prior to grafting (33.19 and 16.39 respectively) recorded the higher effect (Fig.6) and P_4D_2- cytokinin at control+ 5^{th} day prior to grafting (20.07 and 8.64 respectively) showed minimum effect (Fig.6) among all other interaction treatments.

In conclusion, generally the success rate and callus formation differently depended on dose and graft combination. The regeneration of plant cells was varied according to cytokinin concentration in current study. This change might be due to the degree of cell sensitivity towards growth regulators, which depends on plant origin and endogenous levels of growth regulators (Uranbey, 2005). Application of cytokinin (at 100 ppm 150 ppm, 250 ppm) had significantly influenced on the morphological characters as well as other observations of plant graft during growth intervals compared to control treatment in the current study. The control treatment (without cytokinin application) not responded satisfactorily on all graft combinations. These findings were supported by the results of Kose and Guleryuz (2006) in which cytokinin application, except for the 1000 mg/litre concentration, showed higher callusing rate at the grafting point of all graft combinations compared with the untreated control in case of grape vine.

Response of cytokinin on scion prior to grafting (5^{th} and 10^{th} days) was not effectively produced influence on graft during growth intervals. This result was agreement with findings of Yashwanti *et al*.(2017) in which effect of application of plant growth regulators (NAA, IBA and BA) to scion wood at seven days prior to budding showed an inhibitory effect in bael. From the experiment finally we can conclude that application of cytokinin at 200 ppm concentration on the same day of

grafting (T_7 -P_3 D_1) showed higher value in most of the growth parameters on observations like length of scion, number of leaf (24.30), height of graft, leaf area(41.27cm^2),breadth of leaf(30 and 150 DAG), length of leaf(90 to 150 DAG) and girth of stem (90,120,180 DAG). Standardization of effect of cytokinin on graft success in different cultivars of sapota can be considered for further studies as a future line of work.

Summary

6. SUMMARY

The salient findings of the present study entitled, "Refinement of softwood grafting technique in Sapota (*Manilkara zapota* L.)" are summarized in this chapter.

The experimental study was undertaken at college of agriculture Padannakkad Kasaragod during 2019-2021. The first experiment includes three environmental conditions *viz*. open, polyhouse and polytunnel with three cultivars *viz*. Cricket Ball, Pala and Oval and three scion precuring treatments *viz.* defoliation 10 days prior to grafting, defoliation followed by grafting on the same day and grafting without defoliation. Second experiment comprised of different concentration of cytokinin at 100ppm, 150ppm, 200ppm and control levels with different days of application like 0^{th} day, 5^{th} and 10^{th} day prior to grafting. The main objective of first experiment was to know the best method for improving success percent in softwood grafting of sapota cultivars by applying different environmental conditions with different precuring treatments. The aim of second study was to evaluate the effect of cytokinin for improving success of sapota grafting. The experiments were carried out with completely randomized design with factorial concept. First study comprised of twenty seven treatments combinations and second experiment was with twelve treatments combinations.

A close examination to the first experiment indicated that individual effect of environmental conditions on graft success upto final growth stage, grafting under C_3-polytunnel proved to be the better one compared to open and polyhouse conditions for observations *viz.* length of scion (19.28), girth of stem (2.70), number of successful grafts (7.00), success percentage (48.14) , survival percentage (46.66) , leaf area (26.01), length of leaf (9.15), breadth of leaf (3.85), number of leaves (14.79), fresh weight (22.11), dry weight (10.01) and height of graft (33.47) during growth intervals.

Among the individual effect of cultivars on success of grafting indicated that V_1- Cricket Ball noticed higher influence on growth parameters like length of scion (at 60,90,150,180 DAG), leaf area (at 30,60 90 DAG), length of leaf (at 30,60,90 DAG), number of successful grafts (5.22), success percentage (35.92) and survival percentage (34.81). The observations *viz.* girth of stem (2.31), length of leaf (at 90,150 DAG) and

breadth of leaf except 180 DAG (3.30) were significantly influenced by the individual effect of cultivar V_3-Oval.

Regarding the individual effect of scion precuring treatments, defoliation 10 days prior to grafting-S_1 had reported significantly higher values in characters *viz*. number of leaves (13.69), length of scion (18.44), leaf area (22.31), height of graft (32.76), girth of stem (2.59), length of leaf (8.34), breadth of leaf (3.65), fresh weight (17.73), dry weight (7.99), success percentage (42.59) and survival percentage (40.37).

Interaction effect of environmental conditions and cultivars during growth stages of grafts illustrated that C_3 V_3 (Polytunnel+Oval) showed higher on growth parameters like number of leaves (15.30), leaf area (90,150,180 DAG), length of leaf at 90 DAG, 150 DAG, 180 DAG(9.41) and breadth of leaf at 90 DAG, 120 DAG, 150 DAG. C_3V_1(Polytunnel+Cricket Ball) had highest value on height of graft except 30 DAG (34.06), number of successful grafts (8.00), success percentage (54.44), survival percentage (53.33) and dry weight (10.30) of grafts. C_3V_2 (Polytunnel+Pala) had recorded maximum in fresh weight (22.87).

With regard to the interaction effect of cultivars and scion precuring treatments during growth period, V_2S_1 (Pala+10 days prior defoliation) recorded higher value on survival percentage (43.33), fresh weight (19.50) and number of leaves (9.36) (30 DAG to 120 DAG). Interaction effect of V_3S_1 (Oval+10 days prior defoliation) had more value on dry weight (8.92) and height of graft except 90 DAG and180 DAG (31.08).

Considering the interaction effect of environmental conditions and scion precuring treatments during graft growth, C_3S_3 (Polytunnel+ Without defoliation) proved to be best on all growth parameters *viz*. length of scion (20.92), number of successful grafts (11.66), success percentage (77.77), survival percentage (76.66), leaf area (33.72), girth of stem (2.98), length of leaf (10.95), breadth of leaf (4.21), number of leaves (17.78) and height of graft (34.71) from 30 DAG to 180 DAG.

The data showing combined interaction effect of environmental conditions, cultivars and scion precuring up to the final graft growth stage indicated that Cricket

Ball without defoliation of scion kept under polytunnel condition $C_3V_1S_3$ (Polytunnel +Cricket Ball+ Without defoliation) was found to be better treatment combination on all growth parameters *viz.* girth of stem except 30 DAG(3.05),leaf area (35.42), length of leaf except 30 DAG (11.22), breadth of leaf except 60 DAG (4.32), number of leaves except 30 DAG, length of scion except 30 DAG and height of graft (34.75), fresh weight (32.06) and dry weight (15.04). $C_1V_3S_2$(Open+ Oval+ Same day defoliation) was the inferior treatment related to most of the growth parameters like length of scion (16.83), girth of stem (2.32), number of successful grafts (3.00), success percentage (20.00),survival percentage (20.00), leaf area (16.45), length of leaf (7.25), breadth of leaf (3.11), number of leaves (except 120 DAG) and height of graft (31.13). The treatments $C_1V_1S_3$ (Open + Cricket Ball + Without defoliation), $C_1V_2S_3$(Open + Pala + Without defoliation), $C_1V_3S_3$(Open + Oval + Without defoliation), $C_2V_1S_3$ (Polyhouse+ Cricket Ball + Without defoliation), $C_2V_2S_3$ (Polyhouse + Pala + Without defoliation) and $C_2V_2S_3$ (Polyhouse + Pala + Without defoliation) are failed which resulted in dried up grafts.

It is clear from second experiment that, cytokinin application (at 100ppm 150ppm, 250ppm) had significantly influenced on the morphological characters as well as other observations of plant graft during growth stages compared to control treatments. There was no satisfactorily response found in the control treatments (without cytokinin application) of all graft combinations.

Regarding the individual effect of concentration of cytokinin, P_3- cytokinin at 200ppm registered higher value on observations like number of successful grafts (11.50), success percentage (82.22), survival percentage (76.66), length of leaf (12.06), leaf area (35.41), and breadth of leaf. Related to single effect of days of cytokinin application, D_1-0^{th} day prior to grafting had higher value on observations like length of leaf (11.80), number of leaf (22.62), dry weight (11.26), fresh weight (27.05), height of graft, leaf area and girth of stem (3.06), length of scion and breadth of leaf. Days of cytokinin application had no significance on number of successful grafts, success percentage and survival percentage.

The interaction effect of concentration of cytokinin and days of cytokinin application indicated that P_3D_1 (cytokinin at 200ppm+0^{th} day prior to grafting) had

higher value on observations like length of scion, number of leaf (24.30), height of graft, leaf area (41.27 cm^2), breadth of leaf (30 and 150DAG), length of leaf (90 to 150 DAG) and girth of stem (90,120,180 DAG). No significant interaction effect was found in number of successful grafts, success percentage, survival percentage and girth of stem (at 30 DAG). P_4D_3 (control treatment + 10^{th} day prior to grafting) had minimum effect on almost all observations.

Results from the first investigation revealed that grafting of Cricket Ball without defoliation of scion kept under polytunnel condition ($T_{2\ 1}$ -C_3 V_1 S_3) favoured as best treatment which can be recommended in terms of growth parameters *viz.* girth of stem except 30 DAG(3.05), leaf area (35.42), length of leaf except 30 DAG (11.22), breadth of leaf except 60 DAG (4.32), number of leaves except 30 DAG, length of scion except 30 DAG and height of graft (34.75), fresh weight (32.06) and dry weight (15.04). Varietal effect on graft success indicated that cricket Ball had best performance. Establishment of grafts under C_3-polytunnel found to be higher compared to open and polyhouse conditions. Among scion precuring treatments, defoliation 10 days prior to grafting-S_1 provided highest percentage of graft success.

From second experiment, application of cytokinin at 200ppm concentration on the same day of grafting (T_7 -P_3 D_1) found to be better for graft growth. Cytokinin application at 0^{th} day prior to grafting-D_1 was effective. Regarding concentration of cytokinin, application at 200 ppm showed higher value on growth parameters. But, it was on par with P_1 and P_2 in terms of success and survival percentage of grafts. So, economically we can recommend cytokinin application at 100 ppm (lower dose) for graft success.

Future line of work

- There is a need for further investigation on off season production of graft seedlings through modified grafting method
- Application of this modified technique for other fruit crops like mango can also be promoted

- Standardization of effect of cytokinin on success of graft in various cultivars of sapota
- Different combinations of hormones (auxin, cytokinin) can be tried

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Abstract

REFINEMENT OF SOFTWOOD GRAFTING TECHNIQUE IN SAPOTA

(Manilkara zapota* L.*)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

Sapota (*Manilkara zapota* L.) family sapotaceae is one of the fruit trees which is adapted to humid tropical climate and diversified soil conditions. Softwood grafting in sapota has become common among farmers and horticulture nursery sector because it is an easy, as well as cheap method and helps in rapid multiplication of plants with considerable success rate. Generally, Khirni (*Manilkara hexandra* L.) is used as rootstock for grafting in sapota. The investigation entitled "Refinement of softwood grafting technique in sapota (*Manilkara zapota* L.)" was carried out at department of Horticulture, College of Agriculture, Padannakkad, Kasaragod, during 2020-2021.The study was conducted in completely randomized block design with factorial concept.

The first experiment was done with the objective to find out the best practice for enhancing success percent in softwood grafting of sapota varieties under different environmental conditions with different precuring treatments having 27 treatment combinations replicated twice. The factors of first experiment were environmental conditions (open-C_1, polyhouse-C_2 and polytunnel followed by shade net-C_3) with cultivars (Cricket Ball-V_1, Pala-V_2 and Oval-V_3) and scion precuring treatments (defoliation 10 days prior to grafting-S_1 , defoliation followed by grafting on the same day-S_2 and grafting without defoliation-S_3).

Interaction effect of environmental conditions, cultivars and scion precuring up to final stage of growth indicated that $C_3V_1S_3$ (Polytunnel+ Cricket Ball+ Without defoliation) had maximum value with respect to growth parameters *viz.* girth of stem except 30 DAG(3.05),leaf area (35.42), length of leaf except 30 DAG (11.22), breadth of leaf except 60 DAG (4.32), number of leaves except 30 DAG, length of scion except 30 DAG and height of graft (34.75), fresh weight (32.06) and dry weight (15.04). $C_1V_3S_2$ (Open+ Oval+ Same day defoliation) recorded lowest value with respect to growth parameters *viz*. length of scion (16.83 cm), girth of stem (2.32 cm), number of successful grafts (3.00), success percentage (20.00 %), survival percentage (20.00 %), leaf area (16.45cm^2), length of leaf (7.25 cm), breadth of leaf (3.11 cm), number of leaves

(except 120 DAG) and height of graft(31.13 cm).

The second experiment was undertaken to study the effect of cytokinin on success of sapota grafting. Factors are different concentration of cytokinin (P_1 -100 ppm, P_2 -150 ppm, P_3 -200 ppm and P_4 -control) and different days of application (D_1 -0^{th}day, D_2 -5^{th}day and D_3 -10^{th}day prior to grafting). Among the individual effect of cytokinin concentration, P_3- cytokinin at 200ppm was found to be highest in terms of number of successful grafts, success percentage (82.22%), survival percentage (77%), length of leaf(12.06cm), leaf area, breadth of leaf, girth of stem at 30,90 and 120 DAG, length of scion (120,150 and 180 DAG) and number of leaves (except 60 DAG). Considering individual effect of days of cytokinin application, D_1 had the maximum value on observations like length of leaf (11.80cm), number of leaf (22.62), dry weight (11.26g), fresh weight (27.05g), height of graft, leaf area and girth of stem (3.06 cm), length of scion and breadth of leaf. Considering the interaction effect between concentration of cytokinin and days of cytokinin application, P_3D_1 (cytokinin at 200 ppm+ 0^{th} day prior to grafting) proved to be the best treatment combination in terms of observations like length of scion, number of leaf (24.30), height of graft, leaf area (41.27 cm^2), breadth of leaf (30 and 150DAG), length of leaf (90 to 150 DAG) and girth of stem (90,120,180 DAG). P_4D_3 (control treatment+10^{th} day prior to grafting) was found to be lowest in terms of observations like number of leaf (18.80), leaf area (21.27 cm^2) and length of scion (13.40 cm).

The results obtained from present study revealed that grafting of sapota cv. Cricket ball without defoliation of scion and kept under polytunnel condition (T_{21}-C_3 V_1 S_3) as the best treatment which recorded highest graft success and survival percentage. Grafts under C_3-polytunnel found to be better in growth parameters compared to open and polyhouse conditions. Among scion precuring treatments, defoliation 10 days prior to grafting-S_1 provided highest percentage of graft success. Hence, modified grafting technique can be recommended as an ideal approach for sapota propagation during off season also. Application of cytokinin at 200ppm concentration on the same day of grafting (T_7 -P_3 D_1) enhanced graft growth. Regarding concentration of cytokinin, at 200ppm showed higher value which was on par with P_1 and P_2 in terms of success and survival percentage. So, cytokinin application at 100ppm (lower dose) for graft success can be recommend as economically beneficial.

സംക്ഷിപ്തം

സപ്പോട്ടെസൈ കുടുംബത്തിലെ പ്രധാന ഫലവൃക്ഷമായ സപ്പോട്ട വൈവിധ്യമർന്ന മണ്ണിടങ്ങളിലും ആർദ്രതയുള്ള ഊഷ്ണമേഖല കാലാവസ്ഥയിലും വളരാൻ പ്രാപ്തിയുള്ളതാണ്. ഹോർട്ടികൾച്ചർ നഴ്സറികളിലും കർഷകരുടെ ഇടയിലും സപ്പോട്ടയുടെ കായിക പ്രവർധനം മൃദുകാണ്ഡ ഒടിക്കൽ രീതികളിലൂടെയാണ് ഇപ്പോൾ സാധാരണയായി ചെയ്തുവരുന്നത്. ചെലവ് കുറഞ്ഞരീതിയിൽ എളുപ്പത്തിൽ ധാരാളം തൈകളുടെ ഉൽപ്പാദനം ലക്ഷ്യമാക്കിയാണ് ഇത് നടത്തുന്നത്. പൊതുവെ കിർണിയുടെ തൈകളാണ് റൂട്ട്സ്റ്റാക്കായി ഉപയോഗിക്കുന്നത്.

നഴ്സറികളിൽ വിപണനാടിസ്ഥാനത്തിൽ സീസണല്ലാത്ത സമയങ്ങളിലും വളരെ ചുരുങ്ങിയ സമയത്ത് കൂടുതൽ തൈകളുടെ ഉൽപ്പാദനം നടത്തേണ്ടതുണ്ട്. ഇതിനായി മൃദുകാണ്ഡം ഒട്ടിക്കൽ രീതി വഴി ഒരു പരിഷ്ക്കരിച്ച സംവിധാനം പ്രായോഗികമാക്കാൻ വേണ്ടി പടന്നക്കാട് കാർഷികകോളേജിലെ ഫലപുഷ്പവർഗ ശാസ്ത്രവിഭാഗത്തിൽ 2020-2021 കാലയളവിൽ "സപ്പോട്ടയിലെ പരിഷ്ക്കരിച്ച ഒട്ടിക്കൽ മൃദുകാണ്ഡ പരീക്ഷണം" എന്ന തലക്കെട്ടോടെ ഒരു പഠനം നടത്തുകയുണ്ടായി. വിവിധ പരിസ്ഥിതികളിൽ (C_1-തുറസ്സായ സ്ഥലം, C_2-പോളിഹൗസ്, C_3-പോളിടണൽ) പലതരം സപ്പോട്ടയിനങ്ങളിൽ (V_1-ക്രിക്കറ്റ്ബോൾ, V_2-പാലാ, V_3-ഓവൽ), വ്യത്യസ്ത പ്രീക്യൂയറിങ് രീതികൾ (S_1-ഗ്രാഫ്റ്റിങ് 10 ദിനംമുമ്പേ സയോണിന്റെ ഇലപൊഴിക്കൽ, S_2-സയോണിന്റെ ഇലപൊഴിച്ച ദിനം തന്നെ ഗ്രാഫ്റ്റിങ്, S_3-സയോണിന്റ ഇലപൊഴിക്കാതെ ഗ്രാഫ്റ്റിങ്) അവലംബിച്ച് കൊണ്ട് ഗ്രാഫ്റ്റിങ്ങിന്റെ വിജയശതമാനം കൂട്ടുക എന്നതാണ് ഒന്നാമത്തെ പരീക്ഷണം.

പഠനഫലമായി കാണ്ഡത്തിന്റെ ചുറ്റളവ് (3.05), സയോണിന്റെ നീളം (21.36), വിജയിച്ച ഗ്രാഫ്റ്റ് തൈകളുടെ എണ്ണം, വിജയശതമാനം (77.77), അതിജീവന ശതമാനം (76.66), ഇലയുടെ വിസ്തീർണം (35.42), ഇലകളുടെ നീളം (11.22), ഇലകളുടെ വീതി(4.32), ഗ്രാഫ്റ്റിന്റെ ഉയരം(34.75) തുടങ്ങിയ നിരീക്ഷണങ്ങളിലെല്ലാം $C_3V_1S_3$

-പോളിടണലിൽ ക്രിക്കറ്റ്ബാൾ സപ്പോട്ടയിനം സയോണിന്റെ ഇല കളയാതെ ചെയ്ത ഒട്ടിക്കൽ രീതി ഏറ്റവും മികച്ചതായി രേഖപ്പെടുത്തി. എന്നാൽ ഒട്ടുമിക്ക നിരീക്ഷണങ്ങളിലും ഏറ്റവും കുറഞ്ഞ വിജയശതമാനമായാണ് $C_1V_3S_2$-തുറസ്സായസ്ഥലത്ത് ഓവൽ സപ്പോട്ടയിനം സയോണിന്റെ ഇലകൾ ഗ്രാഫ്റ്റിങ് ദിവസം കളഞ്ഞ് കൊണ്ടു ചെയ്യുന്ന രീതികളിലുള്ള ഗ്രാഫ്റ്റുകളിൽ കാണാനിടയായത്. $C_1V_1S_3$, $C_1V_2S_3$, $C_1V_3S_3$, $C_2V_1S_3$, $C_2V_2S_3$, $C_2V_3S_3$ തുടങ്ങിയ രീതികളിൽ വികസിപ്പിച്ച ഗ്രാഫ്റ്റുകൾ പൂർണമായും പരാജയമായിരുന്നു.

സൈറ്റോകൈനിൻ ഹോർമോണിന്റെ പ്രയോഗം സപ്പോട്ട ഗ്രാഫ്റ്റിങ് വിജയശതമാനത്തെ എങ്ങനെ ബാധിക്കുന്നു എന്നത് മനസ്സിലാക്കാനായിരുന്നു രണ്ടാമത്തെ പരീക്ഷണത്തിന്റെ ലക്ഷ്യം. സൈറ്റോകൈനിൻ വിവിധ ഗാഢതയിൽ (P_1-100 ppm, P_2-150 ppm, P_3-200 ppm, കട്രോൾ) വിവിധ ദിവസങ്ങളിൽ (ഗ്രാഫ്റ്റിങ്ങിന് 10 ദിനം മുമ്പേ-D_1, 5 ദിനം മുമ്പേ-D_2, ഗ്രാഫ്റ്റിങ്ങിന്റെ അതെ ദിവസം-D_3) സയോണിൽ പ്രയോഗിക്കലായിരുന്നു പഠനരീതി. പഠനഫലമായി P_3D_1-സൈറ്റോകൈനിൻ 200 ppm ഗാഢതയിൽ ഗ്രാഫ്റ്റിങ്ങിന്റെ അതേ ദിവസം പ്രയോഗിച്ച രീതിയിൽ വികസിപ്പിച്ച ഗ്രാഫ്റ്റുകൾ മികച്ച വിജയശതമാനം കാണിച്ചു. ഇവ ഇലകളുടെ വിസ്തീർണം (41.27), ഇലകളുടെ വീതി (4.37), ഇലകളുടെ നീളം, കാണ്ഡത്തിന്റെ ചുറ്റളവ്, സയോണിന്റെ നീളം,, ഗ്രാഫ്റ്റിന്റെ ഉയരം(35.70) തുടങ്ങിയ നിരീക്ഷണങ്ങളിൽ മികച്ച പ്രകടനം കാഴ്ചവച്ചു. P_4D_3- 10 ദിനം മുമ്പേ സൈറ്റോകൈനിൻ പ്രയോഗം കട്രോൾ ട്രീറ്റ്മെന്റ് രീതിയിൽ വികസിപ്പിച്ച ഗ്രാഫ്റ്റ് തൈകൾ ഏറ്റവും കുറഞ്ഞ വിജയശതമാനം കാണിച്ചു. വിജയിച്ച ഗ്രാഫ്റ്റുകളുടെ എണ്ണം, വിജയശതമാനം, അതിജീവന ശതമാനം, കാണ്ഡത്തിന്റെ ചുറ്റളവ് തുടങ്ങിയ നിരീക്ഷണങ്ങളിൽ ട്രീറ്റ്മന്റുകൾക്ക് പ്രാധാന്യമുള്ള സ്വാധീനം ചെലുത്താൻ കഴിഞ്ഞില്ല.

Annexure

APPENDIX I

Date	Temperature		Relative humidity		Rainfall (mm)
	Max	Min	I	II	
1-11-2020	31	24	88	61	0
2-11-2020	34	22	60	77	0
3-11-2020	34.5	24	84	73	0
4-11-2020	34.5	22.5	84	73	0
5-11-2020	34	21.5	88	100	0
6-11-2020	34.5	24	92	89	0
7-11-2020	32	23.5	92	92	0
8-11-2020	33.5	25	85	67	0
9-11-2020	34	23	92	57	0
10-11-2020	34.5	21.5	91	49	0
11-11-2020	34.5	17.5	70	45	0
12-11-2020	34.5	18	77	85	0
13-11-2020	34.5	20	96	74	0
14-11-2020	34.5	24	96	62	11
15-11-2020	33	23.5	92	56	0
16-11-2020	33	25	96	76	0
17-11-2020	35	23	92	73	16
18-11-2020	35	22	85	86	7.2
19-11-2020	34	24	84	64	0
20-11-2020	33	22	88	73	0
21-11-2020	34	23	96	61	0
22-11-2020	33	20.5	83	48	0
23-11-2020	33	18	82	48	0
24-11-2020	33	18.5	91	48	0
25-11-2020	34	18	83	56	0
26-11-2020	34	23.5	84	64	0
27-11-2020	34	23	76	56	0
28-11-2020	34	21.5	91	58	0
29-11-2020	34	23	88	57	0
30-11-2020	33	23	88	62	0
1-12-2020	34	22.5	91	46	0
2-12-2020	34.5	20	87	47	0
3-12-2020	32	21	91	63	0
4-12-2020	32	24	92	69	0
5-12-2020	32	22.5	91	59	0
6-12-2020	34	23.5	93	59	0
7-12-2020	34	24.8	94	73	0
8-12-2020	34	23.5	91	64	1.1
9-12-2020	33	24	92	58	0
10-12-2020	33	23.5	96	61	0.2
11-12-2020	33	24	92	61	0
12-12-2020	34	24.5	92	72	0

Date	Temperature		Relative Humidity		Rainfall (mm)
	Max	Min	I	II	
13-12-2020	34	22	96	67	92
14-12-2020	34	23.5	88	67	0
15-12-2020	34	22	96	67	0
16-12-2020	34	22	91	67	0
17-12-2020	34	23.5	96	73	0
18-12-2020	34	23.5	96	61	0
19-12-2020	33	20.5	96	68	0
20-12-2020	34	20.8	91	48	0
21-12-2020	33	19	96	76	0
22-12-2020	32	20	91	76	0
23-12-2020	32	20	91	54	0
24-12-2020	34	23.5	91	61	0
25-12-2020	34	23.5	92	61	0
26-12-2020	34	22.5	96	61	0
27-12-2020	32	20	83	83	0
28-12-2020	32	19	92	64	0
29-12-2020	32	21.5	91	56	0
30-12-2020	32	21.5	100	73	0
31-12-2020	33	22.5	91	67	0
01-01-2021	32	23	91	61	0
02-01-2021	34	19.5	91	50	0
03-01-2021	33	24	91	57	0
04-01-2021	33	19	83	61	0
05-01-2021	33	23	96	67	22
06-01-2021	32	23	93	61	0
07-01-2021	32	22	96	79	20
08-01-2021	32	23	96	72	36.6
09-01-2021	32	23	91	70	1.4
10-01-2021	32	23	96	67	0
11-01-2021	32	23	91	66	0
12-01-2021	32	22.5	96	60	0
13-01-2021	33	22	91	59	0
14-01-2021	32	22	96	66	0
15-01-2021	31	24	88	57	0
16-01-2021	32	23	96	65	0
17-01-2021	32	23	96	67	0
18-01-2021	32	23	91	67	0
19-01-2021	31	22.5	96	61	0
20-01-2021	31	21	93	61	0
21-01-2021	34	21	96	61	0
22-01-2021	34	22	96	55	0
23-01-2021	34	24	88	61	0
24-01-2021	34	24	96	64	0
25-01-2021	34	22	96	67	0
26-01-2021	33	20.5	95	56	0
27-01-2021	33	20	91	66	0
28-01-2021	33	20	91	50	0
29-01-2021	32	20.5	91	50	0
30-01-2021	32	20.8	91	50	0

31-01-2021	32	23	92	57	0
01-02-2021	35	20	91	51	0
02-02-2021	33	20	91	59	0
03-02-2021	33	20	94	50	0
04-02-2021	33	22	91	58	0
05-02-2021	32	22.6	95	56	0
06-02-2021	33	21.3	94	64	0
07-02-2021	33	20.9	94	46	0
08-02-2021	33	18	95	32	0
09-02-2021	33	18.2	90	37	0
10-02-2021	33	18.4	91	58	0
11-02-2021	33	19.5	91	61	0
12-02-2021	33	21	93	61	0
13-02-2021	33	22	91	58	0
14-02-2021	33	22	91	64	0
15-02-2021	33	22.3	96	58	0
16-02-2021	33	22	96	58	0
17-02-2021	32	21.5	96	51	0
18-02-2021	33	21	91	53	0
19-02-2021	33	22.5	87	56	0
20-02-2021	33	21	64	61	0
21-02-2021	33	21	91	58	5.8
22-02-2021	33	21.5	87	61	6
23-02-2021	33	21	91	59	0
24-02-2021	34	23	91	56	0
25-02-2021	33	19	92	58	0
26-02-2021	33	22.5	92	64	0
27-02-2021	33	25	92	67	0
28-02-2021	32	25	92	67	0
01-03-2021	33	25	92	64	0
02-03-2021	33	23.5	97	59	0
03-03-2021	34	23	91	67	0
04-03-2021	34	22	92	68	0
05-03-2021	34	21	91	61	0
06-03-2021	37	22.5	87	64	0
07-03-2021	36	23	84	62	0
08-03-2021	35	24.3	93	62	0
09-03-2021	35	24	92	55	0
10-03-2021	34	24.5	88	59	0
11-03-2021	34	24	91	56	0
12-03-2021	34	23.5	89	61	0
13-03-2021	34	24	92	67	0
14-03-2021	34.5	27	85	57	0
15-03-2021	34	24.5	92	59	0
16-03-2021	34	24.5	88	62	0
17-03-2021	34	24	88	62	0
18-03-2021	34	24.5	88	62	0
19-03-2021	34.5	25	88	77	0
20-03-2021	34	25	88	67	0
21-03-2021	34.2	22.8	89	59	1.8
22-03-2021	34	22.8	90	57	0
23-03-2021	34	24.7	88	61	0
24-03-2021	34.5	25.5	85	62	0

25-03-2021	34.7	25.5	88	71	0
26-03-2021	33.8	25.5	90	71	0
27-03-2021	34.6	25.5	88	68	0
28-03-2021	34.5	26	81	68	0
29-03-2021	34.5	26	85	65	0
30-03-2021	34.5	25	51	65	0
31-03-2021	34.5	25	88	62	0
01-04-2021	34	27	88	62	0
02-04-2021	35	24	92	62	0
03-04-2021	33.5	24	92	68	0
04-04-2021	34	24	84	57	0
05-04-2021	35	24	92	73	0
06-04-2021	34	23.5	81	66	0
07-04-2021	34.5	22	75	79	0
08-04-2021	34	28	85	79	0
09-04-2021	34	25	88	63	0
10-04-2021	35	25	88	63	0
11-04-2021	35	28	78	57	0
12-04-2021	35	25	84	57	0
13-04-2021	34.5	24	96	60	0
14-04-2021	34.5	26	78	57	0
15-04-2021	34.5	26	85	64	0
16-04-2021	33	25	85	74	0
17-04-2021	34	24.5	84	55	0
18-04-2021	34.5	26	85	65	0
19-04-2021	34	24.5	100	68	52
20-04-2021	34	24.5	92	81	0
21-04-2021	35	26	92	62	0
22-04-2021	33.5	24.5	92	62	5.6
23-04-2021	32.5	26	88	62	0.2
24-04-2021	33	25.5	92	57	0
25-04-2021	34	26	88	68	0
26-04-2021	35.5	25.7	92	68	0
27-04-2021	34.9	26.5	81	62	0
28-04-2021	34.4	26.2	96	65	0
29-04-2021	35.2	26.2	82	60	0
30-04-2021	35	24.5	88	62	6.2