STANDARDISATION OF GRAFTING IN BITTER GOURD

(*Momordica charantia* L.)

by

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(2017- 12-033)

THESIS

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

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KERALA, INDIA

2019

DECLARATION

I, hereby declare that this thesis entitled **"STANDARDISATION OF GRAFTING IN BITTER GOURD (*Momordica charantia* L.)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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ACKNOWLEDGEMENT

I am greatful to ***God Almighty*** *for all the blessings showered upon me throughout my life and for the perseverance bestowed upon me especially during the course of my research work.*

The foremost person to be thanked is ***M. Rafeekher.*** *Assistant Professor & Head, Department of Pomology and Floriculture, College of Agriculture, Vellayani and Chairman of my advisory committee for his sustained and valuable guidance, constructive suggestions, unfailing patience, friendly approach, constant support and encouragement during the conduct of this research work and preparation of the thesis. I gratefully remember his knowledge and wisdom, which nurtured this research project in the right direction without which fulfillment of this endeavor would not have been possible.*

I also owe my deep sense of gratitude and sincere thanks to ***Dr. I. Sreelathakumary*** *Professor and Head, Department of Vegetable Science, College of Agriculture, Vellayani and member of my advisory committee for her support, untiring interest, suggestions and invaluable guidance throughout the study.*

I take this opportunity to express my heartful gratitude to ***Dr. S. Sarada****, Assistant Professor, Department of Vegetable Science, College of Agriculture, Vellayani and member of my advisory committee for her suggestions, valuable guidance, and accommodating with all facilities for the successful completion of my research work.*

I express my sincere gratitude to ***Dr. Naveen Leno****, Assistant Professor, Department of Soil Science and Agricultural Chemistry and member of my advisory committee for his expert suggestions and critical evaluation of the thesis.*

I accord my sincere thanks to ***O. N. Shruthy****, Assistant Professor, Department of Vegetable Science for her valuable support and guidance throughout my research work. I sincerely thank the facilities rendered by the* ***library, College of Agriculture,*** *Vellayani.*

I also express my gratitude to all the non-teaching staff members and labourers of Department of Vegetable Science for their whole-hearted cooperation and timely assistance.

I do not have words to express my love, affection and gratitude to my seniors ***Merin, Gayathri, Aruna, Pooja, Feba, Airina and Vijeth.*** *Without their help, suggestions and support this thesis would not have been realized. I wish to express my thanks to my batchmates* ***Saranya, Thasni and Sivakumar****, who always provided me good encouragement during difficulties. A special thanks goes to my juniors* ***Arya, Sherin, Maneesha*** *and* ***Yogananda*** *for their help and co-operation during the course of my work. I owe a big thanks to all my seniors* ***Afna, Gayathri, Aparna, Asoontha, Geethu, Pooja, Nidheesh, Naisanth, Tejasree and Ajil*** *for their valuable help and loving wishes for completing the study.*

The encouragement rendered by my friends at various stages of this investigation was invaluable and I thank ***Sappa, Meena, Palli, Fidaa, Aruni, Ponni, S. mol, Liz, Susu, Ammu, Aachi, PV, Susan, Anju, Kavu, Keerthana, Bindu, Deepthi, Lechu, Vava, PR, Nattu, Achu, Rehana, Deepa, Geethu, UA, Pahee, Aura, Rose, Dippu, Jamma, AS, Sarga, Mekha, Sabi, Janu, Anna, Induja, Indu, Kinni, Nivya chechi, Pooja, Vipin, Sruthy, Reni, Lekshmi, Nammu, Safna, Anku, Panchu, Dundu, MR, Jyothi, Anju chechi, Christy, Sayu, Sree, Hari, Dhan, Kubaan, Mappu, Ajmal, Amal, Melvin, Alan, Eldho chettan, Ahal, John, Kichu, Suresh, Ramesha, Anand, Govind and Manu*** *for their love, support and company.*

This thesis would be incomplete if I do not reckon the sacrifices, love, affection and support of my family members, father ***Mr. Vasudevan****, mother* ***Smt. Vilasini,*** *sister* ***Unnimaya*** *and brother* ***Manu*** *for their constant prayers, affection, moral support, personal sacrifice and sincere encouragement throughout the period of my studies.*

Aiswarya V Dev K P

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LIST OF ABBREVIATIONS

B:C	Benefit : Cost
CCC	Chlorocholine chloride
cm	Centimeter
et al.	And others
F_1	First filial generation
Fig.	Figure
FYM	Farm yard manure
g	Gram
g^{-1}	Per gram
GA	Gibberlic acid
i.e.,	That is
KAU	Kerala Agricultural University
Kg	Kilo gram
Kg plant^{-1}	Kilogram per plant
L	Litre
m	Meter
M/F	Male/ Female
mg	milligram
MRL	Maximum residue level
No.	Number
NS	Nonsignificant
Plant^{-1}	Per plant
ppm	Parts per million
SEm	Standard error of mean
t ha^{-1}	Tonnes per hectare
viz.	Namely

LIST OF SYMBOLS

%	Per cent
@	at the rate of
>	greater than
/	per

Introduction

1. INTRODUCTION

India has been recognized as a unique land for the cultivation of a variety of horticultural crops in the world. Apart from nutritional benefits, the production of vegetables improves the economy of the country as these are very good sources of income and employment. The contribution of vegetables remains highest (59 – 61%) in horticultural crop production over the last five years.

Bitter gourd (*Momordica charantia* L.) is one of the most important cucurbitaceous vegetables originated in India and widely grown throughout Asia, East Africa and South America. It is considered as an esteemed vegetable due to its high nutritive value, particularly iron and ascorbic acid. It is relatively a cheaper source of proteins, minerals, fats and vitamins. The fruit contains 2 mg of iron, 88 mg of vitamin C, 2.1 g of protein, 20 mg of calcium, 55 mg of phosphorus and 210 IU of vitamin A in 100 g of edible portion.

Bitter gourd (*Momordica charantia* L.), vernacularly known as 'Pavakka' or 'Kayppaykka', is one of the most popular and remunerative vegetable crops traditionally grown in Kerala.The fruits are used as tonic, purgative, stomachic, carminative, antihelminthic, anti-inflammatory, febrifuge, stimulant, thermogenic, antidiabetic *etc*. The antidiabetic properties of the crop have been studied extensively and a hypoglycaemic principle called 'Cheratin' has been isolated. The bitter principle in bitter gourd is 'momordicine', an alkaloid which is different from 'cucurbitacin' present in other genera of cucurbits.

. The crop is cultivated over an area of 97,000 ha in India with an annual production of 11,37,000 tonnes and the productivity of 11.72 t ha^{-1} (NHB, 2018) Karnataka, Maharashtra, Tamil Nadu and Kerala are the major bitter gourd growing states in India. In Kerala, area under bitter gourd is 2,880 ha with a production of 42,250 tonnes (NHB, 2016). Short duration of crop and premium market price make it remunerative for vegetable growers in Kerala. Preethi is a high yielding bitter gourd variety grown widely in Kerala with an average yield of 25-30 t/ha.

Commercial cultivation of bitter gourd is affected by biotic stresses like mosaic disease, fusarium wilt and root-knot nematode as well as abiotic stress like drought. Hence, this crop requires attention from breeders and production system specialists. One of the possible approaches for achieving the targeted production is to enhance biotic and abiotic stress tolerance, yield potential and quality with appropriate technology for cultivation.

Organic farming is recognised globally as a priority area in view of the growing concerns on environmental pollution due to increased awareness about the consequences of the indiscriminate use of agro-chemicals. Demand for safe and healthy food has been increasing day by day. The ill effects of plant protection chemicals on the flora, fauna, humans and environment as a whole are the major concerns. According to a survey report status of pesticide residues in India (April, 2014 - March, 2015) samples of capsicum, green chilli and cauliflower were found having high number of above MRL residues followed by samples of cabbage, eggplant, tomato, okra, bitter gourd, cucumber, green peas and coriander leaves (GOI, 2015). Though the use of chemical inputs in agriculture is unavoidable to contain dreaded pests and meet the growing demand for food in a populous nation like India, there are opportunities in selected high value fruit and vegetable crops where organic production can be encouraged to meet the domestic and export demand for fresh fruit and vegetables.

Disease control in organic systems relies on use of resistant varieties, but selection is limited and varieties are often not the ones best suited for the region. Grafting with resistant rootstock is a relatively simple and organically-acceptable technique for disease management and is used throughout Asia, Europe and Canada with excellent results.

First attempt in raising grafted vegetable plants was done in Japan and Korea in late 1920s by grafting watermelon onto bottle gourd for imparting resistance to fusarium wilt. Apart from managing soil borne insects and pathogens, grafted plants may offer resistance to abiotic stresses, increase yield, extend harvest period, modify sex expression and improve fruit quality.

The rootstock which possess vigorous root systems than the scion are used for improving quality, yield and tolerance against biotic and abiotic stresses.The widely used rootstocks for bitter gourd are *Luffa* sp., fig leaf gourd (*Cucurbita ficifolia*) and pumpkin (*Cucurbita moschata*) showing good vigour and compatability. Survival rate of grafted plants depends on stock-scion compatibility and post graft management.

The major challenge faced in cucurbit grafting is the lodging of rootstock seedlings before grafting. In order to tackle this problem, growth regulators can be used to prevent the seedling height. Alar and cycocel are widely used growth retardants in seedling plants.

Commercial use of vegetable grafting is a relatively recent technology for farmers in Kerala and the information on the effect of various rootstocks on the performance of cucurbits in Kerala is meagre.

In this background, the present study was undertaken with the following objectives:

- Identify suitable rootstocks
- Identify suitable growth regulator and standardize its concentration to prevent lodging in rootstock seedlings before grafting.
- Standardise grafting techniques
- Evaluate growth and performance of grafts of bitter gourd.

Review of literature

2. REVIEW OF LITERATURE

Bitter gourd, *Momordica charantia* L., is a major cucurbit vegetable grown in tropical countries. The crop is originated in Asia, which is believed to be either India or China. The fruits are tonic, purgative, antihelminthic, stomachic carminative, anti-inflammatory, febrifuge, thermogenic, stimulant and antidiabetic (Longman, 1995). Immature fruit is a chief source of vitamin C, vitamin A, iron and phosphorus (Behera, 2005). Tender fruits and vine tips are highly nutritious. In Asia and some African countries, bitter gourd is consumed as a vegetable and also used as folk medicine for controlling Type 2 diabetes. Bitter gourd is cultivated in vast areas due to high demand in market (Tamilselvi, 2013).

Commercial cultivation bitter gourd is affected by biotic stresses like mosaic disease, fusarium wilt and root-knot nematode as well as abiotic stress like drought (Lin *et al*., 1998). Davis *et al*. (2008) reported that environmental stresses represent the most restraining conditions for horticultural productivity. Moreover, continuous cropping increases salinity, pest incidence and diseases like fusarium wilt.

2.1. VEGETABLE GRAFTING

Grafting is a method of acclimatizing plants to impede environmental stresses. Commercial cultivars are grafted onto vigorous rootstocks (Lee and Oda, 2003). Rivard and Louws (2008) stated that grafting is an environment-friendly method in integrated and organic crop management systems with a sustainable relevance. Some researchers found grafting to be an alternate tool over methyl bromide due to its disease resistance and reduced expenditure over soil fumigant (Miguel, 2004). Lee *et al*. (2010) reported that area of grafted solanaceous and cucubitaceous vegetables has raised enormously in recently since there was a great expansion in grafting motives. Flores *et al*. (2010) reported that currently grafting is regarded as a possible quick choice against the time consuming breeding methodology focused at increasing tolerance against environmental-stress in vegetables. Pradeep *et al.* (2017) reported that grafting has evolved as a method with ambient potential to boost the productivity of modern vegetable cultivation, and increases resistance against stress conditions.

According to Tamilselvi (2013), grafting in vegetables is a tool to check soil borne diseases and nematodes in field as well as in greenhouse. It increased crop duration and fruit quality as a result of more vigorous plants with improved tolerance to abiotic stresses such as soil salinity, alkalinity, low and high soil temperatures and also limited the negative impact of toxicity due to heavy metal. It enhanced the water and nutrient translocation, photosynthesis and increased water use efficiency.

2.2. GRAFTING IN CUCURBITS

Cucurbit grafting started in late 1920s in watermelon with *Cucurbita moschata* as rootstock. Reports by Tateishi (1927) and Sato and Takamatsu (1930) revealed that several studies on grafting were done at Kyushu University, Japan. Tateishi (1931) reported that water melon grafted onto pumpkin rootstocks was a well-known technique at that time. The selection of grafting technique between species could be associated to climatic conditions and vigor of rootstock. By adopting the same grafting technique, the survival rate may be varied according to both rootstock as well as scion (Traka-Mavrona, *et al.,* 2000).

2.3. CUCURBIT ROOTSTOCKS

Rootstocks have a drastic impact on the scion since they can enhance plant vigor, improve disease resistance, improve tolerance against salinity and improve translocation of soil nutrients and water. Additionally, studies revealed that RNA, protein and small molecules produce signal transduction which can translocate from the rootstock to the scion directly affecting the scion physiology (Davis *et al*., 2008).

Matsumoto (1931) found pumpkin (*Cucurbita moschata*), squash (*Cucurbita maxima*), fig leaf gourd (*Cucurbita ficifolia*), cucumber (*Cucumis sativus*) and bottle gourd (*Lagenaria siceraria*) highly compatible with cantaloupe melon (*Cucumis melo* L. var. *cantalupensis*) and also reported that *Cucurbita* spp. and melon (*Cucumis melo*) are compatible with cucumber (*Cucumis sativus*). Imazu (1949) noted that pumpkin, bottle gourd, wax gourd, and luffa [*Luffa cylindrica* (L.) M. Roem.] were also compatible with cucumber and recommended *Cucurbita moschata* as rootstock to watermelon, since it confers resistance to fusarium wilt and improves plant vigor. However, bottle gourd and wax gourd became preferred rootstocks for watermelon grafting on account of their resistance to fusarium wilt, their high compatibility with watermelon, and the highly stable growth of the plants after grafting. (Davis *et al.*, 2008).

Lin *et al.* (1998) reported that *Luffa* sp. serves a best root stock for bitter gourd, by increasing yield through controlling *Fusarium* wilt. Cohen *et al.* (2000) stated that root systems of the rootstocks and the vigour of the scion helps in crop development even in the existence of this pathogen. Pumpkin, fig leaf gourd and luffa (*Luffa spp.*) are rootstocks commonly used for bitter gourd (Lin, 2004). Sun *et al.* (2009) reported that bottle gourd (*Lagenaria siceraria*), pumpkin (*Cucurbita moschata)*, interspecific pumpkin hybrids (*C. maxima* x *C. moschata*) and fig leaf gourd (*C. ficifolia*) are the commonly used rootstocks for bitter gourd.

2.4. ROOTSTOCK VIGOUR

Tamilselvi (2013) observed considerably lesser number of days for germination of *Cucurbita pepo* (3.60) which was on par with *Luffa cylindrica* (3.90 days). Mang (2014) observed that germination of local cultivar of bottle gourd initiated 2 days after sowing and completed the next day. Among the six rootstocks studied by Akhila and George (2017) lesser number of days (3.42 days) was required for germination of oriental pickling melon compared to other cucurbit rootstocks. Bitter gourd took the maximum number of days (6.42 days) for germination which was comparable with smooth gourd (6.00 days).

Punithaveni *et al.* (2014) stated that pumpkin and winter squash took the least number of days (4.38 days and 4.54 days respectively) for germination and african horned cucumber rootstocks recorded the maximum number days (15.54 days) for germination within the seven different rootstocks studied.

Tamilselvi (2013) reported that the two bitter gourd scions, Palee F_1 showed significantly lesser number of days (4.40 days) for germination while CO 1 scion took 7.80 days. Mang Uap (2014) stated that the germination period of *Momordica. charantia* L. was 5 to 8 days after sowing. According to Akhila and George (2017) bitter gourd scion variety Preethi took about 6.47 days to germinate.

Punithaveni *et al.* (2014) reported that fig leaf gourd took 10.55 days to attain graftable size followed by pumpkin (11.52 days) due to wider hypocotyls while sponge gourd took maximum number of days (14.56 days) due to thinner hypocotyls. Ash gourd, bottle gourd, sponge gourd and pumpkin took 37, 25, 23 and 22 days respectively to attain graftable size (Tamilselvi and Pugalendhi, 2017). Akhila and George (2017) stated that standards for the scions and rootstocks to attain graftable size were based on width of scion and rootstock and their aptness for grafting method. In the findings, pumpkin (9.99 days) and bottle gourd (10.43 days) took least number of days to attain graftable size due to higher hypocotyl diameter (7.17 mm and 9.93 mm respectively).

2.5. EFFECT OF GROWTH REGULATORS ON PLANT VIGOUR

Plant growth regulators (PGRs) are chemicals that are designed to affect growth and development of plants They are applied for specific purposes to affect specific plant response (Latimer 1992).

A synthetic organic chemical compound which have an intense effect on growth retardation and other physiological functions in plant by stopping hormone biosynthesis without causing considerable changes in growth are called growth retardants or growth suppressors (Audus, 1972).

Cathey (1964) described cycocel and daminozide (Alar; B-Nine SP) as economically viable and efficient growth regulating substances. According to Latimer (1992), typical growth retardants are B-Nine, Cycocel, A-Rest, Bonzi, and Sumagic for potted plants.

Bora and Sarma (2004) stated that Cycocel is a growth retardant widely used for dwarfing plant parts. Application of CCC significantly reduced the plant height in gladiolus compared to other growth regulator treatment (Khan, 2015).

Vegetative growth is negatively affected by the application of cycocel (Stoddart, 1964). Saikia *et al.* (1981) observed significant reduction in the length of potato plants with the gradual increase in cycocel concentration. Abdul *et al.* (1983) observed a remarkable reduction in plant height of okra by applying CCC (250-1000 ppm) at the 3 to 4 leaf stage. Shinde *et al.* (1994) reported that CCC (1000 ppm) was successful in reducing growth upto 14.72 per cent over control in water melon. Davies (1995) found that plants treated with cycocel had shorter internode length by blocked biosynthesis of GA but improved photosynthesis. Bora and Sarma (2006) revealed that shoot growth was reduced in pea when plant was treated with cycocel. The application of CCC to plants represses the growth of stems, leaves and stolons, but improves photosynthetic capacity by increasing leaf chlorophyll content (Wanga *et al.*, 2009). Usha *et al.* (2009) found that foliar application of CCC at 300 ppm showed decreased shoot length in rhubarb.

Dicks (1980) observed reduction of plant height along with increased radial expansion of the stem in vegetables. Grzyb (1982) stated that CCC increased diameter of shoot in brompton plum. Ugur and Kavak (2007) observed no significant difference between the stem diameters treatments in tomato seedlings treated with P333 and CCC. Sachs and Kofranek (1963) observed that retardants phosfon D, amo- 1618 and cycocel caused transverse division in cell and expansion of sub-apical tissues in chrysanthemum, which resulted in thicker stems than normal.

Working on few growth retardants, Maiko and Musat (1977) stated that B-9 or alar stops biosynthesis of GA as well as its activity. Pinto *et al.* (2005) stated that daminozide @ 2.50 g L^{-1} shortened the plant height in Zinnia.

Yadav and Sreenath (1975) observed that alar applied to cow pea plant as foliar spray significantly lowered plant height but increased the leaf number and yield. Godfrey and Ndoleh (1978) reported that alar concentration above 4000 ppm reduced plant height in okra. The growth retardant daminozide enhanced tuberisation and reduced the height of potato plants (McIntosh and Bateman, 1979). Uprety and Yadava (1985) observed height reduction, increased branch number and dry matter content along with yield as a result of treatment of alar in *Cyamopsis tetragonoloba*. Latimer (1992) stated that tomato transplants showed reduced stem length upto 41 per cent. when sprayed with daminozide 2500 ppm. Alar reduced the growth as well as carbohydrate content in cow pea under saline condition (Siddique and Krishnamurthy, 1995).

Ferree and Stembridge (1967) observed reduced shoot diameters when treated with alar. Brittain (1967) reported that in alar treated peanut plants, pith parenchyma cells had higher diameter than untreated plants.

2.5. GRAFTING METHOD

Xiao (2004) stated that hole insertion grafting is the common method of cucurbit grafting in China with high survival rates, and lesser prevalence of soil borne disease.

Yoshioka (2001) found that one cotyledon grafting is used when rootstocks are thin such as oriental melons, cucumbers and watermelon.

There was no significant difference among the rootstocks on graft success in tongue approach grafting (Akhila and George, 2017).

Ishibashi (1959) stated that the cleft graft was the pioneer grafting method used for watermelon and cucumber. Lin (2004) reported that cleft grafting is preferred in bitter gourd. Davis *et al.* (2008) observed that cleft grafting is used when rootstocks possess wide hypocotyls. Bitter gourd grafted on *Luffa* sp. through wedge grafting had been a trend in China and Taiwan against *Fusarium* wilt (Chung and Chin, 1996) with a remarkable increase in yield (Palada and Chang, 2003).

Hang *et al.* (2005) suggested that the hole insertion and one cotyledon grafting methods are mostly preferred when scion and rootstock possess hollow hypocotyls, He also found that cleft grafting, one cotyledon grafting and hole insertion grafting methods reduces the chance of adventitious roots of scion that may catch soil borne diseases when strikes to ground. Sun *et al.* (2009) suggested the tongue approach, hole insertion and cleft grafting as the most commonly used grafting methods in bitter gourd.

2.6. GRAFT COMPATIBILITY

The success of grafting depends on various factors such as size of scion and rootstock, cultural condition, method of grafting, tissue and structural differences, biochemical and physiological characteristics, growth stage of rootstock and scion, phytohormone and environment. (Davis et al., 2008)

Tamil selvi (2013) studied on eight cucurbit rootstocks for grafting bitter gourd and pumpkin *(Cucurbita moschata)* took the least number of days for graft union on Palee F_1 and CO 1 scions (5.03 and 6.06 days respectvely). Punithaveni *et al.* (2014) stated that bottle gourd rootstock took minimum number of days for graft union in cucumber scions *viz.*, NS 408 (6.70 days) and Green Long (6.75 days).

Tateishi (1927) reported that irrespective method of grafting, the graft union occurred around 10th day. Dhivya (2014) stated that grafting tomato hybrid CO 3 on *S. torvum* recorded the minimum days for graft union (9.10) and maximum percentage of success (90.67 %) with cleft grafting. Punithaveni *et al* (2014) stated that 'Green long'cucumber grafted on bottle gourd took minimum number of days (6.75) for graft union and recorded maximum percentage of success (85%) with hole insertion grafting.

Reyes (1990) noticed that bitter gourd when grafted onto sponge gourd showed higher survival (87 %) than bitter gourd grafted onto bottle gourd (21 %). Grafting bitter gourd scion on *Luffa* sp. rootstock recorded high compatibility with 81.5 per cent survival (Lee, 1994; Chen *et al.*, 1998).

Mang (2014) reported that bottle gourd showed the highest graft compatibility as a rootstock for cucurbits. Punithaveni *et al.* (2014) reported that among the rootstocks used for grafting in cucumber, bottle gourd rootstock gave the highest graft success percentage compared to others. Tamilselvi and Pugalendi (2017) observed that the bitter gourd grafted onto pumpkin (*Cucurbita moschata*) recorded highest success (89.05 %) followed by sponge gourd (*Luffa cylindrica*) and the least success was reported for fig leaf gourd *(Cucurbita ficifolia).* According to Akhila and George (2017), best rootstock was smooth gourd in terms of graft success (80%) followed by pumpkin, bottle gourd, ash gourd, oriental pickling melon and self rootstock.

Temperini *et al.* (2013) revealed that grafting technique affect the rate of survival and splice grafting recorded 78 per cent of graft success than cleft grafting which recorded 73 per cent. Hole insertion grafting method gave the highest success per cent than side grafting when grafted onto bottle gourd rootstock (Punithaveni *et al.*, 2014). In the study conducted by Akhila and George (2017) bitter gourd scion (var. Preethi) was grafted onto six cucurbit rootstocks such as ash gourd, smooth gourd, bottle gourd, oriental pickling melon, pumpkin and bitter gourd itself through wedge grafting and tongue approach grafting and revealed that wedge grafting was adjudged as the best compared to tongue approach grafting in terms of graft success (67% and 15.17% respectively) .

2.7. EFFECT OF GRAFTING ON GROWTH PARAMETERS

Salam *et al.* (2002) and Mohamed *et al.* (2012) reported that watermelon grafts were more vigourous than self grafted and possessed more central stem diameter. There was significant difference in diameter of rootstock hypocotyls at the time grafting and 30 days after grafting. At the time of grafting, bottle gourd had a diameter of 9.93mm and 18.7mm at 30 days after grafting. Scion hypocotyl diameter at grafting and 30 days after grafting did not differ significantly. Noor *et al.* (2019) observed that cucumber plants grafted with bottle gourd rootstock through splice grafting developed a significantly thick plant stem (0.19 cm, 0.18 cm) in 2017 and 2018 respectively.

Akhila and George (2017) reported cent per cent survival rate for non grafted bitter gourd and the least for self grafts. Noor *et al.* (2019) conducted an experiment by grafting cucumber (*Cucumis sativus* L.) cv. Kalaam F_1 and Syngenta onto four local cucurbitaceous rootstocks namely ridge gourd, bitter gourd, pumpkin, bottle gourd using splice grafting, single cotyledon, tongue approach and hole insertion grafting techniques along with self-rooted hybrid cucumber. Bottle gourd rootstocks were found highly compatible with cucumber cv. Kalaam F_1 scion and resulted in maximum plant survival percentage (95%).

Tamilselvi (2013) observed that on 30th day after transplanting, survival percentage was more for bitter gourd grafted onto pumpkin rootstock (81.58 %) and then sponge gourd (71.72 %). Less survival percentage was obtained in fig leaf gourd (40.29 %) and bottle gourd (42.86) when used as rootstocks.

Plant height, leaf number per vine and stem diameter were increased when melon grafted on commercial hybrids of squash 'Xiuli', 'Nanzhen No 3', 'Nanzhen No 4' and 'Quannengtiejia' rootstocks compared to those of ungrafted melon plants (Bie *et al.*, 2010). Salam *et al.* (2002) and Mohamed *et al.* (2012) reported that watermelon grafts recorded 32 per cent more central vine length than non-grafted ones.

Alan *et al.* (2007) stated that the main stem length was also affected by grafting. Control plants had shorter main stem length of 112 cm compared to grafted plants. Similarly, Shahidul *et al.* (2013) observed an increase in main vine length in watermelon grafts compared to non-grafts.

Tamilselvi and Pugalendi (2017) revealed that among the four graft combinations, bitter gourd hybrid Palee F_1 grafted on pumpkin recorded the highest vine length of 844.26 cm. Noor *et al.* (2019) reported that when cucumber (*Cucumis sativus* L.) cv. Kalaam F_1 grafted onto four cucurbit rootstocks in 2017 and 2018, the bottle gourd rootstock had highest shoot length in tongue grafting method (13.50 cm, 13.30cm), splice grafting (12.20 cm, 12.10 cm) respectively and one cotyledon grafting (11.34 cm, 11.28 cm) after first 15 days of grafting.

Akhila and George (2017) observed maximum vine length for non grafted bitter gourd while the least vine length was observed for oriental pickling melon (5.86 m and 4.74m) respectively.

More number of lateral vines are produced by grafted plants compared to non grafted plants (nine/plant and four/plant) respectively (Alan *et al.,* 2007). Tamil selvi and Pugalendi (2017) revealed that bitter gourd variety Paale F1 grafted on pumpkin showed maximum number of primary branches (12.97) followed by sponge gourd rootstock (11.01).

Alan *et al.* (2007) reported that root length was higher (76.33 cm) for watermelon cultivar grafted on C/RS-148. Tamilselvi (2013) revealed that maximum root length was showed by african horned cucumber (16.46 cm) followed by pumpkin *(Cucurbita moschata)* (15.70 cm) and the minimum length was shown by zucchini squash.

According to Alan *et al.* (2007) root dry weight was significantly affected by grafting and watermelon grafted on C/RS-841 and C/Z-148 showed the highest root dry weight and the control showed the least dry weight. According to Tamilselvi (2013), African horned cucumber recorded the highest root fresh weight of 1.81 g and then pumpkin (1.07 g). Ash gourd showed the least root weight of 0.22 g. The same trend followed in root dry weight too. The highest root dry weight (0.21 g) was shown by african horned cucumber and then pumpkin (0.16 g) and the least root dry weight of 0.02 g was shown by ash gourd.

2.8. EFFECT OF GRAFTING ON YIELD PARAMETERS

Reyes (1990) observed early occurrence of female flower in bitter gourd grafted on sponge gourd compared to non grafted plants. Chouka and Jebari (1999) observed early flowering in watermelon grafted on 'RS841', 'Shintoza' and bottle gourd rootstocks. Hamed *et al.* (2012) stated that lesser number of days was taken for female flower appearance in watermelon grafted onto bottle gourd compared to non grafted controls. Tamilselvi (2013) noticed that bitter gourd scion Palee F_1 grafted on pumpkin *(Cucurbita moschata)* rootstock took the least number of days (66.02 days) for first male flower appearance. However, bitter gourd scion CO 1 grafted on sponge gourd *(Luffa cylindrica)* took maximum days (79.07 days) for the same character. The result also revealed that the male flowers appeared earlier in control Palee F_1 and CO 1 than grafted plants.

Hamed *et al.* (2012) reported that in watermelon grafts, a late flowering of about one week was observed, which in turn resulted in an equal postponement in fruit maturity. Noor *et al.* (2019) stated that when cucumber grafted on four cucurbit rootstocks *viz.*, ridge gourd, bitter gourd, pumpkin and bottle gourd, flowering started at 33rd day in bottle gourd, luffa and bitter gourd while pumpkin started flowering on 34th day in splice grafting technique. Hole insertion grafting method took maximum number for flowering. The non-grafted cucumber cv. Kalaam F_1 showed flowers 60 days after sowing.

Reyes (1990) observed that bitter gourd grafted on *Luffa* sp. as well as bottle gourd produced the female flower at earlier nodes. Tamilselvi and Pugalendi (2017) stated that node at which the female flower occur is an important biometric character to measure earliness in cucurbits and revealed that bitter gourd variety Paale F_1 grafted on pumpkin produced female flowers at earlier nodes (25.80) while the scion CO 1 grafted on sponge gourd *(Luffa cylindrica)* rootstock was late to produce the first female flower.

Tamilselvi and Pugalendi (2017) stated that grafted bitter gourd tend to produce higher female and lower male flowers compared to non-grafted plants.

Satoh (1996) stated that sex expression and flowering pattern are regulated by phytohormones. The graft combination may alter amounts of phytohormones produced and hence modify the sex expression in plants Sex ratio is narrowed in grafted water melon compared to non grafts (Shahidul *et al.,* 2013). Tamilselvi and Pugalendi (2017) stated that narrow sex ratio was a desirable trait in cucurbits. Bitter gourd hybrid Palee F_1 grafted on pumpkin showed lower sex ratio (17.89) than that of non grafts.

2.4.4. Days to First Harvest

In the grafted brinjal plants, Uttara x *S. torvum* recorded 79.67 days to reach harvestable maturity (Rahman *et al.,* 2002 a, 2002 b). Rashid *et al.* (2004) reported that tomato grafted on *Solanum torvum* took more days (115 days) to attain maturity than control tomato plants (98 days).

Tamilselvi (2013) stated that bitter gourd hybrid Palee F_1 grafted on pumpkin (*Cucurbita moschata*) rootstock persisted for 194.12 days and bitter gourd variety CO 1 grafted on sponge gourd (*Luffa cylindrica*) rootstock persisted for 144.75 days.

Salam *et al.* (2002) revealed that grafted watermelon plants showed 3.5 times more yield due to superior fruit size, more number of fruits per plant and enhanced plant survival percentage than control plants. Sherly (2010) stated that COBH 2 (Coimbatore Brinjal Hybrid 2) grafted onto *Solanum torvum* gave maximum fruit per plant when compared to others.

Cucumber grafted on pumpkin rootstocks had an increase of 27 per cent marketable fruit per plant than control (Seong *et al.*, 2003). The fruit number was higher (2.6 fruits) in watermelon grafted on bottle gourd rootstocks by splice grafting than tongue-approach technique (1.8 fruits) and minimum (1.0 fruit) in watermelon grafted on watermelon (Hamed *et al.,* 2012).

'Kamel' rootstock of melon contributed the maximum yield with two scions *viz.,* Yuma and Gallium substantiating that rootstock influenced the yield in grafts than non grafts (Zijlstra *et al.*, 1994). Ruiz *et al.* (1997) observed that melon grafted on *C. maxima* gave higher yield compared to non grafted plants. From the three rootstocks viz., *C. maxima*, *C. moschata and C. maxima* x *C. moschata* used for grafting in cucumber, the rootstock *C. maxima* x *C. moschata* recorded maximum yield (Vakalounakis, 1999).

Ruiz and Romero (1999) stated that *Cucumis melo* grafted on *Cucurbita maxima* x *Cucurbita moschata* rootstock gave maximum yield (11.40 kg /vine) than non grafts (5.07 kg / vine). Nisini *et al.* (2002) observed that grafted plants showed higher yield (3.10 kg / m^2) than control plant which ultimately led to a significant change in marketable yield among non grafted and grafted muskmelon plants. Besri (2005) reported that the yield increase of grafted melon and watermelon was 44 and 84 per cent respectively when compared to their non grafted plants.

Alan *et al.* (2007) revealed that fruit yield was influenced by grafting since 18.95 kg fruits per vine was obtained for grafted plants as compared to non grafts (8.98 kg fruits/vine). Rouphael *et al.* (2008) observed that cucumber grafted on commercial cucurbitaceous rootstocks even under high copper concentration recorded higher yield (8.4 kg/vine) than non grafted cucumber plant.

Huang *et al.* (2009) noticed that melon cultivar grafted on hybrid rootstocks *(C. maxima* x *C. moschata)* displayed higher fruit yield compared to ungrafted ones under saline condition. Hua *et al.* (2011) observed an improved yield upto 63.2 per cent in bitter gourd grafts than control plants.

Hamed *et al.* (2012) described that watermelon grafted onto bottle gourd rootstock showed 13.60 kg per vine by splice grafting and 11.42 kg per vine by tongue approach grafting confirming that bottle gourd rootstock was the best for grafting watermelon. Kroggel and Kubota (2017) reported that seedless watermelon grafted on hybrid squash gave twice the yield of non-grafted watermelon plants, without altering the fruit quality.

2.9. EFFECT OF GRAFTING ON FRUIT QUALITY PARAMETERS

Yamasaki *et al.* (1994) reported that diameter was higher (24.0 cm) when watermelon plants were grafted on bottle gourd than non grafted plants (18.5 cm). Studies on watermelon grafting showed that the fruit diameter was higher for grafted ones than control (Salam *et al.,* 2002; Miguel *et al.,* 2004). Tamilselvi (2013) revealed that the higher fruit girth was obtained for Palee F_1 grafted on pumpkin (15.56 cm) and the least fruit girth for Palee F_1 grafted on fig leaf gourd (11.22 cm).

Cucumber cultivars 'Jinyu No.1' and 'Jinchun No.4' were grafted on rootstock fig leaf gourd (*C. ficifolia*) for investigating fruit development and quality by Zhong and Bie (2007) and reported that grafting considerably increased the fruit length by 23.7% and 30.2%, respectively. Tamilselvi (2013) stated that bitter gourd scion Palee F_1 grafted onto pumpkin gave the maximum fruit length of 26.56 cm and bitter gourd scion CO 1 grafted on *Momordica charantia* var *muricata* rootstock recorded the least fruit length of 11.54 cm and within the two scions, CO 1 recorded the maximum fruit length of 22.68 cm.

Bie *et al.* (2010) reported that melon grafted on squash hybrids 'Xiuli', 'Nanzhen No 3', 'Nanzhen No 4' and 'Quannengtiejia' rootstocks showed higher flesh thickness compared to ungrafted plants. Bitter gourd scion Palee F_1 grafted onto pumpkin rootstock showed thicker flesh (0.83 cm) while the least thickness was obtained fig leaf gourd rootstock (Tamilselvi, 2013).

Yamasaki *et al.* (1994) reported that fruit weight of watermelon grafted on bottle gourd was higher (7.40 kg) when compared to non grafted plants. Ruiz and Romero (1999) noticed that when *Cucumis melo* grafted onto *Cucurbita maxima* x *C. moschata* hybrids, fruit weight of grafted plants was twice the fruit weight of controls.

Nisini *et al.* (2002) reported that grafted muskmelon showed higher fruit weight (1.39 kg) than non grafted plants. Alan *et al.* (2007) reported that the fruit weight (5.43 kg) was highest for grafted watermelon compared to control (4.08 kg). Ramirez *et al.* (2009) reported that triploid watermelon (Tri-X 313) grafted onto hybrid rootstocks of *Cucurbita maxima* x *Cucurbita moschata* ('RS841'and 'Shintosa Camelforce') considerably improved the fruit weight.

Camacho *et al.* (2011) observed that average fruit weight was considerably influenced by grafting. Hamed *et al.* (2012) reported higher fruit weight (7.00 kg) in watermelon grafted onto bottle gourd rootstock by tongue approach grafting method compared to non grafted watermelons (4.20 kg).

Zhu *et al.* (2006) reported that grafting can increase ascorbic acid content of fruits. Zhong and Bie (2007) stated that with the fruit development, fruit ascorbic acid, free amino acid and soluble protein content. In contrast, Savvas *et al.* (2011) stated that method of grafting and choice of rootstock had no influence on any quality characteristics when commercial tomato hybrid was grafted on three new commercial tomato rootstocks namely 'Beaufort', 'He-Man', and 'Resistar'. In the twelve graft combinations studied by the Tamilselvi (2013), the scion Palee F1 grafted on pumpkin rootstock showed more ascorbic acid content (106.37 mg / 100 g) than CO 1 grafted onto fig leaf gourd *(Cucurbita ficifolia)* (45.16 mg /100 g). Noor *et al.* (2019) found cucumber cv. Kalaam F_1 fruit produced from grafted plants while using bottle gourd as rootstock higher ascorbic acid content while pumpkin showed the least.

Muramatsu (1981) stated that cucumber showed increased firmness and shortening of fruits due to grafting. However, Robinson and Decker-Walters (1997) suggested that different rootstocks affected quality of grafted cucumber such as fruit shape, skin smoothness, firmness, skin and flesh colour and texture, soluble solids content and rind thickness. Hoyos (2001) stated that grafting had no effect on the quality, taste, size and shape of the fruit.

Materials and Methods

3. MATERIALS AND METHODS

The study 'Standardisation of grafting in bitter gourd (*Momordica charantia* L.)' was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani during 2017-2019. This study has been carried out under two parts:

PART-I	Standardisation of grafting in bitter gourd
PART-II	Evaluation of grafted bitter gourd for growth, yield and quality

3.1 EXPERIMENTAL SITE

The experimental site was located at 8.5^0 30' North latitude and 76.9^0 54' East longitude, at an altitude of 29 m above mean sea level. Predominant soil type of the experimental site was red loam of Vellayani series, texturally classified as sandy clay loam.

3.2. EXPERIMENTAL MATERIALS

Bittergourd (*Momordica charantia* L.) variety Preethi was used as the scion. Sponge gourd (*Luffa cylindrica*) variety Gujarat Junagadh Sponge Gourd-2 (GJSG-2), pumpkin (*Cucurbita moschata*) variety Ambili, bottle gourd (*Lagenaria siceraria*) variety Arka Bahar and bitter gourd (*Momordica charantia* L) variety Preethi were selected as rootstocks and used for grafting (Table 1). Two growth regulators *viz*., alar and cycocel were used to control height of rootstocks. The materials for operations were razor blade, grafting clips and mist chamber. The mist chamber

Table 1. Details of scion and rootstocks used for the study

Sl No.	Common name	Scientific name	Variety
Scion			
1.	Bittergourd	*Momordica charantia*	Preethi
Rootstocks			
1.	Sponge gourd	*Luffa cylindrica*	Gujarat Junagadh Sponge Gourd-2(GJSG-2)
2.	Pumpkin	*Cucurbita moschata*	Ambili
3.	Bottle gourd	*Lagenaria siceraria*	Arka Bahar
4.	Bittergourd	*Momordica charantia*	Preethi

consists of two layers viz., inside made up of high density polyethylene (HDPE) and outside made up of shade net. The relative humidity between 85 and 95 per cent and the temperature between 35°C and 40°C were maintained by bottom cooling with water sprinkled twice a day.

3.3 EXPERIMENTAL METHODS

PART-I: Standardisation of grafting in bittergourd

Bitter gourd scion (Preethi) and four rootstocks (sponge gourd, pumpkin, bottle gourd, bitter gourd) were raised in protrays. Growth regulators were used for control of seedling height of rootstock and grafting was done as separate experiments. The experiments were laid out in Completely Randomized Design (CRD) with three replications. The details of experiments and treatments are given in Table 2.

3.3.1. Raising of Rootstock and Scion

Seeds of rootstocks and scion were sown in 50 cell protrays. The protrays holding the seeds were maintained in the nursery with all necessary care.

3.3.2. Maintenance of Rootstock and Scion

The seeds of cucurbitaceous rootstocks and bitter gourd scions sown in the protrays were watered as required. After germination of seeds, the protrays were kept under partial shade to protect the seedlings from direct solar radiation. Number of days for germination and number of days to attain graftable size in scion and rootstocks were recorded.

3.3.3. Application of Growth Regulators

Two growth regulators *viz.*, alar and cycocel at two different concentrations *viz.*,10 ppm and 50 ppm each were used to prevent the lodging of rootstock along with distilled water as control. Growth regulators were sprayed at cotyledonary leaf stage. The height and diameter of the rootstock hypocotyls were noted.

3.3.4. Methods of Grafting

The experiment was conducted in completely randomized design (CRD) with three replications. A total of twenty-five grafts were maintained per treatment for each replication. The methods of grafting employed were hole insertion grafting, one cotyledon grafting and cleft grafting. The details of treatments is given in Table 2. Grafting was performed in 10-14 days old seedlings.

The procedure of one cotyledon grafting is demonstrated in plate 1. In hole insertion grafting, rootstock seedlings with one small true leaf, and scion seedlings with one or two true leaves were used. The true leaf, the apical meristem (undifferentiated cells), and the axillary buds from the top most growing point of the rootstock plant was removed with a pointed probe. A hole was created in the top of the rootstock where the tissue had been removed with a tooth pick. The scion was cut below the cotyledons at a 45° angle on both sides to form a wedge and inserted into the hole created in the rootstock.

The procedure of one cotyledon grafting is demonstrated in plate 2. Rootstock seedlings should have atleast one true leaf and scion seedlings should have one or two true leaves. Cut the rootstock at a 45° angle so one cotyledon remains and one is removed. Cut the scion at a 45° angle below the cotyledons where its diameter matches that of the rootstock. Bring the two cut stem surfaces together, and hold them in place with a grafting clip.

The procedure of wedge grafting is demonstrated in plate 3. Growing point of rootstock was removed below the cotyledons and a cleft was made for inserting scion. The scion hypocotyl was cut at both sides and a wedge was made. The prepared scion

Table 2. Details of treatments in experiments

Treatments	Treatment details
T_1	Hole insertion grafting and Distilled water (control)
T_2	Hole insertion grafting and Alar @ 10 mgL^{-1}
T_3	Hole insertion grafting and Alar @ 50 mgL^{-1}
T_4	Hole insertion grafting and Cycocel @ 10mgL^{-1}
T_5	Hole insertion grafting and Cycocel @ 50 mgL^{-1}
T_6	One cotyledon grafting and Distilled water (control)
T_7	One cotyledon grafting grafting and Alar @ 10 mgL^{-1}
T_8	One cotyledon grafting and Alar @ 50 mgL^{-1}
T_9	One cotyledon grafting and Cycocel @ 10mgL^{-1}
T_{10}	One cotyledon grafting and Cycocel @ 50 mgL^{-1}
T_{11}	Cleft grafting and Distilled water (control)
T_{12}	Cleft grafting and Alar @ 10 mgL^{-1}
T_{13}	Cleft grafting and Alar @ 50 mgL^{-1}
T_{14}	Cleft grafting and Cycocel @ 10mgL^{-1}
T_{15}	Cleft grafting and Cycocel @ 50 mgL^{-1}

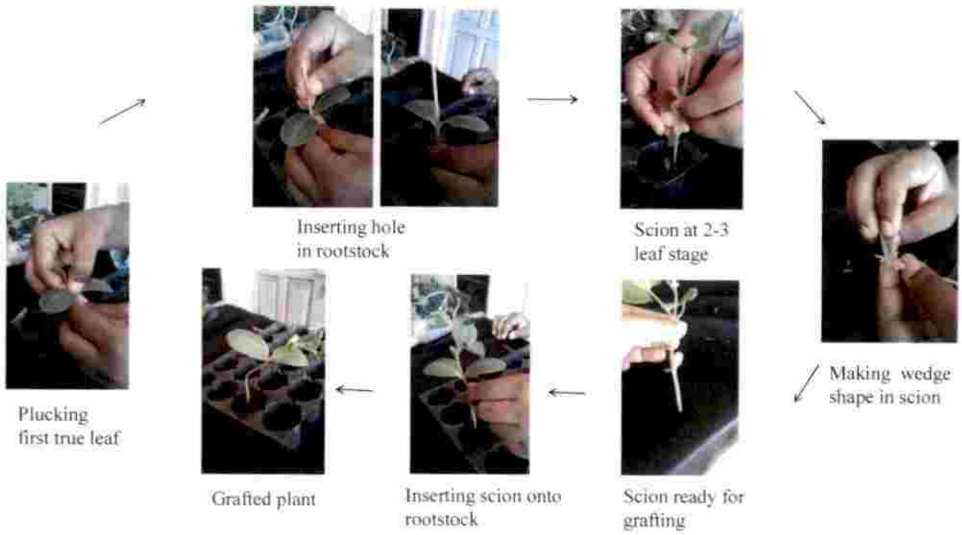

Plate 1. Steps in hole insertion grafting

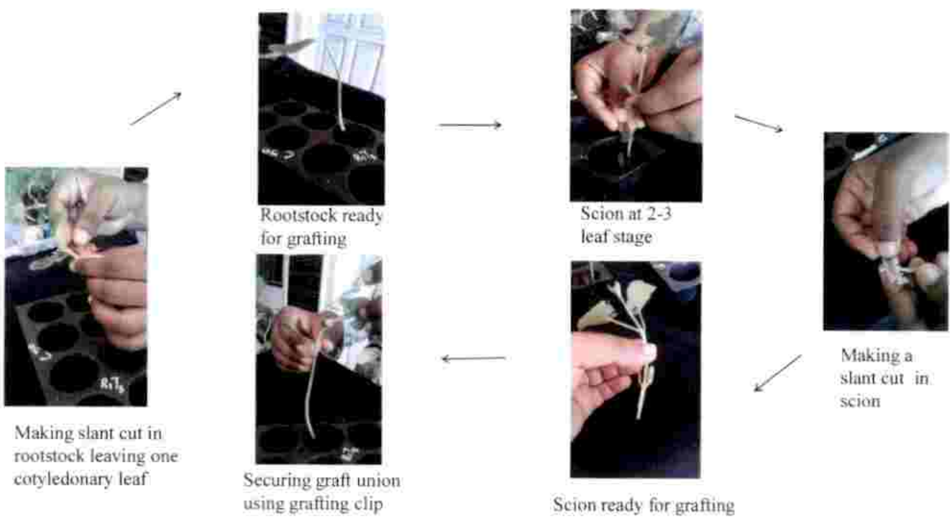

Plate 2. Steps in one cotyledon grafting

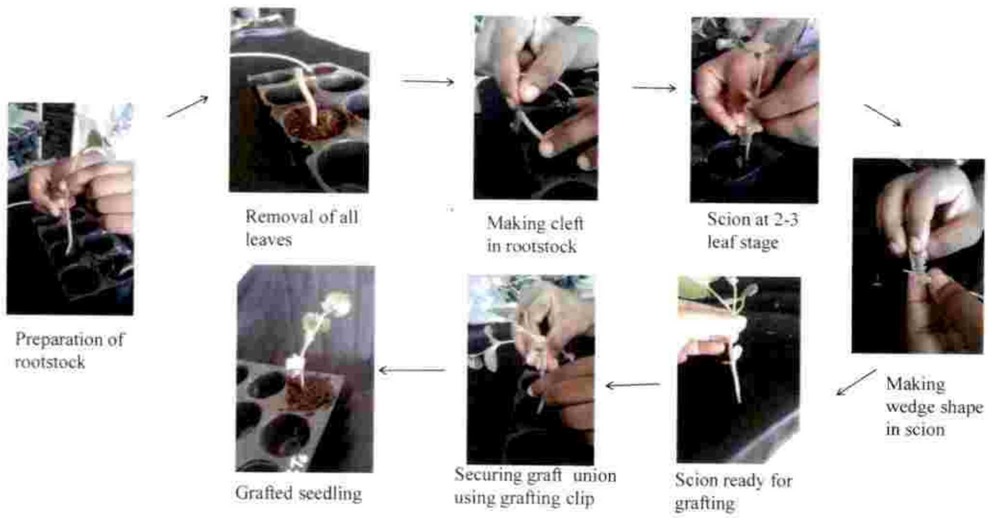

Plate 3. Steps in cleft grafting

was inserted into the cleft made in rootstock. The rootstock and scion hypocotyls were fixed using grafting clip.

The grafted seedlings were kept in the mist chamber for seven days at > 95 per cent relative humidity, 25-30 °C temperature and darkness. The grafting clips were removed after seven days. The number of days for graft union was noted.

3.3.5. Observations for standardisation of grafting in bitter gourd

Periodically observations were recorded on following parameters:

3.3.5.1. Days taken for germination of stock

The number of days taken from sowing till completion of germination was noted.

3.3.5.2. Days taken for germination of scion

The number of days taken from sowing till completion of germination was noted.

3.3.5.3. Days taken to attain graftable size

The number of days taken from sowing to the time when fully opened first true leaf appeared was noted.

3.3.5.4. Height of rootstock at grafting (cm)

Height of rootstock hypocotyls were recorded using scale and twine on the day of grafting.

3.3.5.5. Diameter of rootstock at grafting (mm)

Diameter of rootstock hypocotyls were recorded using vernier caliper on the day of grafting.

3.3.5.6. Days taken for graft union

The number of days taken from sowing to the time when new flush of leaves appeared was noted.

3.3.5.7. Percentage success (%)

Grafting success was recorded 12 days after grafting (DAG). Grafting success was calculated for each graft combination. Partial or complete failure of union coupled with scion wilting was considered as unsuccessful.

The percentage of success was recorded by the formula:

$$\text{Per cent graft success} = \frac{\text{Number of successful grafts}}{\text{Total number of plants grafted}} \times 100$$

PART-II: Evaluation of grafted bitter gourd for growth, yield and quality.

The treatments with highest percentage of success in each experiments of Part-1 were transplanted to the main field 12 days after grafting along with non-grafted control (C) (Table 3). Cultivation practices are followed as per the package of practices recommendations crops (KAU, 2016). The field was ploughed thoroughly to get a fine tilth. During final land preparation, the entire experimental plot was laid out (Fig.1.).

Table 3. Details of different graft combinations and non-grafted plants evaluated in Part-II.

Treatment	Treatment details		
	Rootstock	**Method of grafting**	**Growth regulator and concentration**
T_1	Sponge gourd	Hole insertion grafting	Cycocel @ 50 ppm
T_2	Pumpkin	One cotyledon grafting	Alar @ 10 ppm
T_3	Bottle gourd	One cotyledon grafting	Distilled water
T_4	Bitter gourd	Hole insertion grafting	Cycocel @ 50 ppm
T_5	Non-grafted bitter gourd		

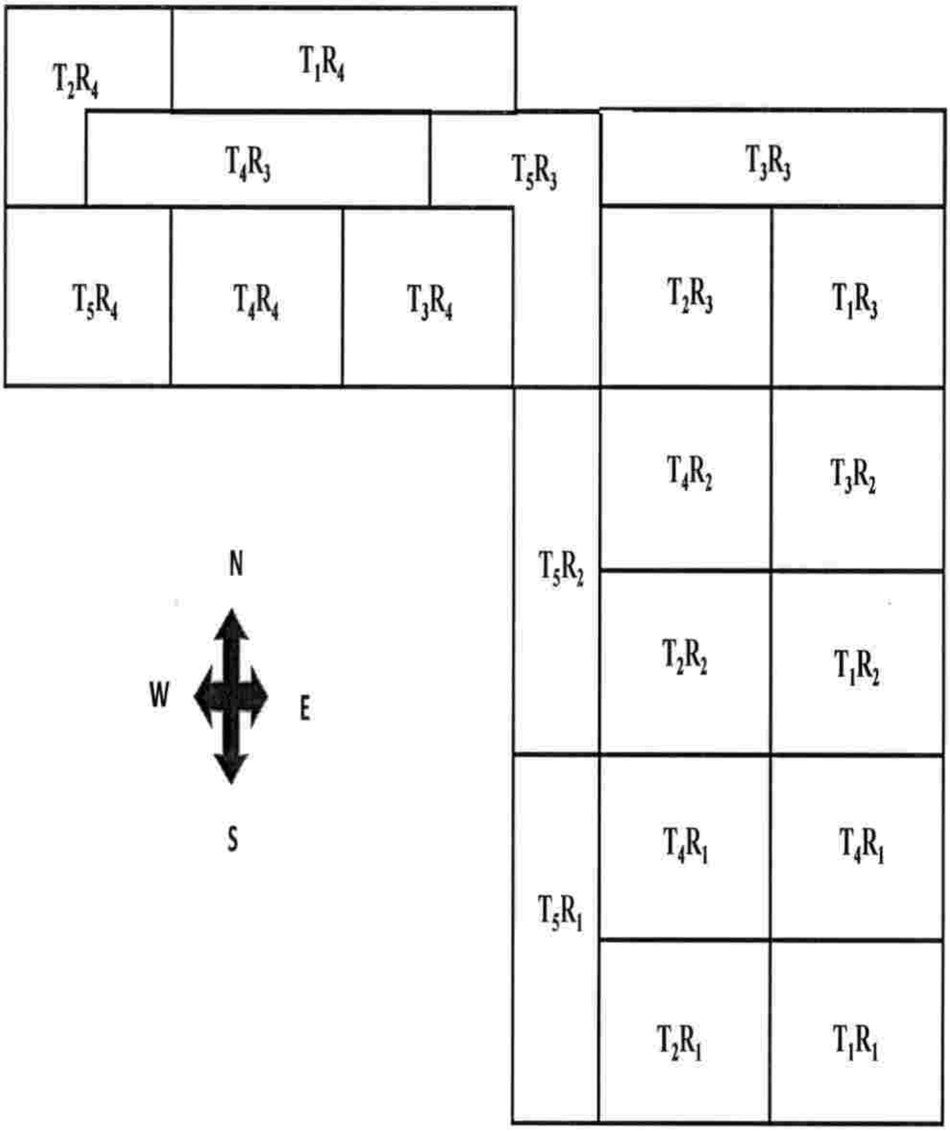

Fig.1. Layout of experimental plot

Pits of 60 cm diameter and 30-45 cm depth at a spacing of 2 x 2 m were taken. Grafts were transplanted to the main field keeping three grafts per pit. The graft union was kept above the soil while planting to prevent the development of adventitious roots from the scion that penetrate the soil. Well rotten FYM and fertilizers were mixed with topsoil in the pit. FYM @ 20-25 t ha^{-1} as basal dose along with half dose of N (35 kg) and full doses of P_2O_5 (25 kg) and K_2O (25 kg) were applied. The remaining dose of N (35 kg) was applied in several split doses at fortnightly intervals. During the initial stages of growth, the field was irrigated at 3-4 days interval and alternate days during flowering or fruiting. Stakes and pandals were erected when the plants start vining. Weeding and raking of the soil at the time of fertilizer application were done (KAU, 2016).

3.3.6. Layout and Design of Part-II.

The field experiment was laid out in Randomized Block Design (RBD) with four replications. Each replication consisted of four pits with three plants in each pit (Plate 4).

3.3.7. Observations for evaluation of grafted bitter gourd for growth, yield and quality.

3.3.7.1. Growth parameters

3.3.7.1.1. Diameter of rootstock hypocotyls (mm) [at fortnightly intervals]

Diameter of the rootstock hypocotyls was taken in five randomly selected plants using vernier caliper at fortnightly intervals and expressed in millimeters.

3.3.7.1.2. Diameter of scion hypocotyls (mm) [at fortnightly interval]

Diameter of the rootstock hypocotyls was taken in five randomly selected plants using vernier caliper at fortnightly intervals and expressed in millimeters.

Plate 4. Bitter gourd grafts planted in main field

3.3.7.1.3. Establishment of grafts (%)

Number of plants established out of number grafts planted in the main field for each treatment was computed.

3.3.7.1.4. Vine length (cm)

At final harvest, the length of plants were measured from first node to tip of the main stem in five randomly selected plants using tapes and expressed in meter.

3.3.7.1.5. Internodal length (cm)

At the end of the crop, average length between first ten nodes were measured using twine and scale in five selected plants and expressed in centimeter.

3.3.7.1.6. Branches / plant

The primary branches arising from the main stem alone were counted at the time of final harvest in five plants of each replication.

3.3.7.1.7. Length of primary root (cm)

Length of primary root was meausured using scale and twine and recorded in centimeters at final harvest.

3.3.7.1.8. Root volume (cm^3)

Root volume was measured by actual volume displacement, in which the volume of root was equated to the volume of water displaced when root were submerged in a vessel of water and expressed in (cm^3).

3.3.7.1.9. Root weight (g)

Root dry weight of five randomly selected plants was recorded after drying the roots in a hot air oven at 60°C until the weight remained constant on subsequent weighing and the mean is expressed in grams.

3.3.7.2. Yield parameters

3.3.7.2.1. Days to first male flower

The number of days taken for the production of first male flower was counted from the date of sowing and expressed in days.

3.3.7.2.2. Days to first female flower

The number of days taken for the production of first female flower was counted from the date of sowing and expressed in days.

3.3.7.2.3. Node number of first male flower

The node number where the production of first male flower occurred was recorded.

3.3.7.2.4. Node number of first female flower

The node number where the production of first female flower occurred was recorded.

3.3.7.2.5. Number of male flowers (M/F)

The total number of male flowers per vine were counted during the entire flower period.

3.3.7.2.6. Number of female flowers

The total number of female flowers per vine were counted during the entire flower period.

3.3.7.2.7. Sex ratio

The sex ratio was calculated with number of male and female flowers (M/F).

3.3.7.2.8. Days to first harvest

The number of days taken for the first harvest of fruits at the optimum harvestable maturity stage from sowing were recorded.

3.3.7.2.9. Duration of the crop

The crop duration from sowing to final harvest was recorded.

3.3.7.2.10. Fruits/plant

The fruits harvested from individual plant till the final harvest was recorded and total number expressed as fruit number per plant.

3.3.7.2.11. Yield per plant (kg)

The weight of fruits per plant was recorded at each harvest and the total weight of fruits of all the harvests were summed up and expressed in kilogram.

3.3.7.3. Fruit quality parameters

3.3.7.3.1. Fruit girth (cm)

Five fruits were selected at random from each replication during peak harvest period. Maximum girth of fruit was measured using twine and scale and recorded and average expressed.

3.3.7.3.2. Fruit length (cm)

Length between the point of pedicel attachment and apex of fruit was measured using twine and scale and recorded as an average of five fruits per replication.

3.3.7.3.3. Flesh thickness (mm)

Flesh thickness was measured using vernier caliper. Average was taken from each replication and expressed in millimeters.

3.3.7.3. 4. Fruit weight (g)

Average weight of five selected fruits were recorded and expressed in grams.

3.3.7.3.5. Vitamin C (mg/100g)

Vitamin C content was estimated by volumetric method as suggested by A.O.A.C (2001).The dried fruits are powdered and passed through 40 mesh sieve. The powdered sample (1g) was dissolved in four per cent oxalic acid, the volume made up to 100 ml and then centrifuged for 30 minutes at 5000 rpm. Supernatant (5 ml) solution was taken out and 100 ml of 4 per cent oxalic acid was added into that and titrated against the dye solution. (Dye solution was prepared by mixing 42 mg of sodium bicarbonate with small volume of distilled water and 52 mg of 2,6 - dichlorophenol indophenol dissolved in it and the final volume was made up to 200 ml with distilled water. The titre value was V_2 ml. Ascorbic acid (100 ml) was dissolved in 100 ml of 4 per cent oxalic acid and 10 ml of this solution was taken out and diluted to 100 ml with 4 per cent oxalic acid. From this solution, 5 ml was taken out and 10 ml of 4 per cent oxalic acid was added and titrated against the dye solution till the appearance of pink colour. This titre value was V_1 ml.

Amount of Vitamin C (mg/100g) in the sample was calculated using the following formula :

$$\text{Vitamin C} = \frac{0.5\text{ mg}}{V_1\text{ml}} \times \frac{V_2\text{ ml}}{5\text{ ml}} \times \frac{100\text{ ml}}{\text{weight of the sample}} \times 100$$

3.3.7.3.6. Organoleptic test

Cooked fruits were used to evaluate organoleptic qualities. Five sensory attributes namely appearance, texture, flavor, taste and overall acceptability were recorded over a five point hedonic scale (Amerine *et. al*., 1965). Sensory attributes were evaluated by a panel of ten semi-trained judges. The score was statistically analysed using Kruskall-Wallis test (chi-square value) to find out whether treatments differed significantly (Shamrez *et al*., 2013).

3.3.7. Statitical Analysis

Statistical analysis of data was done in OPSTAT software and treatments were compared.

Results

4. RESULTS

The study entitled "Standardisation of grafting in bitter gourd (*Momordica charantia* L.)" was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani during 2017-2019 in order to identify suitable rootstocks, standardise grafting techniques and evaluate growth and performance of grafts in bitter gourd. The study was conducted in two parts. Standardisation of grafting in bitter gourd using four rootstocks was done in part I and evaluation of the grafted bitter gourd for growth, yield and quality was attempted in part II.

The result obtained from the study are presented below.

4.1. STANDARDISATION OF GRAFTING IN BITTER GOURD

Bitter gourd scion (Preethi) and four rootstocks (sponge gourd, pumpkin, bottle gourd and bitter gourd) were raised in protrays. Growth regulators (alar and cycocel) at two different concentrations *i.e.*,10 mg L^{-1} and 50 mg L^{-1} were sprayed at two leaf stage for reducing seedling height of rootstocks and then grafted using three methods (hole insertion grafting, one cotyledon grafting and cleft grafting).

The mean of days taken for germination of scion and rootstock was computed and depicted in Table 4.

4.1.1. Days taken for germination of stock

Among the four rootstock, pumpkin and sponge gourd germinated in 2.67 days after sowing, while bitter gourd (self rootstock) took 7.68 days for germination.

4.1.2. Days taken for germination of scion

In the study the scion 'Preethi' variety of bitter gourd took 7.68 days for germination.

4.1.3. Days taken to attain graftable size

The mean of days taken to attain graftable size was presented in table 4. Pumpkin attained graftable size in sevendays, while bitter gourd attained graftable size in 14.00 days.

4.1.4. Experiment -1- Grafting bitter gourd on to sponge gourd

In experiment 1, bitter gourd variety 'Preethi' was grafted on to sponge gourd rootstock using three methods *viz.*, hole insertion method grafting, one cotyledon grafting and cleft grafting. Growth regulators (alar and cycocel) at two different concentrations *i.e.*,10 mg L^{-1} and 50 mg L^{-1} were sprayed at second leaf stage in rootstock for reducing seedling height before grafting.

4.1.4.1. Height of rootstock at grafting (cm)

As shown in table 5, all growth regulator treatments significantly reduced the height of rootstock seedlings over control. Alar @ 10 mg L^{-1} (R_1) significantly reduced the height of rootstock followed by cycocel @ 10 mg L^{-1} (R_3) to 7.50 cm and 8.46 cm respectively. Distilled water (R_0) recorded the highest height of 9.02 cm.

4.1.4.2. Diameter of rootstock at grafting (mm)

As presented in table 3, it is evident that application of growth regulators improved the diameter of rootstock at grafting over control. Alar @ 50 mg L^{-1} (R_2) and alar @ 10 mg L^{-1} (R_1) were on par in enhancing the diameter of the rootstock to 3.01 mm and 2.97 mm respectively and distilled water (R_0) recorded the least diameter of 2.67 mm at grafting.

Table 4. Mean of days taken by rootstocks and scion for germination and to attain graftable size.

Rootstocks	**Days taken for germination**	**Days taken to attain graftable size**
Sponge gourd	3.67	10.33
Pumpkin	2.67	7.00
Bottle gourd	4.33	8.67
Bitter gourd /scion	7.68	14.00

4.1.4.3. Days taken for graft union

The perusal of the data in table 6a and table 6b revealed that though growth regulator had no effect on the days taken for graft union, grafting methods and their interaction significantly altered it.

Analyzing the grafting method, hole insertion grafting (G_1) recorded 4.11 days for graft union while cleft grafting (G_3) united grafts in 5.09 days. One cotyledon grafting (G_2) recorded more number of days (5.67) days.

Among the different combinations, alar @ 10 mg L^{-1} + hole insertion grafting (G_1R_1), cycocel @ 10 mg L^{-1} + hole insertion grafting (G_1R_3), alar @ 50 mg L^{-1} + hole insertion grafting (G_1R_2), distilled water + hole insertion grafting (G_1R_0) and cycocel @ 50 mg L^{-1} + hole insertion grafting (G_1R_4) and were on par in reducing the days taken for graft union (3.89 days, 3.89 days, 4.00 days, 4.22 days and 4.56 days respectively). The combination, cycocel @ 10 mg L^{-1} + one cotyledon grafting (G_2R_3) took more days (6.00 days) for graft union.

4.1.4.4. Percentage success (%)

As given in table 6a and 6b, hole insertion grafting (G_1) exhibited the highest percentage success (77.07 %) followed by one cotyledon grafting (G_2) with a success percentage of 54.93 % and the lowest percentage success (10.93 %) was exhibited by cleft grafting (G_3).

All growth regulators exhibited higher success percentage over control. Among them, cycocel @ 50 mg L^{-1} (R_4) showed the highest percentage success (56.44 %) followed by cycocel @ 10 mg L^{-1} (R_3) with 47.11 per cent success. Distilled water (R_0) showed the least percentage success of 43.56 per cent.

Table 5. Effect of growth regulator on height and diameter of rootstock at grafting in sponge gourd rootstock

Growth regulators (R)	Height of rootstock at grafting (cm)	Diameter of rootstock at grafting (mm)
R_0-Distilled water (control)	9.02	2.67
R_1- Alar @ 10 mgL^{-1}	7.50	2.97
R_2- Alar @ 50 mgL^{-1}	8.86	3.01
R_3-Cycocel @ 10mgL^{-1}	8.46	2.75
R_4-Cycocel @ 50 mgL^{-1}	8.69	2.75
SE (m) $\pm$	0.174	0.084
CD (0.05)	0.506	0.244

Table 6a. Effect of grafting method and growth regulator on days taken for graft union and percentage success in sponge gourd rootstock.

Treatments	Days taken for graft union	Percentage success (%)
Grafting methods (G)		
G_1 - Hole Insertion Grafting	4.11	77.07
G_2 - One Cotyledon Grafting	5.67	54.93
G_3 - Cleft Grafting	5.09	10.93
SE $\pm$ (m)	0.126	1.033
CD (0.05)	0.367	2.997
Growth regulators (R)		
R_0-Distilled water (control)	4.96	43.56
R_1- Alar @ 10 mgL^{-1}	4.74	45.33
R_2- Alar @ 50 mgL^{-1}	5.00	45.78
R_3-Cycocel @ 10mgL^{-1}	5.00	47.11
R_4-Cycocel @ 50 mgL^{-1}	5.07	56.44
SE (m) $\pm$	0.163	1.333
CD (0.05)	NS	3.870

Table 6b. Interaction effect of grafting method and growth regulator on days taken for graft union and percentage success in sponge gourd rootstock.

Interaction (GxR)		
Treatments	**Days taken for graft union**	**Percentage success (%)**
G_1R_0 [Distilled water (control) + Hole Insertion Grafting]	4.22	46.67
G_1R_1 [Alar @ 10 mgL^{-1} + Hole Insertion Grafting]	3.89	76.00
G_1R_2 [Alar @ 50 mgL^{-1} + Hole Insertion Grafting]	4.00	88.00
G_1R_3 [Cycocel @ 10mgL^{-1} + Hole Insertion Grafting]	3.89	88.00
G_1R_4 [Cycocel @ 50 mgL^{-1} + Hole Insertion Grafting]	4.56	86.67
G_2R_0 [Distilled water (control) + One Cotyledon Grafting]	5.44	72.00
G_2R_1 [Alar @ 10 mgL^{-1} + One Cotyledon Grafting]	5.56	38.67
G_2R_2 [Alar @ 50 mgL^{-1} One Cotyledon Grafting]	5.89	44.00
G_2R_3 [Cycocel @ 10mgL^{-1} + One Cotyledon Grafting]	6.00	46.67
G_2R_4 [Cycocel @ 50 mgL^{-1} + One Cotyledon Grafting]	5.44	73.33
G_3 R_0 [Distilled water (control) + Cleft Grafting]	5.22	12.00
G_3R_1 [Alar @ 10 mgL^{-1} + Cleft Grafting]	4.78	21.33
G_3 R_2 [Alar @ 50 mgL^{-1} Cleft Grafting]	5.11	5.33
G_3 R_3 [Cycocel @ 10mgL^{-1} + Cleft Grafting]	5.11	6.67
G_3 R_4 [Cycocel @ 50 mgL^{-1} + Cleft Grafting]	5.22	9.33
SE (m) $\pm$	0.283	2.309
CD (0.05)	0.847	6.702

Among the interaction, alar @ 50 mg L^{-1} + hole insertion grafting (G_1R_2), cycocel @ 10 mg L^{-1} + hole insertion grafting (G_1R_3) and cycocel @ 50 mg L^{-1} + hole insertion grafting (G_1R_4) were on par in exhibiting the success percentage (88.00 %, 88.00 % and 86.67 % respectively) percentage success. The least percentage success (5.33 %) was exhibited by the combination alar @ 50 mg L^{-1} + cleft grafting ($G_3 R_2$).

4.1.5. Experiment -2- Grafting bitter gourd on to pumpkin

4.1.5.1. Height of rootstock at grafting (cm)

Data in table 7 suggests that the application of growth regulators reduced the height of rootstock compared to control. Alar @ 10 mg L^{-1} (R_1) and alar @ 50 mg L^{-1} (R_2) were on par in reducing the height of rootstock to 12.30 cm and 12.85 cm respectively. The highest height of 15.41 cm was recorded by distilled water (R_0).

4.1.5.2. Diameter of rootstock at grafting (mm)

Perusal of the data pertaining the variation between the growth regulators on diameter of rootstock in table 7 revealed that, all growth regulator treatments improved the diameter of the rootstock over control. Among them, cycocel @ 10 mg L^{-1} (R_3) and cycocel @ 50 mg L^{-1} (R_4) were on par in improving the diameter of rootstock to 4.99 mm and 4.77 mm respectively. However, distilled water(R_0) exhibited the least diameter of 3.67 mm.

4.1.5.3. Days taken for graft union

As depicted in table 8a and 8b, days taken for graft union varied significantly within the grafting method and the interactions. However, growth regulator had no significant effect on it.

Among the grafting methods, hole insertion grafting (G_1) and one cotyledon grafting (G_2) took 3.51 days and 4.47 days respectively for graft union, while cleft grafting (G_3) took 7.07 days.

Considering the interaction effect, the combination cycocel @ 10 mg L^{-1} + hole insertion grafting (G_1R_3), alar @ 10 mg L^{-1} + hole insertion grafting (G_1R_1), alar @ 50 mg L^{-1} + hole insertion grafting (G_1R_2), distilled water + hole insertion grafting (G_1R_0) and cycocel @ 50 mg L^{-1} + hole insertion grafting (G_1R_4) were on par for reducing the days taken for grafts (3.33 days, 3.44 days, 3.44 days, 3.56 days and 3.78 days respectively). The combination distilled water + cleft grafting (G_3 R_0) took more days (7.67 days) for graft union.

4.1.5.4. Percentage success (%)

The percentage success varied significantly within grafting method (Table 8a and Table 8b).One cotyledon grafting (G_2) exhibited highest success per cent (68.60%) followed by hole insertion grafting (G_1) with 59.47per cent success. Cleft grafting (G_3)exhibited the least percentage success (11.20 %).

Though growth regulator alar @ 10 mg L^{-1}(R_1), alar @ 50 mg L^{-1}(R_2) and cycocel @ 10 mg L^{-1} (R_3) were on par in exhibiting the highest success percentage (54.11 %, 49.33 % and 47.11 % respectively), R_4 (cycocel @ 50 mg L^{-1}) exhibited the least (40 %).

Among the combinations, alar @ 10 mg L^{-1} + one cotyledon grafting (G_2R_1), cycocel @ 10 mg L^{-1} + one cotyledon grafting (G_2R_3), alar @ 50 mg L^{-1} + hole insertion grafting (G_1R_2) and alar @ 10 mg L^{-1} + hole insertion grafting (G_1R_1) recorded on par success percentage of 81.00 per cent, 77.33 per cent, 74.67 cent and 69.33 per cent respectively, while both cycocel @ 10 mg L^{-1} + cleft grafting (G_3 R_3) and cycocel @ 50 mg L^{-1} + cleft grafting (G_3 R_4)recorded the lowest percentage success of 9.33 per cent.

Table 7. Effect of growth regulator on height and diameter of pumpkin rootstock at grafting.

Growth regulators (R)	Height of rootstock at grafting (cm)	Diameter of rootstock at grafting (mm)
R_0-Distilled water (control)	15.41	3.67
R_1- Alar @ 10 mgL^{-1}	12.30	4.15
R_2- Alar @ 50 mgL^{-1}	12.85	3.84
R_3-Cycocel @ 10mgL^{-1}	13.59	4.99
R_4-Cycocel @ 50 mgL^{-1}	13.63	4.77
SE (m) $\pm$	0.396	0.125
CD (0.05)	1.148	0.313

Table 8a. Effect of grafting method and growth regulator on days taken for graft union and percentage success in pumpkin rootstock

Treatments	Days taken for graft union	Percentage success (%)
Grafting methods (G)		
G_1 - Hole Insertion Grafting	3.51	59.47
G_2 - One Cotyledon Grafting	4.47	68.60
G_3 - Cleft Grafting	7.07	11.20
SE $\pm$ (m)	0.120	2.720
CD (0.05)	0.350	7.893
Growth regulators (R)		
R_0-Distilled water (control)	5.22	41.56
R_1- Alar @ 10 mgL^{-1}	4.81	54.11
R_2- Alar @ 50 mgL^{-1}	5.00	49.33
R_3-Cycocel @ 10mgL^{-1}	4.89	47.11
R_4-Cycocel @ 50 mgL^{-1}	5.15	40.00
SE (m) $\pm$	0.156	3.511
CD (0.05)	NS	10.190

Table 8b. Interaction effect of grafting method and growth regulator on days taken for graft union and percentage success in pumpkin rootstock

Interaction (GxR)		
Treatments	**Days taken for graft union**	**Percentage success (%)**
G_1R_0 [Distilled water (control) + Hole Insertion Grafting]	3.56	52.00
G_1R_1 [Alar @ 10 mgL^{-1} + Hole Insertion Grafting]	3.44	69.33
G_1R_2 [Alar @ 50 mgL^{-1} + Hole Insertion Grafting]	3.44	74.67
G_1R_3 [Cycocel @ 10mgL^{-1} + Hole Insertion Grafting]	3.33	54.67
G_1R_4 [Cycocel @ 50 mgL^{-1} + Hole Insertion Grafting]	3.78	46.67
G_2R_0 [Distilled water (control) + One Cotyledon Grafting]	4.44	58.00
G_2R_1 [Alar @ 10 mgL^{-1} + One Cotyledon Grafting]	4.22	81.00
G_2R_2 [Alar @ 50 mgL^{-1} One Cotyledon Grafting]	4.78	62.67
G_2R_3 [Cycocel @ 10mgL^{-1} + One Cotyledon Grafting]	4.44	77.33
G_2R_4 [Cycocel @ 50 mgL^{-1} + One Cotyledon Grafting]	4.44	64.00
G_3 R_0 [Distilled water (control) + Cleft Grafting]	7.67	14.67
G_3R_1 [Alar @ 10 mgL^{-1} + Cleft Grafting]	6.78	12.00
G_3 R_2 [Alar @ 50 mgL^{-1} Cleft Grafting]	6.78	10.67
G_3 R_3 [Cycocel @ 10mgL^{-1} + Cleft Grafting]	6.89	9.33
G_3 R_4 [Cycocel @ 50 mgL^{-1} + Cleft Grafting]	7.22	9.33
SE (m) $\pm$	0.269	6.082
CD (0.05)	0.768	16.494

4.1.6. Experiment -3-Grafting bitter gourd on to bottle gourd

4.1.6.1. Height of rootstock at grafting (cm)

Perusal of the data in Table 9 regarding effect of growth regulator on height of rootstock at grafting revealed that alar @ 50 mg L^{-1} (R_2) followed by distilled water (R_0) lowered the height of the rootstock to 12.61 cm and 13.53 cm respectively. However, cycocel @ 50 mg L^{-1} (R_4) recorded the height of rootstock as 14.58 cm at grafting.

4.1.6.2. Diameter of rootstock at grafting (mm)

As presented in table 9, alar @ 10 mg L^{-1} (R_1) and cycocel @ 50 mg L^{-1} (R_4) were on par in improving the diameter (4.65 mm and 4.39 mm respectively)and distilled water (R_0) recorded the least diameter of 3.67 mm.

4.1.6.3. Days taken for graft union

The data pertaining days taken for graft union is depicted in table 10a and 10b. Among the grafting methods, hole insertion grafting (G_1) took the least number of days (3.69 days) for graft union while one cotyledon grafting (G_2) united in 5.29 days. Cleft grafting (G_3) took more days (6.27 days) for graft union.

Growth regulator had no influence on days taken for graft union. However, interaction between the grafting method and growth regulator was found to be significant. Cycocel @ 10 mg L^{-1} + hole insertion grafting (G_1R_3), alar @ 50 mg L^{-1} + hole insertion grafting (G_1R_2), cycocel @ 50 mg L^{-1} +hole insertion grafting (G_1R_4), alar @ 10 mg L^{-1} + hole insertion grafting (G_1R_1) and distilled water (G_1R_0)+ hole insertion grafting (G_1R_0) followed the same trend in reducing the days taken for graft union (3.45days, 3.67 days, 3.67 days, 3.78 days and 3.89 days respectively).

However, cycocel @ 50 mg L^{-1} + cleft grafting ($G_3 R_4$) took of more days (6.56 days) for graft union.

4.1.6.4. Percentage success (%)

As depicted in Table 10a and 10b, one cotyledon grafting (G_2) gave the highest success percentage (86.40%) followed by hole insertion grafting (G_1) with 74.40 per cent success. The least percentage success (17.33 %) was observed in cleft grafting (G_3).

Distilled water (R_0), cycocel @ 10 mg L^{-1} (R_3), alar @ 10 mg L^{-1} (R_1) and cycocel @ 50 mg L^{-1} (R_4) were on par in exhibiting higher success percentage (63.11 %, 61.78 %, 59.11 % and 58.22 % respectively). Alar @ 50 mg L^{-1} (R_2) showed the least percentage success of 54.67 per cent.

Among the combinations, alar @ 10 mg L^{-1} + one cotyledon grafting (G_2R_1) and alar @ 50 mg L^{-1} + one cotyledon grafting (G_2R_2), distilled water + one cotyledon grafting (G_2R_0), cycocel @ 10 mg L^{-1} + one cotyledon grafting (G_2R_3), cycocel @ 50 mg L^{-1} + one cotyledon grafting (G_2R_4), alar @ 10 mg L^{-1} + hole insertion grafting (G_1R_1), cycocel @ 50 mg L^{-1} + hole insertion grafting (G_1R_4) and distilled water + hole insertion grafting (G_1R_0) were equally effective and exhibited the success percentage as 88.00 per cent, 88.00 per cent, 85.33 per cent, 85.33 per cent, 85.33 percent, 81.33 per cent, 81.33 per cent and 77.33 per cent respectively.

Both alar @ 10 mg L^{-1} + cleft grafting (G_3R_1) and cycocel @ 50 mg L^{-1} + cleft grafting ($G_3 R_4$) recorded the least success percentage of 8.00 per cent.

Table 9. Effect of growth regulator on height and diameter of rootstock at grafting when grafted on bottle gourd

Growth regulators (R)	Height of rootstock at grafting (cm)	Diameter of rootstock at grafting (mm)
R_0-Distilled water (control)	13.53	3.67
R_1- Alar @ 10 mgL^{-1}	14.27	4.65
R_2- Alar @ 50 mgL^{-1}	12.61	4.21
R_3-Cycocel @ 10mgL^{-1}	13.59	4.16
R_4-Cycocel @ 50 mgL^{-1}	14.58	4.39
SE (m) ±	0.298	0.120
CD (0.05)	0.866	0.347

Table 10a. Effect of grafting method and growth regulator on days taken for graft union and percentage success when grafted on bottle gourd

Treatments	Days taken for graft union	Percentage success (%)
Grafting methods (G)		
G_1 - Hole Insertion Grafting	3.69	74.40
G_2 - One Cotyledon Grafting	5.29	86.40
G_3 - Cleft Grafting	6.27	17.33
SE ± (m)	0.124	1.873
CD (0.05)	0.359	5.436
Growth regulators (R)		
R_0-Distilled water (control)	4.93	63.11
R_1- Alar @ 10 mgL^{-1}	4.96	59.11
R_2- Alar @ 50 mgL^{-1}	5.19	54.67
R_3-Cycocel @ 10mgL^{-1}	5.04	61.78
R_4-Cycocel @ 50 mgL^{-1}	5.30	58.22
SE (m) ±	0.160	2.418
CD (0.05)	NS	7.003

Table 10b. Interaction effect of grafting method and growth regulator days taken for graft union and percentage success when grafted on bottle gourd

Interaction (GxR)		
Treatments	**Days taken for graft union**	**Percentage success (%)**
G_1R_0 [Distilled water (control) + Hole Insertion Grafting]	3.89	77.33
G_1R_1 [Alar @ 10 mgL^{-1} + Hole Insertion Grafting]	3.78	81.33
G_1R_2 [Alar @ 50 mgL^{-1} + Hole Insertion Grafting]	3.67	48.00
G_1R_3 [Cycocel @ 10mgL^{-1} + Hole Insertion Grafting]	3.45	84.00
G_1R_4 [Cycocel @ 50 mgL^{-1} + Hole Insertion Grafting]	3.67	81.33
G_2R_0 [Distilled water (control) + One Cotyledon Grafting]	4.89	85.33
G_2R_1 [Alar @ 10 mgL^{-1} + One Cotyledon Grafting]	5.11	88.00
G_2R_2 [Alar @ 50 mgL^{-1} One Cotyledon Grafting]	5.56	88.00
G_2R_3 [Cycocel @ 10mgL^{-1} + One Cotyledon Grafting]	5.22	85.33
G_2R_4 [Cycocel @ 50 mgL^{-1} + One Cotyledon Grafting]	5.67	85.33
$G_3 R_0$ [Distilled water (control) + Cleft Grafting]	6.00	26.67
G_3R_1 [Alar @ 10 mgL^{-1} + Cleft Grafting]	6.00	8.00
$G_3 R_2$ [Alar @ 50 mgL^{-1} Cleft Grafting]	6.33	28.00
$G_3 R_3$ [Cycocel @ 10mgL^{-1} + Cleft Grafting]	6.44	16.00
$G_3 R_4$ [Cycocel @ 50 mgL^{-1} + Cleft Grafting]	6.56	8.00
SE (m) $\pm$	0.277	4.188
CD (0.05)	0.775	12.555

4.1.7. Experiment - 4- Grafting bitter gourd on to bitter gourd

4.1.7.1. Height of rootstock at grafting (cm)

The data pertaining the effect of growth regulators on height of the rootstock at grafting is depicted in table 11. From the table it is evident that all growth regulator applications were effective in reducing the height of the rootstock over control. Among them, alar @ 10 mg L^{-1} (R_1), cycocel @ 10 mg L^{-1} (R_3) and cycocel @ 50 mg L^{-1} (R_4) were on in reducing the height of rootstock to 10.46 cm, 10.76 cm and 10.87 cm respectively. The least reduction in height (11.57 cm) of the rootstock was shown by distilled water (R_0).

4.1.7.2. Diameter of rootstock at grafting (mm)

As depicted in table 11, cycocel @ 50 mg L^{-1} (R_4), cycocel @ 10 mg L^{-1} (R_3) and alar @ 50 mg L^{-1} (R_2)were on par in enhancing the diameter to 3.88 mm, 3.84 mm and 3.77 mm respectively. However, alar @ 10 mg L^{-1} (R_1) exhibited minimum diameter of 3.50 mm.

4.1.7.3. Days taken for graft union

As presented in table 12a and 12b, hole insertion grafting (G_1) took the least number of days for graft union followed by one cotyledon grafting (G_2) and were 3.57days and 4.85 days respectively. Cleft grafting (G_3) took more days (7.58 days) for graft union.

There was no effect of growth regulator alone on days taken for graft union but their interaction had significant effect. Among the combination, alar @ 50 mg L^{-1} + hole insertion grafting (G_1R_2),distilled water + hole insertion grafting (G_1R_0), cycocel @ 10 mg L^{-1} + hole insertion grafting (G_1R_3), cycocel @ 50 mg L^{-1} + hole insertion grafting (G_1R_4) and alar @ 10 mg L^{-1} + hole insertion grafting (G_1R_1) were equally effective in reducing the days taken for graft union (3.39 days, 3.44 days, 3.61days, 3.67 days and 3.72 days respectively). Cleft grafting + cycocel @ 50 mg L^{-1} ($G_3 R_4$) recorded more days (7.78 days) for graft union.

4.1.7.4. Percentage success (%)

The data pertaining the percentage success is depicted in table 12a and 12b. Hole insertion grafting (G_1) recorded the highest success percent (68.13) followed by one cotyledon grafting (G_2) with 63.87 per cent of success. Cleft grafting (G_3) recorded the least percentage success (23.73 %).

Among the growth regulators, cycocel @ 50 mg L^{-1} (R_4) recorded the highest success percentage (64.44 %) followed by alar @ 50 mg L^{-1} (R_2) with percentage success of 53.33 per cent. The minimum percentage success of 41.33 per cent was observed in alar @ 10 mg L^{-1} (R_1).

Cycocel @ 50 mg L^{-1} + hole insertion grafting (G_1R_4) and cycocel @ 50 mg L^{-1} + one cotyledon grafting (G_2R_4) were equally effective and exhibited the success percentage as 86.67 per cent and 85.33 per cent respectively, while the least success percentage of 17.33 per cent was exhibited by alar @ 10 mg L^{-1} + cleft grafting (G_3R_1).

4.2. EVALUATION OF GRAFTED BITTER GOURD FOR GROWTH, YIELD AND QUALITY

The treatments with highest success percentage in each experiment i.e., the grafts produced by cycocel @ 50 mg L^{-1} + hole insertion grafting in sponge gourd, alar @ 10 mg L^{-1} + one cotyledon grafting in pumpkin, distilled water (control) + one cotyledon grafting in bottle gourd and cycocel @ 50 mg L^{-1} + hole insertion grafting in bitter gourd were selected and planted in main field along with non grafted control for evaluating growth, yield and quality of grafted bitter gourd.

Table 11. Effect of growth regulator on height and diameter of bitter gourd rootstock at grafting

Growth regulators (R)	Height of rootstock at grafting (cm)	Diameter of rootstock at grafting (mm)
R_0-Distilled water (control)	11.57	3.52
R_1- Alar @ 10 mgL^{-1}	10.46	3.50
R_2- Alar @ 50 mgL^{-1}	11.45	3.77
R_3-Cycocel @ 10mgL^{-1}	10.76	3.84
R_4-Cycocel @ 50 mgL^{-1}	10.87	3.88
SE (m) ±	0.219	0.096
CD (0.05)	0.635	0.146

Table 12a. Effect of grafting method and growth regulator on days taken for graft union and percentage success when grafted on bitter gourd.

Treatments	Days taken for graft union	Percentage success (%)
Grafting methods (G)		
G_1 - Hole Insertion Grafting	3.57	68.13
G_2 - One Cotyledon Grafting	4.85	63.87
G_3 - Cleft Grafting	7.58	23.73
SE ± (m)	0.099	0.662
CD (0.05)	0.287	1.922
Growth regulators (R)		
R_0-Distilled water (control)	5.24	52.44
R_1- Alar @ 10 mgL^{-1}	5.43	41.33
R_2- Alar @ 50 mgL^{-1}	5.22	53.33
R_3-Cycocel @ 10mgL^{-1}	5.21	48.00
R_4-Cycocel @ 50 mgL^{-1}	5.56	64.44
SE (m) ±	0.128	0.855
CD (0.05)	NS	2.481

Table 12b. Interaction effect of grafting method and growth regulator on days taken for graft union and percentage success when grafted on bitter gourd

Interaction (GxR)		
Treatments	**Days taken for graft union**	**Percentage success (%)**
G_1R_0 [Distilled water (control) + Hole Insertion Grafting]	3.44	56.67
G_1R_1 [Alar @ 10 mgL^{-1} + Hole Insertion Grafting]	3.72	53.33
G_1R_2 [Alar @ 50 mgL^{-1} + Hole Insertion Grafting]	3.39	81.33
G_1R_3 [Cycocel @ 10mgL^{-1} + Hole Insertion Grafting]	3.61	62.67
G_1R_4 [Cycocel @ 50 mgL^{-1} + Hole Insertion Grafting]	3.67	86.67
G_2R_0 [Distilled water (control) + One Cotyledon Grafting]	4.95	72.67
G_2R_1 [Alar @ 10 mgL^{-1} + One Cotyledon Grafting]	4.83	53.33
G_2R_2 [Alar @ 50 mgL^{-1} One Cotyledon Grafting]	4.61	53.33
G_2R_3 [Cycocel @ 10mgL^{-1} + One Cotyledon Grafting]	4.61	54.67
G_2R_4 [Cycocel @ 50 mgL^{-1} + One Cotyledon Grafting]	5.22	85.33
$G_3 R_0$ [Distilled water (control) + Cleft Grafting]	7.33	28.00
G_3R_1 [Alar @ 10 mgL^{-1} + Cleft Grafting]	7.72	17.33
$G_3 R_2$ [Alar @ 50 mgL^{-1} Cleft Grafting]	7.67	25.33
$G_3 R_3$ [Cycocel @ 10mgL^{-1} + Cleft Grafting]	7.39	26.67
$G_3 R_4$ [Cycocel @ 50 mgL^{-1} + Cleft Grafting]	7.78	21.33
SE (m) $\pm$	0.221	1.481
CD (0.05)	0.646	4.297

The result obtained in part II of the study is detailed below.

4.2.1. Growth Parameters

4.2.1.1. Diameter of rootstock hypocotyls (mm) [at fortnightly intervals]

Performance of treatments on diameter of rootstock hypocotyls (mm) [at fortnightly intervals] is presented in table 13.

All the rootstocks exhibited more diameters over bitter gourd rootstock (T_4) except in first fortnight.

Among the four rootstocks, bitter gourd grafted onto bottle gourd rootstock (T_3) exhibited higher diameter consistently in all fortnights with 16.60 mm, 28.17 mm, 38.50 mm, 48.43 mm, 49.03 mm and 49.40 mm respectively. However, in first fortnight the result was on par with bitter gourd grafted onto pumpkin rootstock (T_2) with the diameter of 15.57 mm and the least was exhibited by bitter gourd grafted onto sponge gourd rootstock (T_1). In all other fortnights, bitter gourd grafted onto bitter gourd rootstock recorded the least diameter of 22.00 mm, 32.17 mm, 41.70 mm, 42.33 mm and 42.53 mm respectively.

4.2.1.2. Diameter of scion hypocotyls (mm) [at fortnightly intervals]

Data pertaining the effect of selected treatments on diameter of scion hypocotyls (mm) [at fortnightly intervals] is displayed in table 14.

Regarding diameter of scion hypocotyls, bitter gourd grafted onto pumpkin rootstock (T_2) consistently recorded the highest diameter of 13.10 mm, 14.00 mm and 34.23 mm in 15 days, 30 days and 45 days respectively over other rootstocks. However on 30^{th} day the result was on par with bitter gourd grafted onto bottle gourd rootstock (T_3) with the diameter of 13.57 mm. The least diameter was observed in

Table 13. Effect of bitter gourd grafts on diameter of rootstock hypocotyls (mm) [at fortnightly intervals]

Treatments	15 days	30 days	45 days	60 days	75 days	90 days
T_1 (sponge gourd)	11.43	22.50	32.50	43.37	44.07	45.13
T_2 (pumpkin)	15.57	24.57	33.67	43.17	44.27	45.43
T_3 (bottle gourd)	16.60	28.17	38.50	48.43	49.03	49.40
T_4 (bitter gourd)	13.00	22.00	32.17	41.70	42.33	42.53
SE (m) $\pm$	0.379	0.366	0.322	0.202	0.265	1.523
CD (0.05)	1.338	1.290	1.134	0.714	0.933	0.432

Table 14. Effect of bitter gourd grafts on diameter of scion hypocotyls (mm) [at fortnightly intervals]

Treatments	15 days	30 days	45 days	60 days	75 days	90 days
T_1 (sponge gourd)	9.57	11.33	28.40	43.57	43.80	44.27
T_2 (pumpkin)	13.10	14.00	34.23	42.87	43.73	44.43
T_3 (bottle gourd)	12.23	13.57	32.27	41.93	42.67	43.73
T_4 (bitter gourd)	10.03	12.37	29.37	42.03	42.73	43.97
SE (m) $\pm$	0.230	0.139	0.290	0.373	0.338	0.435
CD (0.05)	0.812	0.491	1.023	NS	NS	NS

bitter gourd grafted onto sponge gourd rootstock (T_1) with 9.57 mm, 11.33 mm and 28.40 mm in 15 days, 30 days and 45 days respectively. In rest of the fortnights there was no significant variations in the diameter of scion hypocotyls.

4.2.1.3. Establishment of grafts (%)

Perusal of data regarding the establishment of grafts presented in table 15 revealed that non grafted control (T_5) exhibited the highest establishment of 93.67 per cent compared to all other treatments followed by bitter gourd grafted onto sponge gourd rootstock (T_1) with success percentage of 88 per cent. The least establishment of grafts (37.00 %) was recorded by bitter gourd grafted onto pumpkin rootstock (T_2) graft establishment.

4.2.1.4. Vine length (cm)

As depicted in table 15, vine length was significant within the treatments and non grafted control (T_5), bitter gourd grafted onto bottle gourd rootstock (T_3) and bitter gourd grafted onto sponge gourd rootstock were on par in producing the highest vine length (367.00 cm, 360.00 cm and 343.33 cm respectively). Bitter gourd grafted onto pumpkin rootstock (T_2) produced the least vine length of 226.67 cm.

4.2.1.5. Internodal length (cm)

As depicted in table 15, non grafted control (T_5) and bitter gourd grafted onto bitter gourd rootstock (T_4) were on par in increasing the internodal length (6.00 cm and 5.90 cm respectively) compared to other treatments, while the least internodal length of 3.87 cm was observed in bitter gourd grafted onto bottle gourd rootstock (T_3).

4.2.1.6. Branches / plant

As depicted in table 15, bitter gourd grafted onto bitter gourd rootstock (T_4) and bitter gourd grafted onto sponge gourd rootstock (T_1) were on par in producing more branches per plant (9.33and 8.67 respectively) and bitter gourd grafted onto pumpkin rootstock (T_2) recorded the lowest (6.67) branches per plant.

4.2.1.7. Length of primary root (cm)

As depicted in table 16, all the treatments produced more primary root length over non grafted control. Length of primary root was higher (55.07 cm) for bitter gourd grafted onto pumpkin rootstock (T_2) followed by bitter gourd grafted onto sponge gourd rootstock (T_1)with 39.23 cm root length. The lower length was produced by non grafted control (T_5) in which root length was recorded as (30.67 cm).

4.2.1.8. Root volume (cm^3)

As shown in table 16, all the treatments exhibited more root volume over non grafted control. The data revealed that the highest root volume (17.44 cm^3) was recorded in bitter gourd grafted onto pumpkin rootstock (T_2) followed by bitter gourd grafted onto sponge gourd rootstock (T_1) with11.64 cm^3.The lowest volume (9.28 cm^3) was observed in non grafted control (T_5).

4.2.1.9. Root weight (g)

From table 16, all the treatments exhibited more root weight over non grafted control. Root weight was higher (2.86 g) for bitter gourd grafted onto pumpkin rootstock (T_2) followed by bitter gourd grafted onto sponge gourd rootstock (T_1) with 2.12 g. The lowest (0.94 g) root weight was observed in non grafted control (T_5).

Table 15. Evaluation of bitter gourd grafts on graft establishment, vine length, internodal length and branches per plant.

Treatments	Establishment of grafts (%)	Vine length (cm)	Internodal length (cm)	Branches/ plant
T_1 (sponge gourd)	88.00	343.33	4.33	8.67
T_2 (pumpkin)	37.00	226.67	4.23	6.67
T_3 (bottle gourd)	84.33	360.00	3.87	8.00
T_4 (bitter gourd)	86.00	270.00	5.90	9.33
T_5 (control)	93.67	366.67	6.00	7.67
SE (m) ±	0.711	13.208	0.075	0.298
CD (0.05)	2.355	43.741	0.248	0.987

Table 16. Evaluation of bitter gourd grafts on primary root length, root volume and root weight.

Treatments	Length of primary root (cm)	Root volume (cm^3)	Root weight (g)
T_1 (sponge gourd)	39.23	11.64	2.12
T_2 (pumpkin)	55.07	17.44	2.86
T_3 (bottle gourd)	33.00	10.08	2.04
T_4 (bitter gourd)	31.00	9.60	0.95
T_5 (control)	30.67	9.28	0.94
SE (m) ±	0.337	0.178	0.016
CD (0.05)	1.114	0.588	0.054

4.2.2. Yield Parameters

4.2.2.1. Days to first male flower

From table 17 it is clear that the first male flower appeared in 39.67 days in bitter gourd grafted onto pumpkin rootstock (T_2) followed by bitter gourd grafted onto bitter gourd rootstock (T_4) and non grafted control (T_5) which took 43.33 days. Bitter gourd grafted onto sponge gourd rootstock (T_1) took more days (45.00 days) for the appearance of first male flower.

4.2.2.2. Days to First Female Flower

As given in table 17, bitter gourd grafted onto pumpkin rootstock (T_2) and bitter gourd grafted onto bitter gourd rootstock (T_4) were on par in the early production of female flowers (47.33 days and 48.33 days respectively). However, in bitter gourd grafted onto bottle gourd rootstock (T_3) female flower appeared in 51 days.

4.2.2.3. Node number of first male flower

Considering the data given in table 17, bitter gourd grafted onto pumpkin rootstock (T_2), bitter gourd grafted onto sponge gourd rootstock (T_1) and bitter gourd grafted onto bitter gourd rootstock (T_4) were on par in producing first male flower at lower node (8.67, 10.00 and 10.33 respectively), while bitter gourd grafted onto bottle gourd rootstock (T_3) produced the first male flower at higher node (12.33).

4.2.2.4. Node number of first female flower

The data regarding node number of first female flower shown in table 17 revealed that, bitter gourd grafted onto sponge gourd rootstock (T_1), bitter gourd grafted onto pumpkin rootstock (T_2) and bitter gourd grafted onto bitter gourd rootstock (T_4) were on par in producing the first female flower at lower nodes (16.33, 17.33 and 18.33 respectively) while, bitter gourd grafted onto bottle gourd rootstock (T_3) produced the first female flower at higher node (19.67).

4.2.2.5. Number of male Flowers

Number of male flowers varied from 185.00 to 228.33. No significant variation was found in number of male flowers among the treatments.

4.2.2.6. Number of female Flowers

As depicted in table 18, non grafted control (T_5) and bitter gourd grafted onto sponge gourd rootstock (T_1) were on par in producing more female flowers (14.67 and 13.00 respectively). However, bitter gourd grafted onto pumpkin rootstock (T_2) produced less (9.67) female flowers.

4.2.2.7. Sex ratio

From table 18, it is clear that sex ratio was significant among the treatments. Non grafted control (T_5), bitter gourd grafted onto sponge gourd rootstock (T_1), bitter gourd grafted onto bottle gourd rootstock (T_3) and bitter gourd grafted onto bitter gourd rootstock (T_4) were on par in exhibiting lower sex ratio of 15.59, 16.12, 17.89 and 18.67 respectively. However, the highest sex ratio of 21.23 was recorded in bitter gourd grafted onto pumpkin rootstock (T_2).

4.2.2.8. Days to first harvest

As presented in table 18, non grafted control (T_5), bitter gourd grafted onto pumpkin rootstock (T_2) and bitter gourd grafted onto bitter gourd rootstock (T_4) were on par in early production of fruits (62.33 days, 66.3 days and 67.33 days

Table17. Evaluation of bitter gourd grafts on days to first male flower, first female flower, node number of first male flower and node number of first female flower.

Treatments	Days to first male flower	Days to first female flower	Node number of first male flower	Node number of first female flower
T_1 (sponge gourd)	45.00	51.33	10.00	16.33
T_2 (pumpkin)	39.67	47.33	8.67	17.33
T_3 (bottle gourd)	44.00	51.00	12.33	19.67
T_4 (bitter gourd)	43.33	49.67	10.33	18.33
T_5 (control)	43.33	48.33	12.00	19.00
SE (m) $\pm$	0.211	0.522	0.628	0.568
CD (0.05)	0.698	1.728	2.080	1.880

Table18. Evaluation of bitter gourd grafts on number of male flowers, number of female flowers, sex ratio and days to first harvest.

Treatments	Number of male flowers	Number of female flowers	Sex ratio	Days to first harvest
T_1 (sponge gourd)	208.33	13.00	16.12	72.67
T_2 (pumpkin)	204.00	9.67	21.23	66.33
T_3 (bottle gourd)	185.00	10.67	17.89	77.33
T_4 (bitter gourd)	211.33	11.33	18.67	67.33
T_5 (control)	228.33	14.67	15.59	62.33
SE (m) $\pm$	0.119	0.907	1.12	1.650
CD (0.05)	NS	3.003	3.71	5.464

respectively), while bitter gourd grafted onto bottle gourd rootstock (T_3) took 77.33 days for their first harvest.

4.2.2.9. Duration of the crop

Data regarding the duration of the crop given in table 19 revealed that bitter gourd grafted onto sponge gourd rootstock (T_1) and bitter gourd grafted onto bottle gourd rootstock (T_3) were on par in extending the harvest period to 109.33 days and 105.33 days respectively, whereas bitter gourd grafted onto bitter gourd rootstock (T_4) exhibited shorter crop duration (94.33 days).

4.2.2.10. Fruits / plant

Perusal of the data regarding the fruits per plant given in table 19 suggests that non grafted control (T_5) and bitter gourd grafted onto sponge gourd rootstock (T_1) were on par in producing more fruits per plant (14.00 and 12.67 respectively), while fruits were lower (9.67) in bitter gourd grafted onto pumpkin rootstock (T_2).

4.2.2.11. Yield per plant (kg)

As depicted in table 19, yield varied significantly within the treatments. Non grafted control (T_5) and bitter gourd grafted onto sponge gourd rootstock (T_1) were on par in exhibiting higher yield (2.73 kg and 2.47 kg respectively), whereas the yield was lower (1.80 kg) for bitter gourd grafted onto pumpkin rootstock (T_2).

4.2.3. Fruit Parameters

Effect of treatments on fruit quality parameters are depicted in Table 20.

4.2.3.1. Fruit girth (cm)

From the data, it could be inferred that treatments had no significant effect on fruit girth.

4.2.3.2. Fruit length (cm)

As depicted in table 20, non grafted control (T_5), bitter gourd grafted onto bitter gourd rootstock (T_4) and bitter gourd grafted onto sponge gourd rootstock (T_1) were on par in producing longer fruits (25.00 cm, 24.75 cm and 24.25 cm respectively),while the lowest fruit length (20.25 cm) was recorded in bitter gourd grafted onto bottle gourd rootstock (T_3).

4.2.3.3. Flesh thickness (mm)

From table 20 it is evident that bitter gourd grafted onto pumpkin rootstock(T_2), bitter gourd grafted onto sponge gourd rootstock (T_1), non grafted control(T_5) and bitter gourd grafted onto bitter gourd rootstock (T_4) were on par in producing thick flesh fruits (11.50 mm, 10.75 mm, 10.00 mm and 10.00 mm respectively). The least thickness (7.75 mm) was observed in bitter gourd grafted onto bottle gourd rootstock (T_3).

4.2.3.4. Fruit weight (g)

As depicted in table 20, bitter gourd grafted onto bottle gourd rootstock (T_3) and bitter gourd grafted onto bitter gourd rootstock (T_4) recorded the highest fruit weight of 181.50 g followed by bitter gourd grafted onto sponge gourd rootstock (T_1) with an average fruit weight of 168.75 g. The lowest fruit weight of 163.75 g was recorded for bitter gourd grafted onto pumpkin rootstock (T_2).

4.2.3.5. Vitamin C (mg/100g)

Perusal of the data given in table 21 revealed that vitamin C content varied from 98.50 mg/100g to 104.00 mg/100g, but did not differ significantly within the treatments.

4.2.3.6. Organoleptic test

Organoleptic test was found to be non significant within the treatments (Table 21).

4.2.4. Incidence of pest and diseases

Major pests observed in the field were fruit fly, white fly, pumpkin beetle, leaf miner and epilachna beetle. Mosaic was the major disease observed in the field.

4.2.5. B:C Ratio

The B:C ratio was higher (1.67) for non grafted control (T_5) with the value which was followed by bitter gourd grafted onto sponge gourd rootstock (T_1) with a B:C ratio of 1.50 (Table 22).

Table19. Evaluation of bitter gourd grafts on duration of the crop, fruit per plant and yield per plant.

Treatments	Duration of the crop (days)	Fruits/plant	Yield per plant (kg)
T_1 (sponge gourd)	109.33	12.67	2.47
T_2 (pumpkin)	98.00	9.67	1.80
T_3 (bottle gourd)	105.00	10.00	2.10
T_4 (bitter gourd)	94.33	10.67	2.17
T_5 (control)	96.33	14.00	2.73
SE (m) ±	1.817	0.931	0.119
CD (0.05)	6.016	3.083	0.393

Table 20. Evaluation of bitter gourd grafts on fruit parameters

Treatments	Fruit girth (cm)	Fruit length (cm)	Flesh thickness (mm)	Fruit weight (g)	Vitamin C (mg/100g)
T_1 (sponge gourd)	15.00	24.25	10.75	168.75	101.50
T_2 (pumpkin)	14.77	21.50	11.50	163.75	103.25
T_3 (bottle gourd)	15.50	20.25	7.75	181.50	98.50
T_4 (bitter gourd)	18.00	24.75	10.00	181.50	104.00
T_5 (control)	16.00	25.00	10.00	166.75	103.50
SE (m) ±	0.914	0.351	0.534	0.959	1.307
CD (0.05)	NS	1.092	1.664	2.986	NS

Table 21. Organoleptic test for bitter gourd

Treatments	Appearance (mean score)	Texture (mean score)	Taste (mean score)	Flavour (mean score)	Overall acceptability (mean score)
T_1 (sponge gourd)	8.30	7.20	7.10	7.60	6.70
T_2 (pumpkin)	8.40	7.20	7.60	7.90	7.30
T_3 (bottle gourd)	8.00	7.10	8.10	8.20	8.00
T_4 (bitter gourd)	8.40	6.70	7.50	7.80	6.90
T_5 (control)	8.40	7.40	7.80	8.10	7.40
k value	4.19	1.52	3.85	2.11	5.63
χ^2	9.49				

Table 22. B:C Ratio of bitter gourd grafts

Treatments	Net returns (Rs)	Cost of cultivation (Rs)	B:C Ratio
T_1 (sponge gourd)	Rs .926250	Rs.619020	1.50
T_2 (pumpkin)	Rs. 675000	Rs. 642520	1.05
T_3 (bottle gourd)	Rs. 787500	Rs. 641020	1.23
T_4 (bitter gourd)	Rs. 813750	Rs. 629520	1.29
T_5 (control)	Rs. 1012500	Rs. 604980	1.67

Discussion

5. DISCUSSION

Bitter gourd (*Momordica charantia* L.) is an important cucurbit vegetable of Kerala. Grafting with resistant rootstocks can be a tool to manage different biotic and abiotic stress. However, possibilities of grafting in cucurbits is not explored in Kerala till yet. In this context, the study entitled "Standardisation of grafting in bitter gourd (*Momordica charantia* L.)" was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani during 2017-2019 in order to identify suitable rootstocks, standardise grafting techniques and evaluate growth and performance of grafts in bitter gourd. The study was conducted in two parts. Standardisation of grafting in bitter gourd using four rootstocks was done in part I and evaluation of the grafted bitter gourd for growth, yield and quality was attempted in part II. The results obtained are discussed in this chapter

5.1. STANDARDISATION OF GRAFTING IN BITTERGOURD

5.1.1. Days taken for germination of stock and scion

Among the four rootstocks, significantly less number of days (2.67) were required for germination of pumpkin seeds when compared to other rootstocks. Bitter gourd (scion) was slower to germinate (7.68 days). Observation on number of days taken for germination of rootstocks and scion could be crucial in adjusting the sowing time of rootstocks and scion seeds. By adjusting the sowing time, stem diameter of both rootstock and scion could be regulated so that thickness suited for each grafting method was obtained. So it becomes necessary to calculate the number of days taken for seed germination before grafting. Hence, bitter gourd seeds needed to be sown prior to rootstock seeds.

5.1.2. Days taken to attain graftable size

Among the rootstocks, pumpkin attained graftable size earlier (7 days) since it germinated faster compared to other rootstocks followed by bottle gourd. Eventhough sponge gourd germinated faster, it did not reach graftable size earlier like pumpkin because of its thinner stem diameter. Bitter gourd took more days to attain graftable size (14 days) due to its late germination. The result is in conformity with Akhila and George (2017) who stated that standards for the scions and rootstocks to reach graftable size were based on width of scion and rootstock and their aptness for grafting method and observed least number of days to attain graftable size for pumpkin and bottle gourd.

5.1.3. Experiment -1- Grafting bitter gourd on to sponge gourd

Alar @ 10 mg L^{-1} reduced plant height (7.50 cm) compared to all other treatments and seedlings without any growth regulator application showed higher seedling height of 9.02 cm (Fig.2). Maiko and Musat (1977) stated that B-9 or alar stops biosynthesis of gibberlic acid as well as its activity. This might be the cause for shorter plant heights.

Spraying alar @ 10 mg L^{-1} enhanced diameter (2.97 mm) in sponge gourd rootstock. Rootstock seedlings without any growth regulator application exhibited less diameter (Fig. 3.). Brittain (1967) reported that in alar treated peanut plants, pith parenchyma cells showed higher diameter than cells in untreated plants, thus causing the stem diameter to be larger in treated plants.

Faster graft union (4.11 days) was recorded for hole insertion grafting compared to other two methods. Growth regulators did not exert any significant effect on days taken for graft union however all treatments with growth regulator application along with control in combination hole insertion grafting were on par in reducing the number of days taken for graft union. In hole insertion method, cotyledonary leaves could be retained and also avoid grafting clip. This might have led to the faster graft union in hole insertion method compared to other two methods. This is in conformity with Punithaveni *et al.* (2014) who stated that 'Green long'cucumber grafted on bottle gourd took minimum number of days (6.75) for graft union through hole insertion grafting.

Among the three methods, hole insertion grafting recorded the highest success percentage (77.07 %) and all growth regulators exhibited higher success percentage over control (Fig. 4.). Among them, cycocel @ 50 mg L^{-1} showed the highest percentage success (56.44 %) (Fig.5). Hassell *et al.* (2008) who claimed that when rootstock and scion possess hollow hypocotyls, the hole insertion grafting and one-cotyledon grafting methods are more favored. In sponge gourd rootstock, the stem-scion ratio could be approximately one so, hole insertion grafting is favored than one cotyledon grafting.

5.1.4. Experiment -2- Grafting bitter gourd on to pumpkin

All growth regulator treatments significantly reduced the height of rootstock seedlings compared to control. Among them, alar @ 10 mg L^{-1} and 50 mg L^{-1} reduced the height of the rootstock (12.30 cm and 12.85 cm respectively). Treatments without any growth regulators showed increased seedling height of 15.41 cm (Fig. 2.). All rootstock seedlings were erect at grafting. So, grafting process was more convenient due to reduction in height caused by the application of growth regulators in rootstocks.

Application growth regulators were effective in enhancing diameter in rootstock seedlings compared to control. Among them, cycocel @ 10 mg L^{-1} and 50 mg L^{-1} improved the diameter of pumpkin rootstock (4.99 mm and 4.77 mm respectively) (Fig. 3.). The result was in agreement with Grzyb (1982) who stated that CCC showed a very crucial effect on the increasing diameter of shoot in plum.

New leaf emerged faster (3.51 days) in hole insertion grafting compared to other two methods, while cleft grafting took more days for graft union. Spraying of growth regulators had no effect on days taken for graft union but combination of hole insertion grafting with all growth regulator application along with distilled water were equally effective in reducing the days taken for graft union.

Among the three methods studied, one cotyledon grafting recorded the highest success percentage (68.60 %) and cleft grafting recorded the least (Fig. 4.). This is in agreement with the findings of Guan and Zhao (2015) wherein, one-cotyledon method recorded the highest survival rate (100 %) indicating that this method may have a low requirement for the relative sizes of rootstock and scion plants. Alar @ 10 mg L^{-1}, alar @ 50 mg L^{-1} and cycocel @10 mg L^{-1} were equally effective in improving the success percentage (Fig.5), but the combination of alar @ 10 mg L^{-1} + one cotyledon grafting recorded the highest success percentage of 81 per cent and the least success percentage was obtained in the combination cycocel @ 10 mg L^{-1} + cleft grafting and cycocel @ 50 mg L^{-1} + cleft grafting, when bitter gourd was grafted onto pumpkin rootstock.

5.1.5. Experiment -3-Grafting bitter gourd on to bottle gourd

Application of alar @ 50 mg L^{-1} reduced height (12.61 cm) of rootstock seedlings compared to all other treatments followed by distilled water. Cycocel @ 50 mg L^{-1} recorded the height of rootstock as 14.58 cm at grafting (Fig. 2.).

All growth regulator treatments improved diameter of rootstock seedlings over control. Among them, application of alar @ 10 mg L^{-1} and cycocel @ 50 mg L^{-1} onto bottle gourd rootstock were also equally effective in improving diameter of rootstock seedlings (Fig. 3.)

Among the grafting methods, graft united faster (3.69 days) in hole insertion method. Cleft grafting took more days (6.27 days) for graft union. Growth regulator had no role in days taken for graft union. However all the growth regulator treatments along with control in combination with hole insertion grafting were equally successful in producing new flush of leaves compared to other treatment combinations.

Among the grafting methods, success percentage was the highest (86.40 %) for one cotyledon grafting and least for cleft grafting (Fig. 4.). This finding fall in line with the study of Guan and Zhao (2015), who stated that the decline of success percentage in non cotyledon grafted plants may be due to the inhibited root growth resulting from the removal of both cotyledons from the rootstock. Growth regulator could not improve success percentage over distilled water (Fig. 5.).

5.1.6. Experiment - 4- Grafting bitter gourd on to bitter gourd

Application of alar @ 10 mg L^{-1}, cycocel @ 10 mg L^{-1} and 50 mg L^{-1} were equally effective in reducing the height of bitter gourd rootstock. The minimum reduction in height was recorded in the seedlings without any growth regulator treatment (Fig. 2.). The retardation in plant height caused by cycocel might be due to shortening of internodes by decreasing cell division and cell numbers (Child, 1984).

Alar @ 50 mg L^{-1}, cycocel @ 10 mg L^{-1} and 50 mg L^{-1} improved the diameter of the rootstock. However, the rootstock seedlings treated with alar @ 10 mg L^{-1} exhibited lower diameter (Fig. 3.).

Among grafting methods, hole insertion grafting exhibited faster union hence produced new flush of leaves in 3.57 days and cleft grafting took more days (7.58 days) for graft union. Growth regulators had no influence on days taken for graft union. However, combination of all growth regulator treatments with hole insertion grafting united faster compared to other treatment combinations.

Among grafting methods, hole insertion grafting showed highest percentage of success (68.13 %). Cleft grafting recorded the least success percentage (23.73 %) (Fig. 4.). In bitter gourd rootstock, the stem-scion ratio could be approximately one so, hole insertion grafting is favored than one cotyledon grafting. Among the growth regulators, cycocel @ 50 mg L^{-1} recorded the highest percentage success among growth regulators (Fig.5). Considering the effect of treatment combination, cycocel @ 50 mg L^{-1} + hole insertion grafting recorded the highest percentage success of 86.67 per cent and this was on par with cycocel @ 50 mg L^{-1} + one cotyledon grafting where the success percentage was 85.33 per cent.

The success of grafting depends on various factors such as size of scion and rootstock, cultural condition, method of grafting, tissue and structure differences, biochemical and physiological characteristics, growth stage of rootstock and scion, phytohormone and environment (Davis *et al.*, 2008).

5.2. EVALUATION OF GRAFTED BITTER GOURD FOR GROWTH, YIELD AND QUALITY.

Based on the results of part I, grafts produced by cycocel @ 50 mg L^{-1} + hole insertion grafting in sponge gourd, alar @ 10 mg L^{-1} + one cotyledon grafting in pumpkin, distilled water (control) + one cotyledon grafting in bottle gourd and cycocel @ 50 mg L^{-1} + hole insertion grafting in bitter gourd were selected and planted in main field along with non grafted control for evaluating growth, yield and quality of grafted bitter gourd (Plate 5 , Plate 6 and plate 7) and the result obtained is discussed below.

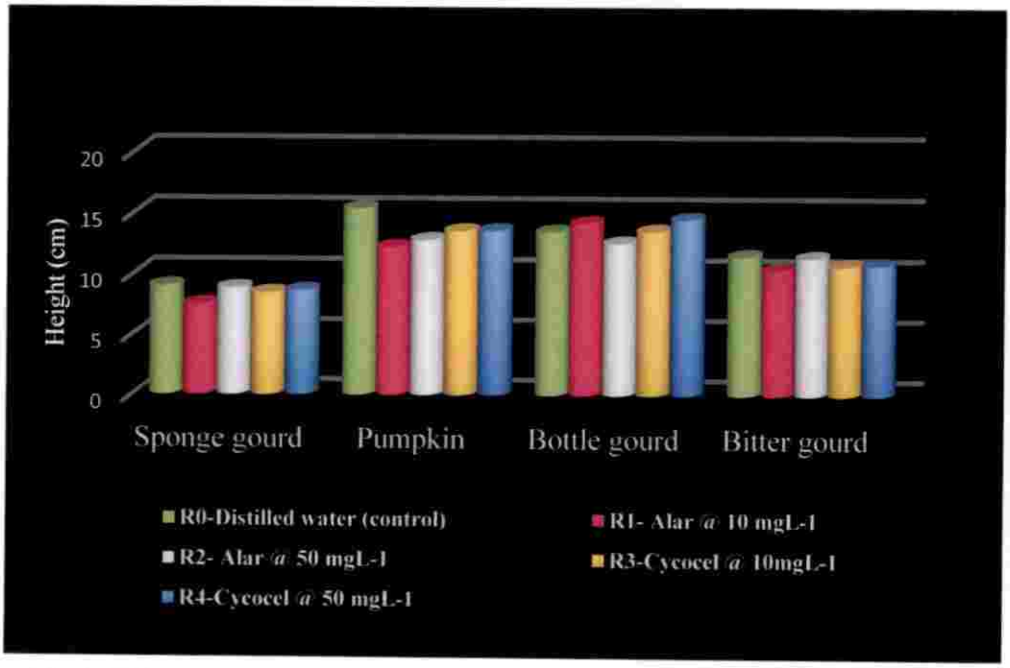

Fig.2. Effect of growth regulator on height of bitter gourd rootstock at grafting

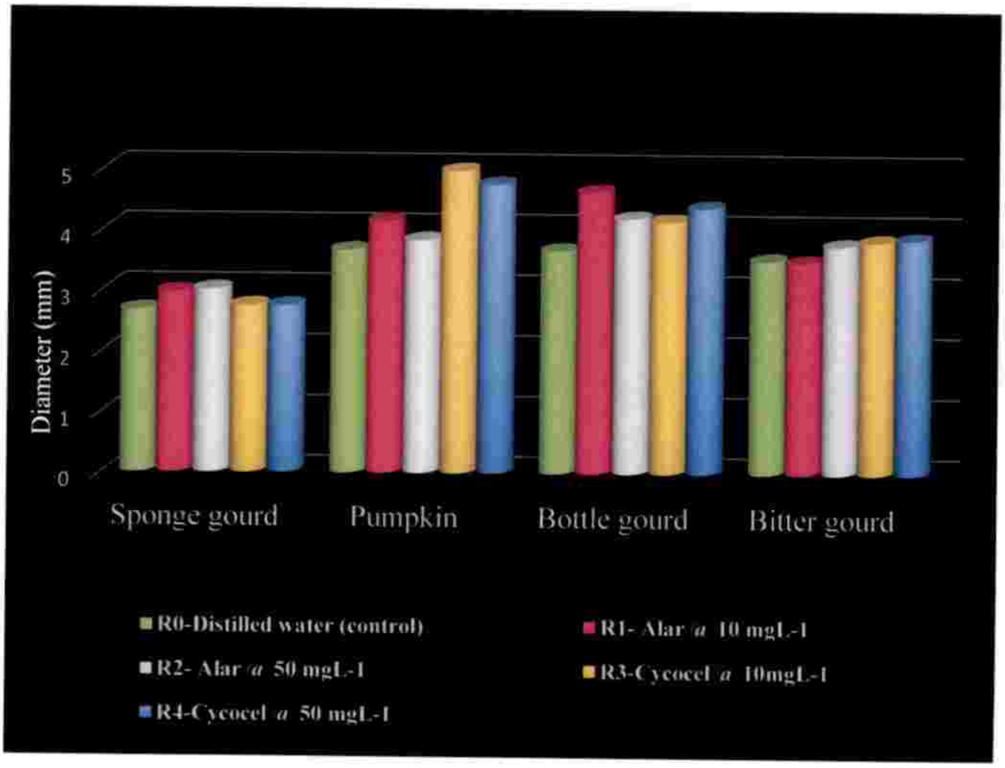

Fig.3. Effect of growth regulator on diameter of bitter gourd rootstock at grafting

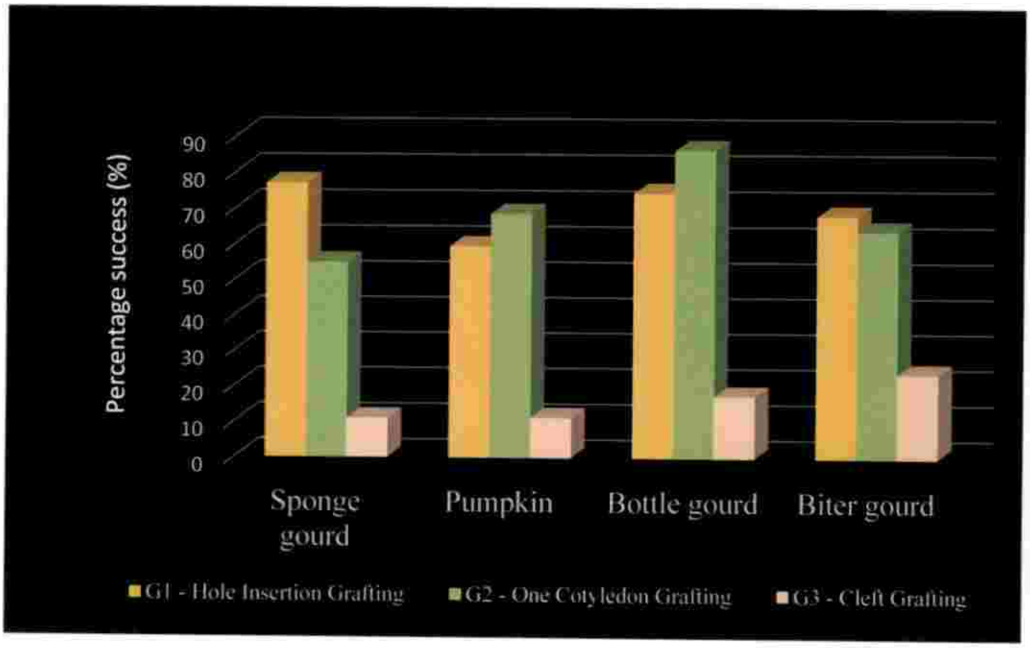

Fig.4. Effect of grafting method on percentage success when bitter gourd grafted on different rootstocks

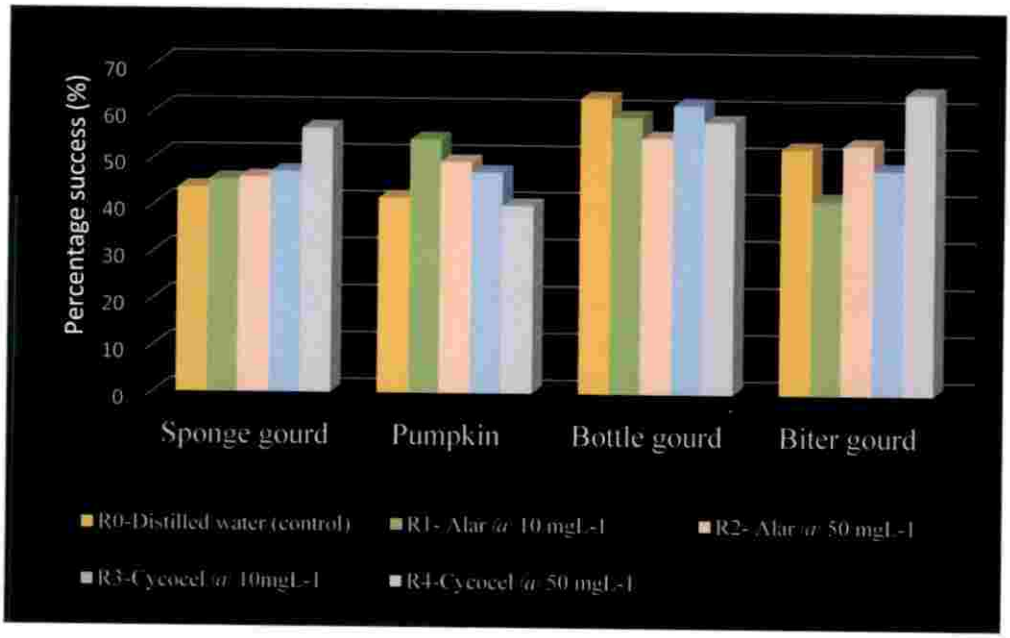

Fig.5. Effect of growth regulator on percentage success when bitter gourd grafted on different rootstocks

T_1 - Cycocel @ 50 mgL^{-1} + Hole Insertion Grafting in sponge gourd root stocks

T_2 - Alar @ 10 mgL^{-1} + One Cotyledon Grafting in pumpkin rootstock

T_3 - Distilled water (control) + One Cotyledon Grafting in bottle gourd rootstock.

T_4 - Cycocel @ 50 mgL^{-1} + Hole Insertion Grafting in bittergourd rootstock.

Plate 5. Best treatments in each experiment selected to Part II

Plate 6. General field view

Sponge gourd | Pumpkin | Bottle gourd | Bitter gourd

Plate 7. Graft union of treatments in main field

5.2.1. Growth parameters

5.2.1.1. Rootstock and scion characters

Significant growth variation could be observed in rootstock hypocotyls throughout the growing period. All rootstock possess thicker hypocotyls than self rootstock among which bottle gourd was thicker and was consistent throughout the entire cropping period.

In the initial growing period, pumpkin rootstock showed thicker scion hypocotyls than other rootstocks. The least diameter was observed in bitter gourd grafted onto sponge gourd rootstock. However, this growth variation became insignificant in later growing period which might be the ability of bitter gourd grafted onto sponge gourd rootstock in enhancing the diameter of scion hypocotyl from fourth fortnight onwards.

Among the grafted treatments, establishment of grafts was higher for bitter gourd grafted on sponge gourd (Fig.6). Yetisir and Sari (2004) demonstrated that the survival rate of grafted plants was inversely correlated with the difference in diameters of scion and rootstock. The stem-root diameter ratio could be approximately 0.98, hence recorded the highest percentage of establishment. Tamilselvi and Pugalendi (2017) also reported that bitter gourd scion grafted onto sponge gourd had the highest survival percentage.

The low survival rate observed in bitter gourd scions grafted pumpkin rootstock (Fig.6) may be due to anatomical mismatching, resulting in misalignment of cambial regions of rootstock and scion. This misalignment of the cambial region led to tissue death in the wounded areas of the rootstock and scion and subsequent scion death (Tamilselvi and Pugalendi, 2017).

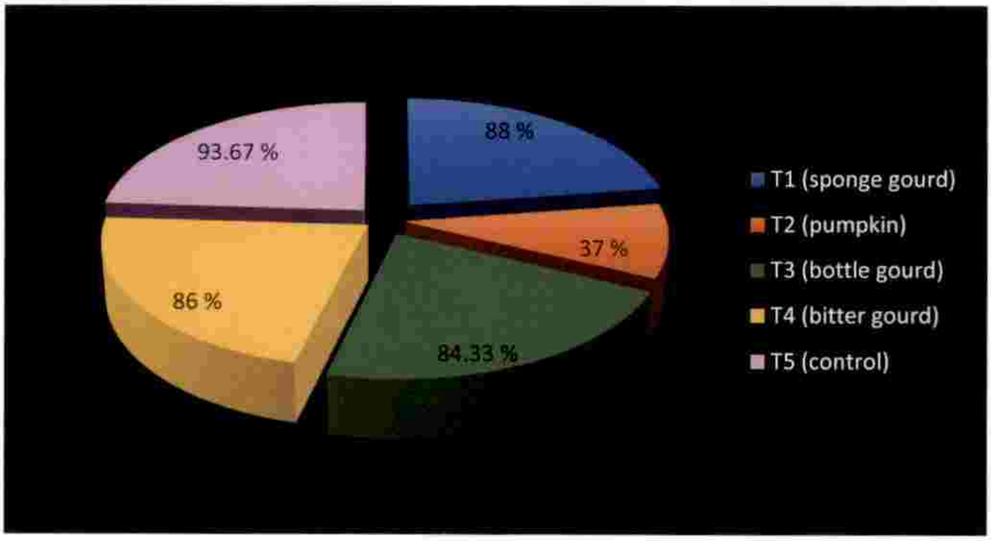

Fig.6. Evaluation of bitter gourd grafts on establishment of grafts.

5.2.1.2. Vegetative characters

In the present study, vine length was significantly higher for non grafted control since, growth retardants were applied in all rootstocks except bottle gourd rootstock. This finding can be justified by Maiko and Musat (1977) who stated that B-9 or alar stops biosynthesis of GA as well as its activity. Bora and Sarma (2006) revealed that shoot growth was reduced in pea when plant was treated with cycocel.

The lowest vine length was recorded in bitter gourd grafted on to pumpkin rootstock as evident from the graft establishment percentage. The low performance of bitter gourd onto pumpkin rootstock justified by inappropriate graft relations that can encourage undergrowth of the scion, which can lead to reduced water and nutrient uptake through the graft union (Hartmann *et al.*, 1997; Davis *et al.,* 2008; Ballesta *et al.*, 2010). It was described that the plant hormones are vital endogenous factors which control all characteristics of vegetative growth and thus are supposed to be important in root-shoot communication (Aloni *et al.*, 2010).

Internodal length was higher for non grafted control. However, the result was on par with bitter gourd grafted on to bitter gourd rootstock. Reduction in intermodal length can be correlated with reduction in plant height of the plant. From this, it is evident that grafting with other rootstock can reduce the internodal length in plants.

The number of primary branches per plant is yet another yield contributing trait in bitter gourd. Bitter gourd grafted onto bitter gourd rootstock and bitter gourd grafted on sponge gourd rootstock significantly produced more primary branches. In both these rootstocks, cycocel @ 50 mg L^{-1} was used as growth regulators for reducing rootstock seedling height. This is in conformity with Mandal *et al.* (1997) who indicated a significant increase in the number of branches per plant due to the application of CCC @ 100 ppm in green gram. Moreover, Alan *et al.* (2007) stated that the grafted watermelon plants produced more lateral vines than non grafted plants.

5.2.1.3. Root characters

Root length, root volume and root weight was highest for pumpkin rootstock. This was in line with the findings of Tamilselvi (2013) who revealed that maximum root length was showed by African horned cucumber (16.46 cm) followed by pumpkin *(Cucurbita moschata)* with 15.70 cm.

5.2.2. Yield Parameters

Earliness is one of the main attributes which is measured in terms of days to first male and female flower appearance and when high yield is coupled with earliness is preferred for commercial cultivation. In the present study, first male flower appeared in bitter gourd grafted on to pumpkin rootstock (Plate 8) and first female flower appeared in bitter gourd grafted on to pumpkin rootstock and self rootstock. Tamilselvi and Pugalendi (2018) when grafted bitter gourd scion Palee F_1 onto pumpkin rootstock exhibited earliness with least days to first flowering when compared to other graft combinations.

Node number for first male and female flower appearance are considered as an important biometric attribute to measure the earliness in cucurbits. The first male and female flower appeared at lower nodes in bitter gourd grafted onto pumpkin, sponge gourd and bitter gourd rootstock. Tamilselvi (2013) also observed that male flowers appeared at the early nodes when bitter gourd ' Palee F_1' and 'CO 1'grafted onto pumpkin rootstock and 'Palee F_1' grafted onto sponge gourd rootstock than the other grafts and non grafted control.

Plate 8. Appearance of first male flower at lower node in bitter gourd grafted onto pumpkin rootstock

Number of male flowers were not influenced by grafting. With regard to number of female flowers, more number of female flowers were noted in non grafted control but at par with bitter gourd grafted on to sponge gourd.

Narrow sex ratio is the desirable trait in cucurbits which depicts the ability of the crop to set fruits. The graft combinations bitter gourd grafted onto sponge gourd and non grafted control had the narrow sex ratio (Fig.7) since more female flowers are produced in these treatments. Sex expression and flowering order is controlled by plant hormones. The rootstock-scion combination may alter the amount of hormones produced and their influence on grafted plants (Davis *et al.*, 2008)

Early harvest was recorded in non grafted control, bitter gourd grafted on pumpkin and bitter gourd. Observation on days to first harvest is yet another sign of the earliness of any vegetables which could procure premium price and catch the early market. Earliness in terms of days to first harvest is one of the yield determining characters, when number of days are reduced, it is expected to give more number of harvests (Tamilselvi and Pugalendi, 2018).

Higher the fruit number might increase yield. The higher fruit number was observed in non grafted control which is on par with bitter gourd grafted on sponge gourd. This increase in yield can be correlated with increase in female flowers.

In the present study, yield was higher in non grafted control which was on par with bitter gourd grafted on to sponge gourd (Fig.7). The amount of the yield was decided in greater extent by average fruit number per plant when compared to the average fruit weight. These results substantiate those recorded by Seong *et al.* (2003) and Al-Debei *et al.* (2012) where the yield increase was mainly due to the increase in number of fruit per plant rather than the increase in average fruit weight. This result is in agreement with (Brajeul and Letard, 1998) in which higher yields were not obtained in grafted cucumber. The increase in yield could be correlated

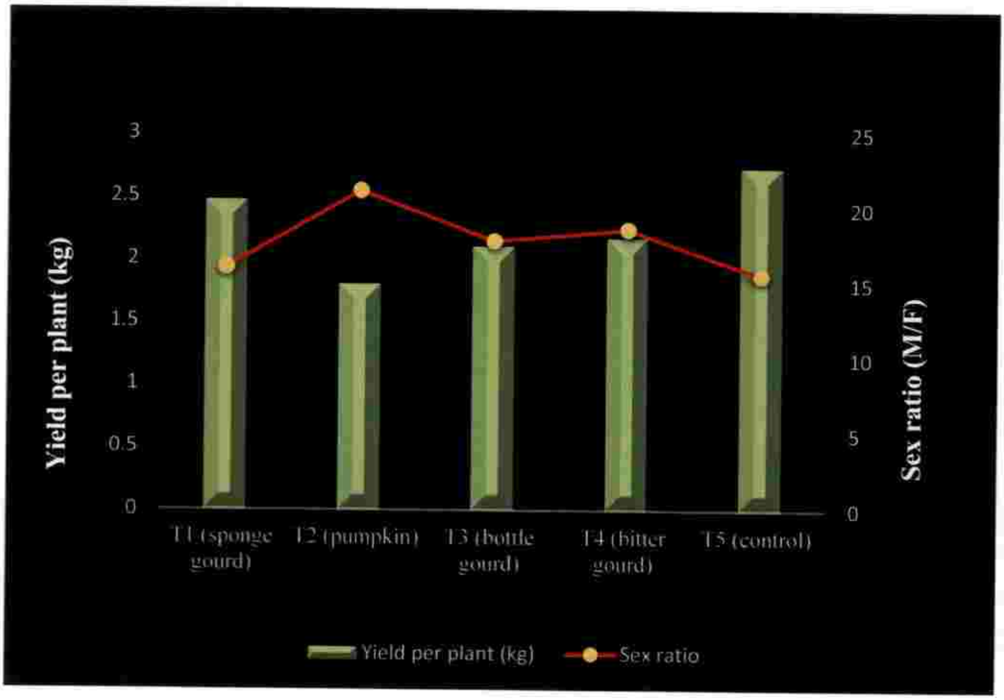

Fig.7. Evaluation of bitter gourd grafts on yield and sex ratio.

with more branches per plant, early harvest, more number of female flowers, narrow sex ratio and extended duration.

In the present investigation, bitter gourd grafted on sponge gourd and bottle gourd rootstock remained in the field for longer time than non grafted control. This is in conformity with Tamilselvi (2013) who reported that bitter gourd variety CO1 grafted on sponge gourd (*Luffa cylindrica*) rootstock persisted for 144.75 days compared to other rootstocks.

Possible mechanism for increased crop productivity for more duration might be due to increased water and nutrient uptake by vigorous rootstock improved stomatal conductance thereby increased crop growth (Ruiz *et al*., 1996; Leonardi and Giuffrida, 2006).

5.2.3. Fruit quality parameters

In the present study, fruit girth varied from 14.77 cm to 18.00 and no significant differences were found in fruit girth of grafted and non grafted plants.

Non grafted control showed the highest fruit length which was on par with bitter gourd grafted onto bitter gourd rootstock and bitter gourd grafted onto sponge gourd rootstock (Plate 9).

Flesh thickness was higher in bitter gourd grafted onto pumpkin rootstock which was on par with bitter gourd grafted onto sponge gourd rootstock, non grafted control and bitter gourd grafted onto bitter gourd rootstock (Plate 10). Similar findings were reported by Tamilselvi (2013) where bitter gourd scion Palee F_1 grafted onto pumpkin rootstock showed the maximum for flesh thickness.

Camacho *et al*. (2011) observed that average fruit weight was influenced by grafting. Considering the fruit weight, bitter gourd grafted onto bottle gourd rootstock

Plate 9. Fruit length

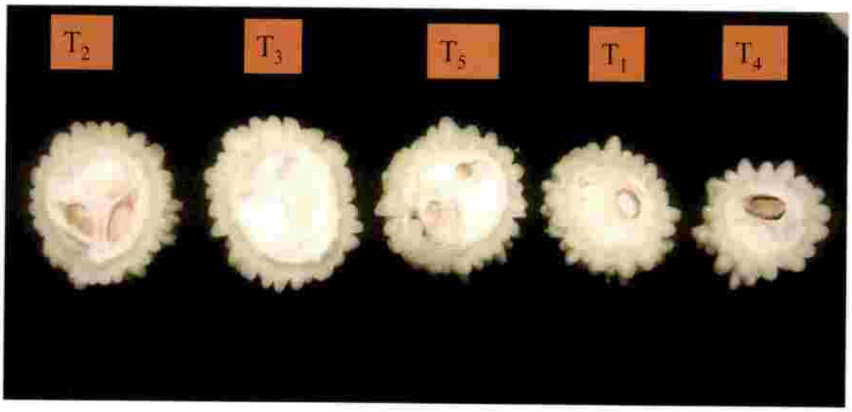

Plate 10. Flesh thickness

and bitter gourd grafted onto bitter gourd rootstock recorded the highest fruit weight. Hamed *et al.* (2012) also reported that maximum fruit weight (7.00 kg) was obtained in watermelon grafted onto bottle gourd rootstock.

Savvas *et al.* (2011) stated that method of grafting and choice of rootstock had no influence on any quality characteristics. In the present study, Vitamin C content did not differ significantly within the treatments. The result is supported by Zhong and Bie (2007) who noticed that with the fruit development, fruit ascorbic acid, free amino acid and soluble protein content did not change in grafts.

Organoleptic test was found to be non significant within the treatments. Similar findings were reported by Hoyos (2001) who stated that grafting had no effect on the quality, taste, size and shape of the fruit.

5.2.4. B:C Ratio

The B:C ratio was highest for non grafted control (1.67) followed by bitter gourd grafted onto sponge gourd rootstock (1.50). The highest B:C ratio for non grafted control may be due to the absence of laborers for grafting, less seed requirement and increase in fruit number.

In conclusion, grafts of bitter gourd variety Preethi can be produced with highest success percentage by cycocel @ 50 mg L^{-1} spray at second leaf stage + hole insertion grafting using sponge gourd as rootstocks, alar @ 10 mg L^{-1} spray at second leaf stage + one cotyledon grafting using pumpkin as rootstock, one cotyledon grafting without growth regulator using bottle gourd as rootstock. Among these grafts, sponge gourd as rootstock produced longest vine, more branches, longer crop duration, on par female flowers, on par sex ratio, on par fruits per plant and yield per plant compared to control. However cultivation of non grafted plants recorded higher B:C ratio.

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Summary

6. SUMMARY

The study entitled "Standardisation of grafting in bitter gourd (*Momordica charantia*L.)" was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani during 2017-2019 in order to identify suitable rootstocks, standardise grafting techniques and evaluate growth and performance of grafts in bitter gourd. The study was conducted in two parts. Standardisation of grafting in bitter gourd using four rootstocks was done in part I and evaluation of the grafted bitter gourd for growth, yield and quality was attempted in part II.

Bitter gourd scion (Preethi) and four rootstocks (sponge gourd, pumpkin, bottle gourd and bitter gourd) were raised in protrays. Separate experiments for each rootstock, were laid out in CRD, replicated thrice for standardization of grafting. Growth regulators (alar and cycocel) at two different concentrations *i.e.*,10 mg L^{-1} and 50 mg L^{-1} were sprayed at second leaf stage for reducing seedling height of rootstocks and then grafted using three methods (hole insertion grafting, one cotyledon grafting and cleft grafting).

Pumpkin and sponge gourd germinated faster but pumpkin attained graftable size earlier (7.00 days) followed by bottle gourd (8.67 days) compared to other rootstocks. Bitter gourd was slower to germinate (7.68 days) and to attain graftable size (14 days).

In experiment 1, alar @ 10 mg L^{-1} reduced plant height (7.50 cm) and enhanced diameter (2.97 mm) in sponge gourd rootstock. Rootstock seedlings without any growth regulator application exhibited more seedling height and less diameter. Faster graft union (4.11 days) was recorded for hole insertion grafting with highest success percentage (77.07 %) followed by cleft grafting. Growth regulators did not exert any significant effect on days taken for graft union but spraying of cycocel @ 50 mg L^{-1} resulted in the highest success percentage of 56.44 per cent followed by cycocel @ 10 mg L^{-1} (47.11 %). Combination of cycocel @ 10 mg L^{-1}+ hole insertion grafting recorded success percentage of 86.67. The least success percentage of 5.33 was recorded by alar @ 50 mg L^{-1}+ cleft grafting, when bitter gourd grafted onto sponge gourd.

In experiment 2, cycocel @ 10 mg L^{-1} and 50 mg L^{-1} improved the diameter of pumpkin rootstock (4.99 mm and 4.77 mm respectively), alar @ 10 mg L^{-1} and 50 mg L^{-1} reduced the height of the rootstock (12.30 cm and 12.85 cm respectively). treatments without any growth regulators showed the least diameter as well as increased seedling height in rootstock. New leaf emerged faster (3.51 days) in hole insertion grafting but one cotyledon grafting recorded the highest success percentage (68.60 %). Cleft grafting not only took more days for graft union but also recorded least success percentage (11.20 %). Spraying of growth regulators had no effect on days taken for graft union. Though alar @ 10 mg L^{-1}, alar @ 50 mg L^{-1} and cycocel @10 mg L^{-1} were equally effective in improving the success percentage but the combination of alar @ 10 mg L^{-1} + one cotyledon grafting recorded the highest success percentage of 81 per cent and the least success percentage was obtained in the combination cycocel @ 10 mg L^{-1} + cleft grafting and cycocel @ 50 mg L^{-1} + cleft grafting, when bitter gourd was grafted onto pumpkin rootstock.

In experiment 3, application of alar @ 10 mg L^{-1} onto bottle gourd rootstock improved diameter (4.65 mm) and @ 50 mg L^{-1} reduced height (12.61 cm). In improving the diameter, cycocel @ 50 mg L^{-1} was also equally effective. Among the grafting methods, graft united faster (3.69 days) in hole insertion method, while success percentage was the highest (86.40 %) for one cotyledon grafting. Cleft grafting took more days (6.27 days) for graft union and also recorded the least success percentage of 17.33 per cent. Growth regulator had no role in days taken for graft union and could not improve success percentage over distilled water. The interaction was also significant in which alar @ 10 mg L^{-1} + one cotyledon grafting and alar @ 50 mg L^{-1} + one cotyledon grafting recorded 88.00 per cent success. The least percentage success exhibited by the combination alar @ 10 mg L^{-1} + cleft grafting and cycocel @ 50 mg L^{-1} + cleft grafting with a success percentage of 8.00 per cent each, when bitter gourd was grafted on to bottle gourd.

In experiment 4, application of alar @ 10 mg L^{-1}, cycocel @ 10 mg L^{-1} and 50 mg L^{-1} were equally effective in reducing the height of bitter gourd rootstock. The minimum reduction in height was recorded in the seedlings without any growth regulator treatment. Alar @ 50 mg L^{-1}, cycocel @ 10 mg L^{-1} and 50 mg L^{-1} improved the diameter of the rootstock.However, the rootstock seedlings treated with alar @ 10 mg L^{-1} exhibited lower diameter. Among grafting methods, hole insertion grafting exhibited faster union (3.57 days) with highest percentage of success (68.13 %). Cleft grafting took more days (7.58 days) for graft union as well as recorded the least success percentage (23.73 %). Growth regulators had no influence on days taken for graft union but cycocel @ 50 mg L^{-1} recorded the highest percentage success among growth regulators. Considering the effect of treatment combination, cycocel @ 50 mg L^{-1} + hole insertion grafting recorded the highest percentage success of 86.67 per cent and this was on par with cycocel @ 50 mg L^{-1} + one cotyledon grafting where the success percentage was 85.33 per cent.

Based on the results of part I, bitter gourd grafts produced by spraying cycocel @ 50 mg L^{-1} + hole insertion grafting in sponge gourd, spraying alar @ 10 mg L^{-1} + one cotyledon grafting in pumpkin, distilled water (control) + one cotyledon grafting in bottle gourd and spraying cycocel @ 50 mg L^{-1} + hole insertion grafting in bitter gourd were selected and planted in main field along with non grafted control in randomised block design replicated four times as part II for evaluating growth, yield and quality of grafted bitter gourd.

In the main field, diameter of the rootstock hypocotyls was highest in bitter gourd grafted onto bottle gourd rootstock in all fortnights. However in first fortnight the result was on par with bitter gourd grafted onto pumpkin rootstock. Regarding diameter of scion hypocotyls, bitter gourd grafted onto pumpkin rootstock recorded the enhanced diameter in 15 days, 30 days and 45 days respectively. However on 30th day the result was on par with bitter gourd grafted onto bottle gourd rootstock. In rest of the fortnights there was no significant variations in the diameter of scion hypocotyls.

All grafts exhibited lower establishment over non grafted control. Within the grafts, bitter gourd grafted on sponge gourd recorded the highest (88 %) success percentage and bitter gourd grafted on pumpkin rootstock recorded the lowest (37 %) success percentage.Bitter gourd grafted on sponge gourd and bottle gourd rootstocks as well as non grafted control had similar vine length. Internodal length was more in non grafted control (6.00 cm) and the least in bitter gourd grafted on bottle gourd rootstock (3.87 cm). More branches (9 .33 and 8.67 respectively) were produced when bitter gourd and sponge gourd were used as rootstocks. Pumpkin rootstock produced longer primary root, higher root volume and root weight. Early appearance of first male and female flowers at lower nodes was also recorded in bitter gourd grafted on pumpkin rootstock.

Though grafting did not significantly influence number of male flowers, the number of female flowers decreased, except in bitter gourd grafted on sponge gourd rootstocks (13.00). Non grafted control, bitter gourd grafted on sponge gourd, bottle gourd and bitter gourd rootstocks exhibited on par sex ratio (15.59, 16.12, 17.89 and 18.67 respectively). Non grafted control, bitter gourd grafted on pumpkin and bitter gourd recorded early harvest but harvesting started slowly in bitter gourd grafted on to bottle gourd rootstock. Bitter gourd grafted on sponge gourd and bottle gourd rootstock extended duration of the crop (109.33 days and 105.00 days respectively).

Non grafted control and bitter gourd grafted on sponge gourd rootstock recorded more fruits per plant (14 and 12.67 respectively) and yield per plant (2.73 kg and 2.47 kg respectively) whereas pumpkin had the least (1.80 kg).

Non grafted control, bitter gourd grafted onto bitter gourd and bitter gourd grafted on to sponge gourd rootstocks exhibited on par fruit length. Bitter gourd grafted onto pumpkin, bitter gourd grafted onto sponge gourd, non grafted control and bitter gourd grafted onto bitter gourd had similar flesh thickness. Bottle gourd and bitter gourd rootstock enhanced fruit weight (181.50 g). Grafts did not differ for fruit girth, vitamin C content and organoleptic properties. Non grafted control recorded highest B:C ratio (1.67) followed by bitter gourd grafted on sponge gourd (1.50).

In conclusion, grafts of bitter gourd variety 'Preethi' can be produced with highest success percentage by cycocel @ 50 mg L^{-1} + hole insertion grafting using sponge gourd as rootstock, alar @ 10 mg L^{-1} + one cotyledon grafting using pumpkin as rootstock, one cotyledon grafting without growth regulator using bottle gourd as rootstock. Among these grafts, sponge gourd as rootstock produced longest vine, more branches, longer crop duration, on par female flowers, sex ratio, fruits per plant and yield per plant compared to control. However, cultivation of non grafted plants recorded higher B:C ratio which necessitate further evaluation of biotic and abiotic tolerance of grafts for benefitting farming community.

In future, biotic and abiotic stress tolerance of bitter gourd grafts may be evaluated, possibility of reducing sex ratio (M/F) through hormonal or cultural modification may be explored and suitability of bitter gourd grafts under organic production systems may be evaluated.

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Abstract

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STANDARDISATION OF GRAFTING IN BITTER GOURD

(*Momordica charantia* L.)

by

AISWARYA V DEV K P

(2017- 12-033)

Abstract of the thesis

Submitted in partial fulfilment of the

requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

Kerala Agricultural University

DEPARTMENT OF VEGETABLE SCIENCE

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM – 695 522

2019

ABSTRACT

The study entitled "Standardisation of grafting in bitter gourd (*Momordica charantia* L.)" was conducted in the Department of Vegetable Science, College of Agriculture, Vellayani during 2017-2019 in order to identify suitable rootstocks, standardise grafting techniques and evaluate growth and performance of grafts in bitter gourd. The study was conducted in two parts. Standardisation of grafting in bitter gourd using four rootstocks was done in part I and evaluation of the grafted bitter gourd for growth, yield and quality was attempted in part II.

Bitter gourd scion (Preethi) and four rootstocks (sponge gourd, pumpkin, bottle gourd and bitter gourd) were raised in protrays. Separate experiments for each rootstock, were laid out in CRD, replicated thrice for standardization of grafting. Growth regulators (alar and cycocel) at two different concentrations *i.e.*,10 mgL^{-1} and 50 mgL^{-1} were sprayed at second leaf stage forreducing seedling height of rootstocks and then grafted using three methods (hole insertion grafting, one cotyledon grafting and cleft grafting).

Alar @10 mg L^{-1} reduced plant height (7.50 cm) and enhanced diameter (2.97 mm) in sponge gourd rootstock. Faster graft union(4.11 days) was recorded forhole insertion grafting withhighest success percentage (77.07 %). Spraying of cycocel @ 50 mg L^{-1} resulted in the highest success percentage of 56.44 per cent. Combination of cycocel @ 50 mg L^{-1}+ hole insertion grafting recorded highest success percentage of 86.67 when bitter gourd grafted onto sponge gourd.

Though cycocel @ 10 mgL^{-1} and 50 mgL^{-1} improved the diameter of pumpkin rootstock, alar@ 10 mgL^{-1} and 50 mgL^{-1}reduced the height of the rootstock. New leaf emerged faster (3.51 days) in hole insertion grafting but one cotyledon grafting recorded the highest success percentage (68.60 %). Cleft grafting not only took more days for graft union but also recorded least success percentage (11.20 %). Though

alar @ 10 mgL^{-1}, alar@50 mg L^{-1} and cycocel @10 mg L^{-1} were equally effective to improve success percentage but the combination of alar @ 10 mg L^{-1} + one cotyledon grafting recorded the highest success percentage of 81 per centwhen bitter gourd was grafted onto pumpkin.

Application of alar @ 10 mg L^{-1}onto bottle gourd rootstock improved diameter (4.65 mm) and @ 50 mg L^{-1} reduced height (12.61 cm). Among the grafting methods, graft united faster (3.69 days) in hole insertion method, while success percentage was the highest (86.40 %) for one cotyledon grafting. Growth regulator had no role in days taken for graft union and could not improve success percentage over distilled water.

Application of alar @ 10mg L^{-1} cycocel @ 10 mg L^{-1} and 50 mg L^{-1} were equally effective in reducing the height of bitter gourd rootstock. Alar @ 50 mg L^{-1}, cycocel @ 10 mg L^{-1}and @ 50 mg L^{-1} improved the diameter of the rootstock. Among grafting methods, hole insertion grafting exhibited faster union (3.57 days) with highest percentage of success (68.13 %). Cycocel @ 50 mg L^{-1} recorded the highest percentage success among growth regulators.

Based on the results of part I, grafts produced by cycocel @ 50 mgL^{-1} + hole insertion grafting in sponge gourd, alar @ 10 mgL^{-1} + one cotyledon grafting in pumpkin, distilled water (control) + one cotyledon grafting in bottle gourd and cycocel @ 50 mg L^{-1} + hole insertion grafting in bittergourd were selected and planted in main field along with non grafted control in randomised block design replicated four times for evaluating growth, yield and quality of grafted bitter gourd.

All grafts exhibited lower establishment over non grafted control.Bitter gourd grafted onsponge gourd andbottle gourd rootstocks as well asnon grafted control had similar vine length. Internodal length was more in non grafted control (6.00 cm). More branches were produced when bitter gourd and sponge gourd were used as

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rootstocks.Pumpkin rootstock produced longer primary root, higher root volume and root weight. Early appearance of first male and female flowers at lower nodes was also recorded in bitter gourd grafted on pumpkin rootstock.

Though grafting did not significantly influence number of male flowers, the number of female flowers was higher in non grafted control and bitter gourd grafted on sponge gourd. Non grafted control, bitter gourd grafted on sponge gourd, bottle gourd and bitter gourd rootstock exhibited on par sex ratio.Non grafted control, bitter gourd grafted on pumpkin and bitter gourd recorded early harvest but bitter gourd grafted on sponge gourd and bottle gourd rootstock extended duration of the crop. Non grafted control and bitter gourd grafted on sponge gourd rootstock recorded more fruits per plant and yield per plant.

Non grafted control, bitter gourd grafted onto bitter gourd and bitter gourd grafted on to sponge gourdexhibited on par fruit length. Bitter gourd grafted onto pumpkin, bitter gourd grafted onto sponge gourd, non grafted control and bitter gourd grafted onto bitter gourd had similar flesh thickness. Bottle gourd and bitter gourd rootstock enhanced fruit weight (181.50 g). Grafts did not differ for fruit girth, vitamin C content and organoleptic properties. Nongrafted control recorded highest B:C ratio (1.67) followed by sponge gourd (1.50).

In conclusion, grafts of bitter gourd variety 'Preethi' can be produced with highest success percentage by cycocel @ 50 mgL^{-1} + hole insertion graftingusing sponge gourd as rootstock, alar @ 10 mgL^{-1} + one cotyledon grafting using pumpkin as rootstock, one cotyledon grafting without growth regulator using bottle gourd as rootstock. Among these grafts, sponge gourd as rootstock produced longest vine, more branches, longer crop duration, on par female flowers, sex ratio, fruits per plant and yield per plant compared to control. However, cultivation of non grafted plants recorded higher B:C ratio which necessitate further evaluation of biotic and abiotic tolerance of grafts for benefitting farming community.

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