STANDARDISATION OF GRAFTING IN BITTER GOURD (*Momordica charantia* L.) AND WATERMELON (*Citrullus lanatus* (Thunb.))

by

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(2015-12-001)

THESIS

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DECLARATION

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

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LIST OF ABBREVIATIONS

^{0}C	Degree Celcius
cm	Centimeter
CMV	Cucumber Mosaic Virus
CRD	Completely Randomised Design
cv.	Cultivar
dwt	Dry weight
E	East
Fig.	Figure
g	gram
HIG	Hole insertion grafting
kg	kilogram
%	Percent
m	Meter
min	Minutes
mg	Milligram
mm	Millimeter
MSL	Mean Sea Level
N	North
PRSV	Potato Ring spot virus
RBD	Randomised Block Design
TAG	Tongue Approach grafting
TSS	Total Soluble Solids
viz.,	Namely
WMV	Watermelon mosaic virus
ZYMV	Zucchini Yellow vein Mosaic Virus

INTRODUCTION

1. INTRODUCTION

Bitter gourd (*Momordica charantia* L.) and watermelon (*Citrullus lanatus* (Thunb.)) are popular warm season vegetables belonging to the family Cucurbitaceae. In India, area under bitter gourd and watermelon are reported to be 75,890 ha and 83,580 ha with an annual production of 7.70 lakh tonnes and 20.49 lakh tonnes respectively. In Kerala, area under bitter gourd and watermelon are 3320 ha and 92 ha and the production being 42,810 tonnes and 1,330 tonnes respectively (NHB, 2015). These crops occupy a unique position among cultivated cucurbits in Kerala. Short duration and premium market price make it remunerative for vegetable growers in Kerala. Bitter gourd and watermelon have high market demand owing to their culinary and dessert value respectively.

Bitter gourd is cultivated throughout the country for its immature fruits which are used as vegetable. Fruits are used in the treatment of rheumatism, gout, leprosy and diseases of liver and spleen. Seeds has antihelminthic property and is used as vermifuge. Vitamin C content in bitter gourd is the highest (88 mg per 100g of edible portion) among other cucurbitaceous vegetables. It also contains fairly high amounts of Sodium (17.8 mg/100 g), Potassium (152 mg/100 g), Phosphorous (70 mg/100 g) and Magnesium (17 mg/100 g) (Rahman *et al.*, 2008). The fruit, fruit juice and dried fruit powder are widely used in traditional medicines for treating diabetes or hyperglycemia. Hypoglycemic compounds reported include a polypeptide (p-insulin) and a steroid mixture (charantin) in fruits and a pyrimidine nucleoside (vicine) in seeds (Raman and Lau, 1996).

Watermelon, a popular dessert vegetable of the tropics contains about 6.00 per cent sugar and 92.00 per cent water by weight and is an excellent source of vitamin A in the form of lycopene, a carotenoid of high antioxidant property. Though widely grown for its ripe fruits, watermelon rind is also used in making pickles. Rind and flesh contains citrulline, a non-essential amino acid which has potential antioxidant and vasodilatation roles. Citrulline content of the flesh ranges from 3.9 to 28.5 mg g^{-1} dry weight. Red fleshed watermelon has slightly less citrulline (7.4 mg g^{-1} dwt) than yellow fleshed (28.5 mg g^{-1} dwt) (Rimando and Perkins-Veazie, 2005). Traditionally fruits are used as expectorant, aphrodisiac, demulcent, and diuretic.

The intensive cultivation of these crops have favoured the incidence of various pests and diseases. Incidence of root knot nematode (*Meloidogyne incognita*) and Fusarum wilt caused by *Fusarium oxysporum* f. sp. *momordicae* in bitter gourd and *Fusarium oxysporum* f. sp. *niveum* in watermelon are the major problems that affect successful cultivation of these crops. Plant parasitic nematodes are soil inhabiting microscopic roundworms that attack the roots of plants. Nematodes damage the root system by disrupting the flow of water and nutrients causing stunted growth and poor crop stand. In addition to the direct crop damage caused by nematodes, many of these species predispose plants to infection by fungal or bacterial pathogens or transmit virus diseases, which contribute to additional yield reductions. Kaur and Pathak, 2011 reported that root knot nematode causes 38.00 to 48.20 per cent yield loss in bitter gourd. Similarly, in watermelon root knot nematode is reported to reduce the number of fruits by 19 per cent and weight of fruits by 23 per cent in non-fumigated plots when compared with methyl bromide fumigated plots (Davis, 2005). Nematode problem is more serious under protected cultivation.

Grafting with resistant rootstocks is one of the best methods to avoid soil borne pathogens and nematodes. Grafting in vegetables is common in many parts of the world. First attempt in raising grafted vegetable plants started in Japan and Korea in late 1920s by grafting watermelon onto bottle gourd for imparting resistance to Fusarium wilt. Using resistant rootstocks for grafting is an environment-friendly technique for sustainable production of vegetables as it reduces the dependence on soil disinfectants (Rivard and Louws, 2008). In organic vegetable production where use of chemicals is restricted, an ecofriendly technique like grafting is promising. Grafting is a potential alternative tool to the conventional breeding methods which demands prolonged screening and selection to impart resistance to a cultivar.

In addition to site specific management tool for soil borne insects and pathogens, grafting also imparts resistance to abiotic stresses, increases yield, extends harvest period, manipulates sex expression and improves fruit quality. Survival rate of grafted plants depends on stock-scion compatibility and post graft management. Kumar and Sanket, 2017 reported that Europe and Spain rank first in grafted seedling production with 129 million seedlings followed by Italy and France.

In India, grafting work in vegetables was initiated by Dr. K. M. Bhatt and his associates in IIHR (Indian Institute of Horticultural Research), Bangalore to identify rootstocks suited for waterlogged situations. In Kerala, NBPGR regional station, Thrissur have grafted female plants of *Momordica cochinchinensis* onto male plants to increase its production (Kumar *et al.*, 2015). Grafting technology standardised in Solanaceous crops at ARS (Agricultural Research Station), Kerala Agricultural University has proved successful against bacterial wilt and grafted plants are of high demand among the farmers. Commercial use of vegetable grafting is a relatively recent innovation. Information on the effect of various rootstocks on the performance of cucurbits in Kerala is meagre. In this study an attempt was made to identify best stock scion combination using resistant/ tolerant rootstocks.

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

- To identify best rootstocks for grafting bitter gourd and watermelon.
- To compare two grafting methods namely, hole insertion grafting and tongue approach grafting.
- To evaluate the effect of various cucurbitaceous rootstocks on survival, growth and yield of bitter gourd and watermelon.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Vegetable grafting in simple terms can be referred to as uniting two living plant parts so that they grow as a single plant. Even though grafting has been practiced in fruit trees for thousands of years, the commercial use of vegetable grafting is relatively recent innovation. Soil borne diseases *viz.*, Fusarium wilt, bacterial wilt and nematodes are serious problems in vegetable cultivation. Therefore, grafting of desired scion on suitable rootstock is practiced especially in vegetables to solve the problem of nematodes and soil borne diseases. Typically, scion is inserted into rootstock so that cambium tissues align and form a graft union. Grafting is a short term, less expensive and more flexible solution for controlling soil borne diseases than breeding new resistant cultivar.

Vegetable grafting originated in Japan and Korea to avoid crop loss caused by soil borne diseases. This practice is spreading and expanding rapidly over the world. Raising of grafted vegetable plants started in Japan and Korea in late 1920s with watermelon (*Citrullus lanatus* (Thunb.)) grafted onto bottle gourd rootstock to overcome problems associated with yield decline caused by soil borne diseases (Lee 1994).

No systematic attempt has been made to study the effect of grafting cucurbits on various resistant rootstocks in Kerala so far. Hence the present study was aimed to standardise grafting technique in bitter gourd and watermelon and to study the performance of successful grafts in the field. The pertinent literature relevant in this aspect is reviewed under the following sub heads.

2.1 Purpose of vegetable grafting

The main objective of grafting is to avoid various biotic and abiotic stresses. Use of resistant rootstocks helps to reduce the need for soil fumigation and frequent pesticide treatment. In sustainable vegetable farming where use of chemicals is restricted, an ecofriendly technique like grafting can be adopted. In addition to suppression of soil borne diseases, grafting provides significant effects on fruit quality, manipulating harvest period, sex expression and suppression of abiotic stresses.

According to Oda (2002) the primary motive of grafting in cucurbits was to overcome damage caused by soil borne pests and pathogens when genetic or chemical approaches for their management is not available.

Wang *et al.*, 2002 conducted a study on antivirus disease mechanism of grafted seedless watermelon and concluded that grafted plants had increased tolerance to viral complexes (CMV, WMV-II, PRSV and ZYMV) compared to non grafted control.

Pandey and Rai, 2003 reported that main objective of grafting is to avoid soil borne diseases such as Fusarium wilt in Cucurbitaceae and bacterial wilt in Solanaceae families. In addition grafting also induces vigour, precocity, minimises autotoxic effect, avoids nematode infection, provides drought, flood and cold hardiness, improves yield and quality, manipulates harvest period, enhances mineral absorption and also influences sex expression.

A resistant cultivar can be developed by grafting susceptible scion onto resistant rootstock there by eliminating prolonged screening and selection procedure needed to develop resistance in a cultivar. In addition, grafting enhanced abiotic stress tolerance, increased fruit yield and quality and also extended harvest periods (Lee and Oda, 2003, Rivero *et al.*, 2003 and Hang *et al.*, 2005).

Grafting using resistant rootstocks reduced nematode gall formation in cucumber (Giannakou and Karpouzas, 2003), watermelon (Miguel *et al.*, 2004), and melon (Siguenza *et al.*, 2005).

Grafts were used to induce resistance against low and high temperature, enhance nutrient uptake, increase synthesis of endogenous hormones, improve water use efficiency, reduce uptake of persistent organic pollutants from agricultural soils, improve alkalinity tolerance, raise salt and flood tolerance, and limit negative effects of boron, copper, cadmium and manganese toxicity (Rivero *et al.*, 2003, Dong *et al.*, 2008, Rouphael *et al.*, 2008, Colla *et al.*, 2010a and Colla *et al.*, 2010b).

Davis *et al.,* 2008 reported that grafting influenced vegetative growth, flowering, fruit ripening date, quality and yield. Rootsock-scion combinations reportedly affected pH, flavor, sugar, carotenoid content, and texture of fruit.

Rivard and Louws, 2008 suggested grafting using resistant rootstocks as an eco-friendly approach for sustainable vegetable production that reduced the dependence on agrochemicals due to tolerance to soil borne diseases.

Grafting for a soil borne pathogen can also assist with the management of additional non target soil borne pathogens. Grafting is an alternative approach to reduce crop damage resulting from soil borne pathogens and increase plant biotic and abiotic stress tolerance, which increases crop production (Wu *et al.,* 2008).

Salehi-Mohammadi *et al.*, 2009 reported plant vigour promotion in grafted plants due to vigorous root system of the rootstock that enhanced water and nutrient absorption in watermelon there by reducing irrigation frequency and agrochemical application to about one-half to one-third recommendation for the non grafted plants.

Many genetic barriers in breeding for disease resistance could be circumvented through the use of selected rootstocks. The requirements of rootstocks are that they are compatible with the scion and provide desired traits without contributing negative traits (King *et al.,* 2010).

Lee *et al.*, 2010 reported that quality characteristics such as fruit shape, skin colour, rind thickness and total soluble solid concentration in watermelon and external colour and bloom development in cucumber are influenced by rootstock. There are several conflicting reports regarding grafting as advantageous or deleterious to quality. Grafting is also associated with fruit yield. There was 25-

55 per cent yield increase in grafted oriental melons as compared to self rooted plants.

2.2 Promising rootstocks for vegetable grafting

Various rootstocks have been screened from the existing cultivars for grafting in each crop. Nowadays breeding for resistant rootstocks is also taken up by breeders in public and private sectors. Selection of particular rootstock for specific crop and climatic requirement is essential for counteracting various biotic and abiotic stresses.

Liao and Lin, 1996 concluded that grafting of flood intolerant bitter gourd (*Momordica charantia* L.) onto flood tolerant *Luffa* spp. imparted flood tolerance.

Lin *et al.*, 1998 reported that bitter gourd (*Momordica charantia* L.) grafted on to sponge gourd (*Luffa cylindrica*) avoided the problem of Fusarium wilt.

Sicyos angulatus and pumpkin are promising rootstocks to avoid nematode infestation in Cucumber (Liu *et al.*, 1998).

Autotoxic effect in cucurbits is a serious problem causing soil sickness during commercial crop production. Grafting cucurbits like watermelon, melon and cucumber on *Cucurbita ficifolia* helped to overcome autotoxicity in these crops (Yu, 2001).

Wild species of watermelon used as rootstock prevented incidence of Fusarium wilt (*Fusarium oxysporum* f.sp. *niveum*) and had good compatibility with cultivated watermelon that increased the fruit quality (Huh *et al.*, 2002).

Pandey and Pandita, 2002 suggested *Cucurbita moschata*, *Lagenaria siceraria*, and *Luffa cylindrica* as promising rootstocks for grafting bitter gourd. The promising rootstocks suggested for watermelon were *Cucurbita moschata*, *Cucurbita maxima* and *Cucurbita moschata* x *Cucurbita maxima*.

Intergeneric grafts were successfully used in Japan for fruit bearing vegetables. In watermelon commonly used rootstocks were bottle gourd (*Lagenaria siceraria*) or interspecific hybrids (*Cucurbita maxima* x *Cucurbita moschata*). Hybrid melon cv. Base, wax gourd cv. Partner and pumpkin cv. Shintosa were widely used in musk melon grafting (Pandey and Rai, 2003).

Lee and Oda, 2003 reported that *Lagenaria siceraria, Cucurbita moschata, Cucurbita maxima* x *Cucurbita moschata, Cucurbita pepo, Benincasa hispida,* and *Cucumis metuliferus* are promising rootstocks for grafting watermelon.

Bitter gourd grafted on rootstocks of pumpkin, smooth luffa and bottle gourd not only increased vigour and yield but also protected against soil borne wilting diseases and nematodes (Grubben *et al.*, 2004).

Lin, 2004 stated that *Luffa spp.*, fig leaf gourd and pumpkin were promising rootstocks for grafting bitter gourd. Luffa rootstocks were used in summer production owing to its resistance to Fusarium wilt and tolerance to heat. Fig leaf gourd and pumpkin were used as rootstocks during low temperature for winter production.

Sakata *et al.*, 2007 stated that watermelon was first grafted onto pumpkin (*Cucurbita moschata*) and later on to bottle gourd (*Lagenaria siceraria*) to avoid soil borne diseases caused by continuous cropping. Ash gourd (*Benincasa hispida*) had good compatibility with watermelon but its susceptibility to low temperature stress delayed the development and flowering in grafted plants.

Davis *et al.*, 2008 based on the graft compatibility concluded that most promising rootstocks for watermelon were *Lagenaria siceraria, Cucurbita moschata, Cucurbita maxima* and wild watermelon (*Citrullus lanatus* var. *citroides*).

Good graft compatibility with watermelon, cucumber and melon and strong resistance to *Fusarium oxysporum* f.sp. *niveum, Fusarium oxysporum* f.sp.

cucumerinum and *Fusarium oxysporum* f.sp. *melonis* resulted in the use of interspecific hybrid (*Cucurbita maxima* x *Cucurbita moschata*) as the most successful rootstock for grafting cucurbits. Tolerence to low soil temperature made *Cucurbita ficifolia*, the preferred rootstock for grafting greenhouse cucumber (Singh and Rao, 2014).

Singh and Bahadur, 2014 reported that *Lagenaria siceraria*, *Cucurbita* spp., and *Benincasa hispida* were the suitable rootstocks for grafting watermelon and for bitter gourd the promising rootstocks were *Cucurbita moschata*, *Lagenaria siceraria* and *Luffa cylindrica*.

Zang *et al.*, 2015 evaluated the response of watermelon grafted onto bottle gourd against *Fusarium oxysporum* f. sp. *niveum*. Disease incidence in ungrafted and grafted plants were 95.70 per cent and 2.30 per cent respectively. The result indicated that grafting on bottle gourd rootstock was an efficient method to control the problem of Fusarium wilt.

2.3 Effect of rootstock on graft success

Several rootstocks protect the scion from diseases caused by soil borne pathogens but the rate of graft success and survival varies with different stock scion combination. So selection of rootstock is important for successful graft formation and establishment.

Cansev and Ozgur, 2010 compared survival rate of two rootstocks in grafting cucumber. Marathon F1 hybrid of cucumber was grafted onto two rootstocks namely, P360 (*Cucurbita maxima* x *Cucurbita moschata*) and Arican 97 (*Cucurbita maxima*). Surival rate of the two rootstocks were 99.2 per cent and 80.8 per cent.

Bekhradi *et al.*, 2011 examined the influence of three different rootstocks: *Cucurbita pepo*, *Lagenaria siceraria*, and *Cucurbita maxima* x *Cucurbita* *moschata* on graft success of watermelon (*Citrullus lanatus*) cv. Charleston Gray. The survival rate of watermelon grafted onto *Lagenaria siceraria, Cucurbita maxima* x *Cucurbita moschata* and *Cucurbita pepo* were 90, 85 and 70 per cent respectively.

Survival rates of cucumber (*Cucumis sativus)* cv. Tainan No. 1 approach grafted onto *Cucurbita* spp. Cv. Heroes and *Cucumis* spp. cv. Qingpi were 78.00 per cent and 80.00 per cent respectively (Chao and Yen, 2013).

Uap, 2014 studied the survival rate of cucumber (*Cucumis sativus*) grafted onto bottle gourd (F1 and local) , bitter gourd (*Momordica charantia* L.) grafted onto bottle gourd (local) and bottle gourd (local) grafted onto self rootstock. The survival rate of plants were recognised by its new leaf emergence. Highest survival rate (26.50 %) was observed for bottle gourd (local) grafted onto self rootstock. Survival rate of cucumber and bitter gourd grafted onto bottle gourd (local) were 20.00 per cent and 21.90 per cent respectively.

Cucumber (*Cucumis sativus*) cultivar 'Soltan' was grafted onto six different rootstocks namely *Cucurbita ficifolia* 'Fig leaf gourd', *Cucurbita pepo* 'Mosamaii', *Cucumis melo* L. var. *flexuosus* 'Chanbar', *Cucumis melo* L. var. *reticulates* 'Talebi', *Cucumis sativus* L. 'Dastgerdi' and *Citrullus lanatus* 'Watermelon'. Survival rate of rootstocks were 88 per cent, 69 per cent, 49 per cent, 42 per cent, 27 per cent and 18 per cent for 'Mosamaii', 'Fig leaf gourd', 'Chanbar', 'Talebi', 'Dastgerdi' and 'Watermelon' respectively (Farhadi and Malek, 2015).

Survival rate of cucumber hybrid grafted onto seven rootstocks namely *Lagenaria siceraria, Cucurbita maxima* and *Cucurbita* interspecific hybrids viz., 909, 913, Ferro, 64-19, and Shintoza were studied by Farhadi *et al.*, 2016. High compatibility between scion and rootstock and survival was achieved with Ferro hybrid (94.00 %), *Cucurbita maxima* (92.00 %), 64-19 and Shintoza (90.00 %). The lowest survival rates were observed with *Lagenaria siceraria* (72.00 %) and 913 hybrid (73.00 %).

Tamilselvi and Pugalendhi, 2017 studied graft success of bitter gourd F1 'Palee' on ten different cucurbitaceous rootstocks namely, mithipakal (*Momordica charantia* var. *muricata*), fig leaf gourd (*Cucurbita ficifolia*), pumpkin (*Cucurbita* moschata), Zucchini squash (*Cucurbita pepo*), Sponge gourd (*Luffa cylindrica*), Ridge gourd (*Luffa acutangula*), Bottle gourd (*Lagenaria siceraria*), Ash gourd (*Benincasa hispida*), Kumatikai (*Citullus colocynthis*), and African horned cucumber (*Cucumis metuliferous*). Highest graft success was observed in bitter gourd grafted on pumpkin (71.71%) followed by sponge gourd (68.26%) and lowest success per cent in mithipakal (49.24 %).

2.4 Effect of method of grafting on graft success

Grafting is a process that involves choice of rootstock and scion, creation of graft union by physical manipulation and acclimatisation which include healing of graft union and hardening of grafted seedlings for survival in the greenhouse or field. Grafting technique and post-grafting management greatly influence the survival rate and performance of grafted plants. Grafting methods adopted vary considerably depending upon kind of crops, number of grafts to be made, farmers' experience and preferences, facilities available, and even by the purpose of grafting such as grafting for their own use by farmers or for sales by commercial growers.

Pandey and Rai, 2003 observed that tongue approach grafting gave higher survival rate as the root system of the scion remained alive until the formation of graft union.

Xiao, 2004 reported that hole insertion grafting had higher survival rate and plants had fewer incidence of soil borne disease because of high grafting position. Compared to tongue approach grafting, hole insertion grafting required skilled workers for grafting and suitable environmentally controlled humid or healing chamber.

Hang *et al.*, 2005 reported that hole insertion grafting and one cotyledon grafting were preferred when scion and rootstock have hollow hypocotyls. Tongue approach and cleft grafting which had higher survival rates was adopted by inexperienced farmers. In contrast, one cotyledon and hole insertion grafting required experienced labour and healing chamber for higher survival rates. Cleft grafting, one cotyledon grafting and hole insertion grafting owing to their high grafting position decreased the chance of scion adventitious roots contracting soil borne diseases.

Per cent share of different grafting methods employed for production of grafted seedlings in Japan was studied by Sakata *et al.*, 2007. For watermelon, hole insertion grafting (53.00 %) was most commonly adopted by farmers as it does not require special grafting facilities. Tongue-approach grafting was used in cucumber (89.00 %) and melon (56.00 %), even though it required more operations and longer time for grafting and healing, since the failure rate was relatively low in all climates. In contrast, nursery growers adopted splice grafting in cucumber (39.00 %) and hole insertion grafting for melons (38.00 %) and watermelon (35.00 %).

Davis *et al.*, 2008 evaluated the efficiency and savings of labour in three different grafting techniques *viz.*, pin grafting, hole insertion grafting and tongue approach grafting. Efficiency was highest for pin grafting (46.0 min/100 plants) followed by hole insertion (60.3 min/100 plants) and tongue approach (71.4 min/100 plants) grafting. Pin grafting saved 35.8 per cent labour while in hole insertion grafting it was 15.6 per cent.

Lee *et al.*, 2010 reported that even though tongue approach grafting needed more space and labour compared to other methods, a higher rate of survival was obtained even for the beginners.

On comparing hole insertion grafting and tube grafting in watermelon cv. Charleston Gray, Bekhradi *et al.*, 2011 observed that hole insertion grafting gave the highest survival rate (90.00 %) with bottle gourd as rootstock.

Abd El-Wanis *et al.*, 2013 conducted a study to identify the best grafting method for producing grafted watermelon seedlings. Watermelon (*Citrullus lanatus* (Thunb.)) cv. Aswan F1 hybrid was grafted onto bottle gourd rootstock (*Lagenaria siceraria*). The grafting methods included one cotyledon grafting (splice grafting), hole insertion grafting (top grafting) and tongue approach grafting. The percentage of survival was 97.00 per cent, 98.00 per cent and 99.00 per cent for one cotyledon grafting, hole insertion grafting and tongue approach grafting respectively. Splice grafting was the best grafting technique in terms of survival rate, vegetative growth characters, yield and yield components followed by hole insertion grafting.

In cucumber, hole insertion grafting was more successful with highest survival rate as compared to side grafting (Punithaveni and Jansirani, 2014).

Uap, 2014 compared the yield of bitter gourd (*Momordica charantia* L.) grafted onto bottle gourd (*Lagenaria siceraria*) rootstock using two different grafting methods namely hole insertion (peg) grafting and splice grafting. The average yield of peg grafted plant was 607.84 g and it was higher than that of splice grafted plant (571.79 g).

2.5 Effect of environmental conditions on post-graft healing and acclimatisation

Graft success depends on the establishment of successful graft union. Attachment of compatible stock and scion results in callus formation between the cut surfaces. Callus differentiation results in vascular connections. The rate of attachment is based on environmental factors such as temperature and humidity.

For some grafting methods, proper environmental conditions are important to facilitate rootstock and scion union.

Suitable temperature was 25-30^0 C for post-graft curing in grafted watermelon (Liang, 1990).

Mii *et al.* (1994) pointed out that the appropriate curing environment for grafted tomato seedlings was 20-30^0 C temperature, more than 80.00 per cent relative humidity and 50-70 per cent shade.

Chang *et al.* (2003) suggested that the survival rate and quality of grafted seedlings were high when the relative humidity in the acclimatization chamber was maintained at 80-90 per cent.

Lee and Oda, 2003 concluded that to maintain high relative humidity, grafted plants were maintained in small plastic tunnels inside the greenhouse. Three to five days after grafting, plants were acclimated to natural field conditions by slowly reducing humidity.

Lee, 2007 reported that for successful formation of graft union, proper environmental conditions including a temperature of 25-30^0 C and relative humidity of 95.00 per cent are required. These conditions promoted vigorous cell differentiation which resulted in successful graft union in about seven days. For successful graft union formation in hole insertion grafting, relative humidity should be at least 95.00 per cent. Tongue approach grafting was successful even at lower relative humidity.

Effect of temperature and humidity during post graft healing and acclimitisation was studied by Vu *et al.*, 2013. High relative humidity (90.00 %) for first 2 or 3 days followed by reduced low relative humidity (70.00 %) at 23^{0}C during healing and acclimatization promoted the graft-take in tomato.

Alai, 2014 reported that environmental elements such as temperature and relative humidity were the critical factors that determined successful graft union formation.

According to Kumar *et al.*, 2015 healing is the most critical process of grafted seedling production. Temperature of 25-30^{0}C, relative humidity of 85-90 per cent and low light intensity were the pre requisites for healing.

2.6 Effect of month on the success of grafting

Nazeema,1992 evaluated the best season for softwood grafting in *Garcinia cambogia* by grafting during six months *viz.*, May, June, July, August, September, October, November and December. Highest graft success was obtained in the month of June with 92.00 per cent, 87.00 per cent and 84.00 per cent respectively on 30, 60 and 90 days after grafting. Lowest graft success was noticed in the month of December with 43.00 per cent, 32.00 per cent and 12.00 per cent respectively on 30, 60 and 90 days after grafting.

The effect of month of grafting (June, July and August) on the success of softwood grafting in mango (*Mangifera indica*) was studied by Geetha,1993 in Kerala Agricultural University. Graft success was high (82.78 %) in June and maximum percentage survival (23.68 %) was obtained when grafting was done during August.

Islam *et al.*, 2003 studied the effect of time of grafting on the success of epicotyl grafting in jackfruit (*Artocarpus heterophyllus* L.). The experiment was carried out during seven months *viz.*, April, May, June, July, August, September and October. The highest success (49.55 %) and survival (45.47 %) followed by maximum growth of the grafts were observed in the month of June. On the contrary, the grafts made in the month of April had lowest success (10.08 %) and survival (13.92 %). The maximum (24.79 days) and minimum (20.72 days) time to bud break was observed in the month of October and July, respectively.

Sathish kumar *et al.*, 2003 studied the influence of season on success of wedge grafting in Tamarind (*Tamarindus indica* L.). Grafting was carried out in seven months starting from August to February. The highest percentage of success (92.49%) was recorded in the grafts prepared in the month of February followed by January (58.57%). The lowest percentage of success (24.98%) was recorded in the grafts made during September.

An experiment was conducted to study the effect of time of softwood grafting on graft success in aonla (*Emblica officinalis*). Grafting was carried out at four different times viz., 1st week of December, 3rd week of December, 1st week of January, and 3rd week of January. Maximum graft success (62.07 per cent) was observed in 1st week of January and minimum success (54.43 per cent) was observed in 1st week of December (Roshan *et al.*, 2013).

2.7 Effect of grafting on vegetative traits, yield and quality

Yamasaki *et al.*, 1994 observed that watermelon (*Citrullus lanatus* (Thunb.)) grafted onto interspecific squash hybrid showed more vigorous vegetative growth and had firmer flesh than plants grafted onto bottle gourd (*Lagenaria siceraria*). Decrease in sweetness was also noticed in grafted plants compared to ungrafted control.

Salam *et al.* (2002) reported that grafting watermelon onto bottle gourd produced larger fruit (30.30 cm length), higher number of fruits per plant (5.25) which resulted in 3.5 times higher yield (56.92 t ha^{-1}) than ungrafted control plants.

Lee and Oda, 2003 reported that grafted plants showed different vegetative growth responses based on vigour of the rootstock and rootstock-scion compatibility.

Cucumber plants grafted onto pumpkin rootstocks had 27.00 per cent more marketable fruit per plant than self-rooted cucumber (Seong *et al.*, 2003).

Alan *et al.*, 2007 studied the effect of different rootstocks on watermelon with respect to plant growth, fruit yield and quality. Stem length, laterals and root dry weight were significantly lower in control plants. Grafting positively influenced fruit yield and among the grafts interspecific *Cucurbita* hybrid showed maximum (20.13 kg plant^{-1}) and bottle gourd showed minimum (10.95 kg plant^{-1}) yield.

Superiority in vigour and vegetative traits of grafted plants compared to self rooted plants could be attributed to resistance to soil borne diseases and better root system activity of the rootstock (Salehi-Mohammadi *et al.*, 2009).

F1 hydrid of cucumber grafted onto P360 (*Cucurbita maxima* x *Cucurbita moschata*) and Arican 97 (*Cucurbita maxima*) showed respectively 86. 5 per cent and 148 per cent more yield than ungrafted control (Canzev and Ozgur, 2010).

Watermelon grafted onto bottle gourd and *Cucurbita pepo* promoted vegetative growth but had no significant effect on total soluble solid, length and weight of fruit. Total fruit yield was higher in control plants (28.44 t ha^{-1}) compared to plants grafted onto bottle gourd (27.49 t ha^{-1}) and *Cucurbita pepo* (14.54 t ha^{-1}) (Bekhradi *et al.*, 2011).

Watermelon plants grafted onto bottle gourd rootstocks showed better plant growth performance and produced higher yield than ungrafted watermelon plants in field contaminated with root-knot nematodes (Ozarsladan *et al.*, 2011). It was concluded that bottle gourd rootstocks were not directly tolerant to nematode but they can tolerate nematode due to their rapid growth habit.

Lagenaria siceraria f. *clavata* and *Lagenaria siceraria* f. *pyrotheca* and RS 841 F1 (*Cucurbita maxima* x *Curcurbita moschata*) were used as rootstocks for grafting watermelon cv. Sugar Baby. Plant height, leaf number and leaf area were significantly higher in grafted plants than self rooted control plants. The total soluble solids was positively affected by grafting on RS 841 F1 but not by other scion rootstock combinations. Mean fruit weight was in the order Sugar Baby x *Lagenaria siceraria* f. *clavata*, Sugar Baby x *Lagenaria siceraria* f. *pyrotheca*, Sugar Baby x RS 841 F1 and control (Petropoulos *et al.*, 2012).

Chao and Yen, 2013 studied the effect of *Cucumis* and *Cucurbita* rootstock on vegetative traits, yield and quality of 'Tainan No 1' cucumber. Grafted plants had better vegetative growth than non-grafted plants. There was no significant difference among the final stem length, scion/rootstock diameter, intermodal length and leaf number among the two rootstocks. Fruit length, fruit width and fruit weight had no significant difference among the control and grafted plants. However the plants grafted on *Cucumis* showed significant effect on fruit quality due to high total solube solids.

Tamilselvi *et al.*, 2014 reported that bitter gourd F1 hybrid (Palee) grafted onto pumpkin rootstock was the best as it expressed good performance for vine length (856.66 cm), number of branches (13.66), fruit number per vine (27.88), fruit weight (183.66 g) and fruit yield per vine (3.62 kg) as compared to other graft combinations and non grafted plants.

Farhadi and Malek, 2015 grafted cucumber (*Cucumis sativus*) cultivar 'Soltan' onto six different rootstocks namely *Cucurbita ficifolia* (Fig leaf gourd), *Cucurbita pepo* (Mosamaii), *Cucumis melo* L. var. *flexuosus* (Chanbar), *Cucumis melo* L. var. *reticulates* (Talebi), *Cucumis sativus* L. (Dastgerdi) and *Citrullus lanatus* (Watermelon). Non-grafted cucumber 'Soltan' was used as control. Early flowering was noticed in 'Mosamaii' while total yield was greater in 'Fig leaf gourd' followed by 'Mosamaii'. The fruit yield of 'Fig leaf gourd', 'Mosamaii', non-grafted control 'Soltan', 'Talebi', 'Chanbar', 'Dastgerdi' and 'Watermelon' were 3.1, 2.3, 1.8, 1.6, 1.5, 0.9 and 0.4 (kg plant^{-1}) respectively.

Farhadi *et al.*, 2016 examined the efficacy of grafting cucumber hybrid onto various cucurbitaceous rootstocks namely *Lagenaria siceraria*, *Cucurbita maxima* and *Cucurbita* interspecific hybrids *viz.*, 909, 913, Ferro, 64-19, and Shintoza in a greenhouse experiment. Cucumber production was not improved by grafting. Highest yield was obtained with *Lagenaria siceraria* as rootstock and it was comparable to ungrafted control plants. Cucumber grafted onto other rootstocks showed significantly lower production than control. Total Soluble Solids (TSS) of fruits produced by control plants was significantly higher than other treatments.

2.8 Organoleptic evaluation

In vegetables, characteristics that impart distinctive quality can be described by four different attributes namely, colour and appearance, flavor (taste and aroma), texture and nutritional value. Organoleptic evaluation is a technique that uses man as a measuring instrument to analyse the sensory qualities of a product.

Traka-Mavrona *et al.*, 2000 reported that chemical effect of rootstock modify the scion quality. Taste and texture of the melons grafted on *Cucurbita* spp. were inferior compared to ungrafted control plants.

Farhadi and Malek, 2015 evaluated organoleptic traits of cucumber 'Soltan' grafted on different rootstocks namely, *Cucurbita ficifolia* 'Fig leaf gourd', *Cucurbita pepo* 'Mosamaii', *Cucumis melo* L. var. *flexuosus* 'Chanbar', *Cucumis melo* L. var. *reticulates* 'Talebi', *Cucumis sativus* L. 'Dastgerdi' and *Citrullus lanatus* 'Watermelon'. Cucumber grafted onto 'Dastergi' cucumber rootstock was of good quality in terms of texture. Taste of cucumber grafted onto figleaf gourd inclined to taste and quality of squash which was not acceptable.

Sensory characteristics of cucumber grafted onto five rootstocks namely, *Lagenaria siceraria, Cucurbita moschata, Cucurbita maxima, Cucurbita maxima* x *Cucurbita moschata,* and *Luffa cylindrica* were evaluated by Velkov and Pevicharova, 2016. There was significant variation in the value of sensory traits like appearance, aroma and taste depending on the rootstock used. C. *maxima* × C. *moschata, Lagenaria* and C. *maxima* rootstocks demonstrated good compatibility.

2.9 Anatomical studies of graft union

The use of grafted plants in vegetable crop production is now being expanded greatly. However, few data is available on the formation of graft union in vegetables. Grafting results in the formation of necrotic or proliferation layer followed by generation of rapidly dividing parenchymatous cells. As the callus cells multiply, they produce callus bridge made of vascular tissues. This helps in the movement of water and nutrients between the rootstock and scion which ensures graft compatibility.

The main determinant of graft-compatibility is the degree of callus formation at the graft union shortly after grafting operation (Celik, 2000).

Shehata *et al.*, 2000 studied the anatomy of successful graft union in cucumber (Passandra F_1 hybrid) plants grafted on rootstocks of fig leaf gourd (*Cucurbita ficifolia*), bottle gourd (*Lagenaria siceraria*), pumpkin (*C. moschata*) and squash (*C. pepo*). Cell division in the scion and rootstock at the graft union (dedifferentiation), redifferentiation of the callus tissue, rapid connection between the vascular bundles of the scion and rootstock, and secondary growth of the scion and rootstock resulted in successful grafts. Incompatible grafts lacked connection between the vascular bundles of the scion and rootstock.

A successful graft union formation includes the appearance of necrotic layer, generation of callus cells, adhesion of scion and rootstock at the callus junction, differentiation of callus and establishment of vascular connection, reduction or elimination of necrotic layer in callus, differentiation of some cells to the cambial cells, bridging of cambium tissues of stock and scion, and finally formation of vascular tissues (Estrada *et al.*, 2002; Sitarek, 2006; Pina and Errea, 2008).

Lilieth *et al.*, 2012 reported that establishment of wound repair xylem across the graft union allowed movement of water and mineral nutrients between the rootsock and scion in chilli grafts.

Histological analysis of watermelon (Aswan F_1) grafted on to bottle gourd (*Lagenaria siceraria*) was conducted by Abd El-Wanis *et al.*, 2013. Experiment included three grafting methods namely, one cotyledon grafting (splice grafting), hole insertion grafting and tongue approach grafting. Strong connection between the stock and scion was noticed in splice grafting compared to other two methods.

The cambial region capable of meristematic activity produced parenchymatic cells that resulted in better vascular activity which promoted vigorous growth and yield of splice grafted plant.

Priyadarshini and Vethamoni, 2015 grafted annual moringa (Pkm1) on perennial moringa and observed histological development during union of rootstock and scion. Fifteen days after grafting, formation of necrotic layer followed by enlargement of callus cells between rootstocks and scion were identified. Thirty days after grafting, cambium linkage and healing of graft union in the edge were also noticed which resulted in successful graft union formation.

Anatomical studies were conducted to determine the graft compatibility of bitter gourd scion (Palee F_1) with two different rootstocks namely, pumpkin (*Cucurbita moschata*) and fig leaf gourd (*Cucurbita ficifolia*). Grafting method adopted was side grafting. Transvere sections of the graft union were studied seven days after grafting. Dark strands of necrotic or proliferation layers were seen in outer sides and interfaces of Palee F_1 grafted on to pumpkin rootstock. In case of Palee F_1 grafted onto fig leaf gourd rootstock, there was discontinuous xylem elements in the graft union indicating incompatibility (Tamilselvi and Pugalendhi, 2017).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on 'Standardisation of grafting in bitter gourd (*Momordica charantia* L.) and watermelon (*Citrullus lanatus* (Thunb.)) was carried out in the vegetable research farm of the Department of Olericulture, College of Horticulture, Vellanikkara. The experiment site was located at an altitude of 23 m above M. S. L. and between 10°32'' N latitude and 76°16'' E longitude. The area experienced typical warm humid tropical climate and received an average rainfall of 2663 mm per year. The soil of the site was laterite having sandy clay loam texture and acidic in reaction. The experiment was conducted during April 2016 – March 2017. Monthly weather data during the period of study are given in Appendix I.

3.1 Experimental materials

Bitter gourd (*Momordica charantia*) variety Preethi and watermelon (*Citrullus lanatus*) variety Sugar Baby were the scion materials used for standardisation of grafting technique. Five different rootstocks namely ash gourd (*Benincasa hispida*) variety KAU Local, bottle gourd (*Lagenaria siceraria*) variety Arka Bahar, smooth gourd (*Luffa cylindrica*), pumpkin (*Cucurbita moshchata*) variety Ambili and OP melon (*Cucumis melo* var. *conomon*) variety Mudicode were selected (Table 1). The requirements for grafting operation were razor blade, grafting clips and healing chamber with mist system (Plate 1).

3.2 Experimental methods

3.2.1 Standardisation of grafting technique and evaluation of promising rootstocks

3.2.1.1 Raising of rootstocks and scions for grafting

Table 1: Details of rootstocks and scions used for the study

Sl. No.	Common name	Scientific name	Variety
Scions			
1.	Bitter gourd	*Momordica charantia*	Preethi
2.	Watermelon	*Citrullus lanatus*	Sugar Baby
Rootstocks			
1.	Ash gourd	*Benincasa hispida*	KAU local
2.	Bottle gourd	*Lagenaria siceraria*	Arka Bahar
3.	Smooth gourd	*Luffa cylindrica*	Local cultivar
4.	Pumpkin	*Cucurbita moschata*	Ambili
5.	OP melon	*Cucumis melo* var. *conomon*	Mudicode
6.	Bitter gourd /Watermelon	*Momordica charantia/ Citrullus lanatus*	Preethi/ Sugarbaby

(A) Grafting clips and razor blade

(B) Healing chamber

(C) Healing chamber with mist system

Plate 1: Basic requirements for grafting (A) grafting clips and razor blade, (B) and (C) healing chamber with mist system

Seeds were sown in 98 well pro-trays containing two parts coir pith compost, one part vermicompost and one part soil. They were kept in the potting shed for germination. Number of days taken for germination and number of days to attain graftable size for rootstocks and scions were noted. Sowing time of rootstock and scion seeds were adjusted such that they attain grafting stage uniformily. Hole insertion and tongue approach grafting were carried out in all the five inter-generic rootstocks and self rootstocks.

3.2.1.2 Methods of grafting

Grafting was performed in the shade net preferably during morning or evening hours. Two grafting methods namely, hole insertion grafting and tongue approach grafting were evaluated in the study. Immediately after grafting, the plants were transferred to a healing chamber or mist chamber and they were maintained at high relative humidity by intermittent application of mist to facilitate the formation of graft union. Once the graft union was established, grafts were transferred to shade nets and kept for two to three days for acclimatization before planting in the main field.

Hole insertion grafting (HIG) is also known as top insertion grafting. The procedure is demonstrated in plate 2 and 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 was inserted into the cleft made in rootstock. The rootstock and scion hypocotyls were fixed using grafting clip and placed in mist chamber for three days. The clips were removed and grafts kept in net house for acclimatization.

In Tongue Approach Grafting (TAG), the rootstock and scion were cut through the hypocotyl at 35^0 to 45^0 angle upwards and downwards respectively (or viceversa). The cut surfaces were joined and grafting clip was used to hold the

(A)

(B)

(C)

(D)

(E)

Plate 2 : Steps in hole insertion grafting in bitter gourd

(A) Top portion of scion removed from seedling (B)Scion hypocotyl made in form of wedge

(C) Cleft made in rootstock hypocotyl (D) Scion inserted into cleft in the rootstock

(E) Graft union fixed using grafting clip

(A)

(B)

(C)

(D)

(E)

Plate 3 : Steps in hole insertion grafting in watermelon

(A) Scion hypocotyl made in form of wedge (B) Cleft made in rootstock hypocotyl

(C) Scion inserted into cleft in the rootstock (D) Graft union fixed using grafting clip

(E) Grafts kept in mist chamber

graft union. The procedure is demonstrated in plate 4 and 5. The grafts were kept in mist chamber for three days. After three days, the top of rootstock was removed and again kept in mist chamber. The bottom portion of the scion just below the graft union was removed five to seven days after grafting. The clips were removed and grafts kept in net house for acclimatization.

Percentage success was recorded at three, six, nine and twelve days after grafting to study the influence of type of rootstocks and methods of grafting on graft success.

3.2.1.3 Influence of age of rootstock on graft success

To study the effect of age of rootstock on graft success, hole insertion grafting was done in six selected rootstocks in both bitter gourd and watermelon. The age of scions were kept constant at 7-10 days after germination. In all the six rootstocks, three different age groups *viz.*, 5-7 days, 10-12 days, and 15-17 days after germination were selected. Observation on graft success was recorded 9-12 days after grafting.

3.2.1.4. Influence of month of grafting on graft success

To study the effect of season on success of grafting, hole insertion grafting was done on every 15th day of each month commencing from May to October in bitter gourd and watermelon using all the six rootstocks. Weather parameters like maximum temperature, minimum temperature, relative humidity and rainfall at monthly intervals during the period of grafting were noted (Appendix 1). Observation on graft success was recorded 9-12 days after grafting.

Layout and design of grafting experiments

The grafting experiment was laid out in Completely Randomized Design (CRD) with four replications and 25 plants per replication. Results were evaluated based on graft success separately for bitter gourd and watermelon.

(A)

(B)

(C)

(D)

Plate 4: Steps in tongue approach grafting in bitter gourd

(A) Upward cut in rootstock hypocotyl

(B) Downward cut in scion hypocotyl

(C) Joining the cut surfaces of rootstock and scion

(D) Graft union fixed using grafting clip

(E)

(F)

(G)

Plate 4 (Contd.) : Steps in tongue approach grafting in bitter gourd

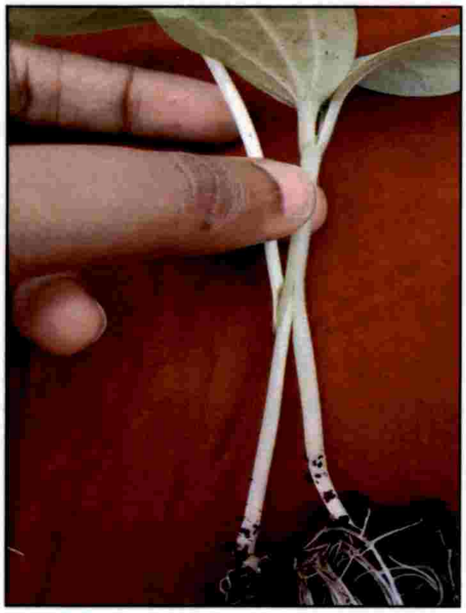
(E) Grafts kept in protrays

(F) Removal of top portion of rootstock

(G)Removal of bottom portion of scion

(A)

(B)



(C)

(D)

Plate 5 : Steps in tongue approach grafting in watermelon

(E) Upward cut in rootstock hypocotyl

(F) Downward cut in scion hypocotyl

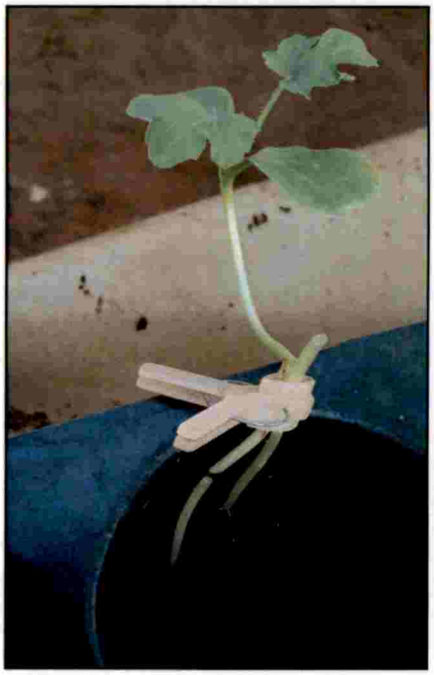
(G) Joining the cut surfaces of rootstock and scion

(H) Graft union fixed using grafting clip

(E)

(F)

(G)



(H)

Plate 5 (Contd.): Steps in tongue approach grafting in watermelon

(E) Grafts kept in protrays

(F) Protrays filled with potting mixture

(G) Removal of top portion of rootstock

(H) Removal of bottom portion of scion

Treatments

Rootstocks are represented as follows:

R_1 – Ash gourd

R_2 – Bottle gourd

R_3 – Smooth gourd

R_4 – Pumpkin

R_5 – OP melon

R_6 – Self rootstock

Grafting methods are represented as follows:

G_1 : Hole insertion grafting

G_2 : Tongue approach grafting

3.2.1.5 Performance of grafted plants in the field

The successful grafts were transplanted to the main field 12-15 days after grafting. The field was prepared thoroughly by repeated deep ploughing to get a fine tilth. During final land preparation, the entire experimental field was leveled and plot was laid out. The crops were raised as per Package of Practices Recommendations (KAU, 2016) for bitter gourd and watermelon.

Pits were taken at a spacing of 2m x 2m. Successful grafts were planted in the pits at the rate of three plants per pit. Full dose of FYM, half dose of N and full dose of P_2O_5 and K_2O were applied as basal dose. While planting, graft union was kept above the soil surface, to avoid development of adventitious roots from the scion that penetrate the soil. Twigs of trees were given as initial support to the bitter gourd vines which were later trained on iron frames. Dried twigs were used to trail watermelon on the ground. Irrigation was given regularly. Hand weeding was done to keep the field free of weeds. Light earthing up was done along with

(A)

(B) (C)

Plate 6: Field view of (A) bitter gourd plot, (B) and (C) Watermelon plot

top dressing of remaining nitrogen. Plant protection chemicals were applied as and when required.

Layout and Design of field experiments

The field experiment was laid out in Randomized Block Design (RBD) with three replications (Plate 6). Each replication consisted of three plants.

Treatments

R_1 – Ash gourd

R_2 – Bottle gourd

R_3 – Smooth gourd

R_4 – Pumpkin

R_5 – OP melon

R_6 – Self rootstock

R_0 – Self rooted seedlings

3.3 Observations recorded

3.3.1 Observations on grafts

a. Number of days taken for germination

Number of days taken by seeds of rootstocks and scions to germinate was noted.

b. Number of days to attain graftable size

Number of days taken from sowing to the time when seedlings are ready for grafting was noted.

c. Percentage success

Graft success was calculated by counting the number of grafts survived out of total plants grafted per replication. Percentage survival was calculated at three, six, nine and twelve days after grafting in hole insertion grafting (HIG) and tongue approach grafting (TAG). Graft success was assessed by emergence of new leaves on scion.

$$\text{Percentage of graft success} = \frac{\text{Number of successful grafts}}{\text{Total number of grafts made}} \times 100$$

d. Diameter of rootstock hypocotyls (mm) [at the time of grafting, 30 and 60 days after grafting]

Diameter of rootstock hypocotyls was recorded using vernier calipers on the day of grafting and 30 and 60 days after grafting.

e. Diameter of scion hypocotyls (mm) [at the time of grafting, 30 and 60 days after grafting]

Diameter of scion hypocotyls was recorded using vernier calipers on the day of grafting and 30 and 60 days after grafting.

f. Anatomical studies

Graft compatibility was studied by anatomical examination of cross sections of graft union. Thin sections were taken from the region of graft union 20 days after grafting using sharp razor blade. Sections were stained using safranine and placed on glass slides. Slides were analysed microscopically and photomicrographs were taken.

3.3.2 Observations after field planting

a. Survival rate in the main field

Number of plants survived out of total number of grafts planted in the main field for each treatment was counted and percentage was calculated.

b. Vine length (m)

At final harvest, the length of plants were measured from first cotyledonary node to tip of the main stem in three randomly selected plants using tape and expressed in meters.

c. Internodal length (cm)

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

d. Number of primary branches

The number of branches that arise from main stem were counted from three selected plants and recorded during the period of peak flowering.

e. Days to first male flower

Number of days from planting to first male flower opening were counted and recorded as an average of three plants per replication.

f. Days to first female flower

Number of days from planting to first female flower opening were counted and recorded as an average of three plants per replication.

g. Days to first harvest

The number of days from planting to first harvest were counted and recorded as an average of three plants per replication.

h. Node to first male flower

Node number at which first male flower appeared was counted and recorded as an average of three plants per replication.

i. Node to first female flower

Node number at which first female flower appeared was counted and recorded as an average of three plants per replication.

j. Fruit girth (cm)

Ten fruits were selected at random from each replication during peak harvest period. Maximum girth of fruit was measured using twine and scale and recorded. Average of ten fruits was taken and expressed in centimeters.

k. 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 ten fruits per replication.

l. Flesh thickness (cm)

Flesh thickness was measured using twine and scale. Average was taken from ten fruits from each replication and expressed in centimeters.

m. Fruit weight (g)

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

n. No. of fruits per plant

Number of fruits per plant was recorded as cumulative number of fruits from plants and average was calculated.

o. Yield per plant (kg)

Total weight of harvested fruits from each replication was recorded and average calculated.

p. Number of harvests

Total number of harvests from each replication was recorded and average calculated.

q. Duration of the crop

Duration of crop from transplanting till final harvest was recorded from each replication.

r. Occurrence of pest and diseases

Observation on occurrence of pest and diseases was recorded throughout the period of crop growth.

s. Organoleptic test

Cooked fruits were used to evaluate organoleptic qualities. Five sensory attributes namely appearance, texture, flavor, taste and overall accepability 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 card is given in Appendix-II. For organoleptic evaluation, Kendall's coefficient of concordance was performed and mean scores were taken to identify the best treatment.

3.4 Statistical Analysis

Statistical analysis of data was done using WASP 2.0 software and treatments were compared using C. D. value. Analysis was carried out at the computer centre, Department of Agricultural Statistics, Kerala Agricultural University.

RESULTS

4. RESULTS

Results of the experiment entitled "Standardisation of grafting in bitter gourd (*Momordica charantia* L.) and watermelon (*Citrullus lanatus* (Thunb)) " are presented in this chapter.

4.1 STANDARDISATION OF GRAFTING IN BITTER GOURD

4.1.1 Number of days taken for germination of rootstocks

Number of days taken for germination of rootstocks varied from 3.42 days to 6.42 days (Table 2). Among the six rootstocks studied significantly lesser number of days was required for germination of R_5 (3.42 days) compared to other rootstocks. However, results were on par with R_4 (3.85 days) and R_1 (4.14 days). Highest number of days for germination was recorded by R_6 (6.42 days) which was on par with R_3 (6.00 days).

4.1.2 Number of days taken by rootstocks to attain graftable size

Data on number of days taken to attain graftable size for the rootstocks varied significantly and ranged from 9.99 days to 18.27 days (Table 2). Among the treatments, R_4 recorded significantly less (9.99) number of days to attain graftable size closely followed by R_2 (10.43 days). Days taken to attain graftable size for rootstocks R_1, R_6 and R_3 respectively were 12.99 days, 15.42 days and 17.57 days respectively. The rootstock R_5 (18.27 days) recorded highest number of days to attain graftable size.

4.1.3 Standardisation of age of rootstocks for grafting

Analysis of data on graft success in three different age groups of rootstocks is given in table 3. In the rootstock R_1, age group A_2 gave highest graft success (68.00 %) which was on par with A_3 (65.00 %) and graft success was least in A_1 (50.00 %). There was no significant difference in graft success in R_2 among 81the age groups studied and it varied between 79.00 per cent in A_3 and

Table 2: Days taken by various rootstocks for germination and to attain graftable size for grafting bitter gourd

Rootstocks	Number of days taken for germination (days)	Number of days taken to attain graftable size (days)
R_1	4.14^{bc}	12.99^{d}
R_2	4.43^{b}	10.43^{e}
R_3	6.00^{a}	17.57^{b}
R_4	3.85^{bc}	9.99^{f}
R_5	3.42^{c}	18.27^{a}
R_6	6.42^{a}	15.42^{c}
C. D. (0.05)	0.825	0.079

Table 3: Influence of age of rootstocks on graft success in bitter gourd

Age of rootstocks	Graft success in different rootstocks (%)					
	R_1	R_2	R_3	R_4	R_5	R_6
A_1	50.00^{b}	81.00	67.00^{b}	79.00	48.00^{b}	48.00
A_2	68.00^{a}	82.00	80.00^{a}	77.00	68.00^{a}	51.00
A_3	65.00^{a}	79.00	80.00^{a}	75.00	75.00^{a}	50.00
C. D. (0.05)	11.093	NS	9.032	NS	11.250	NS

A_1: 5-7 days **A_2: 10-12 days** **A_3:15-17 days**

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Bitter gourd**

81.00 per cent in A_1. In R_3, age A_2 and A_3 gave highest graft success of 80.00 per cent and graft success was lowest in A_1 (67.00 %). There was no significant difference in graft success in R_4 among the age groups studied and it varied between 67.00 per cent in A_3 and 79.00 per cent in A_1. In the rootstock R_5, age A_3 gave highest graft success (75.00 %) which was on par with A_2 (68.00 %) and graft success was least in A_1 (48.00 %). There was no significant difference in graft success in R_6 among the age groups studied and it varied between 48.00 per cent in A_1 and 51.00 per cent in A_2.

4.1.4 Standardisation of method of grafting

4.1.4.1 Effect of rootstocks on graft success in Hole Insertion Grafting (HIG)

Per cent graft success differed significantly among different rootstocks studied at three, six, nine and twelve days after grafting in hole insertion method. Rootstock R_4 (92.00 %) recorded highest graft success on third day after grafting which was on par with R_2 (88.00 %) and R_3 (82.00 %). Success per cent was lowest in R_6 (68.00 %) which was on par with R_5 (70.00 %) and R_1 (73.00 %).

The rootstock R_4 (86.00 %) recorded highest success on sixth day after grafting which was on par with R_3 (82.00 %) and R_2 (81.00%). Lowest value was recorded in R_6 (53.00 %) which was on par with R_5 (60.00 %) and R_1 (68.00 %).

Analysis of graft success nine days after grafting showed significant difference among the rootstocks. Highest success was observed in R_3 (80.00 %) which was on par with R_4 (77.00 %) and R_2 (75.00 %). Least graft success per cent was recorded in R_6 (48.00 %) which was on par with R_5 (56.00 %). Graft success per cent at twelve days after grafting showed similar results as nine days after grafting (Table 4).

Table 4: Effect of rootstocks on graft success in hole insertion grafting in bitter gourd

Rootstocks	Graft success at 3 days interval (%)			
	3 DAG	6 DAG	9 DAG	12 DAG
R_1	73.00^{bc}	68.00^{bc}	66.00^{bc}	66.00^{bc}
R_2	88.00^{a}	81.00^{ab}	75.00^{ab}	75.00^{ab}
R_3	82.00^{ab}	82.00^{ab}	80.00^{a}	80.00^{a}
R_4	92.00^{a}	86.00^{a}	77.00^{ab}	77.00^{ab}
R_5	70.00^{bc}	60.00^{c}	56.00^{cd}	56.00^{cd}
R_6	68.00^{c}	53.00^{c}	48.00^{d}	48.00^{d}
C. D. (0.05)	13.634	15.56	12.41	12.41

Table 5: Effect of rootstocks on graft success in tongue approach grafting in bitter gourd

Rootstocks	Graft success at 3 days interval (%)			
	3 DAG	6 DAG	9 DAG	12 DAG
R_1	85.00	71.00^{ab}	24.00	16.00
R_2	91.00	74.00^{a}	26.00	17.00
R_3	90.00	60.00^{c}	24.00	13.00
R_4	92.00	73.00^{a}	27.00	17.00
R_5	90.00	68.00^{b}	24.00	15.00
R_6	86.00	58.00^{c}	22.00	13.00
C. D. (0.05)	NS	4.317	NS	NS

DAG: Days after grafting

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Bitter gourd**

4.1.4.2 Effect of rootstocks on graft success in Tongue Approach Grafting (TAG)

There was no significant difference between the rootstocks in per cent graft success on three, nine and twelve days after grafting (Table 5). The success per cent varied from 85.00 per cent to 92.00 per cent among the rootstocks on the third day after grafting. The per cent graft success was 92.00 % in R_4, 91.00 % in R_2, 90.00 % in R_3 and R_5, 86.00 % in R_6 and 85.00 % in R_1.

Six days after grafting, analysis of data showed significant difference in successful graft per cent among the different rootstocks studied. Rootstock R_2 had highest graft success (74.00 %) six days after grafting which was on par with R_4 (73.00 %) and R_1 (71.00 %). Lowest success was noticed in R_6 (58.00 %) which was on par with R_3 (60.00 %).

Graft success when observed nine days after grafting showed no significant difference among the treatments and it varied from 22.00 per cent to 27.00 per cent. Graft success was very low in all the rootstocks studied after 12 days. Success per cent was not significant among the treatments and it varied from 13.00 per cent in R_3 and R_6 to 17.00 per cent in R_2 and R_4.

4.1.4.3 Interaction effect of rootstocks and methods of grafting on graft success

Analysis of data on graft success showed significant difference among the type of rootstocks, methods of grafting and interaction between rootstocks and methods of grafting (Table 6).

On third day after grafting, R_4 showed maximum graft success per cent of 92.00 which was on par with R_2 (89.50 %), R_3 (86.00 %) and R_5 (80.00 %). Minimum graft success was recorded in R_6 (77.00 %) which was on par with R_1 (79.00 %). Graft success analysed on sixth day after grafting showed significant difference among the rootstocks. Highest success per cent was noticed in R_4

Table 6: Interaction effect of rootstocks and methods of grafting on graft success in bitter gourd

Rootstocks	Graft success at three days interval (%)											
	3 DAG			6 DAG			9 DAG			12 DAG		
	G_1	G_2	Mean (Treatments)	G_1	G_2	Mean (Treatments)	G_1	G_2	Mean (Treatments)	G_1	G_2	Mean (Treatments)
R_1	73.00^{b}	85.00^{a}	79.00^{cd}	68.00^{cd}	71.00^{c}	69.50^{bc}	66.00^{b}	24.00^{e}	45.00^{bc}	66.00^{b}	16.00^{d}	41.00^{abc}
R_2	88.00^{a}	91.00^{a}	89.50^{a}	81.00^{a}	74.00^{ab}	77.50^{ab}	75.00^{a}	26.00^{e}	50.50^{ab}	75.00^{a}	17.00^{d}	46.00^{ab}
R_3	82.00^{ab}	90.00^{a}	86.00^{ab}	82.00^{a}	60.00^{de}	71.00^{b}	80.00^{a}	24.00^{e}	52.00^{a}	80.00^{a}	13.00^{d}	46.50^{ab}
R_4	92.00^{a}	92.00^{a}	92.00^{a}	86.00^{a}	73.00^{c}	79.50^{a}	77.00^{a}	27.00^{e}	52.00^{a}	77.00^{a}	17.00^{d}	47.00^{a}
R_5	70.00^{bc}	90.00^{a}	80.00^{abc}	60.00^{de}	68.00^{cd}	64.00^{d}	56.00^{cd}	24.00^{e}	40.00^{cd}	56.00^{c}	15.00^{d}	35.50^{bc}
R_6	68.00^{bc}	86.00^{a}	77.00^{d}	53.00^{e}	58.00^{de}	55.50^{e}	48.00^{ed}	22.00^{e}	35.00^{d}	48.00^{c}	13.00^{d}	30.50^{c}
Mean (Grafting method)	78.83^{b}	89.00^{a}		71.67^{a}	67.33^{b}		67.00^{a}	24.50^{b}		67.00^{a}	15.17^{b}	
C. D. (0.05)	4.33^{1}, 7.51^{2}, 10.62^{3}			3.978^{1},6.89^{2},9.745^{3}			3.613^{1}, 6.258^{2}, 8.85^{3}			3.527^{1}, 6.109^{2}, 8.64^{3}		

[1]Methods, [2]Treatments, [3]Interaction

R_1 – Ash gourd R_2- Bottle gourd R_3 – Smooth gourd R_4– Pumpkin R_5– OP melon R_6 – Self rootsctock

G_1- Hole Insertion Grafting G_2- Tongue Approach Grafting

(79.50 %) which was on par with R_2 (77.50 %) followed by R_3 (71.00 %) and R_1 (69.50 %) while lowest graft success was noticed in R_6 (55.50 %).

On ninth day after grafting, the graft success varied significantly among the rootstocks studied. Highest graft success was noticed in R_3 and R_4 (52.00 %) which was on par with R_2 (50.50 %). Graft success was lowest in R_6 (35.00 %) which was on par with R_5 (40.00 %). Evaluation of graft success twelve days after grafting showed significant difference among the treatments. Highest graft success was recorded in R_4 (47.00 %) which was on par with R_3 (46.50 %), R_2 (46.00 %) and R_1 (41.00 %). R_6 recorded the minimum graft success of 30.5 per cent which was on par with R_5 (35.50 %).

The effect of method of grafting on graft success was evaluated. Statistically analysed data revealed that the treatments were significantly different. Per cent graft success three days after grafting was more in G_2 (89.00 %) compared to G_1 (78.83 %). Per cent graft success was 67.33 % in G_2 while it was 71.67 % in G_1 on sixth day after grafting. Grafting method G_1 recorded higher success per cent of 67.00 in comparison to G_2 which was 24.50 per cent on nine days after grafting. Analysis of graft success twelve days after grafting revealed that for G_1 the per cent success was same as that of nine days after grafting while in G_2, it was still lower (15.17 %).

Differential response of graft success per cent among rootstocks and grafting methods at three, six, nine and twelve days after grafting was studied. Graft success three days after grafting recorded highest in the treatment combination of R_4G_1 (92.00 %) and R_4G_2 (92.00 %). Lowest graft success was recorded in R_6G_1 (68.00 %) which was on par with R_1G_1 (73.00 %) and R_5G_1 (70.00 %). R_4G_1 showed maximum graft success of 86.00 % on sixth day after grafting, which was on par with R_3G_1 (82.00 %), R_2G_1 (81.00 %) and R_2G_2 (74.00 %). R_6G_1 recorded minimum graft success of 53.00 % which was on par with R_6G_2 (58.00 %), R_5G_1 (60.00 %), R_3G_2 (60.00 %). Ninth day after grafting, graft success was highest in R_3G_1 (80.00 %) which was on par with R_4G_1 (77.00 %) and

R_2G_1 (75.00 %). Graft success was lowest in R_6G_2 (22.00 %) which was on par with all the treatment combinations in G_2 and R_6G_1 (48.00 %). Graft success was highest in R_3G_1 (80.00 %) which was on par with R_4G_1 (77.00 %) and R_2G_1 (75.00 %) when observed twelve days after grafting. Success per cent was least in R_3G_2 (13.00 %) and R_6G_2 (13.00 %) which was on par with all the treatment combinations in G_2.

4.1.5 Standardisation of month of grafting

Data showing the effect of month of grafting, rootstock and interaction effect of month and rootstock on graft success is tabulated in Table 7. On comparison, it was observed that graft success differed significantly for different months of grafting. Highest success of 68.33 per cent was observed in M_3 which was on par with M_2 and M_4 with success per cent of 67.00. Graft success in M_5 and M_6 was 58.83 per cent and 57.83 per cent respectively. Minimum success was noticed in M_1 with a success per cent of 51.16.

Significant difference in per cent graft success was noticed among the rootstocks studied during the grafting season. R_3 recorded highest success per cent of 74.00 % which was on par with R_4 (71.83 %) and R_2 (67.83 %). Lowest success per cent was recorded in R_6 (43.83 %) followed by R_5 (52.16 %) and R_1 (60.50 %).

Among the interactions between month of grafting and rootstocks R_3M_2, R_3M_3, R_3M_4 and R_4M_3 recorded highest graft success of 80.00 % while the lowest value of 37.00 % was recorded in R_6M_5 and R_6M_6 which was on par with R_6M_1 (38.00 %), R_5M_1 (44.00 %), R_1M_1 (48.00 %), R_6M_2 (48.00 %).

Table 7: Interaction effect of rootstocks and month of grafting on graft success in bitter gourd

Rootstocks	Graft success in different months of grafting (%)						
	M_1	M_2	M_3	M_4	M_5	M_6	Mean (Rootstocks)
R_1	48.00^{ed}	66.00^{ab}	67.00^{ab}	64.00^{ab}	62.00^{b}	56.00^{d}	60.50^{b}
R_2	56.00^{d}	75.00^{a}	74.00^{a}	74.00^{a}	64.00^{ab}	64.00^{ab}	67.83^{a}
R_3	56.00^{d}	80.00^{a}	80.00^{a}	80.00^{a}	74.00^{a}	72.00^{a}	74.00^{a}
R_4	65.00^{ab}	77.00^{a}	80.00^{a}	77.00^{a}	66.00^{ab}	66.00^{ab}	71.83^{a}
R_5	44.00^{e}	56.00^{d}	59.00^{c}	54.00^{d}	50.00^{d}	52.00^{d}	52.16^{c}
R_6	38.00^{e}	48.00^{ed}	50.00^{d}	53.00^{d}	37.00^{e}	37.00^{e}	43.83^{d}
Mean	51.16^{d}	67.00^{a}	68.33^{a}	67.00^{a}	58.83^{b}	57.83^{bc}	
C. D.(0.05)	4.28[1], 4.28[2], 10.49[3]						

Table 8: Correlation of weather and graft success in bitter gourd

Rootstocks	Correlation coefficient		
	Relative humidity	Maximum temperature	Minimum temperature
R_1	0.64**	0.74**	0.56**
R_2	0.69**	0.69**	0.63**
R_3	0.61**	0.74**	0.58**
R_4	0.55**	0.49*	0.54**
R_5	0.51**	0.49*	0.59**
R_6	0.52**	0.47*	0.46*

M_1 – May **M_2 – June** **M_3 – July**
M_4 – August **M_5 – September** **M_6 – October**
R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Bitter gourd**

1: C. D. for comparing month of grafting
2: C. D. for comparing rootstocks
3: C. D. for comparing interaction

* Significant at 0.05 level
** Significant at 0.01 level

4.1.5.1 Correlation of weather and graft success

Data on graft success of different rootstocks were subjected to correlation analysis. The correlation coefficients between graft success and monthly mean weather parameters *viz.*, relative humidity, maximum and minimum temperature were estimated and presented in table 8. Relative humidity had highly significant and positive correlation with graft success. Maximum and minimum temperature had negative correlation with graft success.

4.1.6 Anatomical studies

Transverse sections of graft union were taken from plants grafted by hole insertion method on 20th day after grafting for anatomical studies. Histological observation at graft interface revealed formation of necrotic layer in response to wound repair and proliferation of cells of rootstocks and scion which is the stage prior to callus formation (Plate 7).

4.1.7 Performance of grafted bitter gourd plants

Since the graft success and survival were very poor in tongue approach grafts, only hole insertion grafts were evaluated in the main field for studying the performance of various rootstocks.

4.1.7.1 Diameter of rootstock hypocotyl (mm) [at the time of grafting, 30 and 60 days after grafting]

Analysis of data on the diameter of rootstock hypocotyls showed significant difference at the time of grafting (Table 9). Maximum diameter of 9.93 mm was observed in R_2 followed by R_4 (7.17 mm) and R_6 (7.16 mm). Minimum diameter was noticed in R_5 (3.13 mm) followed by R_1 (4.40 mm).

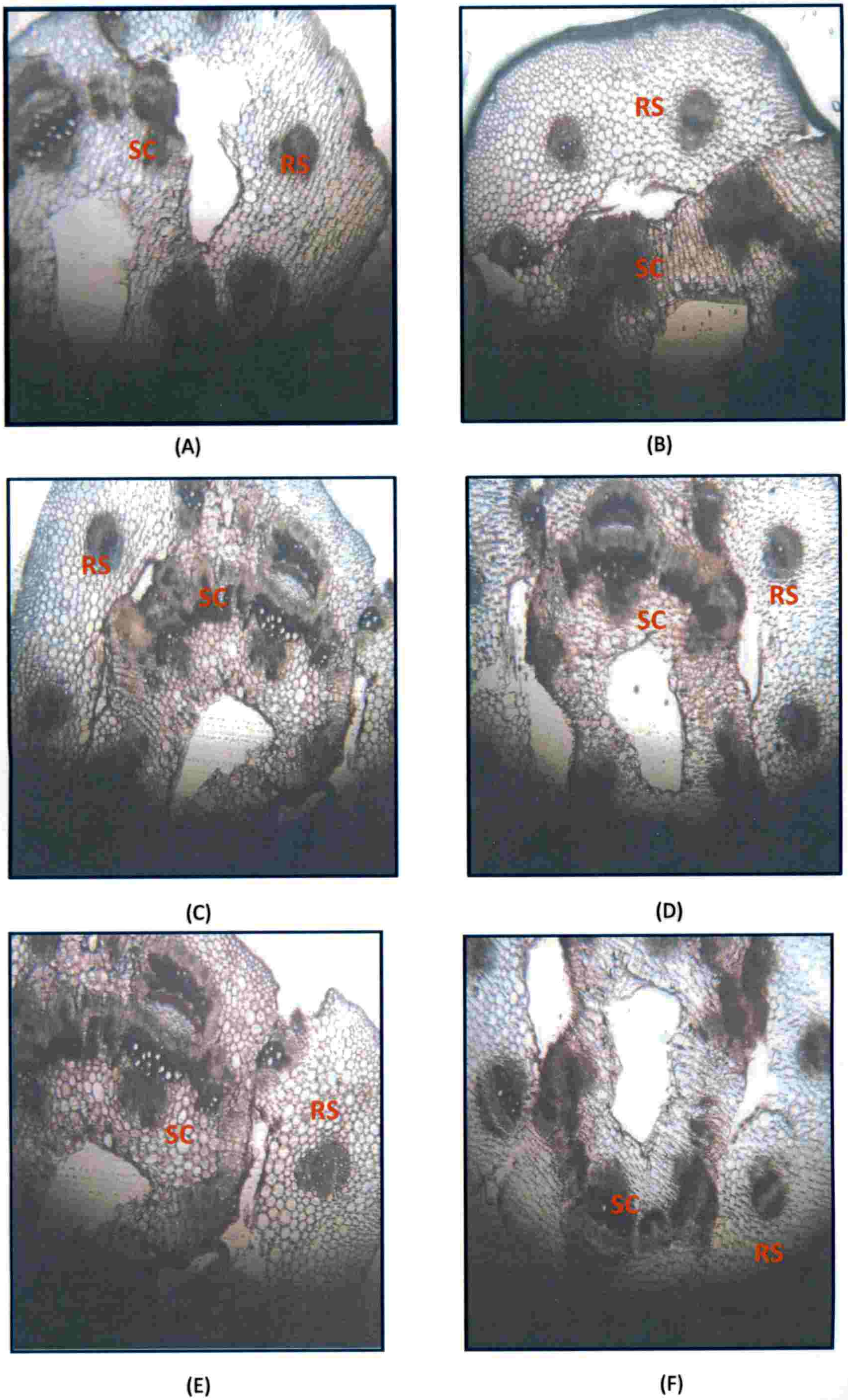


Plate 7: Cross-section of graft union in bitter gourd grafted on (A) Ash gourd (B) Bottle gourd (C) Smooth gourd D) Pumpkin (E) OP melon and (F) Self rootstock

Table 9: Diameter of Rootstock Hypocotyl (mm) in bitter gourd grafts

Rootstocks	At the time of grafting	30 days after grafting	60 days after grafting
R_1	4.40[d]	14.33[c]	41.67
R_2	9.93[a]	18.67[a]	48.33
R_3	6.90[c]	16.66[b]	43.34
R_4	7.17[b]	17.00[a]	43.33
R_5	3.13[e]	12.67[d]	39.67
R_6	7.16[b]	13.00[cd]	41.67
C. D.(0.05)	0.21	1.51	NS

Table 10: Diameter of scion hypocotyl (mm) in bitter gourd grafts

Rootstocks	At the time of grafting	30 days after grafting	60 days after grafting
R_1	7.16	13.67	42.34
R_2	7.20	13.33	41.67
R_3	7.20	13.33	43.33
R_4	7.16	13.00	44.00
R_5	7.13	12.00	43.67
R_6	7.20	13.66	42.67
C. D.(0.05)	NS	NS	NS

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Bitter gourd**

Statistical evaluation of mean rootstock diameter 30 days after grafting showed significant difference among the treatments. Diameter of rootstock R_2 (18.67 mm) was found to be the highest which was followed by R_4 (17.00 mm) and R_3 (16.66 mm). R_5 showed lowest diameter of 12.67 mm. Hypocotyl diameter of the rootstocks had no significant difference when evaluated at 60 days after grafting. Rootstock diameter varied between 39.67 mm and 48.33 mm for R_5 and R_2 respectively.

4.1.7.2 Diameter of scion hypocotyl (mm) [at the time of grafting, 30 and 60 days after grafting]

Scion hypocotyls had no significant difference among the treatments during the time of grafting, 30 and 60 days after grafting (Table 10). Diameter varied from 7.13 mm to 7.20 mm, 12.00 mm to 13.67 mm and 41.67 to 44.00 mm on the day of grafting, 30 and 60 days after grafting respectively. Diameter of scion hypocotyl increased proportionally with the rootstock.

4.1.7.3 Survival rate in the main field

There was significant difference among the treatments for the rate of survival in the main field (Table 11). Survival rate was highest in R_0 (100.00 %) which was on par with R_3 (84.44 %) and R_2 (77.78 %). Per cent survival for treatments R_4 and R_1 were 75.55 per cent and 71.10 per cent which were on par. Least survival rate was for R_6 (68.22 %) which was on par with R_5 (68.83 %).

4.1.7.4 Vine length (m)

The data on vine length showed significant difference among the treatments (Table 12). The longest vine length of 5.86 m was recorded in R_0. It was statistically on par with R_4 (5.53 m), R_3 (5.45 m) and R_2 (5.43 m). Shortest vine length was observed for R_5 (4.74 m) which was on par with R_1 (4.92 m) and R_6 (5.08 m).

Table 11: Survival rate of bitter gourd grafts in the main field

Rootstocks	Survival rate (%)
R_1	71.10^{cd}
R_2	77.78^{bc}
R_3	84.44^{b}
R_4	75.55^{cd}
R_5	68.83^{de}
R_6	68.22^{e}
R_0	100.00^{a}
C. D. (0.05)	6.848

Table 12: Effect of rootstocks on vine length (m), internodal length (cm) and number of primary branches in bitter gourd

Rootstocks	Vine length (m)	Internodal length (cm)	Number of primary branches
R_1	4.92^{c}	6.94	13.67^{b}
R_2	5.43^{ab}	7.73	16.33^{a}
R_3	5.45^{ab}	7.67	17.00^{a}
R_4	5.53^{ab}	6.61	15.67^{ab}
R_5	4.74^{c}	6.97	13.33^{b}
R_6	5.08^{bc}	7.53	16.67^{a}
R_0	5.86^{a}	7.64	18.00^{a}
C. D. (0.05)	0.477	NS	2.506

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Bitter gourd**
R_0 : Control

4.1.7.5 Internodal length (cm)

Statistical analysis of internodal length revealed that among the treatments, internodal length had no significant variation. Internodal length ranged from 6.61 cm in R_4 to 7.73 cm in R_2 (Table 12).

4.1.7.6 Number of primary branches

Number of primary branches showed significant variation between the treatments (Table 12). Highest number of branches was recorded in R_0 (18.00) which was on par with R_3 (17.00), R_6 (16.67), R_2 (16.33) and R_4 (15.67). Least number of branches was observed in R_5 (13.33) which was on par with R_1 (13.67).

4.1.7.7 Days to first male flower

Days to first male flower recorded significant difference among the treatments (Table 13). Days to first male flower ranged between 28 and 32.78. R_0 was the earliest to flower (28.00 days) which was on par R_2 (28.45 days), R_6 (28.56 days) and R_1 (28.65 days). R_5 (32.78 days) recorded the maximum number of days for first flowering which was on par with R_3 (32.33 days).

4.1.7.8 Days to first female flower

Days to first female flower also recorded significant difference among the treatments and ranged between 29.89 and 35.78.Among the grafts, R_0 (29.89 days) was the earliest to flower, closely followed by R_2 (31.45 days), R_1 (31.55 days) and R_6 (31.55 days) which were on par. Maximum number of days for first female flower was noticed in R_5 (35.78 days) (Table 13).

4.1.7.9 Days to first harvest

Table 13: Effect of rootstocks on days to first male flower, female flower and harvest in bitter gourd

Rootstocks	Days to first male flower	Days to first female flower	Days to first harvest
R_1	28.65^{bc}	31.55^{cd}	46.77^{b}
R_2	28.45^{bc}	31.45^{cd}	44.33^{d}
R_3	32.33^{a}	33.67^{b}	47.00^{b}
R_4	30.11^{b}	32.44^{bc}	45.89^{c}
R_5	32.78^{a}	35.78^{a}	48.11^{a}
R_6	28.56^{bc}	31.55^{cd}	45.33^{c}
R_0	28.00^{c}	29.89^{d}	43.69^{d}
C. D (0.05)	1.74	1.68	0.77

Table 14: Effect of rootstocks on node to first male flower and female flower in bitter gourd

Rootstocks	Node to first male flower	Node to first female flower
R_1	16.33^{a}	18.67^{d}
R_2	13.00^{cd}	28.00^{a}
R_3	15.67^{ab}	23.00^{a}
R_4	12.00^{d}	19.00^{cd}
R_5	14.67^{abc}	19.00^{cd}
R_6	14.00^{bc}	21.33^{bc}
R_0	14.00^{bc}	19.67^{cd}
C. D. (0.05)	1.915	2.388

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Bitter gourd**
R_0 : Control

Analysis of variance showed that there was significant difference among the treatments for the days to first harvest (Table 13). Days to first harvest was lowest in control plants R_0 (43.69 days) which was on par with R_2 (44.33 days). Days to first harvest was 45.33 days, 45.89 days, 46.77 days and 47.00 days for R_6, R_4, R_1 and R_3 respectively. R_5 recorded highest number of days to first harvest (48.11 days).

4.1.7.10 Node to first male flower

Node to first male flower varied significantly as shown in table 14. Male flower appeared in the lower node of treatment R_4 (12.00) which was on par with R_2 (13.00). Node to first male flower in R_6, R_0, R_5, R_3 and R_1 were 14.00, 14.00, 14.67, 15.67 and 16.33 respectively.

4.1.7.11 Node to first female flower

Node to first female flower significantly varied among the treatments (Table 14). Female flower appeared at the lowest node in R_1 (18.67) which was on par with R_4 (19.00), R_5 (19.00) and R_0 (19.67). Node to first female flower was highest in R_2 (28.00) followed by R_3 (23.00) which were on par.

4.1.7.12 Fruit girth (cm)

Treatments differed significantly in girth of fruits (Table 15). Highest fruit girth of 17.73 cm was observed for R_0 followed by 17.60 cm for R_2, 17.20 for R_5, 17.10 for R_4 and 16.77 for R_3 which was statistically on par. Lowest fruit girth was observed in R_6 (15.46 cm) which was on par with R_1 (16.06 cm).

4.1.7.13 Fruit length (cm)

Analysis of data on fruit length showed significant difference among the treatments (Table 15). Highest fruit length of 21.12 cm was recorded in R_0 which was on par with R_1 (21.03 cm). Treatments R_3, R_6 and R_5 were statistically

Table 15: Effect of rootstocks on fruit girth (cm), fruit length (cm), flesh thickness (cm) and fruit weight (g) in bitter gourd

Rootstocks	Fruit girth (cm)	Fruit length (cm)	Flesh thickness (cm)	Fruit weight (g)
R_1	16.06^{bc}	21.03^{a}	1.07^{b}	154.33^{b}
R_2	17.60^{a}	15.56^{d}	1.33^{a}	180.67^{a}
R_3	16.77^{ab}	18.43^{b}	1.17^{ab}	183.33^{a}
R_4	17.10^{ab}	16.53^{cd}	1.23^{ab}	182.33^{a}
R_5	17.20^{ab}	17.76^{bc}	1.07^{b}	153.67^{b}
R_6	15.46^{c}	18.26^{b}	1.20^{ab}	138.33^{c}
R_0	17.73^{a}	21.12^{a}	1.33^{a}	189.33^{a}
C. D. (0.05)	1.244	1.49	0.19	10.94

Table 16: Effect of rootstocks on fruit number per plant, yield per plant, number of harvests and crop duration (days) in bitter gourd

Rootstocks	Fruit number per plant	Yield per plant (kg)	Number of harvests	Crop duration (days)
R_1	17.11	2.64^{bc}	9.89^{a}	91.33^{cd}
R_2	16.33	2.95^{ab}	10.55^{a}	103.33^{b}
R_3	18.00	3.30^{a}	10.67^{a}	110.67^{b}
R_4	16.67	3.04^{a}	10.55^{a}	101.67^{a}
R_5	15.78	2.42^{cd}	8.56^{b}	93.33^{b}
R_6	16.11	2.23^{d}	8.55^{b}	90.33^{d}
R_0	16.78	3.18^{a}	10.22^{a}	96.33^{c}
C. D. (0.05 %)	NS	0.372	1.083	5.197

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Bitter gourd**
R_0 : Control

on par with a fruit length of 18.43 cm, 18.26 cm and 17.76 cm respectively. Fruit length was least in R_2 (15.56 cm) which was on par with R_4 (16.53 cm).

4.1.7.14 Flesh thickness (cm)

The data on mean flesh thickness of fruits showed significant difference among the treatments. Highest flesh thickness of 1.33 cm was observed in treatments R_2 and R_0. It was statistically on par with R_4, R_6 and R_3 with flesh thickness of 1.23 cm, 1.20 cm and 1.17 cm respectively while treatments R_5 and R_1 had lowest fruit flesh thickness of 1.07 cm (Table 15).

4.1.7.15 Fruit weight (g)

Treatments differed significantly for fruit weight (Table 15). Highest fruit weight of 189.33 g was observed in R_0 which was statistically on par with the treatments R_3 (183.33 g), R_4 (182.33 g) and R_2 (180.67 g) respectively. Treatments R_1 and R_5 were statistically on par. Lowest fruit weight was observed in R_6 (138.33 g).

4.1.7.16 Number of fruits per plant

Analysis of data on number of fruits per plant showed no significant difference among the treatments (Table 16). Fruit number varied from 15.78 in R_5 to 18.00 in R_3.

4.1.7.17 Yield per plant (kg)

There was significant difference in fruit yield per plant among the treatments (Table 16). Maximum yield was observed in R_3 (3.30 kg) which was on par with R_0 (3.18 kg) and R_4 (3.04 kg). Per plant yield of R_2 and R_1 were 2.95 kg and 2.64 kg respectively. Yield per plant was minimum in R_6 (2.23 kg) which was on par with R_5 (2.42 Kg).

4.1.7.18 Number of harvests

Number of harvests varied significantly among the treatments (Table 16). Highest number of harvests were obtained from R_3 (10.67) which was on par with R_2, R_4, R_0 and R_1 with number of harvests 10.55, 10.55, 10.22 and 9.89 respectively. Lowest number of harvests was observed in R_6 (8.55) which was on par with R_5 (8.56).

4.1.7.19 Duration of the crop

Mean values of total crop duration of all the treatments were analysed statistically and were found to be significant (Table 16). Crop duration varied between 90.33 days and 110.67 days. Maximum crop duration was observed for treatment R_3 (110.67 days). It was followed by R_2 (103.33 days) and R_4 (101.67 days). Control plants had crop duration of 96.33 days which was on par with R_5 (93.33 days) and R_1 (91.33 days). Minimum duration was observed in R_6 (90.33 days).

4.1.7.20 Occurrence of pest and diseases

Pest observed during vegetative stage of the crop was pumpkin beetle (*Raphidopalpa foveicollis*). During fruiting stage, major pests observed were fruit fly (*Bactrocera cucurbitae*) and leaf eating caterpillar (*Diaphinia indica*). Plants were severly affected by phyllody during late fruiting stage.

4.1.8 Organoleptic test

Five quality characters viz., appearance, colour, texture, flavor and taste of cooked fruits were assessed in organoleptic evaluation of grafted and ungrafted control plants and is presented in Table 17.

4.1.8.1 Appearance

The treatment R_1 was more appealing in appearance with a score of 4.30 followed by R_4 (4.20) and R_0 (4.10). The lowest score of 2.60 was recorded for the treatment R_3.

4.1.8.2 Texture

The score for texture varied between 2.50 and 4.00. The highest score of 4.00 was recorded in R_1 followed by R_5 (3.90) and R_2 (3.80) and lowest score was recorded in R_6.

4.1.8.3 Flavour

For flavour, the maximum score of 4.30 was recorded for R_4 followed by R_2 (4.20). The minimum score for flavour was 2.70 recorded by R_5.

4.1.8.4 Taste

The treatment R_2 recorded maximum score of 4.30 followed by R_4 with a score of 3.90. Lowest score obtained with regard to taste was recorded in R_5 (2.60).

4.1.8.5 Overall Acceptability

The score for overall acceptability varied between 2.90 and 4.00 out of five. Highest score of 4.00 was recorded by R_2 and R_5 and the lowest score was recorded by R_3.

4.1.8.6 Total score

From the total score obtained by different treatments, it could be concluded that R_2 with a total score of 20.00 out of 25.00 was the most acceptable one closely followed by R_4 (19.90), R_1 (18.10) and R_0 (17.50). It could also be observed that the least accepted treatment was R_3 with a score of 14.00.

Table 17: Organoleptic test of bitter gourd

Rootstocks	Characters					Total score
	Appearance	Texture	Flavour	Taste (Bitterness)	Overall acceptability	
R_1	4.30 (5.30)	4.00 (5.20)	3.00 (3.30)	3.10 (4.00)	3.70 (4.20)	18.10
R_2	3.70 (4.10)	3.80 (4.85)	4.20 (5.50)	4.30 (5.65)	4.00 (4.95)	20.00
R_3	2.60 (2.10)	2.60 (2.40)	3.10 (3.65)	2.80 (3.15)	2.90 (2.80)	14.00
R_4	4.20 (5.00)	3.50 (4.10)	4.30 (5.60)	3.90 (4.80)	4.00 (5.35)	19.90
R_5	3.50 (3.60)	3.90 (4.90)	2.70 (2.55)	2.60 (2.80)	3.30 (3.80)	16.00
R_6	3.00 (3.00)	2.50 (2.25)	2.90 (3.20)	3.20 (3.95)	3.10 (3.25)	14.70
R_0	4.10 (4.00)	3.60 (4.30)	3.40 (4.20)	3.10 (3.65)	3.30 (3.65)	17.50
Kendall's W	0.376	0.375	0.402	0.227	0.213	

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Bitter gourd**
R_0 : Control

Figures in paranthesis indicate mean rank scores based on Kendall's W.

4.2 STANDARDISATION OF GRAFTING IN WATERMELON

4.2.1 Number of days taken for germination of rootstocks

Among the six rootstocks studied, significantly lesser number of days was required for germination of R_5 (3.42 days) compared to other rootstocks (Table 18). However, results were on par with R_4 (3.85 days), R_1 (4.14 days) and R_6 (4.28 days). Maximum number of days for germination was recorded by R_3 (6.00 days).

4.2.2 Number of days taken for rootstocks to attain graftable size

Data on number of days taken to attain graftable size for the rootstocks after germination varied significantly. Among the treatments, R_4 and R_2 recorded significantly less (9.99 and 10.43 respectively) number of days to attain graftable size. The rootstock R_5 (18.27 days) recorded maximum number of days to attain graftable size (Table 18).

4.2.3 Standardisation of age of rootstocks for grafting

Analysis of data on graft success in three different age groups of rootstocks is given in table 19. For the rootstock R_1, age A_2 and A_3 gave highest graft success of 53.00 per cent and graft success was least in A_1 (45.00 %). There was no significant difference in graft success in R_2 among the age groups studied and it varied between 72.00 per cent in A_3 and 75.00 per cent in A_2. For the rootstock R_3, age A_3 gave highest graft success of 74.00 per cent which was on par with A_2 (73.00 %) and graft success was least in A_1 (64.00%). There was no significant difference in graft success in R_4 among the age groups studied and it varied between 64.00 per cent in A_3 and 67.00 per cent in A_1 and A_2. For the rootstock R_5, age A_3 gave highest graft success (48.00 %) which was on par with A_2 (45.00 %). Graft success was lowest in A_1 (40.00%). There was no significant difference in graft success in R_6 among the age groups studied and graft success was nil in the three age groups.

Table 18: Days taken by various rootstocks for germination and to attain graftable size for grafting watermelon

Rootstocks	Number of days taken for germination (days)	Number of days taken to attain graftable size (days)
R_1	4.14^{bc}	12.99^{c}
R_2	4.43^{b}	10.43^{e}
R_3	6.00^{a}	17.57^{b}
R_4	3.85^{bc}	9.99^{f}
R_5	3.42^{c}	18.27^{a}
R_6	4.28^{bc}	11.13^{d}
C. D. (0.05)	0.825	0.018

Table 19: Influence of age of rootstocks on graft success in watermelon

Age of rootstocks	Graft success in different rootstocks (%)					
	R_1	R_2	R_3	R_4	R_5	R_6
A_1	45.00^{b}	73.00	64.00^{b}	67.00	40.00^{b}	0.00
A_2	53.00^{a}	75.00	73.00^{a}	67.00	45.00^{a}	0.00
A_3	53.00^{a}	72.00	74.00^{a}	64.00	48.00^{a}	0.00
C. D. (0.05)	4.907	NS	7.602	NS	4.907	NS

A_1: 5-7 days **A_2: 10-12 days** **A_3 :15-17 days**

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Watermelon**

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4.2.4. Standardisation of method of grafting

4.2.4.1 Effect of type of rootstocks on graft success in Hole Insertion Grafting (HIG)

Per cent success of grafts differed significantly among different rootstocks studied at three, six, nine and twelve days after grafting (Table 20).Rootstock R_2 (89.00 %) recorded highest success per cent which was on par with R_4 (84.00 %) and R_3 (81.00 %). Graft success in R_5 and R_1 was respectively 67.00 per cent and 63.00 per cent.

Significant variation in graft success was noticed in different rootstocks six days after grafting. R_2 recorded the highest success with 78.00 per cent which was on par with R_3 (74.00 %) and R_4 (69.00 %). Graft success in R_1 and R_5 was 59.00 per cent and 57.00 per cent respectively.

Analysis of graft success nine after grafting showed significant difference among the rootstocks used. R_2 showed maximum success per cent of 75.00 which was on par with R_3 (73.00 %). R_1 and R_5 had graft success of 50.00 per cent and 46.00 per cent respectively. Graft success per cent at twelve days after grafting showed similar results as nine days after grafting.

4.2.4.2 Effect of type of rootstocks on graft success in Tongue Approach Grafting (TAG)

There was significant difference among the rootstocks in per cent graft success on three, six, nine and twelve days after grafting (Table 21). The highest per cent graft success was exhibited by R_2 (94.00 %) which was on par with R_3 (88.00 %). Graft success in R_4, R_5 and R_1 was respectively 87.00 per cent, 85.00 per cent and 83.00 per cent which was on par. Rootstock R_2 had highest graft success (72.00 %) six days after grafting which was on par with all the rootstocks.

Table 20: Effect of rootstocks on graft success in hole insertion grafting in watermelon

Rootstocks	Graft success at 3 days interval (%)			
	3 DAG	6 DAG	9 DAG	12 DAG
R_1	63.00[b]	59.00[b]	50.00[c]	50.00[c]
R_2	89.00[a]	78.00[a]	75.00[a]	75.00[a]
R_3	81.00[a]	74.00[a]	73.00[a]	73.00[a]
R_4	84.00[a]	69.00[a]	66.00[b]	66.00[b]
R_5	67.00[b]	57.00[b]	46.00[c]	46.00[c]
C. D. (0.05)	10.537	10.210	8.955	8.955

Table 21: Effect of rootstocks on graft success in tongue approach grafting in watermelon

Rootstocks	Graft success at 3 days interval (%)			
	3 DAG	6 DAG	9 DAG	12 DAG
R_1	83.00[b]	69.00	33.00	14.00
R_2	94.00[a]	72.00	35.00	16.00
R_3	88.00[ab]	64.00	26.00	15.00
R_4	87.00[b]	66.00	24.00	16.00
R_5	85.00[b]	63.00	25.00	12.00
C. D. (0.05)	6.145	NS	NS	NS

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon**

Graft success when observed nine days after grafting recorded highest success in R_2 (35.00 %) which was on par with R_1 (33.00 %). Graft success in R_3, R_5 and R_4 was respectively 26.00 per cent, 25.00 per cent and 24.00 per cent which was on par. Graft success was very low in all the rootstocks studied after 12 days of grafting. Highest graft success of 16.00 per cent was recorded in R_2 and R_4 which was on par with all the rootstocks.

4.2.4.3 Interaction effect of rootstocks and methods of grafting on graft success

Analysis of data on graft success showed significant difference among the rootstocks, methods of grafting and interaction between rootstocks and methods of grafting (Table 22).

On third day after grafting, R_2 showed maximum graft success per cent of 91.50 which was closely followed by R_4 (85.50 %) and R_3 (84.50 %). Graft success of R_6 was 0.00 per cent. Graft success analysed on sixth day after grafting showed significant difference among the rootstocks. Highest success per cent was noticed in R_2 (75.00 %) which was on par with R_3 (69.00 %) followed by R_4 (67.50 %).

On nine days after grafting, the graft success varied significantly among the rootstocks studied. Highest graft success was noticed in R_2 (55.00 %) which was followed by R_3 (49.50 %). Evaluation of graft success 12 days after grafting showed significant difference among the treatments. Graft success was highest in R_2 (45.00%) which was on par with R_3 (44.00 %).

The effect of methods of grafting on graft success were evaluated. Statistically analysed results revealed that the treatments were significantly different. Per cent graft success three days after grafting was more in G_2 (72.83 %) compared to G_1 (64.00 %). Per cent graft success was 55.17 % in G_2 while it was 56.17 % in G_1. Grafting method G_1 recorded higher success of 51.67 % in comparison to G_2 which was 23.83 % on nine days after grafting. Analysis of graft success twelve days after grafting revealed that for G_1 the per cent success

Table 22: Interaction effect of rootstocks and methods of grafting on graft success in watermelon

Rootstocks	Graft success at three days interval (%)											
	3 DAG			6 DAG			9 DAG			12 DAG		
	G_1	G_2	Mean (Treatments)	G_1	G_2	Mean (Treatments)	G_1	G_2	Mean (Treatments)	G_1	G_2	Mean (Treatments)
R_1	63.00^{c}	83.00^{b}	73.00^{d}	59.00^{c}	69.00^{bc}	64.00^{b}	50.00^{c}	33.00^{ed}	41.50^{b}	50.00^{c}	14.00^{d}	32.00^{b}
R_2	89.00^{ab}	94.00^{a}	91.50^{a}	78.00^{a}	72.00^{ab}	75.00^{a}	75.00^{a}	35.00^{d}	55.00^{a}	75.00^{a}	16.00^{d}	45.50^{a}
R_3	81.00^{b}	88.00^{ab}	84.50^{c}	74.00^{a}	64.00^{bc}	69.00^{ab}	73.00^{ab}	26.00^{e}	49.50^{ab}	73.00^{a}	15.00^{d}	44.00^{a}
R_4	84.00^{b}	87.00^{ab}	85.50^{bc}	69.00^{ab}	66.00^{bc}	67.50^{b}	66.00^{b}	24.00^{e}	45.00^{b}	66.00^{b}	16.00^{d}	41.00^{a}
R_5	67.00^{c}	85.00^{b}	76.00^{cd}	57.00^{c}	63.00^{bc}	60.00^{b}	46.00^{c}	25.00^{e}	35.50^{c}	46.00^{c}	12.00^{d}	29.00^{c}
Mean (Grafting method)	76.80^{a}	87.40^{b}		67.40	66.80		62.00^{a}	28.60^{b}		62.00^{a}	14.60^{b}	
C. D. (0.05)	3.799[1], 6.006[2], 8.494[3]			NS[1], 6.575[2], 9.299[3]			3.958[1],6.258[2],8.850[3]			3.081[1], 4.871[2], 6.889[3]		

[1]Methods, [2]Treatments, [3]Interaction
R_1-- Ash gourd R_2-- Bottle gourd R_3 – Smooth gourd R_4–Pumpkin R_5–OP melon
G_1- Hole Insertion Grafting G_2- Tongue Approach Grafting

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was same as that of nine days after grafting while in G_2, it was still lower (12.17 %).

Data on graft success per cent differed significantly among the interactions between treatments and grafting methods at three, six, nine and twelve days after grafting. Graft success three days after grafting recorded highest in the treatment combination of R_2G_2 (94.00 %) on par with R_2G_1 (89.00 %) and R_3G_2 (88.00 %) and R_4G_2 (87.00 %). R_2G_1 showed maximum graft success of 78.00 % on sixth day after grafting, which was on par with R_3G_1 (74.00 %) and R_2G_2 (72.00 %). Nine days after grafting, graft success was highest in R_2G_1 (75.00 %) which was on par with R_3G_1 (73.00 %). The rootstock R_2G_1 (75.00 %) recorded highest graft success on twelve days after grafting which was on par with R3G1 (73.00 %).

4.2.5. Standardisation of month of grafting

Data showing the effect of month of grafting, rootstock and interaction effect of month and rootstock on graft success is given in table 23. On comparison, it was observed that graft success varied significantly for different months of grafting. Grafting operation done during M_4 recorded highest success of 51.67 per cent which was on par with M_3 (51.00 %), M_2 (50.83 %) and M_5 (48.67 %). Least success was noticed in the M_1 with a success per cent of 42.83 per cent.

Among the rootstocks, maximum graft success was noticed in R_2 (69.83 %) which was on par with R_3 (67.67 %). Graft success in R_4, R_1 and R_5 were 64.33 per cent, 47.00 per cent and 43.33 per cent respectively.

Among the interactions between month of grafting and rootstocks R_2M_2 and R_2M_3 recorded highest graft success of 75.00 % while the lowest value of 40.00 % was recorded in R_5M_1.

Table 23: Interaction effect of rootstocks and month of grafting on graft success in watermelon

Rootstocks	Graft success in different months of grafting (%)						
	M_1	M_2	M_3	M_4	M_5	M_6	Mean
R_1	46.00^{d}	49.00^{cd}	49.00^{cd}	50.00^{cd}	46.00^{d}	42.00^{d}	47.00^{c}
R_2	54.00^{c}	74.00^{ab}	75.00^{a}	75.00^{a}	71.00^{ab}	70.00^{ab}	69.83^{a}
R_3	54.00^{c}	72.00^{ab}	71.00^{ab}	73.00^{ab}	69.00^{ab}	67.00^{b}	67.67^{a}
R_4	63.00^{b}	67.00^{b}	65.00^{b}	66.00^{b}	63.00^{b}	62.00^{b}	64.33^{b}
R_5	40.00^{d}	43.00^{d}	46.00^{d}	46.00^{d}	43.00^{d}	42.00^{d}	43.33^{d}
Mean	51.40^{c}	61.00^{ab}	61.20^{ab}	62.00^{a}	58.40^{b}	56.60^{b}	
C. D.(0.05)	3.755^{1}, 3.428^{2}, 7.553^{3}						

Table 24: Correlation of weather and graft success in watermelon

Rootstocks	Correlation coefficient		
	Relative humidity	Maximum temperature	Minimum temperature
R_1	0.64**	0.72**	0.51**
R_2	0.63**	0.82**	0.61**
R_3	0.61**	0.77**	0.54**
R_4	0.62**	0.73**	0.52**
R_5	0.59**	0.52**	0.58**

M_1 – May **M_2 – June** **M_3 – July**
M_4– August **M_5 – September** **M_6 – October**
R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon**

1: C. D. for comparing month of grafting
2: C. D. for comparing rootstocks
3: C. D. for comparing interaction

* Significant at 0.05 level
** Significant at 0.01 level

4.2.5.1 Correlation of weather and graft success

Data on graft success of different rootstocks were subjected to correlation analysis. The correlation coefficients between graft success and monthly mean weather parameters *viz.*, relative humidity, maximum and minimum temperature were estimated and presented in table 24. Relative humidity had highly significant positive correlation with graft success while maximum and minimum temperature had highly significant negative correlation with graft success.

4.2.6 Anatomical studies

Transverse sections of graft union were taken from plants grafted by hole insertion method on 20th day after grafting for anatomical studies. Histological observation at graft interface revealed formation of necrotic layer in response to wound repair and proliferation of cells of rootstocks and scion which is the stage prior to callus formation (Plate 8).

4.2.7 Performance of grafted watermelon plants

Since the graft success and survival were very poor in tongue approach grafts, only hole insertion grafts were evaluated in the main field for studying the performance of various rootstocks.

4.2.7.1 Diameter of rootstock hypocotyls (mm) [at the time of grafting, 30 and 60 days after grafting]

Analysis of data on the diameter of rootstock hypocotyls showed significant difference at the time of grafting (Table 25). Maximum diameter of 9.93 mm was observed in R_2 followed by R_4 (7.17 mm) and R_3 (6.90 mm). Minimum diameter was noticed in R_5 (3.13 mm) followed by R_1 (4.40 mm) and R_6 (4.56 mm).Statistical evaluation of mean rootstock diameter 30 days after grafting showed no significant difference among the treatments. Diameter of rootstock hypocotyls varied from 12.75 to 13.64.

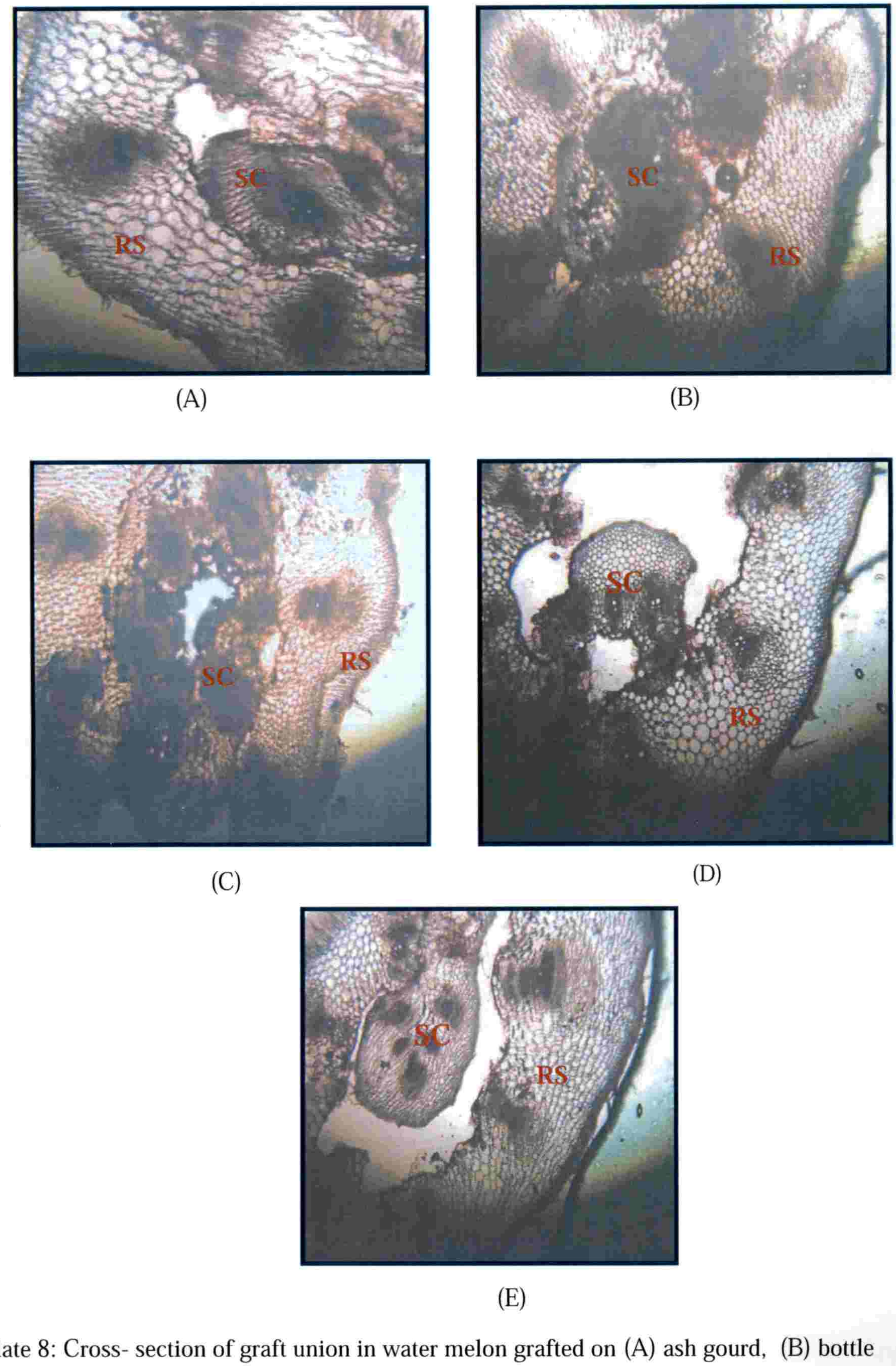


Plate 8: Cross- section of graft union in water melon grafted on (A) ash gourd, (B) bottle gourd, (C) smooth gourd (D) pumpkin (E) OP melon

Table 25: Diameter of rootstock hypocotyl (mm) in watermelon grafts

Rootstocks	At the time of grafting	30 DAG
R_1	4.40[d]	13.33
R_2	9.93[a]	13.64
R_3	6.90[c]	12.75
R_4	7.17[b]	13.37
R_5	3.13[e]	13.65
R_6	4.56[d]	-
C. D.(0.05)	0.21	NS

Table 26: Diameter of scion hypocotyl (mm) in watermelon grafts

Rootstocks	At the time of grafting	30 DAG
R_1	4.24	12.98
R_2	4.32	12.54
R_3	3.49	13.10
R_4	4.12	12.24
R_5	4.53	13.34
R_6	4.43	-
C. D.(0.05)	NS	NS

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_6: Watermelon**

4.2.7.2 Diameter of scion hypocotyls (mm) [at the time of grafting, 30 and 60 days after grafting]

Diameter of scion hypocotyl increased proportionally with the rootstock. Scion hypocotyls had no significant difference among the treatments during the time of grafting and 30 days after grafting (Table 26).

4.2.7.3 Survival rate in the main field

There was significant difference among the treatments for the rate of survival in the main field (Table 27). Survival rate was maximum for R2 (79.99 %) which was on par with R_1, R_3 and R_5 with survival rates of 77.78 per cent, 77.78 per cent and 75.55 per cent respectively. Control plants had a survival rate of 75.55 %. Least survival rate was for R_4 (46.67 %).

4.2.7.4 Days to first male flower

Days to first male flower appearance had no significant difference among the grafts. It varied from 38.81 in R_0 to 41.00 in R_1 (Table 28).

4.2.7.5 Days to first female flower

Days to first female flower appearance varied significantly among the rootstocks studied (Table 28). Least number of days was noticed in R_0 (40.67 days) which was on par with R_1 (42.33). Days to first female flower in the treatment R_4, R_2 and R_3 were 44.00 days, 43.67 days and 43.33 days respectively and were on par. Female flower appearance was late in R_5 (46.34 days).

4.2.7.6 Node to first male flower

There was significant difference among the graft combinations with respect to node number for first male flower appearance. Male flower appeared in the lower nodes in R_0 (11.80) and R_4 (12.00) which were statistically on par.

Plants grafted onto R_5 (17.67) recorded maximum value for the same trait (Table 28).

4.2.7.7 Node to first female flower

Node number to first female flower varied significantly among the rootstocks studied (Table 28). Female flower appeared in lower nodes of R_0 (21.00) which was on par with R_2 (22.97) and R_1 (23.53). Female flower appeared in higher nodes of R_5 (28.00).

Table 27: Survival rate of watermelon grafts in the main field

Rootstocks	Survival rate
R_1	77.78[a]
R_2	79.99[a]
R_3	77.78[a]
R_4	46.67[c]
R_5	75.55[a]
R_0	57.78[b]
C. D. (0.05)	6.885

Table 28: Effect of rootstocks on days to first male flower, female flower and node to first male flower, female flower in watermelon

Rootstocks	Days to first male flower	Days to first female flower	Node to first male flower	Node to first female flower
R_1	41.00	42.33[bc]	16.90[ab]	23.53[bc]
R_2	39.33	43.67[b]	14.83[b]	22.97[bc]
R_3	40.30	43.33[b]	14.93[b]	23.86[b]
R_4	40.46	44.00[b]	12.00[c]	24.30[b]
R_5	39.40	46.34[a]	17.67[a]	27.10[a]
R_0	38.81	40.67[c]	11.80[c]	21.00[c]
C. D (0.05)	NS	2.169	2.214	2.594

R_1: Ash gourd **R_2: Bottle gourd** **R_3: Smooth gourd**
R_4: Pumpkin **R_5: OP melon** **R_0: Control**

DISCUSSION

5. DISCUSSION

Cucurbits belonging to gourd family Cucurbitaceae comprises of group of tropical plants used for vegetable and dessert purposes. Cucurbits as a group occupy largest area in India and other tropical countries. One of the most important cucurbitaceous vegetables grown in India is bitter gourd (*Momordica charantia* L.) Bitter gourd is highly valued for its high nutritive and medicinal value especially for its hypoglycemic property. Watermelon (*Citrullus lanatus* (Thunb.)) is an important dessert vegetable among the cultivated cucurbits. Watermelon contains about 6 per cent sugar and 92 per cent water by weight and is a source of vitamin C.

Major limiting factors in the successful cultivation of these crops are incidence of diseases caused by soil borne pathogens and root knot nematode. Monocropping and intensive cropping of vegetable crops especially protected cultivation has increased the incidence of soil borne diseases and nematodes. Chemical control is highly expensive and hazardous creating residual effect causing environmental pollution. Grafting with resistant rootstocks ensures better protection against soil borne pathogens. Disease control in grafted plants is mainly attributed to enhanced nutrient uptake and inherent resistance of the rootstocks. Pina and Errea, 2005 defined grafting as the natural or deliberate fusion of plant parts so that vascular continuity is established between them and the resulting genetically composite organism functions as a single plant. The grafting technology in vegetable in India is in developmental stage only. Hence it is right time to standardise grafting technology for bitter gourd and watermelon.

The present investigation was envisaged to standardise grafting technique, to evaluate promising cucurbitaceous rootstocks for bitter gourd and watermelon and to study the performance of grafted plants in the field. The results of the study are discussed in the ensuing pages.

5.1. Days to germination and days to attain graftable size

Observation on number of days taken for germination of seeds of rootstocks and scions are important in order to adjust the time of sowing such that both stock and scion attain grafting stage uniformly. Johnson *et al.*, 2011 suggested that since the germination and growth rate of rootstock and scion is not uniform, preliminary trial is essential to determine the graftable size of rootstock and scion. Thus, a preliminary study was conducted to determine number of days taken for germination and number of days to attain graftable size for rootstocks and scions.

The scions used in the study were bitter gourd (Preethi) and watermelon (Sugar Baby). Five inter-generic rootstocks namely, ash gourd (KAU Local), bottle gourd (Arka Bahar), smooth gourd (Local cultivar), pumpkin (Ambili) and oriental pickling melon (Mudicode) and self rootstocks were selected for the study. Among the six rootstocks studied in bitter gourd, oriental pickling melon recorded least number of days for germination (3.42 days) followed by pumpkin (3.85 days), ash gourd (4.14 days), bottle gourd (4.43 days) and smooth gourd (6.00 days). Bitter gourd seeds took maximum days to germinate (6.42 days). Watermelon, as self rootstock for grafting, recorded 4.48 days for germination which was on par with ash gourd, pumpkin and OP melon.

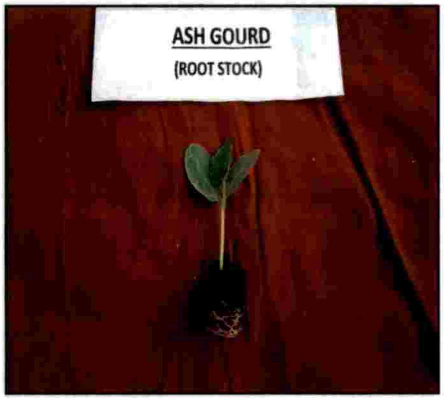
Number of days taken from sowing till the seedlings are ready for grafting was noted in case of rootstocks and scions. Criteria for the rootstocks and scions to attain graftable size was based on thickness of the stock and scion and its suitability for grafting operation. In case of rootstocks studied, least number of days to attain graftable size was noted in pumpkin (9.99 days) followed by bottle gourd (10.43 days). Maximum number of days was taken by oriental pickling melon (18.27 days) followed by smooth gourd (17.57 days). Bottle gourd and pumpkin took lesser days to attain graftable size due to larger diameter of hypocotyls (9.93 mm and 7.17 mm respectively). Even though oriental pickling melon took less number of days for germination, days taken to attain graftable size was more due to its slender hypocotyls having diameter of 3.13 mm. In case of scions, bitter gourd took 15.42 days while watermelon took 11.13 days to attain graftable size. The results were supported by the reports of Punithaveni *et al.*, 2014. They reported that fig leaf gourd (10.55 days) and pumpkin (11.52 days) took least number of days to attain graftable size due to higher diameter of hypocotyls while sponge gourd (14.56 days) took maximum number of days, due to smaller diameter of hypocotyls.

Accordingly, for grafting bitter gourd the scion seeds should be sown two, four and five days before sowing the seeds of ash gourd, bottle gourd and pumpkin respectively. The seeds of rootstocks smooth gourd and oriental pickling melon should be sown three and four days respectively prior to sowing seeds of bitter gourd.

For grafting watermelon, scions seeds should be sown one and two days before sowing the seeds of bottle gourd and pumpkin respectively. The seeds of ash gourd, smooth gourd and oriental pickling melon should be sown two, six and seven days respectively prior to sowing of watermelon seeds. In both the cases self rootstocks are ready for grafting on the same day of scion maturity. Similar results were also obtained by Leonardi and Romano, 2004. They reported that for grafting watermelon, to attain graftable size uniformily, the seeds of scion should be sown 2-3 days before sowing seeds of rootstock (*Cucurbita* spp.). They suggested that scheduling time of sowing helps to ensure that appropriate grafting stage for both scion and rootstock is achieved uniformily. Optimum stage of rootstocks and scions for grafting is depicted in plate 9 and 10.

5.2 Influence of age of rootstocks on graft success

Age of rootstock is known to have pronounced influence on graft success. To confirm the best stage of rootstocks for grafting bitter gourd and watermelon, three age groups of rootstocks *viz.*, 5-7 days, 10-12 days and 15-17 days were used for grafting both bitter gourd and watermelon scion of age group



(A)

(B)

(C)

(D)

(E)

Plate 9: Optimum stage of rootstocks for grafting (A) Ash gourd, (B) Bottle gourd, (C) Smooth gourd, (D) Pumpkin and (E) OP melon

(A)

(B)

Plate 10: Optimum stage of scions for grafting (A) Bitter gourd and (B) Watermelon

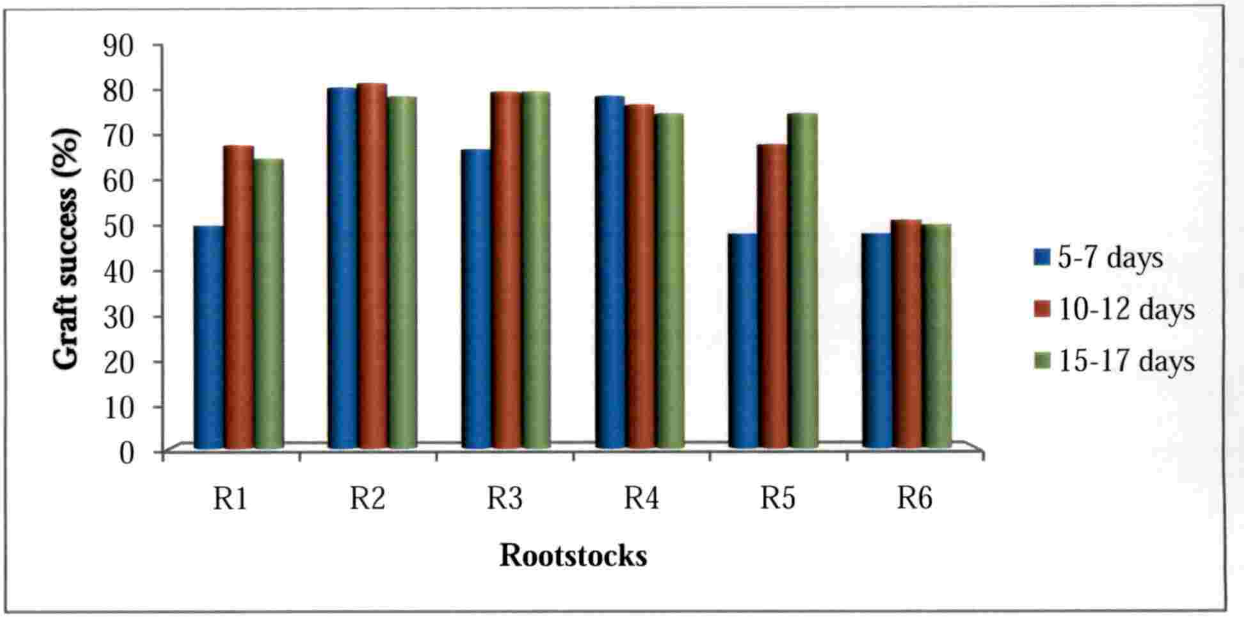


Fig. 1: Influence of age of rootstocks on graft success in bitter gourd

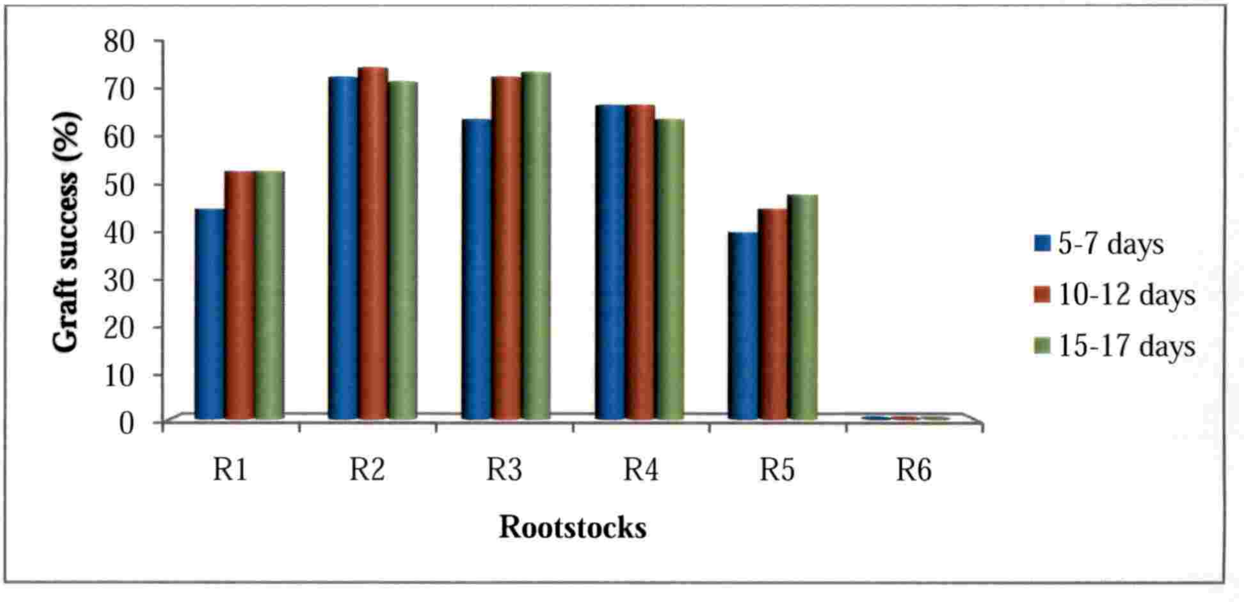


Fig. 2: Influence of age of rootstocks on graft success in watermelon

R1: Ash gourd R2: Bottle gourd R3: Smooth gourd

R4: Pumpkin R5: OP melon R6: Self rootstock

7-10 days. Method adopted was hole insertion grafting. Based on graft success of each rootstocks in different age groups, age of grafting was standardized. In grafting bitter gourd and watermelon, age of rootstocks had profound influence on graft success in three rootstocks studied *viz.*, ash gourd, smooth gourd and oriental pickling melon. The rest of the rootstocks *viz.*, bottle gourd, pumpkin and self rootstocks (bitter gourd and watermelon) there was no significant difference in graft success in the three age groups studied (Fig.1 and Fig. 2). For ash gourd, smooth gourd and oriental pickling melon rootstocks optimum stage for grafting was from 10-12 days after germination. Graft success in these rootstocks in the age group 5-7 days was low compared to age groups 10-12 days and 15-17 days. This could be due to slender and succulent seedlings with smaller diameter of hypocotyls. For rootstocks bottle gourd, pumpkin and bitter gourd, grafting could be performed irrespective of age starting from 5-7 days after germination to 15-17 days after germination. This could be due to sturdy seedlings with higher diameter of hypocotyls even at younger age. When watermelon was used as rootstock, graft success was nil. In a study by Tamilselvi and Pugalendhi, 2017 on days taken by cucurbitaceous rootstocks to attain graftable size, rootstocks ash gourd, bottle gourd, sponge gourd and pumpkin took 36.50 days, 24.80 days, 23.10 days and 22.70 while scion bitter gourd (CO1) took 26.40 days to attain graftable size. But in the present study considerable graft success was obtained even at younger age of stock and scion.

After finalizing the best age of rootstocks for grafting, the effect of type of rootstock and method of grafting on graft success was evaluated based on two methods of grafting namely, hole insertion grafting (HIG) and tongue approach grafting (TAG). Per cent graft success was evaluated at three, six, nine and twelve days after grafting.

5.3 Influence of type of rootstocks on graft success

In bitter gourd, for hole insertion grafting, pumpkin rootstock recorded highest graft success of 92.00 per cent and 86.00 per cent on three and six days after grafting respectively. Later, graft success was reduced to 77.00 per cent. In

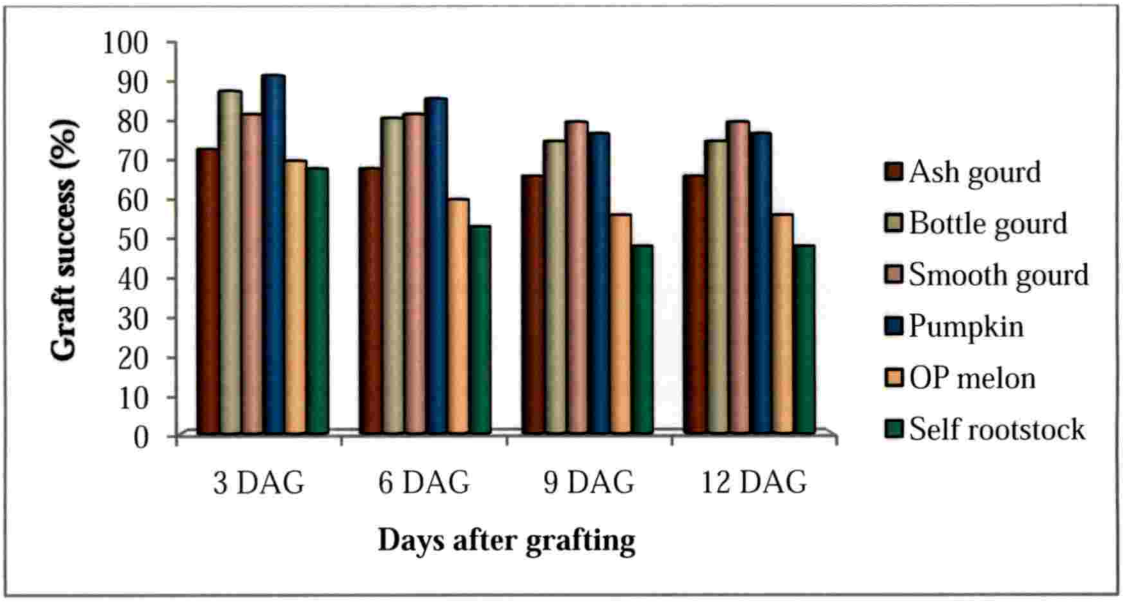


Fig. 3: Percentage graft success in different rootstocks in hole insertion grafting at three days interval in bitter gourd

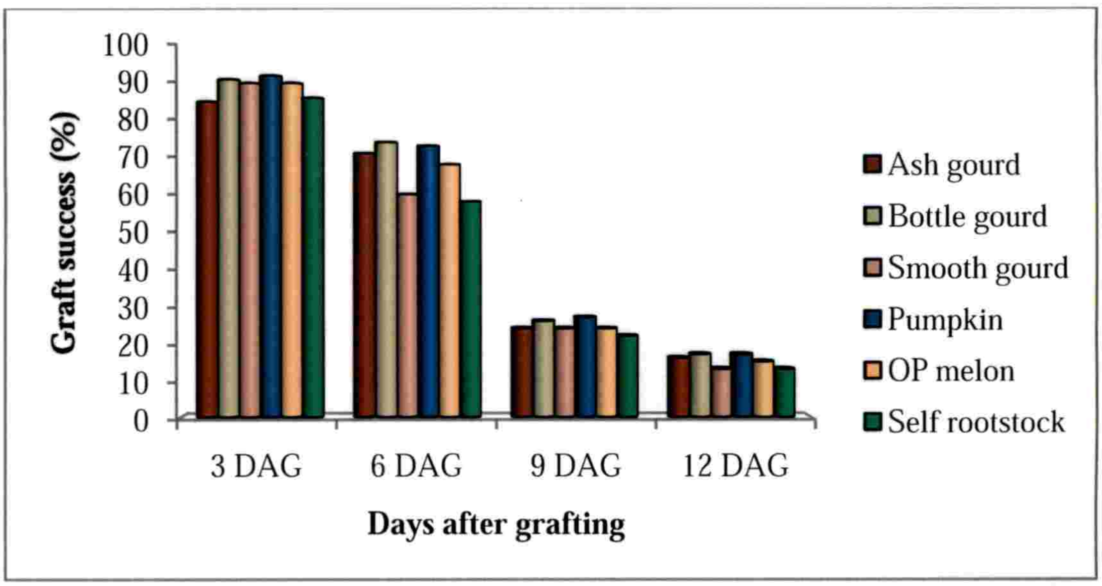


Fig. 4: Percentage graft success in different rootstocks in tongue approach grafting at three days interval in bitter gourd

bottle gourd, high initial graft success of 88.00 per cent and 81.00 per cent was observed on three and six days after grafting respectively but it reduced to 75.00 per cent when observed at nine days after grafting. The graft success in smooth gourd rootstock was 82.00 per cent on third and sixth day after grafting. The final graft success was 80.00 per cent in smooth gourd which was highest among all the six rootstocks studied. Graft success was least for homografts at three, six, nine and twelve days after grafting (68.00 %, 53.00 %, 48.00 %, and 48.00 % respectively). Influence of rootstocks on graft success in hole insertion grafting is depicted in fig. 3.

In tongue approach grafting, there was no significant difference among the rootstocks on initial and final graft success in bitter gourd (Fig. 4). In pumpkin rootstock, graft success on three, six, nine and twelve days after grafting was 92.00 per cent, 73.00 per cent, 27 per cent and 17.00 per cent respectively. Bottle gourd also had similar final graft success (17.00 %). Smooth gourd and bitter gourd rootstocks had final graft success of 13.00 per cent.

When interaction effect was studied, the rootstock pumpkin had graft success of 92.00 per cent, 79.50 per cent, 52.00 per cent and 47.00 per cent respectively on three, six, nine and twelve days after grafting. In the case of bottle gourd initial success was 89.50 per cent while it was reduced to 46.00 per cent on 12^{th} day of grafting. In smooth gourd, even though initial graft success was less than bottle gourd, final success per cent was 46.50 per cent. At all the intervals studied, bitter gourd as rootstock had least graft success.

Thus among the type of rootstocks studied for grafting bitter gourd, in hole insertion grafting best rootstock was smooth gourd followed by pumpkin, bottle gourd, ash gourd, oriental pickling melon and self rootstock. For tongue approach grafting, the graft success was not significant among the rootstocks. Interaction effect revealed that best rootstock for grafting bitter gourd was pumpkin followed by smooth gourd, bottle gourd, ash gourd, oriental pickling melon and self rootstock. It was in agreement with the findings of Tamilselvi and

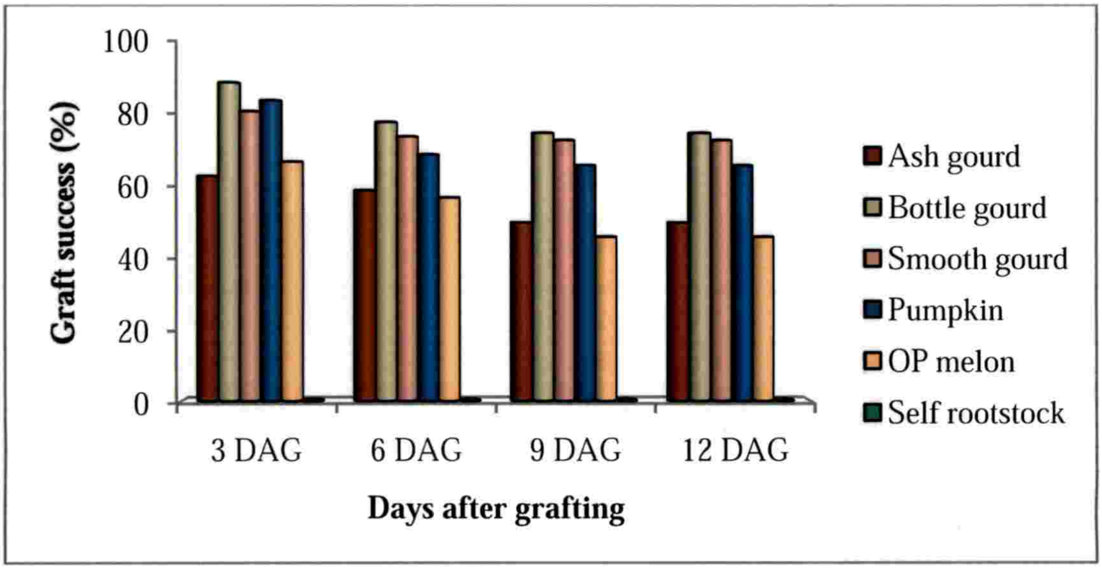


Fig. 5: Percentage graft success in different rootstocks in hole insertion grafting at three days interval in watermelon

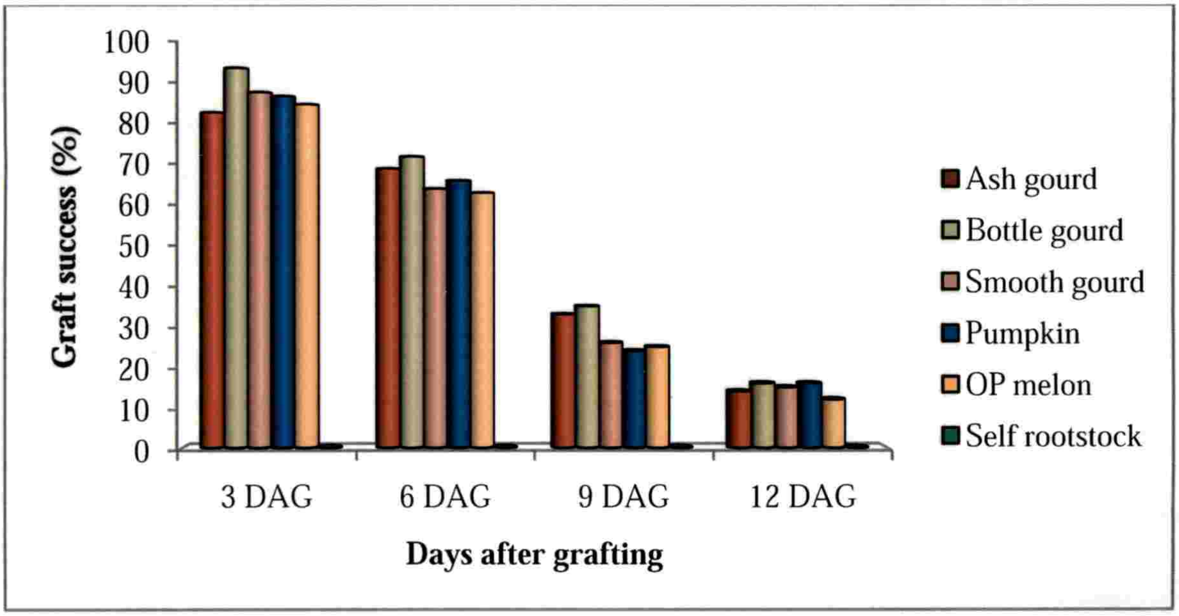


Fig. 6: Percentage graft success in different rootstocks in tongue approach grafting at three days interval in watermelon

Pugalendhi, 2017. They reported pumpkin as the best rootstock for grafting bitter gourd with a success per cent of 71.71 followed by smooth gourd (68.26 %). Least success (49.24) was observed in mithipakal (*Momordica charantia* var. *muricata*).

In watermelon, for hole insertion grafting, bottle gourd recorded highest graft success (89.00 %, 78.00 %, and 75.00 % respectively) on three, six and nine days after grafting (Fig. 5). Pumpkin rootstock had high initial graft success of 84.00 per cent while it was reduced to 69.00 per cent and 66.00 per cent respectively on six and nine days after grafting. In case of smooth gourd, eventhough initial graft success was low compared to bottle gourd, final graft success was 73.00 per cent. Among the heterografts, least success was in oriental pickling melon on six and nine days after grafting (57.00 % and 46.00 %) while homografts had no success.

In tongue approach grafting in watermelon, bottle gourd recorded highest graft success at three, six, nine and twelve days after grafting (94.00 %, 72.00 %, 35.00%, and 16.00 % respectively). Final graft success was low in all the rootstocks studied and among the heterografts the per cent graft success was not significant. Final graft success varied from 16.00 per cent in bottle gourd and pumpkin to 12.00 per cent in oriental pickling melon. There was no graft success in self rootstock (Fig. 6).

When interaction effect was studied, bottle gourd recorded highest success of 91.50 per cent, 75.00 per cent, 55.00 per cent, and 45.50 per cent on three, six, nine and twelve days after grafting. Final graft success for the rootstocks smooth gourd and pumpkin were 44.00 per cent and 41.00 per cent. There was no graft success in autografts.

Thus among the type of rootstocks studied for grafting watermelon, in hole insertion grafting best rootstock was bottle gourd followed by smooth gourd, pumpkin, ash gourd and oriental pickling melon. For tongue approach grafting, the graft success was not significant among the heterografts.

Interaction effect revealed that best rootstock for grafting watermelon was bottle gourd followed by smooth gourd, pumpkin, ash gourd and oriental pickling melon. The results are in accordance with Bekhradi *et al.*, 2011. They reported 90.00 per cent graft success in watermelon grafted onto bottle gourd.

From the above observations, it can also be concluded that for the same method of grafting studied in similar rootstocks, graft success varied in relation to scions used. Similar statement was also given by Traka-Mavrona, *et al.*, 2000. They reported that by adopting same grafting method, graft success vary in relation to rootstocks and scions.

5.4 Influence of methods of grafting on graft success

Two methods of grafting, namely hole insertion and tongue approach grafting was done in six different rootstocks to identify the best method for grafting bitter gourd and watermelon.

In bitter gourd, there was significant difference in graft success among the two grafting methods studied at three, six, nine and twelve days after grafting. In hole insertion grafting, per cent graft success gradually decreased from third day (78.83 %) to ninth day (67.00 %) after grafting. In tongue approach grafting, even though graft success was high during initial days (89.00 %), it was reduced to 15.17 per cent on 12^{th} day of grafting (Figure 7). In watermelon, there was significant difference in graft success among the two grafting methods studied at three, nine and twelve days after grafting. In hole insertion grafting, per cent graft success gradually decreased from 3^{rd} day (64.00 %) to 9^{th} day (51.67 %) after grafting. In tongue approach grafting, even though graft success was high during initial stage, it was reduced to 12.17 per cent on 12^{th} day of grafting (Figure 8). Initial high success per cent in tongue approach grafting compared to hole insertion grafting could be attributed to the presence of root system of scion upto five days after grafting.

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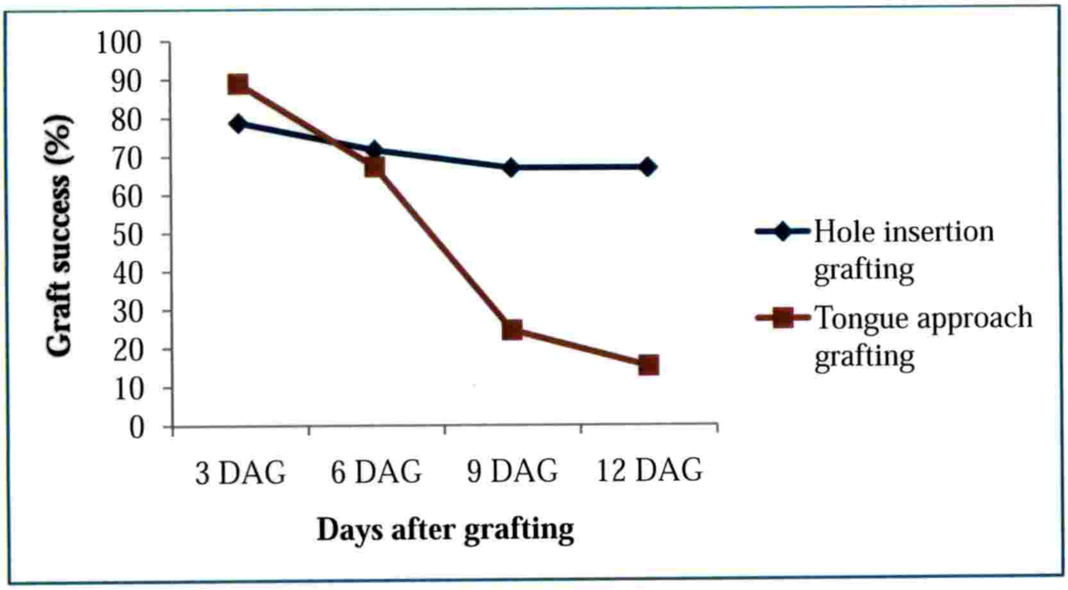

Fig. 7: Influence of grafting methods on graft success in bitter gourd

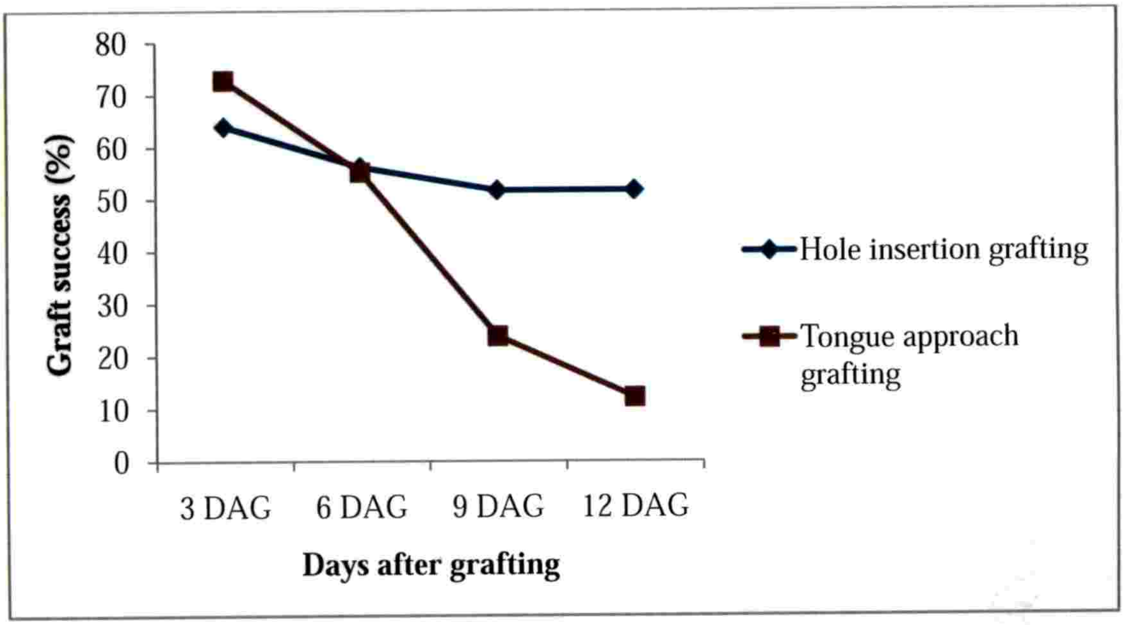

Fig. 8: Influence of grafting methods on graft success in watermelon

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In the present study, hole insertion method was found to be superior over tongue approach method in terms of graft success for both bitter gourd and watermelon. Davis *et al.*, 2008 suggested that tongue approach grafting is more suited for rootstocks with solid hypocotyls. Thus low success per cent could be due to hollow hypocotyls in cucurbitaceous rootstocks. Success of hole insertion grafting for bitter gourd and watermelon might be due to the suitability of smaller seedling size of both the scions for insertion to rootstocks. In watermelon, similar observations were made by Lee, 1994. He suggested that convenient method for grafting in watermelon is hole insertion because of their small seedling size compared to size of stock seedlings such as gourd and squash. Salehi *et al.*, 2008 reported that hole insertion grafting was highly effective in watermelon and cucumber.

There have been reports of difference in graft success based on methods of grafting irrespective of the rootstocks used in watermelon (Khankahdani *et al.*, 2012). Difference in response may be due to difference in growth rate of scion and rootstock before grafting, wetness of cut surface in contact and number of vascular bundles in contact (Oda *et al.*, 2000).

5.5 Influence of month of grafting on graft success

To study the effect of month on graft success, hole insertion grafting was done in bitter gourd and watermelon during six months (May to October). Weather conditions prevailing in a region influence graft success and it varies from one region to another within a season. Influence of month of grafting on graft success could be ascribed to the prevailing mean temperature and humidity.

In bitter gourd, graft success was high in the month of July (68.33 %) which was on par with graft success in June and August (67.00 %). Graft success during September and October were 58.83 per cent and 57.83 per cent respectively. Least success was noticed in the month of May with a success per cent of 51.16 (Figure 9). In watermelon, graft success was high in the month of

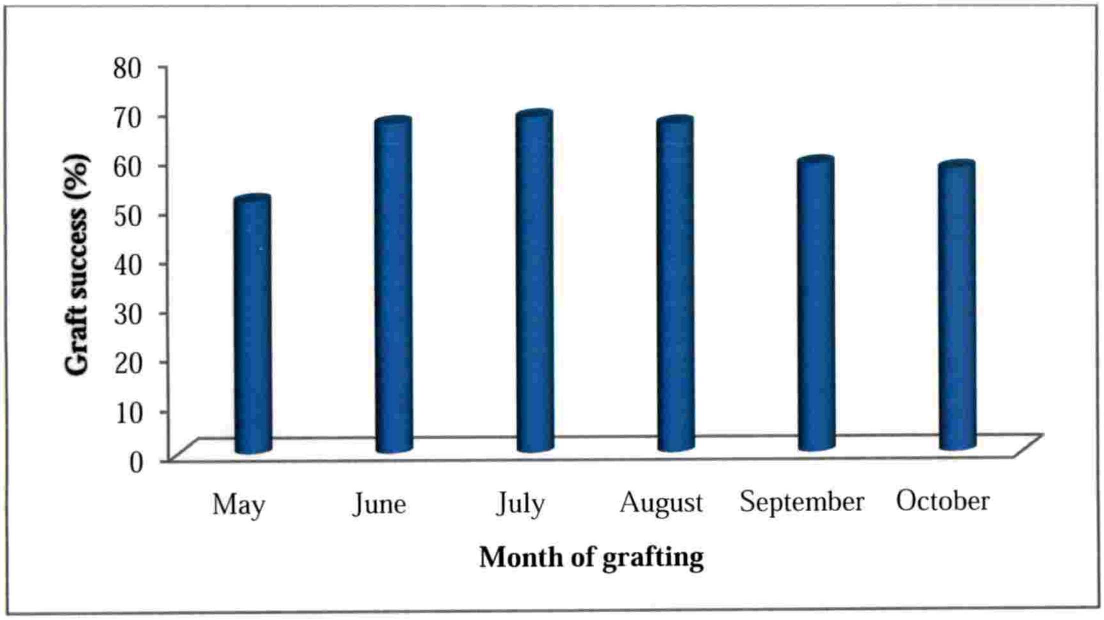


Fig. 9: Influence of month of grafting on graft success in bitter gourd

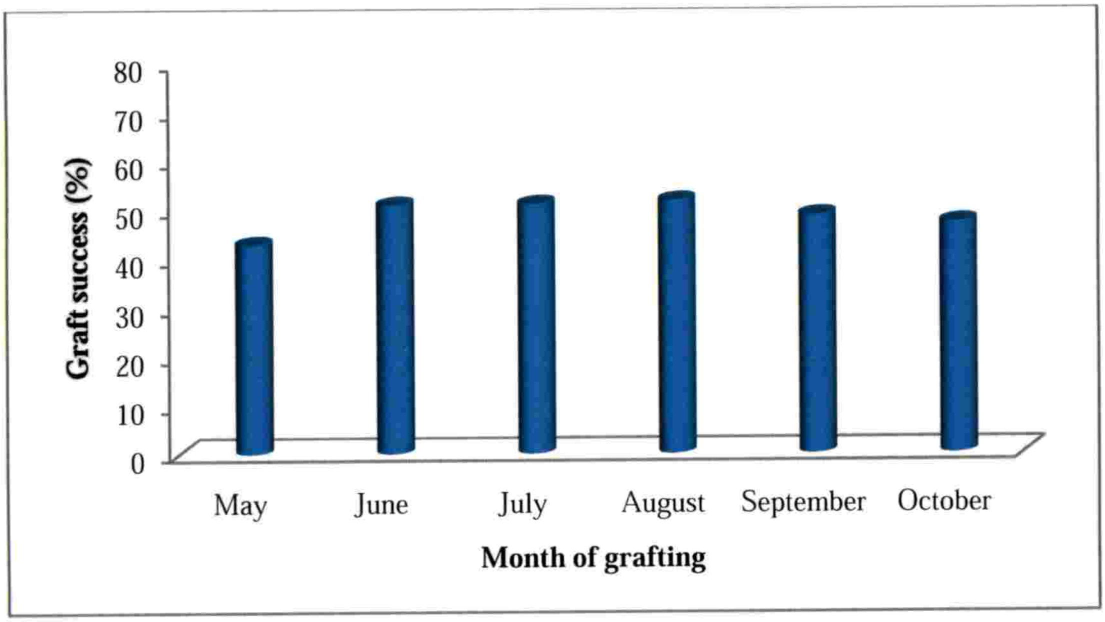


Fig. 10: Influence of month of grafting on graft success in watermelon

August (51.67 %) which was on par with graft success in July (51.00 %). Graft success during June, September and October were 50.83 per cent, 48.67 per cent and 47.17 per cent respectively. Least success was noticed in the month of May with a success per cent of 42.83 (Figure 10).

Thus grafting operation done during June, July and August recorded maximum graft success per cent with highest success of 68.33 per cent in July for bitter gourd and 51.67 per cent in August for watermelon. The reason for high graft success during these months could to attributed to low temperature and high relative humidity during the period compared to other months (Appendix 1). The findings were in accordance with Liang, 1990; Mii *et al.*, 1994; Lee, 2007; Kumar *et al.*, 2015. Similar results with highest graft success per cent was obtained in June for softwood grafting in *Garcinia cambogia* (Nazeema, 1992), August for softwood grafting in *Mangifera indica* (Geetha,1993) and June for epicotyl grafting in *Artocarpus heterophyllus* (Islam *et al.*, 2003).

5.6 Anatomical studies

In order to study the cellular changes of grafted plants, anatomical studies were carried out at 20 days after grafting under microscope. Sections were micrographed. Transverse sections were taken from hole insertion grafts of bitter gourd and watermelon.

Hartmann *et al.* (2002) described the sequence events during graft union formation of grafted herbaceous plants. Initially, new parenchymatous cells proliferate from both rootstock and scion and generate callus tissues that fill up the space between the scion and the stock. The new cambial cells differentiate from the newly formed callus tissues thereby forming a continuous cambial connection between the rootstock and scion. The first differentiated tissue to bridge the graft union is wound - repair xylem followed by wound - repair phloem. Finally cambial activity results in formation of new vascular tissues (xylem and phloem) thus permitting vascular connection between the scion and rootstock.

Histological observation of bitter gourd and watermelon at graft interface during the present study revealed formation of necrotic layer in response to wound repair and proliferation of cells of rootstock and scion which is the stage prior to callus formation.

5.7 Performance of grafted plants in the field

Successful grafts were transplanted to the main field 12-15 days after grafting (Plate 11 and 12). While planting, graft union of seedlings were kept above the soil surface, to avoid development of adventitious roots from the scion that penetrate the soil. The crops were raised as per Package of Practices Recommendations (KAU, 2016) for bitter gourd and watermelon. Since the graft success and survival were very poor in tongue approach grafts, only hole insertion grafts were evaluated in the main field for studying the performance of various rootstocks.

5.7.1 Survival rate in the main field

Influence of various rootstocks on survival rate of bitter gourd and watermelon grafts in the main field is depicted in Figure 11 and Figure 12 respectively.

In bitter gourd, survival rate in the main field was highest in self rooted control plants (100.00 %) followed by plants grafted on smooth gourd (84.44 %) and bottle gourd (77.78 %). Survival rate for plants grafted on pumpkin and ash gourd were 75.55 per cent and 71.10 per cent. Significantly lower survival rate was noticed in autografts (68.22 %).The results are closely in accordance with findings of Tamilselvi, 2013 who reported that bitter gourd plants grafted on pumpkin and smooth gourd gave higher survival rate in the main field.

In watermelon, among the graft combinations studied, survival rate was highest in plants grafted on bottle gourd (79.99 %) which was on par with

(A)

(B)

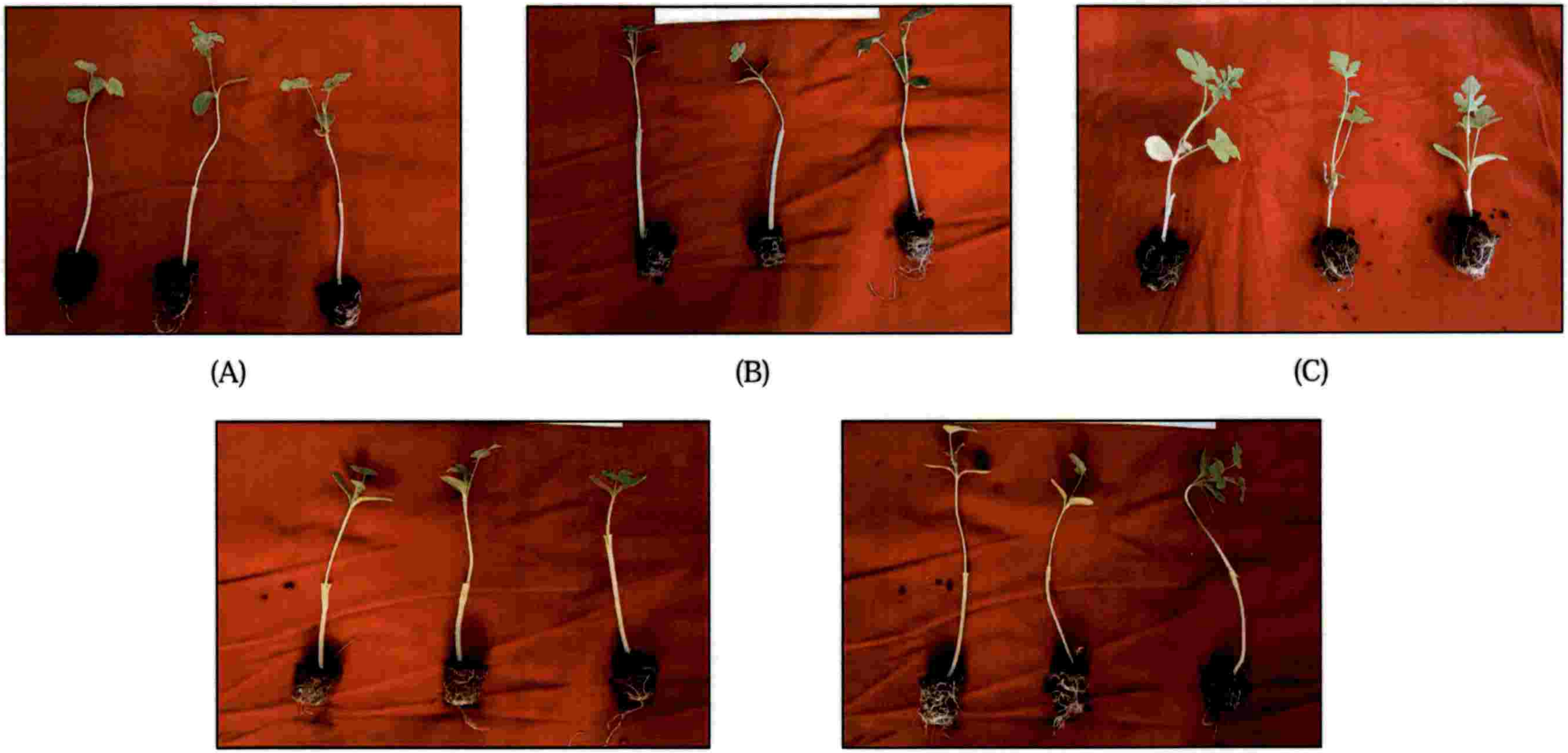
(C)

(D)

(E)

(F)

Plate 11: Bitter gourd plants grafted on (A) Ash gourd, (B) Bottle gourd, (C) Smooth gourd, (D) Pumpkin, (E) OP melon, and (F) bitter gourd



(A) (B) (C)

(D) (E)

Plate 12: Watermelon plants grafted on (A) Ash gourd, (B) Bottle gourd, (C) Smooth gourd, (D) Pumpkin, and (E) OP melon

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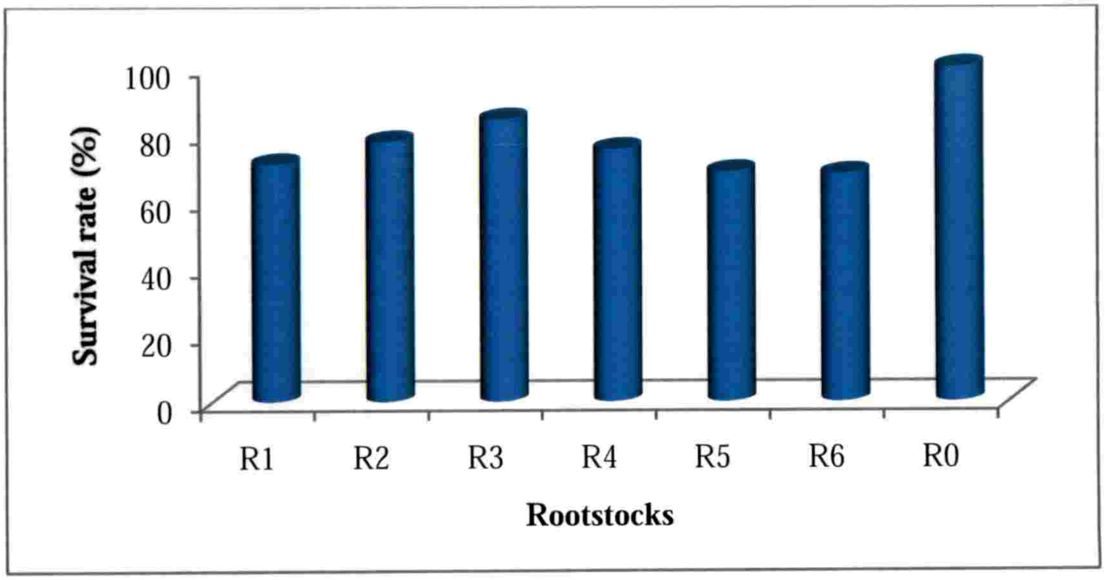

Fig. 11: Survival rate of bitter gourd grafts in the main field

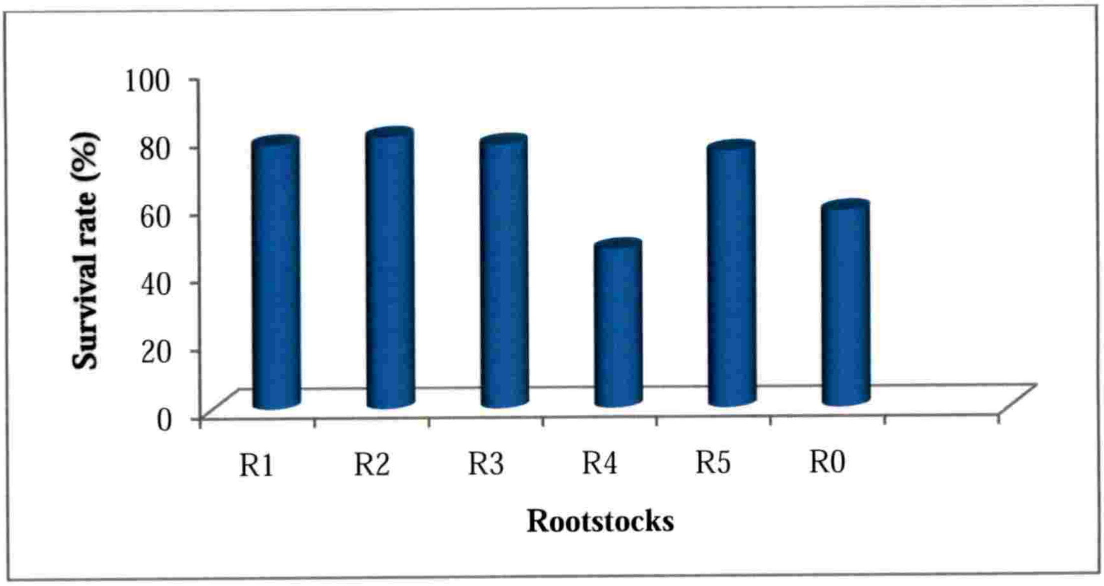

Fig. 12 : Survival rate of watermelon grafts in the main field

R1: Ash gourd　R2: Bottle gourd　R3: Smooth gourd

R4: Pumpkin　R5: OP melon　R6: Self rootstock

R0: Self rooted control

rootstocks ash gourd (77.78 %), smooth gourd (77.78 %), and oriental pickling melon (75.55 %). Control plants had a survival rate of 75.55 %. Least survival rate was noticed in plants grafted on pumpkin (46.67 %). Yetisir and Sari, 2004 reported that rootstock genotype significantly affected survival rate of grafted plants in the main field. They concluded that bottle gourd had a higher survival rate compared to other rootstocks in watermelon.

Oda *et al.*, 1993 reported that smaller the difference between diameter of hypocotyl of scion and rootstock, greater will be the survival rates. However in this study, the results are contradictory and is difficult to make the assumption that survival rate could be explained solely by difference in hypocotyl diameter of rootstock and scion. Also, Chao and Yen, 2013 pointed out that providing better acclimatization conditions for graft healing help to in better graft survival despite the difference in stem diameter.

5.7.2 Diameter of rootstock and scion hypocotyls (mm) [at the time of grafting, 30 and 60 days after grafting]

In bitter gourd, analysis of data on the diameter of rootstock hypocotyls showed significant difference at the time of grafting. Maximum diameter of 9.93 mm was observed in rootstock bottle gourd followed by pumpkin (7.17 mm). Minimum diameter was noticed in oriental pickling melon (3.13 mm) followed by ash gourd (4.40 mm). Statistical evaluation of mean rootstock diameter 30 days after grafting showed significant difference among the treatments. Diameter of rootstock smooth gourd (18.67 mm) was found to be the highest which was followed by pumpkin (17.00 mm) and bottle gourd (16.66 mm). Oriental pickling melon showed lowest diameter of 12.67 mm. Hypocotyl diameter of the rootstocks had no significant difference when evaluated at 60 days after grafting. Diameter of scion hypocotyl increased proportionally with the rootstock. Scion hypocotyls had no significant difference among the treatments during the time of grafting, 30 and 60 days after grafting.

In watermelon, analysis of data on the diameter of rootstock hypocotyls showed significant difference at the time of grafting. Maximum diameter of 9.93 mm was observed in rootstock bottle gourd followed by pumpkin (7.17 mm) and smooth gourd (6.90 mm). Minimum diameter was noticed in oriental pickling melon (3.13 mm) followed by ash gourd (4.40 mm) and watermelon (4.56 mm).Statistical evaluation of mean rootstock diameter 30 days after grafting showed no significant difference among the treatments. Diameter of rootstock hypocotyls varied from 12.75 to 13.64. Diameter of scion hypocotyl increased proportionally with the rootstock. Scion hypocotyls had no significant difference among the treatments during the time of grafting and 30 days after grafting. Similar reports of proportional increase in rootstock and scion diameter in compatible grafts were also given by Salehi-Mohammadi *et al*, 2009.

5.7.3 Vegetative characters

Vine length is an important parameter that influence vigour and yield of cucurbits. Growth rate of scion plants could serve as an important selection criteria for good rootstock. In the present study, vine length of ungrafted control plants of bitter gourd was 5.86 m which was on par with plants grafted on smooth gourd (5.45 m) and bottle gourd (5.43 m). Shortest vine length was observed for oriental pickling melon rootstock (4.74 m).

In bitter gourd, study on growth rate of grafted and self rooted plants revealed that there was appreciable growth in plants grafted on bottle gourd and smooth gourd and it was comparable with the seedlings. Even though the initial growth rate was slow in autografts, later on it was on pace with the control plants. The rate of growth was minimum in plants grafted on ash gourd and oriental pickling melon (Figure 13). Lee, 1994 suggested that vigorous root system of rootstocks promotes efficient uptake of water and nutrients, thus leading to increased growth and yield.

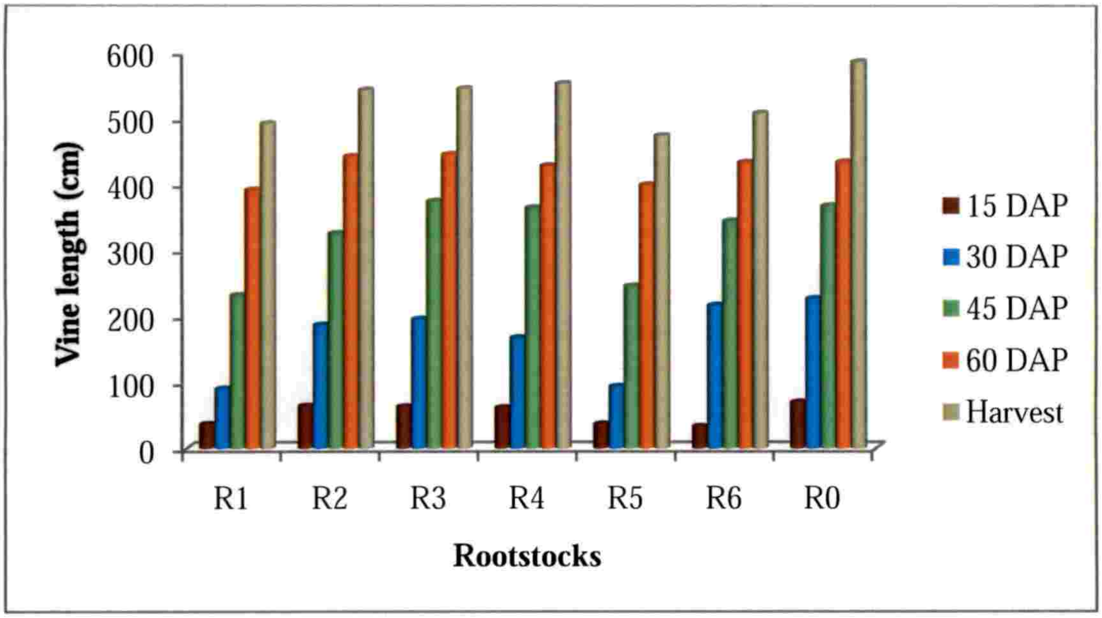

Fig. 13: Effect of rootstocks on vine length (cm) at 15, 30, 45, 60 days after planting and at final harvest in bitter gourd

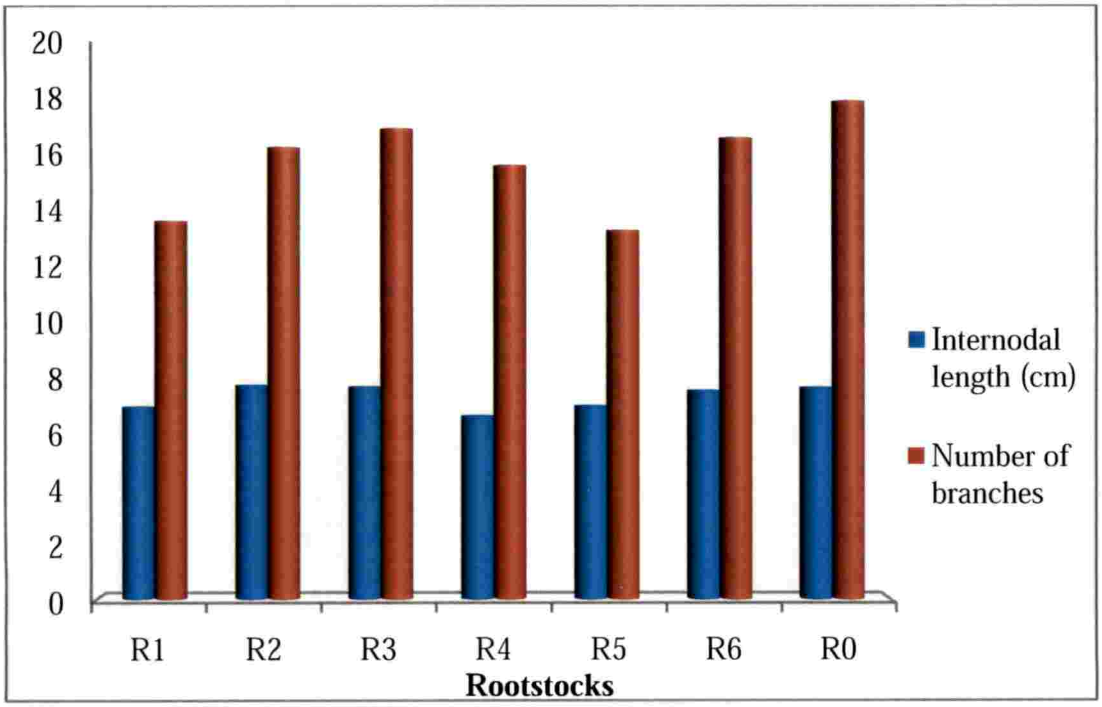

Fig.14: Effect of rootstocks on internodal length (cm) and number of branches in bitter gourd

R1: Ash gourd	R2: Bottle gourd	R3: Smooth gourd
R4: Pumpkin	R5: OP melon	R6: Self rootstock
R0: Self rooted control		

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Internodal length of grafted and ungrafted control plants had no significant difference. In bitter gourd, internodal length was highest for plants grafted onto bottle gourd (7.73 cm) closely followed by plants grafted on smooth gourd rootstock (7.67 cm) and ungrafted control plants (7.64 cm). Lowest internodal length of 6.61 cm was noticed when the rootstock used was pumpkin. The result is also supported by the findings of Chao and Yen, 2013. They found that there was no significant difference in internodal length of cucumber plants grafted on *Cucumis* and *Cucurbita* rootstocks and non-grafted cucumber plants.

Number of primary branches varied significantly among six different rootstocks studied. Control plants had highest number of primary branches (18.00). Among the grafts, primary branch was highest when the rootstock used was smooth gourd (17.00). Number of branches in plants grafted on self rootstock, bottle gourd, and pumpkin were 16.67, 16.33, and 15.67 respectively. Least number of primary branches was observed in plants grafted on oriental pickling melon (Figure 14). Cucumber plants grafted on pumpkin rootstocks recorded high dry mass content than cucumber autografts (Shimada and Moritani, 1977). Bitter gourd grafts in the field is shown in plate 13 and 14.

5.7.4 Flowering traits

The effect of different treatments on days to first male and female flowers (Figure 15, 16) and node to first male and female flowers are discussed here. In bitter gourd, days to first male flower recorded significant difference among the rootstocks studied. Earliest among the treatments was non-grafted control plants which took 28.00 days to flower. It was on par with plants grafted onto bottle gourd (28.45 days), bitter gourd (28.56 days) and ash gourd (28.67 days). Plants grafted onto oriental pickling melon was late to produce first male flower among the rootstocks used (32.78 days) followed by smooth gourd (32.33 days). In watermelon, days to first male flower was not significant among the grafts studied

(A)

(B)

(C)

(D)

Plate 13: Grafted bitter gourd plants in the field

(A) Rootstock: Ash gourd (B) Rootstock: Bottle gourd

(C) Rootstock: Smooth gourd (D) Rootstock: Pumpkin

(E)

(F)

(G)

Plate 14: Grafted bitter gourd plants in the field
(E) Rootstock: OP melon (F) Rootstock: Bitter gourd
(G) Self rooted control plants

and it varied from 38.81 days in self rooted control to 41.00 days in plants grafted on ash gourd.

Days to first female flower is an indication of earliness of the crop. Early crop fetches more returns to the farmers. In the present study, there was and it varied from 38.81 days in self rooted control to 41.00 days in plants grafted on ash gourd. significant difference among the treatments for the appearance of first female flower in bitter gourd. Control plants produced first female flower in minimum number of days after planting (29.89 days). Plants grafted on bottle gourd produced first female flower on 31.45 days after planting. When the rootstocks used were ash gourd and bitter gourd, it took 31.55 days for first female flower appearance. Maximum number of days was taken by plants grafted on oriental pickling melon (35.78 days).

In watermelon, there was significant difference among the treatments in days to appearance of first female flower. Least number of days was noticed in self rooted control plants (40.67 days) which was on par with plants grafted on ash gourd (42.33). Days to first female flower in the plants grafted on pumpkin, bottle gourd and smooth gourd were 44.00 days, 43.67 days and 43.33 days respectively and were on par. Female flower appearance was late in plants grafted on oriental pickling melon (46.34 days).

Thus in bitter gourd, among the grafts earliness in terms of days to first male and female flower was observed in plants grafted onto bottle gourd. In watermelon, there was no significant difference in days to first male and days to first female flower was observed in plants grafted on ash gourd. Similar trend of delayed flowering in grafted plants was reported by Satoh, 1996. Flower formation in cucumber plants grafted on squash rootstocks (*Cucurbita maxima* x *Cucurbita moschata*) was inhibited by a factor produced by squash roots. He suggested that, the rootstock scion combination influence floral transition by altering the amount of flowering hormone produced. Seven to ten days delay in

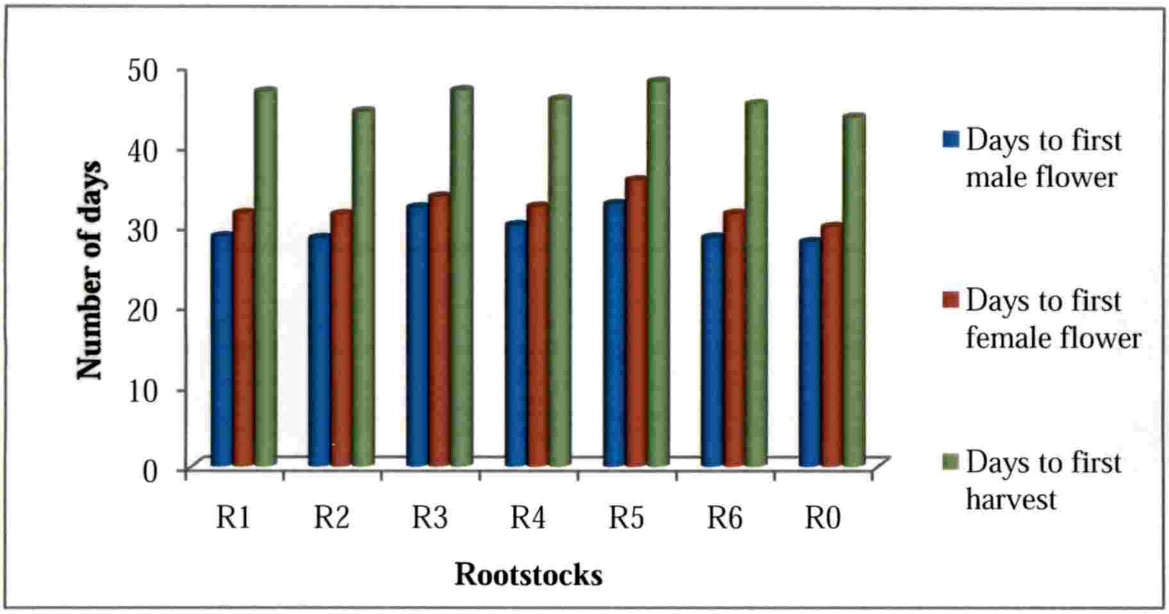


Fig. 15 : Effect of rootstocks on days to first male flower, female flower and harvest in bitter gourd

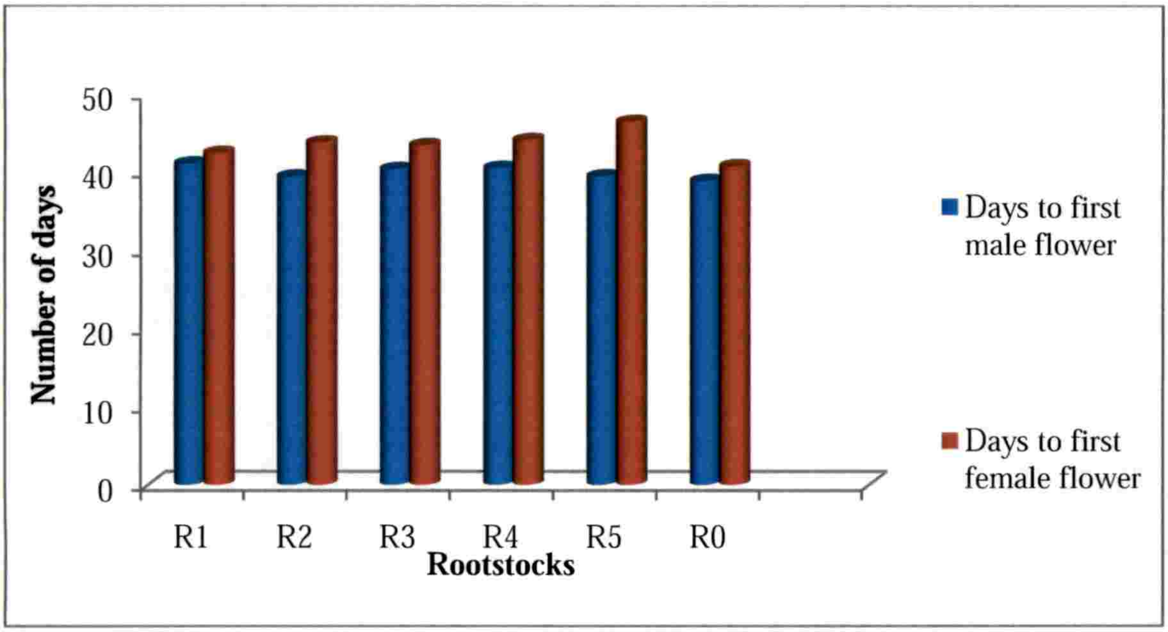


Fig.16 : Effect of rootstocks on days to first male flower and female flower in watermelon

R1: Ash gourd R2: Bottle gourd R3: Smooth gourd

R4: Pumpkin R5: OP melon R6: Self rootstock

R0: Self rooted control

flowering was noticed in grafted watermelon plants compared to control which was attributed to stress during graft union process (Salam *et al.*, 2002).

Another important trait to measure earliness in cucurbits is node to first male and female flower. In bitter gourd, male flower appeared in the lower node (12.00) in plants grafted on pumpkin rootstocks which was closely followed by bottle gourd rootstocks (13.00). Node to first male flower in plants grafted on bitter gourd, ungrafted contol plants, oriental pickling melon, smooth gourd and ash gourd were 14.00, 14.00, 14.67, 15.67 and 16.33 respectively. In watermelon, there was significant difference among the graft combinations with respect to node number for first male flower appearance. Male flower appeared in the lower nodes in self rooted control plants (11.80) and plants grafted on smooth gourd (12.00) which were statistically on par. Plants grafted onto oriental pickling melon (17.67) recorded highest value for the trait.

Female flower appeared at lower node in bitter gourd plants grafted on ash gourd (18.67) which was on par with plants grafted on oriental pickling melon (19.00), pumpkin (19.00) and ungrafted control plants (19.67). Female flower appeared in later nodes (28.00) when bottle gourd was used as rootstock. Node number to first female flower varied significantly among the rootstocks studied in watermelon grafts. Female flower appeared in lower nodes of control plants (21.00) which was on par with plants grafted on bottle gourd (22.97) and ash gourd (23.53). Female flower appeared in later nodes when the rootstock used was oriental pickling melon (21.00).

In bitter gourd and watermelon plants grafted on pumpkin produced male flowers at lower node while lower node to first female flower was noticed in ash gourd and bottle gourd respectively. Yamasaki *et al.*, 1994 reported pronounced influence of rootstock on node to first pistillate flower in watermelon. Node to first female flower was lowered when watermelon plants was grafted on bottle gourd and squash compared to self rooted control.

5.7.5 Yield parameters

Number of days to first harvest is one of the yield determining character as early harvest from a plant results in more number of total harvests. In bitter gourd, lowest value for days to first harvest was recorded in ungrafted control plants (43.69 days). Among the grafts, bitter gourd grafted on bottle gourd gave early harvest (44.33 days) which was on par with self rooted bitter gourd. Days taken for harvest was highest in plants grafted on oriental pickling melon (45.33 days). Delayed harvest in grafts could be due to delayed flowering which is attributed to heavy stress during graft union formation (Figure 15).

The influence of different rootstocks on fruit characters in bitter gourd in relation to fruit girth, fruit length, flesh thickness are depicted in figure 17 and fruit weight is depicted in figure 18. Fruits from grafted plants is given in plate 15.

Ungrafted bitter gourd plants was found to be the best in terms of fruit girth with 17.73 cm followed by plants grafted on bottle gourd which was statistically on par. Fruit girth was lowest in bitter gourd plants grafted on self rootstock (15.46 cm) which was on par with plants grafted on ash gourd (16.06 cm).

Regarding fruit length also, self rooted control plants showed maximum value of 21.12 cm which was statistically on par when the rootstock used was ash gourd (21.03 cm). Fruit length of plants grafted on smooth gourd, bitter gourd and oriental pickling melon were 18.43 cm, 18.26 cm and 17.76 cm respectively. Fruits from plants grafted on bottle gourd recorded 15.56 cm fruit length which was lowest among all the treatments followed by ash gourd (16.06 cm).

Among the rootstocks tested, flesh thickness of fruits was highest in plants grafted on bottle gourd (1.33 cm) and ungrafted control plants (1.33 cm). Flesh thickness of fruits of grafted plants were 1.23 cm, 1.20 cm and 1.17 cm

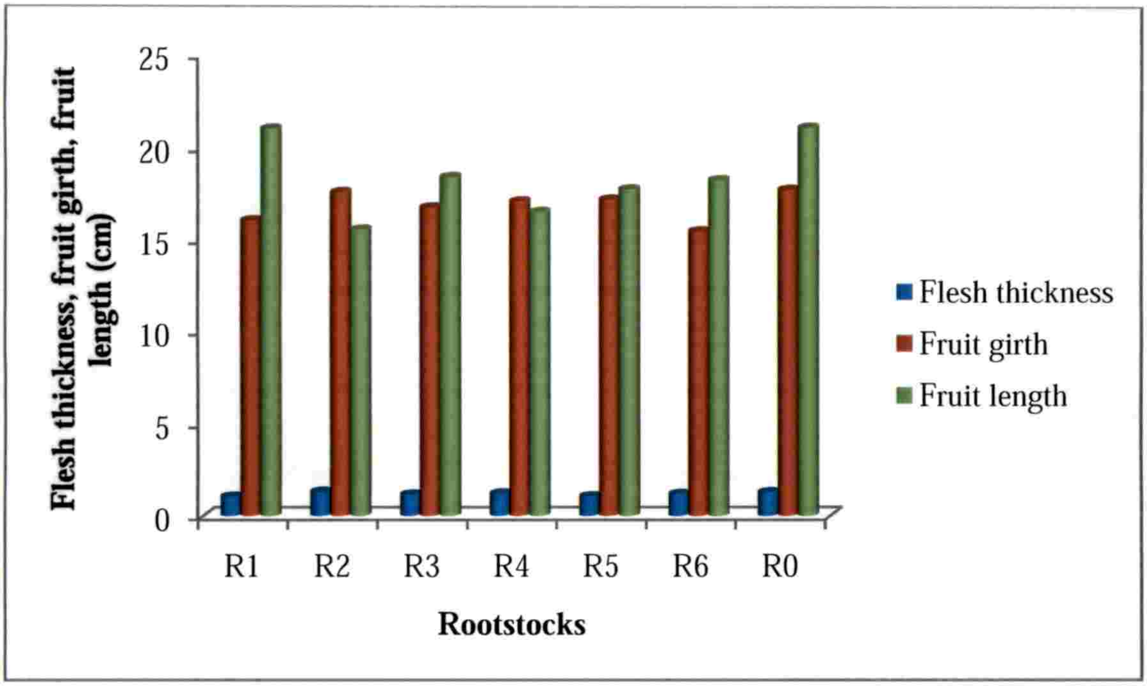


Fig. 17: Effect of rootstocks on flesh thickness, fruit girth and fruit length (cm) in bitter gourd

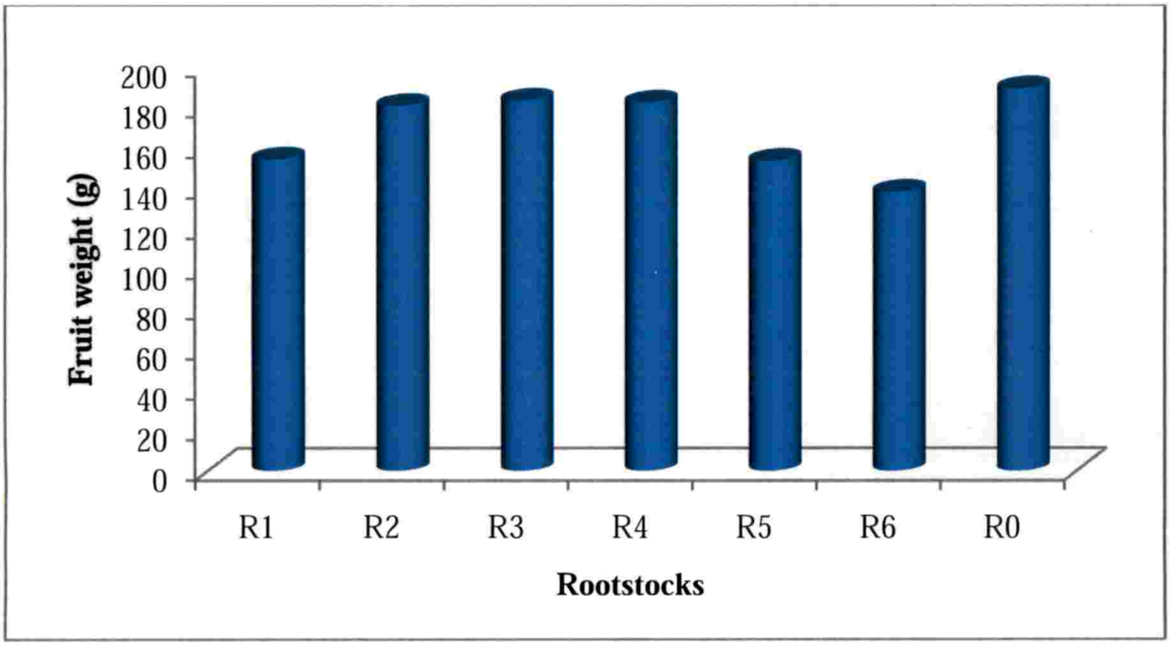


Fig. 18: Effect of rootstocks on average fruit weight (g) in bitter gourd

R1: Ash gourd R2: Bottle gourd R3: Smooth gourd

R4: Pumpkin R5: OP melon R6: Self rootstock

R0: Self rooted control

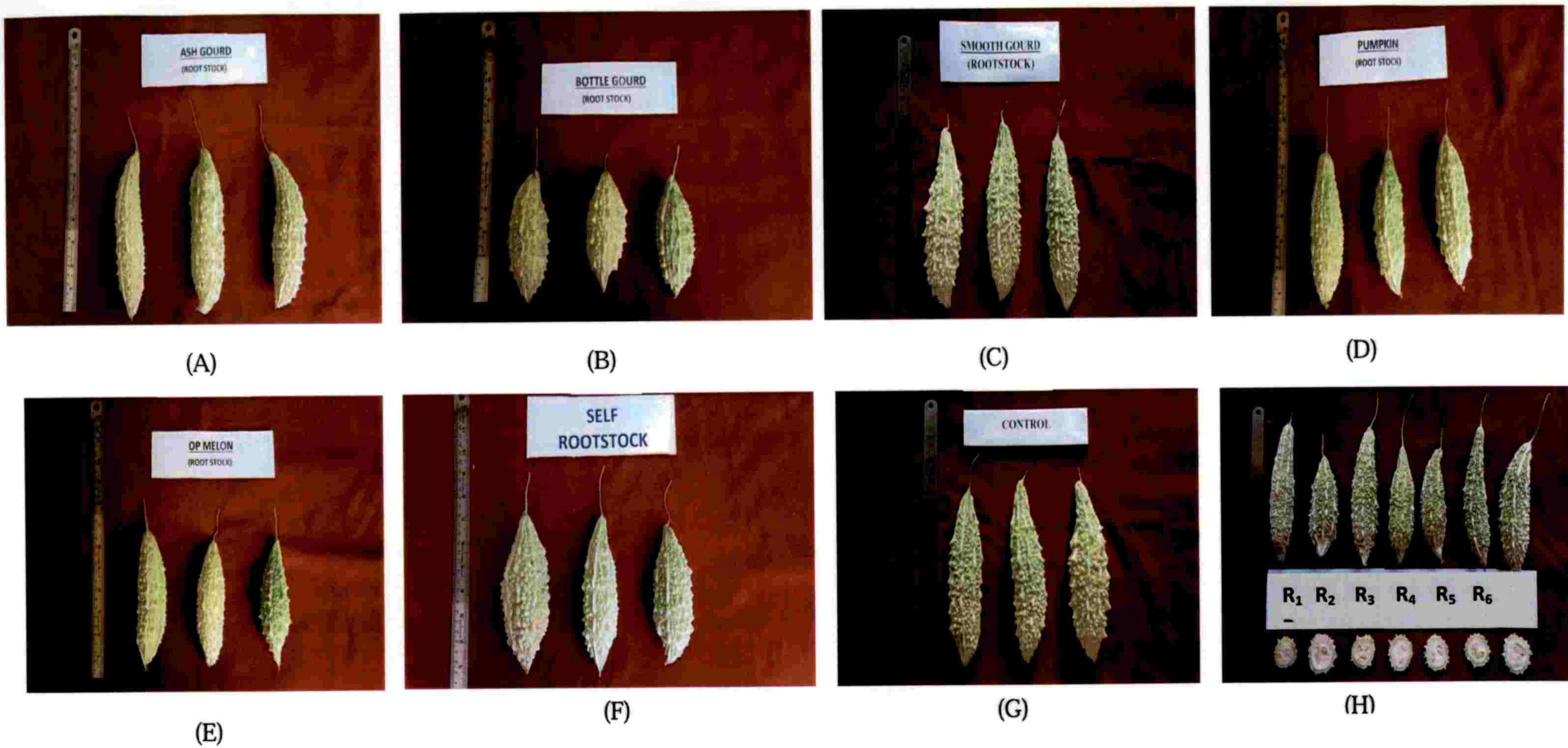


Plate 15 : Fruits from bitter gourd grafted on (A) Ash gourd, (B) Bottle gourd, (C) Smooth gourd (D) Pumpkin, (E) OP melon, (F) Self rootstock, and (G) self rooted control. (H) Comparison of length, girth and flesh thickness of fruits from different graft combinations

when the rootstocks used was pumpkin, bitter gourd and smooth gourd respectively. Lowest flesh thickness of 1.07 cm was observed for the fruits from plants grafted onto oriental pickling melon and ash gourd.

Self rooted control plants showed highest fruit weight (189.33 g) among the treatments which was on par with plants grafted on smooth gourd (183.33 g), pumpkin (182.33 g) and bottle gourd (180.67 g). Lowest fruit weight was observed in self rootstock (138.33 g).

Maximum crop duration was noted in plants grafted onto smooth gourd (110.67 days), followed by bottle gourd (103.33 days), and pumpkin (101.67 days). Ungrafted plants had a crop duration of 96.33 days, which was on par with grafted plants on oriental pickling melon (93.33 days) and ash gourd (91.33 days). Plants grafted on self rootstock had minimum crop duration (90.33 days) (Figure 19).

In the present study, significant difference was observed among the treatments with respect to number of harvests. Maximum number of harvests (10.67) was taken from the plants grafted on smooth gourd which could be attributed to higher crop duration. It was on par with bottle gourd (10.55), control plants (10.22), ash gourd (9.89). Least number of harvests was obtained from plants grafted on bitter gourd (8.55).

The present study revealed that there was no notable difference in number of fruits per plant among the rootstocks studied. Number of fruits per plant for plants grafted on smooth gourd, ash gourd, pumpkin, bottle gourd, bitter gourd, and oriental pickling melon were 18.00, 17.11, 16.67, 16.33, 16.11, and 15.58 respectively. Number of fruits per plant in self rooted control plants was 16.78. Significantly higher fruit number per plant was observed in grafted plants compared to control by Nisini *et al.*, 2002 in muskmelon.

Among the different rootstocks used for grafting, smooth gourd was found to be the best with per plant yield of 3.30 kg (Figure 20). It was closely

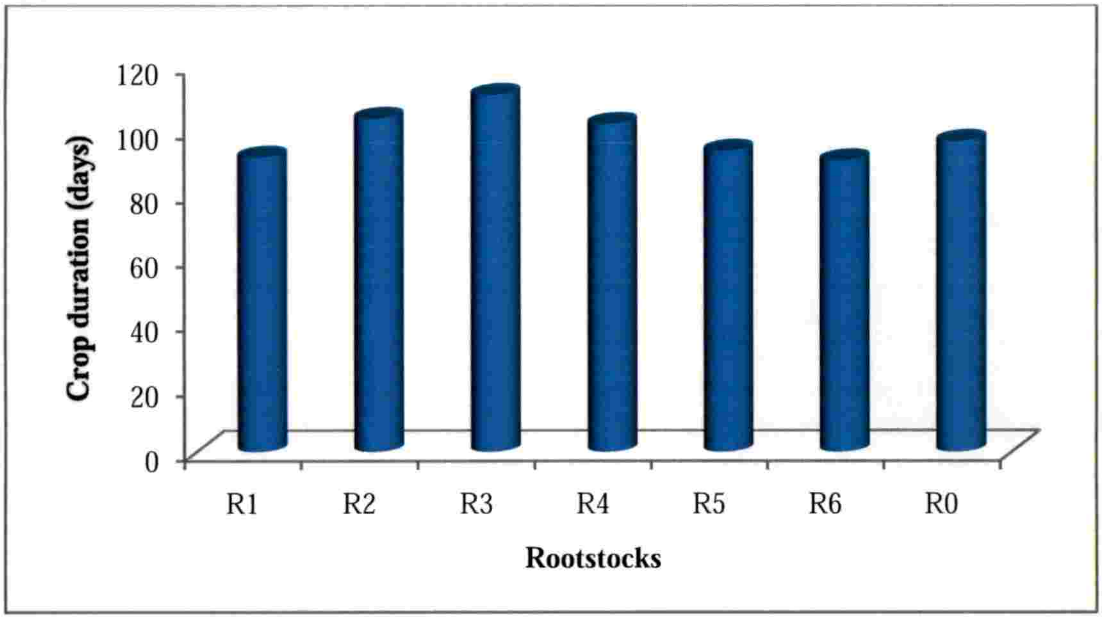


Fig. 19: Effect of rootstocks on crop duration (days) in bitter gourd

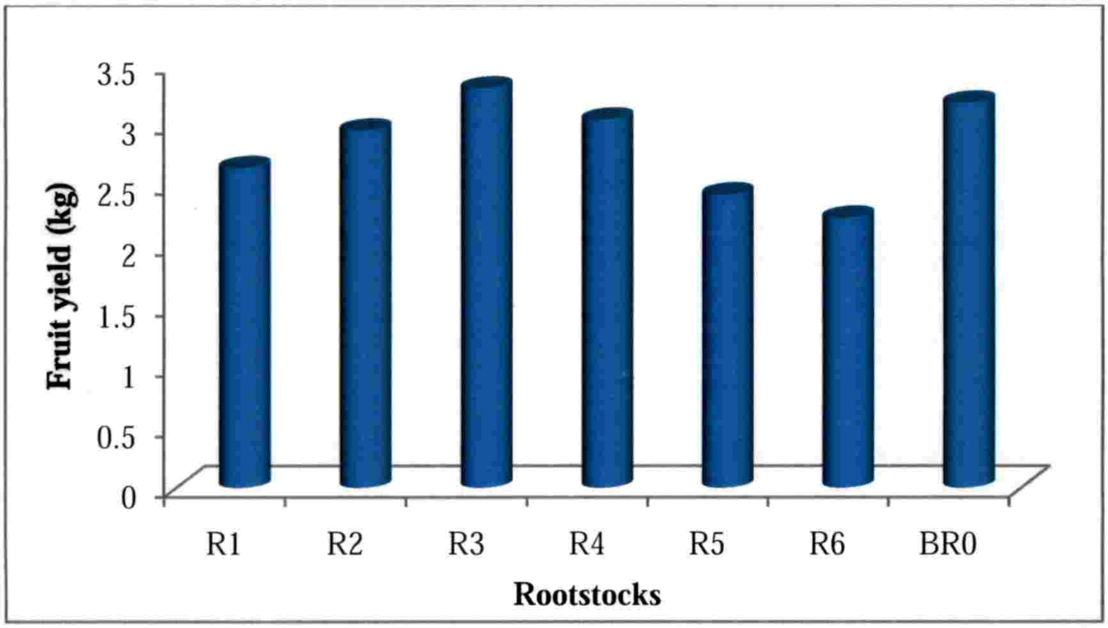


Fig. 20: Effect of rootstocks on fruit yield per plant (kg) in bitter gourd

R1: Ash gourd R2: Bottle gourd R3: Smooth gourd

R4: Pumpkin R5: OP melon R6: Self rootstock

R0: Self rooted control

followed by control (3.18 kg) and plants grafted on pumpkin (3.04 kg) (Figure 23). Farhadi *et al.*, 2016 reported that there was no significant improvement in fruit production in grafted cucumber plants. Highest yield was obtained with *Cucurbita* interspecific hybrid 'Ferro' as rootstock but it was not different to ungrafted control plants. A significant lower fruit yield was observed with bottle gourd, pumpkin and other commercial *Cucurbita* interspecific hybrids (909,913, 64-19 and Shintoza). Yield per plant was minimum in plants grafted on self rootstocks (2.23 kg). Yield per plant is closely associated with fruit number per plant and crop duration. Similar results were also obtained by Guan and Zhao, 2014 when specialty melons (*Cucumis melo*) were grafted on *Cucumis metulifer*. No significant difference in total yield and marketable yield was observed between grafted, non-grafted and self grafted plants.

Final size, yield and quality of grafted plants obviously depend on the scion variety but rootstocks can drastically alter these characters (Lee, 1994; Lee and Oda, 2004).

5.7.6 Occurrence of pest and diseases

Pest observed during vegetative stage of the crop was pumpkin beetle (*Raphidopalpa foveicollis*). During fruiting stage, major pests observed were fruit fly (*Bactrocera cucurbitae*) and leaf eating caterpillar (*Diaphinia indica*) (Plate 16). Major disease observed during late fruiting stage was phyllody (Plate 17).

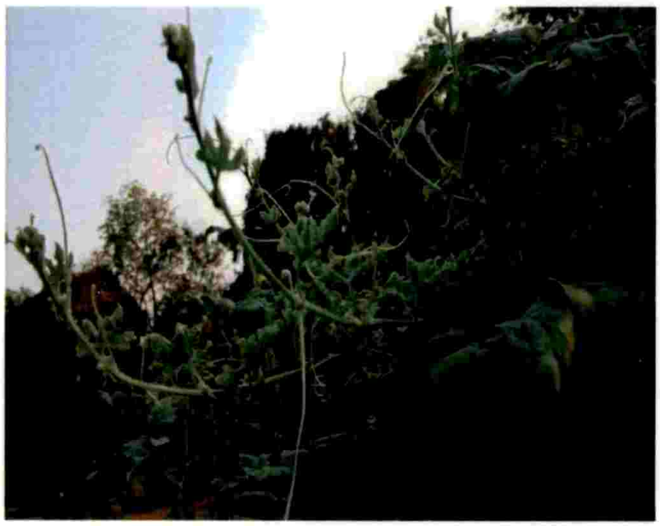
5.7.7 Organoleptic evaluation

Five quality characters viz., appearance, colour, texture, flavor and taste of cooked fruits were assessed in organoleptic evaluation of bitter gourd (Plate 18). Highest score for appearance (4.30) and texture (4.00) was recorded for fruits from plants grafted on ash gourd. Lowest score was recorded in smooth gourd grafted plants. Fruits from plants grafted on pumpkin recorded maximum

(A)

(B)

Plate 16: Pest and disease incidence in bitter gourd (A) Fruit fly (B) Leaf eating caterpillar (C) Phyllody



(C)

Plate 17: Cooked bitter gourd fruits for organoleptic test

score for flavour (4.30) closely followed by bottle gourd (4.20). Plants grafted on bottle gourd scored maximum in taste (4.30) and overall acceptability (4.00).

In organoleptic evaluation, fruits obtained from plants grafted on bottle gourd with a total score of 20.00 out of 25.00 was the most accepted one closely followed by pumpkin (19.90), ash gourd (18.10) and control (17.50). The least accepted was fruits from plants grafted on smooth gourd (14.00). Similar results were also reported by Yetisir *et al.*, 2003. He stated that there was only minor difference in fruit quality in control plants and plants grafted onto bottle gourd rootstocks.

It has been reported that grafting may have adverse effect on fruit quality, mostly dependent on rootstock used for grafting (Lee, 1994; Nissini *et al.,* 2002; Traka-Mavrona *et al.*, 2000) but in the present study, grafting had no detrimental effect on fruit quality.

Conclusion

Grafting susceptible scions on resistant rootstocks avoid contact of roots of sensitive plants with the soil borne pathogens there by imparting resistance to the scion plant. The objectives of the present study was to standardize grafting technique in bitter gourd and watermelon, to identify best rootstock-scion combination and to evaluate the performance of grafted plants in the field. Six rootstocks were used in the study out of which five were selected based on Fusarium wilt and nematode resistance/ tolerance and one being self rootstock used as control. Days to germination and days to attain graftable size of rootstocks and scions was recorded and accordingly the sowing dates were adjusted so that they attain grafting stage uniformily.

The basic requirements for grafting included razor blade, grafting clips and mist chamber for healing of graft union. During initial days of grafting, scion is unable to receive water from the rootstock. It is therefore important to ensure least transpiration loss from scion by maintaining proper environmental conditions. Healing chamber with plastic covering maximizes humidity and reduces light thereby allowing healing of grafted plants. Humidity inside the system was maintained depending upon the environmental conditions using mist system or hand held spray bottle. To minimise water stress in newly grafted plants, grafting during a time of day when transpiration is lowest, such early morning or late evening hours is recommended.

In order to adjust the sowing date of rootstocks and scion, preliminary trial was conducted to analyse days taken for germination and days to attain graftable size for rootstocks and scions. Based on suitability for carrying out grafting operation, days to attain graftable size was calculated. Using hole insertion method, age of rootstocks for grafting bitter gourd and watermelon were standardized by comparing the graft success at varying ages of rootstocks *viz.*, 5-7 days, 10-12 days and 15-17 days and keeping the age of scions constant at 7-10 days after germination. Effect of rootstock on graft success was assessed by both the methods of grafting namely hole insertion and tongue approach grafting. For hole insertion grafting in bitter gourd best rootstock was smooth gourd while for tongue approach grafting, the graft success was not significant among the rootstocks. For hole insertion grafting in watermelon best rootstock was bottle gourd while for tongue approach grafting, the graft success was not significant among the inter-generic rootstocks. Homografts had zero graft success.

Two methods of grafting were compared to standardize method of grafting in bitter gourd and water melon. The superiority of grafting methods were confirmed based on per cent graft success at three days interval. On evaluating the graft success, hole insertion was found to be better in terms of final graft success. Suitability of month of grafting were also assessed by evaluating the graft success in hole insertion method for bitter gourd and watermelon during six months *viz.*, May, June, July, August, September and October. Highest graft success was obtained during the months of June, July and August compared to other months studied. This could be attributed to high mean RH and low temperature during these months.

Survival rate in the main field was highest for self rooted bitter gourd followed by plants grafted on smooth gourd and bottle gourd. On evaluation of bitter gourd grafts based on vegetative traits, best rootstock was smooth gourd in terms of vine length, growth rate and number of primary branches closely followed by bottle gourd. Plants grafted on bottle gourd showed earliness in terms of days to first male and female flowers and days to first harvest. Fruit girth of non-grafted control plants were on par with fruit girth of plants grafted on bottle gourd. In terms of fruit length, rootstock ash gourd was found to be best among the grafts. Flesh thickness was also high for bottle gourd grafted plants and control. Fruit weight, number of fruits per plant, number of harvests per plant, crop duration and total yield was higher in plants grafted on smooth gourd among the grafts studied. In organoleptic evaluation, fruits obtained from plants grafted on bottle gourd was the most accepted one closely followed by pumpkin.

In watermelon, survival rate was more for plants grafted onto bottle gourd compared to control. With respect to days to first male flower, all the treatments were insignificant but less number of days to first female flower appearance was noted in plants grafted on pumpkin. Lower node to first female flower appearance was noted in control plants followed by plants grafted on bottle gourd. The period of graft success did not coincide with the actual planting season of watermelon in Kerala. There was severe vine decline during reproductive stage of watermelon crop. Thus further observations could not be obtained. The experiment was again repeated but graft success was almost nil during hot months *viz.*, January, February, March, April and May. Grafting experiment was successful in June but survival rate of grafts in the field was poor during the rainy season which is off-season for cultivation of watermelon in Kerala.

SUMMARY

6. SUMMARY

The present study on 'Standardisation of grafting in bitter gourd (*Momordica charantia* L.) and watermelon (*Citrullus lanatus* (Thunb.))' was carried out in the vegetable research farm of the Department of Olericulture, College of Horticulture, Vellanikkara.

The experiment was conducted to standardise grafting technique in bitter gourd and watermelon, to identify promising rootstocks for grafting bitter gourd and watermelon and to evaluate the performance of grafts in the field. Grafting experiment was conducted in completely randomized design with six treatments and four replications. Graft success was evaluated separately for bitter gourd and watermelon. Age of rootstock and month of grafting was standardized using hole insertion grafting. Two grafting techniques viz., hole insertion and tongue approach grafting were carried out to determine the best method for grafting bitter gourd and watermelon. The successful grafts were evaluated in the field. The field experiment was laid out in randomized block design with seven treatments including self rooted control plants with three replications.

The salient findings of the study are summarized below:

1. Days taken for germination of rootstocks varied between 3.42 days to 6.42 days in case of bitter gourd whereas it varied between 3.42 days to 6.00 days in the case of watermelon. The days taken for germination of bitter gourd and watermelon were 6.42 days and 4.28 days respectively. Number of days taken by rootstocks attain graftable size was least in pumpkin (9.99 days) while it was highest in oriental pickling melon (18.27 days). In case of scions, bitter gourd and watermelon took 15.42 days and 11.13 days respectively to attain graftable size. Accordingly the sowing dates of stock aand scion seeds were adjusted.
2. Age of rootstocks for grafting was standardized by evaluating graft success in three age groups *viz.*, 5-7 days, 10-12 days and 15-17 days by keeping the age of scions constant at 7-10 days. For ash gourd, smooth

gourd and oriental pickling melon optimum stage for grafting was from 10-15 days after germination while bottle gourd, pumpkin and bitter gourd, grafting could be performed irrespective of age starting from 5-7 days after germination. Grafting was not successful when watermelon was used as rootstock in all the three age groups.

3. Study on effect of type of rootstock on graft success revealed that, for hole insertion grafting in bitter gourd best rootstock was smooth gourd while for tongue approach grafting, the graft success was not significant among the rootstocks. Interaction effect of methods of grafting and type of rootstocks revealed that best rootstock for grafting bitter gourd is pumpkin. Rest of the rootstocks follow the order, smooth gourd, bottle gourd, ash gourd, oriental pickling melon and self rootstock. For hole insertion grafting in watermelon best rootstock was bottle gourd while for tongue approach grafting, the graft success was not significant among the inter-generic rootstocks. Interaction effect of methods of grafting and type of rootstocks also revealed that the best rootstock for grafting watermelon is bottle gourd. Rest of the rootstocks follow the order, smooth gourd, pumpkin, ash gourd, oriental pickling melon and self rootstock.
4. In the present study hole insertion method was found to be superior over tongue approach grafting in terms of success per cent for both bitter gourd and watermelon. In bitter gourd and watermelon graft success evaluated 3 days after grafting revealed that tongue approach grafting had higher success of 89.00 per cent and 72.83 per cent respectively. On nine and twelve days after grafting, graft success in hole insertion grafting was 67.00 per cent and 51.67 per cent in bitter gourd and watermelon respectively. In, bitter gourd graft success on nine and twelve days grafting was 24.50 per cent and 15.17 per cent respectively whereas in watermelon, graft success on nine and twelve days grafting was 23.83 per cent and 12.17 per cent respectively.
5. In bitter gourd, graft success was high in the month of July (68.33 %) which was on par with graft success in June and August (67.00 %). Least

success was noticed in the month of May with a success per cent of 51.16. In watermelon, graft success was high in the month of August (51.67 %) which was on par with graft success in July (51.00 %). Least success was noticed in the month of May with a success per cent of 42.83. Relative humidity had highly significant positive correlation with graft success while temperature had highly significant negative correlation.

6. Histological observation of bitter gourd and watermelon at graft interface during the present study revealed formation of necrotic layer in response to wound repair and proliferation of cells of rootstocks and scion which is the stage prior to callus formation.
7. Since the graft success and survival were very poor in tongue approach grafts, only hole insertion grafts were evaluated in the main field for studying the performance of various rootstocks.
8. In bitter gourd, survival rate in the main field was highest in self rooted control plants (100.00 %) followed by plants grafted on smooth gourd (84.44 %) and bottle gourd (77.78 %). Significantly lower survival rate was noticed in autografts (68.22 %). In watermelon, among the graft combinations studied, survival rate was highest in plants grafted on bottle gourd (79.99 %) which was on par with rootstocks ash gourd (77.78 %), smooth gourd (77.78 %), and oriental pickling melon (75.55 %). Least survival rate was noticed in plants grafted on pumpkin (46.67 %).
9. Hypocotyl diameter of rootstock and scion increased proportionally from 30 days after grafting indicating graft compatibility.
10. In the present study, vine length of ungrafted control plants of bitter gourd was 5.86 m which was on par with plants grafted on smooth gourd (5.45 m) and bottle gourd (5.43 m). Shortest vine length was observed for oriental pickling melon rootstock (4.74 m). Study on growth rate of grafted and self rooted plants revealed that that there was appreciable growth in plants grafted on bottle gourd and smooth gourd. Even though the initial growth rate was slow in autografts, later on it was on pace with

the control plants. The rate of growth was minimum in plants grafted on ash gourd and oriental pickling melon.

11. Internodal length of grafted and ungrafted control plants had no significant difference. In bitter gourd, internodal length was highest for plants grafted onto bottle gourd (7.73 cm) closely followed by plants grafted on smooth gourd rootstock (7.67 cm) and ungrafted control plants (7.64 cm). Lowest internodal length of 6.61 cm was noticed when the rootstock used was pumpkin.
12. Number of primary branches varied significantly among six different rootstocks studied in bitter gourd. Control plants had highest number of primary branches (18.00). Among the grafts, primary branch was highest when the rootstock used was smooth gourd (17.00). Number of branches in plants grafted on self rootstock, bottle gourd, and pumpkin were 16.67, 16.33, and 15.67 respectively. Least number of primary branches was observed in plants grafted on oriental pickling melon.
13. In bitter gourd, days to first male flower recorded significant difference among the rootstocks studied. Earliest among the treatments was non-grafted control plants which took 28.00 days to flower. It was closely followed by plants grafted onto bottle gourd (28.45 days), bitter gourd (28.56 days) and ash gourd (28.67 days). Plants grafted onto oriental pickling melon was late to produce first male flower among the rootstocks used (32.78 days) followed by smooth gourd (32.33 days). In watermelon, days to first male flower was not significant among the grafts studied and it varied from 32.81 days in self rooted control to 41.00 days in plants grafted on ash gourd.
14. In the present study, there was significant difference among the treatments for the appearance of first female flower. In bitter gourd, control plants produced first female flower in minimum number of days after planting (29.89 days). Plants grafted on bottle gourd produced first female flower on 31.45 days after planting. Highest number of days was taken by plants grafted on oriental pickling melon (35.78 days). In watermelon, least

number of days was noticed in self rooted control plants (40.67 days) which was on par with plants grafted on ash gourd (42.33). Female flower appearance was late in plants grafted on oriental pickling melon (46.34 days).

15. In bitter gourd and watermelon, there was significant difference among the graft combinations with respect to node number for first male flower appearance. Male flower appeared in the lower node (12.00) of bitter gourd grafted on pumpkin rootstocks which was closely followed bottle gourd rootstocks (13.00). In watermelon, male flower appeared in the lower nodes in self rooted control plants (11.80) and plants grafted on smooth gourd (12.00) which were statistically on par. Plants grafted onto oriental pickling melon (17.67) recorded highest value for the trait.
16. Female flower appeared at lowest node in bitter gourd plants grafted on ash gourd (18.67 days) which was on par with plants grafted on oriental pickling melon (19.00), pumpkin (19.00) and ungrafted control plants (19.67). Female flower appeared in later nodes (28.00) when bottle gourd was used as rootstock. In watermelon female flower appeared in lower nodes of control plants (21.00) which was on par with plants grafted on bottle gourd (22.97) and ash gourd (23.53). Female flower appeared in later nodes when the rootstock used was oriental pickling melon (21.00).
17. In bitter gourd, lowest value for days to first harvest was recorded in ungrafted control plants (43.69 days). Among the grafts, bitter gourd grafted on bottle gourd gave early harvest (44.33 days). Days taken for harvest was highest in plants grafted on oriental pickling melon (45.33 days).
18. In bitter gourd, with respect to fruit girth, ungrafted control plants was found to be the best with 17.73 cm followed by plants grafted on bottle gourd which was statistically on par. Fruit girth was lowest in bitter gourd plants grafted on self rootstock (15.46 cm).Fruit length of self rooted control plants (21.12 cm) was statistically on par with the fruit length of plants grafted on ash gourd (21.03 cm). Fruits from plants grafted on bottle

gourd recorded 15.56 cm fruit length which was lowest among all the treatments. Among the rootstocks tested, flesh thickness of fruits was highest in plants grafted on bottle gourd and ungrafted control plants. Lowest flesh thickness of 1.07 cm was observed fruits from plants grafted onto oriental pickling melon and ash gourd. Self rooted control plants showed highest fruit weight (189.33 g) among the treatments which was on par with plants grafted on smooth gourd (183.33 g), pumpkin (182.33 g) and bottle gourd (180.67 g). Lowest fruit weight was observed in self rootstock (138.33 g).

19. In bitter gourd, maximum crop duration was noted in plants grafted onto smooth gourd (110.67 days), followed by bottle gourd (103.33 days), and pumpkin (101.67 days). Plants grafted on self rootstock had minimum duration of crop (90.33 days). In the present study, significant difference was observed among the treatments with respect to number of harvests. Maximum number of harvests (10.67) was taken from the plants grafted on smooth and least number of harvests was obtained from plants grafted on bitter gourd (8.55).There was no notable difference in number of fruits per plant among the rootstocks studied. Number of fruits per plant for plants grafted on smooth gourd, ash gourd, pumpkin, bottle gourd, bitter gourd, and oriental pickling melon were 18.00, 17.11, 16.67, 16.33, 16.11, and 15.58 respectively. Number of fruits per plant in self rooted control plants was 16.78. Among the different rootstocks used for grafting, smooth gourd was found to be the best with per plant yield of 3.30 kg. It was closely followed by control (3.18 kg) and plants grafted on pumpkin (3.04 kg).

20. Five quality characters *viz.*, appearance, colour, texture, flavor and taste of cooked fruits were assessed in organoleptic evaluation of bitter gourd. In organoleptic evaluation, fruits obtained from plants grafted on bottle gourd with a total score of 20.00 out of 25.00 was the most accepted one closely followed by pumpkin with a total score of 19.90.

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APPENDICES

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APPENDIX –I

Monthly Weather Data (April 2016 – March 2017)

Months	Temperature		Relative Humidity			Rainfall (mm)	Rainy days	Sunshine hours	Mean sunshine hours
	Mean Maximum	Mean Minimum	Mean Morning (%)	Mean Evening (%)	Mean RH				
April	35.8	26.2	83	56	69	25.8	2	238.2	7.9
May	34.0	24.2	90	66	78	270.7	2	182.2	5.9
June	29.8	21.7	95	83	89	654.7	19	49.3	1.6
July	29.9	21.6	96	75	85	390.4	22	71.2	2.3
August	30.4	23.2	95	71	83	183.5	19	152.4	4.9
September	30.3	23.6	95	69	82	086.0	10	144.5	4.8
October	31.5	22.7	93	68	81	037.3	4	170.3	5.5
November	32.9	22.2	83	54	69	013.8	1	174.7	5.8
December	32.4	22.3	85	52	69	0529	3	200.7	6.5
January	34.1	22.9	68	37	53	0.0	0	235.2	7.6
February	36.0	23.2	70	31	51	0.0	0	243.0	8.7
March	36.1	24.7	85	48	67	13.2	1	29.9	7.4

APPENDIX-II

SCORE CARD

Name of the scorer :

Date :

SCORE	INFERENCE
5	Like very much
4	Like
3	Neither like or dislike
2	Dislike
1	Dislike very much

Treatments	Appearance	Texture	Flavour	Taste (Bitterness)	Overall acceptability	Total
R_1						
R_2						
R_3						
R_4						
R_5						
R_6						
R_0						

Remarks:

Signature

ABSTRACT

STANDARDISATION OF GRAFTING IN BITTER GOURD (*Momordica charantia* L.) AND WATERMELON (*Citrullus lanatus* (Thunb.))

by

AKHILA A. N.
(2015-12-001)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

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2018

ABSTRACT

The present study entitled 'Standardisation of grafting in bitter gourd (*Momordica charantia* L.) and watermelon (*Citrullus lanatus* (Thunb.))' was undertaken with the objectives of identifying the best rootstocks for grafting bitter gourd and watermelon, comparison of two grafting methods namely, hole insertion grafting (HIG) and tongue approach grafting (TAG) and evaluation of various cucurbitaceous rootstocks on survival, growth and yield of bitter gourd and watermelon.

Bitter gourd (var. Preethi) and watermelon (var. Sugar Baby) were used as the scion materials for standardisation of grafting. Six different rootstocks namely ash gourd, bottle gourd, smooth gourd, pumpkin, oriental pickling melon and self rootstocks were used in the study. Grafting experiments were laid out in completely randomized design (CRD) with four replications and 25 plants per replication. Field experiments were laid out in randomised block design (RBD) with three replications and three plants per replication.

Based on days taken for germination and days to attain graftable size, sowing of rootstock and scion seeds were adjusted so that they attain grafting stage uniformly. Criteria for rootstock and scion to attain graftable size was based on hypocotyl thickness of stock and scion and its suitability for grafting operation. Pumpkin (9.99 days) and bottle gourd (10.43 days) took lesser number of days to attain graftable size due to larger diameter of hypocotyls (7.17 mm and 9.93 mm respectively). Even though OP melon took less number of days for germination, days taken to attain graftable size (17.57 days) was more due its slender hypocotyl (3.13 mm). To confirm the best stage of rootstocks for grafting, three age groups *viz.*, 5-7, 10-12 and 15-17 days old rootstocks were used for grafting scions of age group 7-10 days. For ash gourd, smooth gourd and OP melon, optimum age group was from 10-12 days after germination while bottle gourd, pumpkin and bitter

gourd had no significant difference in graft success among the age groups studied and all the age groups performed equally well. Grafting was not successful when watermelon was used as rootstock in all the three age groups.

In terms of graft success, in HIG, for bitter gourd the best rootstock was smooth gourd (80.00 %) followed by pumpkin (77.00 %), bottle gourd (75.00 %), ash gourd (66.00 %), OP melon (56.00 %) and self rootstock (48.00 %) and for watermelon the best rootstock was bottle gourd (75.00 %) followed by smooth gourd (73.00 %), pumpkin (66.00 %), ash gourd (50.00 %) and OP melon (46.00 %). In TAG, graft success was not significant among the rootstocks in both bitter gourd and watermelon. On comparing the two grafting methods in terms of final graft success, HIG was superior to TAG. In bitter gourd and watermelon final graft success was 67.00 per cent and 62.00 per cent respectively for HIG while for TAG graft success was 15.17 per cent and 14.60 per cent respectively. Grafting done during the months of June, July and August gave higher graft success compared to May, September and October. Relative humidity had highly significant positive correlation with graft success while temperature had highly significant negative correlation. Anatomical studies of graft union revealed formation of necrotic layer in response to wound repair and proliferation of cells of rootstock and scion which is the stage prior to callus formation. Since the graft success and survival were very poor in tongue approach grafts, only hole insertion grafts were evaluated in the main field for studying the performance of various rootstocks.

In bitter gourd, self rooted plants had highest survival rate (100.00 %) in the main field followed by plants grafted on smooth gourd (84.44 %) and bottle gourd (77.78 %). Plants grafted on bottle gourd showed earliness in terms of days to first male flower (28.45 days) and female flower (31.45 days) and days to first harvest (44.33 days) among the grafts and they were on par with self rooted control plants. Vine length, growth rate and number of primary branches were high in seedling plants and they were on par with plants grafted on smooth gourd.

Plants grafted on ash gourd had fruit length of 21.03 cm which was on par with control plants. Among the grafts, highest fruit girth of 17.60 cm was noted in plants grafted on bottle gourd which was comparable to fruit girth of control plants (17.73 cm). Highest flesh thickness of 1.33 cm was noted in plants grafted on bottle gourd and self rooted control. Number of harvests per plant (10.67), crop duration (110.67 days) and total yield (3.30 kg) were higher in plants grafted on smooth gourd compared to self rooted control plants. In organoleptic evaluation, fruits obtained from plants grafted on bottle gourd was the most accepted one with a total score of 20.00, closely followed by fruits from grafts on pumpkin rootstock. Fruits were less bitter in grafts on bottle gourd and pumpkin compared to other grafts.

In watermelon, survival rate was highest in plants grafted onto bottle gourd (79.99 %) followed by plants grafted on ash gourd (77.78 %) and smooth gourd (77.78 %). Least number of days to first female flower was noted in seedling plants (40.67) which was on par with plants grafted on ash gourd (42.33 days). Lower node to first female flower appearance was noted in control plants (21.00) followed by plants grafted on bottle gourd (22.97). The period of graft success did not coincide with the actual planting season of watermelon in Kerala and therefore the performance of grafts in the field was very poor. There was severe vine decline during reproductive stage of watermelon crop.

Further research should focus on screening of rootstocks for pest and disease resistance, optimisation of graft healing conditions for year round production of grafted seedlings and optimisation of grafting time in watermelon such that it coincides with planting season in Kerala.