INFLUENCE OF GROWING ENVIRONMENT AND GROWTH REGULATORS ON GRAFT COMPATIBILITY OF CUCURBITS

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CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF GROWING ENVIRONMENT AND GROWTH REGULATORS ON GRAFT COMPATIBILITY OF CUCURBITS"** submitted by **Miss DEEPA ADIVEPPA HOLER ID. No. UHS17PGD199** for the degree of **DOCTOR OF PHILOSOPHY** in **VEGETABLE SCIENCE** to the University of Horticultural Sciences, Bagalkot is a record of bonafide research work carried out by her during the period of her study at University of Horticultural sciences, Bagalkot under my guidance, supervision and the thesis has not previously been formed the basis for the award of any other degree, diploma, associateship, fellowship or similar titles.

ARABHAVI

Date: **JANUARY 2021**

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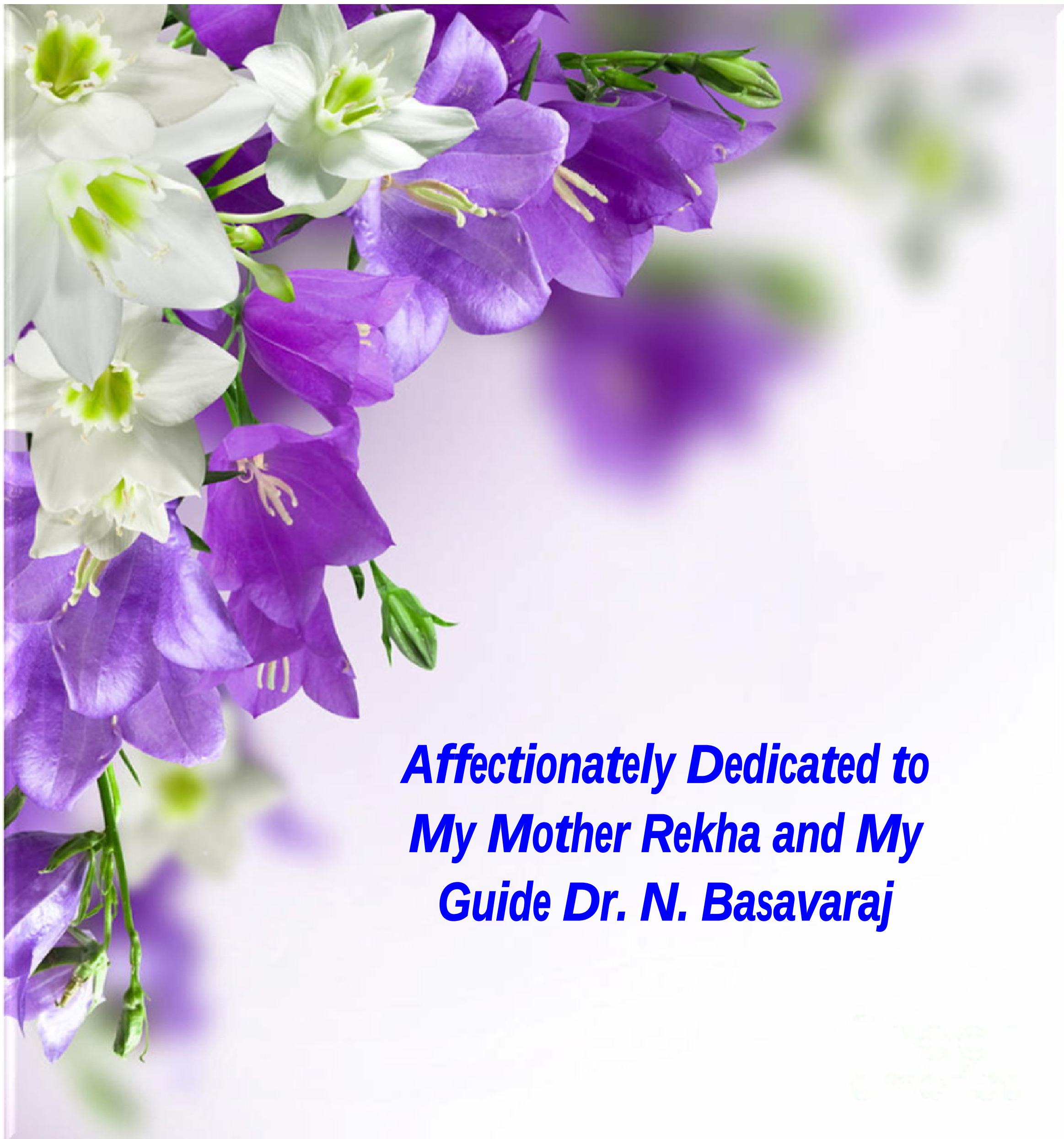

Affectionately Dedicated to
My Mother Rekha and My
Guide Dr. N. Basavaraj

CONTENTS

LIST OF ABBREVIATIONS

cm	Centi meter
et al.,	*Et allii* (co workers)
viz.,	*Videlicet* (namely)
G	Grammes
Ha	Hectare
J	Journal
ppm	Parts per million
L	Litre
mg	Milligram
Rs.	Rupees
sq cm	Square centimetre
m^2	Meter square
S. Em ±	Standard error of mean
CD	Critical difference
CV	Coefficient of Variation
T	Treatments
DAG	Days after grafting
Fig.	Figure
IBA	Indole Butyric Acid
%	Per cent
Viz.,	Namely
No.	Number
cfu	Colony forming unit
°C	Degree Celsius
mm	Millimeter
RBD	Randomized Block Design
m^{-2}	Per meter square

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1. INTRODUCTION

Vegetable crops are nutritionally rich, often referred as ‘Protective food’ and are highly remunerative. Among vegetable crops cucurbits occupy largest area in India and in other tropical countries. The Cucurbitaceae family comprises of about 117 genera and 825 species in warmer parts of the world. In India, Chakravarty (1982) estimated 36 genera and 100 species of cucurbits. It includes crops like cucumber, squashes, *Luffa*, melons and watermelons. It consists of wide range of vegetables either used for salad purpose (Cucumber) or for cooking (all gourds), pickling (West Indian gherkins) or as a dessert food (Muskmelon, Watermelon) or candied or preserved (Ash gourd).

India is the world’s second largest producer of vegetable crops after China and in India vegetable crops cover a total area of 10.25 million hectare with the production of 18.43 metric tons and 17.97 tons per hectare productivity. Bottle gourd has a 1.57 lakh hectare area and produces 26.83 lakh metric tonnes, watermelon has a 101 thousand hectare and 2520 thousand metric tonnes, bitter gourd has a 97 thousand hectare and 1137 thousand metric tonnes, cucumber has an 82 thousand hectare and 1260 thousand metric tonnes, and pumpkin has a 78 thousand hectare area and produces 1714 thousand metric tonnes (Anonymous, 2018). To be successful on global scale these crops requires attention from breeders and production system specialists. One of the possible approaches for achieving the targeted production is to identify suitable hybrids/varieties with biotic and abiotic stress tolerance, high yield, good quality and finding a suitable technology (Grafting) for cultivation. Grafting technology would pave the right way to overcome all these constrains.

Since the origin of agriculture, the progressive domestication of food crops has been intimately related to a series of innovations in plant propagation. Among plant propagation techniques, grafting is the common. Grafting in fruit trees has long history, but commercial grafting in vegetable crops is relatively new (Sakata *et al.*, 2007). China, Japan and Korea are the countries to publish first reports on vegetable grafting and recently it has been commercially performed. Vegetable production with grafted seedlings was originated in Japan and Korea to avoid the serious crop loss caused by infection of soil-borne diseases aggravated by successive cropping. This practice is now rapidly spreading and expanding over the world. Vegetable grafting has been safely adapted for the production of organic as well as environmental friendly produce and minimizes uptake of undesirable agrochemical residues (Lee *et al.,* 2010).

Grafting is a method of propagation technique in which two living parts of different plants *i.e.*, rootstock and scion are joined together in such a manner that they would unite together and subsequently grow into a composite plant. The first attempt in vegetable grafting was done by grafting watermelon (*Citrullus lanatus* L.) onto pumpkin (*Cucurbita moschata* L.) rootstock in Japan and Korea in the late 1920s (Lee, 1994). A serious crop loss caused by soil-borne diseases aggravated by successive cropping was avoided by production of vegetables with grafted seedlings. In many fruit-bearing vegetables such as watermelon, cucumber, melon, tomato, eggplant and pepper the use of grafted seedlings has become increasingly popular. Grafting is an environment-friendly approach which is used to control soil borne diseases and increasing the yield of susceptible cultivars (Lee and Oda, 2003). This technique is eco-friendly for sustainable vegetable production and by using resistant rootstocks; it reduces dependence on agrochemicals (Rivard and Louws, 2008) and most importantly induce resistance against biotic and abiotic stresses (Venema *et al*., 2008).

Grafting increases the yield and promotes biotic/abiotic stress tolerance. Grafting is also used to induce tolerance to abiotic stresses *viz.,* flooding, drought and salinity by using desired rootstocks. Asia, Japan, Korea, China and Taiwan were the countries that used grafting methods more than other Asian countries for vegetable production. The countries like Japan (92 %), Korea (98 %) and China (20 %) has major share in watermelon production from grafted seedlings. Europe and Spain is leading in grafted seedlings production with 129 million grafted seedlings followed by Italy (47 million grafted seedlings) and France (28 million grafted seedlings) (Anonymous, 2008). Grafting as a technology for the commercial production of vegetables was later on adopted by many countries in Europe, Middle East, Northern Africa, Central America and other parts of Asia (Kubota *et al*., 2008).

To reduce the time and increase the speed of grafting the first grafting robots were made in Japan in 1993 and are still used. Presently, complete automatic and semi automatic grafting robots are used for producing grafts. A semiautomatic robot have the capacity of producing 600-800 grafts per hour but needs an operator and a simple worker, its maximum capacity equals 5-6 expert workers. Recently, completely automatic robots produce more than 750 grafts per hour and 90 per cent of them are successful (Lee *et al.,* 2010), they can feed rootstocks and seedlings and only need a skillful worker.

In India, grafting work has been started in IIHR Bangalore by Dr R. M. Bhatt and his associates. The experiment was conducted with an objective of identification of rootstocks for waterlogged conditions by importing semi automated grafting machine. NBPGR regional station, Thrissur, Kerala have done work on cucurbit grafting by involving *Momordica cochinchinensis*, a dioecious plant. The female plants were grafted on to the male plants to increase its production. Graft success was 98 per cent. CSKHPKV, Palampur initiated work on grafting and identified more than 22 rootstocks of brinjal, chilli, tomato and cucurbits for importing resistance to bacterial wilt and nematodes (Kumar *et al*., 2015).

Due to limited availability of arable land and high market demand for off-season vegetables, cucurbits are continuously cultivated under unfavorable conditions in some countries. These conditions include environments that are too cold, wet or dry, or are cool low-light winter greenhouses. Successive cropping can increase salinity, the incidence of cucurbit pests, and soil borne diseases like fusarium wilt caused by *Fusarium* spp. These conditions cause various physiological and pathological disorders leading to severe crop loss. Chemical pest control is expensive, not always effective, and can harm the environment (Davis *et al*., 2008). Grafting can overcome many of these problems. At present few seed companies now offer watermelon transplants grafted on to squash or bottle gourd rootstocks and some transplant facilities offer grafting services. Identification of compatible multi-disease-resistant rootstocks with tolerance to biotic and abiotic stresses is a basic requirement for continued success.

Keeping all these points in view the present study on the influence of growing environment and growth regulators on graft compatibility of cucurbits was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi (University of Horticultural Sciences, Bagalkot) with the following objectives:

1. To study the effect of growing environments on graft compatibility and graft success with different rootstocks of cucurbits.
2. To study the effect of growth regulators on graft compatibility of cucurbits.
3. To work out the benefit cost ratio.

2. REVIEW OF LITERATURE

Grafting has long history in fruit crops, but commercial grafting in vegetable crops is relatively new (Sakata *et al*., 2007). The first report of vegetable grafting was published in China, Japan and Korea and first grafting in cucurbits was done in Japan and Korea in 1930, *Citrullus lanatus* L. was grafted on *Laganaria siceraria* L. rootstocks (Sakata *et al*., 2007). Grafting with suitable rootstocks provide tolerance to biotic and abiotic stress and improve soil nutrient and water use efficiency through vigorous root system. The information available on these aspects are very meager, hence an attempt was made to review the available literature.

Review of work done on influence of growing environment and growth regulators on graft compatibility of cucurbits, work done in related crops and related aspects were also included here under.

2.1 Grafting methods

The survival rate of grafted plants depends on compatibility between scion and rootstock, quality and age of seedlings, quality of joined section and post grafting management. Different grafting techniques are adapted for different scions and rootstock depending on grafting objectives, farmers experience and post grafting management conditions.

Lin (2004) studied the cleft or cleft inarch grafting method in bitter gourd using loofah rootstock. The growing of grafted seedlings in the field for several years has resulted in gradual disappearance of Fusarium wilt.

Hang *et al*. (2005) revealed that the suitable grafting method for the scion and rootstock with hollow hypocotyls were one cotyledon and hole insertion.

Akhila and George (2017) reported that wedge grafting (67 %) was superior to tongue approach grafting (15.17 %) in terms of final graft success for bitter gourd.

Noor *et al*. (2019) studied that local cucurbitaceous rootstocks showed a high compatibility with hybrid cucumber scion in splice grafting method compared to tongue approach, single cotyledon and hole insertion grafting techniques.

Thangamani *et al*. (2019) concluded that hole insertion grafting method was more advantageous over the side grafting in cucumber.

2.2 Environmental condition

Khah *et al*. (2006) studied that tomato grafting on suitable rootstocks has positive effects on the cultivation performance, especially in the greenhouse conditions in tomato.

Gotur *et al*. (2017) stated that the poly house condition gave better response than the open field condition with respect to number of days taken for first sprouting, graft take per cent, sprouting per cent, number of leaves per new shoot, height of the graft, girth of graft and graft survival percentage in guava.

Jalal *et al*. (2018) reported that the maximum number of leaves, maximum scion diameter and highest graft survival was achieved under open field condition as compared to polyhouse condition using cleft grafting method in aonla.

Djidonou *et al*. (2020) found that high tomato yields could be consistently achieved with grafted combination (HM1823/Multifort & HM1823/Estamino) especially under high tunnel production system as compared to open field condition across the regions of texas.

2.3 Graft compatibility

Unifying of two or more pieces of plant tissues to grow as a single plant is a horticulture technique known as grafting and the graft composition of two different plants. Some beneficial and negative effects (apart from the effect of soil borne pathogens) may arise after grafting. Graft incompatibility is differentiated from graft failure that results from environmental factors or lack of skill of grafter (Andrews and Marquez, 1993). Graft incompatibility could be attributed to failure of rootstock and scion to form a strong graft union, premature death of rootstock and scion after grafting, lack of cellular recognition, wounding response, presence of growth regulators and incompatibility toxins. Generally graft incompatibility induces under growth or overgrowth of scions which leads to decreased water and nutrient flow through the graft union and cause wilting of the plant. Generally graft compatibility is related to taxonomic affinity but there are significant exceptions. Several authors have defined sequence of structural events during healing of the grafts in woody and herbaceous plants (Hartmann *et al*., 2002).

Xu *et al.* (2015) studied the physiological aspects of compatibility and incompatibility in grafted cucumber and found that the compatible graft combinations present a stronger resistance to the oxidative damage resulting from grafting and had relatively weak phenylpropanoid metabolisms. The results also indicated that the chlorophyll fluorescence levels of incompatible combinations were lower, except compared with the original fluorescence. These differences at the morphological, physiological and cellular levels may govern compatibility and incompatibility and may provide valuable information for determining the symbiotic affinity of grafted seedlings at an early stage.

2.3.1 Graft success

Reyes (1990) reported that bitter gourd grafted onto sponge gourd recorded higher plant survival (87 %) than bitter gourd grafted onto bottle gourd (21 %).

Yetisir and sari (2003) studied that high survival rate was observed with *Lagenaria* (95 %) type rootstocks, while low (65 %) in *Cucurbita* type in watermelon.

Melon and *Luffa* had higher compatibility with netted melon (*Cucumis melo* var. *reticulatus*) compared to Chinese pumpkin (*Cucurbita moschata* L.) and wax gourd (Wei *et al*., 2006).

Salehi *et al.* (2008) studied that hole insertion grafting was highly effective in watermelon and cucumber (90-95 %) when summer and winter squash were used as rootstocks.

Marathon F_1 hybrid cucumber grafted on P360 (*Cucurbita maxima* L. × *Cucurbita moschata* L.) and Arican 97 (*Cucurbita maxima* L.) recorded survival rate of 99.20 and 80.80 per cent respectively (Cansev and Ozgur, 2010).

Heidari *et al*. (2010) found that among different cucurbitaceous rootstocks *Cucurbita moschata* L. (71 %) recorded highest survival rate and lowest (37 %) was recorded with Ferro in cucumber.

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

Mohsen *et al.* (2012) assessed that grafting Nubian watermelon (*Citrullus lanatus* var. *Colocynthoide*) onto *Cucurbita ficifolia L.* and *Lagenaria siceraria* L. gave greatest survival percentage.

Punithaveni *et al.* (2014) found that highest graft success per cent was recorded in hole insertion grafting method with NS 408 (85.81 % & 83.26 %) and Green Long (85.00 % & 82.35 %) grafted on bottle gourd rootstock on 15 and 30 days after grafting (DAG) respectively in cucumber.

Uap (2014) reported that survival rate of cucumber and bitter gourds grafted onto bottle gourd (Local) were 20 and 21.90 per cent respectively.

Farhadi and Malek (2015) suggested that *Cucumis pepo* mosamaii (88 %) and fig leaf gourd (69 %) rootstocks recorded highest survival percentage for cucumber.

Zhang *et al*. (2015) studied *in vitro* micro grafting of watermelon and found that the survival rate was more than 90 per cent when scions are grafted onto rootstocks using cleft grafting method.

Farhadi *et al*. (2016) revealed that the highest survival rates were recorded using rootstocks like Ferro hybrid (94 %), *Cucurbita maxima* L. (Tanbal) (92 %), 64-19 and Shintoza (90 %) in watermelon.

Akhila and George (2017) revealed that in wedge grafting, best rootstock in terms of graft success was smooth gourd (80 %) followed by pumpkin and wedge grafting (67 %) was superior to tongue approach grafting (15.17 %) in terms of final graft success for bitter gourd.

Tamilselvi and Pugalendhi (2017) reported that the highest survival percentage (71.70 %) was observed in Palee F_1 grafted onto pumpkin (*Cucurbita moschata* L.) rootstock followed by sponge gourd (*Luffa cylindrical* L.) rootstock (68.26 %) and lowest success per cent (12.12 %) was obtained in mithipakal (*Momordica charantia* var. *muricata*).

Noor *et al*. (2019) studied that *Lagenaria siceraria* L. rootstocks were found highly compatible with cucumber cv Kalaam scion which gave significantly maximum plant survival rates (95 %).

2.3.2 Days to first sprout and 50 per cent sprout

Nadeem *et al*. (2014) reported that significant differences among various grafting methods and results showed that minimum days (36) to sprouting was recorded in side grafting method followed by cleft (49 days) grafting method .

Kavya (2017) reported that significant and least number of days were observed for first sprouting at a temperature of 28.4°C and relative humidity of 94 per cent during first fortnight of July (15.33 days) which was followed by second fortnight of September (17.33 days) and second fortnight of July (18.01 days) and similar trend was also noticed for days taken for 50 per cent sprouting.

2.3.3 Length of the scion/ vine length

Alan *et al*. (2007) studied that main stem length was significantly influenced by grafting when compared with non grafted plants in watermelon.

Melon plants grafted on to Xiuli, Nanzhen No. 3, 4 and Quannengtiejia rootstocks recorded higher vine length when compared to those of non grafted control plants (Bie *et al*., 2010).

Khankahdani *et al*. (2012) reported that the longest main stem was observed in grafted watermelons on bottle gourd by splice grafting technique (180 cm) and shortest in seedy watermelons (103 cm).

Islam *et al*. (2013) revealed that length of the main vine was significantly higher in grafted plants than that of non-grafted plants in watermelon.

Punithaveni (2015) studied that the graft combination NS 408 hybrid scion onto winter squash rootstock recorded significantly highest vine length of (316.52 cm, 576.43 cm and 660.50 cm) followed by NS 408 hybrid scion grafted onto fig leaf gourd as rootstock (293.25 cm, 501.26 cm and 595.63 cm) at 45, 60 days after planting and at final harvest respectively.

Tamilselvi and Pugalendhi (2017) revealed that the highest vine length at final harvest (856.6 cm) was found with Palee F_1 grafted on pumpkin rootstock.

2.3.4 Girth of the graft union

Punithaveni (2015) reported that the graft combination NS 408 hybrid scion onto winter squash recorded the highest stem diameter at all stages of crop development. At final harvest this graft combination recorded the highest stem diameter of 35.84 mm, 29.47 mm and 20.42 mm at final stage of harvest at graft union, rootstock and scion respectively.

2.3.5 Days to first female flowering

Reyes (1990) revealed that earliness to first female flower appearance was noticed in bitter gourd grafted on to sponge gourd rootstock compared to non grafted plants.

Punithaveni (2015) reported that among ten graft combinations and non-grafted scions, days to first female flower appearance was ranged from 27.94 to 48.23 days. The least number of days to first female flower appearance was noticed in NS 408 hybrid scion grafted onto pumpkin rootstock (27.94 days) followed by NS 408 hybrid scion grafted onto winter squash and fig leaf gourd rootstocks (28.82 days and 29.13 days) respectively.

Tamilselvi and Pugalendhi (2017) recorded that among different graft combinations, Palee F_1 hybrid bitter gourd grafted onto pumpkin rootstock exhibited earliness with less number of days to first female flower (70.32 days) appearance.

2.3.6 Node number to first female flower appearance

Punithaveni (2015) studied that the cucumber hybrid NS 408 scion grafted onto winter squash rootstock recorded lesser (7.32 days) number of nodes to first female flower appearance followed by NS 408 hybrid scion grafted onto pumpkin rootstock (7.96 days) which were significantly different from the other graft combinations and nongrafted plants.

Tamilselvi and Pugalendhi (2017) revealed that among different graft combinations, Palee F_1 hybrid bitter gourd grafted onto pumpkin rootstock produced female flowers at early nodes (25.80 days).

2.3.7 Yield

Study conducted by Echerbarria (2001) revealed that grafting reduces precocity, but the total yield increased significantly. The highest total yield was obtained from Shintoza and it was 32 per cent higher than non-grafted ones. The plants grafted with the other rootstocks (*Cucurbita pepo* L., *Cucurbita maxima* L. and *Cucurbita ficifolia* L.) also recorded higher yields (15 %) than non-grafted plants.

Watermelon grafted onto bottle gourd produced larger fruit (30.30 cm), 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 (Salam *et al*., 2002).

Seong *et al*. (2003) observed that cucumber plants grafted on pumpkin rootstocks had 27.00 Per cent more marketable fruits per plant than self rooted cucumber.

Yetisir and Sari (2003) reported that *Lagenaria* type rootstocks produced higher yield but *Cucurbita* type rootstocks produced a lower yield than the control.

Alan *et al*. (2007) studied that grafting significantly influenced fruit yield in watermelon 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 respectively.

Oztekin *et al*. (2012) revealed that the highest yield was obtained from Maximus which was 89.9 and 66.3 per cent higher than non-grafted and self-grafted treatments respectively.

Turhan *et al*. (2012) reported that the total yield and marketable yield were significantly influenced by grafting as compared to the non-grafted plant in watermelon.

Uysal *et al*. (2012) assessed that the highest yield was obtained from the plants grafted on Nunhems 9075 in spring and Maximus in autumn that is 23.5 and 26.5 per cent higher than the yield of self-grafted treatment respectively. Grafting on *C. maxima* L. × *C. moschata* L. hybrids increased plant biomass, yield parameters and water use efficiency in both growing cycles. Plant height, total plant dry weight and water use efficiency were found highly correlated with marketable yield in spring in cucumber.

Islam *et al*. (2013) studied the effect of grafting on watermelon growth and yield and revealed that fruit yield was one and half times higher in grafted fields as compared to non grafted counterparts.

Ban *et al*. (2014) reported that the plants grafted onto Strong Tosa rootstock had higher total number of fruits (19.9) and yield (5.38 kg) compared to other rootstocks or non-grafted plants in first season and the same result was found for two interspecific rootstocks in the second season (6.96 kg and more than 28.9 fruits per plant) in cucumber.

Esmaeli *et al*. (2015) found that the marketable yield was higher by 18.85 per cent in grafted plants compared to non grafted plants in muskmelon and also increasing N fertilization rates from (60 to 120 kg.ha^{-1}) increased fruit dry biomass with the highest value recorded with (120 kg.ha^{-1}) of nitrogen.

Farhadi and Malek (2015) reported that the total yield was significantly influenced by grafting. Grafted plants on ‘RZ426’ rootstock had higher yield and plant length compared to non grafted ones.

Mohammadi *et al*. (2015) reported that the grafting increased total yield by 23.5 per cent with increasing fruit number per plant in grafted muskmelon plants.

Salar *et al*. (2015) revealed that the increasing N fertilization rates from 75 to 150 kg ha^{-1} increased above-ground dry biomass with the highest value recorded with 150 kg ha^{-1} of N.

Farhadi *et al*. (2016) showed that the highest yield was obtained with Ferro rootstock, but there was no difference compared to ungrafted plants. A significantly lower production than the control was observed with Ghalyani (-44 %), 913 (-73 %) and 64-19 (-35 %) rootstocks.

Grafting melons on pumpkin (*Cucurbita maxima* L.×*Cucurbita moschata* L.) rootstock significantly increased growth and fruit yield and enhanced photosynthetic capacities (Fu *et al*., 2016).

Velkov and Galina (2016) assessed that the highest yield was recorded in combination *cv.* 'Kiara F_1' grafted on *Cucurbita maxima* L. × *C. moschata* L. F_1. rootstocks of *Lagenaria* and *C. maxima* L. and control treatments showed great earliness of cucumber scions. *C. maxima* L. × *C. moschata* L. F_1 rootstock induced the highest fruit number per plant.

Tamilselvi and Pugalendhi (2017) revealed that grafted plants had higher yield than non grafted plants. Palee F_1 grafted onto pumpkin recorded maximum fruit number (28.02) and fruit yield per vine (3.55 kg/vine).

Yetisir and Sari (2018) observed that the fruit yield was significantly affected by rootstocks and the grafted plants produced higher yield than the ungrafted control plants regardless of growing year.

Watermelon grafted onto *Lagenaria* rootstock had better fruit yield than those onto *Cucurbita* rootstocks (Meng *et al*., 2019).

Noor *et al*. (2019) studied that *Lagenaria siceraria* L. rootstocks were recorded maximum fruit yield when compared with other rootstocks by employing the splice grafting method followed by tongue approach, single cotyledon and hole insertion grafting.

Omar and Hamahmy (2019) observed that the Hesham *cv.* had the highest leaf area and yield per plant with high concentration of N in leaves and roots as well as P in roots. Yield increased by 70.7 and 67.6 per cent in Hesham *cv.* after grafting on Ferro rootstock in both seasons respectively in cucumber.

2.4 Effect of growth regulators

Shimomura and Fujihara (1977) found that auxin translocation from the scion to the rootstock was found to accelerate the formation of a successful graft in cactus.

Aloni *et al.* (1990) and Aloni (1993) studied the vascular regeneration experiments in which hormones were applied exogenously to stem segments, indicating that low concentrations (0.1%, w/w, applied in lanolin) of indolic acetic acid (IAA) stimulate phloem differentiation, whereas higher levels (1.0%, w/w) induce xylem differentiation. Other phytohormones, particularly cytokinins at a concentration of 10 g/ml, have been shown to induce vascular elements differentiation in wounded stems.

Lu *et al.* (1996) revealed that the exogenous application of plant hormones helps the formation of graft unions by increasing the rate of formation and number of vascular bridges.

Sureshkumar *et al.* (2016) studied that GA_3 @ 25 ppm recorded maximum number of fruits per vine, fruit length, fruit weight, fruit diameter, where as fruit yield per hectare was maximum with the treatment ethrel @ 250 ppm.

Kavya (2017) reported that the scions treated with IBA @ 75 ppm took least number of days for days to first and 50 per cent sprouting. Maximum sprout length (vine length) and maximum number of leaves per vine were recorded with IBA @ 50 ppm followed by IBA @ 75 ppm. Maximum increament in the girth of graft union was observed in the scions treated with IBA @ 75 ppm and highest graft success was observed with the treatment IBA @ 50 ppm.

2.5 Physiological parameters

Abdelmageed and Gruda (2009) reported that grafted plants showed significantly higher value for leaf area than non grafted plants in tomato.

Liu *et al*. (2011) revealed grafting muskmelon on inter-specific rootstocks enhances photosynthesis and translocation of sugars in muskmelon leaves.

Zeist *et al*. (2018) revealed that the tomato plant grafted on mini tomato accession RVTC-66 showed high photosynthetic rate and had the lowest transpiration rate (E).

Zhang and Guo (2018) studied that the net photosynthetic rate was slightly higher than that of self rooted and ungrafted tomato.

Omar and Hamahmy (2019) observed that the Hesham *cv.* grafted on Ferro rootstock had the highest leaf area in both the season.

2.6 Disease incidence

Chung and Chin (1996) stated that in bitter gourd wedge grafting on *Luffa* rootstock had been vogue in China and Taiwan for the control of *Fusarium* wilt.

Vakalounakis (1999) found that cucumber grafted onto rootstocks like *Cucurbita maxima* L., *Cucurbita moschata* L. *and C. maxima* L. × *C. moschata* L. was very effective to control *Fusarium* wilt.

Lin (2004) stated that *Luffa* sp., fig leaf gourd and pumpkin are common rootstocks and cleft grafting is good method in bitter gourd for resistance against *Fusarium* wilt.

Tamilselvi *et al*. (2016) studied the screening of cucurbitaceous rootstocks against Fusarium wilt and revealed that *Citrullus colocynthis* L., *Cucumis metuliferus L.* and *Cucurbita moschata* L. exhibited no symptom and manifested as resistant to *Fusarium* wilt and the less disease incidence of was observed in *Luffa cylindrical* L. followed by *Momordica charantia var. muricata* rootstock (23.58, 42.18 and 50.34 %) at 30, 45 and 60 days after inoculation.

2.7 Economics

Punithaveni (2015) reported that among the different graft combinations and non grafted control plants NS 408 hybrid scion grafted onto winter squash and fig leaf gourd rootstock recorded the highest benefit cost ratio of 3.82 and 3.58 respectively, under insect proof net house condition.

Kavya (2017) revealed that the highest net income and higher returns per rupees invested was observed in scion sticks treated with IBA-50 ppm (Rs. 691.50/15 plants) followed by vermiwash 10 per cent (Rs. 626.50/15 plants) at Rs. 2.69 and 2.67, respectively in bell pepper.

Latifah *et al*. (2018) reported that the tomato *var*. Timothy grafted on the rootstock *Solanum torvum* L. had the highest benifit-cost ratio (2.03) compared to contol (0.36).

Sharma *et al*. (2019) studied the costs and returns of grafted and non grafted tomatoes in 250 m^2 polyhouse and revealed that grafted plants grown under protected conditions resulted in higher benefit: cost ratio than non-grafted ones. The net returns of grafted tomato production was increased by Rs. 210.47 /m^2 during 2016-17 (with benefit-cost ratio of 5.32) and Rs. 211.36 /m^2 (with benefit-cost ratio of 5.42) in 2017-18 as compared to non-grafted tomato which were Rs. 103.76 /m^2 (with benefit-cost ratio of 4.52) during 2016-17 and Rs 104.65 /m^2 (with benefit-cost ratio of 4.67) during 2017-18.

3. MATERIAL AND METHODS

Present study entitled with “Influence of growing environment and growth regulators on graft compatibility of cucurbits” was carried out at Kittur Rani Channamma College of Horticulture (KRCCH), Arabhavi, Belagavi district, Karnataka, University of Horticultural Sciences (UHS), Bagalkot during *Kharif* (2018-19) and *Rabi* (2019-2020). The details pertaining to different experiments have been presented clearly with material details and objective wise methodology discussed here under.

3.1 Experimental site

The experiment was conducted in the field of Vegetable Science unit of Kittur Rani Channamma College of Horticulture (KRCCH), Arabhavi, Belagavi district, Karnataka.

3.2 Climatic conditions

Arabhavi is located in northern dry Zone of Karnataka state at 16°15' North latitude, 74°45' East longitude and at an altitude of 612.05 m above MSL. Arabhavi comes under the zone-3 and region-2 among the agro-climatic zones of Karnataka and benefited from both South-West and North-East monsoons. The command area receives water from Ghataprabha left bank canal from mid-July to mid-March. The meteorological data during the experimental period was recorded and presented in Appendix I.

3.3 Experimental details

Title of the research problem : Influence of growing environment and growth regulators on graft compatibility of cucurbits

Location : KRCCH, Arabhavi, Karnataka, India

Season : Two seasons {*Kharif* (2018-19) and *Rabi* (2019-2020)}

The study has been conducted under two different experiments.

Experiment No. 1	Effect of growing environment on graft compatibility and graft success in cucurbits
Experiment No. 2	Effect of growth regulators on graft compatibility and yield of cucurbits

3.3.1 Experimental materials

The experimental materials collected from different institutions and their details were furnished below.

Details of the cucurbitaceous species used in the study

Genotypes	**Variety**	**Source**
Rootstocks		
Bottle gourd (*Lagenaria siceraria* L.)	Samrat	MPKV, Rahuri
Pumpkin (*Cucurbita moschata* L.)	Arka Chandan	IIHR, Bengaluru
Coccinia (*Coccinia indica* L.)	*Coccinia indica*	KRCCH, Arabhavi
Sponge gourd (*Luffa cylindrica* L.)	Santosh F_1 hybrid	Vokkal seeds
Snake gourd (*Trichosanthus anguina* L.)	Harita Sree	KAU, Vellankera, Thrissur
Scions		
Watermelon (*Citrullus lanatus* L.)	Arka Manik	IIHR, Bengaluru
Cucumber (*Cucumis sativus* L.)	Shubra	KAU, Thrissur
Muskmelon (*Cucumis melo* L.)	NS-910	Namdhari seeds
Bitter gourd (*Momordica charantia* L.)	Phule Green Gold and Ankur Shreya	MPKV Rahuri and Ankur seeds
Ridge gourd (*Luffa acutangula* L.)	Ankur Latika	Ankur seeds

3.4 Experiment No. 1: Effect of growing environment on graft compatibility and graft success in cucurbits

Design : Factorial randomized completely block design (FRCBD)

Number of factors : 3

Treatment combinations : 50

Number of replications : 3

Seasons : 2 {*Kharif* (2018-2019) and *Rabi* (2019-2020)}

The experiment was conducted to study the Effect of growing environment on graft compatibility and graft success in cucurbits by using five cucurbitaceous species as a rootstocks *viz.,* bottle gourd *(Lagenaria siceraria* L.*),* pumpkin (*Cucurbita moschata* L.*),* ivy gourd (*Coccinia indica* L.) sponge gourd *(Luffa cylindrical* L.*),* snake gourd (*Trichosanthes cucumerina* L.) and five different cucurbitaceous species as scions *viz.,* watermelon (*Citrullus lanatus L.*), cucumber (*Cucumis sativus* L.), muskmelon *(Cucumis melo* L.), bitter gourd (*Momordica charantia* L.) and ridge gourd *(Luffa acutangula* L.*)* for grafting. The details of different graft combinations are furnished as below**.**

Treatment details

Treatments	**Growing environment (Factor – 1)**	**Rootstock (Factor – 2)**	**Scion (Factor - 3)**
	Open field (E_1)	Bottle gourd (R_1)	Watermelon (S_1)
	Protected condition (E_2)	Coccinia (R_2)	Cucumber (S_2)
		Pumpkin (R_3)	Muskmelon (S_3)
		Sponge gourd (R_4)	Bitter gourd (S_4)
		Snake gourd (R_5)	Ridge gourd (S_5)

3.4.1 General conditions of propagation structures

3.4.1.1 Healing chamber

A low cost healing chamber was constructed by using PVC pipe. It consists of a high density polyethylene for construction of healing chamber and a layer of shade net was spread on that. The relative humidity between 85 and 95 per cent and the temperature between 25°C and 30°C were maintained by cooling the healing chamber with water by misting the water twice a day and the details regarding maintenance of temperature and relative humidity during healing period were presented in Appendix II.

3.4.1.2 Shade house

Shade house (green color) of 500 m^2 area allowing 50 per cent shade was used. In the structure relatively low temperature with high humidity was maintained compared with outside environment. The temperature inside the shade net was 29-32°C and the relative humidity was 60-80 %.

3.4.2 Procedure/ Methodology

3.4.2.1 Preparation of rootstock:

Seeds of rootstocks were sown in 155 cell protray. Trays were placed in warm, light area immediately after sowing and covered with clear plastic to avoid dehydration of the seed. Plastic mulching sheet was removed as soon as the very first green spot is visible. Humidity was kept high as the seedling will otherwise dry out. 15-20 days old seedlings (2-3 leaf stage) were chosen for grafting.

3.4.2.2 Preparation of scion:

Seeds of scion were sown in 155 cell portray ten days after sowing rootstock. Trays were placed in warm, light area immediately after sowing and covered with clear plastic to avoid dehydration of the seed. Plastic mulching sheet was removed as soon as the very first green spot is visible. Humidity was kept high to avoid drying out of seedlings. 15-20 days (2-3 leaf stage) old scions of 4-6 cm in length were chosen for grafting.

Bottle gourd (*Lagenaria siceraria* L.)

Snake gourd (*Trichosanthus anguina* L.)

Pumpkin (*Cucurbita moschata* L.)

Ivy gourd cuttings (*Coccinia indica* L.)

Watermelon (*Citrullus lanatus* L.)

Bitter gourd (*Momordica charantia* L.)

Ridge gourd (*Luffa acutangula* L.)

Plate 1a. Cucurbitaceaus rootstock and scion materials used for grafting (*Kharif,* 2018-19)

Plate 1b. Nursery of cucurbitaceaus stock and scion raised under polyhouse at Vegetable section, KRCCH, Arabhavi (*Kharif,* 2018-19)

a) Inserting the stock and scion

b) Grafted plants

c) Healing of grafted plants

d) Hardening of healed plants

e) Transplanting in main field

Plate 2. Chronology of grafting methodology in cucurbits (*Kharif,* 2018-19)

3.4.2.3 Method of grafting : Wedge method

- ✓ Grafting was performed in 15-20 days old seedlings. Wedge grafting was performed when seedlings are ready for grafting.

- ✓ In wedge grafting the rootstock is cut below cotyledon and a vertical slit is given on stock.

- ✓ The cotyledonery leaves from scion was removed to avoid over weight and the scion is cut in the shape of wedge. The cut surfaces of both scion and stock were bound tightly together with grafting clips.

- ✓ Healing and acclimatization are very important operation for serving maximum percentage of success. After grafting, the plants were placed in healing chamber for five to seven days at 90-95 per cent relative humidity, 25-30ºC temperature and darkness. Relative humidity was reduced for acclimatization.

- ✓ After healing, the plants were subjected to hardening for 2-4 days under shade net or poly house in shaded area.

- ✓ The clips were removed once the graft portion gets united. Watering was done by just wetting the tray by submerging with water (mixed with Chlorpyriphos 2 ml/l and Copper oxychloride 2 g/l) as needed. Stock growth was removed periodically and by this time graft union was completed and the scions were able to get water and nutrients through the rootstocks.

Procedure:

- ✓ The successful graft combination was planted in the main field for its performance. Out of fifty graft combinations twelve graft combinations with higher survival percentage were raised in factorial randomized block design (FRCBD) with three replications.

- ✓ The research was carried out in both open field and under shade net condition to study the effect of growing conditions on graft compatibility and graft success.

- ✓ The grafted plants were transplanted in the main field and under shade net condition after healing and hardening of plants at a spacing of 2 × 1.5 m. Totally 10 plants were maintained in each treatment per replication and five healthy plants of each treatment were tagged and observations were recorded.
- ✓ Open field transplanted plants died at 20 days after transplanting. The observations were recorded upto 20 days and thereafter the experiment is continued to know the performance under shade net condition. The list of graft combinations further studied was furnished as below.

Details of different graft combination

Treatments	**Treatment combination details**	
T_1	R_1S_1	Bitter gourd grafted on Bottle gourd
T_2	R_1S_2	Ridge gourd grafted on Bottle gourd
T_3	R_2S_1	Bitter gourd grafted on Pumpkin
T_4	R_2S_2	Ridge gourd grafted on Pumpkin
T_5	R_3S_1	Bitter gourd grafted on Snake gourd
T_6	R_3S_2	Ridge gourd grafted on Snake gourd

Scions were treated with 0.1 % carbendazim before they are grafted

3.4.3. Observation recorded

The details of the observations recorded are furnished below.

3.4.3.1. Days to first sprout and days to 50 per cent sprout

The number of days taken for first sprouting was observed and recorded from first day after grafting and days taken for 50 per cent sprouting was recorded when 50 per cent of the grafted plants sprouted under each treatment per replication was calculated out of total number of grafted plants.

3.4.3.2 Sprout length of the scion (cm)

The length of scion was measured using centimeter scale from the graft union to the tip of the scion at 10, 15, 20, 25, 30 and 40 days after grafting. Mean of five plants per treatment and replication wise length was calculated and expressed in centimeters.

3.4.3.3 Number of nodes per graft

The number of nodes produced in each plant was recorded above the graft union up to 60 days at 15 days interval starting from 15 days after grafting. The mean of the five plants per treatment and replication wise numbers was calculated.

3.4.3.4 Initial girth of graft union (mm)

The diameter of the plants at the graft union (stock) was recorded using vernier calipers at 10, 20 and 30 days after grafting. Mean girth of five plants per treatment and replication wise girth was calculated and expressed in terms of millimeter.

3.4.3.5 Final girth of graft union (mm)

The diameter of the plants at the graft union (stock) was recorded using vernier calipers at 60 and 90 days after grafting. Mean girth of five plants per treatment and replication wise girth was calculated and expressed in terms of millimeter.

3.4.3.6 Percentage of graft success

Percentage of graft success was calculated by using formula

$$= \frac{\text{Number of grafts survived}}{\text{Total number of plants grafted}} \times 100$$

3.4.3.7 Days to first flowering (days)

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

3.4.3.8 Node number to first female flower appearance

The node number where the production of first female flower was counted and expressed in number.

3.4.3.9 Statistical analysis

The experiment was conducted in a Factorial Randomized Completely Block Design (FRCBD). The mean values of the each treatment were subjected to analysis of variance as suggested by Panse and Sukhatme (1974).

3.5 Experiment No. 2: Effect of growth regulators on graft compatibility and yield of cucurbits

Design	: Factorial randomized completely block design (FRCBD)
Number of factors	: 2
Treatment combinations	: 33
Number of replications	: 2
Seasons	: 2 {*Kharif* (2018-19) and *Rabi* (2019-2020)}
Growth condition	: Shade net (50 % shade)

The experiment was carried out under shade net condition to know the effect of growth regulators on graft compatibility and yield of cucurbits at Kittur Rani Channamma College of Horticulture, Arabhavi in two seasons of *kharif* (2018-2019) and *rabi* (2019-2020). Watermelon, bitter gourd and muskmelon were used as scion materials. The experiment was laid out in factorial randomized block design with two factors, factor – a consist of different scions and factor – b consist of different growth regulators with two replications. The details were furnished below;

Treatment details for duration and method of application of growth regulators for grafting

Treatment	Scion (Factor – 1)	Growth regulators (Factor – 2)	Time and method of application
S_1 S_2 S_3	Watermelon Muskmelon Bitter gourd	GA_3 @ 25 ppm (P_1)	The scions were treated with GA_3@ 25 ppm as per treatment, dipped up to 1.5–2.0 cm deep in the solution for one minute, and air dried subsequently for a minute and grafted immediately
		GA_3 @ 50 ppm (P_2)	The scions were treated with GA_3@ 50 ppm as per treatment, dipped up to 1.5–2.0 cm deep in the solution for one minute, and air dried subsequently for a minute and grafted immediately
		IBA @ 25 ppm (P_3)	The scions were treated with IBA @ 25 ppm as per treatment, dipped up to 1.5–2.0 cm deep in the solution for one minute, and air dried subsequently for a minute and grafted immediately
		IBA @ 50 ppm (P_4)	The scions were treated with IBA @ 50 ppm as per treatment, dipped up to 1.5–2.0 cm deep in the solution for one minute, and air dried subsequently for a minute and grafted immediately
		Cow urine @ 1 % (P_5) (v/v)	The scions were treated with cow urine @ 1 % by dipping up to 1.5–2.0 cm deep for 15 minutes.

		Cow urine @ 1.5 % (P_6) (v/v)	The scions were treated with cow urine @ 1.5 % by dipping up to 1.5–2.0 cm deep for 15 minutes
		Cow urine @ 2% (P_7) (v/v)	The scions were treated with cow urine @ 2 % by dipping up to 1.5–2.0 cm deep for 15 minutes.
		Coconut milk @ 10 % (P_8) (v/v)	The scions were treated with coconut milk @ 10 % by dipping up to 1.5–2.0 cm deep for 15 minutes.
		Coconut milk @ 15 % (P_9) (v/v)	The scions were treated with coconut milk @ 15 % by dipping up to 1.5–2.0 cm deep for 15 minutes.
		Coconut milk @ 20 % (P_{10}) (v/v)	The scions were treated with coconut milk @ 20 % by dipping up to 1.5–2.0 cm deep for 15 minutes.
		Water (control) (P_{11})	Scions were treated with distilled water

Rootstocks used: Bottle gourd, Pumpkin, Muskmelon and bitter gourd

3.5.1 General conditions of propagation structures

3.5.1 Were same as explained in 3.4.1

3.5.2 Procedure/ Methodology

3.5.2.1 Preparation of rootstock:

3.5.2.1. Were same as explained in 3.4.2.1.

3.5.2.2 Preparation of scion:

3.5.2.2 Were same as explained in 3.4.2.2.

Healing of grafted plants under healing chamber

Healing Chamber

Plate 3. Healing of grafted plants (*Kharif,* 2018-19)

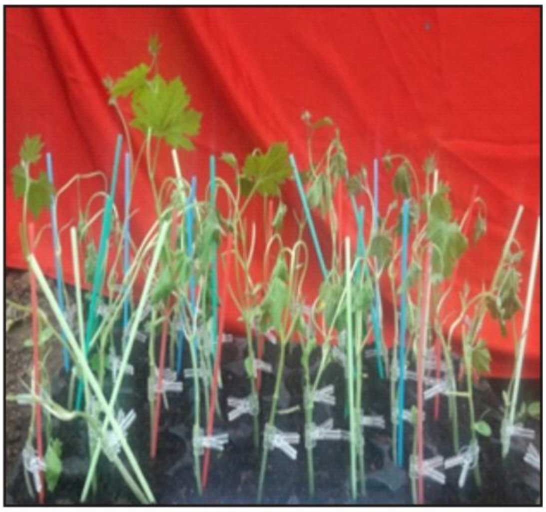
Ridge gourd on Snake gourd

Ridge gourd on Pumpkin

Bitter gourd on Snake gourd

Ridge gourd on Bottle

Bitter gourd on Pumpkin



Bitter gourd on Bottle gourd

Plate 4. Hardened plants ready for transplanting (*Kharif,* 2018-19)

2018-19 (*Kharif*)

2019-20 (*Rabi*)

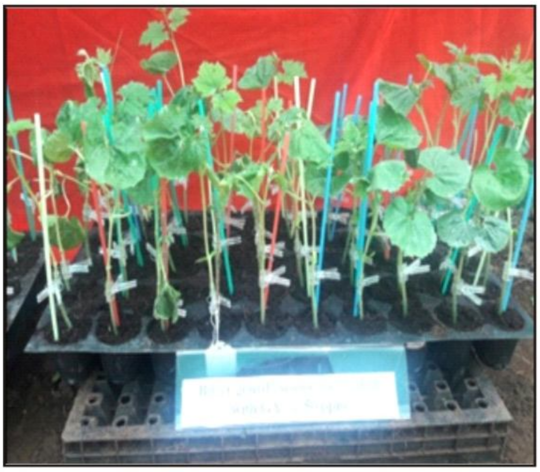
Plate 5. Exp. No. 1 Effect of growing environment on graft compatibility and graft success in cucurbits (*Kharif,* 2018-19)

a) Scion treatment with growth regulators

c) Joining the stock and scion

d) Grafted plants

e) Healing of grafted plants



f) Hardening of healed plants

g) Transplanting in main field

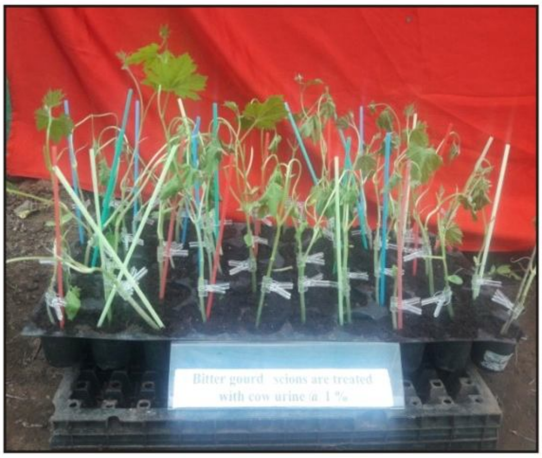
Plate 6. Chronology of grafting methodology in cucurbits (*Kharif,* 2018-19)

Bitter Gourd scions treated with GA_3 @ 25 ppm

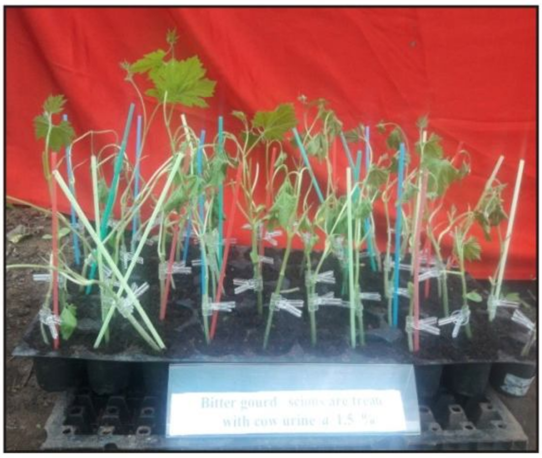
Bitter Gourd scions treated with GA_3 @ 50 ppm

Bitter Gourd scions treated with IBA @ 25 ppm

Bitter Gourd scions treated with IBA @ 50 ppm

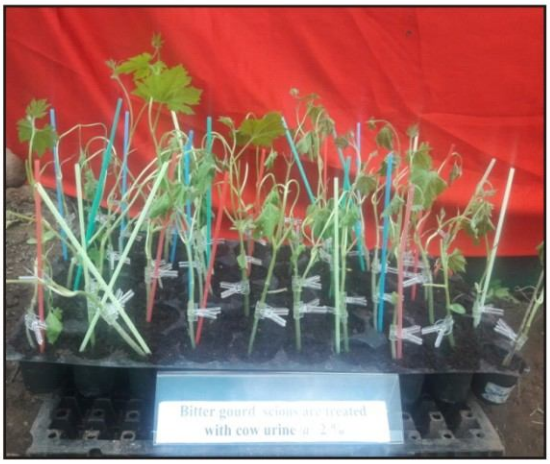


Bitter Gourd scions treated with cow urine @ 1%



Bitter Gourd scions treated with cow urine @ 1.5%

Plate 7a. An over view of hardening of grafted bitter gourd scion treated with different growth regulators and organic promoter on pumpkin root stock (*Kharif,* 2018-19)



Bitter Gourd scions treated with cow urine @ 2%

Bitter Gourd scions treated with cow urine @ 10%

Bitter Gourd scions treated with coconut milk @ 15%

Bitter Gourd scions treated with coconut milk @ 20%

Bitter gourd scions treated with distil water (Control)

Plate 7b. An over view of hardening of grafted bitter gourd scion treated with different growth regulators and organic promoter on pumpkin root stock (*Kharif*, 2018-19)

Plate 8. Field view of grafted cucurbitacous plant (transplanting and establishment) (*Kharif*, 2018-19)

2018-19 (*Kharif*)

2019-20 (*Rabi*)

Plate 9. Exp. No. 2 Effect of growth regulators on graft compatibility and yield of cucurbits (*Kharif*, 2018-19)

3.5.2.3 Method of grafting : Wedge method

- ✓ Grafting was performed in 15-20 days old seedling. Wedge grafting was performed when seedlings were ready for grafting.

- ✓ In wedge grafting the rootstock is cut below cotyledon and a vertical slit is given on stock.

- ✓ The cotyledonery leaves from scion were removed to avoid over weight and the scion is cut in the shape of wedge and scions were treated with different growth regulators as per treatment and then the cut surfaces of both scion and stock were bound tightly together with grafting clips.

- ✓ Healing and acclimatization are very important operation, for serving maximum percentage of success. After grafting, the plants were placed in healing chamber for five to seven days at 90-95 per cent relative humidity, 25-30ºC temperature and darkness. Relative humidity was reduced for acclimatization.

- ✓ After healing, the plants were subjected to hardening for 3-4 days under shade net or poly house in shaded area. The clips were removed once the graft portion gets united. Watering was done by just wetting the tray by submerging with water (mixed with Chlorpyriphos 2ml/l and Copper oxychloride 2 g/l) as needed.

- ✓ Stock growth was removed periodically and by this time grafting union was completed and the scions were able to get water and nutrients through the rootstocks.

After healing and hardening only bitter gourd scions treated with different growth regulators were found successful with pumpkin as a rootstock and are subjected to further study. A total of ten plants were maintained in each treatment and replications. The successful graft combinations were planted under shade net for further evaluation under randomized completely block design (RCBD). The list of graft combinations further studied are furnished below.

Details of different treatments

Treatment	Treatment combination details
T_1	Bitter gourd scions are treated with GA_3 @ 25 ppm
T_2	Bitter gourd scions are treated with GA_3 @ 50 ppm
T_3	Bitter gourd scions are treated with IBA @ 25 ppm
T_4	Bitter gourd scions are treated with IBA @ 50 ppm
T_5	Bitter gourd scions are treated with cow urine @ 1.0 %
T_6	Bitter gourd scions are treated with cow urine @ 1.5 %
T_7	Bitter gourd scions are treated with cow urine @ 2.0 %
T_8	Bitter gourd scions are treated with coconut milk @ 10.0 %
T_9	Bitter gourd scions are treated with coconut milk @ 15.0 %
T_{10}	Bitter gourd scions are treated with coconut milk @ 20.0 %
T_{11}	Bitter gourd scions are treated with distilled water (control)

Scions were treated with 0.1 % carbendazim before they are grafted

3.5.2.4 Preparation of coconut milk

Coconut milk was extracted from the tender form of copra inside after siphoning out of coconut water, macerated by using mixer grinder and stored under refrigerated condition.

3.6 Observation recorded

The details of the observations recorded are furnished below.

3.6.1. Growth parameters

3.6.1.1 Days to first sprout and days to 50 per cent sprout

The number of days taken for first sprouting was observed and recorded from first day after grafting and days taken for 50 per cent sprouting was recorded when 50 per cent of the grafted plants sprouted under each treatment per replication was calculated out of total number of grafted plants.

3.6.1.2 Sprout length of the scion (cm)

The length of scion was measured using centimeter scale from the graft union to the tip of the scion at 10, 15, 20, 25, 30 and 40 days after grafting. Mean of five plants per treatment and replication wise length was calculated and expressed in centimeters.

3.6.1.3 Number of nodes per graft

The number of nodes produced in each plant was recorded above the graft union up to 60 days at 15 days interval starting from 15 days after grafting. Mean of the five plants per treatment and replication wise numbers was calculated.

3.6.1.4 Initial girth of graft union (mm)

The diameter of the plants at the graft union (stock) was recorded using vernier callipers at 10, 20 and 30 days after grafting. Mean girth of five plants per treatment and replication wise girth was calculated and expressed in terms of millimeter.

3.6.1.5 Final girth of graft union (mm)

The diameter of the plants at the graft union (stock) was recorded using vernier callipers at 60 and 90 days after grafting. Mean girth of five plants per treatment and replication wise girth was calculated and expressed in terms of millimeter.

3.6.1.6 Percentage of graft success (%)

Percentage of graft success was calculated by using formula

$$= \frac{\text{Number of grafts survived}}{\text{Total number of plants grafted}} \times 100$$

3.6.1.7 Days to first female flower appearance (days)

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

3.6.1.8 Node number to first female flower appearance

The node number where the production of first female flower was counted and expressed in number.

3.6.1.9 Average fruit weight (g)

Average fruit weight is obtained by taking mean of five fruits per treatment per replication and expressed in gram.

3.6.1.10 Fruit length (cm)

Fruit length is measured from stalk end to tip of the fruit and the mean of five fruits expressed in centimeter.

3.6.1.11 Fruit girth (mm)

Girth of the fruit was measured with the help of vernier calipers and the mean of five fruits was expressed in mili meter

3.6.1.12 Yield per vine (kg)

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

3.6.1.13 Yield per hectare (t)

From the per vine yield of fruits, yield per hectare was computed and recorded accordingly in tons.

3.6.2 Physiological parameters

3.6.2.1. Number of leaves per vine

The number of leaves per vine was recorded at 30, 45 and 60 days after grafting. Mean of the five plants per treatment and replication wise numbers was calculated.

3.6.2.2. Leaf area (cm^2)

Leaf area was measured at 30, 45 and 60 days after grafting with help of digital image scanning leaf area meter. Mean of five plants per treatment and replication wise numbers was calculated and expressed in centimeter square.

3.6.2.3. Photosynthetic rate ($\mu molCo_2m^{-2}s^{-1}$)

Photosynthetic rate was measured using Infra Red Gas Analyzer (IRGA). Mean of five plants per treatment and replication wise was calculated and expressed in $\mu molCo_2m^{-2}s^{-1}$.

3.6.2.4.Transpiration rate ($mmolH_2Om^{-2}s^{-1}$)

Transpiration rate was measured using Infra Red Gas Analyzer (IRGA). Mean of five plants per treatment and replication wise was calculated and expressed in $mmolH_2Om^{-2}s^{-1}$.

3.6.2.5. Stomatal conductance to water ($molH_2Om^{-2}s^{-1}$)

Stomatal conductance to water was measured using Infra Red Gas Analyzer (IRGA). Mean of five plants per treatment and replication wise was calculated and expressed in $molH_2Om^{-2}s^{-1}$.

3.6.3.1. Disease incidence

The symptoms for foliar infection of *Fusarium* and Bacterial wilt were observed and recorded as Per cent disease incidence and grade were given based on visual observation using following scale (Anon, 2004).

Scale	Symptoms (Range)
0	Nil
1	Initial signs of wilting (Yellowing)
2	Upto 25 %
3	More than 25-50 %
4	Upto 75 %
5	100 %

3.6.4.1. Statistical analysis

The experiment was conducted in a randomized completely block design (RCBD) and the mean values for each character were tabulated and subjected to analysis of variance (Panse and Sukhatame, 1974).

3.6.5. Economics

Economics of grafting of cucurbits calculated by considering fixed cost (land revenue and depreciation cost @ 10 %) and variable cost (cost of chemicals and growth hormones, grafting charges, scion and root stock material cost, labour charges, *etc.*) based on market prices that were prevailing at the time of conducting experiment (2018), and returns per rupee invested was calculated based on number of grafts survived, price per one grafted cucurbit plant and finally net profit. The details of economics furnished in appendix-III.

3.6.5.1 Depreciation cost

Depreciation cost was worked out by using the formula:

$$\text{Depreciation cost} = \frac{\text{Original value- Junk value}}{\text{Economic life}}$$

3.6.5.2 Gross income

Gross income was worked out by taking into account total number of grafts survived in each treatment and the prevailing selling price per grafted cucurbit fruits.

3.6.5.3 Net returns

Net returns for each treatment was calculated by using the formula

$$\text{Net returns} = \text{Gross income} - \text{total cost of production}$$

3.6.5.4 Returns per rupee invested (B: C Ratio)

A return per rupee invested was worked out by using the formula:

$$\text{Returns per rupee invested} = \frac{\text{Net returns}}{\text{Total cost of production}}$$

4. EXPERIMENTAL RESULTS

The results of the experiments carried out on the influence of growing environment and growth regulators on graft compatibility of cucurbits are described here under.

4.1 Experiment I: Effect of growing environment on graft compatibility and graft success in cucurbits

4.1.1 Days to first sprout and days to 50 per cent sprout

The data on days to first sprout and days to 50 per cent sprouting recorded in *Kharif* (2018-19) and *Rabi* (2019-20) were presented in Table 1.

4.1.1.1 Rootstock and scion effects

Significant differences were noticed among the rootstocks on number of days taken for first sprouting. Significant and minimum number of days for first sprouting was noticed in snake gourd (R_3) (3.17 days) as a rootstock followed by pumpkin (R_2) (4.33 days) as a rootstock. Whereas, significant and maximum number of days to first sprouting was observed in bottle gourd (R_1) (5.83 days) as a rootstock during *kharif* season (2018-19). Similarly in *rabi* season (2019-20) significant and least number of days to first sprouting was noted in snake gourd (R_3) (4.67 days) as a rootstock and maximum number of days to first sprouting in bottle gourd (R_1) (6.67 days) as a rootstock (Table 1).

The pooled data presented in table 1 revealed least number of days to first sprouting (3.92 days) when snake gourd (R_3) was used as a rootstock. Whereas, maximum number of days to first sprouting (6.25 days) was recorded in bottle gourd (R_1) as a rootstock.

Similar results were also observed for days taken to fifty per cent sprouting. Significant and minimum number of days to fifty per cent sprouting was noted in snake gourd (R_3) (4.17 & 6.50 days) followed by pumpkin (R_2) (6.50 & 8.00 days) and maximum number of days to fifty per cent sprouting (9.50 & 9.67 days) was observed when bottle gourd (R_1) was used as a rootstock during both *kharif* (2018-19) and *rabi* (2019-20) season (Table 1).

Table 1: Influence of cucurbitaceous rootstock and scion on days to first and 50 % sprout under protected environment (Shade net)

Treatment		Days to first sprout			Days to 50 % sprout		
		2018-19	2019-20	Mean	2018-19	2019-20	Mean
Rootstock	R_1	5.83 (2.42)	6.67 (2.58)	6.25 (2.50)	9.50 (3.08)	9.67 (3.11)	9.58 (3.10)
	R_2	4.33 (2.08)	5.50 (2.35)	4.92 (2.22)	6.50 (2.54)	8.00 (2.83)	7.25 (2.69)
	R_3	3.17 (1.78)	4.67 (2.16)	3.92 (1.98)	4.17 (2.04)	6.50 (2.55)	5.33 (2.31)
	SEm±	**0.17**	**0.21**	**0.11**	**0.42**	**0.27**	**0.24**
	CD at 5 %	**0.56**	**0.65**	**0.37**	**1.34**	**0.87**	**0.75**
Scion	S_1	4.77 (2.19)	5.89 (2.43)	5.33 (2.31)	6.11 (2.47)	7.67 (2.77)	6.89 (2.62)
	S_2	4.11 (2.03)	5.33 (2.31)	4.72 (2.17)	7.33 (2.71)	8.44 (2.91)	7.89 (2.81)
	SEm±	**0.14**	**0.16**	**0.09**	**0.34**	**0.22**	**0.20**
	CD at 5 %	**0.46**	**0.53**	**0.30**	**1.10**	**0.71**	**0.61**
Interactions	R_1S_1	6.67 (3.58)	7.33 (2.71)	7.00 (2.64)	9.67 (3.11)	9.67 (3.11)	9.67 (3.11)
	R_1S_2	5.00 (2.24)	6.00 (2.45)	5.50 (2.35)	9.33 (3.10)	9.67 (3.11)	9.50 (3.08)
	R_2S_1	4.33 (2.08)	5.33 (2.31)	4.83 (2.20)	4.33 (2.08)	6.67 (2.58)	5.50 (2.35)
	R_2S_2	4.33 (2.08)	5.67 (2.38)	5.00 (2.24)	8.67 (2.94)	9.33 (3.06)	9.00 (3.00)
	R_3S_1	3.33 (1.83)	5.00 (2.24)	4.17 (2.04)	4.33 (2.08)	6.67 (2.58)	5.50 (2.35)
	R_3S_2	3.00 (1.73)	4.33 (2.08)	3.67 (1.91)	4.00 (2.00)	6.33 (2.52)	5.17 (2.27)
	SEm±	**0.25**	**0.29**	**0.16**	**0.60**	**0.38**	**0.34**
	CD at 5 %	**0.79**	**0.92**	**0.52**	**1.90**	**1.23**	**1.07**
	CV (%)	**9.78**	**9.01**	**5.65**	**15.52**	**8.38**	**7.97**

*Figures in the parenthesis are square root transformation DAG- Days after grafting

* Rootstocks: R_1-Bottle gourd, R_2-Pumpkin, R_3- Snake gourd

Scions: S_1-Bitter gourd, S_2-Ridge gourd

Whereas, pooled data noted minimum number of days to fifty per cent sprouting in snake gourd (R_3) (5.33 days) as a rootstock and maximum number of days to fifty per cent sprouting in bottle gourd (R_1) (9.58 days) as a rootstock (Table 1).

The results also revealed significant differences among the scions for days taken to first sprouting. In *kharif* season (2018-19) significant and least number days to first sprouting was observed when ridge gourd (S_2) (4.11 days) was used as a scion whereas, maximum number of days to first sprouting was noted in bitter gourd (S_1) (4.77 days) as a scion (Table 1).

Similarly in 2019-20 (*Rabi*), significant and least number of days to first sprouting was observed in ridge gourd (S_2) (5.33) as a scion and maximum number of days to first sprouting was noticed in bitter gourd (S_1) (5.89) as a scion (Table 1).

The pooled data recorded the least number of days to first sprouting (4.72 days) in ridge gourd (S_2) as a scion and maximum number of days to first sprouting (5.33 days) in bitter gourd (S_1) as a scion.

Similar results were also observed for days to fifty per cent sprouting among different scions tried. Bitter gourd (S_1) scion showed minimum number of days to fifty per cent sprouting (6.11, 7.67 & 6.89 days) compared to ridge gourd (S_2) as a scion during *kharif* (2018-19), *rabi* (2019-20) and mean respectively (Table 1).

4.1.1.2 Rootstock and scion interaction effects

The interaction effects of different rootstock and scion was also found to be significant during both *kharif* (2018-19) and *rabi* (2019-2020) season.

In 2018-19 (*Kharif*), significant and least number of days to first sprouting (3.00 days) was recorded in ridge gourd scions grafted on snake gourd rootstock using wedge grafting method (R_3S_2) and it was at par with bitter gourd scions grafted on snake gourd (R_3S_1) (3.33 days) as a rootstock. Whereas, maximum number of days to first sprouting (6.67 days) was observed in bitter gourd grafted on bottle gourd (R_1S_1) as rootstock. Similar trend was also observed in the *rabi* season (2019-20). Significant and least number of days to first sprouting was observed in ridge gourd scions grafted on snake gourd (R_3S_2) (4.33 days) as a rootstock and it was at par with bitter gourd scions grafted on snake gourd (R_3S_1) (5.00) as a rootstock. Whereas, maximum number of days to first sprouting was noted in bitter gourd scions grafted on bottle gourd (R_1S_1) (7.33 days) as a rootstock using wedge grafting method (Table 1).

The pooled data recorded minimum number of days to first sprouting (3.67 days) in ridge gourd scions grafted on snake gourd (R_3S_2) and maximum number of days to first sprouting in bitter gourd scions grafted on bottle gourd (R_1S_1) (7.00 days) rootstock using wedge grafting method (Table 1).

Similar trend was also observed for days to fifty per cent sprouting. Significant and least number of days to fifty per cent sprouting was noted in ridge gourd scions grafted on snake gourd (R_3S_2) (4.00 & 6.33 days) as a rootstock which was at par with bitter gourd scions grafted on snake gourd and pumpkin (R_3S_1 & R_2S_1) (4.33 & 6.67 days) rootstock. Whereas, maximum number of days to fifty per cent sprouting was found in bitter gourd scions grafted on bottle gourd (R_1S_1) (9.67 days) rootstock during both *kharif* (2018-19) and *rabi* (2019-20) season (Table 1).

Pooled data recorded significant and least number of days to fifty per cent sprouting in ridge gourd scions grafted on snake gourd (R_3S_2) (5.17 days) which was similar with bitter gourd scions grafted on both snake gourd and pumpkin (R_3S_1 & R_2S_1) (5.50 days) rootstock and maximum number of days to fifty per cent sprouting was noted in bitter gourd scions grafted on bottle gourd (R_1S_1) (9.67 days).

4.1.2 Sprout length of the scion (cm)

The data on sprout length of scion was recorded at 10, 15, 20, 25, 30 and 40 days after grafting (DAG). Sudden wilting of grafted plants was observed in field transplanted plants 20 days after grafting (DAG) and the data recorded upto 20 days was mentioned in Table 2. Further the experiment was continued to assess the performance of grafted plants under protected condition (Shade net).

Table 2: Influence of cucurbitaceous rootstock and scion on scion length, girth of graft union and number of nodes per graft at 20 days after grafting (DAG)

Treatment	Length of the scion (cm)			Initial girth of graft union (mm)		Number of nodes per graft
	10 DAG	15 DAG	20 DAG	10 DAG	20 DAG	15 DAG
R_1	16.22	20.73	15.90	4.83	4.22	1.95
R_2	16.18	20.53	16.52	5.53	5.08	2.28
R_3	20.23	24.21	19.89	5.28	4.62	3.23
SEm±	0.89	1.35	1.15	0.05	0.08	0.34
CD at 5 %	2.80	NS	NS	0.17	0.25	NS
S_1	18.52	21.60	18.12	5.01	4.33	2.48
S_2	16.56	22.03	16.75	5.42	4.95	2.48
SEm±	0.73	1.10	0.94	0.04	0.06	0.28
CD at 5 %	NS	NS	NS	0.14	0.20	NS
$R_1 S_1$	15.49	20.55	16.45	4.62	3.92	1.89
$R_1 S_2$	16.95	20.90	15.34	5.04	4.52	2.00
$R_2 S_1$	20.94	20.91	18.45	5.47	5.03	3.22
$R_2 S_2$	11.41	20.14	14.58	5.58	5.12	1.34
$R_3 S_1$	19.14	23.35	19.45	4.93	4.03	2.34
$R_3 S_2$	21.32	25.06	20.34	5.63	5.20	4.11
SEm±	1.26	1.1	1.62	0.07	0.11	0.48
CD at 5 %	3.96	NS	NS	0.24	0.35	1.51
CV (%)	12.41	15.12	16.10	2.49	4.13	33.31

R_1S_1- Bitter gourd scions grafted on bottle gourd rootstock
R_1S_2- Ridge gourd scions grafted on bottle gourd rootstocks
R_2S_1-Bitter gourd scions grafted on pumpkin rootstock
R_2S_2- Ridge gourd scions grafted on pumpkin rootstocks
R_3S_1-Bitter gourd scions grafted on snake gourd rootstock
R_3S_2- Ridge gourd scions grafted on snake gourd rootstocks

DAG- Days after grafting
NS- Non significant

Table 3: Sprout length/vine length of scion as influenced by cucurbitaceous rootstock and scion under protected environment (Shade net)

Treatment		10 DAG			15 DAG			20 DAG			25 DAG			30 DAG			40 DAG		
		2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
Rootstock	R_1	16.97	20.75	18.86	19.90	26.15	23.03	33.63	35.05	34.34	69.40	53.08	61.24	119.10	71.63	95.36	207.11	190.69	198.90
	R_2	17.57	19.33	18.45	22.20	28.26	25.23	41.12	43.42	42.26	80.49	67.86	74.17	147.90	93.76	120.83	227.62	221.63	224.63
	R_3	21.24	19.62	20.43	31.95	30.91	31.43	48.91	43.63	46.27	95.08	68.32	81.70	154.82	90.22	122.52	250.26	246.95	248.60
	SEm±	**1.16**	**1.12**	**0.65**	**1.03**	**0.94**	**0.78**	**1.42**	**1.46**	**1.01**	**2.04**	**2.06**	**1.17**	**1.63**	**2.32**	**1.34**	**2.36**	**2.53**	**1.71**
	CD at 5 %	**NS**	**NS**	**NS**	**3.26**	**2.98**	**2.45**	**4.48**	**4.63**	**3.18**	**6.44**	**6.48**	**3.68**	**5.15**	**7.31**	**4.23**	**7.43**	**7.99**	**5.39**
Scion	S_1	17.81	19.95	18.88	22.45	25.35	23.90	36.50	37.96	37.23	74.27	52.33	63.30	135.46	80.33	107.89	221.08	203.98	212.53
	S_2	19.38	19.85	19.61	26.91	31.53	29.23	45.95	43.44	44.69	89.03	73.83	81.43	145.76	90.07	117.91	235.58	235.54	235.56
	SEm±	**0.95**	**0.91**	**0.53**	**0.84**	**0.77**	**0.63**	**1.16**	**1.20**	**0.82**	**1.67**	**1.68**	**0.95**	**1.33**	**1.90**	**1.10**	**1.92**	**2.07**	**1.40**
	CD at 5 %	**NS**	**NS**	**NS**	**2.66**	**2.43**	**1.99**	**3.66**	**3.78**	**2.60**	**5.25**	**6.48**	**3.01**	**4.21**	**5.97**	**3.45**	**6.06**	**6.52**	**4.04**
Interaction	R_1S_1	15.26	21.20	18.23	19.33	24.78	22.06	33.38	32.28	32.83	70.37	50.15	60.26	124.12	74.40	99.26	206.50	189.44	197.97
	R_1S_2	18.67	20.30	19.49	20.46	27.52	23.99	33.98	37.82	35.85	68.42	56.01	62.22	114.08	68.85	91.47	207.73	191.94	199.83
	R_2S_1	19.31	19.40	19.35	21.60	25.56	23.58	41.69	45.07	43.38	76.58	53.88	65.23	142.17	89.56	115.87	229.87	194.77	212.32
	R_2S_2	15.84	19.27	17.55	22.79	30.97	26.88	40.54	41.77	41.16	84.39	81.83	83.11	153.63	97.95	125.79	225.37	248.50	236.94
	R_3S_1	18.88	19.27	19.07	26.42	25.71	26.07	34.42	36.52	35.47	75.86	52.97	64.42	140.08	77.02	108.55	226.87	227.72	227.30
	R_3S_2	23.61	19.27	21.79	37.49	36.11	36.80	63.40	50.74	57.07	114.29	83.66	98.98	169.56	103.42	136.49	273.65	266.17	269.91
	SEm±	**1.65**	**1.58**	**0.92**	**1.45**	**1.33**	**1.05**	**2.01**	**2.08**	**1.43**	**2.89**	**2.91**	**1.65**	**2.31**	**3.28**	**1.90**	**6.39**	**4.05**	**2.42**
	CD at 5 %	**NS**	**NS**	**NS**	**4.61**	**4.21**	**3.46**	**6.34**	**6.55**	**4.50**	**9.10**	**9.17**	**5.21**	**7.29**	**10.34**	**5.98**	**10.50**	**11.29**	**7.63**
	CV (%)	**15.37**	**13.83**	**8.32**	**10.27**	**8.13**	**6.89**	**8.46**	**8.84**	**6.04**	**6.13**	**7.99**	**3.96**	**2.85**	**6.67**	**2.91**	**2.53**	**2.83**	**1.87**

* Rootstocks : R_1-Bottle gourd, R_2-Pumpkin, R_3- Snake gourd

Scion(S) : S_1-Bitter gourd, S_2-Ridge gourd

DAG- Days after grafting

NS- Non significant

Sprout length of scion under shade net condition recorded at 10 days after grafting was found to be non significant whereas at 15, 20, 25, 30 and 40 days after grafting it was significantly affected by different treatment combinations (Table 3).

15 Days after grafting

4.1.2.1 Rootstock and scion effects

Significant and maximum length of vine (31.95 cm) was observed in snake gourd (R_3) as a rootstock followed by pumpkin (R_2) (22.20 cm) as a rootstock and lowest length of vine (19.90 cm) was noted in bottle gourd (R_1) as a rootstock during *kharif* season (2018-19). Similarly in *rabi* season (2019-20), maximum vine length was found when snake gourd (R_3) (30.91 cm) was used as a rootstock and it was similar with pumpkin (R_2) (28.26 cm) as a rootstock. Whereas, pooled data showed maximum vine length (31.43 cm) in snake gourd (R_3) as a rootstock and lowest vine length (23.03 cm) in bottle gourd (R_1) as a rootstock (Table 3).

Significant differences among the scions was noticed for vine length and it was maximum in ridge gourd scions (S_2) (26.91 & 31.53 cm) and minimum in bitter gourd scions (22.45 & 25.35 cm) (S_1) during both the crop seasons (2018-19 & 2019-20). Mean of two cropping seasons revealed maximum vine length (29.23 cm) in ridge gourd (S_2) as a scion compared to bitter gourd (S_1) (23.90 cm) as a scion (Table 3).

4.1.2.2 Rootstock and scion interaction effects

Significant differences among different graft combinations were observed for sprout length of the vine during both the crop seasons (2018-19 & 2019-20).

In 2018-19 (*Kharif*), among different graft combinations ridge gourd scions grafted on snake gourd rootstock (R_3S_2) recorded maximum vine length (37.49 cm) whereas minimum vine length (19.33 cm) was noticed in bitter gourd scions grafted on bottle gourd rootstock (R_1S_1). Meanwhile, in 2019-20 (*Rabi*), maximum vine length was found in ridge gourd scions grafted on snake gourd (R_3S_2) (36.11 cm) and minimum vine length in bitter gourd scions grafted on bottle gourd (R_1S_1) (24.78 cm) rootstock.

Mean of two seasons revealed maximum vine length (36.80 cm) in ridge gourd scions grafted on snake gourd (R_3S_2) followed by ridge gourd scions grafted on pumpkin (R_2S_2) (26.88) rootstock. Whereas minimum length of vine (22.06 cm) was noticed in bitter gourd scions grafted with bottle gourd (R_1S_1) as a rootstock (Table 3).

20 Days after grafting

4.1.2.3 Rootstock and scion effects

Vine length at 20 days after grafting (DAG) presented in table 3 revealed that, significant and maximum length of vine was noticed when snake gourd was used as a rootstock (R_3) (48.91 cm) whereas bottle gourd as a rootstock (R_1) recorded minimum vine length (33.63 cm). However, significant differences were also noticed among the two different scions. Significant and maximum vine length of the scion was recorded in ridge gourd (S_2) (45.95 cm) as a scion whereas, minimum vine length was observed in bitter gourd (S_1) (36.50 cm) as a scion during *kharif* season (2018-19).

Similarly, in *rabi* season (2019-20), maximum vine length was noted in snake gourd as a rootstock (R_3) (43.63 cm) and it was at par with pumpkin as a rootstock (R_2) (43.44 cm). Whereas, significant and minimum length of vine was recorded in bottle gourd (R_1) (35.05 cm) as a rootstock. Significant differences were also observed among the two scions and maximum vine length was observed in ridge gourd (S_2) (43.44 cm) and minimum vine length in bitter gourd (S_1) (37.96 cm) as a scion (Table 3).

Pooled data indicated maximum vine length in snake gourd as a rootstock (R_3) (46.27 cm) followed by pumpkin as a rootstock (R_2) (42.26 cm) whereas lowest length of vine was noticed in bottle gourd as a rootstock (R_1) (34.34 cm). Among the scions ridge gourd (S_2) recorded maximum vine length (44.69 cm) and minimum vine length by bitter gourd (S_1) (37.23 cm) as a scion (Table 3).

4.1.2.4 Rootstock and scion interaction effects

Interaction effects between different rootstocks and scions were also found to be significant. Among the different graft combinations, maximum vine length was recorded by ridge gourd scions grafted on snake gourd (R_3S_2) (63.40 cm & 50.74 cm) followed by bitter gourd scions grafted on pumpkin (R_2S_1) (41.69 & 45.07 cm) rootstock using wedge grafting method in both *kharif (*2018-19) and *rabi (*2019-20) season (Table 3).

Pooled data recorded maximum vine length (57.07 cm) in ridge gourd scions grafted on snake gourd rootstock (R_3S_2) followed by bitter gourd scions grafted on pumpkin rootstock (R_2S_1) (43.38 cm) and minimum vine length was noticed in bitter gourd scions grafted on bottle gourd (R_1S_1) (32.83 cm) as a rootstock.

25 Days after grafting

4.1.2.5 Rootstock and scion effects

Similarly, at 25 days after grafting (DAG) the vine length of scion was found to be significant and maximum vine length was observed in snake gourd as a rootstock (R_3) (95.08 cm) followed by pumpkin (R_2) (80.49 cm) as a rootstock and among two scions tried ridge gourd (S_2) recorded maximum vine length (89.03 cm). Whereas, minimum vine length was noted in bottle gourd as a rootstock and bitter gourd as a scion (R_1 & S_1) (69.40 & 74.27 cm) during *kharif* season (2018-19).

During *rabi* season (2019-20*)*, maximum vine length was observed in snake gourd as a rootstock (R_3) (68.32 cm) which was at par with pumpkin (R_2) (67.86 cm) as a rootstock and lowest vine length in bottle gourd (R_1) (53.08 cm) as a rootstock. Similarly, among two scions used ridge gourd (S_2) recorded maximum vine length (73.83 cm) and bitter gourd (S_1) scions recorded minimum vine length (52.33 cm) (Table 3).

Observation on pooled data revealed maximum vine length in snake gourd (R_3) (81.70 cm) and minimum in bottle gourd (R_1) (61.24 cm) as a rootstock. Among scions ridge gourd (S_2) recorded maximum vine length (81.43 cm) and minimum vine length was recorded in bitter gourd (S_1) (63.30 cm) as a scion (Table 3).

4.1.2.6 Rootstock and scion interaction effects

In 2018-19 (*Kharif*), significant and maximum vine length was noticed in ridge gourd scions grafted on snake gourd (R_3S_2) (114.29 cm) rootstock followed by ridge gourd scions grafted on pumpkin (R_2S_2) (84.39 cm) as a rootstock while bitter gourd recorded maximum vine length when grafted on pumpkin as a rootstock (R_2S_1) (76.58 cm) using wedge grafting method. Whereas, minimum vine length was observed in both ridge gourd and bitter gourd scions when bottle gourd (R_1S_2 & R_1S_1) (68.42 & 70.37 cm) was used as a rootstock (Table 3).

Similarly, in 2019-20 (*Rabi*), maximum vine length was recorded in ridge gourd scions grafted on snake gourd (R_3S_2) (83.66 cm) rootstock and lowest vine length in both bitter gourd and ridge gourd scions grafted on bottle gourd (R_1S_1 & R_1S_2) (50.15 & 56.01 cm) as a rootstock. However, pooled data showed maximum vine length in ridge gourd scions grafted on snake gourd (R_3S_2) (98.98 cm) rootstock and lowest vine length in bitter gourd scions grafted on bottle gourd (R_1S_1) (60.26 cm) as a rootstock (Table 3).

30 Days after grafting

4.1.2.7 Rootstock and scion effects

A glance of results on vine length of scion recorded at 30 days after grafting (DAG) indicated that, maximum vine length was observed in snake gourd (R_3) (154.82 cm) as a rootstock followed by pumpkin (R_2) (147.90 cm) as a rootstock and lowest vine length was noticed in bottle gourd (R_1) (119.10 cm) as a rootstock. Among scions ridge gourd (S_1) recorded maximum vine length (145.76 cm) and minimum vine length (135.46 cm) was recorded by bitter gourd (S_1) as a scion during *kharif* season (2018-19) (Table 3).

During *rabi* season (2019-20), pumpkin (R_2) recorded maximum vine length (93.76 cm) and it was at par with snake gourd (R_3) (90.22 cm) whereas minimum vine length (71.63 cm) was noticed in bottle gourd (R_1) as a rootstock. Among two scions used, ridge gourd (S_2) recorded longest vine length (90.07 cm) as compared to bitter gourd as a scion (S_1) (80.33 cm) (Table 3).

However**,** pooled mean revealed that snake gourd rootstock (R_3) had maximum vine length (122.52 cm) which was at par with pumpkin (R_2) (120.83 cm) as a rootstock and minimum vine length (95.36 cm) was observed in bottle gourd (R_1) as a rootstock. As concerned to scions, ridge gourd (S_2) recorded longest vine length (117.91 cm) and shortest vine length (107.88 cm) was recorded by bitter gourd (S_1) as a scion (Table 3).

4.1.2.8 Rootstock and scion interaction effects

Among interaction effects, ridge gourd grafted on snake gourd (R_3S_2) recorded maximum vine length (169.56 cm) followed by ridge gourd grafted on pumpkin (R_2S_2) (153.63 cm) and bitter gourd scions grafted on pumpkin (R_2S_1) (142.17 cm) rootstock. Whereas, lowest vine length (114.08 cm) was noted in ridge gourd scions grafted on bottle gourd rootstock (R_1S_2) followed by bitter gourd scion grafted on bottle gourd (R_1S_1) (124.12 cm) as a rootstock during *kharif* season (2018-19) (Table 3).

Similar trend was also observed during *rabi* season (2019-20). Ridge gourd scions grafted on snake gourd rootstock (R_3S_2) recorded maximum vine length (103.42 cm) followed by ridge gourd scions grafted on pumpkin rootstock (R_2S_2) (97.95 cm) and lowest vine length (68.85 cm) in ridge gourd scions grafted on bottle gourd (R_1S_2) as a rootstock using wedge grafting method (Table 3).

The results of pooled data showed maximum vine length in ridge gourd scions grafted on snake gourd rootstock (R_3S_2) (136.49 cm) followed by ridge gourd and bitter gourd scions grafted on pumpkin rootstock (R_2S_2 & R_2S_1) (125.79 & 115.86 cm) and minimum vine length (91.47 & 99.26 cm) in both ridge gourd and bitter gourd scions grafted on bottle gourd (R_1S_2 & R_1S_1) rootstock (Table 3).

40 Days after grafting

4.1.2.9 Rootstock and scion effects

Vine length at 40 days after grafting (DAG) was significant and maximum in snake gourd (R_3) (250.26 cm) as a rootstock followed by pumpkin (R_2) (227.62 cm) and it was found to be lowest (207.11 cm) in bottle gourd (R_1) as a rootstock. Among two scions tried, ridge gourd (S_2) recorded maximum vine length (235.58 cm) compared to bitter gourd (S_1) (221.08 cm) as a scion during *kharif* season (2018-19) (Table 3).

Vine length at 40 days after grafting (DAG) was also found to be maximum during *rabi* season (2019-20) in snake gourd (R_3) (246.95 cm) followed by pumpkin (R_2) (221.63 cm) and lowest vine length (190.69 cm) was noted when bottle gourd (R_1)

was used as a rootstock. Similarly among two scions used, ridge gourd (S_2) recorded maximum vine length (235.54 cm) compared to bitter gourd (S_1) (203.98 cm) as a scion.

The combined data of two years presented in table 3 recorded maximum vine length (248.60 cm) in snake gourd (R_3) followed by pumpkin (R_2) (224.63 cm) and lowest vine length (198.90 cm) in bottle gourd (R_1) as a rootstock. Among two scions tried, ridge gourd (S_2) recorded longest vine length (235.56 cm) as compared to bitter gourd as a scion (S_1).

4.1.2.10 Rootstock and scion interaction effects

Ridge gourd scions grafted on snake gourd (R_3S_2) noted maximum vine length (273.65 cm) followed by bitter gourd scions grafted on pumpkin (R_2S_1) (229.87 cm) and lowest vine length (206.50 & 207.73 cm) in both bitter gourd and ridge gourd scions grafted on bottle gourd (R_1S_1 & R_1S_2) rootstock during *kharif* season (2018-19).

Similarly in 2019-20 (*Rabi*), ridge gourd scions grafted on snake gourd (R_3S_2) recorded maximum vine length (266.17 cm) followed by ridge gourd scions grafted on pumpkin (R_2S_2) (248.50 cm) and lowest vine length was observed in bitter gourd scions grafted on bottle gourd (R_1S_1) (189.44 cm) rootstock using wedge grafting method.

The results of pooled data showed maximum vine length (269.91 cm) in ridge gourd scions grafted on snake gourd (R_3S_2) followed by ridge gourd scions grafted on pumpkin rootstock (R_2S_2) (236.94 cm) and lowest vine length was (197.97 & 199.83 cm) observed in both bitter gourd and ridge gourd scions grafted on bottle gourd (R_1S_1 & R_1S_2) rootstock using wedge grafting method (Table 3).

4.1.3 Number of nodes per graft

Number of nodes per graft is considered as an important yield attributing trait. The data on number of nodes per graft was recorded at 15, 30, 45 and 60 days after grafting. At 15 days after grafting (DAG) number of nodes per graft per vine was found to be non significant and at 30, 45 and 60 days after grafting significant differences among different treatment combinations was found during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20) (Table 4).

Table 4: Number of nodes per graft as influenced by cucurbitaceous rootstock and scion under protected environment (Shade net)

Treatment		Number of nodes per graft											
		15 DAG			30 DAG			45 DAG			60 DAG		
		2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
Roots tock	R_1	2.72	5.56	4.14	12.23	9.50	10.86	39.39	36.95	38.25	81.84	80.04	80.94
	R_2	2.26	4.83	3.64	13.54	13.12	13.33	45.98	41.34	43.88	90.90	95.14	93.02
	R_3	3.28	5.32	4.29	13.11	12.28	12.70	46.20	41.39	43.90	92.73	96.99	94.85
	SEm±	**0.31**	**0.18**	**0.16**	**0.25**	**0.57**	**0.32**	**0.41**	**0.79**	**0.49**	**1.03**	**1.09**	**1.25**
	CD at 5 %	**NS**	**NS**	**NS**	**0.79**	**1.79**	**1.03**	**1.29**	**2.52**	**1.56**	**3.23**	**3.45**	**2.61**
Scion	S_1	2.73	5.37	4.05	15.15	13.37	14.26	52.87	50.63	51.86	126.78	126.46	126.62
	S_2	2.78	5.10	4.00	10.77	9.89	10.32	34.84	29.15	32.16	50.19	54.98	52.58
	SEm±	**0.26**	**0.14**	**0.13**	**0.20**	**0.47**	**0.27**	**0.34**	**0.65**	**0.40**	**0.84**	**0.89**	**1.02**
	CD at 5 %	**NS**	**NS**	**NS**	**0.64**	**1.46**	**0.84**	**1.06**	**2.06**	**1.27**	**2.64**	**2.81**	**2.13**
Inter actio n	R_1S_1	3.11	5.56	4.34	13.67	10.89	12.28	51.22	47.11	49.34	124.45	120.40	122.43
	R_1S_2	2.34	5.56	3.95	10.78	8.99	9.45	27.56	26.78	27.17	39.23	39.67	39.45
	R_2S_1	2.40	5.00	3.73	16.89	16.56	16.73	54.33	54.11	54.31	130.45	130.13	130.29
	R_2S_2	2.11	4.67	3.56	10.18	9.67	9.93	37.63	28.67	33.48	51.34	60.15	55.75
	R_3S_1	2.67	5.56	4.08	14.89	12.67	13.78	53.07	50.67	51.92	125.45	128.85	127.15
	R_3S_2	3.89	5.08	4.49	11.34	11.89	11.62	39.33	32.00	35.84	60.00	65.12	62.56
	SEm±	**0.45**	**0.26**	**0.23**	**0.35**	**0.83**	**0.46**	**0.58**	**1.13**	**0.70**	**1.45**	**1.55**	**1.77**
	CD at 5 %	**NS**	**NS**	**NS**	**1.11**	**2.53**	**1.46**	**1.83**	**3.56**	**2.21**	**4.57**	**4.88**	**3.69**
	CV (%)	**8.16**	**8.53**	**10.22**	**4.71**	**11.97**	**6.53**	**2.29**	**4.91**	**2.86**	**2.81**	**2.96**	**2.26**

* Rootstocks : R_1-Bottle gourd, R_2-Pumpkin, R_3- Snake gourd; Scions: S_1-Bitter gourd S_2-Ridge gourd DAG- Days after grafting NS- Non significant

30 Days after grafting

4.1.3.1 Rootstock and scion effects

Significant and maximum number of nodes per graft per vine was noticed when pumpkin (R_2) (13.54, 13.12 & 13.33) was used as a rootstock and it was at par with snake gourd (R_3) (13.11, 12.28 & 12.70) as a rootstock. Whereas, minimum number of nodes per graft per vine (12.23, 9.50 & 10.86) was observed when bottle gourd (R_1) was used as a rootstock during *kharif* (2018-19), *rabi* (2019-20) and in pooled data respectively (Table 4).

Among scions bitter gourd recorded maximum number of nodes per graft per vine (15.15, 13.37 & 14.26) as compared to ridge gourd (S_2) as a scion in both the crop seasons (2018-19, 2019-20) and pooled mean respectively (Table 4).

4.1.3.2 Rootstock and scion interaction effects

The interaction effects was found to be significant and maximum number nodes per graft per vine (16.89) was noted in bitter gourd scions grafted on pumpkin (R_2S_1) rootstock followed by bitter gourd scions grafted on snake gourd (R_3S_1) (14.89) rootstock. Ridge gourd recorded maximum number of nodes per graft per vine when it was grafted on snake gourd (R_3S_2) (11.34) rootstock during *kharif* season (2018-19). Whereas, both bitter gourd and ridge gourd recorded lowest number of nodes per graft per vine when grafted on bottle gourd and pumpkin (R_1S_1 & R_2S_2) (13.67 & 10.17) rootstock using wedge grafting method (Table 4).

Similar trend was also observed for number of nodes per graft per vine during *rabi* season (2019-20). Significant and maximum number of nodes per graft per vine was noted in bitter gourd scions grafted on pumpkin and snake gourd rootstock (R_2S_1 & R_3S_1) (16.56 & 12.67). Whereas, ridge gourd recorded maximum number of nodes per graft per vine when it was grafted on snake gourd (R_3S_2) (11.89) rootstock (Table 4).

Mean of two year data revealed the maximum number of nodes per graft per vine in bitter gourd scions grafted on pumpkin and snake gourd (R_2S_1 & R_3S_1) (16.73 & 13.78) rootstock. Whereas, ridge gourd recorded maximum number of nodes when snake gourd and pumpkin (R_3S_2 & R_2S_2) (11.62 & 9.93) were used as rootstock.

45 Days after grafting

4.1.3.3 Rootstock and scion effects

Number of nodes per graft per vine at 45 days after grafting (DAG) was also found to be significant and maximum in snake gourd (R_3) (46.20, 41.39, 43.90) as a rootstock which was similar with pumpkin (R_2) (41.39, 41.34 & 43.88) as a rootstock and least number of nodes per graft per vine was noticed in bottle gourd (R_1) (39.39, 36.95 & 38.25) as a rootstock during both crop seasons (2018-19, 2019-20) and pooled data respectively (Table 4).

Among two different scions tried, bitter gourd (S_1) recorded maximum number of nodes per graft per vine (52.87, 50.63 & 51.86) and least number of nodes per graft per vine was noted in ridge gourd (S_2) as a scion during both the crop seasons (2018-19, 2019-20) and mean respectively (Table 4).

4.1.3.4 Rootstock and scion interaction effects

During 2018-19 (*Kharif*), significant and maximum number of nodes per graft per vine (54.33) was noted in bitter gourd scions grafted on pumpkin (R_2S_1) rootstock which was similar with bitter gourd scions grafted on snake gourd (R_3S_1) (53.07) rootstock. Whereas ridge gourd recorded maximum number of nodes per graft per vine when it was grafted on snake gourd and pumpkin (R_3S_2 & R_2S_2) (39.33 & 37.63) rootstock and lowest number of nodes per graft per vine was observed in both bitter gourd and ridge gourd scions grafted on bottle gourd (R_1S_1 & R_1S_2) rootstock.

The results were consistent during second year (2019-20) experimentation also (*Rabi*). Significant and maximum number of nodes per graft per vine was observed in bitter gourd scions grafted on pumpkin and snake gourd rootstock (R_2S_1 & R_3S_1) (54.11 & 50.67). Whereas, ridge gourd recorded maximum number of nodes per graft per vine when it was grafted on snake gourd and pumpkin rootstock (R_3S_2 & R_2S_2) (32.00 & 28.67) while least number of nodes per graft per vine was noted by bitter gourd and ridge gourd scions grafted on bottle gourd rootstock (R_1S_1 & R_1S_2) (47.11 & 26.78).

Pooled data presented in table 4 indicated maximum number of nodes per graft per vine in bitter gourd scions grafted on pumpkin (R_2S_1) (54.31) followed by bitter gourd scions grafted on snake gourd (R_3S_1) (51.92) rootstock. Ridge gourd grafted on snake gourd rootstock recorded maximum number of nodes per graft per vine (R_3S_2) (35.84) which was at par with ridge gourd grafted on pumpkin (R_2S_2) (33.48) rootstock. Both bitter gourd and ridge gourd recorded lowest number of nodes per graft per vine when grafted using bottle gourd (R_1S_1 & R_1S_2) (49.34 & 27.17) as a rootstock (Table 4).

60 DAG

4.1.3.5 Rootstock and scion effects

Rootstock and scion effects indicated significant and maximum number of nodes per graft per vine when snake gourd (R_3) (92.73 & 96.99) was used as a rootstock which was at par with pumpkin (R_2) (90.90 & 95.14) as a rootstock and least number of nodes per graft per vine in bottle gourd (R_1) (81.84 & 80.04) as a rootstock. Among two scions used, bitter gourd recorded maximum number of nodes per graft per vine (S_1) (126.78 & 126.46) as compared to ridge gourd (S_2) (50.19 & 54.98) as a scion during both *kharif* (2018-19) and *rabi* (2019-20) season (Table 4).

Pooled data showed maximum number of nodes per graft per vine in snake gourd (R_3) (94.85) and it was similar with pumpkin (R_2) (93.02) as a rootstock and least number of nodes per graft per vine was noticed in bottle gourd (R_1) (80.94) as a rootstock. Among two different scions, bitter gourd (S_1) (126.62) recorded maximum number of nodes as compared to ridge gourd (S_2) (52.58) as a scion (Table 4).

4.1.3.6 Rootstock and scion interaction effects

Significant and maximum number of nodes per graft per vine was noticed in bitter gourd scions grafted on pumpkin (R_2S_1) (130.45, 130.13 & 130.29) which was at par with bitter gourd scions grafted on snake gourd (R_3S_1) (125.45, 128.85 & 127.15) rootstock. With respect to ridge gourd maximum number of nodes per graft per vine was observed when it was grafted on snake gourd and pumpkin (R_3S_2 & R_2S_2) rootstock during both the crop seasons (2018-19, 2019-20) and pooled mean respectively.

Whereas, least number of nodes per graft per vine was observed in both bitter gourd and ridge gourd scions grafted on bottle gourd (R_1S_1 & R_1S_2) (124.45, 120.40, 122.43 & 39.23, 39.67, 39.45) rootstock using wedge grafting method during both the crop seasons (2018-19 & 2019-20) and mean respectively (Table 4).

4.1.4 Initial girth of graft union (mm)

The data pertaining to initial girth of graft union recorded at 10, 20 and 30 days after grafting (DAG) was presented in table 5 and it was found to be non significant during both *kharif* (2018-19) and *rabi* (2019-20) season.

4.1.5 Final girth of graft union (mm)

The data on final girth of graft union recorded at 60 and 90 days after grafting (DAG) was found to be significant and illustrated in Table 5.

60 Days after grafting

4.1.5.1 Rootstock and scion effects

Significant and maximum girth of graft union (14.96, 14.78 & 14.87 mm) was recorded with snake gourd (R_3) as a rootstock followed by pumpkin (R_2) (12.91, 13.31 & 13,11 mm) and minimum girth of graft union (10.92, 12.17 & 11.55 mm) was noted by bottle gourd (R_1) as a rootstock during *kharif* (2018-19), *rabi* (2019-20) and pooled mean respectively (Table 5).

Among the scions, bitter gourd (S_1) recorded maximum girth of graft union (13.60, 14.33 & 13.96 mm) and lowest girth of graft union was recorded in ridge gourd as a scion (S_2) (12.26, 12.51 & 12.38) during both crop seasons (2018-19, 2019-20) and pooled mean respectively (Table 5).

4.1.5.2 Rootstock and scion interaction effects

Interaction effects between different rootstocks and scions were found to be significant. Bitter gourd scions grafted on snake gourd recorded maximum girth of graft union (R_3S_1) (16.39, 16.33 & 16.36 mm) followed by bitter gourd scions grafted on

Table 5: Initial and final girth of graft union as influenced by cucurbitaceous rootstock and scion under protected environment (Shade net)

Treatment		Initial and final girth of graft union (mm)														
		10 DAG			20 DAG			30 DAG			60 DAG			90 DAG		
		2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
Root stock	R_1	4.51	4.99	4.75	4.94	5.18	5.06	5.18	6.16	5.67	10.92	12.17	11.55	12.79	13.41	13.10
	R_2	5.04	5.20	5.02	5.13	5.44	5.37	5.78	6.44	6.11	12.91	13.31	13.11	14.96	15.46	15.21
	R_3	4.81	5.34	5.07	5.34	5.53	5.44	5.53	6.67	6.10	14.96	14.78	14.87	18.13	18.31	18.21
	SEm±	**0.17**	**0.13**	**0.10**	**0.16**	**0.11**	**0.09**	**0.15**	**0.14**	**0.14**	**0.33**	**0.28**	**0.21**	**0.34**	**0.44**	**0.36**
	CD at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**1.04**	**0.89**	**0.67**	**1.06**	**1.41**	**1.16**
Scion	S_1	4.65	5.25	4.95	5.04	5.47	5.26	5.33	6.52	5.92	13.60	14.33	13.96	16.32	16.58	16.45
	S_2	4.93	5.10	5.02	5.36	5.30	5.33	5.67	6.34	6.00	12.26	12.51	12.38	14.26	14.88	14.56
	SEm±	**01.4**	**0.10**	**0.08**	**0.12**	**0.09**	**0.08**	**0.12**	**0.12**	**0.11**	**0.27**	**0.23**	**0.17**	**0.27**	**0.37**	**0.30**
	CD at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**0.85**	**0.73**	**0.54**	**0.86**	**1.15**	**0.95**
Interaction	R_1S_1	4.28	5.12	4.70	4.74	5.28	5.01	5.12	6.19	5.65	11.03	12.63	11.83	13.73	13.78	13.76
	R_1S_2	4.74	4.86	4.80	5.14	5.09	5.11	5.24	6.14	5.69	10.81	11.71	11.26	11.85	13.04	12.45
	R_2S_1	5.01	5.35	5.18	5.36	5.64	5.50	5.61	6.54	6.07	13.40	14.03	13.72	15.36	15.74	15.55
	R_2S_2	5.08	5.06	5.07	5.28	5.24	5.25	5.96	6.35	6.15	12.43	12.60	12.51	14.55	15.18	14.87
	R_3S_1	4.65	5.28	4.97	5.02	5.50	5.26	5.28	6.83	6.05	16.39	16.33	16.36	19.88	20.21	20.04
	R_3S_2	4.98	5.40	5.19	5.66	5.57	5.61	5.79	6.52	6.15	13.53	13.22	13.37	16.37	16.41	16.39
	SEm±	**0.24**	**0.18**	**0.15**	**0.22**	**0.17**	**0.14**	**0.21**	**0.20**	**0.19**	**0.46**	**0.40**	**0.30**	**0.47**	**0.63**	**0.52**
	CD at 5 %	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**1.48**	**1.26**	**0.94**	**1.50**	**2.00**	**1.65**
	CV (%)	**8.89**	**6.35**	**5.25**	**7.48**	**5.36**	**4.62**	**6.71**	**5.65**	**5.75**	**6.28**	**5.17**	**3.92**	**5.38**	**6.99**	**5.83**

* Rootstocks: R_1-Bottle gourd, R_2-Pumpkin, R_3- Snake gourd

Scions: S_1-Bitter gourd, S_2-Ridge gourd

DAG- Days after grafting

NS- Non significant

pumpkin (R_2S_1) (13.40, 14.03 & 13.72 mm) rootstock. While ridge gourd recorded maximum girth of graft union when it was grafted on snake gourd (R_3S_2) (13.53, 13.22 & 13.37 mm) followed by pumpkin (R_2S_2) rootstock using wedge grafting method during *kharif* (2018-19), *rabi* (2019-20) and mean respectively (Table 5).

Whereas, minimum girth of graft union was observed in both bitter gourd and ridge gourd scions grafted on bottle gourd rootstock (R_1S_1 & R_1S_2) (11.03, 12.63, 11.83 & 10.81, 11.71, 11.26 mm) using wedge grafting method during *kharif* (2018-19), *rabi* (2019-20) and mean respectively (Table 5).

90 Days after grafting

4.1.5.3 Rootstock and scion effects

Final girth of graft union at 90 days after grafting (DAG) was also found to be significant and maximum in snake gourd (R_3) (18.13, 18.31 & 18.21 mm) followed by pumpkin (R_2) (14.96, 15.46 & 15.21 mm) and lowest value for final girth of graft union was recorded by bottle gourd (R_1) (12.79, 13.41 7 13.10 mm) as a rootstock during both the crop seasons (*Kharif* 2018-19, *rabi* 2019-20) and mean respectively (Table 5).

Similarly among the scions, bitter gourd (S_1) recorded maximum girth of graft union (16.32, 16.58 & 16.45 mm) and lowest value for girth of graft union was noted by ridge gourd (S_2) (14.26, 14.88 & 14.56 mm) scion during both the crop seasons (*Kharif* 2018-19, *rabi* 2019-20) and mean respectively (Table 5).

4.1.5.4 Rootstock and scion interaction effects

Bitter gourd scions grafted on snake gourd (R_3S_1) recorded significant and maximum girth of graft union (19.88, 20.21 & 20.04 mm) followed by bitter gourd scions grafted on pumpkin (R_2S_1) (15.36, 15.74 & 15.55 mm). Whereas ridge gourd recorded maximum girth of graft union when it was grafted on snake gourd (R_3S_2) (16.37, 16.41 7 16.39 mm) followed by pumpkin (R_2S_2) (14.55, 15.18 & 14.87 mm) as a rootstock during both the crop seasons (2018-19, 2019-20) and mean respectively.

Whereas, both bitter gourd and ridge gourd scions grafted on bottle gourd rootstock using wedge grafting method recorded minimum girth of graft union (R_1S_1 &

R_1S_1

R_1S_2

R_2S_1

R_2S_2

R_3S_1

R_3S_2

R_1S_1 –Bitter gourd scions grafted on bottle gourd
R_2S_1- Bitter gourd scions grafted on pumpkin
R_3S_1- Bitter gourd scions grafted on snake gourd
R_1S_2- Ridge gourd scions grafted on bottle gourd
R_2S_2- Ridge gourd scions grafted on pumpkin
R_3S_2- Ridge gourd scions grafted on snake gourd

Plate 10a. Stem girth of graft union 30 days after grafting (*Kharif,* 2048-19)

T_1

T_2

T_2

T_4

T_5

T_6

R_1S_1 –Bitter gourd scions grafted on bottle gourd
R_2S_1- Bitter gourd scions grafted on pumpkin
R_3S_1- Bitter gourd scions grafted on snake gourd
R_1S_2- Ridge gourd scions grafted on bottle gourd
R_2S_2- Ridge gourd scions grafted on pumpkin
R_3S_2- Ridge gourd scions grafted on snake gourd

Plate 10b. Stem girth of graft union at 90 days after grafting (*Kharif,* 2018-19)

R_1S_2) (13.73, 13.78, 13.76 & 11.85, 13.04, 12.45 mm) during both the crop seasons (2018-19, 2019-20) and pooled mean respectively (Table 5).

4.1.6 Percentage of graft success (%)

The percentage of graft success was assessed in five cucurbitaceous rootstocks (Bottle gourd, *Coccinia*, pumpkin, sponge gourd and snake gourd) and five different cucurbitaceous scions (Watermelon, cucumber, muskmelon, bitter gourd and ridge gourd). Among these combinations, only bitter gourd and ridge gourd scions grafted on bottle gourd, pumpkin and snake gourd rootstocks were found compatible and other all combinations were found to be incompatible (Table 6) and more than 50 per cent graft success combinations were used for further investigation (Table 7).

4.1.6.1 Rootstock and scion effects

Among different rootstocks used, highest percentage of graft success (10 DAG) was recorded by snake gourd (R_3) (92.50 & 90.50 %) followed by pumpkin (R_2) (87.83 & 85.50 %) and lowest percentage of graft success was observed in bottle gourd (R_1) (71.00 & 68.00 %) as a rootstock during both the *kharif* (2018-19) and *rabi* (2019-20) season. The results of pooled mean showed highest percentage of graft success in snake gourd (R_3) (92.25 %) followed by pumpkin (R_2) (87.00 %) and lowest percentage of graft success in bottle gourd (R_1) (70.00 %) as a rootstock (Table 7).

Similarly among two scions tried, ridge gourd (S_2) recorded maximum percentage of graft success (86.00 & 84.67 %) when compared to bitter gourd (S_1) (81.56 & 78.00 %) as a scion during both crop seasons of *kharif* and *rabi* (2018-19 & 2019-20). Pooled mean recorded maximum percentage of graft success in ridge gourd (S_2) (85.39 %) compared to bitter gourd (S_1) (80.78 %) as a scions (Table 7).

4.1.6.2 Rootstock and scion interaction effects

An interaction effects was found to be significant during both the crop seasons. In 2018-19 (*Kharif*), ridge gourd scions grafted on snake gourd (R_3S_2) recorded maximum percentage of graft success (97.00 %) followed by bitter gourd scion grafted on pumpkin (R_2S_1) (90.67 %) and lowest percentage of graft success was observed by bitter gourd scions grafted on bottle gourd (R_1S_1) (66.00 %) as a rootstock.

Table 6. Graft compatibility of cucurbitaceous rootstocks and scions

Treatment	Graft compatibility				
Rootstocks	Scions (% success)				
	S_1	S_2	S_3	S_4	S_5
R_1	15.00	12.00	18.00	64.00	76.00
R_2	1.00	5.00	9.00	8.00	7.00
R_3	9.00	20.00	16.00	85.00	84.00
R_4	*	*	*	*	*
R_5	9.00	12.00	5.00	89.00	96.00

Rootstocks: R_1-Bottle gourd
R_2 – Coccinia
R_3-Pumpkin
R_4- Sponge gourd
R_5- Snake gourd

Scions: S_1-Watermelon
S_2- Cucumber
S_3-Muskmelon
S_4- Bitter gourd
S_5- Ridge gourd

Graft success with > 50 % were considered as compatible
Graft success with < 50 % were considered as incompatible
* Stem diameter not suitable for grafting

Further > 50 % graft success combinations were used for further investigation

Table 7: Influence of cucurbitaceous rootstock and scion on graft success (%) at 10 DAG

Treatment		Graft success (%)		
		2018-19	**2019-20**	**Mean**
Rootstock	R_1	71.00 (57.48)	68.00 (55.63)	70.00 (56.85)
	R_2	87.83 (69.71)	85.50 (67.60)	87.00 (68.92)
	R_3	92.50 (74.94)	90.50 (72.92)	92.25 (74.45)
	SEm±	**0.40**	**1.10**	**0.47**
	CD at 5 %	**1.26**	**3.46**	**1.49**
Scion	S_1	81.56 (65.43)	78.00 (62.70)	80.78 (64.80)
	S_2	86.00 (69.31)	84.67 (68.06)	85.39 (68.68)
	SEm±	**0.33**	**0.90**	**0.38**
	CD at 5 %	**1.03**	**2.83**	**1.22**
Interaction	R_1S_1	66.00 (54.32)	62.00 (51.93)	64.83 (53.61)
	R_1S_2	76.00 (60.65)	74.00 (59.33)	75.17 (60.09)
	R_2S_1	90.67 (72.22)	86.33 (68.28)	89.33 (70.92)
	R_2S_2	85.00 (67.19)	84.67 (66.92)	84.66 (66.93)
	R_3S_1	88.00 (69.75)	85.67 (67.91)	88.17 (69.86)
	R_3S_2	97.00 (80.09)	95.33 (77.94)	96.33 (79.04)
	SEm±	**0.56**	**1.56**	**0.66**
	CD at 5 %	**1.78**	**4.87**	**2.11**
	CV (%)	**1.16**	**3.30**	**1.39**

*Figures in the parenthesis are arcsine transformation DAG- Days after grafting

* Rootstocks: R_1-Bottle gourd
R_2-Pumpkin
R_3- Snake gourd

Scions: S_1- Bitter gourd
S_2-Ridge gourd

Similar trend for per cent graft success was also noticed during *rabi* season (2019-20). Significant and maximum percentage of graft success was observed in ridge gourd scions grafted on snake gourd rootstock (R_3S_2) (95.33 %) followed by bitter gourd scions grafted on pumpkin rootstock (R_2S_1) (86.33 %) and minimum percentage of graft success was noticed in bitter gourd scions grafted on bottle gourd rootstock (R_1S_1) (62.00 %) using wedge grafting method (Table 7).

Similarly, pooled data showed maximum percentage of graft success in ridge gourd scions grafted on snake gourd rootstock (R_3S_2) (96.33 %) followed by bitter gourd scions grafted on pumpkin rootstock (R_2S_1) (89.33 %) and minimum percentage of graft success was found in bitter gourd scions grafted on bottle gourd rootstock (R_1S_1) (64.83 %) using wedge grafting method (Table 7).

4.1.7 Days to first flowering

Days to first flowering is an important trait for earliness and the data pertaining to days to first female flower appearance was depicted in Table 8.

4.1.7.1 Rootstock and scion effects

Rootstock and scion effects was found to be significant and least number of days to first female flower appearance was noticed in snake gourd (R_3) as a rootstock (39.94) which was at par with pumpkin (R_2) (41.50) as a rootstock and maximum number of days to first female flower appearance was observed in bottle gourd (R_1) (45.77) as a rootstock during *kharif* season (2018-19) (Table 8).

Similar trend was also seen during *rabi* season (2019-20). Significant and minimum number of days to first female flower appearance was observed in snake gourd (R_3) (38.83) as a rootstock and it was similar with pumpkin (R_2) (42.02) as a rootstock and maximum number of days to first female flower appearance was found in bottle gourd (R_1) (45.37) as a rootstock (Table 8).

Mean of two year data revealed minimum number of days to first female flower appearance in snake gourd (R_3) (39.39) which was at par with pumpkin (41.76) and maximum number of days to first female flower appearance was recorded in bottle gourd (R_1) (45.57) as a rootstock (Table 8).

Similarly among the scions, ridge gourd (S_2) recorded minimum number of days for first female flower appearance (39.44 & 36.95) as compared to bitter gourd as a scion during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20). Pooled data also showed minimum number of days to first female flower appearance in ridge gourd (S_2) (38.19) compared to bitter gourd (S_1) as a scion (Table 8).

4.1.7.2 Rootstock and scion interaction effects

Number of days taken for first female flower appearance was found to be significant and lesser in ridge gourd scions grafted on snake gourd (R_3S_2) (34.74 & 31.55) followed by ridge gourd scions grafted on pumpkin (R_2S_2) (38.00 & 36.63) and bitter gourd scions grafted on pumpkin and snake gourd (R_2S_1 &R_3S_1) (45.00 & 46.11) rootstock. Whereas maximum number of days to first female flower appearance was taken by bitter gourd scions grafted on bottle gourd (R_1S_1) (45.94 & 48.07) as a rootstock during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20).

Mean of both the years presented in table 8 showed minimum number of days to first female flower appearance in ridge gourd scions grafted on snake gourd rootstock (R_3S_2) (33.15) followed by ridge gourd scions grafted on pumpkin rootstock (R_2S_2) (37.32) and maximum number of days to first female flower appearance in bitter gourd scions grafted on bottle gourd as a rootstock (R_1S_1) (47.00).

4.1.8 Node number to first female flower appearance

The perusal data on node number to first female flower appearance recorded during two crop seasons of *kharif* and *rabi* (2018-19 & 2019-20) was also found to be significant and mentioned in table 8.

Table 8: Node number to first female flower appearance and days to first female flower appearance as influenced by cucurbitaceous rootstock and scion under protected environment (Shade net)

Treatment		Node number to first female flower appearance			Days to first female flower appearance		
		2018-19	2019-20	Mean	2018-19	2019-20	Mean
Rootstock	R_1	18.60	19.23	18.92	45.77	45.37	45.57
	R_2	14.70	14.53	14.61	41.50	42.02	41.76
	R_3	13.68	13.74	13.71	39.94	38.83	39.39
	SEm±	**0.93**	**1.18**	**0.91**	**1.25**	**1.03**	**0.99**
	CD at 5 %	**2.95**	**3.73**	**2.88**	**3.95**	**3.24**	**3.14**
Scion	S_1	21.87	22.97	22.42	45.36	47.19	46.28
	S_2	9.46	8.70	9.08	39.44	36.95	38.19
	SEm±	**0.77**	**0.96**	**0.74**	**1.02**	**0.83**	**0.81**
	CD at 5 %	**2.41**	**3.05**	**2.36**	**3.23**	**2.64**	**2.56**
Interaction	R_1S_1	27.00	29.36	28.18	45.94	48.07	47.00
	R_1S_2	10.20	9.11	9.65	45.60	42.67	44.14
	R_2S_1	19.64	20.23	19.93	45.00	47.41	46.21
	R_2S_2	9.77	8.83	9.30	38.00	36.63	37.32
	R_3S_1	18.97	19.31	19.14	45.13	46.11	45.62
	R_3S_2	8.40	8.17	8.28	34.74	31.55	33.15
	SEm±	**1.33**	**1.67**	**1.29**	**1.77**	**1.45**	**1.41**
	CD at 5 %	**4.18**	**5.29**	**4.08**	**5.59**	**4.58**	**4.44**
	CV (%)	**14.66**	**18.35**	**14.24**	**7.25**	**5.98**	**5.78**

* Rootstocks: R_1-Bottle gourd, R_2-Pumpkin, R_3- Snake gourd

Scions: S_1-Bitter gourd, S_2-Ridge gourd

DAG- Days after grafting

4.1.8.1 Rootstock and scion effects

Significant and appearance of first female flower at early node was noticed in snake gourd (R_3) (13.68) as a rootstock which was similar with pumpkin (R_2) (14.70) and appearance of first female flower at later nodes was observed in bottle gourd (R_1) (18.60) as a rootstock. Among two scions tried, ridge gourd (S_2) recorded first female flower at early nodes (9.46) compared to bitter gourd (S_1) (21.87) as a scion during *kharif* season (2018-19) (Table 8).

Similar results were also noticed during *rabi* season (2019-20). Snake gourd (R_3) recorded first female flower at early nodes (13.74) followed by pumpkin (R_2) (14.53). Whereas, bottle gourd (R_1) as a rootstock recorded first female flower at later nodes (19.23). Among two scions used, ridge gourd (S_2) produced first female flower at early node (8.70) as compared to bitter gourd (S_1) (22.97) as a scion (Table 8).

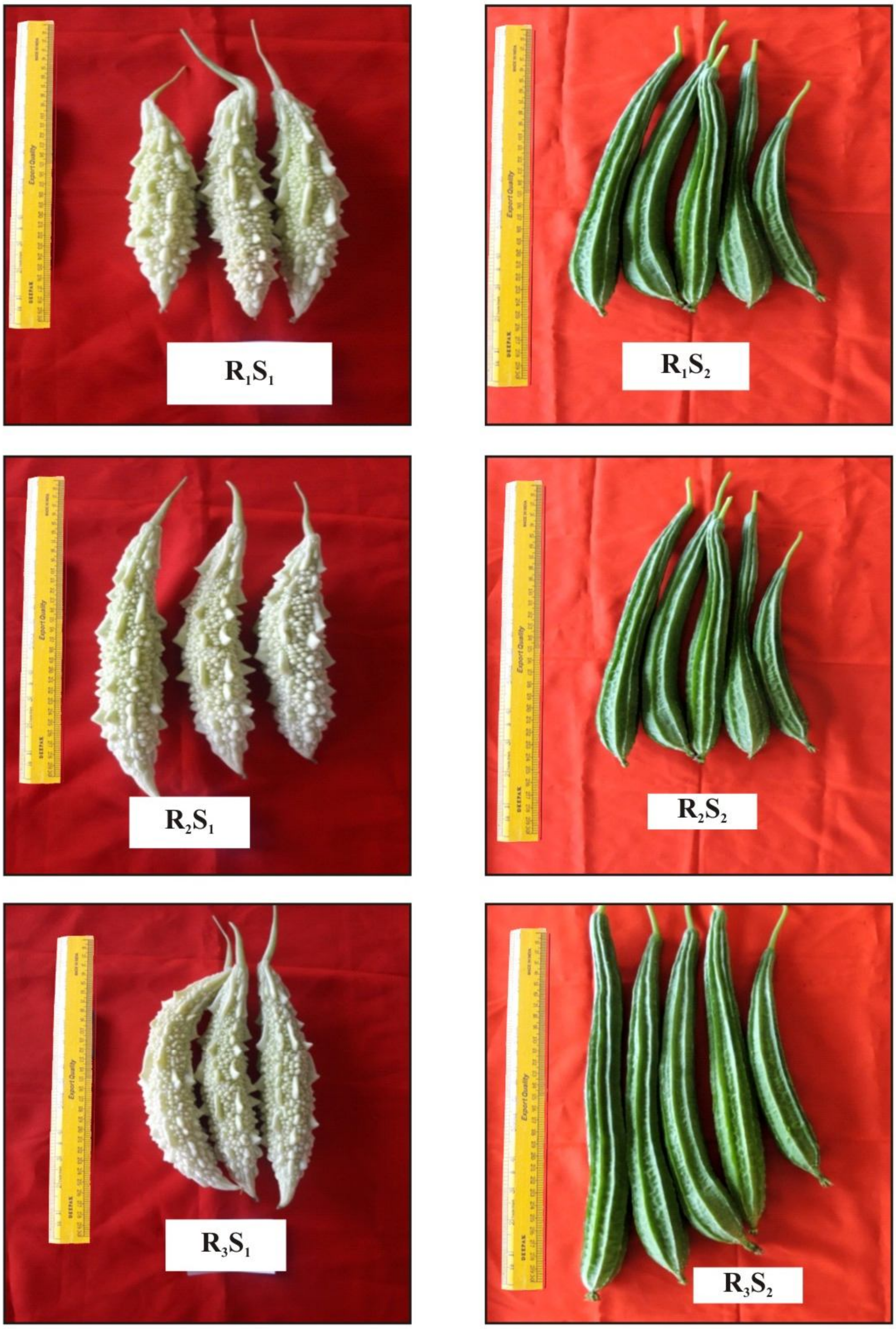
Pooled data depicted in table 8 recorded lesser number of nodes to first female flower appearance (13.71) in snake gourd (R_3) followed by pumpkin (R_2) and maximum number of nodes to first female flower appearance in bottle gourd (R_1) (18.92) as a rootstock. Among scions ridge gourd (S_2) showed minimum number of nodes to first female flower appearance (9.08) as compared to bitter gourd (S_1) (22.42) as a scion.

4.1.8.2 Rootstock and scion interaction effects

An interaction effects was also found to be significant. Ridge gourd grafted on snake gourd (R_3S_2) rootstock showed appearance of first female flower at early node (8.40 & 8.17) and bitter gourd grafted on snake gourd (R_3S_1) (18.97 & 19.31). Whereas maximum number of nodes to first female flower appearance was observed in bitter gourd and ridge gourd scions grafted on bottle gourd (R_1S_1 & R_1S_2) (27.00, 29.36 & 10.20, 9.11) rootstock during both the crop seasons (2018-19 & 2019-20) (Table 8).

Pooled data recorded minimum number of nodes to first female flower appearance in ridge gourd scions grafted on snake gourd rootstock (R_3S_2) (8.28) and maximum number of nodes to first female flower appearance in bitter gourd scions grafted on bottle gourd rootstock (R_1S_1) (28.18) using wedge grafting method (Table 8).

Plate 11. Different reproductive stages of bitter gourd and ridge gourd scion grafted on bottle gourd, pumpkin and snake gourd root stock (*Kharif,* 2018-19)



R_1S_1 –Bitter gourd scions grafted on bottle gourd
R_2S_1- Bitter gourd scions grafted on pumpkin
R_3S_1- Bitter gourd scions grafted on snake gourd
R_1S_2- Ridge gourd scions grafted on bottle gourd
R_2S_2- Ridge gourd scions grafted on pumpkin
R_3S_2- Ridge gourd scions grafted on snake gourd

Plate 12. Bitter gourd and ridge gourd fruits as affected by cucurbitaceous rootstocks (*Kharif*, 2018-19)

4.2 Experiment II: Effect of growth regulators on graft compatibility and yield of cucurbits

4.2.1 Growth Parameters

4.2.1.1 Days to first sprout and days to 50 per cent sprout

The data on number of days taken for first and fifty per cent sprouting recorded during *kharif* (2018-19) and *rabi* (2019-20) was presented in table 9.

A perusal of data given in table 9 reveals that, in *kharif* season (2018-19) the number of days taken to first sprouting was found to be in the range of 3.00 to 5.50 days. Bitter gourd scions treated with GA_3 @ 50 ppm (T_2) and IBA @ 50 ppm (T_4) and grafted on pumpkin rootstock using wedge grafting method recorded least number of days to first sprouting (3.00) and it was at par with bitter gourd scions treated with coconut milk @ 10.0 per cent, bitter gourd scions treated with distilled water and bitter gourd scions treated with GA_3 @ 25 ppm ($T_{8,}$ T_{11} & T_1) (3.50, 3.50 & 4.00 days).

Whereas, bitter gourd scions treated with cow urine @ 1.0 per cent and coconut milk @ 20.0 per cent (T_5 & T_{10}) recorded maximum number of days to first sprouting (5.50 days) (Table 9).

Similarly in *rabi* season (2019-20), bitter gourd scions treated with IBA and GA_3 @ 50 ppm (T_4 & T_2) and grafted on pumpkin rootstock recorded minimum number of days to first sprouting (4.00) which was similar with T_1 (bitter gourd scions treated with GA_3@ 25 ppm) (5.00) and maximum number of days to first sprouting was noted in bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) (7.50 days).

The pooled data showed significant and least number of days to first sprouting (3.50 days) in bitter gourd scions treated with IBA @ 50 ppm and it was at par with bitter gourd scions treated with GA_3 @ 25 ppm, coconut milk @ 10.0 per cent and distilled water (4.50 days) (T1, T8 & T11). Whereas bitter gourd scions treated with GA_3 and IBA @ 50 ppm (T_2 & T_4) (3.50 days) and bitter gourd scions treated with cow urine @ 1.0 % (T_5) showed maximum number of days to first sprouting (Table 9).

Table 9: Effect of growth regulators and organic promoters on days to first and 50 % sprouting of bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatments	Days to first sprout			Days to 50 per cent sprout		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	4.00 (2.24)	5.00 (2.45)	4.50 (2.12)	8.50 (3.08)	10.50 (3.39)	9.50 (3.24)
T_2	3.00 (1.73)	4.00 (2.24)	3.50 (1.87)	5.50 (2.55)	7.50 (2.91)	6.50 (2.74)
T_3	4.50 (2.12)	5.50 (2.55)	5.00 (2.45)	9.00 (3.16)	11.00 (3.46)	10.00 (3.31)
T_4	3.00 (1.73)	4.00 (2.24)	3.50 (1.87)	5.00 (2.45)	7.00 (2.83)	6.00 (2.64)
T_5	5.50 (2.55)	7.50 (2.91)	6.50 (2.74)	8.50 (3.08)	10.50 (3.39)	9.50 (3.24)
T_6	5.00 (2.45)	5.50 (2.64)	5.25 (2.29)	8.50 (3.08)	10.50 (3.39)	9.50 (3.24)
T_7	4.50 (2.12)	6.50 (2.74)	5.50 (2.55)	9.00 (3.16)	14.00 (3.87)	11.50 (3.52)
T_8	3.50 (1.87)	5.50 (2.64)	4.50 (2.12)	6.50 (2.74)	8.50 (3.08)	7.50 (2.91)
T_9	4.50 (2.12)	6.50 (2.74)	5.50 (2.64)	8.50 (3.08)	10.50 (3.39)	9.50 (3.24)
T_{10}	5.50 (2.64)	6.00 (2.64)	5.75 (2.40)	8.50 (3.08)	10.50 (3.39)	9.50 (3.24)
T_{11}	3.50 (1.87)	5.50 (2.55)	4.50 (2.12)	9.00 (3.16)	11.00 (3.46)	10.00 (3.31)
SEm ±	0.39	0.46	0.42	0.42	0.50	0.45
C.D at 5 %	1.24	1.46	1.33	1.31	1.59	1.42
CV (%)	13.15	11.69	12.17	7.47	7.04	7.11

*Figures in the parenthesis are square root transformation DAG- Days after grafting

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm,
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with distilled water (control)

Similarly, the day taken for 50 per cent sprouting was also found to be significant among the different treatments.

Significant and minimum number of days for 50 per cent sprouting (5.00 & 7.00 days) was exhibited by bitter gourd scions treated with IBA @ 50 ppm (T_4) and it was at par with bitter gourd scions treated with GA_3 @ 50 ppm (T_2) (5.50 & 7.50 days) and bitter gourd scions treated with coconut milk @ 10.0 % (T_8) (8.50 days) grafted on pumpkin rootstock during both *kharif* (2018-19) and *rabi* (2019-20) season (Table 9).

The pooled data recorded minimum number of days for 50 per cent sprouting (6.00 days) in bitter gourd scions treated with IBA @ 50 ppm (T_4) and it was at par with bitter gourd scions treated with GA_3 @ 50 ppm (T_2) (6.50 days) and grafted on pumpkin rootstock. Whereas, the bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) took maximum number of days (11.50 days) to 50 per cent sprouting (Table 9).

4.2.1.2 Sprout length of the scion/vine length (cm)

The data related to sprout length of scion recorded at 10, 15, 20, 25, 30 and 40 days after grafting was depicted in table 10. Vine length at 10 and 15 days after grafting was found to be non significant. Whereas at 20 to 40 days after grafting the vine length was significantly affected by different treatments. There was gradual increase in vine length from 10 days to 40 days after grafting was observed during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20).

20 Days after grafting

In 2018-19 (*Kharif* season), on 20th day after grafting, the maximum length of vine (41.52 cm) was recorded in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with all the treatments except bitter gourd scions treated with cow urine @ 1.0, 1.5 and 2.0 per cent (T_5, T_6 & T_7) grafted on pumpkin rootstock using wedge grafting method. Whereas, the minimum vine length (26.72 cm) was observed in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) and grafted on pumpkin rootstock using wedge grafting method (Table 10).

Similarly, in 2019-20 (*Rabi* season), bitter gourd scions treated with GA_3 @ 25 ppm (T_1) grafted on pumpkin rootstock using wedge grafting method exhibited maximum vine length (44.77 cm) and it was at par with bitter gourd scions treated with coconut milk @ 20.0 % (T_{10}). Whereas, the lowest vine length (26.57 cm) was observed in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) and grafted on pumpkin rootstock using wedge grafting method (Table 10).

The pooled data depicted in table 10 revealed significant and maximum length of vine (43.15 cm) in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with bitter gourd scions treated with coconut milk @ 20.0 per cent, IBA @ 25 and 50 ppm (T_{10}, T_3, T_4) grafted on pumpkin rootstock using wedge grafting method. Minimum length of vine (26.64 cm) was recorded in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) and grafted on pumpkin rootstock using wedge grafting method (Table 10). vg

25 Days after grafting

Significant and maximum vine length (75.92 cm) at 25 days after grafting (DAG) was observed in T_1 (bitter gourd scions treated with GA_3 @ 25 ppm) it was at par with bitter gourd scions treated with coconut milk @ 20.0 per cent (T_{10}) and bitter gourd scions treated with IBA @ 50 ppm (T_4) grafted on pumpkin rootstock using wedge grafting method. Whereas, the minimum vine length (48.65 cm) was observed in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) and grafted on pumpkin rootstock using wedge grafting method during *kharif* season (2018-19) (Table 10).

The application of GA_3 @ 25 ppm (T_1) had a pronounced effect on vine length during 2019-20 (*Rabi* season) and recorded maximum vine length (79.25 cm) which was at par with bitter gourd scions treated with IBA and GA_3 @ 50 ppm (T_4 & T_2) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum vine length (38.73 cm) was recorded by bitter gourd scions treated with distilled water (T_{11}) and grafted on pumpkin rootstock using wedge grafting method (Table 10).

Table 10: Effect of growth regulators and organic promoters on sprout length of scion/vine length of bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatment	Sprout length of scion/length of vine (cm)																	
	10 DAG			15 DAG			20 DAG			25 DAG			30 DAG			40 DAG		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	18.92	23.10	21.01	26.45	29.32	27.89	41.52	44.77	43.15	75.92	79.25	77.59	123.99	149.99	136.99	249.04	253.49	251.26
T_2	14.00	24.40	19.20	20.28	27.20	23.74	38.00	31.17	34.59	66.30	72.12	69.21	107.13	123.34	115.24	191.92	188.25	190.09
T_3	20.07	22.15	21.11	23.62	24.82	24.22	40.75	33.72	37.24	58.02	43.90	50.96	81.99	105.87	93.93	236.76	240.59	238.68
T_4	17.77	22.82	20.30	25.57	25.67	25.62	35.09	39.01	37.05	69.97	75.89	72.93	95.78	103.35	99.57	181.07	189.52	185.30
T_5	14.05	21.72	17.89	23.00	27.89	25.45	27.36	32.30	29.83	53.20	42.54	47.87	85.22	71.32	78.27	143.90	152.80	148.35
T_6	19.22	18.19	18.71	23.07	23.72	23.40	26.72	26.57	26.64	48.65	49.35	49.00	78.51	63.75	71.13	146.02	156.49	151.26
T_7	16.37	22.37	19.37	20.63	25.34	22.99	30.08	33.04	31.56	51.39	54.14	52.77	74.27	68.95	71.61	173.68	177.17	175.43
T_8	17.97	19.47	18.72	24.72	23.07	23.90	37.79	29.60	33.70	61.49	53.32	57.41	106.75	90.14	98.45	161.64	153.17	157.41
T_9	16.45	19.32	17.89	20.55	23.70	22.13	37.40	31.00	33.20	55.27	52.72	54.00	106.27	77.47	91.87	166.18	146.17	155.68
T_{10}	20.40	23.90	22.15	26.42	28.85	27.64	40.13	42.77	41.20	71.88	51.02	61.45	107.81	99.09	103.45	231.67	229.92	230.80
T_{11}	17.99	21.35	19.67	24.97	25.02	25.00	34.12	30.90	32.51	49.37	38.73	44.05	89.45	78.17	83.81	110.75	97.99	104.37
SEm ±	2.34	1.90	1.55	2.58	1.68	1.27	2.87	1.63	2.46	2.73	3.22	4.50	4.76	5.00	2,63	3.22	4.19	4.78
CD at 5 %	NS	NS	NS	NS	NS	NS	9.05	5.14	8.07	8.62	10.15	14.17	15.01	15.75	8.29	10.14	13.20	15.08
CV (%)	18.80	12.37	11.19	15.50	9.21	7.26	11.49	6.77	10.44	6.43	8.18	10.98	7.01	7.54	3.92	2.51	3.28	3.74

DAG- Days after grafting NS- Non significant

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with distilled water (control)

Pooled data presented in table 10 showed maximum vine length (77.59 cm) in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with bitter gourd scions treated with IBA and GA_3 @ 50 ppm (T_4 & T_2) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum vine length (44.05 cm) was recorded in bitter gourd scions treated with distilled water (T_{11}) and grafted on pumpkin rootstock using wedge grafting method.

30 Days after grafting

Significant and maximum vine length (123.99 & 149.99 cm) was noticed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and minimum vine length (74.27 & 63.75 cm) was recorded in bitter gourd scions treated with cow urine @ 2.0 and 1.5 per cent (T_7 & T_6) grafted on pumpkin rootstock using wedge grafting method during *kharif* (2018-19) and *rabi* (2019-20) season respectively (Table 10).

The results of the pooled data indicated maximum vine length (136.99 cm) in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and minimum vine length (71.13 cm) in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) and grafted on pumpkin rootstock using wedge grafting method (Table 10).

40 Days after grafting

In 2018-19 (*Kharif*), maximum vine length (249.04 cm) was observed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and minimum vine length (110.75 cm) in bitter gourd scions treated with distilled water (T_{11}) and grafted on pumpkin rootstock using wedge grafting method. Similarly, in 2019-20 (*Rabi*), maximum vine length (253.49 cm) was recorded in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with bitter gourd scions treated with IBA @ 25 ppm (T_3) (240.59 cm) grafted on pumpkin rootstock using wedge grafting method. Whereas minimum vine length (97.99 cm) was recorded in bitter gourd scions treated with distilled water (T_{11}) and grafted on pumpkin rootstock using wedge grafting method.

Pooled data illustrated in table 10 revealed maximum vine length (251.26 cm) in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with T_3 (Bitter gourd scions treated with IBA @ 25 ppm) (238.68 cm) grafted on pumpkin rootstock using wedge grafting method. Whereas minimum vine length (104.37 cm) was observed

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

Plate 13. Performance of grafted bitter gourd at 20 days after grafted on pumpkin root stock (*Kharif,* 2018-19)

Table 11: Effect of growth regulators and organic promoters on number of nodes per graft in bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatment	Number of nodes per graft (no.)											
	15 DAG			30 DAG			45 DAG			60 DAG		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	5.21	5.39	5.30	16.51	16.67	16.59	72.17	66.34	69.25	154.50	143.17	151.08
T_2	3.79	4.43	4.11	14.17	14.83	14.50	105.17	107.83	106.50	208.67	211.33	210.00
T_3	3.75	4.80	4.25	12.17	15.34	13.76	63.50	67.67	65.59	125.56	142.73	134.15
T_4	4.09	5.00	4.55	15.00	15.00	15.00	78.51	70.51	74.51	175.17	163.17	169.17
T_5	3.84	4.59	4.22	13.00	14.34	13.67	40.00	45.28	42.64	138.34	143.62	140.98
T_6	3.42	4.92	4.17	9.34	13.50	11.42	40.67	44.84	42.75	110.50	118.67	114.58
T_7	3.07	3.77	3.42	12.34	14.50	13.42	33.51	35.68	34.59	98.50	104.68	103.59
T_8	3.34	4.33	3.83	10.67	15.33	13.00	61.84	68.50	65.17	115.17	109.83	112.50
T_9	4.00	4.33	4.17	11.50	15.17	13.34	58.84	62.51	60.68	129.00	140.67	134.84
T_{10}	4.95	5.12	5.04	14.33	17.00	15.67	72.17	78.84	75.51	147.50	154.17	150.84
T_{11}	3.50	4.17	3.84	9.01	12.84	10.92	49.17	53.01	51.09	93.67	97.51	95.59
SEm ±	0.16	0.26	0.20	1.06	0.56	0.83	2.80	2.68	2.40	3.14	2.68	5.06
CD at 5 %	0.50	0.26	0.62	3.32	1.76	2.61	8.81	8.43	7.56	9.89	8.43	15.93
CV (%)	5.75	7.98	6.54	11.89	5.30	8.53	6.44	5.94	5.43	3.26	2.72	5.18

DAG- Days after grafting

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with distilled water (control)

in bitter gourd scions treated with distilled water (T_{11}) and grafted on pumpkin rootstock using wedge grafting method (Table 10).

4.2.1.3 Number of nodes per graft

The data pertaining to number of nodes per graft per vine recorded at 15, 30, 45 and 60 days after grafting was illustrated in Table 11. Significant differences were observed between the treatments for number of nodes per graft per vine during both the crop seasons of *kharif* (2018-19) and *rabi* (2019-20).

15 Days after grafting

In 2018-19 (*Kharif*), significant and maximum number of nodes (5.21) per graft per plant was observed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with bitter gourd scions treated with coconut milk @ 20.0 % (T_{10}) (4.95) grafted on pumpkin rootstock using wedge grafting method. Whereas minimum number of nodes (3.07) per graft per plant was noticed in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) and grafted on pumpkin rootstock using wedge grafting method (Table 11).

Similarly, in *rabi* season (2019-20), bitter gourd scions treated with GA_3 @ 25 ppm (T_1) showed maximum number of nodes (5.39) per grafted plant. Whereas, least number of nodes per graft per vine (3.77) was noted in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) and grafted on pumpkin rootstock using wedge grafting method (Table 11).

However, pooled data exhibited maximum number of nodes (5.30) in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with bitter gourd scions treated with coconut milk @ 20.0 % (T_{10}) (5.04) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum number nodes (3.42) per graft per vine was observed in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) (Table 11).

30 Days after grafting

Maximum numbers of nodes per graft per vine (16.51) was noticed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with bitter gourd scions treated with IBA @ 50 ppm and coconut milk @ 20.0 per cent (T_4 & T_{10}) (15.00 & 14.33) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum number of nodes (9.01) per graft per vine was observed in bitter gourd scions treated with distilled water (T_{11}) and grafted on pumpkin rootstock using wedge grafting method during *kharif* season (2018-19).

Similarly, in 2019-20 (*Rabi*), bitter gourd scions treated with coconut milk @ 20.0 per cent (T_{10}) showed maximum number of nodes (17.00) per graft per vine and it was at par with bitter gourd scions treated with GA_3 and IBA @ 25 ppm and coconut milk @ 10.0 per cent (T_1, T_3 & T_8). Meanwhile, bitter gourd scions treated with distilled water (T_{11}) recorded minimum number of nodes (12.84) per graft per vine grafted on pumpkin rootstock using wedge grafting method.

The observations on pooled data indicated maximum number of nodes (16.59) per graft per vine in T_1 (GA_3 @ 25 ppm) and was at par with bitter gourd scion treated with coconut milk @ 20.0 per cent, IBA and GA_3 @ 50 ppm (T_{10}, T_4 & T_2) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum number of nodes (10.92) per graft per vine was observed in bitter gourd scions treated with distilled water (T_{11}) and grafted on pumpkin rootstock using wedge grafting method (Table 11).

45 Days after grafting

Significant and maximum number of nodes (105.17) per graft per vine was noticed in bitter gourd scions treated with GA_3 @ 50 ppm (T_2) followed by bitter gourd scions treated with IBA @ 50 ppm (T_4) (78.51) and minimum number of nodes (33.51) per graft per vine in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) and grafted on pumpkin rootstock using wedge grafting method during *kharif* season (2018-19) (Table 11).

Similarly, in *rabi* season (2019-20), maximum number of nodes (107.83) per graft per vine was observed in bitter gourd scions treated with GA_3 @ 50 ppm (T_2)

followed by bitter gourd scions treated with coconut milk @ 20.0 per cent (T_{10}) (78.84) and minimum number of nodes (35.68) per graft per vine in bitter gourd scions treated with cow urine @ 2.0 % (T_7) and grafted on pumpkin rootstock using wedge grafting method.

Pooled data presented in table 11 revealed maximum number of nodes (106.50) in bitter gourd scions treated with GA_3 @ 50 ppm (T_2) followed by bitter gourd scions treated with coconut milk @ 20.0 per cent (T_{10}) and minimum number of nodes (34.59) in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) grafted on pumpkin rootstock using wedge grafting method (Table 11).

60 Days after grafting

Significant and maximum number of nodes (208.67 & 211.33) per graft per plant was recorded in bitter gourd scions treated with GA_3 @ 50 ppm (T_2) followed by bitter gourd scions treated with IBA @ 50 ppm (T_4) (175.17 & 163.17) and minimum number of nodes (93.67 & 97.51) per graft per vine was noticed in bitter gourd scions treated with distilled water (T_{11}) grafted on pumpkin rootstock using wedge grafting method during both *kharif* (2018-19) and *rabi* (2019-20) season respectively (Table 11).

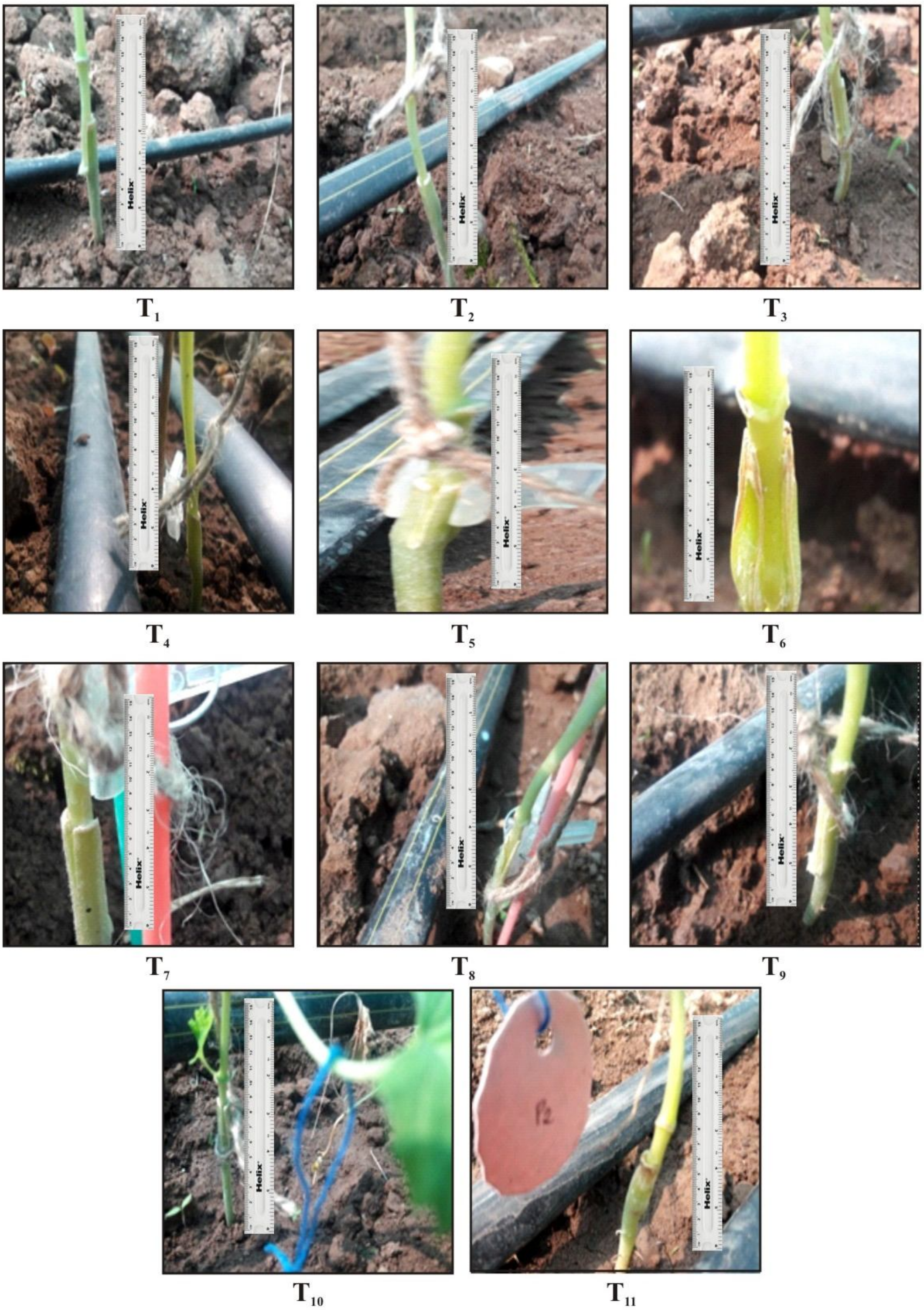
Pooled data recorded maximum number of nodes (210.00) in bitter gourd scions treated with GA_3 @ 50 ppm (T_2) followed by bitter gourd scions treated with IBA @ 50 ppm (T_4) and minimum number of nodes (95.59) per graft per vine was recorded in bitter gourd scions treated with distilled water (T_{11}) and grafted on pumpkin rootstock using wedge grafting method (Table 11).

4.2.1.4 Initial girth of graft union (mm)

Initial girth of graft union noted at 10, 20 and 30 days after grafting was found to be non significant and illustrated in table 12.

4.2.1.5 Final girth of graft union (mm)

Final girth of graft union measured at 60 and 90 days after grafting (DAG) was found to be significant during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20) and presented in Table 12.



T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

Plate 14a. Stem girth of graft union at 30 days after grafting (DAG) (*Kharif,* 2018-19)

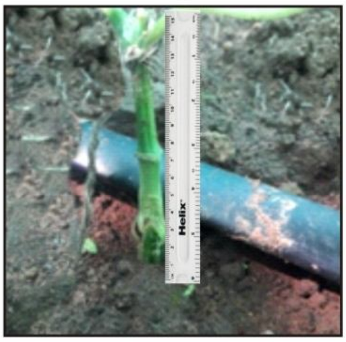
T_1

T_2

T_2

T_4

T_5



T_6

T_7

T_8

T_9

T_{10}

T_{11}

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

Plate 14b. Stem girth of graft union at 90 days after grafting (DAG) (*Kharif,* 2018-19)

60 Days after grafting

Stem girth of the graft union recorded at 60 days after grafting (DAG) was found to be maximum (18.27 mm) in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was par with bitter gourd scions treated with IBA @ 50 ppm (T_4) (17.24 mm) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum girth of graft union (9.59 mm) was observed in bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) and grafted on pumpkin rootstock using wedge grafting method during *kharif* season (2018-19) (Table 12).

Similarly, in 2019-20 (*Rabi* season), maximum girth of graft union (16.61 mm) was observed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with bitter gourd scions treated with IBA and GA_3 @ 25-50 ppm and coconut milk @ 20.0 per cent (T_3, T_{10} & T_2) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum girth of graft union was observed in bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) (9.70 mm) and grafted on pumpkin rootstock using wedge grafting method (Table 12).

The combined data of two years illustrated in table 12 revealed maximum girth of graft union (17.44 mm) in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) which was statistically similar with bitter gourd scions treated with coconut milk @ 20.0 per cent, IBA @ 25 ppm and GA_3 @ 50 ppm (T_{10}, T_3, T_2) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum girth of graft union (9.64 mm) was recorded in bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) and grafted on pumpkin rootstock using wedge grafting method (Table 12).

90 Days after grafting

The final girth of graft union recorded at 90 days after grafting was found to be maximum in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (19.00 mm) which was at par with bitter gourd scions treated with coconut milk @ 20.0 per cent, GA_3 and

Table 12: Effect of growth regulators and organic promoters on initial and final girth of bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatment	Initial girth (mm)									Final girth (mm)					
	10 DAG			20 DAG			30 DAG			60 DAG			90 DAG		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	5.21	5.18	5.20	5.60	5.41	5.51	7.15	6.73	6.94	18.27	16.61	17.44	19.00	20.56	19.78
T_2	4.76	5.00	4.88	5.53	5.48	5.51	7.37	7.30	7.34	16.21	15.14	15.67	17.58	17.87	17.73
T_3	4.89	5.13	5.01	5.24	5.37	5.31	6.60	7.45	7.03	15.36	16.21	15.78	17.43	18.12	17.77
T_4	4.94	4.64	4.79	5.52	5.39	5.46	7.05	6.58	6.82	17.24	13.77	15.51	17.38	18.44	17.91
T_5	4.80	5.17	4.99	5.51	5.51	5.51	6.78	6.89	6.84	9.59	9.70	9.64	12.17	14.12	13.14
T_6	4.96	4.25	4.61	5.70	4.59	5.15	7.00	5.92	6.46	13.85	12.77	13.31	15.43	14.06	14.75
T_7	4.57	4.94	4.76	5.16	5.22	5.19	6.54	6.50	6.52	10.27	10.23	10.25	14.71	15.62	15.16
T_8	4.77	4.72	4.75	5.55	5.04	5.30	7.18	6.54	6.86	12.21	11.57	11.89	15.62	16.01	15.81
T_9	4.81	4.75	4.78	5.45	5.09	5.27	6.90	7.28	7.09	13.09	13.47	13.28	12.96	16.67	14.81
T_{10}	4.80	4.64	4.72	5.16	5.13	5.15	7.15	7.33	7.24	16.26	15.94	16.35	18.42	19.44	18.93
T_{11}	4.58	4.81	4.70	5.38	5.12	5.25	6.84	6.59	6.72	13.82	12.71	13.26	13.93	15.62	14.77
SEm ±	0.12	0.23	0.16	0.12	0.17	0.17	0.24	0.38	0.26	0.64	0.54	0.58	0.69	0.64	0.47
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS	2.01	1.70	1.84	2.18	2.02	1.47
CV (%)	3.39	6.85	4.78	3.02	4.73	4.64	4.96	7.92	5.39	6.35	5.68	5.97	6.16	5.34	4.04

DAG- Days after grafting NS- Non significant

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with distilled water (control)

IBA @ 50 and 25 ppm (T_{10}, T_2 & T_3) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum girth of graft union (12.17 mm) was observed in bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) and grafted on pumpkin rootstock using wedge grafting method (Table 12).

During *rabi* season (2019-20), maximum girth of graft union (20.56 mm) was observed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was statistically similar with bitter gourd scions treated with coconut milk @ 20.0 per cent (T_{10}) (19.44 mm) and minimum girth of graft union (14.06 mm) was noticed in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) and it was at par with bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) (14.12 mm) grafted on pumpkin rootstock using wedge grafting method (Table 12).

However, mean of two year data that showed maximum girth of graft union in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (19.78 mm) and it was at par with bitter gourd scions treated with coconut milk @ 20.0 per cent (T_{10}) (18.93 mm) grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum girth of graft union was noticed in bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) (13.14 mm) and grafted on pumpkin rootstock using wedge grafting method (Table 12).

4.2.1.6 Percentage of graft success (%)

In the present investigation three cucurbitaceous species *viz.*,, watermelon, muskmelon and bitter gourd were used as scions and these scions were treated with growth regulators and organic promoters at different dosages. After the treatment with growth regulators these scions were grafted on four cucurbitaceous rootstocks (Bottle gourd, pumpkin, muskmelon and bitter gourd). The stem thickness of bitter gourd was not matched with the stem thickness of watermelon and muskmelon and thus discarded from the present study. Whereas, watermelon and muskmelon grafted on bottle gourd, pumpkin and bitter gourd rootstocks were found incompatible and bitter gourd scions grafted on bottle gourd and bitter gourd rootstock were also found incompatible (Table 13). Only bitter gourd scions grafted on pumpkin rootstock was found to be compatible and used for further evaluation.

Table 13: Effect of growth regulators and organic promoters on graft success (%) of cucurbits at 10 DAG

Graft success (%) 10 DAG			
Treatment details	**Total no. of plants grafted**	**No. of plants survived**	**Graft success**
T_1-Watermelon scions treated with GA_3 @ 25 ppm	50.00	0.00	0.00
T_2-Watermelon scions treated with GA_3 @ 50 ppm	50.00	0.00	0.00
T_3-Watermelon scions treated with IBA @ 25 ppm	50.00	0.00	0.00
T_4-Watermelon scions treated with IBA @ 50 ppm	50.00	0.00	0.00
T_5-Watermelon scions treated with cow urine @ 1.0 %	50.00	0.00	0.00
T_6-Watermelon scions treated with cow urine @ 1.5 %	50.00	0.00	0.00
T_7-Watermelon scions treated with cow urine @ 2.0 %	50.00	0.00	0.00
T_8-Watermelon scions treated with coconut milk @ 10.0 %	50.00	0.00	0.00
T_9-Watermelon scions treated with coconut milk @ 15.0 %	50.00	0.00	0.00
T_{10}-Watermelon scions treated with coconut milk @ 20.0 %	50.00	0.00	0.00
T_{11}-Watermelon scions treated with water (control)	50.00	0.00	0.00
T_{12}-Muskmelon scions treated with GA_3 @ 25 ppm	50.00	0.00	0.00
T_{13}-Muskmelon scions treated with GA_3 @ 50 ppm	50.00	0.00	0.00
T_{14}-Muskmelon scions treated with IBA @ 25 ppm	50.00	0.00	0.00
T_{15}-Muskmelon scions treated with IBA @ 50 ppm	50.00	0.00	0.00
T_{16}- Muskmelon scions treated with cow urine @ 1.0 %	50.00	0.00	0.00
T_{17}-Muskmelon scions treated with cow urine @ 1.5 %	50.00	0.00	0.00
T_{18}-Muskmelon scions treated with cow urine @ 2.0 %	50.00	0.00	0.00
T_{19}-Muskmelon scions treated with coconut milk @ 10.0%	50.00	0.00	0.00
T_{20}-Muskmelon scions treated with coconut milk @ 15.0 %	50.00	0.00	0.00
T_{21}-Muskmelon scions treated with coconut milk @ 20.0 %	50.00	0.00	0.00
T_{22}-Muskmelon scions treated with water (control)	50.00	0.00	0.00
T_{23}-Bitter gourd scions treated with GA_3 @ 25 ppm	50.00	38.00	76.00
T_{24}-Bitter gourd scions treated with GA_3 @ 50 ppm	50.00	48.00	96.00
T_{25}-Bitter gourd scions treated with IBA @ 25 ppm	50.00	39.00	78.00
T_{26}-Bitter gourd scions treated with IBA @ 50 ppm	50.00	49.00	98.00
T_{27}-Bitter gourd scions treated with cow urine @ 1.0 %	50.00	36.00	72.00
T_{28}-Bitter gourd scions treated with cow urine @ 1.5 %	50.00	34.00	68.00
T_{29}-Bitter gourd scions treated with cow urine @ 2.0 %	50.00	29.00	58.00
T_{30}-Bitter gourd scions treated with coconut milk @ 10.0%	50.00	30.00	60.00
T_{31}-Bitter gourd scions treated with coconut milk @ 15.0 %	50.00	42.00	84.00
T_{32}-Bitter gourd scions treated with coconut milk @ 20.0 %	50.00	36.00	72.00
T_{33}-Bitter gourd scions treated with water (control)	50.00	39.00	78.00
		SEm±	**2.31**
		CD at 5 %	**6.66**
		CV (%)	**12.84**

*Rootstocks: Pumpkin, Bottle gourd, Bitter gourd, Muskmelon

Table 14: Effect of growth regulators and organic promoters on graft success (%) of bitter gourd grafted on pumpkin at 10 and 30 DAG

Treatments	Graft success (%)					
	10 DAG			30 DAG		
	2018-2019	**2019-2020**	**Pooled**	**2018-2019**	**2019-2020**	**Pooled**
T_1	76.00 (60.67)	77.88 (61.96)	77.94 (61.98)	75.00 (60.01)	76.88 (61.27)	75.94 (60.64)
T_2	96.00 (79.99)	94.00 (76.99)	95.00 (77.11)	95.00 (77.11)	93.00 (75.16)	94.00 (76.28)
T_3	78.00 (62.03)	85.75 (67.84)	81.88 (65.31)	77.50 (61.70)	84.75 (67.02)	81.13 (64.25)
T_4	98.00 (81.84)	99.00 (84.23)	98.50 (83.03)	97.50 (80.95)	98.50 (83.07)	98.00 (81.87)
T_5	72.00 (58.05)	71.46 (57.75)	71.73 (57.86)	70.50 (57.11)	69.96 (56.79)	70.23 (56.94)
T_6	68.00 (55.57)	67.25 (55.07)	67.63 (55.30)	66.50 (54.65)	65.75 (54.18)	66.13 (54.41)
T_7	58.00 (49.60)	60.50 (51.05)	59.25 (50.31)	56.00 (48.45)	58.50 (49.90)	57.25 (49.17)
T_8	60.00 (50.83)	64.75 (53.61)	62.38 (52.15)	58.50 (49.94)	63.25 (52.70)	60.88 (51.32)
T_9	84.00 (66.60)	87.75 (69.51)	85.88 (67.94)	82.50 (65.35)	86.75 (68.65)	84.63 (66.94)
T_{10}	72.00 (58.04)	89.25 (71.04)	80.63 (64.43)	70.50 (57.10)	88.25 (70.04)	79.38 (62.99)
T_{11}	78.00 (62.18)	77.50 (61.93)	78.25 (62.18)	76.00 (60.73)	75.50 (60.45)	75.75 (60.58)
SEm ±	3.93	3.70	2.81	2.74	2.45	2.37
CD at 5 %	12.38	11.65	8.84	8.63	7.71	7.45
CV (%)	7.28	6.57	5.08	5.61	4.42	4.36

*Figures in the parenthesis are arcsine transformation DAG- Days after grafting

T_1-Bitter gourd scions treated with GA_3 @ 25 ppm
T_2-Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4-Bitter gourd scions treated with IBA @ 50 ppm
T_5-Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7-Bitter gourd scions treated with cow urine @ 2.0 %
T_8-Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}-Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with distilled water (control)

The data pertaining to the percentage of graft success in bitter gourd scions treated with different growth regulators and organic promoters grafted on pumpkin rootstock using wedge grafting method was presented in Table 14. Significant differences were observed among the treatments for percentage of graft success recorded at 10 and 30 days after grafting during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20).

Significant and maximum percentage of graft success (98.00, 97.50 & 99.00, 98.50 %) was recorded in bitter gourd scion treated with IBA @ 50 ppm (T_4) and it was similar with bitter gourd scions treated with GA_3 @ 50 ppm (T_2) (96.00, 95.00 & 94.00, 93.00 %) and grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum percentage of graft success was noticed in bitter gourd scions treated with cow urine @ 2.0 % (T_7) (58.00, 56.00 & 60.50, 58.50 %) during both *kharif* (2018-19) and *rabi* (2019-20) season (Table 14). The pooled data revealed, maximum percentage of grafting success (98.50 & 98.00 %) in bitter gourd scions treated with IBA @ 50 ppm (T_4) which was at par with bitter gourd scions treated with GA_3 @ 50 ppm (T_2) (95.00 & 94.00 %) and minimum percentage of graft success (59.25 & 57.25 %) in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7).

4.2.1.7 Days to first female flower appearance

The observation on number of days taken for first female flower appearance from the date of grafting was illustrated in Table 15.

During 2018-19 (*Kharif*), number days to first female flower appearance counted from the date of grafting ranged from 44.67 to 56.67 days. Least number of days for first female flower appearance (44.67) was recorded in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) and it was at par with bitter gourd scions treated with GA_3 @ 50 ppm (T_2) (46.17) and grafted on pumpkin rootstock using wedge grafting method. Whereas, maximum number of days for first female flower appearance (56.67) was noticed in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6).

In *rabi* season (2019-20), minimum number of days for first female flower appearance was observed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (44.62)

Plate 15. Different reproductive stages of bitter gourd scion grafted on pumpkin root stock (*Kharif*, 2018-19)

Table 15: Effect of growth regulators and organic promoters on days to first female flower and node number to first female flower of bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatment	Days to first female flower			Node number to first female flower		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	44.67	44.62	44.65	21.09	20.84	20.96
T_2	46.17	46.52	46.35	19.09	18.59	18.84
T_3	47.50	46.00	46.75	19.00	18.01	18.50
T_4	48.83	49.84	49.33	18.38	17.72	18.05
T_5	49.84	57.00	53.42	24.50	21.32	22.91
T_6	56.67	51.90	54.28	23.50	23.01	23.25
T_7	51.34	52.72	52.03	21.50	22.50	22.00
T_8	48.83	50.12	49.47	20.00	19.44	19.72
T_9	50.50	48.12	49.31	22.67	19.84	21.26
T_{10}	50.83	47.17	49.00	21.17	20.70	20.94
T_{11}	49.34	55.34	52.34	24.00	26.00	25.00
SEm ±	0.73	0.70	0.47	0.68	0.76	0.50
CD at 5 %	2.31	2.22	1.54	2.13	2.38	1.58
CV (%)	2.10	1.99	1.39	4.48	5.16	3.36

DAG- Days after grafting

T_1- Bitter gourd scions are treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions are treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions are treated with IBA @ 25 ppm
T_4- Bitter gourd scions are treated with IBA @ 50 ppm
T_5- Bitter gourd scions are treated with cow urine @ 1.0 %
T_6-Bitter gourd scions are treated with cow urine @ 1.5 %
T_7- Bitter gourd scions are treated with cow urine @ 2.0 %
T_8- Bitter gourd scions are treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions are treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions are treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions are treated with distilled water (control)

and it was similar with bitter gourd scions treated with IBA @ 25 ppm (T_3) (46.00) and bitter gourd scions treated with GA_3 @ 50 ppm (T_2) (46.52). Whereas, maximum number of days for first female flower appearance was noticed in bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) (57.00) which was at par with bitter gourd scions treated with distilled water (T_{11}) (55.34) and grafted on pumpkin rootstock. Pooled data recorded minimum number of days to first female flower appearance (44.65) in bitter scions treated with GA_3 @ 25 ppm (T_1) and maximum number of days to first female flower appearance (54.28) in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) which was at par with bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) (53.42) and grafted on pumpkin rootstock using wedge grafting method (Table 15).

4.2.1.8 Node number to first female flower appearance

Node number to first female flower appearance is an important attribute of earliness in cucurbits and significant differences among the treatments was found during both the years (2018-19 & 2019-20) and mentioned in Table 15.

In 2018-19 (*Kharif* season), bitter gourd scions treated with IBA @ 50 ppm (T_4) exhibited first female flower at early node (18.38) and it was at par with bitter gourd scions treated with IBA @ 25 ppm, GA_3 @ 50 ppm and coconut milk @ 10.0 per cent (T_3 , T_2 & T_8) and grafted on pumpkin rootstock using wedge grafting method. Whereas, bitter gourd scions treated with cow urine @ 1.0 per cent (T_5) recorded highest value for node number to first female flower appearance (24.50) and it was similar with control treatment *i.e.,* bitter gourd scions treated distilled water (T_{11}) (24.00) (Table 15).

Bitter gourd scions treated with IBA @ 50 ppm (T_4) (17.72) recorded significant and lesser number of nodes to first female flower appearance and it was similar with bitter gourd scions treated with IBA @ 25 ppm, GA_3 @ 50 ppm and coconut milk @ 10.0-15.0 per cent (T_3, T_2, T_8 and T_9) whereas highest number of nodes to first female flower appearance was noticed in bitter gourd scions treated with distilled water (T_{11}) (26.00) and grafted on pumpkin rootstock using wedge grafting method during *rabi* season (2019-20) (Table 15).

However, pooled data showed significant and lesser number of nodes to first female flower appearance in bitter gourd scions treated with IBA @ 50 ppm (T_4) (18.04) and it was at par with bitter gourd scions treated with IBA @ 25 ppm and GA_3 @ 50 ppm (T_3 & T_2) (18.50 & 18.84) grafted on pumpkin rootstock using wedge grafting method and maximum number of nodes (25.00) to first female flower appearance in bitter gourd scions treated with distilled water (T_{11}) and grafted on pumpkin rootstock using wedge grafting method (Table 15).

4.2.1.9 Average fruit weight (g)

Fruit weight is the direct indicator of yield potential. The average weight of fruits recorded in *kharif* (2018-19) and *rabi* (2019-20) was illustrated in table 16.

Significant and maximum average fruit weight (112.50 & 117.00 g) was noticed in bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by bitter gourd scions treated with IBA @ 25 ppm (T_3) (103.53 & 107.43 g) and minimum average fruit weight in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) (49.80 & 57.34 g) grafted on pumpkin rootstock using wedge grafting method during both *kharif* (2018-19) and *rabi* (2019-20) respectively (Table 16).

The results of pooled data indicated, highest value for average weight of five fruits (114.75 g) in bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by bitter gourd scions treated with IBA @ 25 ppm (T_3) (105.48 g) and lowest value in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) (53.57 g) grafted on pumpkin rootstock using wedge grafting method (Table 16).

4.2.1.10 Fruit length (cm)

A glance of the results presented in table 16 on fruit length was also found to be significant during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20).

Significant and maximum fruit length was observed in bitter gourd scions treated with IBA @ 50 ppm (T_4) (22.53 cm) and it was similar with bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (19.35 cm) whereas, bitter gourd scions treated with coconut milk @ 10.0 % (T_8) showed minimum length of fruit (15.00 cm) which was at par with bitter gourd scions treated with cow urine @ 1.5 % (T_6) (16.50 cm) grafted on pumpkin rootstock using wedge grafting method during *kharif* season (2018-19).

During *rabi* season (2019-20), maximum fruit length (19.77 cm) was observed in bitter gourd scions treated with IBA @ 50 ppm (T_4) and it was at par with bitter gourd scions treated with GA_3 @ 50 and 25 ppm (T_2 & T_1) and minimum fruit length was observed in bitter gourd scions treated with coconut milk @ 10.0 per cent (T_8) (15.88 cm) and grafted on pumpkin rootstock using wedge grafting method.

However, pooled data showed maximum fruit length (21.15 cm) in bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (18.88 cm) and minimum fruit length (15.44 cm) was observed in bitter gourd scions treated with coconut milk @ 10.0 per cent (T_8) and grafted on pumpkin rootstock using wedge grafting method (Table 16).

4.2.1.11 Fruit girth (mm)

A significant difference among the treatments was observed for girth of fruit during both crop seasons (2018-19 and 2019-20) (Table 16).

Significant and maximum fruit girth (42.10 & 41.17 mm) was noticed in bitter gourd scions treated with IBA @ 50 ppm (T_4) and it was similar with bitter gourd scions treated with coconut milk @ 10.0 per cent, distilled water and IBA @ 25 ppm (T_8, T_{11} & T_3) whereas minimum fruit girth (22.53 & 24.73 mm) was observed in bitter gourd scions treated with coconut milk @ 20.0 and cow urine @ 2.0 per cent (T_{10} &T_7) grafted on pumpkin rootstock during both the crop seasons (2018-19 & 2019-20).

The results of pooled data presented in Table 16 revealed highest value for fruit girth (41.64 mm) in bitter gourd scions treated with IBA @ 50 ppm (T_4) and it was at par with T_8, T_{11}, T_3 whereas minimum fruit girth (25.68 mm) was observed in bitter gourd scions treated with coconut milk @ 20.0 per cent (T_{10}) grafted on pumpkin rootstock using wedge grafting method (Table 16).

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

Plate 16. Influence of growth regulator on fruit character of bitter gourd grafted on pumpkin root stock (*Kharif*, 2018-19)

Table 16: Effect of growth regulators and organic promoters on average fruit weight, length and girth of bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatment	Average fruit weight (g)			Length of the fruit (cm)			Girth of the fruit (mm)		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	80.00	77.25	78.63	19.35	18.40	18.88	29.58	28.95	29.26
T_2	67.00	71.12	69.06	17.00	18.67	17.83	35.03	29.98	32.50
T_3	103.50	107.45	105.48	19.00	18.00	18.50	39.71	37.58	38.64
T_4	112.50	117.00	114.75	22.53	19.77	21.15	42.10	41.17	41.64
T_5	77.88	85.45	81.66	17.05	16.13	16.59	38.08	25.01	31.54
T_6	69.89	71.00	70.45	16.50	16.10	16.30	34.54	24.83	29.69
T_7	49.80	57.34	53.57	17.10	16.17	16.64	38.25	24.73	31.49
T_8	77.75	79.34	78.55	15.00	15.88	15.44	41.21	40.03	40.62
T_9	74.75	70.75	72.75	17.65	16.61	17.13	38.71	37.90	38.30
T_{10}	97.65	90.45	94.05	19.30	17.66	18.48	22.53	28.83	25.68
T_{11}	94.75	84.00	89.38	19.05	15.99	17.52	40.73	39.23	39.98
SEm ±	2.68	2.96	2.72	1.02	0.48	0.65	0.96	1.48	0.96
CD at 5 %	8.46	9.31	8.56	3.22	1.52	2.05	3.04	4.66	3.02
CV (%)	4.61	5.05	4.65	7.96	3.97	5.20	3.74	6.42	3.94

DAG- Days after grafting

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm

T_2- Bitter gourd scions treated with GA_3 @ 50 ppm

T_3-Bitter gourd scions treated with IBA @ 25 ppm

T_4- Bitter gourd scions treated with IBA @ 50 ppm

T_5- Bitter gourd scions treated with cow urine @ 1.0 %

T_6-Bitter gourd scions treated with cow urine @ 1.5 %

T_7- Bitter gourd scions treated with cow urine @ 2.0 %

T_8- Bitter gourd scions treated with coconut milk @ 10.0 %

T_9-Bitter gourd scions treated with coconut milk @ 15.0 %

T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %

T_{11}- Bitter gourd scions treated with distilled water (control)

4.2.1.12 Yield per vine (kg)

A perusal data presented in table 17 on fruit yield per vine recorded during two crop seasons of *kharif* and *rabi* (2018-19 and 2019-20) was found to be significant.

Significant and maximum fruit yield (4.01 & 3.90 kg) was recorded by bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by bitter gourd scions treated with IBA @ 25 ppm (T_3) (3.11 & 3.22 kg) grafted on pumpkin rootstock using wedge grafting method and lowest yield (1.50 &1.72 kg) was observed in bitter gourd scions treated with cow urine @ 2.0 % (T_7) during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20).

The pooled data showed significant and maximum fruit yield (3.95 kg) in bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by bitter gourd scions treated with IBA @ 25 ppm (T_3) (3.16 kg) and lowest yield (1.61 kg) in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) grafted on pumpkin rootstock.

4.2.1.13 Yield per hectare (t)

There was a significant difference noticed among the treatments for yield per hectare in both the years (2018-19 and 2019-20) and presented in Table 17. Significant and maximum fruit yield per hectare (22.08 & 21.47 t) was observed in bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by bitter gourd scions treated with IBA @ 25 ppm (T_3) (17.12 & 17.75 t) and minimum fruit yield (8.24 & 9.48 t) in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) grafted on pumpkin rootstock during both the *kharif* and *rabi* (2018-19 & 2019-20) season respectively.

The results of pooled data presented in table 17 showed maximum yield (21.77 t) in bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by bitter gourd scions treated with IBA @ 25 ppm (T_3) (17.43 t) and lowest fruit yield (8.86 t) in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) grafted on pumpkin rootstock using wedge grafting method.

Table 17: Effect of growth regulators and organic promoters on yield per vine and yield per hectare of bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatment	Yield per vine (kg)			Yield/ha (t)		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	2.40	2.31	2.36	13.23	12.74	12.98
T_2	2.01	2.14	2.07	11.08	11.77	11.42
T_3	3.11	3.22	3.16	17.12	17.75	17.43
T_4	4.01	3.90	3.95	22.08	21.47	21.77
T_5	2.34	2.57	2.45	12.87	14.14	13.50
T_6	2.10	2.13	2.11	11.55	11.74	11.64
T_7	1.50	1.72	1.61	8.24	9.48	8.86
T_8	2.33	2.38	2.36	12.84	13.12	12.98
T_9	2.25	2.13	2.19	12.38	11.71	12.04
T_{10}	2.95	2.72	2.83	16.12	14.97	15.56
T_{11}	2.84	2.52	2.68	15.65	13.89	14.77
SEm ±	0.19	0.20	0.09	1.07	1.08	0.49
CD at 5 %	0.61	0.62	0.29	3.37	3.42	1.55
CV (%)	10.87	11.04	5.07	10.85	11.04	5.00

DAG- Days after grafting
T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5.0 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

4.2.2 Physiological parameters

4.2.2.1 Number of leaves per vine

The observation on number of leaves per vine recorded at 30, 45 and 60 days after grafting (DAG) was found to be significant during both *kharif* and *rabi* (2018-19 & 2019-20) (Table 18).

30 Days after grafting

During 2018-19 (*Kharif* season), number of leaves per vine at 30 days after grafting (DAG) was ranged from 9.33 to 15.83. Among the different treatments bitter gourd scions treated with GA_3 @ 25 ppm recorded maximum number of leaves per vine (T_1) (15.83) and it was at par with bitter gourd scions treated with IBA @ 50 ppm, GA_3 @ 50 ppm and coconut milk @ 20. 0 per cent (T_4, T_2 & T_{10}) and grafted on pumpkin rootstock using wedge grafting method. Whereas, minimum number of leaves per vine was recorded by bitter gourd scions treated with cow urine @ 2.0 % (T_7) (9.33).

Similar trend was also observed during *rabi* season (2019-20). Significant and maximum number of leaves per vine was observed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (14.84) and it was at par with bitter gourd scions treated with IBA @ 50 ppm (T_4) (14.17) and coconut milk @ 20.0 per cent (T_{10}). Whereas, minimum number of leaves per vine was observed in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) (10.50) grafted on pumpkin rootstock using wedge grafting method.

However, pooled data showed maximum number of leaves per vine in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (15.34) and it was similar with bitter gourd scions treated with IBA 50 ppm, GA_3 @ 50 ppm and coconut milk @ 20.0 per cent (T_4, T_2 & T_{10}). Whereas, minimum number of leaves per vine was noticed in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) (9.92) and grafted on pumpkin rootstock using wedge grafting method (Table 18).

Table 18: Effect of growth regulators and organic promoters on number of leaves per graft of bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatment	Number of leaves (no.)								
	30 DAG			45 DAG			60 DAG		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	15.83	14.84	15.34	96.01	94.33	95.17	188.50	186.82	187.66
T_2	14.51	13.50	14.01	61.00	56.01	58.51	138.67	141.68	140.18
T_3	12.34	12.83	12.59	60.50	65.66	63.08	126.34	127.50	126.92
T_4	14.67	14.17	14.42	65.33	59.66	62.50	146.50	144.83	145.67
T_5	10.50	12.50	11.50	35.01	37.01	36.01	109.84	111.84	110.84
T_6	11.33	12.34	11.84	32.67	37.68	35.18	78.67	87.68	83.18
T_7	9.33	10.50	9.92	33.83	39.00	36.42	66.17	71.34	68.76
T_8	12.67	13.00	12.84	55.50	56.16	55.83	98.50	105.16	101.83
T_9	11.33	13.17	12.25	49.00	54.34	51.42	104.84	122.68	113.76
T_{10}	14.00	13.33	13.67	69.50	71.67	70.59	133.17	147.00	140.08
T_{11}	10.67	11.83	11.25	35.34	36.50	35.92	99.34	84.50	91.92
SEm ±	0.73	0.53	0.54	3.75	3.08	2.02	7.57	7.54	4.34
CD at 5 %	2.29	1.66	1.70	11.82	9.71	6.36	23.84	23.77	13.67
CV (%)	8.23	5.76	6.03	9.83	7.88	5.23	9.12	8.82	5.15

DAG- Days after grafting

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with distilled water (control)

45 Days after grafting

Significant and maximum number of leaves per vine at 45 days after grafting was observed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (96.01 & 94.33) and minimum number of leaves per vine was observed in bitter gourd scions treated with cow urine @ 1.5 per cent and distilled water (T_6 & T_{11}) (32.67 & 36.50) grafted on pumpkin rootstock using wedge grafting method during both *kharif* and *rabi* (2018-19 & 2019-20) season respectively (Table 18).

However, pooled data revealed maximum number of leaves in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (95.17) and minimum number of leaves in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) (35.18) grafted on pumpkin rootstock using wedge grafting method (Table 18).

60 DAG

Significant and maximum number of leaves per vine at 60 days after grafting was noticed in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (188.50 & 186.82) and minimum number of leaves per vine was observed in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) (66.17 & 71.34) grafted on pumpkin rootstock using wedge grafting method during both *kharif* and *rabi* (2018-19 & 2019-20) season respectively (Table 18).

The results of pooled data depicted in table 18 revealed maximum number of leaves per vine in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) (187.66) followed by bitter gourd scions treated with IBA @ 50 ppm (T_4) (145.65) and minimum number of leaves was noticed in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) (68.76) grafted on pumpkin rootstock using wedge grafting method.

4.2.2.2 Leaf area (cm^2)

The observations on leaf area as influenced by different treatments recorded at 30, 45 and 60 days after grafting (DAG) was presented in Table 19.

30 Days after grafting

Significant and maximum leaf area was recorded in bitter gourd scions treated with IBA @ 50 ppm (T_4) (1630.86 and 1615.47 cm^2) and minimum leaf area was

Table 19: Effect of growth regulators and organic promoters on leaf area of bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatment	Leaf area (cm^2)								
	30 DAG			45 DAG			60 DAG		
	2018-19	2019-20	Mean	2018-19	2019-20	Mean	2018-19	2019-20	Mean
T_1	1531.11	1518.10	1524.60	8415.22	7908.98	8162.10	9650.27	8890.00	9270.14
T_2	1023.56	1006.27	1014.92	9545.34	9039.86	9292.60	9877.50	9146.77	9512.14
T_3	927.56	904.87	916.22	9245.68	8700.31	8972.99	9740.98	9000.69	9370.83
T_4	1630.86	1615.47	1623.17	9908.85	9300.50	9658.45	9999.34	9408.05	9703.69
T_5	637.80	610.25	624.03	8620.51	8099.86	8360.18	9121.37	8380.71	8751.04
T_6	564.89	557.89	561.39	5753.21	5237.89	5495.55	6213.97	5481.65	5847.81
T_7	629.80	610.25	620.03	7886.41	7366.19	7626.30	8086.43	7346.21	7716.32
T_8	821.34	808.98	815.16	7855.02	7335.52	7595.27	8794.23	8060.23	8427.23
T_9	644.09	617.48	630.78	7651.29	7141.55	7396.42	9240.48	8500.73	8870.60
T_{10}	997.56	975.24	986.40	8722.06	8212.78	8467.42	9559.15	8800.85	9180.00
T_{11}	1005.56	967.67	986.62	5805.98	5294.71	5550.35	7105.20	6400.93	6753.06
SEm±	3.14	4.96	3.68	9.42	2.86	4.72	9.22	6.47	5.92
CD at 5 %	9.88	15.63	11.60	29.69	9.03	14.88	29.04	20.40	18.64
CV (%)	0.47	0.76	0.56	0.16	0.05	0.08	0.15	0.11	0.10

DAG- Days after grafting

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with distilled water (control)

noticed in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) (564.89 & 557.89 cm^2) and grafted on pumpkin rootstock using wedge grafting method during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20).

Pooled data presented in table 19 indicated significant and maximum leaf area (1623.17 cm^2) in bitter gourd scions treated with IBA @ 50 ppm (T_4) and minimum leaf area (561.39 cm^2) was noticed in bitter gourd scions treated with cow urine @ 1.5 % (T_6) and grafted on pumpkin rootstock using wedge grafting method.

45 Days after grafting

Significant and maximum leaf area was recorded in bitter gourd scions treated with IBA @ 50 ppm (T_4) (9908.85 & 9300.50 cm^2) and minimum leaf area in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) (5753.21 & 5237.89 cm^2) grafted on pumpkin rootstock using wedge grafting method during both *kharif* (2018-19) and *rabi* (2019-20) season (Table 19).

Combined data of two years showed maximum leaf area in bitter gourd scions treated with IBA @ 50 ppm (T_4) (9658.45 cm^2) and minimum leaf area in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) (5495.55 cm^2) grafted on pumpkin rootstock using wedge grafting method (Table 19).

60 Days after grafting

Significant and maximum leaf area at 60 days after grafting was also noticed in bitter gourd scions treated with IBA @ 50 ppm (T_4) (9999.34 & 9408.05 cm^2) and minimum leaf area was recorded in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) (6213.97 & 5481.65 cm^2) grafted on pumpkin rootstock using wedge grafting method during both *kharif* (2018-19) and *rabi* (2019-20) season respectively.

Pooled data revealed maximum leaf area (9703.69 cm^2) in bitter gourd scions treated with IBA @ 50 ppm (T_4) and minimum leaf area was observed in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) (5847.81 cm^2) grafted on pumpkin rootstock using wedge grafting method (Table 19).

4.2.2.3 Photosynthetic rate (µmol$Co_2m^{-2}S^{-1}$)

Photosynthetic rate recorded at 30 days after grafting was illustrated in table 20.

Significant and maximum photosynthetic rate was recorded in bitter gourd scions treated with IBA @ 50 ppm (T_4) (16.10 & 18.40 µmol$Co_2m^{-2}S^{-1}$) which was at par with bitter gourd scions treated with coconut milk @ 15.0 per cent (T_9) (15.08 & 16.92 µmol$Co_2m^{-2}S^{-1}$) and minimum photosynthetic rate was noticed in bitter gourd scions treated with cow urine @ 1.0 and 1.5 per cent (T_6) (4.10 & 8.10 µmol$Co_2m^{-2}S^{-1}$) and grafted on pumpkin rootstock using wedge grafting method during *kharif* and *rabi* (2018-19 & 2019-20) season respectively (Table 20).

Pooled data illustrated in table 20 revealed maximum photosynthetic rate in bitter gourd scions treated with IBA @ 50 ppm (T_4) (17.25 µmol$Co_2m^{-2}S^{-1}$) and it was at par with T_9 whereas minimum photosynthetic rate was noticed in bitter gourd scions treated with cow urine @ 1.5 per cent (T_6) (7.94 µmol$Co_2m^{-2}S^{-1}$) grafted on pumpkin rootstock using wedge grafting method.

4.2.2.4 Transpiration rate (mmol$H_2Om^{-2}s^{-1}$)

Significant difference among different treatments was also observed for transpiration rate recorded at 30 days after grafting during both the years (2018-19 & 2019-20) and depicted in table 20.

Significant and lowest transpiration rate was recorded in bitter gourd scions treated with IBA @ 50 ppm (T_4) (1.74 & 1.78 mmol$H_2Om^{-2}s^{-1}$) which was similar with bitter gourd scions treated with GA_3 @ 50 ppm, GA_3 @ 25 ppm and distilled water (T_2, T_1 & T_{11}) (2.21, 2.39, 2.68 & 2.51, 2.70, 2.64). Whereas, maximum transpiration rate was recorded in bitter gourd scions treated with coconut milk @ 10.0 per cent and cow urine @ 1.5 per cent (T_8 & T_6) (3.98 & 4.05 mmol$H_2Om^{-2}s^{-1}$) grafted on pumpkin rootstock using wedge grafting method during both the crop seasons of *kharif* and *rabi* (2018-19 & 2019-20) respectively.

However, pooled data recorded lowest value for transpiration rate in bitter gourd scions treated with IBA @ 50 ppm (T_4) (1.76 mmol$H_2Om^{-2}s^{-1}$) which was at par with bitter gourd scions treated with GA_3 @ 50 and 25 ppm and with distilled water (T_2, T_1 & T_{11}) (2.36, 2.54 & 2.66) and highest value in bitter gourd scions treated with coconut milk @ 20.0 per cent (T_{10}) (3.99 mmol$H_2Om^{-2}s^{-1}$) and grafted on pumpkin rootstock using wedge grafting method (Table 20).

4.2.2.5 Stomatal conductance to water (mol$H_2Om^{-2}s^{-1}$)

Stomatal conductance to water was recorded at 30 days after grafting and presented in table 20.

Significant and maximum stomatal conductance to water was noticed in bitter gourd scions treated with IBA @ 50 ppm (T_4) (0.42 & 0.46 mol$H_2Om^{-2}s^{-1}$) which was at par with T_{11}, T_9 and T_8 and grafted on pumpkin rootstock using wedge grafting method. Whereas lowest value was recorded in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) (0.01 & 0.11 mol$H_2Om^{-2}s^{-1}$**)** during *kharif* and *rabi* (2018-19 & 2019-20) season respectively (Table 20).

Pooled data recorded highest value for stomatal conductance in bitter gourd scions treated with IBA @ 50 ppm (T_4) (0.44) and lowest value in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) (0.10) grafted on pumpkin rootstock using wedge grafting method (Table 20).

4.2.3 Disease incidence

The grafted plants irrespective of the treatments did not show any symptoms of *Fusarium* and Bacterial wilt during the study period.

4.2.4.1 Economics

Economics of different treatments calculated during both the crop seasons (2018-19 & 2019-20) was found to be significant.

Significant and highest benefit cost ratio (4.29 & 4.20) was observed in bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by bitter gourd scions treated

Table 20: Effect of growth regulators and organic promoters on transpiration rate (E), stomatal conductance (gs) and photosynthetic rate (A) of bitter gourd grafted on pumpkin under protected environment (Shade net)

Treatment	Photosynthetic rate(A) ($\mu molCo_2m^{-2}s^{-1}$)			Transpiration rate(E) ($mmolH_2Om^{-2}s^{-1}$)			Stomatal conductance(gs) ($molH_2Om^{-2}s^{-1}$)		
	2018-19	**2019-20**	**Mean**	**2018-19**	**2019-20**	**Mean**	**2018-19**	**2019-20**	**Mean**
T_1	7.42	11.35	9.38	2.39	2.70	2.54	0.20	0.17	0.18
T_2	7.77	8.71	8.24	2.21	2.51	2.36	0.24	0.25	0.24
T_3	9.74	10.18	9.96	3.80	3.45	3.62	0.23	0.20	0.21
T_4	16.10	18.40	17.25	1.74	1.78	1.76	0.42	0.46	0.44
T_5	10.83	8.10	9.46	3.62	3.16	3.39	0.25	0.31	0.28
T_6	4.10	11.78	7.94	3.35	4.05	3.70	0.12	0.13	0.12
T_7	5.84	10.27	8.06	3.94	3.03	3.48	0.09	0.11	0.10
T_8	10.06	10.21	10.13	3.98	3.96	3.97	0.31	0.32	0.31
T_9	15.08	16.92	16.00	3.71	3.76	3.74	0.36	0.38	0.37
T_{10}	9.92	10.33	10.12	3.96	4.03	3.99	0.23	0.24	0.23
T_{11}	8.51	10.20	9.35	2.68	2.64	2.66	0.36	0.36	0.36
SEm ±	**1.03**	**1.62**	**1.13**	**0.33**	**0.41**	**0.21**	**0.04**	**0.05**	**0.01**
C.D at 5 %	**3.24**	**5.09**	**3.57**	**1.04**	**1.30**	**0.66**	**0.13**	**0.16**	**0.04**
CV (%)	**15.21**	**19.89**	**15.22**	**14.58**	**18.28**	**9.31**	**23.39**	**27.27**	**7.11**

DAG- Days after grafting

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3-Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6-Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9-Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

with IBA @ 25 ppm (T_3) whereas lowest benefit cost ratio (0.15 & 0.40) was noticed in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) grafted on pumpkin rootstock using wedge grafting method during *kharif* (2018-19) and *rabi* (2019-20) season respectively (Table 21).

The results on pooled data indicated highest benefit cost ratio (4.27) in bitter gourd scions treated with IBA @ 50 ppm (T_4) and lowest benefit cost ratio (0.26) in bitter gourd scions treated with cow urine @ 2.0 per cent (T_7) grafted on pumpkin rootstock using wedge grafting method (Table 22).

Table 21: Benefit cost ratio of bitter gourd production through grafting by treating with different growth regulators (2018-2019 & 2019-2020)

Treatments	No. of grafted plants	No. of survived plants		Fixed cost (A) (Rs. / 10 grafts)	Variable cost (B) (Rs. / 10 grafts)	Total cost (Rs. / 10 grafts)	Yield per treatment (kg)		Gross Income (Rs.)		Net Returns (Rs.)		Returns /Rs. invested	
		2019	2020				2019	2020	2019	2020	2019	2020	2019	2020
T_1	10.00	7.50	7.70	73.50	217.50	291.28	18.00	17.80	720.00	712.00	428.72	420.28	1.47	1.44
T_2	10.00	9.50	9.30	73.50	217.50	291.28	19.10	19.90	764.00	796.00	472.72	504.72	1.60	1.73
T_3	10.00	7.70	8.50	73.50	220.25	293.75	23.95	27.37	958.00	1094.80	664.25	801.05	2.26	2.72
T_4	10.00	9.70	9.80	73.50	220.25	293.75	38.90	38.22	1556.00	1528.80	1262.25	1235.05	4.29	4.20
T_5	10.00	7.05	6.90	73.50	216.50	290.00	16.50	17.73	660.00	709.20	370.00	419.20	1.28	1.45
T_6	10.00	6.60	6.60	73.50	216.50	290.00	13.86	14.10	554.40	564.00	264.40	274.00	0.91	0.94
T_7	10.00	5.60	5.90	73.50	216.50	290.00	8.40	10.15	336.00	406.00	46.00	116	0.15	0.40
T_8	10.00	5.80	6.30	73.50	236.50	310.00	13.51	14.99	540.40	599.60	230.40	289.60	0.74	0.93
T_9	10.00	8.20	8.70	73.50	236.50	310.00	18.45	18.53	738.00	741.20	428.00	431.20	1.38	1.39
T_{10}	10.00	7.05	8.80	73.50	236.50	310.00	20.80	23.94	832.00	957.60	522.00	647.60	1.68	2.09
T_{11}	10.00	7.60	7.50	73.50	216.50	290.00	21.60	18.90	864.00	756.00	554.00	446.00	1.79	1.44

NB: Details of the variable and fixed costs are furnished in Appendix II.

Table 22: Benefit cost ratio of bitter gourd production through grafting and use of growth regulators (Pooled)

Treatments	No. of grafted plants	No. of survived plants	Fixed cost (A) (Rs. / 10 grafts)	Variable cost (B) (Rs. / 10 grafts)	Total cost (Rs. / 10 grafts)	Yield per treatment (kg)	Gross Income (Rs.)	Net Returns (Rs.)	Returns /Rs. invested
T_1	10.00	7.5	73.50	217.50	291.28	17.70	708.00	416.72	1.43
T_2	10.00	9.4	73.50	217.50	291.28	19.46	786.80	495.52	1.70
T_3	10.00	8.1	73.50	220.25	293.75	25.60	1024.00	730.25	2.49
T_4	10.00	9.8	73.50	220.25	293.75	38.71	1548.40	1254.65	4.27
T_5	10.00	7.02	73.50	216.50	290.00	17.20	688.00	398.00	1.37
T_6	10.00	6.60	73.50	216.50	290.00	13.93	557.20	267.20	0.92
T_7	10.00	5.70	73.50	216.50	290.00	9.18	367.20	77.00	0.26
T_8	10.00	6.08	73.50	236.50	310.00	14.35	574.00	264.00	0.85
T_9	10.00	8.4	73.50	236.50	310.00	18.40	753.20	443.20	1.43
T_{10}	10.00	7.9	73.50	236.50	310.00	22.36	894.40	584.40	1.89
T_{11}	10.00	7.5	73.50	216.50	290.00	20.10	804.00	494.00	1.59

NB: Details of the variable and fixed costs are furnished in Appendix II.

5. DISCUSSION

India is second largest producer of vegetable crops after China. In 2018-19, Indian acreage of vegetable cultivation is around 10.1 million hectare with an annual production 180.7 million tons with productivity of 17.8 tons per hectare (Anonymous, 2018). Grafting of vegetables is one of the tools for sustainable production by using resistant rootstocks. It reduces the dependence on agrochemicals, soil borne diseases like *fusarium* wilt, bacterial wilt, nematodes and also some foliar diseases. In recent years grafting of vegetables is also used to induce vigor, precocity, better yield, quality and to enhance tolerance against abiotic stresses and also to get off-season production by using desired rootstocks (Kumar and Kumar, 2017).

Cucurbits constitute the largest group of tropical vegetables grown extensively throughout India and other tropical and sub tropical regions of the world. There is high market demand for off-season vegetables. Cucurbits are continuously cultivated under prejudicial conditions (environments that are too cold, wet, or dry, or cool low light winter greenhouses). Continuous cropping can increase salinity, incidence of cucurbit pest and soil borne diseases (fusarium wilt, bacterial wilt and verticillium wilt) leading to severe crop loss. Chemical pest control is expensive and not always effective and can harm environment (Davis *et al.*, 2008). To overcome many of these problems an alternative technology is grafting. Although there are many literatures on cucurbit grafting but there are only few literatures found on the effect of growing environments and the use of growth regulators in grafting studies for better results.

Therefore the present study was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi, UHS, Bagalkot, Karnataka, to know the influence of growing environment and growth regulators on graft compatibility of cucurbits using wedge grafting method. The conclusions drawn based on the results obtained during the course of investigation have been discussed here under with light of relevant available literature.

5.1 Experiment I: Effect of growing environment on graft compatibility and graft success in cucurbits

5.1.1 Grafting Parameters

A trial on effect of growing environment on graft compatibility and graft success in cucurbits using wedge grafting method was conducted in two seasons *kharif* (2018-19) and *rabi* (2019-20). The observations on number of days taken for first and 50 per cent sprouting recorded significant differences among different rootstocks and scions tried. Minimum number of days to first and fifty per cent sprouting was noticed in snake gourd (R_3) followed by pumpkin (R_2) when used them as rootstocks (Fig. 1a & 2a). This may be due to early callus formation and wound healing due to faster cell multiplication and cell division at graft portion resulting in early sprouting. Whereas maximum number of days to first and fifty per cent sprouting was noticed in bottle gourd (R_1) which may be attributed to delayed callus formation and wound healing process.

Sprouting of grafted scion varied significantly in two species and ridge gourd (S_2) took minimum number of days to first sprouting compared to bitter gourd (S_1) (Fig. 1a & 2a). This is logically due to physiological conditions of juvenile and younger scions favored early callus formation due to higher cellular activity.

Among the interaction effects significant and minimum numbers of days were taken to first and fifty per cent sprouting in ridge gourd and bitter gourd grafted on snake gourd and pumpkin rootstocks (Fig. 1b & 2b) using wedge grafting method. This may be attributed due to synergistic effects of higher temperature and relative humidity inside the healing chamber and also high compatibility of scion and rootstock which ultimately helps in early callus formation due to higher cellular activity and early wound healing. These findings are in line with the results of earlier workers in different crops *viz.*, Kavya (2017) in black pepper and Khandekar *et al.* (2006) in nutmeg under Kerala condition.

Success in grafting depends on the identification of a compatible rootstock (RS) that promotes rapid formation of vascular connections between the rootstock and the scion, rapid resumption of root and shoot growth (Aloni *et al.*, 2008) and other factors such as size of scion and rootstock, culture condition, grafting method, tissue and

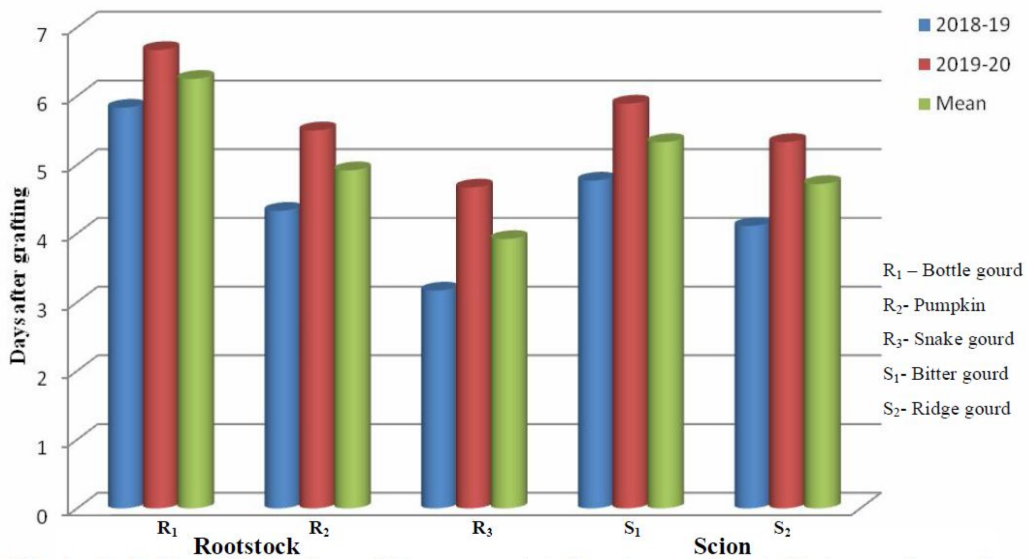


Fig. 1a: Individual effects of cucurbitaceous rootstocks scions on days to first sprouting under protected environment (Shade net)

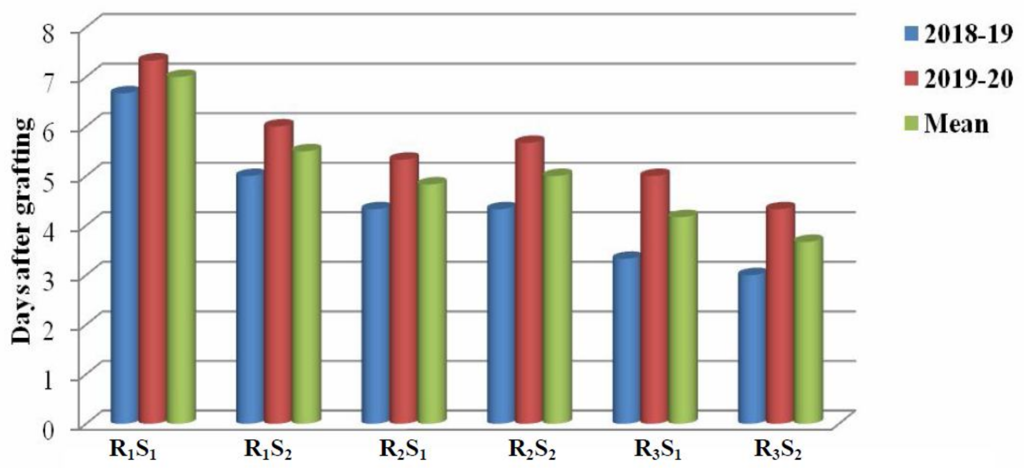


Fig. 1b: Interaction effects of cucurbitaceous rootstocks scions on days to first sprouting under protected environment (Shade net)

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R_1S_1 –Bitter gourd scions grafted on bottle gourd

R_2S_1- Bitter gourd scions grafted on pumpkin

R_3S_1- Bitter gourd scions grafted on snake gourd

R_1S_2- Ridge gourd scions grafted on bottle gourd

R_2S_2- Ridge gourd scions grafted on pumpkin

R_3S_2- Ridge gourd scions grafted on snake gourd

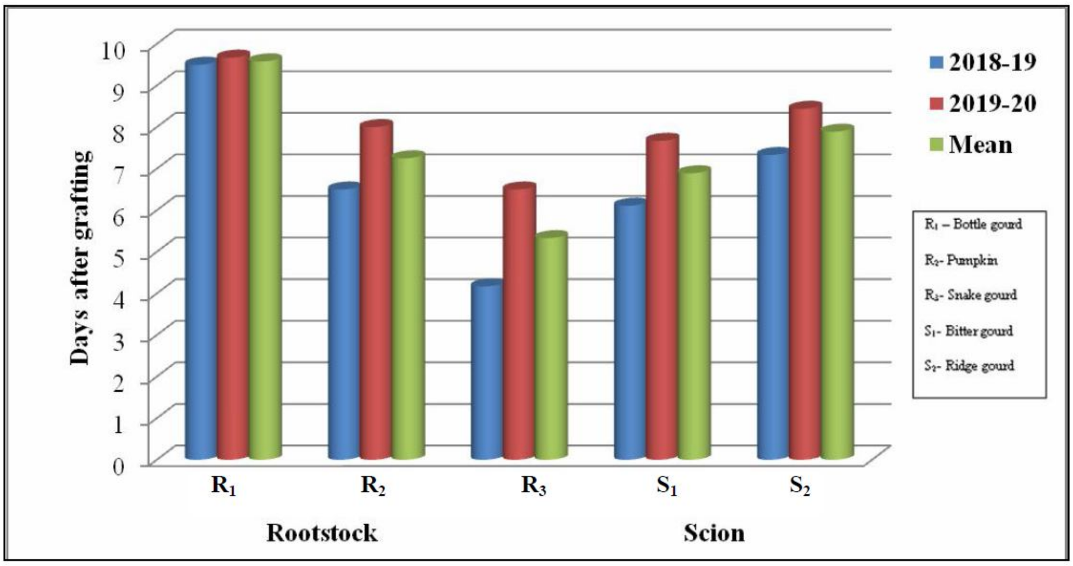

Fig. 2a: Individual Effects of cucurbitaceous root stock and scion on days to 50% sprouting

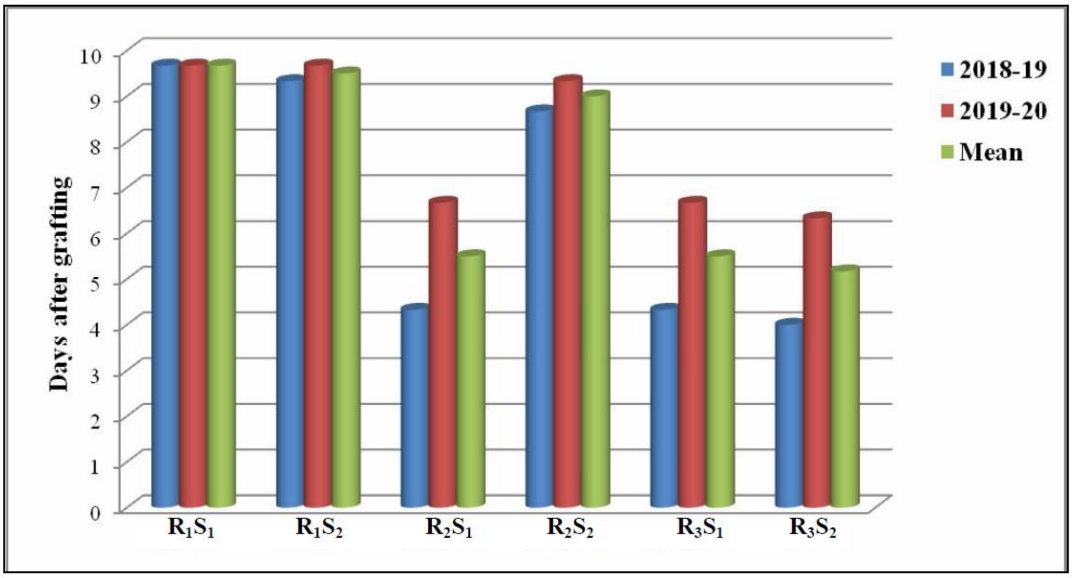

Fig. 2b: Interaction Effects of cucurbitaceous root stock and scion on days to 50% sprouting

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R_1S_1 –Bitter gourd scions grafted on bottle gourd
R_2S_1- Bitter gourd scions grafted on pumpkin
R_3S_1- Bitter gourd scions grafted on snake gourd
R_1S_2- Ridge gourd scions grafted on bottle gourd
R_2S_2- Ridge gourd scions grafted on pumpkin
R_3S_2- Ridge gourd scions grafted on snake gourd

structure differences, physiological and biochemical characteristics, growing stage of rootstock and scion, presence and activity of phytohormone. The environment also plays a major role on graft success (Davis *et al*., 2008). Although a rootstock material has good sprouting ability, it should have enough capacity of graft success when grafted with a scion. The success of grafting is also dependent upon the weather conditions and thus varies from region to region within a season. The seasonal influence could be ascribed to the influence of prevailing temperature and humidity (Davis and Veazie, 2006).

In the present study wedge grafting was done during *kharif* season (2018-19) using five cucurbitaceous rootstocks and five cucurbitaceous scions. The grafted plants were placed inside the healing chamber for healing of grafted plants. The humidity inside the healing chamber favor better success in graft which may help in forming callus bridge between scion and rootstock.

Among five cucurbitaceous rootstocks, stem diameter of sponge gourd rootstock did not matched with scions and therefore it was excluded from the present investigation. Whereas, watermelon, muskmelon and cucumber grafted on four different rootstocks were found incompatible (Fig. 3). This may be attributed to environmental factors, lack of skill of the grafter or premature death of either rootstock or scion due to incompatibility. Aloni *et al*. (2008) studied the physiological and biochemical changes in compatilible and incompatible *Cucurbita* rootstocks with a melon scion (*Cucumis melo* L. Arava) and the results suggests that a physical barrier is unlikely to be formed between the incompatible partners early after grafting, but that lower anti-oxidant enzyme activities and higher levels of reactive oxygen species (ROS) in the incompatible rootstock-scion interface may be responsible for degradation of the grafting zone and concluded that these changes are the primary factors for graft incompatibility or it may also be due to unequal diameters of both scion and rootstock to ensure maximum cambial contact between them. Incompatibility may also be due to chromosomal aberrations as studied by Ogure (1987) who concluded that the chromosomal aberrations may be the causes for wilting of plants in inter generic grafting of mulberry. Meanwhile, bitter gourd and ridge gourd scions grafted on bottle gourd, pumpkin and snake gourd rootstocks were found compatible and were used for further evaluation during two seasons of the experiment.

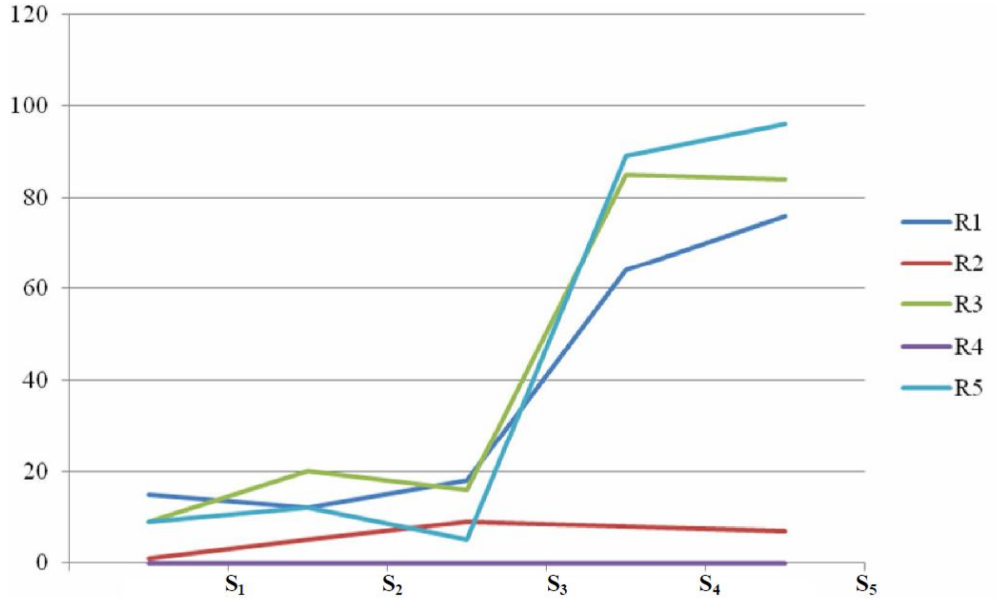
Percentage of graft success was assessed at 10 days after grafting (DAG) and the results on graft success revealed that among the different rootstocks, the graft success was more with snake gourd rootstock (R_3) followed by pumpkin (R_2) (Fig. 4a). Oda *et al.* (1993) revealed that maximum percentage of graft success in pumpkin may be due to larger number of vascular bundles which was assumed to increase the chance of contact between the vascular bundles at the cut surfaces of hypocotyls.

Among two scions ridge gourd (S_2) recorded maximum percentage of graft success when compared to bitter gourd (S_1) (Fig. 4a). This may be attributed to the fact that the survival rate of grafted plants was inversely correlated with the difference in diameters of scion and rootstock and number of vascular bundles positively affected the growth rate as observed by Yetisir and Sari (2004) in watermelon grafted on *Cucurbita* spp., *viz., Luffa cylindrica, Benincasa hispida* and *Lagenaria siceraria.*

Among the interaction effects of different scions and rootstocks, the maximum percentage of graft success was observed in ridge gourd and bitter gourd scions grafted with snake gourd and pumpkin rootstocks using wedge grafting method (Fig. 4b). These present findings are in line with the findings of many reporters (Tamilselvi and Pugalendhi, 2017; Akhila and George, 2017) in bitter gourd.

Compatibility between scion and rootstock was due to differentiation and re differentiation of callus tissue at the graft union followed by rapid connection between the vascular bundles of scion and rootstock subsequently secondary growth of scion (Shehata *et al.*, 2000). Grafting causes wound response at graft interface leading to formation of necrotic layer. As graft union heals, callus tissues are produced from undamaged, rapidly dividing parenchyma cells to internal necrotic layers. As these callus tissue multiply, they begin to absorb necrotic layer thus leads to formation of callus bridge between the scion and rootstock. This bridge allows the flow of xylem exudates between rootstock and scion tissue thereby increasing survival in graft combinations or it may also be due to same diameters of rootstock and scion in which the cambial layers are easily placed in contact with one another which may lead to strong and successful graft union as observed by Hartmann *et al.* (2002) in oregano.

Lowest percentage of graft success in both bitter gourd and ridge gourd scions grafted on bottle gourd rootstock may be attributed to unsuitable graft relations that can



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Rootstocks:	R_1-Bottle gourd	Scions:	S_1-Watermelon
	R_2 – Coccinia		S_2- Cucumber
	R_3-Pumpkin		S_3-Muskmelon
	R_4- Sponge gourd		S_4- Bitter gourd
	R_5- Snake gourd		S_5- Ridge gourd

Fig. 3: Compatibility of cucurbitaceous rootstocks and scions on graft success

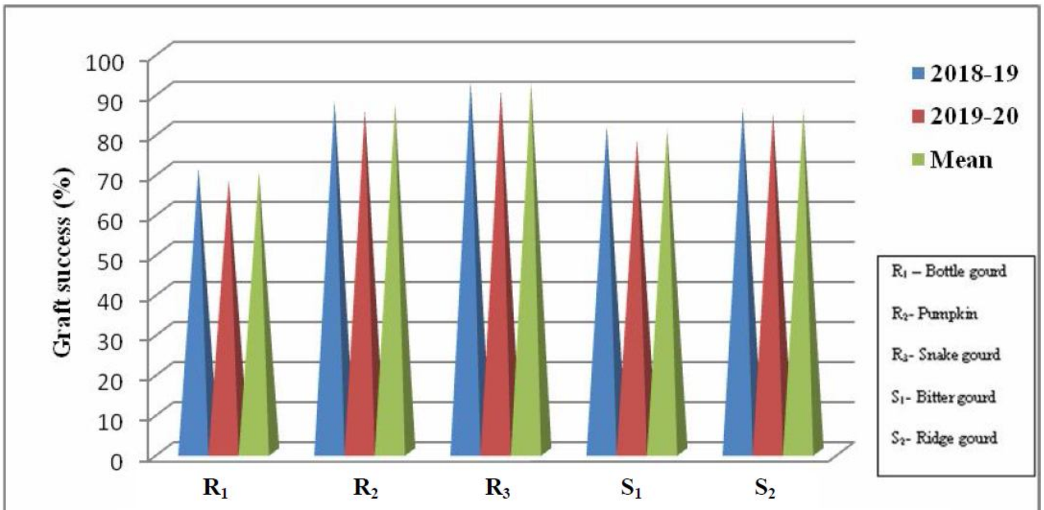

Fig. 4a: Individual effects of cucurbitaceous rootstocks scions on graft success at 10 days after grafting (DAG)

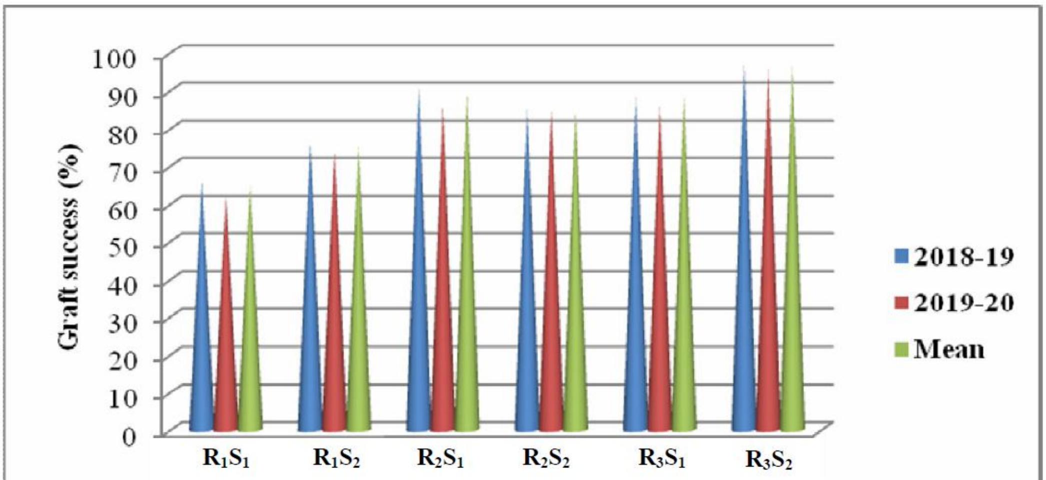

Fig. 4b: Interaction effects of cucurbitaceous rootstocks scions on graft success at 10 days after grafting (DAG)

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R_1S_1 –Bitter gourd scions grafted on bottle gourd
R_2S_1- Bitter gourd scions grafted on pumpkin
R_3S_1- Bitter gourd scions grafted on snake gourd
R_1S_2- Ridge gourd scions grafted on bottle gourd
R_2S_2- Ridge gourd scions grafted on pumpkin
R_3S_2- Ridge gourd scions grafted on snake gourd

induce undergrowth or overgrowth of the scion, which can lead to decreased water and nutrient flow through the graft union as observed by Hartmann *et al.* (1997).

Among two seasons the highest percentage of graft success was noticed during *kharif* (2018-19) than *rabi* (2019-20). Similar findings (Akhila and George, 2017) were also noticed in standardization of grafting in bitter gourd. The probable reasons may the fact that the temperature (30.70°C) and humidity (87.10 %) play important role that influence graft healing by callus formation (Hartmann *et al.*, 2002).

5.1.2 Vegetative and flowering parameters

Successful graft combinations were transplanted under open field and shade net condition 8 days after grafting (after healing). The sudden wilting of grafted plants under open field condition was observed 20 days after grafting (DAG). This may be due to sudden transplant shock or disease attack or climatic condition of the place which may not be suitable for cultivation of grafted plants under open field condition. Aloni *et al.* (2008) also reported that the disruption of rootstock–scion connections in grafted plants occurred approximately at 25 days after grafting. They proposed that the main cause for incompatibility is the occurrence of hormonal imbalance primarily of auxin and ethylene in the root system following the establishment of the grafting connections. They reported that exposure of the grafted transplants to high temperature regime (day/night, 32/28 °C) after grafting establishment resulted in substantial inhibition of root and shoot development and seedling collapse of the grafts. Several scientists reported that environmental conditions directly affect graft success. Davis *et al.* (2008) has reported that environment also plays a major role on graft success.

5.1.2.1 Sprout length (Vine length) of the scion (cm)

Sprout length of scion recorded at 10, 15, 20, 25, 30 and 40 days after grafting. The length of scion at 10 days after grafting was found non significant during both *kharif* (2018-19) and *rabi* (2019-20) seasons. The probable reason for this might be the slow growth at initial stage. Whereas, sprout length of the scion was found to be significant at 15, 20, 25, 30 and 40 days after grafting (DAG) (Fig. 5a & 5b).

Among different cucurbitaceous rootstocks, snake gourd (R_3) and pumpkin (R_2) recorded maximum vine length compared to bottle gourd (R_1) (Fig. 5a). This might be attributed to strong and vigorous root system of both pumpkin and snake gourd rootstocks which promoted growth (Davis *et al*., 2008).

With respect to scions, ridge gourd (S_2) recorded maximum vine length compared to bitter gourd (S_1) (Fig. 5a). These results might be attributed due to difference in nature of plant growth.

Among the interaction effects, ridge gourd recorded maximum vine length when grafted with snake gourd and pumpkin (R_3S_2, R_2S_2) rootstocks using wedge grafting method. Whereas bitter gourd recorded maximum vine length when it was grafted with pumpkin and snake gourd (R_2S_1, R_3S_1) rootstock using wedge grafting method (Fig. 5b). This may be due to strong and extended roots of both pumpkin and snake gourd which helps to absorb more water and nutrient elements leading to vigorous plant growth and also weather conditions like temperature and humidity which played important role in growth of grafts. Similar results were also reported by Tamilselvi and Pugalendhi (2017) in bitter gourd. Meanwhile, minimum vine length was noticed in bitter gourd and ridge gourd grafted with bottle gourd rootstock (R_1S_1, R_1S_2) (Fig. 5b). Minimum vine length shown by these graft combinations might be due to unsuitable graft relations leading to under growth or overgrowth of the scion due to decreased water and nutrient flow through graft union (Hartmann and Kester, 1997). Aloni *et al*. (2010) has also reported that endogenous plant hormones regulate the all aspects of vegetative growth and thus are believed to be important factors in root-shoot communication.

Vine length at initial 30 days after grafting was maximum during *kharif* season (2018-19) when compared to *rabi* season (2019-20) but at 40 days after grafting there was only 2.73 % difference found between two seasons. This clearly indicates that the rootstocks were more stable under different environmental conditions, giving nearly the same vegetative and fruit yield parameters. Similar findings were also observed by Mohamed *et al*. (2012) in watermelon.

5.1.2.2 Number of nodes per graft

The observation on number of nodes per graft per vine was recorded at 15, 30, 45 and 60 days after grafting (DAG) (Fig. 6a & 6b). A significant difference was found

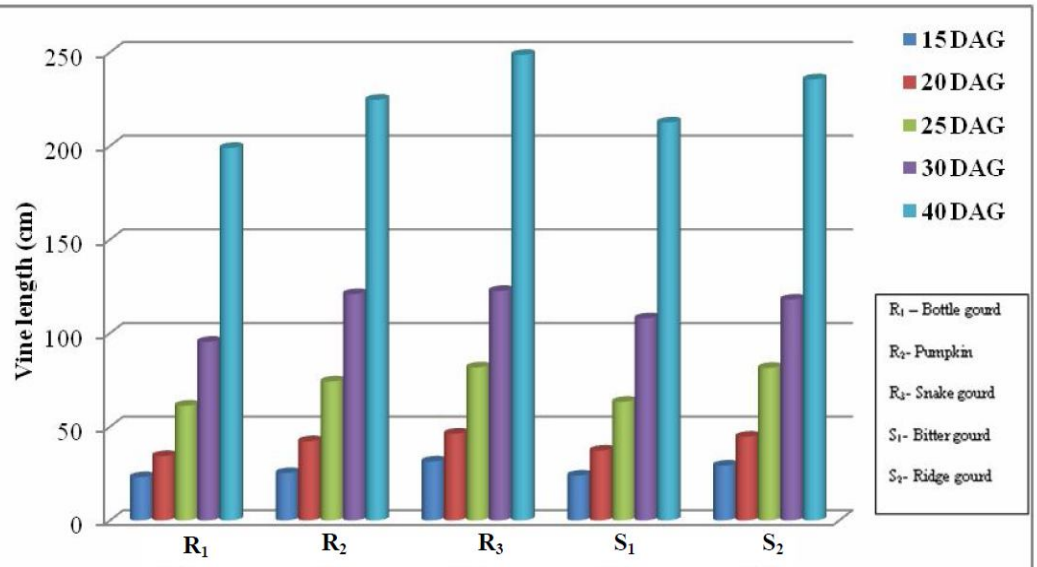

Fig. 5a: Individual effects of cucurbitaceous root stocks and scions on vine length (2018-19 and 2019-20)

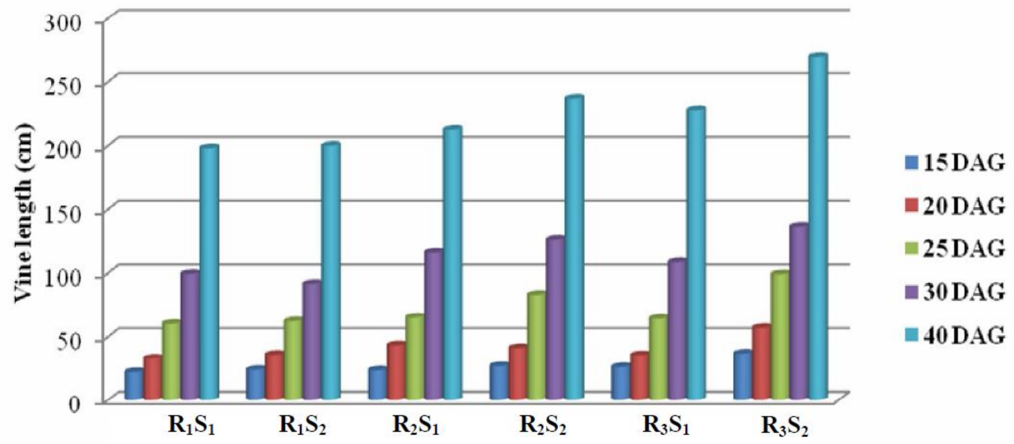

Fig. 5b: Interaction effects of cucurbitaceous root stocks and scions on vine length (2018-19 and 2019-20)

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R$_1$S$_1$ –Bitter gourd scions grafted on bottle gourd
R$_2$S$_1$- Bitter gourd scions grafted on pumpkin
R$_3$S$_1$- Bitter gourd scions grafted on snake gourd
R$_1$S$_2$- Ridge gourd scions grafted on bottle gourd
R$_2$S$_2$- Ridge gourd scions grafted on pumpkin
R$_3$S$_2$- Ridge gourd scions grafted on snake gourd

among different treatments except at 15 days after grafting (2018-19 & 2019-20). This might be due to slow growth at initial stage.

Significant and maximum number of nodes per graft per vine was observed in pumpkin (R_2) and snake gourd (R_3) (Fig. 6a) rootstock. This might be due to maximum vine length which leads to increased number of nodes per graft per vine and influence of stock on scion. Whereas, least number of nodes per graft per vine was noticed in bottle gourd (R_1) may be because of lesser vine length. This might be due to less compatible nature of rootstock on scion.

Among scions tested, bitter gourd (S_1) recorded maximum number of nodes per graft per vine compared to ridge gourd (S_2) (Fig. 6a). Lesser number of nodes in ridge gourd compared to bitter gourd is may be because of maximum distance between the two internodes and also due to genetic characters of each genotype.

With respect to interactive effects, bitter gourd scions grafted with pumpkin and snake gourd using wedge grafting method recorded maximum number of nodes per graft per vine (R_2S_1 & R_3S_1). Whereas, ridge gourd recorded maximum number of nodes per graft per vine when it was grafted with snake gourd and pumpkin rootstocks using wedge grafting method (R_3S_2 & R_2S_2) (Fig. 6b). Maximum vine length in these graft combinations were attributed maximum number of nodes per graft per vine. Meanwhile, minimum number of nodes per graft per vine was noticed when both bitter gourd and ridge scions were grafted with bottle gourd (R_1S_1 & R_1S_2) (Fig. 6b). The reason may be better graftage and transportation of nutrients for maximum vine length which attributed to maximum number of nodes and *vice-versa* for minimum nodes.

5.1.2.3 Initial and final girth of graft union (mm)

Initial girth of graft union recorded at 10, 20 and 30 (DAG) days after grafting was found to be non significant during both *kharif* (2018-19) and *rabi* (2019-20) seasons. The probable reason may be slow growth at initial stage.

With respect to final girth of graft union, recorded at 60 and 90 days after grafting was found to be significant in both the seasons (2018-19 & 2019-20) (Fig.7a & 7b).

Among the rootstocks, snake gourd (R_3) recorded maximum girth of graft union followed by pumpkin (R_2) and minimum girth of graft union by bottle gourd (R_1) (Fig. 7a). With respect to scions tried, bitter gourd recorded maximum stem girth compared to ridge gourd. The probable reason might be wider diameter and strong stem of snake gourd and pumpkin compared to bottle gourd with more number of vascular bundles (Yetisir and Sari, 2004).

The interaction effects were significant and maximum girth of graft union was noticed in bitter gourd scions grafted on snake gourd (R_3S_1) followed by bitter gourd scions grafted on pumpkin and ridge gourd scions grafted on snake gourd rootstock using wedge grafting method (R_2S_1 & R_3S_2) (Fig. 7b). Reserve food in both stock and scion helped in better plant growth by easy uptake of nutrients and minerals by stock plant which lead to quicker graft union and in turn resulted in higher stem girth and better graft survival. Similar results were also obtained by Kavya (2017) in black pepper, Punithaveni *et al.* (2014) in cucumber. Meanwhile, minimum girth of graft union was recorded by bitter gourd and ridge gourd scions grafted on bottle gourd rootstock (R_1S_1 & R_1S_2) (Fig. 7b).

5.1.2.4 Days to first flowering

In the present investigation the observation recorded on number of days taken for first female flower appearance was found to be significant in both *kharif* (2018-19) and *rabi* (2019-20) seasons.

Snake gourd rootstock (R_3) recorded less number of days to first female flower appearance followed by pumpkin (R_2) (Fig. 8a). This might be due to the effect of stock on scion.

With respect to scions, ridge gourd (S_2) took less number of days to first female flower appearance compared to bitter gourd (S_1) (Fig. 8a). This might be attributed to genetic characters of each genotype.

Among the interaction effects, ridge gourd took less number of days for first female flower appearance when it was grafted on snake gourd and pumpkin rootstock using wedge grafting method (R_3S_2 & R_2S_2). Whereas, bitter gourd took less number of days to first female flower appearance when grafted on snake gourd and pumpkin using

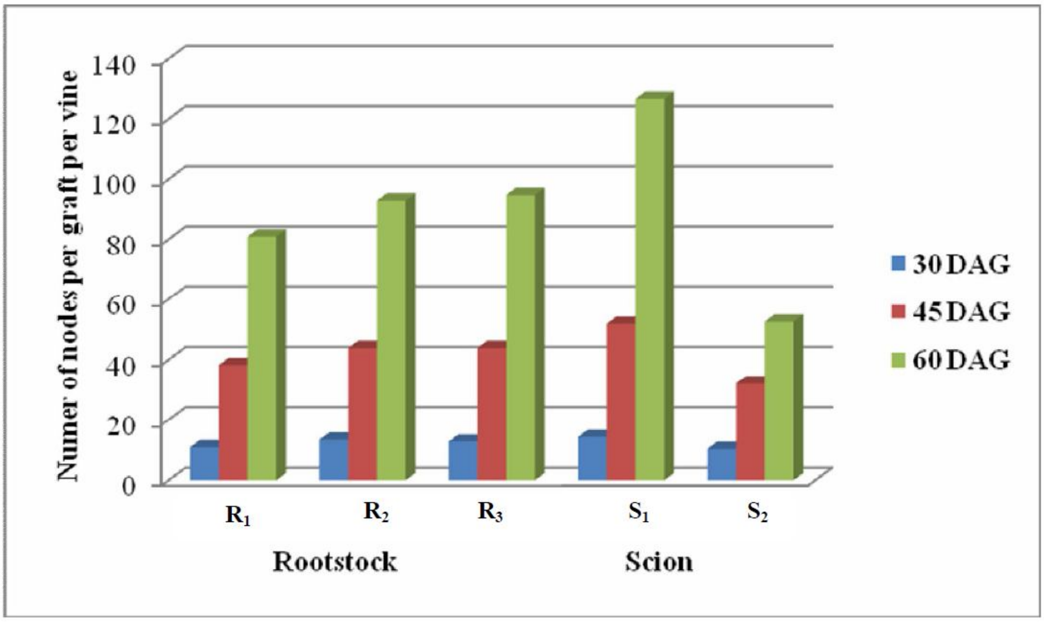

Fig. 6a: Individual effects of root stocks and scions on number of nodes per graft under protected environment (2018-19 and 2019-20)

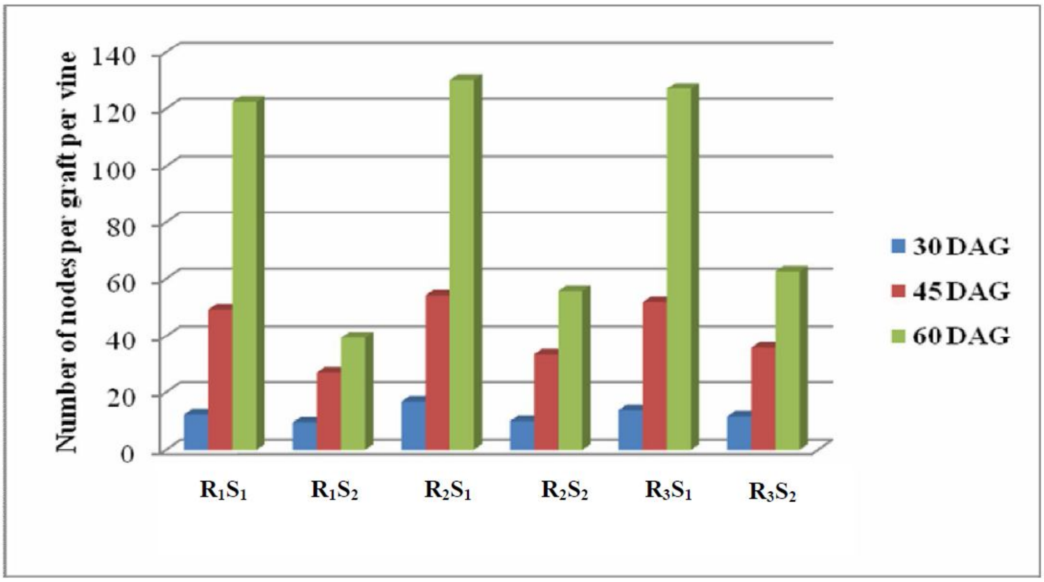

Fig. 6b: Interaction effects of root stocks and scions on number of nodes per graft under protected environment (2018-19 and 2019-20)

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R_1S_1 –Bitter gourd scions grafted on bottle gourd
R_2S_1- Bitter gourd scions grafted on pumpkin
R_3S_1- Bitter gourd scions grafted on snake gourd
R_1S_2- Ridge gourd scions grafted on bottle gourd
R_2S_2- Ridge gourd scions grafted on pumpkin
R_3S_2- Ridge gourd scions grafted on snake gourd

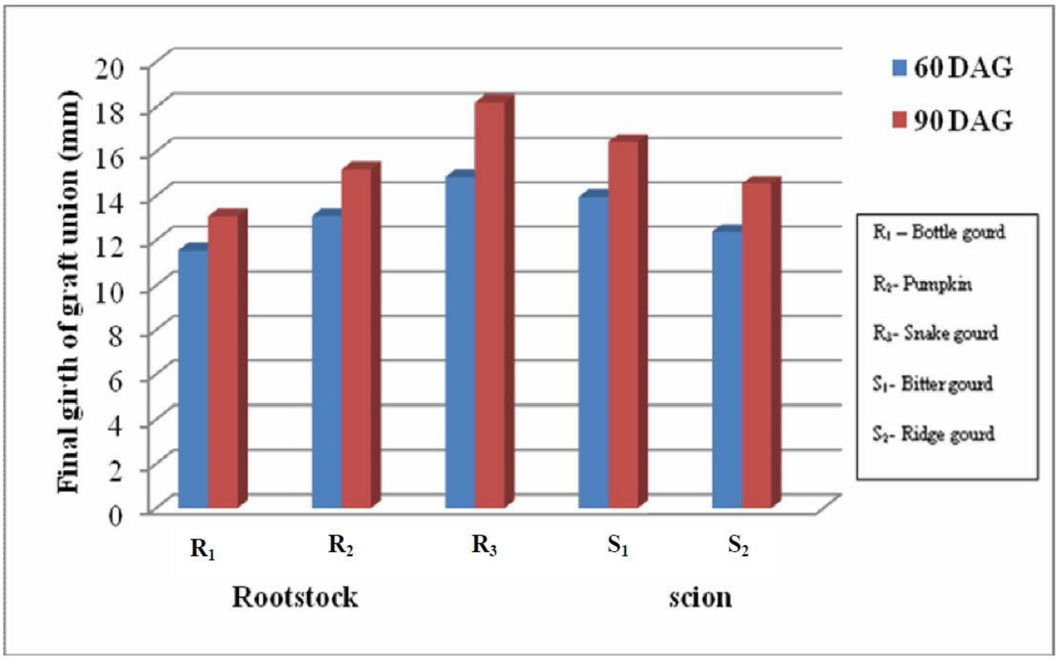

Fig. 7a: Individual effects of cucurbitaceous root stocks and scions on final girth of graft union (2018-19 and 2019-20)

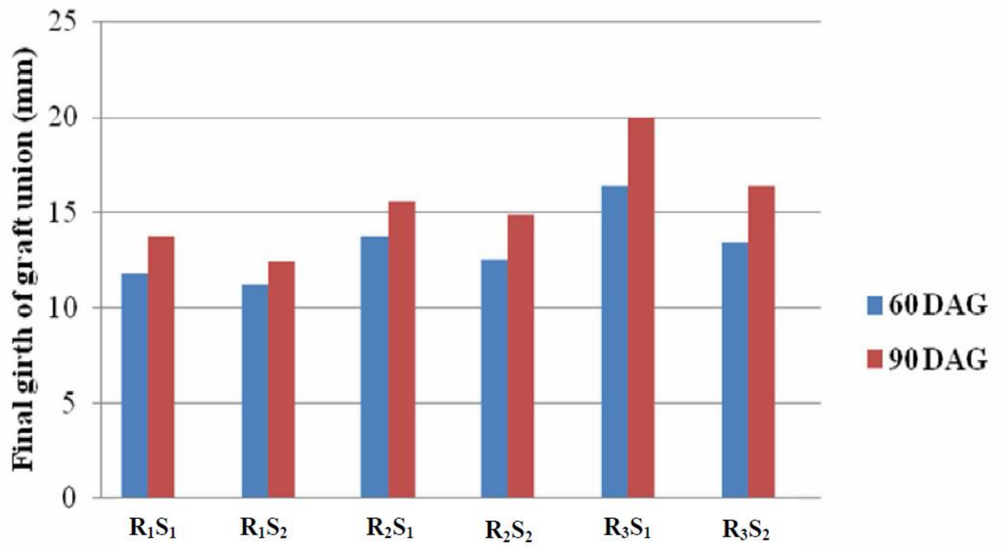

Fig. 7b: Interaction effects of cucurbitaceous root stocks and scions on final girth of graft union (2018-19 and 2019-20)

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R_1S_1 –Bitter gourd scions grafted on bottle gourd
R_2S_1- Bitter gourd scions grafted on pumpkin
R_3S_1- Bitter gourd scions grafted on snake gourd
R_1S_2- Ridge gourd scions grafted on bottle gourd
R_2S_2- Ridge gourd scions grafted on pumpkin
R_3S_2- Ridge gourd scions grafted on snake gourd

wedge grafting method (R_3S_1 & R_2S_1) (Fig. 8b). Usually number of days taken for first female flower appearance in grafted plants is higher than the ungrafted plants because of healing process of grafted plants which cause delayed flowering nearly by a week. The present results are in line with Tamilselvi and Pugalendhi (2017) who reported that the flowering was delayed in grafted plants when compared to non grafted plants and among different treatments bitter gourd scion Palee F_1 grafted on pumpkin took less number of days to first female flower appearance. Xu *et al*. (2005) reported that the differences in flower initiation are negligible when suitable temperatures occur at the beginning of the growing season, but with less than optimal conditions, grafting to these rootstocks can delay flowering for up to one week, resulting in an equal delay in fruit maturity. On the other hand Punithaveni (2015) revealed that early flowering of both male and female flowers in the grafted plants compared to non grafted scions except the scions grafted with bottle gourd and sponge gourd rootstocks. The scion NS 408 hybrid grafted onto fig leaf gourd and pumpkin rootstocks exhibited earliness with least days to first male and female flowering respectively. Sakata *et al*. (2007) stated that roots of grafts were different from the original roots of scions and inter-generic grafting might have altered the physiology of scions to induce early female flowering in watermelon grafted onto bottle gourd. The reason may be the rootstock-scion combination might have probably changed the concentration of plant hormones and therefore influenced sex expression and early flowering. There is also more role of environmental factors such as high temperature and high relative humidity will induce better success and *vice-versa* for poor performance.

5.1.2.5 Node number to first female flower appearance

Appearance of first female flower at earliest node was observed in snake gourd (R_3) followed by pumpkin (R_2) and appearance of first female flower at later nodes in bottle gourd (R_1) (Fig 9a). The probable reason might be influence of stock on scion for appearance of female flower at early nodes and *vice-versa*.

Among scions, appearance of first female flower at earliest node was noticed in ridge gourd (S_2) compared to bitter gourd (S_1) (Fig. 9a). This might be due to nature of plant growth and also due to genetic characters of each genotype.

With respect to interactive effects, ridge gourd produced female flower at early nodes grafted with snake gourd and pumpkin (R_3S_2 & R_2S_2) whereas bitter gourd produced female flower at earliest node when grafted with snake gourd and pumpkin rootstock using wedge grafting method (R_3S_1 & R_2S_1) (Fig 9b). Tamilselvi (2013) also reported flowering at earlier node when bitter gourd was grafted onto pumpkin rootstock. Punithaveni (2015) reported that the NS 408 hybrid scion on winter squash rootstock followed by NS 408 hybrid scion on pumpkin rootstocks gave the female flower appearance on the earlier nodes in cucumber. Meanwhile, both bitter gourd and ridge gourd produced flower at later nodes grafted with bottle gourd (R_1S_1 & R_1S_2). Aloni *et al*. (2010) reported that the plant hormones were important endogenous factors which regulate all aspects of vegetative and reproductive growth and thus were believed to be important players in root-shoot communication. The concept expands that the hormones are produced in one part of the plant and affect a remote part. According to this concept auxin which is produced in shoot apexes is translocated to the root where it affects root development, morphology and functioning. Auxin has also been shown to affect the production and activity of cytokinins which are known to be produced in the root and translocated to the shoot where they control important developmental processes such as shoot growth and productivity.

5.2 Experiment II: Effect of growth regulators on graft compatibility and yield of cucurbits

5.2.1 Grafting parameters

The results of the present study declared that, minimum number of days taken for first sprouting and fifty per cent sprouting was noticed in bitter gourd scions treated with GA_3 @ 50 ppm (T_2) followed by IBA @ 50 ppm (T_4) and coconut milk @ 10 per cent (T_8) (Fig. 10) and grafted on pumpkin rootstock using wedge grafting method. This may be attributed to better utilization of stored carbohydrates, nitrogen and other factors leading to early sprouting and subsequent growth of the plants. Whereas, maximum number of days taken for first and fifty per cent sprouting in bitter gourd scions treated with cow urine @ 1.0 and 2.0 per cent (T_5 & T_7) may be due to lack of growth promoting substances which might have resulted in delayed sprouting. Kavya (2017)

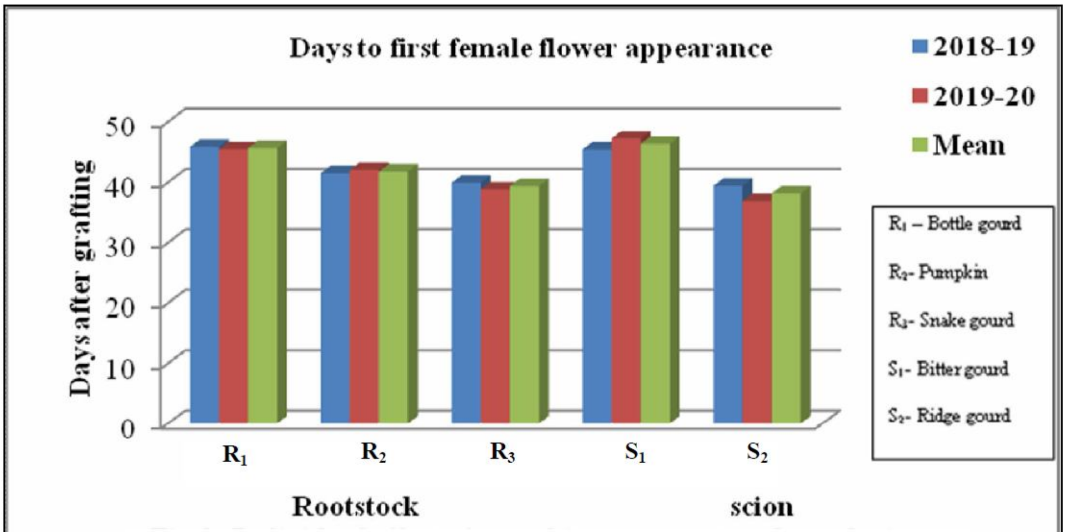

Fig. 8a: Individual effects of cucurbitaceous root stocks and scions on days to first female flower appearance

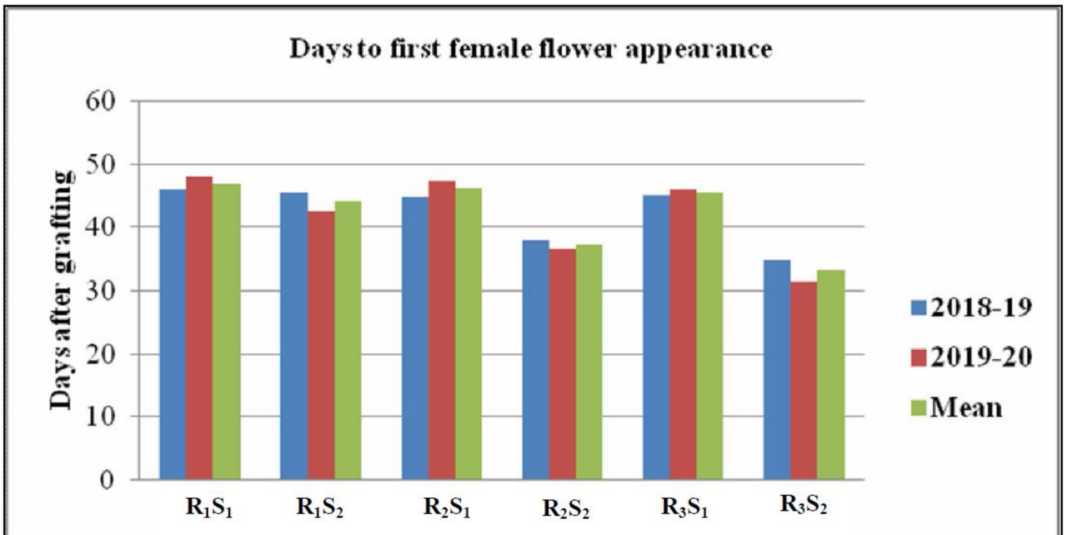

Fig. 8b: Interaction effects of cucurbitaceous root stocks and scions on days to first female flower appearance

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R_1S_1 –Bitter gourd scions grafted on bottle gourd
R_2S_1- Bitter gourd scions grafted on pumpkin
R_3S_1- Bitter gourd scions grafted on snake gourd
R_1S_2- Ridge gourd scions grafted on bottle gourd
R_2S_2- Ridge gourd scions grafted on pumpkin
R_3S_2- Ridge gourd scions grafted on snake gourd

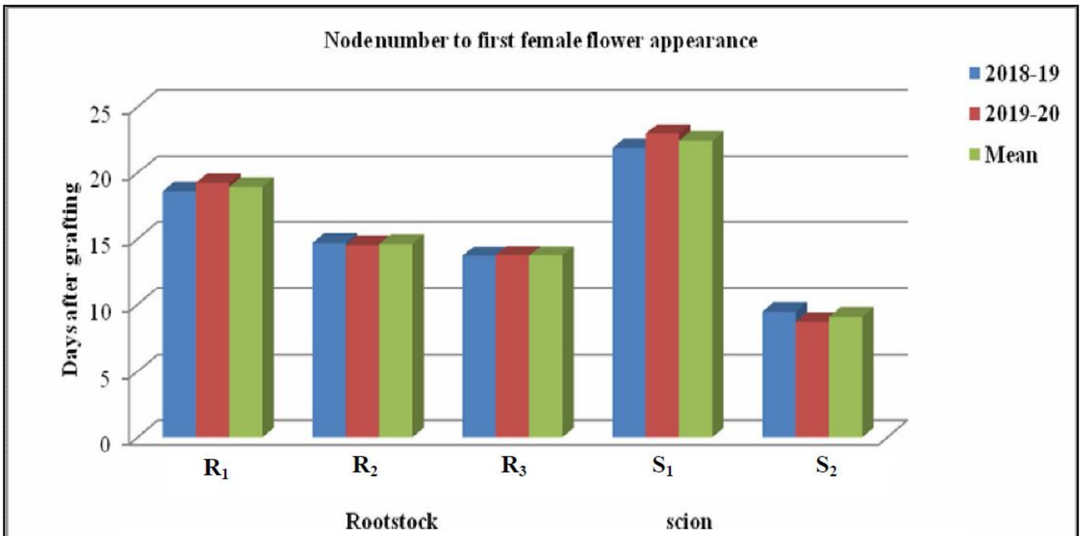

Fig. 9a: Individual effects of cucurbitaceous root stocks and scions on node number to first female flower appearance

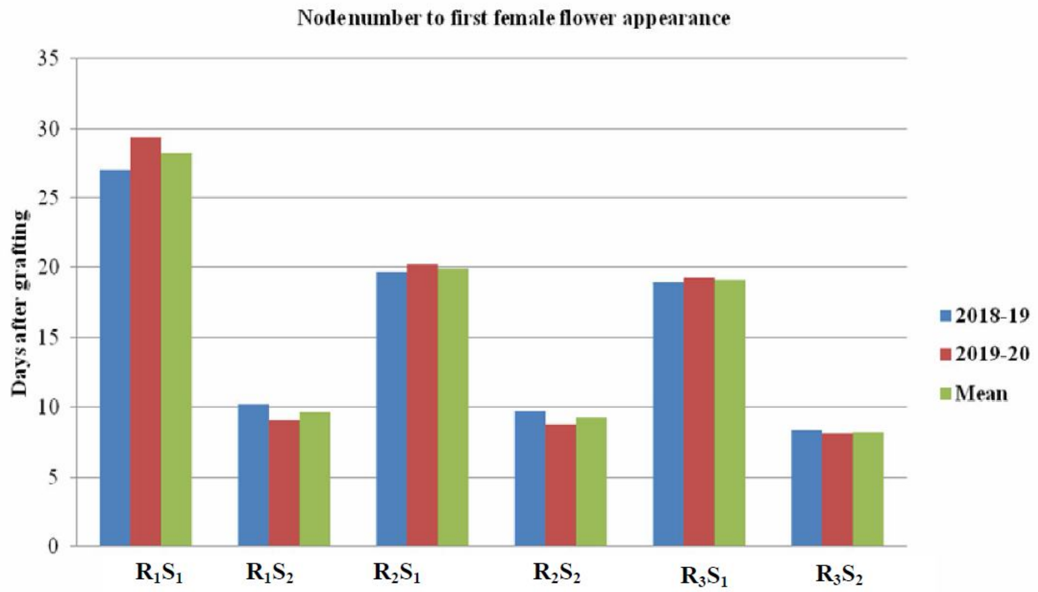

Fig. 9b: Interaction effects of cucurbitaceous root stocks and scions on node number to first female flower appearance

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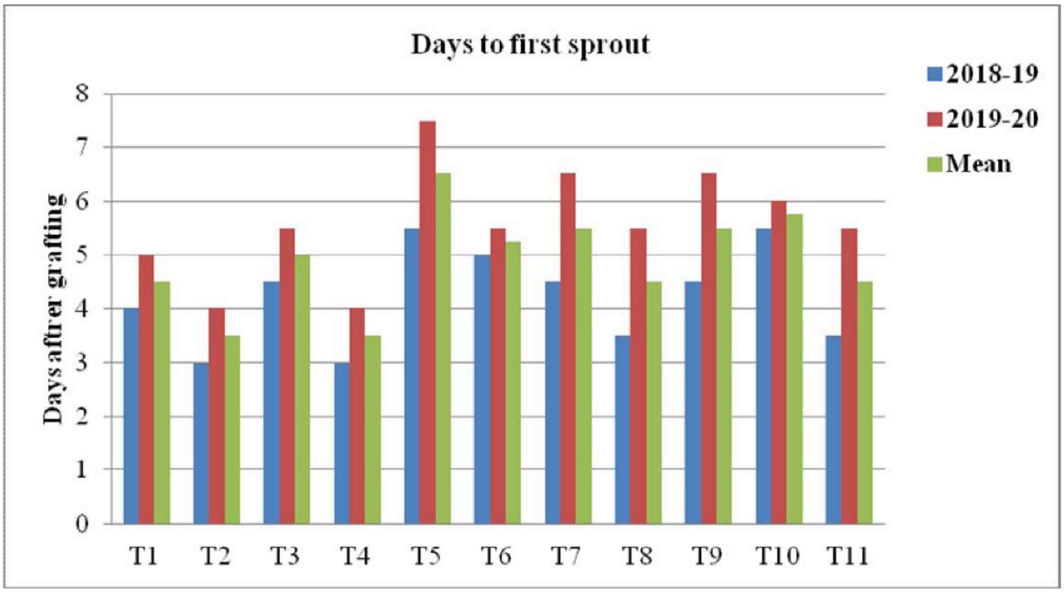
R_1S_1 –Bitter gourd scions grafted on bottle gourd
R_2S_1- Bitter gourd scions grafted on pumpkin
R_3S_1- Bitter gourd scions grafted on snake gourd
R_1S_2- Ridge gourd scions grafted on bottle gourd
R_2S_2- Ridge gourd scions grafted on pumpkin
R_3S_2- Ridge gourd scions grafted on snake gourd



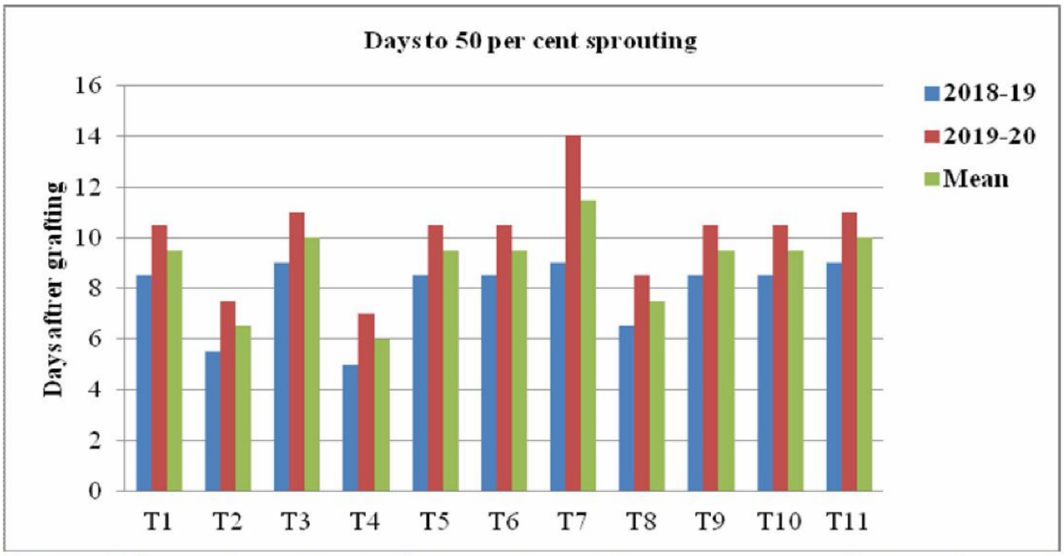


Fig 10: Effects of growth regulators and organic promoters on days to first and 50 % sprouting of bitter gourd grafted on pumpkin under protected environment

Index

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3- Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6- Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9- Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

who also reported that early as well as higher percentage of grafting success was recorded when scions treated with IBA @ 75 ppm in black pepper.

Among two different experimental seasons minimum number of days for first and 50 per cent sprouting was noticed during *kharif* (2018-19) when compared to *rabi* (2019-20). This may be attributed to the period of rainy months and higher temperature (30.70 °C) and relative humidity (87.10 %) which was congenial for sprouting as compared to *rabi* where temperature (25.12°C) and relative humidity (71.26 %) is usually lower. Hartman and Kester (1979) also suggested that temperature and humidity activates the cambial cells during mansoon.

Three cucurbitaceous species were selected as scion for the present investigation *viz.*, watermelon, muskmelon and bitter gourd. After treating these scions with different growth regulators at different concentrations these three scions were grafted with rootstocks like bottle gourd, pumpkin, muskmelon and bitter gourd. The stem thickness of bitter gourd was not matched with the stem thickness of watermelon and muskmelon. Hence these combinations were discarded. After grafting only bitter gourd scions grafted with pumpkin was found to be compatible. This might be due to the fact that the compatibility of both scion and stock were matching. Whereas, in rest all other combinations drying out of scion or stock was observed three days after grafting which may be due to incompatibility of scion and stock species. Incompatible rootstocks are either more sensitive to auxin or accumulates more auxin than the compatible rootstocks, therefore, the rate of root decay is high (Aloni *et al*., 2008) in melons grafted on *Cucurbita* rootstocks. Even though many reports recorded graft success of watermelon with bottle gourd and pumpkin (Salehi *et al*., 2008, Bekhradi *et al*., 2011). Further the graft success depends on methods of grafting, varies with varieties, species and skill of grafter. Tamada (1969) stated that graft success varies with even cultivars of same species. Further the investigation was continued to know the effect of growth regulators and organic promoters on graft success and yield of bitter gourd grafted on pumpkin rootstock under protected environment (Shade net).

Highest percentage of graft success recorded at 10 and 30 days after grafting (2018-19 & 2019-20) was noticed in bitter gourd scions treated with IBA @ 50 ppm followed by GA_3 @ 50 ppm (Fig. 11). Similar findings were observed by Kavya (2017) who reported high success rate of 73.33 per cent in black pepper cuttings treated with IBA @ 50 ppm using wedge grafting method. Vascular regeneration experiments conducted by Aloni (1980, 1987, 1995, 2001) in which hormones were applied exogenously to stem segments, revealed that low concentrations (0.1%, w/w, applied in lanolin) of indolic acetic acid (IAA) stimulate phloem differentiation, whereas higher levels (1.0%, w/w) induce xylem differentiation. Other phytohormones, particularly cytokinins at a concentration of 10 g/ml, have been shown to induce vascular elements differentiation in wounded stems. Likewise, in grafting an important substance involved in the development of compatible graft union is auxin, which is released from vascular strands of the stock and the scion which induces the differentiation of vascular tissues, functioning as morphogenic substances (Aloni, 1987; Mattsson *et al*., 2003). Lu and Song (1999) and Seong *et al*. (2003) reported that the differentiation and possibly the induction of the vascular bridge in *Cucumis sativus* requires high levels of the auxin, indole-3-acetic acid (IAA), which induces callus proliferation from the two partners at the graft union and mentioned that IAA and zeatin plus zeatin riboside are required for vascular bundle regeneration in the graft union. Whereas, lowest percentage of graft success in bitter gourd scions treated with cow urine 2.0 % (T_7) (Fig. 11) is due to the absence or minimum quantity of auxins and morphogeneric substances.

5.2.2 Shoot parameters

The vine length of the scion varied significantly among the treatments in the present study. Significant and maximum vine length of the scion was recorded in bitter gourd scion treated with GA_3 @ 25 ppm (T_1) which was followed by IBA @ 25 ppm (T_3) (Fig. 12) and grafted on pumpkin rootstock using wedge grafting method. Auxins affect the production and activity of cytokinins which are known to be produced in the root and translocated to the shoot where they control important developmental processes such as cell multiplication, shoot growth and productivity. The results of the present study are in agreement with earlier studies (Kavya, 2017) who revealed that, the auxins activated shoot growth which might have resulted in elongation of stem through cell division resulting higher shoot length in black pepper. Similar findings were also reported by Noor *et al.* (1995) in apple. Minimum vine length of the scion was recorded in control *i.e.*, bitter gourd scions treated with distilled water (T_{11}) and cow urine @ 1 to 2.0 per cent (Fig. 12). This may be attributed to lack of growth promoting substances

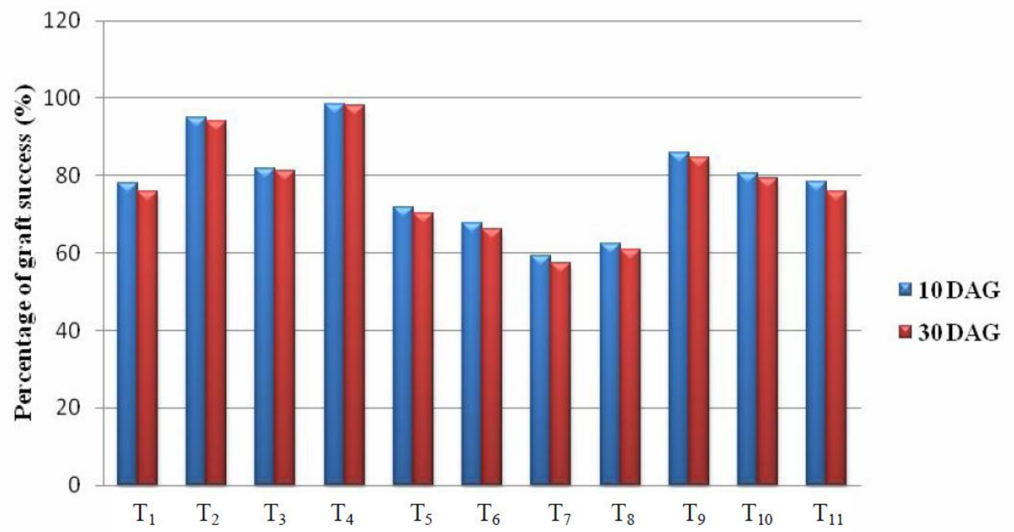


Fig. 11: Effect of growth regulators and organic promoters on graft success (%) of bitter gourd grafted on pumpkin at 10 and 30 DAG (2018-19 and 2019-20)

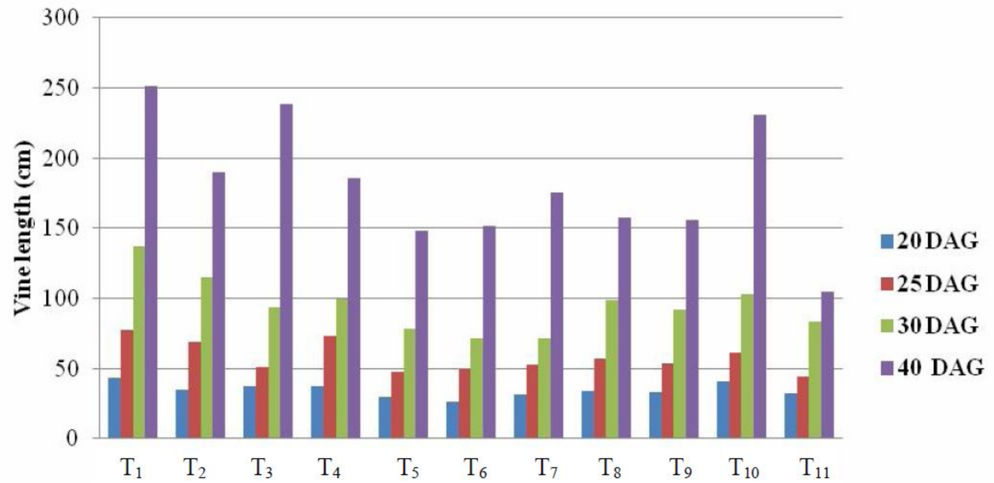


Fig. 12: Effect of growth regulators and organic promoters on length of scion/vine length of bitter gourd grafted on pumpkin at 10 and 30 DAG (2018-19 and 2019-20)

Index

DAG- Days after grafting

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3- Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6- Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9- Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

resulting in lower cell activities like cell elongation and cell division which resulted in poor growth. There was not much difference between the two seasons (*Kharif* & *rabi*) indicating that the rootstocks were more stable under different environmental conditions.

The bitter gourd scions treated with GA_3 @ 50 ppm and IBA @ 50 ppm (T_2 & T_4) followed by coconut milk @ 10-20 per cent has recorded higher number of nodes per graft during both the seasons (Fig. 13). Application of IBA helps in enhancement of cell division leading to early callus formation and chlorophyll accumulation which in turn reflected on the increased vegetative growth parameters like sprout length of the scion and higher number of nodes. The results of the present study were corroborated with the earlier findings by Sharangi *et al.* (2010) who reported that pepper cuttings treated with IBA were found to increase number of nodes and higher survivability of grafted black pepper.

5.2.3 Stem girth of graft union (cm)

The results of the present investigation revealed that, the intial girth of graft union recorded at 10, 20 and 30 days after grafting was found to be non significant. This might be attributed to the facts that slow growth at initial stage. Whereas, final girth of graft union recorded at 60 and 90 days after grafting was found to be significant during both *kharif* (2018-19) and *rabi* (2019-20) (Fig. 14). The maximum increment in girth of graft union was noticed in bitter gourd scions treated with GA_3 @ 25 ppm followed by T_3 and T_4 (IBA @ 25 & 50 ppm) and coconut milk @ 20 per cent (T_{10}). This may be due to that auxins helps in cellular activity which resulted in higher photosynthetic activity which had lead to accumulation of reserved food material that ultimately facilitated the increase in girth of graft union. Similar findings were reported by Ahmed *et al.* (2003) who agreed that, thicker stem in hard wood cuttings of peach when treated with IBA gave good grafting success.

5.2.4 Flowering parameters

A glance of the results presented in fig 15 revealed significant and less number of days for first female flower appearance in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) grafted on pumpkin rootstock using wedge grafting method. The experimental findings are in line with Ghani *et al*. (2013) who opinined that application of GA_3 @ 25, 50 and 75 ppm stimulate both pistilate and staminate flowers.

Whereas, lesser number of nodes to first female flower appearance during *kharif* and *rabi* (2018-19, 2019-20) seasons was observed in bitter gourd scions treated with IBA @ 50 ppm (T_4) which was at par with bitter gourd scions treated with IBA @ 25 ppm (T_3) (Fig. 15). The probable reason may be the sexual differentiation is controlled by endogenous levels of auxins, which developed flowering primordial and during flowering act as anti-gibberellins. This anti-gibberellin effect suppressed staminate flowers and promotes more number of pistilate flowers (Ghani *et al*., 2013). The highest number of nodes to first female flower appearance in T_{11} (Bitter gourd scions treated with distilled water). This may be due to absence of growth promoting substances which might lead to poor growth of the grafted plants.

5.2.5 Fruit parameters

In the present investigation, fruit parameters (Average fruit weight, fruit length & fruit girth) recorded during both *kharif* (2018-19) and *rabi* (2019-20) seasons was found to be significant (Fig. 16).

Maximum average fruit weight, length and girth was recorded in bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by T_1 and T_3 (GA_3 @ 25 ppm & IBA @ 25 ppm) (Fig 16). This may be due to activating cell division and cell elongation along with increasing the metabolic activities (Ghani *et al*., 2013). Maximum length and girth of fruit leads highest average fruit weight.

5.2.6 Yield parameters

Maximum yield per vine and per hectare during the two consecutive years (2018-19 & 2019-20) was recorded in bitter gourd scions treated with IBA @ 50 ppm (T_4) (Fig. 17) and grafted on pumpkin rootstock using wedge grafting method. This might be attributed to maximum length and girth of fruits which ultimately leads to highest yield. Whereas lowest yield in bitter gourd scions treated with cow urine @ 1.0 per cent was also observed.

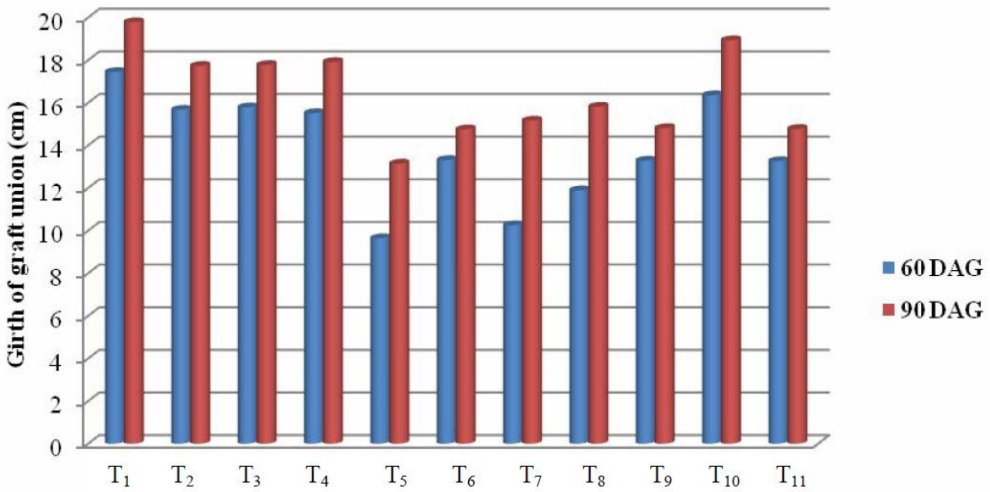


Fig. 13: Effects of growth regulators and organic promoters on initial and final girth of bitter gourd grafted on pumpkin under protected environment (2018-19 and 2019-20)

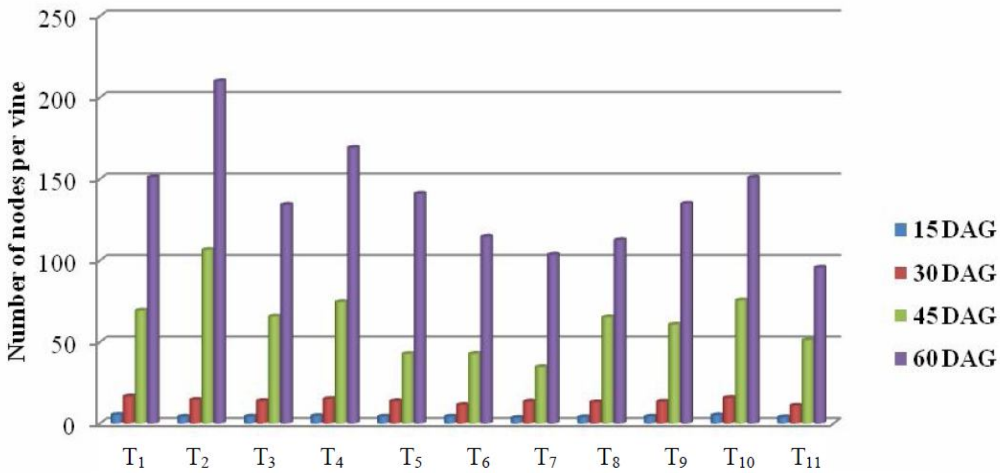
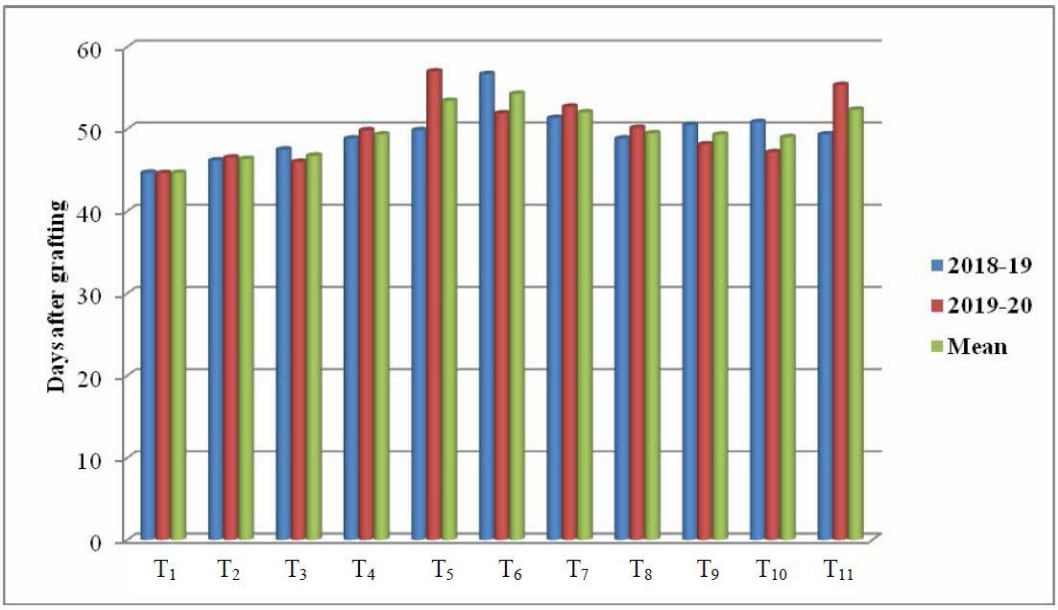


Fig. 14: Effects of growth regulators and organic promoters on number of nodes per graft in bitter gourd grafted on pumpkin under protected environment (2018-19 and 2019-20)

DAG- Days after grafting

Index

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3- Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6- Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9- Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)



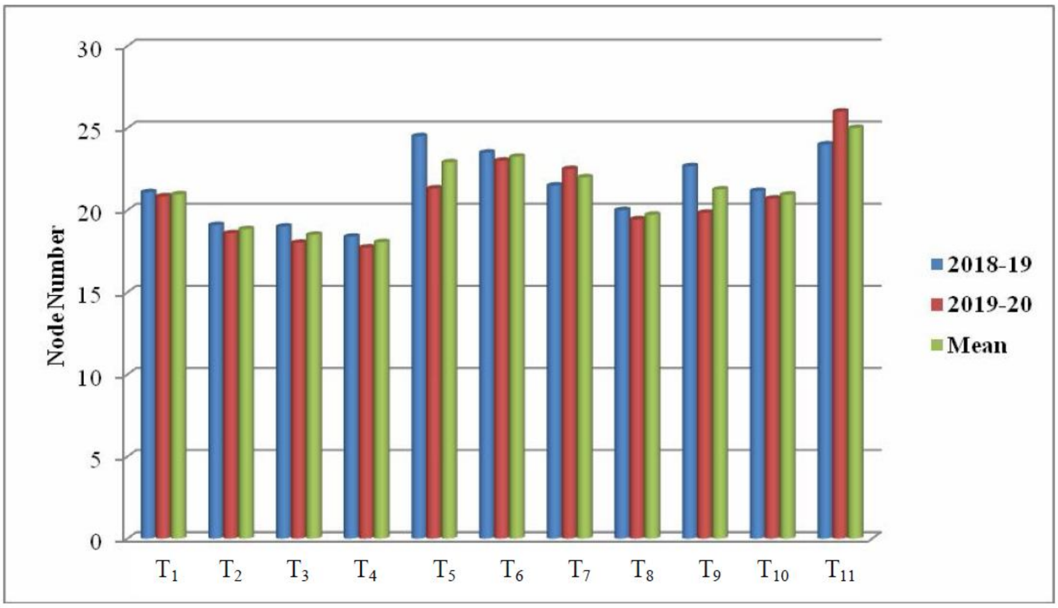


Fig 15: Effects of growth regulators and organic promoters on days to first female flower and node number to first female flower appearance of bitter gourd grafted on pumpkin under protected environment

Index

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3- Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6- Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9- Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

5.2.7 Physiological parameters

Maximum number of leaves per vine at 30, 45 and 60 days after grafting (2018-19 & 2019-20) was recorded in bitter gourd scions treated with GA_3 @ 25 ppm (T_1) followed by IBA @ 50 ppm (T_4). Whereas, maximum leaf area in bitter gourd scions treated with IBA @ 50 ppm (T_4) (Fig.18).The probable reason may be due to increasing plasticity of cell wall followed by hydrolysis of starch to sugars which lowers the water potential of cell, resulting in the entry of water into the cell causing elongation. These osmotic driven responses under the influence of gibberellins might have attributed to increase in photosynthetic activity, accelerated translocation and efficiency of utilizing photosynthetic products, thus resulting in increased cell elongation and rapid cell division in the growing portion (Aishwarya *et al.*, 2019).

With respect to photosynthetic rate, significant and maximum photosynthetic rate was recorded in bitter gourd scions treated with IBA @ 50 ppm (T_4) which was at par with bitter gourd scions treated with coconut milk @ 15.0 per cent (T_9) and lowest photosynthetic rate was noticed in T_6 and T_5 (Bitter gourd scions treated with cow urine @ 1.5 & 1.0 %). Meanwhile with respect to transpiration rate bitter gourd scions treated with IBA @ 50 ppm (T_4) recorded lowest transpiration rate and it was similar with T_2 and T_1 (GA_3 @ 50 & 25 ppm). Whereas highest transpiration rate in bitter gourd scions treated with coconut milk @ 10, 15 and 20 per cent (T_8, T_9, and T_{10}) may be they contained more epidermal pavement cells and more stomata which lead to higher transpiration rate in this treatment. Similar result was also observed by Ferber *et al.* (2016) in tomato. Maximum stomatal conductance was noticed in bitter gourd scions treated with IBA @ 50 ppm (T_4) and lowest stomatal conductance in bitter gourd scions treated with cow urine @ 2.0 % (T_7) (Fig. 19). This might be attributed to maximum leaf area and more number of leaves in scions treated with IBA and GA_3 which ultimately leads to increased photosynthetic activity and stomatal conductance with decreased transpiration rate because of the characteristic of the growth regulator, since auxins stimulate root vigor, favoring the early adaptive capacity of plants. The root vigor allows better absorption of water and nutrients, favoring allometric growth and leading to a greater accumulation of shoot and root dry mass (Franca *et al.*, 2018) in *Passiflora mucronata* Lam. (Passifloraceae).

5.2.8 Disease incidence

The grafted plants irrespective of the treatments did not show any symptoms of *Fusarium* and Bacterial wilt during the study period. Lin (2004) has also stated that *Luffa* sp., fig leaf gourd and pumpkin are common rootstocks and wedge grafting is good method in bitter gourd for resistance against *Fusarium* wilt. However, the resistance mechanisms are not clearly known yet, scientist believe that some compounds are made in rootstocks and transferred by the xylem to the scion and these compounds would not be produced in scions thus might have given tolerance to grafted plants.

5.2.9 Economics

Highest benefit cost ratio was observed in bitter gourd scions treated with IBA @ 50 ppm (T_4) followed by bitter gourd scions treated with IBA @ 25 ppm (T_3) and grafted on pumpkin rootstock using wedge grafting method. Whereas least B:C ratio was noted in bitter gourd scions treated with cow urine @ 2.0 % (T_7) during both crop seasons (2018-19 & 2019-20) (Fig.20). Increase in returns per rupees invested was mainly due to higher grafting success obtained by treating scion sticks with IBA @ 25-50 ppm and maximum yield in this treatment. Present findings are in line with Kavya (2017), who reported that the treatment of black pepper scions with IBA @ 50 ppm has recorded highest net income and higher returns per rupees invested (2.69).

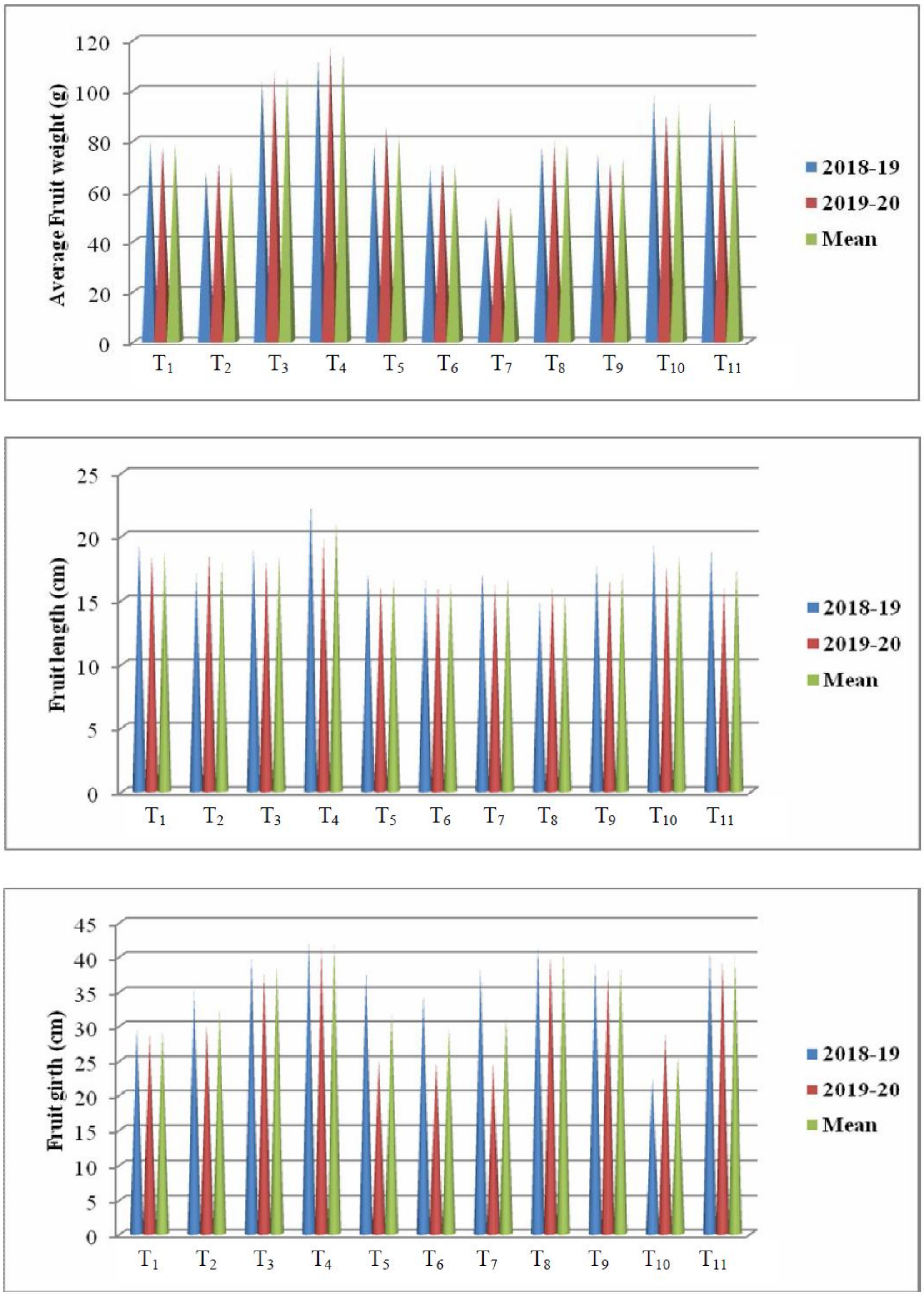


Fig 16: Effects of growth regulators and organic promoters on average fruit weight, length and girth of bitter gourd grafted on pumpkin under protected environment

Index

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm

T_2- Bitter gourd scions treated with GA_3 @ 50 ppm

T_3- Bitter gourd scions treated with IBA @ 25 ppm

T_4- Bitter gourd scions treated with IBA @ 50 ppm

T_5- Bitter gourd scions treated with cow urine @ 1.0 %

T_6-Bitter gourd scions treated with cow urine @ 1.5 %

T_7- Bitter gourd scions treated with cow urine @ 2.0 %

T_8- Bitter gourd scions treated with coconut milk @ 10.0 %

T_9- Bitter gourd scions treated with coconut milk @ 15.0 %

T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %

T_{11}- Bitter gourd scions treated with water (control)

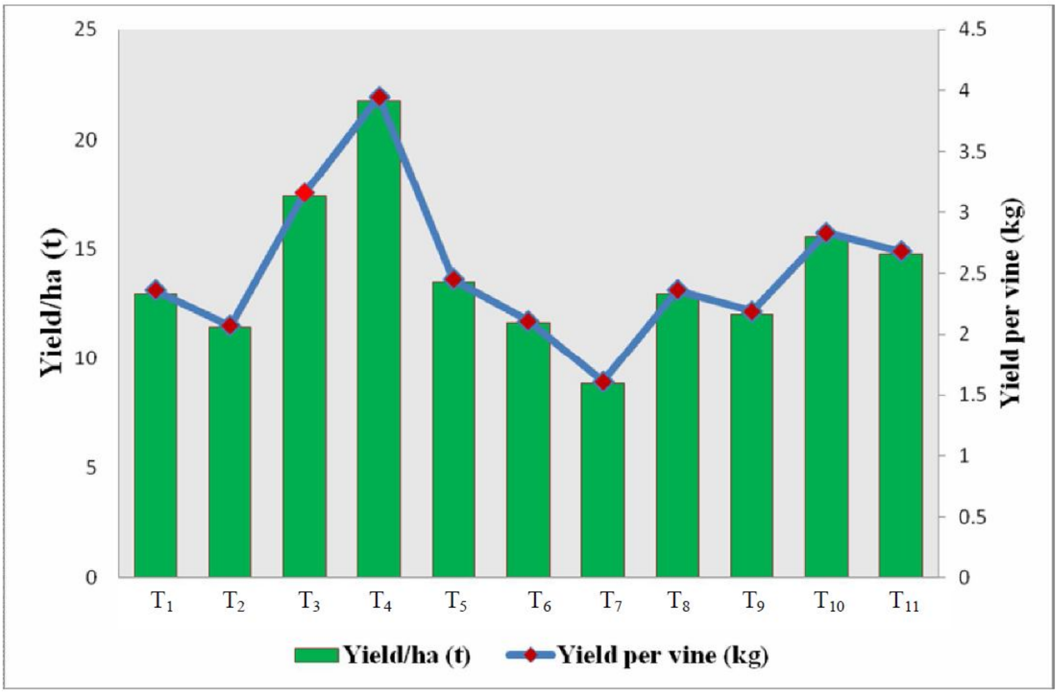


Fig. 17: Effects of growth regulators and organic promoters on yield per vine and yield per hectare of bitter gourd grafted on pumpkin under protected environment (2018-19 and 2019-20)

Index

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm

T_2- Bitter gourd scions treated with GA_3 @ 50 ppm

T_3-Bitter gourd scions treated with IBA @ 25 ppm

T_4- Bitter gourd scions treated with IBA @ 50 ppm

T_5- Bitter gourd scions treated with cow urine @ 1.0 %

T_6-Bitter gourd scions treated with cow urine @ 1.5 %

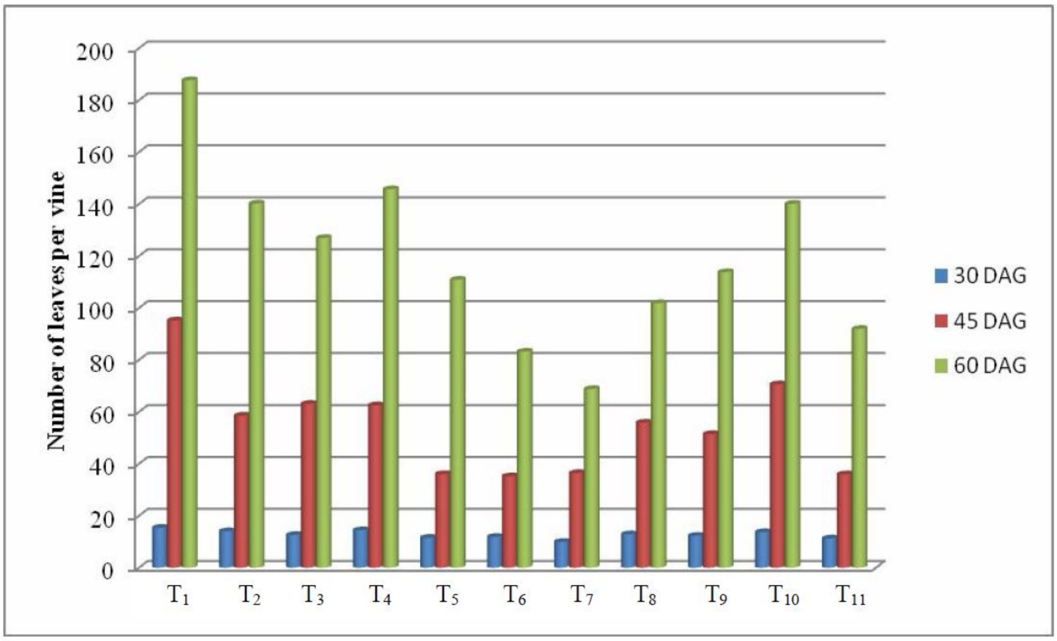
T_7- Bitter gourd scions treated with cow urine @ 2.0 %

T_8- Bitter gourd scions treated with coconut milk @ 10.0 %

T_9-Bitter gourd scions treated with coconut milk @ 15.0 %

T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %

T_{11}- Bitter gourd scions treated with water (control)



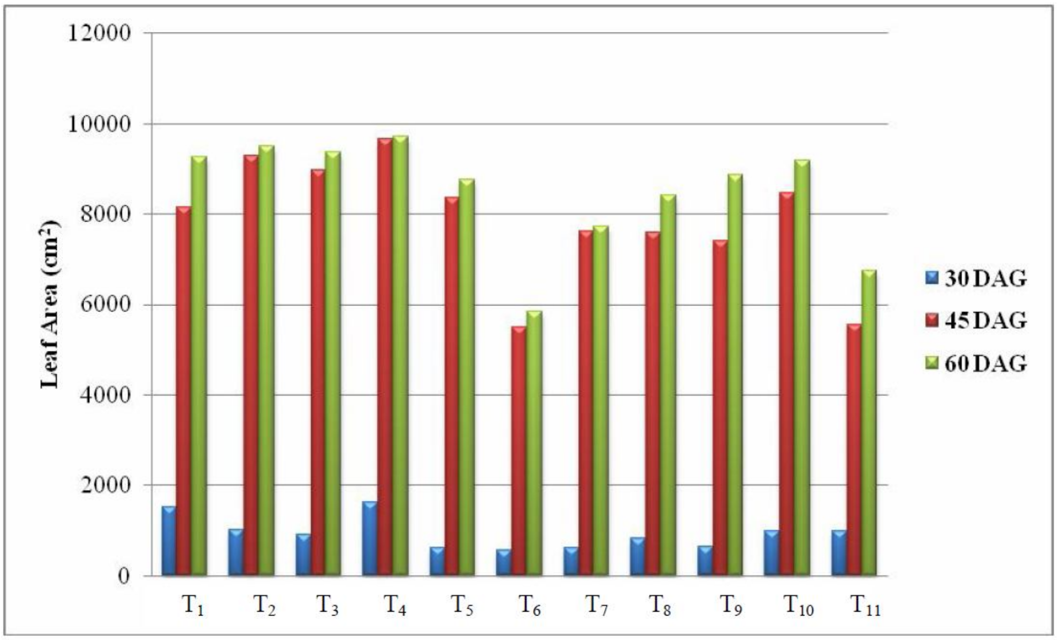


Fig 18: Effects of growth regulators and organic promoters on leaf area of bitter gourd grafted on pumpkin under protected condition (2018-19 and 2019-20)

Index

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm

T_2- Bitter gourd scions treated with GA_3 @ 50 ppm

T_3-Bitter gourd scions treated with IBA @ 25 ppm

T_4- Bitter gourd scions treated with IBA @ 50 ppm

T_5. Bitter gourd scions treated with cow urine @ 1.0 %

T_6-Bitter gourd scions treated with cow urine @ 1.5 %

T_7- Bitter gourd scions treated with cow urine @ 2.0 %

T_8- Bitter gourd scions treated with coconut milk @ 10.0 %

T_9-Bitter gourd scions treated with coconut milk @ 15.0 %

T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %

T_{11}. Bitter gourd scions treated with water (control)

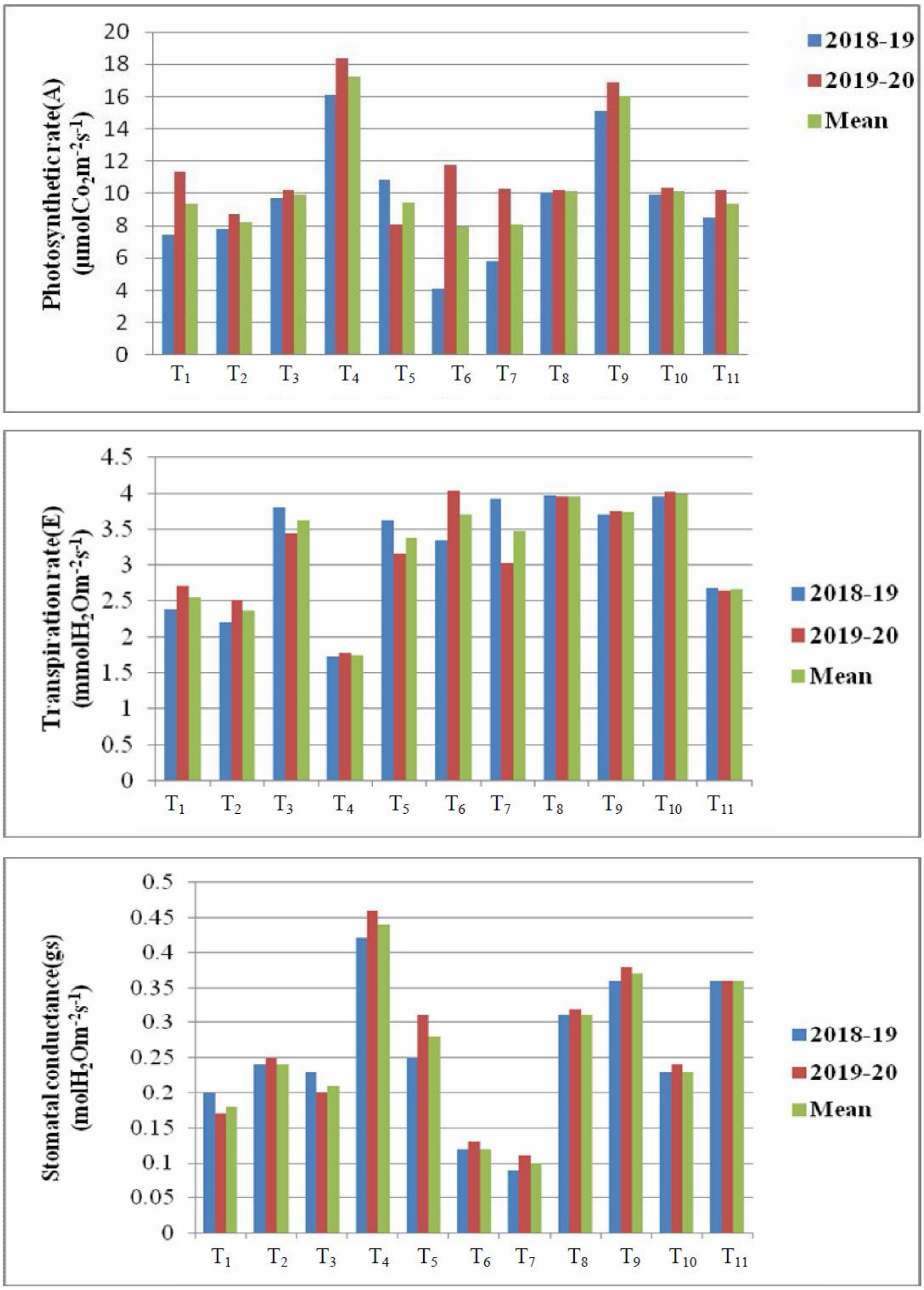


Fig 19: Effects of growth regulators and organic promoters on transpiration rate(E), stomatal conductance (gs) and photosynthetic rate(A) of bitter gourd grafted on pumpkin under protected environment

Index

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm

T_2- Bitter gourd scions treated with GA_3 @ 50 ppm

T_3-Bitter gourd scions treated with IBA @ 25 ppm

T_4- Bitter gourd scions treated with IBA @ 50 ppm

T_5. Bitter gourd scions treated with cow urine @ 1.0 %

T_6-Bitter gourd scions treated with cow urine @ 1.5 %

T_7- Bitter gourd scions treated with cow urine @ 2.0 %

T_8- Bitter gourd scions treated with coconut milk @ 10.0 %

T_9-Bitter gourd scions treated with coconut milk @ 15.0 %

T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %

T_{11}. Bitter gourd scions treated with water (control)

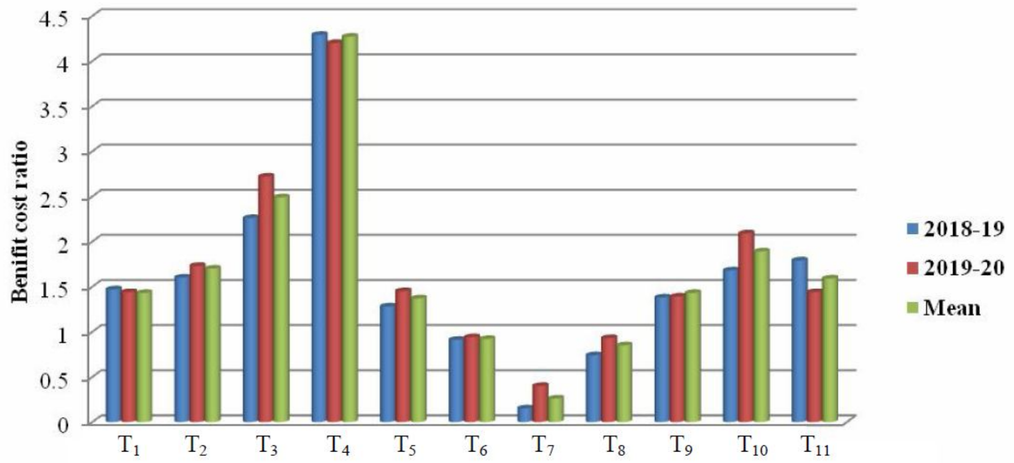


Fig. 20: Effect of growth regulators and organic promoters on benefit cost ratio on bitter gourd grafted on pumpkin under protected condition (Shade net)

Index

T_1- Bitter gourd scions treated with GA_3 @ 25 ppm
T_2- Bitter gourd scions treated with GA_3 @ 50 ppm
T_3- Bitter gourd scions treated with IBA @ 25 ppm
T_4- Bitter gourd scions treated with IBA @ 50 ppm
T_5- Bitter gourd scions treated with cow urine @ 1.0 %
T_6- Bitter gourd scions treated with cow urine @ 1.5 %
T_7- Bitter gourd scions treated with cow urine @ 2.0 %
T_8- Bitter gourd scions treated with coconut milk @ 10.0 %
T_9- Bitter gourd scions treated with coconut milk @ 15.0 %
T_{10}- Bitter gourd scions treated with coconut milk @ 20.0 %
T_{11}- Bitter gourd scions treated with water (control)

6. SUMMARY AND CONCLUSIONS

The investigation on “Influence of growing environment and growth regulators on graft compatibility of cucurbits” was undertaken at Kittur Rani Channama College of Horticulture, Arabhavi, University of Horticultural Sciences (UHS), Bagalkot, Karnataka during *kharif* (2018-19) and *rabi* (2019-20) season. The results are summarized here under.

6.1 Experiment I- Effect of growing environment on graft compatibility and graft success in cucurbits

The experiment was conducted during two consecutive years 2018-19 (*Kharif*) and 2019-20 (*Rabi*) and recorded the observations on the following growth parameters *viz.*, number of days to first sprout and 50 per cent sprout, sprout length of scion, number of nodes, Initial and final girth of graft union, percentage of graft success, days to first female flower appearance, node number to first female flower appearance were studied by comparing with rootstock and scions of different cucurbitaceous species.

Pooled data exhibited significant and minimum number of days to first sprout (3.67, 4.17 & 5.00, 4.83 days) and fifty per cent sprout (5.17, 5.50 days) in ridge gourd and bitter gourd scions grafted with snake gourd and pumpkin rootstock and maximum number of days to first (7.00, 5.50 days) and fifty per cent sprouting (9.67, 9.50 days) was noticed in bitter gourd and ridge gourd scions grafted with bottle gourd rootstock. Percentage of graft success was also highest in ridge gourd and bitter gourd scions grafted with snake gourd and pumpkin (96.33 & 89.33 %) rootstocks and lowest percentage of graft success in bitter gourd scions grafted with bottle gourd as a rootstock (64.83 %). This might be due to differentiation and re differentiation of callus tissue at the graft union followed by rapid connection between the vascular bundles of scion and rootstock subsequently secondary growth of scion.

Significant and maximum vegetative components *viz.*, sprout length or vine length of scion, final girth of graft union (16.39, 20.04 mm 90 DAG) (14.87, 15.55 mm 90 DAG) were noticed in ridge gourd and bitter gourd scions grafted on snake gourd followed by pumpkin as a rootstock. Whereas, lowest values for these parameters was observed in bitter gourd and ridge gourd scions grafted with bottle gourd. This may be due to strong and extended roots of both pumpkin and snake gourd which helps to absorb more water and nutrient elements leading to vigorous plant growth.

Maximum number of nodes per graft per vine was recorded in bitter gourd and ridge gourd scions grafted with pumpkin and snake gourd (130.29, 127.15). Whereas both ridge gourd and bitter gourd scions grafted on snake gourd rootstock produced first female flower (8.28, 19.14) at early nodes and minimum number of days to first female flower appearance (33.15, 45.62). This might be due to altered physiology of scions to induce early female flowering.

In view of the present findings and reports by various workers with different crops, it would be concluded that the grafting success is mainly depends on the compatibility between the scion and rootstock, grafting method and temperature (25-32 °C) and relative humidity (90-92 %).

6.2 Experiment II- Effect of growth regulators on graft compatibility and yield of cucurbits

Significant and maximum growth and yield components *viz.*, days to first sprout (3.50 days) and days to fifty percent sprout (6.50, 6.00), number of nodes per scion (210.00, 169.17), per cent graft success (95.00, 94.00 & 98.50, 98.00 %) were observed in bitter gourd scions treated with GA_3 and IBA @ 50 ppm and grafted on pumpkin rootstock using wedge grafting method. Whereas, sprout length of the scion (251.26, 238.68 cm) was recorded by bitter gourd scions treated with GA_3 and IBA @ 25 ppm. Final girth of graft union (19.78, 18.93 mm) was recorded by bitter gourd scions treated with GA_3 @ 25 ppm and coconut milk @ 20.0 % grafted on pumpkin rootstock using wedge grafting method. Whereas, bitter gourd scions treated with GA_3 @ 25 and 50 ppm grafted on pumpkin rootstock using wedge grafting method recorded minimum number of days to first female flower appearance (44.65, 46.35).

Earliest node number to first female flower appearance (18.05, 18.50) was noticed in bitter gourd scions treated with IBA @ 50 and 25 ppm grafted on pumpkin rootstock using wedge grafting method. Maximum average fruit weight (114.75 g), fruit length (21.15 cm), fruit girth (41.64 mm), yield per plot (3.95 kg) and yield per hectare

(21.77 t) were recorded in bitter gourd scions treated with IBA @ 50 ppm and grafted on pumpkin rootstock using wedge grafting method. The reason might be due to application of IBA and GA_3 helps in enhancement of cell division leading to early callus formation and chlorophyll accumulation which in turn reflected on the increased vegetative growth and yield.

Significant and maximum physiological components *viz.*, number of leaves per vine (187.66, 145.67) was noticed in bitter gourd scions treated with GA_3 @ 25 ppm and IBA @ 50 ppm grafted on pumpkin rootstock using wedge grafting method. Whereas, maximum leaf area (9703.69, 9512.54 cm^2) in IBA and GA_3 @ 50 ppm and grafted on pumpkin rootstock using wedge grafting method. Maximum photosynthetic rate (17.25), minimum transpiration rate (1.76) and maximum stomatal conductance (0.44) were noticed in bitter gourd scions treated with IBA @ 50 ppm and grafted on pumpkin rootstock using wedge grafting method.

Highest benefit cost ratio was observed in bitter gourd scions treated with IBA @ 50 ppm followed (4.27) by IBA @ 25 ppm (2.53) and grafted on pumpkin rootstock using wedge grafting method. Increase in returns per rupees invested was mainly due to higher grafting success and yield obtained by treating scion sticks with IBA @ 50 ppm.

In the context of present findings and work of others with growth regulators, it could be concluded that IBA @ 25-50 ppm followed by GA_3 @ 25-50 ppm could be effectively used for grafting in bitter gourd using pumpkin as rootstock by wedge grafting method.

Conclusion

Grafting of bitter gourd and ridge gourd using pumpkin and snake gourd as root stock using wedge grafting method was found to be better with maximum growth and flowering parameters.

Higher percentage of graft success in bitter gourd with respect to all growth, flowering, yield and physiological parameters were obtained by treating the scions with growth regulators like IBA @ 25-50 ppm, GA_3 @ 25-50 ppm followed by coconut milk @ 20.0 per cent grafted on pumpkin rootstock using wedge grafting method and it also found to be economical and remunerative under protected environment (Shade net).

Future line of work

- Compatible rootstocks of present study *viz.*, pumpkin and snake gourd can be utilized for disease screening.
- Assessing the effects of different grafting methods on graft compatibility and graft success in cucurbits may be tried.
- Assessing the performance of grafted plants under open field condition can be tried with mulching and drip irrigation.
- There is higher scope to evaluate quality parameters of grafted cucurbits over non grafted cucurbits and semi mechanization, commercialization of pumpkin and snake gourd as rootstock grafting may be initiated and robotics may be tried.
- Plant growth regulators either natural or synthetic are not in common use in practical propagation of grafted vegetable seedlings. As there is a good prospect of utilizing PGR in grafting technology. Further more studies on effect of growth regulators at different concentrations can be tried to increase graft success and also to reduce the cost of production.
- Assessing the effect of higher concentrations of cow urine may be tried to increase the grafting success and also to reduce the cost of production.
- Anatomical studies need to be conducted to know the mechanism of compatibility and incompatibility.

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Appendix I: Meteorological data recorded during the period of experimentation at Agricultural Research Station, Arbhavi (2019-2020)

Month	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Maximum	Minimum	Maximum	Minimum	
August 2019	30.70	12.30	87.10	75.80	338.60
September 2019	32.80	13.40	85.70	78.80	65.20
October 2019	34.00	15.50	87.50	77.80	356.20
November 2019	32.40	15.40	86.80	71.40	0.00
December 2019	32.70	15.90	84.20	68.10	12.30
January 2020	25.12	14.50	71.26	64.45	0.00
February 2020	31.21	17.50	75.00	39.00	0.00
March 2020	37.50	18.50	72.00	34.00	0.00
April 2020	37.80	18.50	76.00	38.00	21.00
May 2020	38.60	29.90	79.00	61.00	42.40

Appendix II: Temperature and relative humidity of healing chamber recorded during healing of grafted plants

Days	Temperature (°C)		Relative humidity (%)	
	2018-19	2019-20	2018-19	2019-20
Day -1	31	31	92	90
Day -2	30	29	92	90
Day-3	29	27	90	89
Day-4	28	26	90	89
Day-5	27	25	89	87

Appendix III: Details of variables and fixed costs prevailed during experimental period: Experiment-II

Sl. No	Particulars	Rs./plant	No. of plants /treatment	Total expenditure (Rs./ 10 grafts)
I. Variable cost (VC) (A)				
1.	Root stock	1.00	10.00	10.00
2.	Scion	1.00	10.00	10.00
3.	Grafting clips(3 Rs/clip)	3.00	10.00	30.00
4.	Grafting charges	3.00	10.00	30.00
5.	IBA (75 mg)	-	-	3.75
6.	GA_3 (75 mg)	-	-	1.28
7.	Coconut milk	-	-	20.00
8.	Fertilizers	-	-	16.50
9.	Insecticides and fungicides	-	-	50.00
10.	Labor charges (for maintenance after care)	7.00	10.00	70.00
			Total VC (Rs.)	**241.53**
II. Fixed cost (FC) (B)				
1	Land revenue (Rs.)			6.00 /1 m^2 area /year
2	Depreciation cost (Rs.)			67.50/ 1 m^2 area /year
			Total FC (Rs.)	**73.50**
Total cost: Cost (A)+ Cost (B) = Rs. 216.50+73.50=290.00				
Selling price of grafted fruits / kg= Rs. 40				

INFLUENCE OF GROWING ENVIRONMENT AND GROWTH REGULATORS ON GRAFT COMPATIBILITY OF CUCURBITS

DEEPA ADIVEPPA HOLER **2021** **Dr. N. BASAVARAJA**
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ABSTRACT

An investigation was carried out at Kittur Rani Channamma College of Horticulture, Arabhavi during 2018-19 and 2019-20 to study the “influence of growing environment and growth regulators on graft compatibility of cucurbits”. The study pointed out that, among the different rootstocks (Bottle gourd, Pumpkin, Snake gourd) and scions (Bitter gourd, Ridge gourd) tried, both ridge gourd and bitter gourd scions grafted on snake gourd and pumpkin rootstock using wedge grafting method recorded significant and minimum number of days to first sprout and fifty per cent sprouting (3.67, 5.17 days) and maximum percentage of graft success (96.33 & 89.33 %), length of the scion, final girth of graft union. Whereas, Maximum number of nodes per graft per vine was recorded in bitter gourd and ridge gourd scions grafted on pumpkin and snake gourd (130.29, 127.15) as rootstock. Ridge gourd and bitter gourd scions grafted on snake gourd rootstock produced first female flower (8.28, 19.14) at early nodes and minimum number of days (33.15, 45.62) to first female flower appearance. The study revealed that, grafting of bitter gourd and ridge gourd using pumpkin and snake gourd as root stock was found to be better with maximum growth and flowering parameters.

In another study conducted to find out the Effect of growth regulators compatibility and yield of cucurbits, which reveals that, among the different growth regulators and organic promoters tried {T_1- GA3@ 25 ppm, T_2- GA3 @ 50 ppm, T_3- IBA @ 25 ppm, T_4- IBA @ 50 ppm, T_5- Cow urine @ 1.0 %, T_6- Cow urine @ 1.5 %, T_7- Cow urine @ 2.0 %, T_8- Coconut milk @ 10.0 %, T_9- Coconut milk @ 15.0 %, T_{10}- Coconut milk @ 20.0 % and T_{11}- distil water treatment (control)}, bitter gourd scions treated with GA_3 and IBA @ 50 ppm and grafted on pumpkin rootstock using wedge grafting method has recorded significant and minimum number of days to first sprout (3.50 days) and fifty percent sprout (6.00, 6.50), maximum number of nodes per scion (210.00, 169.17), per cent graft success (98.50, 98.00 95.00, 94.00 %) whereas, maximum length of the scion (251.26, 238.68 cm) and final girth of graft union (19.78, 18.93 mm) was recorded with bitter gourd scions treated with GA_3 and IBA @ 25 ppm and grafted on pumpkin rootstock. Whereas bitter gourd scions treated with GA_3 @ 50 ppm and IBA @ 25 ppm grafted on pumpkin recorded minimum number of days to first female flower appearance (44.65, 46.35), earliest node number to first female flower appearance (18.05, 18.50) was noticed in bitter gourd scions treated with IBA @ 50 and 25 ppm grafted on as pumpkin rootstock. Maximum average fruit weight (114.75 g), fruit length (21.15 cm), fruit girth (41.64 mm), yield per plot (3.95 kg) and yield per hectare (21.77 t) were recorded in bitter gourd scions treated with IBA @ 50 ppm and grafted on as pumpkin rootstock. Significant and maximum physiological parameters *viz*., number of leaves per vine (187.66, 145.67) was noticed in bitter gourd scions treated with GA_3 @ 25 ppm and IBA @ 50 ppm grafted on pumpkin rootstock using wedge grafting method. Whereas, maximum leaf area (9703.69, 9512.14 cm^2) in IBA @ 50 and 25 ppm grafted on pumpkin as rootstock. Maximum photosynthetic rate (17.25), minimum transpiration rate (1.76) and maximum stomatal conductance (0.44) were noticed in bitter gourd scions treated with IBA @ 50 ppm and grafted on as pumpkin rootstock. Highest benefit cost ratio was observed in bitter gourd scions treated with IBA @ 50 ppm followed (4.27) by IBA @ 25 ppm (2.53) and grafted on pumpkin as rootstock.

The grafted plants in all the treatments did not show any symptoms of *fusarium* and bacterial wilt during the study period.

PÀRgÀÀmïUÀ½ÀPÀ ºÉAzÁtPÉÆIÀ ªÉÃ¯É ÉÆÉÃwgÀªÀ¥À¸gÀªÀvÀ¸ÀÀ¥ÀÉÃzÀÀÀ¥Às ªÀ

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PÀÄA§½À eÁwAiÀÄ vÀgÀPÁjUÀ½À PÀ¹ ºÉÆAzÁtPÉAiÀÄ ªÉÃ¯É ¥Àj¸ÀgÀ ªÀÄvÀÄ ¸À¸Àå ¥ÀZÉÆÃzÀPÀUÀ½À ¥ÀjuÁªÀÄUÀ½À PÀÄjvÀ CzÀåAiÀÄ£ÀªÀ£ÀÄß vÉÆÃlUÁjPÁ ªÀÄºÁ«zÁå®AiÀÄ, CgÀ¨Á«AiÀÄ°è 2018-19 ªÀÄvÀÄÛ 2019-20 gÀ°è PÉÊUÉÆ¼Àî¯Á¬ÄvÀÄ. ªÉÆzÀ® CzÀåAiÀÄ£ÀzÀ°è ¨ÉÃgÉ ¨ÉÃgÉ eÁwAiÀÄ ¨ÉÃgÀÄ ¸À¹ (¸ÉÆÃgÉPÁ¬Ä, PÀÄA§½ÀPÁ¬Ä, ¥ÀqÀªÀ®PÁ¬Ä) ºÁUÀÆ PÀÄrUÀ½À£ÀÄß (ºÁUÀ®PÁ¬Ä, »ÃgÉPÁ¬Ä) PÀ¹ ªÀiÁqÀ®Ä G¥ÀAiÉÆÃV¸À¯Á¬ÄvÀÄ. EzÀgÀ°è »ÃgÉPÁ¬Ä ºÁUÀÆ ºÁUÀ®PÁ¬Ä PÀÄrUÀ½À£ÀÄß ¥ÀqÀªÀ®PÁ¬Ä ªÀÄvÀÄÛ PÀÄA§½ÀPÁ¬ÄUÀ½À ªÉÃ¯É PÀ¹ ªÀiÁrzÀjAzÁV, Cw PÀrªÉÄ CªÀ¢AiÀÄ°è ªÉÆzÀ® ªÉÆ¼ÀPÉ aUÀÄgÀ®Ä ªÀÄvÀÄÛ ±ÉÃPÀqÀ 50 gÀµÀÄÖ ªÉÆ¼ÀPÉ aUÀÄgÀ®Ä (3.67, 5.17 ¢£ÀUÀ¼ÀÄ) UÀÄgÀÄw¸À¯Á¬ÄvÀÄ. PÀ¹AiÀÄ AiÀÄ±À¸ÀÄì (±ÉÃ. 96.33, 89.33), PÀÄrAiÀÄ GzÀÝ, PÀ¹ ¨ÁUÀzÀ PÁAqÀzÀ ¸ÀÄvÀÛ¼ÀvÉ ºÉaÀvÀÄ. DzÀgÉ PÀÄA§½ÀPÁ¬Ä ªÀÄvÀÄÛ ¥ÀqÀªÀ®PÁ¬Ä ¨ÉÃgÀÄPÁAqÀzÀ ªÉÃ¯É PÀ¹ ªÀiÁrzÀ ºÁUÀ®PÁ¬Ä ºÁUÀÆ »ÃgÉPÁ¬ÄAiÀÄ°è UÀtÄÛUÀ½À ¸ÀASÉåAiÀÄ£ÀÄß (130.29, 127.15/VqÀ) ºÉa¹vÀÄ. ªÉqÀÎ ªÀiÁzÀjAiÀÄ PÀ¹ vÀAvÀeÁÕ£ÀªÀ£ÀÄß §¼À¹PÉÆAqÀÄ ¥ÀqÀªÀ®PÁ¬Ä ªÀÄvÀÄÛ PÀÄA§½ÀPÁ¬Ä ¨ÉÃgÀÄPÁAqÀzÀ ªÉÃ¯É PÀ¹ ªÀiÁrzÀ »ÃgÉPÁ¬Ä ºÁUÀÆ ºÁUÀ®PÁ¬ÄAiÀÄ°è ªÉÆzÀ® ºÉtÄÚ ºÀÆªÀ£ÀÄß DgÀA©PÀ UÀtÄÛUÀ½À°è (8.28, 19.14) ªÀÄvÀÄÛ ªÉÆzÀ® ºÉtÄÚ ºÀÆ«£À CgÀ½ÀÄ«PÉUÉ (33.15, 45.62) Cw PÀrªÉÄ CªÀ¢AiÀÄ£ÀÄß vÉUÉzÀÄPÉÆArvÀÄ. F CzÀåAiÀÄ£À¢AzÀ w½zÀÄ§gÀÄªÀÅzÉÃ£ÉAzÀgÉ, ªÉqÀÎ ªÀiÁzÀjAiÀÄ PÀ¹ vÀAvÀeÁÕ£ÀªÀ£ÀÄß §¼À¹PÉÆAqÀÄ ¥ÀqÀªÀ®PÁ¬Ä ªÀÄvÀÄÛ PÀÄA§½ÀPÁ¬Ä ¨ÉÃgÀÄPÁAqÀzÀ ¸À¹ ªÉÃ¯É »ÃgÉPÁ¬Ä ºÁUÀÆ ºÁUÀ®PÁ¬Ä PÀ¹ªÀiÁqÀÄªÀÅzÀjAzÀ ¸À¸Àå C©ªÀÈ¢ÞAiÀÄ°è ºÉa£À AiÀÄ±À¸ÀÄì ¥ÀqÉAiÀÄ§ºÀÄzÁVzÉ.

E£ÉÆßAzÀÄ CzÀåAiÀÄ£ÀzÀ°è ¸À¸Àå ¥ÀZÉÆÃzÀPÀUÀ¼ÁzÀ {fJw @ 25 ¦¦JªÀiï, fAJw @ 50 ¦¦JªÀiï, L©J @ 25 ¦¦JªÀiï, L©J @ 50 ¦¦JªÀiï, UÉÆÃ ªÀÄÆvÀæ - ±ÉÃPÀqÀ 1.0, 1.5, 2.0, vÉAV£À ºÁ®Ä - ±ÉÃPÀqÀ 10.0, 15.0, 20.0 ªÀÄvÀÄÛ G¥ÀZÁgÀuÉ E®èzÉ} ºÁUÀ®PÁ¬Ä PÀ¹ PÁAqÀªÀ£ÀÄß G¥ÀZÀj¹ PÀÄA§½ÀPÁ¬Ä ¨ÉãgÀÄ ¸À¹ G¥ÀAiÉÆÃV¹ PÀ¹ ªÀiÁqÀ¯Á¬ÄvÀÄ. CªÀÄUÀ½À°è, ¸À¸Àå ¥ÀZÉÆÃzÀPÀªÁzÀ fJw ªÀÄvÀÄÛ L©J 50 ¦¦JªÀiï G¥ÀZÀj¹, PÀ¹ªÀiÁrzÀ VqÀUÀ½À°è Cw PÀrªÉÄ ¸ÀªÀÄAiÀÄzÀ°è ªÉÆzÀ®£ÉAiÀÄ (3.50 ¢£ÀUÀ¼ÀÄ) ªÀÄvÀÄÛ ±ÉÃ. 50 ªÉÆ¼ÀPÉAiÉÆqÉAiÀÄ®Ä (6.00, 6.50 ¢£ÀUÀ¼ÀÄ) ¥ÁgÀA¨ÀªÁ¬ÄvÀÄ ºÁUÀÆ ºÉa£À ¸ÀASÉAiÀÄ UÀtÄÛUÀ¼ÀÄ (210.0, 169.17/VqÀ), PÀ¹AiÀÄ AiÀÄ±À¸ÀÄì (±ÉÃ. 98.50, 98.00 95.00, 94.00 %) zÉÆgÀQvÀÄ. DzÀgÉ ºÁUÀ®PÁ¬Ä PÀ¹ PÁAqÀªÀ£ÀÄß ¸À¸Àå ¥ÀZÉÆÃzÀPÀªÁzÀ L©J 25 ¦¦JªÀiï G¥ÀZÀj¹ PÀ¹ ªÀiÁrzÀ VqÀUÀ½À°è Cw ºÉZÀÄÑ PÀÄrAiÀÄ GzÀÝ (251.26, 238.68 ¸ÉA. «ÄÃ.) PÀÀqÀÄ §A¢vÀÄ ºÁUÀÆ ªÉÆzÀ® ºÉtÄÚ ºÀÆªÀ£ÀÄß DgÀA©PÀ UÀtÄÛUÀ½À°è (19.78, 18.50) ªÀÄvÀÄÛ ªÉÆzÀ® ºÉtÄÚ ºÀÆ«£À £ÉÆÃlPÉÌ (44.65, 46.35) Cw PÀrªÉÄ CªÀ¢AiÀÄÄ ºÁUÀ®PÁ¬Ä PÁAqÀªÀ£ÀÄß ¸À¸Àå ¥ÀZÉÆÃzÀPÀUÀ¼ÁzÀ L©J 25 ¦¦JªÀiï ªÀÄvÀÄÛ fJw 50 G¥ÀZÀgÀuÉAiÀÄ°è PÀÀqÀÄ§A¢vÀÄ. UÀj¥À ºÀtÂ£À vÀÆPÀ (114.75 UÁå), ºÀtÂ£À GzÀÝ (21 «ÄÃ), ºÀtÂ£À ¸ÀÄvÀÛ¼ÀvÉ (41.64 «ÄÃ.«ÄÃ), ¥Àw ¥ÁèlUÉ E¼ÀÄªÀj (3.95 PÉf), ¥Àw ºÉPÀÖgïUÉ E¼ÀÄªÀj (21.77 l£ï) ºÁUÀ®PÁ¬Ä ¸À¹ PÁAqÀªÀ£ÀÄß ¸À¸Àå ¥ÀZÉÆÃzÀPÀªÁzÀ L©J 50 ¦¦AiÀÄªÀiï £À°è PÀÀqÀÄ§A¢vÀÄ. fJw 25 ¦¦AiÀÄªÀiï ªÀÄvÀÄÛ L©J 50 ¦¦AiÀÄªÀiï UÀªÀÄ£ÁðºÀ ªÀÄvÀÄÛ UÀjµÀ× WÀlPÀUÀ¼ÀÄ, ¥ÀwÃ §½îUÉ J¯ÉUÀ½À ¸ÀASÉå (187.66, 145.67) PÀÀqÀÄ§A¢zÉ. DzÀgÉ L©J 50 ªÀÄvÀÄÛ 25 ¦¦AiÀÄªÀiï£À°è UÀjµÀ× J¯É «¹ÛtðÀ (9703.69, 9512.14 ¸ÉA. «ÄÃ ¸ÉÃgï) PÀÀqÀÄ§A¢zÉ. L©J 50 ¦¦AiÀÄªÀiï£À°è UÀjµÀ× zÀÄåw¸ÀA±ÉèµÀPÀ zÀgÀ (17.25), PÀ¤µÀ× ¨Á¶àPÀgÀt zÀgÀ (1.76) ªÀÄvÀÄÛ UÀjµÀ× ¸ÉÆÃÕªÀiÁå l¯ï PÀÀqÀPÀÕ£Àì (0.44) PÀÀqÀÄ§gÀÄªÀzÀ®èzÉÃ DyðPÀªÁV ¸ÀºÀ ¯Á¨ÀzÁAiÀÄPÀªÉÃzÀÄ PÀÀqÀÄ§A¢zÉ.

ªÉÃÃ¯É w½¹zÀ jÃwAiÀÄ PÀ¹ ªÀiÁrzÀ PÀÄA§½À eÁwUÀ½À°è AiÀiÁªÀÅzÉÃ VqÀUÀ½À°è ¸ÉÆgÀUÀÄ gÉÆÃUÀzÀ ®PÀëtUÀ¼ÀÄ PÀÀqÀÄ§A¢gÀÄªÀÅ¢®è.