

**EFFECT OF ROOTSTOCKS AND GRAFTING TECHNIQUES ON
HORTICULTURAL TRAITS AND GUMMY STEM BLIGHT IN
PARTHENO-CARPIC CUCUMBER**

THESIS

By

**ANJALI
(A-2017-30-059)**

Submitted to



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CERTIFICATE – I

This is to certify that the thesis entitled, “**Effect of rootstocks and grafting techniques on horticultural traits and gummy stem blight in parthenocarpic cucumber**” submitted in partial fulfilment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the discipline of **Horticulture (Vegetable Science)** of CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur is a bonafide research work carried out by **Ms. Anjali (Admission No. A-2017-30-059)** daughter of **Smt. Nirmala and Sh. Navjeevan Kumar** under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of this investigation have been fully acknowledged.

Place : Palampur
Dated: 24th April, 2019

(Dr. Pardeep Kumar)
Major Advisor

CERTIFICATE- II

This is to certify that the thesis entitled, “**Effect of rootstocks and grafting techniques on horticultural traits and gummy stem blight in parthenocarpic cucumber**” submitted by **Ms. Anjali (Admission No. A-2017-30-059)** daughter of **Sh. Navjeevan Kumar** to the CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture)** in the discipline of **Horticulture (Vegetable Science)** has been approved by the Advisory Committee after an oral examination of the student in collaboration with an External Examiner.

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(Anjali)

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LIST OF ABBREVIATIONS USED

Sr No.	Abbreviations	Meaning
1.	et al.	et alii (and other)
2.	i.e.	id est (that is)
3.	viz.,	vi delictet (namely)
4.	cv.	cultivar
5.	/	per
6.	@	at the rate
7.	°	degree
8.	°C	degree Celsius
9.	%	per cent
10.	TSS	Total soluble solids
11.	FYM	Farmyard manure
12.	N:P: K	Nitrogen:Phosphorus:Potassium
13.	hrs	hours
14.	g	gram
15.	m	meter
16.	mm	millimetre
17.	kg	kilogram
18.	kg/m ²	kilogram per square meter
19.	m ²	square meter
20.	cm	centimetre
21.	w.r.t	with respect to
22.	Fig.	Figure
23.	No.	Number
24.	PDA	Potato dextrose agar

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ABSTRACT

Grafting has a potential for higher yield and disease control in the cultivation of cucurbitaceous crops. Considering this aspect the field experiment entitled “Effect of rootstocks and grafting techniques on horticultural traits and gummy stem blight in parthenocarpic cucumber” was undertaken at the Vegetable Research Farm, Department of Vegetable Science and Floriculture, CSK HPKV, Palampur Himachal Pradesh with two objectives- in vitro screening of different rootstocks for gummy stem blight, and to study the effect of rootstocks and grafting techniques on yield and quality attributes in cucumber. The seeds of local varieties of different rootstocks ie. Summer squash, bottle gourd, pumpkin, ash gourd, luffa, cucumber and bitter gourd were procured from the local farmers. The seven cucurbit rootstocks were screened in vitro against the disease gummy stem blight by inoculating fungus *Didymella bryoniae*. All the rootstocks screened showed resistance to the fungal pathogen *Didymella bryoniae*. The experiment was laid out in a Randomized Block Design with three replications and data were recorded on various horticultural and quality traits of grafted plants viz. Days to first flowering, Days to first fruit set, Days to first harvest, Number of marketable fruits per plant, Marketable fruit yield per plant (kg), Average fruit weight (g), Marketable fruit yield per square meter (kg/m²), Fruit length (cm), Fruit diameter (cm), Harvest duration (days), Vine length (cm), Internodal length (cm), TSS (°Brix), Shelf life and Grafting success per cent (%). Most of the characters under investigation were significantly influenced by the interaction effect of rootstocks and grafting techniques. Treatment RS₅GT₃ (RS₅= Bitter gourd, GT₃= Splice grafting) resulted in minimum number of days to first flower (16.17 days), days to first fruit set (24 days) and minimum number of days to first fruit harvest (32.89 days). Treatment RS₂GT₃ (RS₂= Bottle gourd, GT₃= Splice grafting) resulted in the highest grafting success per cent (96.67%), maximum number of marketable fruits per plant (16.35), maximum marketable fruit yield per plant (2.53 kg), maximum marketable fruit yield per square meter (12.66 kg/m²) and maximum vine length (350 cm). Treatment RS₁GT₃ (RS₁= Summer squash, GT₃= Splice grafting) resulted in the highest average fruit weight (160.06 g) and fruit length (17.25 cm). Minimum internodal length (9.83 cm) was observed in treatment RS₆GT₂ (RS₆= Luffa, GT₂= Hole insertion grafting) and highest TSS of (3.60°Brix) was observed in treatment RS₄GT₂ (RS₄= Cucumber, GT₂= Hole insertion grafting). The interaction effect of rootstocks and grafting techniques had no significant effect on fruit diameter and harvest duration. Therefore, it is inferred from the study that bottle gourd is best compatible rootstock along with splice grafting technique for securing high yield in parthenocarpic cucumber as well as for resistance against gummy stem blight under protected conditions.

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1. INTRODUCTION

Vegetable grafting is a new concept in India, whereas it is very old technique in other countries like Japan, South Korea, Spain, China and Italy. It is defined as an art of joining together two plant parts (a rootstock and a scion) by means of tissue regeneration, in which the resulting combination of plant parts achieves physical reunion and grows as a single plant (Janick, 1986). Grafting occurs commonly in nature and the observation of natural grafts may have inspired human use of this technique in horticulture thousands of years ago. It also acts as a site-specific management tool for soil and seed borne diseases. The key attributes of the root to be used as a good rootstock lies in its resistance to soil borne diseases, its ability to assimilate and transport nutrients and act as an interface with the soil ecosystem. Recently, vegetable production by grafting on resistant rootstocks has become a common popular practice to control soil-borne pathogens, especially for the cultivation of cucumber, melon, watermelon, tomato, pepper and egg plants in greenhouses in many countries. (Lee, 1994).

Parthenocarpic cucumber (*Cucumis sativus* L.) is one of the most important commercial vegetable crop being grown on a large scale under protected environment. It is popular throughout the world due to its crisp texture and taste. At present, in India cucumber is being cultivated in open field conditions, over an area of about 82,000 hectares with an annual production of 12,60,000 metric tonnes (Anonymous, 2018a). In Himachal Pradesh area under cucurbits in open fields is 2578 hectares with a total production of 69,298 metric tonnes (Anonymous, 2018b), whereas in Himachal Pradesh the area and production statistics for cucumber are not available.

Polyhouse technology is becoming popular in Himachal Pradesh due to concerted efforts of state and central governments through sponsored schemes like HTM, MIDH, RKVY, Pt Deen Dyal Kisan Bagwan Samridhi Yojna, Dr Y.S. Parmar Kisan Swarozgar Yojna and Chief Minister Greenhouse Technology Scheme. Due to these reasons Himachal Pradesh occupies a prime place in protected cultivation in the country. Parthenocarpic cucumber is the most popular crop grown under protected conditions due to its short life cycle. Under protected environment, parthenocarpic type of cucumber is preferred over open pollinated or hybrid due to cross pollination nature of the cucumber as open pollinated varieties need cross pollination which is not possible under protected structures as well as for higher yield per unit area. Parthenocarpic and gynoecious cucumber cultivars increase the potential yield to high fruit load in controlled environments resulting in a high harvest

index. In Himachal Pradesh parthenocarpic varieties of cucumber are being grown under protected structure in mid and lower areas of H.P. The area under parthenocarpic cucumber in Bilaspur, Kangra, Kullu, Sirmour districts is 9.49%, 27.88 %, 4.17%, 24.74% with productivity of 5.34 q/100m², 5.02 q/100m², 10.89 q/100m², 4.39 q/100m², respectively (Sharma et al., 2015).

Recently gummy stem blight has emerged as a serious problem in cucurbits in low hill areas of H.P like Kangra, Una, Hamirpur and Bilaspur. Farmers growing cucurbits like bottle gourd and cucumber are facing this serious problem. Gummy stem blight is a common disease found worldwide in greenhouse cucumber. It is caused by the fungus *Didymella bryoniae*, previously named *Mycosphaerella melonis* and *M. citrullina*. The pathogen is seedborne on variety of cucurbits by Brown et al. (1970) and reported as soil borne by Nawaliya (2017). This pathogen infects only members of the cucurbit family such as cucumber, squash, melon, pumpkin, vegetable marrows and bitter melon. The incidence of the disease is influenced by climatic conditions (Van Steekelenburg and Vooren, 1980).

The fungus attacks all parts of the plant and under favourable conditions, causes severe economic losses. The disease is characterized by sudden collapse of the whole crop at the time between first fruit set and first fruit maturation. The disease causes a rapid wilt of mature plants and may lead to a total loss of the crop. No specific chemical control measure is available to control this disease. Hence, plants produced using resistant rootstocks through grafting is an effective, chemical free and an alternative technique to counter this burning problem.

Grafting commercial cultivar on desirable rootstock is an effective method to decrease the harmful effects of biotic and abiotic stresses as well as improve yield and fruit quality. Canizares and Goto, 1998 reported that grafting leads to increased vegetative growth, plant height and fruit quality compared to the non-grafted ones. Providing resistant rootstocks to susceptible scions prevent primary source of infection, resulting in reduced incidence of disease (Davis et al., 2008). Grafting techniques and seedling stage also affect the survival and development of grafted plants. The use of grafting techniques i.e. tongue, approach, slant-cut, cleft and tube result in significant difference on plant survival rate (Rojas and Riveros, 1999). The grafting success depends on the appropriate choice for scion and rootstock combinations, use of proper grafting method and post graft management.

Despite the potential of grafting for higher yields and disease control in the cultivation of cucumber and other cucurbitaceous crops, this technique has been rarely adopted and studied. No research work has been done in the past on this aspect in Himachal

Pradesh as well as in the country. Therefore, the aim of this study was to evaluate the effect of rootstocks and grafting techniques on horticultural traits and gummy stem blight in cucumber hybrid Kian. Considering all these aspects, an experiment entitled “Effect of rootstocks and grafting techniques on horticultural traits and gummy stem blight in parthenocarpic cucumber” was undertaken with the following objectives:

- In vitro screening of different rootstocks for gummy stem blight, and
- to study the effect of rootstocks and grafting techniques on yield and quality attributes in cucumber.

2. REVIEW OF LITERATURE

The relevant literature pertaining to rootstocks and grafting techniques in cucumber is scanty, therefore necessary information and available literature on other cucurbits has also been reviewed under following sub-heads as:-

2.1 Effect of rootstocks and grafting techniques on gummy stem blight (*Didymella bryoniae*) and other diseases.

2.2 Effect of rootstocks and grafting techniques on horticultural traits.

2.1 Effect of rootstocks and grafting techniques on gummy stem blight (*Didymella bryoniae*) and other diseases.

Neergaard et al. (1993) inoculated *Didymella bryoniae* in cucumber plants of different cultivars grown under various levels of nutrient supply, climatic conditions and different pruning practices and concluded that reduced pruning, leaving wilted leaves and shoots on the plants increased the incidence of nodal and internodal lesions and external fruit rot.

Amand and Wehner (1995) developed a useful method, for gummy stem blight (*Didymella bryoniae*) in cucumber, highly correlated ($r = 0.82$ to 0.96) with field ratings for screening germplasm in the greenhouse.

Nisini et al. (2000) evaluated rootstocks of melon in glasshouse for resistance to *Didymella bryoniae* on different cucurbits previously selected as resistant or partially resistant to race 1,2 of *Fusarium oxysporum* f. sp. *melonis* and concluded that *Cucumis anguria*, *C. ficifolius*, *C. figareii*, *C. metuliferus*, *C. zeyheri* and *Benincasa hispida* showed a very high degree of resistance to *Didymella bryoniae* both on leaves and stems.

Crino et al. (2007) evaluated the effect of grafted F₁ hybrid Incas on the commercial rootstocks under greenhouse conditions, in terms of productivity and fruit quality and concluded that the *Cucurbita* rootstocks ('RS 841', 'P 360', 'ES 99-13', 'Elsi') were highly resistant both to the race 1,2 of FOM (100% survival) and to *Didymella bryoniae* (almost absent crown lesions and low leaf disease index).

Ito et al. (2009) evaluated seventeen cucurbit genotypes to select rootstocks resistant to gummy stem blight (*Didymella bryoniae*) and their effects on production of lancewok melon cv. 'Bonus no 2' and concluded that the *Benincasa hispida* rootstock was the most suitable to melon.

Islam et al. (2013) evaluated watermelon for resistance against fusarium wilt by grafting on rootstock bottle gourd and concluded that grafted watermelon plants remain alive up to harvesting, while more than one-third non-grafted plants died from vegetative to fruiting stage and they also reported that fruit yield was one and half times higher in grafted fields as compared to non-grafted counterparts.

Keinath (2013) conducted an experiment by applying nine fungicides as foliar treatments to nongrafted seedlings of watermelon and five rootstock cultivars and concluded that mancozeb or cyprodinil + fludioxonil were most effective to manage gummy stem blight on watermelon and rootstock seedlings during greenhouse production.

Gasparotto et al. (2016) concluded from the study on the effect of grafting on the control of gummy stem blight in four muskmelon hybrids under greenhouse conditions that, grafting on immune rootstocks significantly reduced the severity of gummy stem blight in the four melon hybrids by 34.3%, 34.8%, 45.8% and 49.6%, respectively.

Miceli et al. (2016) evaluated the effect of grafting and mycorrhizal inoculum on yield and quality of mini-watermelon and concluded that grafted inoculated plants had a greater vigour and productivity than ungrafted uninoculated plants.

Papadaki et al. (2017) evaluated six rootstocks against fusarium wilt of cucumber by grafting susceptible Cretan cv. 'Knossos' on the commercial interspecific hybrid rootstocks Leon, Vivere, Mirage, Mammoth and on species *Cycios angulatus* and *Lagenaria siceraria* and concluded that plants grafted on all tested rootstocks were significantly more resistant to fusarium wilt than control.

2.2 Effect of rootstocks and grafting techniques on horticultural traits

Traka-Mavrona et al. (2000) reported from the study on the effect of different *Cucurbita spp* rootstocks on melon cultivars that landraces of *C. moschata* are the best source of material for rootstocks for honey dew melons.

Fernandez et al. (2001) evaluated Almeria variety of watermelon by grafting on four different rootstocks, Shintoza (*Cucurbita maxima* x *Cucurbita moschata*), Squash (*Cucurbita pepo*), Gourd Black Seed (*Cucurbita maxima*) and a selection of *Cucurbita ficifolia* and concluded that the highest total yield 32% higher than non-grafted plants was obtained, whereas grafting did not influence quality; the taste, size and shape of the fruit.

Yetisir and Sari (2003) grafted watermelon cultivar Crimson Tide on ten different rootstocks and concluded that *Lagenaria* type rootstocks produced a higher yield but *Cucurbita* type rootstocks produced a lower yield than the control.

Yetisir et al. (2003) evaluated the effects of grafting on watermelon yield and quality using four commercial *Lagenaria* and two *Cucurbita* rootstocks and concluded that fruit yield was positively (21–112%) affected by *Lagenaria* rootstocks while only minor differences in fruit quality were determined in control and grafted plants on *Lagenaria* rootstocks.

Colla et al. (2006) studied the effects of grafting on growth, yield, fruit quality, gas exchange and mineral composition of watermelon plants and concluded that the total fruit yield was 81% higher in grafted than in ungrafted plants.

Davis and Perkins-Veazie (2006) evaluated watermelon plants by grafting on squash and gourd rootstocks and concluded that grafted watermelon plants produced higher yield and maximum lycopene content as compared to non-grafted plants.

Alan et al. (2007) studied the effect of different rootstocks on watermelon plant growth, yield and quality by comparing grafted plants with non-grafted ones and concluded that grafted plants improved plant growth and yield without any harmful effects on fruit quality.

Zhong and Bie (2007) recorded in their experiment the effect on fruit development and quality by grafting cucumber cultivars ‘Jinyu No.1’ and ‘Jinchun No.4’ (scion) on rootstock figleaf gourd (*C. ficifolia* Bouché) and found that grafting significantly increased the growth of cucumber fruits, whereas fruit ascorbic acid, soluble protein and free amino acid content gradually decreased.

Huitron et al. (2008) evaluated the effects of grafting using different rootstocks on the production and quality of watermelon cv. Reina de Corazones and concluded that the highest production values were obtained with the combination of ‘Reina de Corazones’ scion with *Citrullus lanatus*, *Lagenaria siceraria* or the inter-specific hybrid RS841 (*Cucurbita maxima* × *Cucurbita moschata*) rootstock.

Salehi et al. (2008) concluded from their study on the effects of hole insertion grafting on survival of cucumber, watermelon and melon plants grafted on *Cucurbita spp.* rootstocks summer squash landrace (*Cucurbita pepo* L.), a winter squash landrace

(*Cucurbita moschata* L.) and a Figleaf, that the method hole insertion grafting was highly effective in watermelon and cucumber had 90-95% survival ratio when summer and winter squash were applied as rootstocks.

Bruton et al. (2009) studied the effects of grafting on fruit quality of watermelon using five different rootstocks and concluded that *Cucurbita ficifolia* or *Cucurbita maxima* x *Cucurbita moschata* hybrid as the rootstock, watermelon fruit consistently had higher fruit firmness values and grafting had no effect on lycopene and TSS.

Mohammadi et al. (2009) studied scion-rootstock compatibility and plant performance of 'Khatooni' melon by grafting on three *Cucurbita* rootstocks 'ShintoHongto', Ace and Shintozwa and reported that among the grafted seedlings, all the rootstocks have beneficial effect on Iranian melon.

Heidari et al. (2010) examined scion-rootstock compatibility by grafting cucumber on commercial cultivars, 'Azman', 'Ferro' and 'RS841' and '*C. maxima*' and '*C. moschata*' and found that among the tested rootstocks, 'RS841' is the best one for cucumber cv. 'Khassib' due to its high survival rate and high fruit yield.

Marsic and Jakse (2010) evaluated the effects of three rootstocks on growth and yield of cucumber and concluded that grafted plants had a larger stem diameter, bigger root system and higher yield than non-grafted plants.

Yetisir & Uygur (2010) concluded from their study on effects of grafting watermelon cultivar 'Crimson Tide' on three different rootstocks *Cucurbita maxima* and two *Lagenaria siceraria* landraces that grafted watermelon had higher plant growth than non-grafted plant under saline conditions.

Bekhradi et al. (2011) studied the effect of tube and hole insertion grafting technique in watermelon by grafting scion Matsum and Nakai cv. Charleston gray on three rootstocks: *Cucurbita pepo*, *Lagenaria siceraria* and *Cucurbita maxima* x *C. moschata* and reported that, hole insertion grafting technique resulted in better survival rate and better vegetative growth than non grafted (control) and had no significant effect on fruit quality and yield.

Debei et al. (2012) studied the graft success rate under the impact of root-knot nematode of cucumber cultivar Zezia by grafting on the three cucurbit rootstocks (Strongtosa, Shintosa supreme and Tetsukabuto) using two grafting techniques approach and hole insertion and found 100% graft success rate with hole-insertion method and further

concluded that using Strongtosa and Shintosa supreme as rootstocks for 'Zezia' cucumber improves plant vigor and yield, which confers tolerance to root-knot nematode.

Karaca et al. (2012) evaluated twenty one bottle gourd (*Lagenaria siceraria*) rootstocks for grafting with watermelon with regard to plant growth, yield and fruit quality and concluded that germplasm from Turkish bottle gourd has a high rootstock potential for watermelon with regard to the investigated parameters.

Khankahdani et al. (2012) studied the effect of different rootstocks and grafting techniques on graft union percent, yield and yield components of Watermelon cv. 'Crimson sweet' by performing grafting technique (hole insertion, splice and tongue-approach grafting) on the rootstocks 'Bottle gourd' (*Lagenaria siceraria*), 'Shintoza' (*Cucurbita maxima* × *C. moschata*) and 'Pumpkin' (*C. maxima*) and concluded that using 'Bottle gourd' and 'Shintoza' as rootstocks and splice grafting technique had the highest graft union percent.

Mohamed et al. (2012) studied the plant growth and fruit quality by grafting watermelon variety Aswan F₁ on five rootstocks (Nun 6001 F₁, Strongtosa F₁, Tetsukabuto F₁, Ferro F₁ and Shintoza F₁) hybrids between *Cucurbita maxima* and *Cucurbita moschata* and reported that grafting watermelon on specific rootstock influences growth, productivity, and quality of the fruit as well as disease resistance.

Turhan et al. (2012) found from their experiment on the effect of tongue approach grafting and rootstocks on yield by grafting three hybrid squashes of 'Dynamo', 'RS-841', and 'Shintosa' on watermelon cultivars of 'Crimson Tide', 'Dumara', and 'Farao' that fruit shape index, rind thickness, fruit weight, total yield and marketable yield were significantly influenced by grafting and thus the use of rootstocks was considered economically feasible and an advantageous alternative in watermelon production.

Yarsi et al. (2012) grafted melon (*Cucumis melo* L. var. *cantalupensis*) cultivars 'Falez' and 'Galia C-8' on seven different rootstocks and concluded that plants grafted on rootstocks P360, RS841 and TZ148 had much more early and total yield than ungrafted control plants.

Chao and Yen (2013) conducted an experiment in which cucumber cv. 'Tainan No.1' was grafted on two rootstocks, viz., *Cucumis* and *Cucurbita* and concluded that both kinds

of grafted plants had similar graft-survival rate and better vegetative growth than non-grafted plants.

Mona et al. (2013) studied the effect of grafting techniques on scion watermelon cv. (Aswan F1 hybrid) using the local variety rootstock bottle gourd (*Lagenaria siceraria*) and concluded that splice graft was the best grafting technique in survival rate followed by hole insertion grafting and also the splice grafting gave highly significant increment in all characteristics under study compared to other methods and control.

Ban et al. (2014) studied the effect of rootstocks on the growth and yield of cucumber (*Cucumis sativus* L.) and concluded that plants grafted on the interspecific hybrid rootstocks, 'Strong Tosa' and 'RS 841 Improved', had the highest vegetative growth and yield despite the high root-knot nematode reproduction.

El-Sayed et al. (2014) evaluated scion cucumber (*Cucumis sativus* L.) cultivar "Hady" under high and low temperatures by grafting on four rootstocks namely Bottle Gourd (*Lagenaria siceraria* Standl.), Supper Shintosa (*Cucurbita maxima* Duchesne × *Cucurbita moschata* Duchesne), Squash 3 (*Cucurbita pepo*) and Ferro' (*C. maxima* × *C. moschata*) and concluded that Ferro rootstock increased plant height, physical characters, early and total yields of cucumber fruits in both summer and winter seasons, as compared to non-grafted control.

Eslamboly and Deabes (2014) grafted cucumber scion using tongue approach grafting method on eleven rootstocks namely Bottle gourd, Calabash gourd, Emphasis (*Lagenaria siceraria*), *Cucurbita* rootstocks pumpkin, fig leaf gourd, the interspecific hybrid rootstocks Shintosa, Ercole Nun 6001, Ferro RZ F2, Super Shintosa, Balsam pear and horned cucumber and recorded the highest vegetative growth, early and total yield to non-grafted (control) plants.

Gonzalez et al. (2014) reported from their study that pumpkin and figleaf gourd rootstocks favoured a significant ($P \leq 0.05$) increase in cucumber yield, while the luffa rootstock showed a negative effect on all growth variables and fruit yield.

Farhadi and Rezaie (2015) evaluated the effects of hole insertion grafting of cucumber cultivar 'Khassib' on different rootstocks 'RZ Ferro', 'RZ426', 'ES107', 'ES101', 'ES152', 'RS841', the landrace of winter squash *Cucurbita moschata* ('Halvaii'), *Cucurbita pepo* var. *styriaca* ('Post Kaghazi'), *Cucurbita maxima* ('Tanbal'), *Lagenaria*

siceraria ('Ghelyani') and concluded that grafted plants on 'RZ426' rootstock had the higher yield and plant length compared to non-grafted ones.

Farhadi and Malek (2015) studied the quality and quantity characters by grafting cucumber (*Cucumis sativus* L. 'Soltan') on six different rootstocks namely: *Cucurbita ficifolia* Bouche 'Fig leaf gourd', *Cucurbita pepo* 'Mosamaii', *Cucumis melo* L. var. *flexuosus* 'Chanbar', *Cucumis melo* L. var. *reticulatus* 'Talebi', *Cucumis sativus* L. 'Dastgerdi' and *Citrullus lanatus* 'Watermelon', and non-grafted cucumber 'Soltan' as control and concluded that the most suitable rootstocks for grafting were pumpkin, 'Fig leaf gourd' and squash 'Mosamaii'.

Tamilselvi and Pugalendhi. (2015) studied the effect of cucurbitaceous rootstocks on bitter melon (*Momordica charantia* L.) growth and yield and revealed that the grafted plants had better vegetative growth and yield than the non-grafted plant.

El-Gazzar et al. (2016) studied the effect of different rootstocks and grafting techniques on growth, yield and fruit quality of watermelon by grafting on four rootstocks [Jumbo F₁ and Nun 6001 F₁ hybrids (*Cucurbita maxima* × *Cucurbita moschata*), Bottle gourd (*Lagenaria siceraria* Standl.) and Pumpkin (*Cucurbita moschata* L.)] using three grafting methods [Hole insertion (HIG), Splice (SG) and Tongue approach (TAG)] and concluded that, Jumbo rootstock and tongue approach as grafting method found to increase vegetative growth, yield and fruit quality of watermelon cv. Aswan F₁.

Velkov and Pevicharova (2016) studied the effects of cucumber grafting on yield and fruit sensory characteristics under glasshouse conditions and concluded that most suitable rootstocks for higher yield were *Cucurbita maxima* × *C. moschata* F₁ (cv. 'Carnivor'), *Lagenaria* (landrace) and *C. maxima* ('Plovdivski', old local cultivar).

Akhila and George (2017) studied the effects of grafting bitter melon on cucurbitaceous rootstocks using two grafting techniques i.e. wedge grafting (WG) and tongue approach grafting (TAG) and concluded that best rootstock for grafting bitter melon was pumpkin followed by smooth gourd, bottle gourd, ash gourd, oriental pickling melon and self-rootstock and they further reported that wedge grafting was superior over tongue approach grafting in terms of final graft success.

Dawa et al. (2017) studied the fruit yield and quality by grafting cucumber (*Cucumis sativus* L.) c.v Nabeela plants on three rootstocks i.e. Jumbo, Star and Felxi and results

indicated that grafting on the different rootstocks and foliar application treatments exerted significant effects on many growth aspects i.e. survival rate, stem length, number of lateral branches, leaf area, fresh and dry weights of plants, fruit yield (total yield and early yield).

Khodadadi and Aghabeigi (2017) conducted experiment to find the best rootstock by grafting cucumber varieties "Soltan and Extreme" as scion on rootstock consisting eleven varieties of squash by approach method and concluded that among the cucumber varieties, the percentage survival was high in Soltan variety as compared to Extreme.

Tamilselvi and Pugalendhi (2017a) grafted bitter gourd cultivars viz., Palee F₁ and CO₁ on six cucurbitaceous rootstocks by adopting side grafting technique and recorded higher success percentage (89.05% and 85.35%) with rootstocks pumpkin and sponge gourd and they further revealed that, the grafted plants had better vegetative growth and yield than the non-grafted plants.

Tamilselvi and Pugalendhi (2017b) studied the graft compatibility of bitter gourd scions (Palee F₁ and CO₁) with ten different cucurbitaceous rootstocks and concluded that pumpkin (*C. moschata*) rootstock could be the compatible rootstock for grafting with bitter gourd scions.

Alan et al. (2018) evaluated the effects of growth cycle on fruit quality for grafted watermelon combinations and concluded that most of the fruit quality attributes increased when a specific rootstock/scion combination and growth season was used and these combinations may change in relation to cultivar.

Ceylan et al. (2018) studied the effect of grafting and rootstock-scion combinations on the yield and nutrient contents of watermelon by grafting two watermelon varieties Crisby and Crimstar on rootstocks Ferro and RS 841 and the commercial hybrids of *Cucurbita maxima* x *Cucurbita moschata* and concluded that the Crimstar-Ferro combination had the highest yield.

Tamilselvi and Pugalendhi (2018) studied the effects of grafting on plant growth, yield and quality of bitter gourd using side grafting technique and concluded that among the twelve graft combinations, pumpkin (*C. moschata* Duch.ex Poir) followed by sponge gourd (*Luffa cylindrica* L.) rootstocks were identified as best rootstocks for grafting with bitter gourd scions due to better graft affinity, compatibility and vigorous root systems which help to increase growth, yield and productivity without any quality deterioration.

Yetisir and Sari (2018) studied the effects of the cultivar Crimson Tide by grafting on *Lagenaria* rootstock to investigate rootstock effects on seed yield and concluded that fruit yield, seed number/kg fruit flesh, seed number per fruit and unit area were significantly affected by rootstocks and the grafted plants produced higher seed yield than the ungrafted control plants.

Zhang et al. (2019) evaluated the grafting effects of rootstock 'Wanzhen No. 2' on three watermelon cultivars ('Xiuli', 'Jinlvhongling', and 'Xinong No. 8') subjected to double-root-cutting grafting and concluded that 'Wanzhen No. 2' is a suitable rootstock for grafted seedlings in three watermelon cultivars.

3. MATERIALS AND METHODS

The present investigation entitled “Effect of rootstocks and grafting techniques on horticultural traits and gummy stem blight in parthenocarpic cucumber” was undertaken in a modified naturally ventilated polyhouse at the Experimental Farm of Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during spring summer season in 2018. The details of materials used and methods employed in the present investigation are presented below: -

3.1 Experimental site

3.1.1 Location

The present study was carried out in a modified naturally ventilated polyhouse (25 m x 10 m) during off-season i.e. 10th July, 2018 onwards at the Experimental Farm of Department of Vegetable Science and Floriculture which is situated at 32°6’ N latitude and 76°3’ E longitude at an elevation of 1290.80 m above mean sea level with East-West orientation which falls under mid hill zone of Himachal Pradesh. It is an ideal polyhouse with essential features like double door, side and top ventilation, drip and fogging facilities and internal shading with 50% green agro UV stabilized shade net.

3.1.2 Climate

The climate of the area is generally sub-temperate and semi-humid with mild summers (March to June) and cool winters (October to February) with high rainfall mainly during rainy season (June to September). The mean weekly meteorological data recorded during the crop growth period have been depicted in fig. 3.1 and appended in Appendix I. A brief perusal of weekly meteorological data revealed that the weekly maximum and minimum temperature ranged from 23.57 (43rd standard week: October) to 32.89°C (21st standard week: May) and 10.14 (43rd standard week: October) to 20.64 °C (23rd standard week: June), respectively. The mean relative humidity ranged from 24.07 (21st standard week: May) to 94.93 per cent (32nd standard week: August) and total of 2619.4 mm rainfall was received during the crop season. The mean bright sunshine hours ranged from 0.5 (32nd standard week: August) to 9.5 (43rd standard week: October).

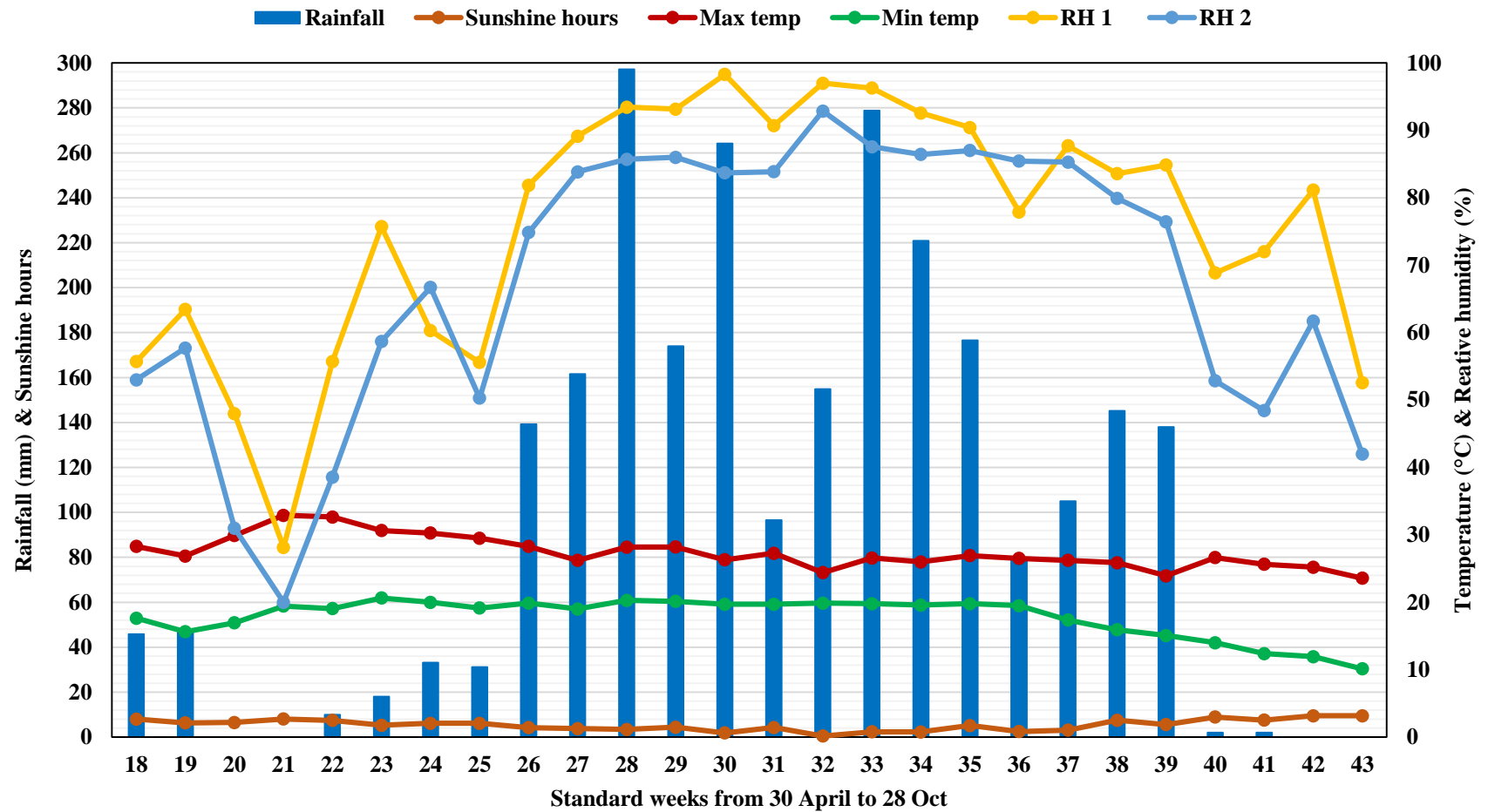


Fig. 3.1 Mean weekly weather data at Palampur (H.P.) for the crop period (30th April to 28th Oct 2018)

3.2 Experimental material and layout plan

3.2.1 Experimental material

The experimental material used for the present study comprised of seven Cucurbit rootstocks of local varieties namely Summer squash, Bottle gourd, Pumpkin, Cucumber, Bitter gourd, Luffa and ash gourd; and parthenocarpic cucumber hybrid Kian as scion. The seeds of different rootstocks were procured from local farmers, whereas the seeds of scion were procured from the Nunhems India Pvt. Ltd.

Table 3.1 Local rootstocks used in the study.

Sr. No.	Rootstock	Source
1	Summer squash (RS ₁) (<i>Cucurbita pepo</i>)	Local variety
2	Bottle gourd (RS ₂) (<i>Lagenaria siceraria</i>)	Local variety
3	Pumpkin (RS ₃) (<i>Cucurbita moschata</i>)	Local variety
4	Cucumber (RS ₄) (<i>Cucumis sativus</i>)	Local variety
5	Bitter gourd (RS ₅) (<i>Momordica charantia</i>)	Local variety
6	Luffa (RS ₆) (<i>Luffa acutangula</i>)	Local variety
7	Ash gourd (RS ₇) (<i>Benincasa hispida</i>)	Local variety

3.2.2. Gummy stem blight (*Didymella bryoniae*) incidence (%)

The diseased samples of bottle gourd (i.e. leaves, vines, roots) were collected from district Una, Himachal Pradesh. The diseased samples were examined in the laboratory and observed microscopically to identify the associated pathogen(s). The fungal pathogen(s) were isolated by cutting the small pieces of tissue aseptically from the margins of the lesions of the fresh tissue. These bits were then disinfected for 15-20 seconds in 1% sodium hypochlorite and were rinsed with sterile distilled water. The bits were then transferred to potato dextrose agar (PDA) medium slants under aseptic conditions and were incubated in BOD incubator at 25°C under 24 hrs continuous photoperiod. A small piece was cut from an area of a colony to

obtain a pure culture from single conidia. Fungal colony arising from single spore was multiplied on PDA for further study.

Further, seven cucurbit rootstocks were screened in pot culture by inoculating *Didymella bryoniae* culture to know the disease reaction. Soil inoculation method was followed in which the spore suspension was prepared and poured in the soil around the rhizosphere and was kept humid at 25°C. Disease incidence (%) was calculated by the formula given below:

$$\text{Disease incidence (\%)} = \frac{\text{Number of infested plants}}{\text{Total number of plants planted}} \times 100$$

The resistant rootstocks were grafted using scion Kian.

3.2.3 Grafting techniques: - Three grafting techniques were followed, including:

- a. Approach grafting (GT₁)
- b. Hole insertion grafting (GT₂)
- c. Splice grafting (GT₃)

3.2.4 Experimental layout and design

Twenty-two treatments in total, comprising of seven rootstocks and three grafting techniques and control were laid out in a Randomized Block Design (Factorial) with three replications in a 25m x 10m modified naturally ventilated quonset polyhouse. Experimental layout plan is given in Appendix II.

3.2.5 Nursery sowing of scion and rootstocks

The nursery of the rootstock and scion varieties were raised in plug trays by using soil-less media having mixture of Cocopeat:Perlite:Vermiculture in the ratio of 3:1:1 in growth chamber. To obtain an equal stem-diameter in scion and the rootstock, rootstock seeds were planted 7 days earlier than scion variety.

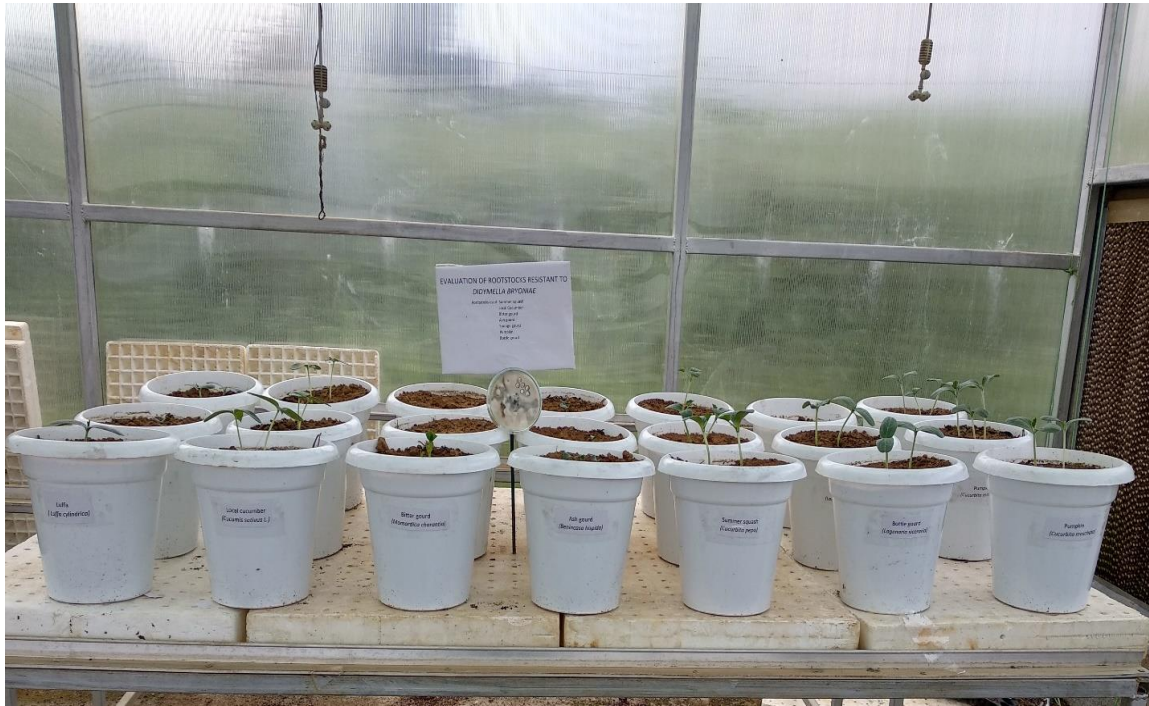


Plate 1: Evaluation of rootstocks for *Didymella bryoniae* disease reaction

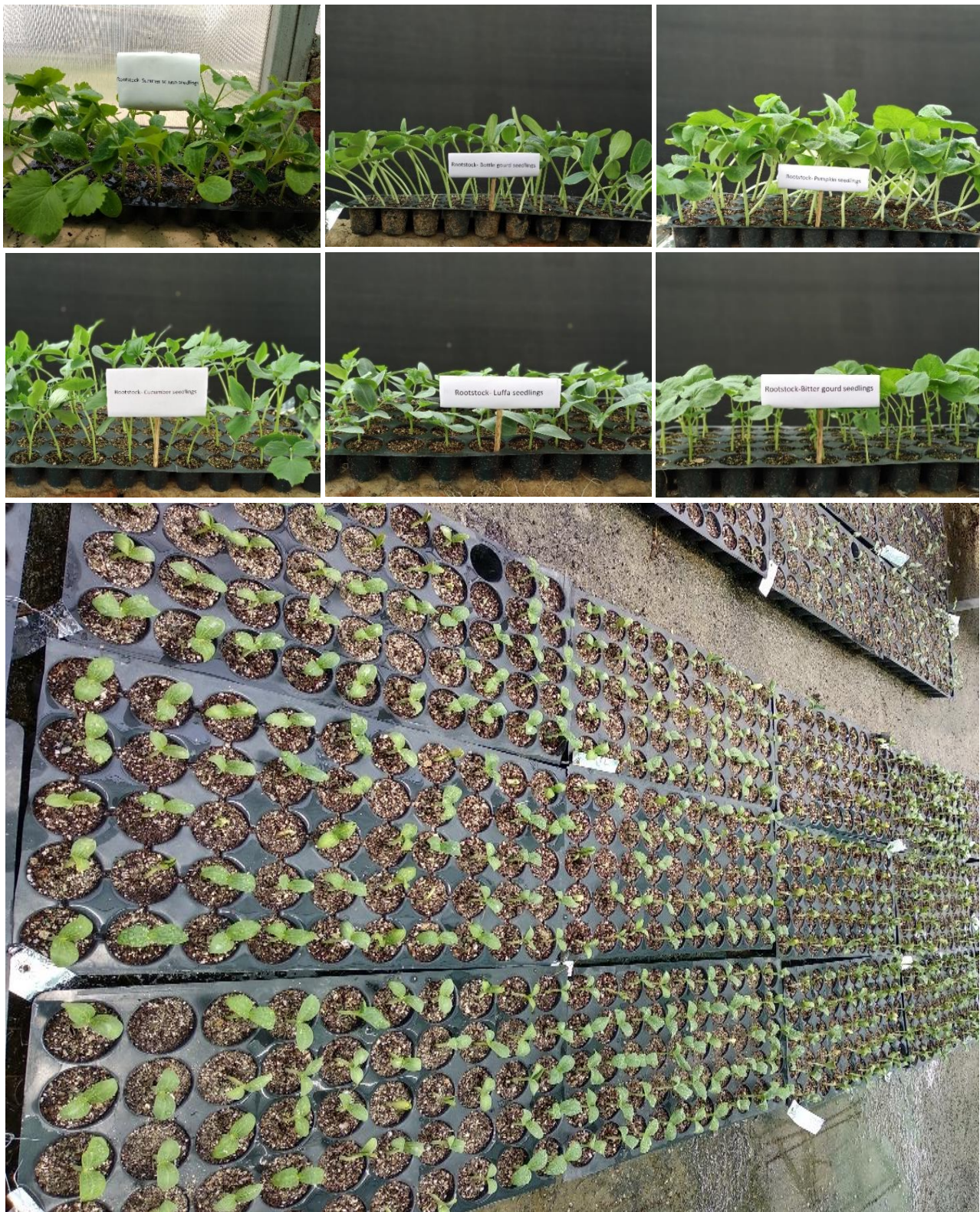


Plate2: Nursery of scion and rootstocks

3.2.6 Bed preparation

The beds were thoroughly prepared for transplanting of cucumber seedlings inside the naturally ventilated polyhouse accommodating ten plants per plot. FYM @ 3kg/m², whole of the vermicompost @ 1 kg/m² and chemical fertilizers NPK @5:5:5 g/m² were applied in beds before transplanting of cucumber seedlings.



Plate 3: Bed preparation

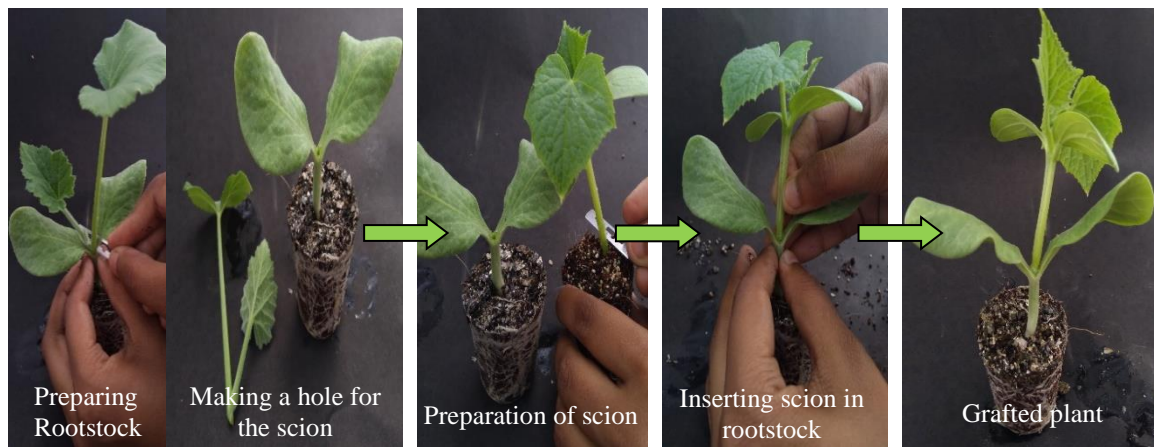
3.2.7 Grafting

The seedlings grown in an environment-controlled greenhouse were grafted on the different rootstocks at the cotyledon stage with cucumber as a scion using three grafting techniques i.e. approach, hole insertion and splice grafting. The best time for grafting was when the rootstock and scion stems have the same diameter.

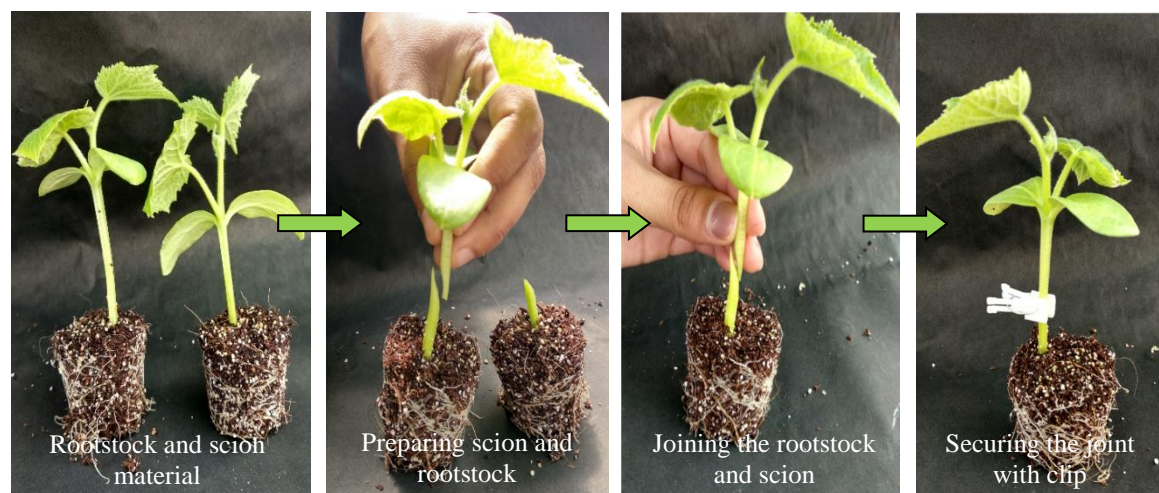
In approach grafting technique the rootstock and scion of approximately the same diameter, were cut through the hypocotyl at 35° to 45° angle with the help of a sharp sterilized grafting/razor blade. The scion was cut from bottom to top, while the rootstocks were cut from top to bottom. Each slit of rootstock and scion were like a tongue and were fitted together with self-adhesive clear tape or grafting clips. In hole insertion grafting technique the rootstock and scion taken were uniform and strong enough to undergo the grafting operations. The true leaf including the growing point was carefully and thoroughly removed and a hole was made with bamboo skewer at a slant angle to the longitudinal direction. The scion was prepared by giving a slant cut to have a tapered end for easy insertion. In slice grafting technique the growing tip was removed from the rootstock by giving a slant cut from the base of the cotyledon. The length of cut of the scion hypocotyl should be same as that of the rootstock and should be at a 35° to 45° angle.



Steps for approach grafting technique



Steps for hole insertion grafting technique



Steps for splice grafting technique

Plate 4: Grafting methods employed

The scion was attached to the rootstock and fused tightly by a grafting clip or ordinary self-adhesive clear tape to ensure good vascular contact and successful healing of the grafted components.

3.2.8 Aftercare and healing

Grafted plants were sprayed with water immediately after grafting with the help of a hand-held sprayer. The grafted plants were transferred immediately to the healing chamber or mist chamber for post-graft care where optimum Relative humidity (>95 per cent), temperature (25-30°C) and dark conditions prevailed for five to seven days to ensure a complete graft union. Under these conditions it took a total of five to seven days for rootstock and scion to establish a good vascular connection and continue normal growth as a single plant. Relative humidity was reduced gradually for acclimatization. Acclimatization involves healing of the cut surface and hardening for field and greenhouse survival (Lee and Oda, 2003). After the graft was firmly established the silicon/plastic clips and tapes were removed from the graft union and the grafted seedlings were transplanted to soil.

3.2.9 Transplanting of seedlings

Ten plants in each plot were transplanted on 10th July, 2018. The grafted seedlings at 2-3 true leaf stage were transplanted at inter row distance of 70cm and plant to plant distance of 30 cm in the beds, respectively. The experimental design consisted of Randomized block design (RBD) with three replications. There were ten plants per treatment per replication. The graft union of grafted seedlings was kept above the soil line, to avoid development of adventitious roots from the scion that penetrate the soil and cause disease bypassing of resistant rootstock that may lead to infection and death of the entire plant.

3.2.10 Fertilizer application

The fertigation was given thrice a week by applying liquid fertilizer (19:19:19) @ 2.0 g/m² after third week of transplanting and was stopped 15 days before final harvest.

3.2.11 Cultural practices

Recommended package of practices was followed to raise a healthy crop. Irrigation was applied through drip on alternate day during the cropping period. The cucumber plants were trained on one stem through nylon twines by retaining one primary stem per plant. Pruning was done at regular intervals to remove unwanted shoots arising from the main stem and rootstocks to ensure proper growth of the main stem trained on twine.



Summer squash



Bottle gourd



Pumpkin



Cucumber

Plate 5a: Ready to transplant grafts- illustrating three grafting techniques



Bitter gourd



Luffa



Ash gourd



Transplanting of seedlings

Plate 5b: Ready to transplant grafts- illustrating three grafting techniques



Plate 6a: Plants after transplantation - illustrating different grafting techniques



Plate 6b: Plants after transplantation - illustrating different grafting techniques



Plate 6c: Plants after transplantation - illustrating different grafting techniques

3.3 Observations recorded

Five plants were randomly selected from each treatment in each replication from the experimental plots to assess the effect of treatments on both qualitative and quantitative characters:

A. Phenological traits

(i) Days to first flowering

The number of days taken from the date of transplanting to the date of opening of first female flower, for each treatment, was recorded and mean number of days worked out.

(ii) Days to first fruit set

The number of days taken from the date of transplanting to the date of first fruit set were recorded and mean number of days worked out.

(iii) Days to first harvest

The number of days taken from the date of transplanting to the date of first fruit harvest were recorded and mean number of days worked out.

B. Yield and its horticultural traits.**(i) Number of marketable fruits per plant**

Number of fruits harvested from five randomly selected plants at each harvest were counted and finally summed up to work out the average number of fruits per plant.

(ii) Marketable fruit yield per plant (kg)

Fruits harvested from five tagged plants were weighed separately at every picking. By adding total produce of tagged plants and dividing by number of tagged plants in every plot, yield per plant in kilograms was calculated.

(iii) Average fruit weight (g)

Fruits were taken from the pooled product of tagged plants at every picking, their weight was recorded and then average fruit weight in grams was calculated. Average fruit weight was calculated by dividing the total marketable yield by total number of marketable fruits.

(iv) Marketable fruit yield per square meter (kg/m²)

Fruit yield per square meter was calculated by counting the number of plants per square meter and multiplied by yield per plant.

(v) Fruit length (cm)

The length of five randomly selected fruits from five tagged plants in each plot was measured in between the polar ends with the help of Vernier caliper and average fruit length was calculated.

(vi) Fruit width (cm)

The fruits used for recording the length were also considered to measure the fruit width. The fruit width was measured on the equatorial side with the help of vernier caliper and the mean value was worked out.

(vii) Harvest duration (days)

Days were counted from the first picking to final harvest of cucumber fruits for each treatment and were averaged for all the selected plants to determine the total harvest duration.

C. Structural traits

(i) Internodal length (cm)

Distance between two nodes was measured in a vine at five spots and average was worked out.

(ii) Vine length (cm)

The height of five randomly selected plants from each plot was measured in centimetres from soil line to the tip of the plant at the time of last harvesting and average was worked out to express the plant height in centimetres.

D. Quality traits

(i) TSS (°Brix)

Marketable fruits from tagged plants in each treatment were obtained during harvest and crushed in pestle and mortar, the liquid extract obtained was used to record total soluble solids (°Brix) with the help of ERMA hand refractometer.

(ii) Shelf life (days)

Five fruits were randomly selected from each treatment and were kept at room temperature and their shelf life was recorded.

E. Grafting success rate (%)

(i) Grafting success rate was worked out by using the following formula for each treatment;

$$\text{Grafting success rate (\%)} = \frac{\text{Plants survived till the end of trial}}{\text{Number of successful grafts}} \times 100$$

3.4 Statistical analysis

Collected average values for each treatment in each replication for the characters studied were subjected for further statistical analysis. Data were statistically analyzed using standard procedures of analysis of variance (ANOVA) for factorial RBD. A brief outline of the procedure adopted for the estimation of statistical parameter is given below.

3.4.1 Analysis of variance

The data recorded on various aspects in the present study was subjected to the statistical analysis using analysis of variance for factorial RBD. The table for analysis of variance (ANOVA) for factorial RBD was set as below:-

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F cal ratio
Replications (r)	(r-1)	Sr	Mr = Sr/(r-1)	Mr/Me
Treatments (t)	(t-1)	St	Mt = St/(t-1)	Mt/Me
Rootstocks (a)	(a-1)	Sa	Ma = Sa/(a-1)	Ma/Me
Grafting methods (b)	(b-1)	Sb	Mb = Sb/(b-1)	Mb/Me
R×G interaction	(a-1)(b-1)	Sab	Mab=Sab/(a-1)(b-1)	Mab/Me
Error (e)	(r-1)(ab-1)	Srab	Me=Srab/(r-1)(ab-1)	
Total	(rab-1)	S _(rab-1)		

where,

- r = Number of replications
- t = Number of treatments
- a = Number of rootstocks
- b = Number of grafting methods

For comparing the means of any two treatments the standard error of mean SE(m) and critical difference (CD) were calculated as follows:

$$SE(m) = \pm (Me/r)^{1/2}$$

$$SE(d) = \pm (2me/r)^{1/2}$$

$$\text{Critical difference (CD)} = SE(d) \times t(5\%) \text{ value at error degree of freedom}$$

The tabulated 'T' value and calculated 'F' value are compared at 5% level of significance. If the calculated 'F' value was higher than the tabulated one, it was then considered significant. All the characters showing significant differences among different treatments were subjected further for analysis of different parameters.

$$\text{Coefficient of Variation (CV \%)} = \frac{(Me)^{1/2}}{\bar{X}} \times 100$$

4. RESULTS AND DISCUSSION

The field experiment entitled “Effect of rootstocks and grafting techniques on horticultural traits and gummy stem blight in parthenocarpic cucumber” was carried out at Vegetable Research Farm, Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur during summer season (kharif) 2018. The results obtained from the present study are presented and discussed with the help of data in tables with possible scientific explanation and supportive evidences based on available literature. The results have been presented and discussed under the following heads:

4.1 Disease incidence

4.1.1 Gummy stem blight (*Didymella bryoniae* incidence %)

4.2 Phenological traits

4.2.1 Days to first flowering

4.2.2 Days to first fruit set

4.2.3 Days to first harvest

4.3 Yield and its horticultural traits

4.3.1 Number of marketable fruits per plant

4.3.2 Marketable fruit yield per plant (kg)

4.3.3 Average fruit weight (g)

4.3.4 Marketable fruit yield per square meter (kg/m²)

4.3.5 Fruit length (cm)

4.3.6 Fruit width (cm)

4.3.7 Harvest duration (days)

4.4 Structural traits

4.4.1 Internodal length (cm)

4.4.2 Vine length (cm)

4.5 Grafting success rate (%)

4.6 Quality traits

4.6.1 TSS (°Brix)

4.6.2 Shelf life (days)

4.1 Disease incidence

4.1.1 Gummy stem blight (*Didymella bryoniae* incidence %)

In present experiment seven rootstocks used in the study were inoculated with *Didymella bryoniae* culture in pots to screen the rootstocks for disease reaction. The examined rootstocks in pot culture did not show any incidence of fungi *Didymella bryoniae*. The results showed that all the rootstocks used were resistant to *Didymella bryoniae* incidence. It may be due to the fact that *Didymella bryoniae* is either a seed borne or soil borne fungi and all rootstocks were not affected by this fungal disease (Brown et al. 1970; Nawaliya 2017). Whereas, as per the reports from the field, hybrid varieties are highly susceptible to this pathogen.

Table 4.1 Reaction of cucurbit rootstocks on the incidence of gummy stem blight (*Didymella bryoniae*)

S. No.	Rootstock	Reaction
1.	Summer squash (RS ₁)	Resistant
2.	Bottle gourd (RS ₂)	Resistant
3.	Pumpkin (RS ₃)	Resistant
4.	Cucumber (RS ₄)	Resistant
5.	Bitter gourd (RS ₅)	Resistant
6.	Luffa (RS ₆)	Resistant
7.	Ash gourd (RS ₇)	Resistant

4.2 Phenological traits

4.2.1 Days to first flowering

Number of days taken to first female flower appearance in cucumber under protected as well as under open field conditions is an important character. It is an indicator of getting early and uniform fruit yield of cucumber. From the data presented in the Table 4.2 it is clear that all the seven rootstocks tried in the study influenced the number of days taken to first flower appearance significantly. Rootstock (RS₂) Bottle gourd produced significantly early flowers than other rootstocks used. It took minimum number of days (18.82) to first flowering. Rootstocks (RS₃) Pumpkin, Cucumber (RS₄), Luffa (RS₆) and Ash gourd (RS₇) were statistically at par for number of days taken to first flower appearance.



Plate 7: Resistant rootstocks after inoculation of *Didymella bryoniae*

Grafting techniques also played a significant role in influencing the days to first flower. Various grafting techniques applied in the present study affected first flowering significantly (Table 4.2). Splice grafting technique (GT₃) took minimum number of days (19.85) to first flower which was significantly superior w.r.t earliness than other grafting techniques i.e. approach (GT₁) and hole insertion (GT₂).

Grafted plants (others) took significantly lesser number of days to first flowering (20.38 days) than control with 21.80 days to first flowering.

The interaction among rootstocks and grafting techniques also significantly affected the days to first flowering (Table 4.3). Treatment RS₅GT₃ (RS₅= Bitter gourd, GT₃= Splice grafting) took minimum number of days (16.17) to first flowering which was statistically less than all other interactions except RS₂GT₂ (RS₂= Bottle gourd, GT₂= Hole insertion grafting) which whom it was statistically at par (17.99 days). Earliness is the main index which demonstrates the significant role of the rootstock. Minimum number of days to first flower appearance recorded in grafted cucumber may be due to better scion-rootstock compatibility and better nutrient uptake. These results are in confirmity with the findings of Farhadi and Malek (2015), Velkov and Pevicharova (2016) and Tamilselvi and Pugalendhi (2017).

4.2.2 Days to first fruit set

The observations recorded on the effect of rootstocks and grafting methods and their interactions on days to first fruit set in cucumber are presented in Table 4.2 and 4.3 respectively. From the perusal of data in Table 4.2, it is clear that rootstocks and grafting techniques influenced the days to first fruit set significantly. Rootstock Bottle gourd (RS₂) took minimum number of days (26.59) to first fruit set, however, these were statistically at par with rootstocks Bitter gourd (RS₅) (26.66 days) and Summer squash (RS₁) (27.12 days).

Splice grafting method resulted in minimum number of days (27.11) to first fruit set which was statistically superior (earlier) to other methods employed in the study.

Grafted plants (others) recorded significantly lesser number of days (27.84) to first fruit set than non-grafted plants (control) which took 30 days to first fruit set.

Rootstock and scion interactions significantly affected the number of days to first fruit set. Significantly lesser number of days (24) to first fruit set were recorded in treatment RS₅GT₃ (RS₅= Bitter gourd, GT₃= Splice grafting) followed by treatments RS₁GT₃ (25.97 days), RS₂GT₃ (25.60 days) and RS₁GT₂ (26.33 days), which were statistically at par with treatment RS₅GT₃ .

4.2.3 Days to first harvest

Days to first harvest is an important observation which affect the market price in the market. Early crop in comparison to main season crop provide good returns to the grower. Although the scion genotype often has a dominant effect on most agronomic traits, the rootstock introduces new sources of genotypic and phenotypic variability in the crop, due to rootstock-scion-environment interactions. From the Table 4.2 and 4.3 it is inferred that the rootstocks and grafting techniques and their interactions significantly affected the number of days to first harvest.

Rootstock Bottle gourd (RS₂) grafted with popular parthenocarpic hybrid Kian as scion took significantly lesser number of days (34.78) to first harvest which were, however statistically at par with rootstocks Ash gourd (35.26 days), Bitter gourd (35.74 days) and Cucumber (36.10 days).

Different grafting techniques are selected depending on the type of the crop, technical expertise, personal choice, the number of grafts required and the purpose of the grafting. It is clear from the data in the Table 4.2 that grafting techniques used in the study also significantly influenced the number of days taken to first harvest. Splice grafting technique (GT₃) took minimum number (36.01) of days to first harvest which were statistically at par with approach grafting technique (GT₁).

Table 4.2 Effect of rootstocks and grafting techniques on days to first flowering, days to first fruit set and days to first harvest.

Treatment	Days to first flowering	Days to first fruit set	Days to first harvest
A. Rootstocks			
Summer squash (RS ₁)	20.04	27.12	37.81
Bottle gourd (RS ₂)	18.82	26.59	34.78
Pumpkin (RS ₃)	21.20	28.58	38.16
Cucumber (RS ₄)	21.13	28.54	36.10
Bitter gourd (RS ₅)	19.01	26.66	35.74
Luffa (RS ₆)	21.06	28.41	38.04
Ash gourd (RS ₇)	21.37	29.01	35.26
CD (P=0.05)	1.07	1.42	1.49
B. Grafting techniques			
Approach (GT ₁)	20.55	28.32	36.31
Hole insertion (GT ₂)	20.73	28.10	37.35
Splice (GT ₃)	19.85	27.11	36.01
CD (P=0.05)	0.70	0.93	1.0
C. Control vs Others			
Control (Non-grafted)	21.80	30.00	39.00
Others	20.38	27.84	36.55
CD (P=0.05)	1.34	1.78	1.86

Grafted plants (others) significantly took minimum number of days to first harvest (36.55 days), whereas the non-grafted (control) took 39 days. On an average non-grafted plants (control) took 2.45 more days to harvest first fruit as compared to the other treatment combinations.

The interactions among rootstocks and grafting techniques also resulted in significant variations for number of days to first harvest. The treatment RS₅GT₃ (RS₅= Bitter gourd, GT₃= Splice grafting) produced fruits in significantly lesser number of days i.e. 32.89 days, followed by treatments RS₂GT₃ (33.53 days), RS₇GT₂ (34.25 days), RS₂GT₁ (34.40 days), RS₄GT₃ (35.42 days), RS₆GT₁ (35.47) and RS₄GT₂ (35.47 days), which were statistically at par with RS₅GT₃.

Lesser number of days taken for first fruit harvest in grafted plants may be due to ability of grafting rootstock for faster establishment and better coordination with environment. Farhadi and Rezaie (2015) also reported fruit earliness in grafted plants.

Table 4.3 Interaction effect of rootstocks and grafting techniques on days to first flowering, days to first fruit set and days to first harvest.

Treatment (RS×G)	Days to first flowering	Days to first fruit set	Days to first harvest
RS ₁ GT ₁	21.47	29.07	37.20
RS ₁ GT ₂	19.67	26.33	40.00
RS ₁ GT ₃	19.00	25.97	36.22
RS ₂ GT ₁	20.00	27.62	34.40
RS ₂ GT ₂	17.99	26.53	36.40
RS ₂ GT ₃	18.47	25.60	33.53
RS ₃ GT ₁	21.23	28.80	37.47
RS ₃ GT ₂	20.78	28.67	40.67
RS ₃ GT ₃	21.58	28.28	36.33
RS ₄ GT ₁	20.20	27.80	37.40
RS ₄ GT ₂	22.67	29.53	35.47
RS ₄ GT ₃	20.53	28.29	35.42
RS ₅ GT ₁	19.53	27.13	36.33
RS ₅ GT ₂	21.33	28.83	38.00
RS ₅ GT ₃	16.17	24.00	32.89
RS ₆ GT ₁	20.80	28.40	35.47
RS ₆ GT ₂	22.00	29.00	36.67
RS ₆ GT ₃	20.39	27.83	42.00
RS ₇ GT ₁	20.62	29.44	35.89
RS ₇ GT ₂	20.67	27.83	34.25
RS ₇ GT ₃	22.83	29.77	35.64
CD(P=0.05)	1.85	2.47	2.58

4.3 Yield and its horticultural traits

4.3.1 Number of marketable fruits per plant

Number of marketable fruits per plant generally affects overall yield of parthenocarpic cucumber. It has direct correlation with average yield of the crop. A cursory look at Table 4.4 and 4.5 indicate that different rootstocks and grafting techniques and their interactions, respectively resulted in significant variations w.r.t number of marketable fruits per plant.

Rootstock Bottle gourd (RS₂) produced significantly higher number of marketable fruits per plant (15.38) than all other rootstocks, whereas minimum number of fruits per plant (12.31) were found in rootstock Bitter gourd.

Various grafting techniques such as hole insertion, approach and splice, used in the present investigation, affected the number of fruits per plant significantly. Splice grafting technique (GT₃) resulted in the highest number (14.22) of marketable fruits per plant.

Non-grafted plants (control) significantly produced higher number (15) of marketable fruits per plant. While other treatment combinations (grafted plants) on an average produced (13.57) number of marketable fruits per plant.

The interaction effects among different rootstocks and grafting techniques also exhibited significant variations for number of marketable fruits per plant. The interaction effect of rootstock and grafting technique RS₂GT₃ (RS₂ = Bottle gourd, GT₃= Splice grafting) produced significantly higher number of marketable fruits per plant (16.35) than all other interactions except treatment RS₂GT₂ (15.67) with whom it was statistically at par. Minimum number of marketable fruits per plant (11.17) were recorded in treatment RS₅GT₂ (RS₅= Bitter gourd, GT₂ = Hole insertion grafting). Similar results were also obtained by Velkov and Pevicharova (2016), where they revealed that the variation in number of fruits per plant was affected more strongly by rootstock and their interaction regardless of the cucumber scion varieties.

4.3.2 Marketable fruit yield per plant (kg)

It was seen from the Table 4.4 and 4.5 that the rootstocks and grafting techniques and their interaction, respectively exerted significant variations w.r.t marketable fruit yield per plant. Maximum fruit yield per plant (2.28 kg) was observed in plants grafted on rootstock Bottle gourd (RS₂), which was significantly superior to all other rootstocks used in the study. Minimum fruit yield per plant was recorded in rootstock Bitter gourd (RS₅) (1.72kg).

It is pertinent to mention here that grafting techniques also influenced the marketable fruit yield per plant and splice grafting technique recorded the highest fruit yield per plant (2.05kg), which was significantly superior to all other grafting techniques.

Non-grafted (control) significantly produced the highest marketable fruit yield per plant (2.13 kg) than average of other treatment combinations which produced 1.93 kg of yield per plant.

Table 4.4 Effect of rootstocks and grafting techniques on number of marketable fruits per plant, marketable fruit yield per plant (kg), average fruit weight (g) and marketable fruit yield per square meter (kg/m²)

Treatment	No of marketable fruits per plant	Marketable fruit yield per plant (kg)	Average fruit weight (g)	Marketable fruit yield per square meter (kg/m ²)
A. Rootstocks				
Summer squash (RS ₁)	13.53	2.02	149.08	10.08
Bottle gourd (RS ₂)	15.38	2.28	148.05	11.39
Pumpkin (RS ₃)	12.98	1.83	141.07	9.17
Cucumber (RS ₄)	14.29	1.97	138.13	9.87
Bitter gourd (RS ₅)	12.31	1.72	139.68	8.61
Luffa (RS ₆)	13.16	1.83	139.00	9.14
Ash gourd (RS ₇)	13.36	1.84	137.30	9.19
CD (P=0.05)	0.91	0.14	5.53	0.70
B. Grafting techniques				
Approach (GT ₁)	13.55	1.90	140.13	9.49
Hole insertion (GT ₂)	12.95	1.83	140.87	9.15
Splice (GT ₃)	14.22	2.05	144.28	10.26
CD (P=0.05)	0.59	0.09	NS	0.46
C. Control vs Others				
Control (Non-grafted)	15.00	2.13	133.87	10.67
Others	13.57	1.93	141.76	9.63
CD (P=0.05)	1.14	0.18	6.92	0.88

Interactions among rootstocks and grafting techniques also resulted in significant variations w.r.t fruit yield per plant (kg). Maximum yield (2.53kg) was noticed in RS₂GT₃ (RS₂= Bottle gourd, GT₃= Splice grafting) which was statistically at par with treatment RS₂GT₂ (RS₂= Bottle gourd, GT₂= Hole insertion grafting) and RS₁GT₃ (RS₁= Summer squash, GT₃= Splice grafting) with yield 2.32 kg and 2.21 kg, respectively. The lowest fruit

yield (1.51 kg) was found in treatments RS₃GT₂ and RS₅GT₂ which was statistically at par with treatments RS₇GT₁ (1.68kg), RS₆GT₂ (1.70kg) and RS₅GT₃ (1.73kg).

The results presented in the table indicated that rootstock ‘bottle gourd’ and splice grafting technique had better potential than other techniques and rootstocks used in the study. Increase in the yield is mainly due to the increase in number of fruits per plant and average fruit weight. Similar findings were also reported by Debei et al. (2012) and Chao and Yen (2013).

4.3.3 Average fruit weight (g)

Average fruit weight varied depending on scion and rootstock. An examination of data presented in the Table 4.4 and 4.5 indicated that plants raised on different rootstocks using different grafting techniques significantly influenced the average fruit weight of cucumber. Among the various rootstocks used, plants grafted on rootstock Summer squash resulted in the highest average fruit weight (149.08 g) per fruit which was statistically at par with rootstock Bottle gourd (RS₂) (148.05 g). Grafting techniques had no significant effect on average fruit weight.

Grafted plants produced fruits with significantly higher average fruit weight (141.76 g) when compared to non-grafted (control) having fruits of average weight (133.87 g).

The interaction effects of rootstocks and grafting techniques also significantly affected the average fruit weight. Interaction effect of treatment RS₁GT₃ (RS₁= Summer squash, GT₃= Splice grafting) resulted in the highest average fruit weight (160.06 g) however was statistically at par with treatment RS₂GT₃ (RS₂= Bottle gourd, GT₃= Splice grafting) with average weight (155.96 g).

Highest fruit weight in plants grafted on summer squash rootstocks may be due to different factors such as increase in absorption of water and nutrients by the widespread root system of summer squash. The results are in agreement with the findings of Khankahdani et al. (2012), who also found the highest fruit weight in watermelon grafted on rootstock ‘bottle gourd’.

4.3.4 Marketable fruit yield per square meter (kg/m²)

It is evident from the scrutiny of figures presented in Table 4.4 and 4.5 that marketable fruit yield per square meter was affected significantly by rootstocks and grafting techniques and their interactions respectively. The highest fruit yield per square meter area (11.39 kg/m²) was found in cucumber plants grafted on rootstock Bottle gourd which was significantly higher than plants grafted on all other rootstocks, whereas minimum

marketable fruit yield per meter square was recorded in plants grafted on rootstock Bitter gourd (8.61 kg/m²). It is interesting to note here that Bottle gourd proved a better rootstock in comparison to other rootstocks and it recorded 2.78 kg more yield per square meter in comparison to the rootstock Bitter gourd.

Grafting techniques also influenced marketable fruit yield per square meter significantly. Splice grafting technique (GT₃) recorded maximum yield (10.26 kg/m²) in comparison to other grafting techniques employed in the study.

Non-grafted plants (control) produced significantly higher marketable fruit yield per square meter (10.67 kg/m²) whereas the other treatment combinations produced on an average 9.63 kg/m² of yield. Higher marketable yield per meter square may be because of significantly higher number of marketable fruits and marketable fruit yield per plant produced by the non-grafted plants.

Table 4.5 Interaction effect of rootstocks and grafting techniques on number of marketable fruits per plant, marketable fruit yield per plant (kg), average fruit weight (g) and marketable fruit yield per square meter (kg/m²)

Treatment (RS×G)	No of marketable fruits per plant	Marketable fruit yield per plant (kg)	Average fruit weight (g)	Marketable fruit yield per square meter (kg/m ²)
RS ₁ GT ₁	13.87	1.90	137.26	9.52
RS ₁ GT ₂	12.89	1.93	149.93	9.66
RS ₁ GT ₃	13.83	2.21	160.06	11.05
RS ₂ GT ₁	14.13	1.98	140.24	9.91
RS ₂ GT ₂	15.67	2.32	147.95	11.58
RS ₂ GT ₃	16.35	2.53	155.96	12.66
RS ₃ GT ₁	12.91	1.92	149.94	9.62
RS ₃ GT ₂	11.56	1.51	130.28	7.53
RS ₃ GT ₃	14.48	2.07	142.98	10.36
RS ₄ GT ₁	13.57	1.97	144.91	9.84
RS ₄ GT ₂	14.60	2.05	140.20	10.24
RS ₄ GT ₃	14.71	1.90	129.27	9.52
RS ₅ GT ₁	13.27	1.93	145.29	9.63
RS ₅ GT ₂	11.17	1.51	135.42	7.56
RS ₅ GT ₃	12.50	1.73	138.33	8.65
RS ₆ GT ₁	13.80	1.90	137.49	9.50
RS ₆ GT ₂	12.17	1.70	139.94	8.51
RS ₆ GT ₃	13.50	1.88	139.57	9.42
RS ₇ GT ₁	13.31	1.68	125.76	8.40
RS ₇ GT ₂	12.61	1.79	142.35	8.97
RS ₇ GT ₃	14.16	2.04	143.78	10.19
CD(P=0.05)	1.57	0.25	9.57	1.22

In interactions among rootstocks and grafting techniques, treatment RS₂GT₃ (RS₂= Bottle gourd, GT₃= Splice grafting) recorded maximum marketable fruit yield per square meter (12.66 kg/m²) which was statistically at par with treatment RS₂GT₂ (RS₂= Bottle gourd, GT₂= Hole insertion grafting) with yield (11.58 kg/m²) respectively. The lowest yield per square meter (7.53 kg/m²) was recorded in treatment RS₃GT₂ (RS₃= Pumpkin, GT₂= Hole insertion grafting). The best treatment combination i.e. RS₂GT₃ (RS₂= Bottle gourd, GT₃= Splice grafting) recorded 5.13 kg higher yield as compared to treatment combination RS₃GT₂ (RS₃= Pumpkin, GT₂= Hole insertion grafting). The above results obtained are in agreement with those of Velkov and Pevicharova (2016) who also reported that cucumber cultivar grafted on rootstocks *Lagenaria* and *C. maxima* recorded the highest yield.

4.3.5 Fruit length (cm)

A cursory glance at Table 4.6 and 4.7 clearly depicted that different rootstocks and their interactions with grafting techniques, respectively exhibited significant response w.r.t fruit length of the parthenocarpic cucumber. Significantly longer fruits (16.10 cm) were observed when cucumber plants were grafted on Summer squash rootstock (RS₁) as compared to other rootstocks, whereas minimum fruit length (13.74 cm) was recorded in plants grafted on rootstock Bitter gourd (RS₅).

Different grafting techniques used in the study did not show any significant effect on fruit length.

Non-grafted plants (control) recorded significantly higher fruit length of 15.83 cm as compared to average of other treatments (grafted plants) (14.56 cm).

Among interactions between rootstocks and grafting techniques, treatment RS₁GT₃ (RS₁= Summer squash, GT₃= Splice grafting) produced significantly longer fruits (17.25 cm) and was statistically at par with treatment RS₁GT₂ (RS₁= Summer squash, GT₂= Hole insertion grafting) (16.64 cm).

Hassanzadeh et al. (2012) in watermelon also found longer fruits from grafted plants than the fruits produced through seeds and transplanted watermelons. Other workers like Tamilselvi and Pugalendhi (2017a) also reported that bitter gourd variety Palee (F1 hybrid) when grafted on Pumpkin rootstock (*Cucurbita moschata*) followed by Sponge gourd, produced longer fruits.

4.3.6 Fruit width (cm)

The data pertaining to fruit width as influenced by different rootstocks and grafting techniques and their interactions have been presented in Table 4.6 and 4.7, respectively. It is apparent from the data presented however that fruit width was significantly affected by different rootstocks. Plants grafted on rootstock (RS₂) Bottle gourd resulted in maximum fruit width (4.31 cm) which was statistically at par with rootstock (RS₇) Ash gourd with fruit width of 4.12 cm.

Non-grafted plants (control) resulted in significantly higher fruit width of 4.53 cm as compared to the other treatment combinations which resulted in fruit width of 4.10 cm. Grafting techniques and their interactions with rootstocks did not affect the fruit width.

Table 4.6 Effect of rootstocks and grafting techniques on fruit length (cm), fruit width (cm) and harvest duration (days).

Treatment	Fruit length (cm)	Fruit width (cm)	Harvest duration (days)
A. Rootstocks			
Summer squash (RS ₁)	16.10	4.07	46.02
Bottle gourd (RS ₂)	14.53	4.31	48.38
Pumpkin (RS ₃)	14.61	4.05	47.54
Cucumber (RS ₄)	14.37	4.08	46.98
Bitter gourd (RS ₅)	13.74	4.02	47.75
Luffa (RS ₆)	13.87	4.03	47.01
Ash gourd (RS ₇)	14.69	4.12	46.83
CD (P=0.05)	0.79	0.19	1.16
B. Grafting techniques			
Approach (GT ₁)	14.56	4.07	46.82
Hole insertion (GT ₂)	14.32	4.13	47.63
Splice (GT ₃)	14.79	4.09	47.20
CD (P=0.05)	NS	NS	NS
C. Control vs Others			
Control (Non-grafted)	15.83	4.53	46.80
Others	14.56	4.10	47.22
CD (P=0.05)	0.98	0.23	NS

4.3.7 Harvest duration (days)

In vegetable, harvest duration is very important to regulate the continuous supply in the market for better market price and to avoid glut in the market. It is apparent from the data presented in the Table 4.6 and 4.7 that different rootstocks used in the study influenced harvest duration significantly. Significantly long harvest duration (48.38 days) was observed in rootstock Bottle gourd (RS₂), which was, however statistically at par with rootstock Pumpkin (RS₃) (47.54 days) and rootstock Bitter gourd (RS₅) (47.75 days).

The various grafting techniques applied in the experiment and their interactions with different rootstocks did not affect the harvest duration. More number of harvests and longer harvest duration in grafted plants may be due to fruit maturity at different time intervals. Similar findings have also been observed by Tamilselvi and Pugalendhi (2017b).

Table 4.7 Interaction effect of rootstocks and grafting techniques on fruit length (cm), fruit width (cm) and harvest duration (days).

Treatment (RS×G)	Fruit length (cm)	Fruit width (cm)	Harvest duration (days)
RS ₁ GT ₁	14.40	4.01	45.73
RS ₁ GT ₂	16.64	4.15	46.00
RS ₁ GT ₃	17.25	4.03	46.33
RS ₂ GT ₁	14.60	4.33	47.53
RS ₂ GT ₂	14.10	4.28	50.13
RS ₂ GT ₃	14.89	4.31	47.47
RS ₃ GT ₁	15.00	3.99	47.42
RS ₃ GT ₂	14.60	4.09	48.06
RS ₃ GT ₃	14.21	4.05	47.14
RS ₄ GT ₁	14.80	4.06	47.27
RS ₄ GT ₂	14.09	4.12	46.67
RS ₄ GT ₃	14.21	4.07	47.00
RS ₅ GT ₁	14.46	4.05	47.29
RS ₅ GT ₂	12.42	3.97	47.62
RS ₅ GT ₃	14.33	4.03	48.33
RS ₆ GT ₁	13.87	4.00	46.20
RS ₆ GT ₂	13.93	4.07	48.40
RS ₆ GT ₃	13.80	4.04	46.43
RS ₇ GT ₁	14.79	4.06	46.27
RS ₇ GT ₂	14.43	4.21	46.50
RS ₇ GT ₃	14.86	4.08	47.72
CD(P=0.05)	1.36	NS	NS

4.4 Structural traits

4.4.1 Internodal length (cm)

The data on inter-nodal length as influenced by various rootstocks and grafting techniques and their interactions, respectively have been given in Table 4.8 and 4.9. Internodal length determines the height and number of nodes per plant. It is clear from the data presented in the Table 4.8 that different rootstocks and grafting techniques exhibited significant response to internodal length. Minimum internodal length (10.23 cm) was observed when cucumber plants were grafted on rootstock Bitter gourd (RS₅) and was statistically at par with rootstocks Ash gourd (RS₇), Luffa (RS₆), Cucumber (RS₄) and Summer squash (RS₁) with internodal lengths of 10.30 cm, 10.60 cm, 11.05 cm and 11.12 cm respectively.

Grafting techniques also affected internodal length significantly. Minimum internodal length of 10.47 cm was observed when plants were grafted using approach grafting technique (GT₁) and it was statistically at par with grafting technique GT₃ (Splice grafting) with internodal length of 10.95 cm.

Table 4.8 Effect of rootstocks and grafting techniques on internodal length (cm) and vine length (cm).

Treatment	Internodal length (cm)	Vine length (cm)
A. Rootstocks		
Summer squash (RS ₁)	11.12	303.33
Bottle gourd (RS ₂)	11.63	327.89
Pumpkin (RS ₃)	11.34	327.22
Cucumber (RS ₄)	11.05	324.56
Bitter gourd (RS ₅)	10.23	297.56
Luffa (RS ₆)	10.60	289.44
Ash gourd (RS ₇)	10.30	288.33
CD (P=0.05)	0.92	15.71
B. Grafting techniques		
Approach (GT ₁)	10.47	310.8
Hole insertion (GT ₂)	11.27	305.0
Splice (GT ₃)	10.95	309.2
CD (P=0.05)	0.60	NS
C. Control vs Others		
Control (Non-grafted)	10.57	286.33
Others	10.90	308.81
CD (P=0.05)	NS	19.67

It is apparent from the data presented in the Table 4.9 that there was a significant effect on internodal length due to the interaction effect between rootstocks and grafting techniques. Treatment RS₆GT₂ (RS₆= Luffa, GT₂= Hole insertion grafting) resulted in minimum internodal length (9.83cm). The interaction effect of the rootstock luffa grafted by hole insertion technique resulted in minimum internodal length which may be due to the compatible difference of scion variety with different rootstocks.

Lee and Oda (2003) also reported different responses of vegetative growth to the grafting combinations related to vigour of rootstocks and compatibility of rootstocks and scions.

Table 4.9 Interaction effect of rootstocks and grafting techniques on internodal length (cm) and vine length (cm).

Treatment	Internodal length (cm)	Vine length (cm)
RS ₁ GT ₁	10.14	300.00
RS ₁ GT ₂	12.48	306.67
RS ₁ GT ₃	10.74	303.33
RS ₂ GT ₁	10.08	332.00
RS ₂ GT ₂	12.17	301.67
RS ₂ GT ₃	12.63	350.00
RS ₃ GT ₁	10.80	320.00
RS ₃ GT ₂	12.58	326.67
RS ₃ GT ₃	10.64	335.00
RS ₄ GT ₁	11.49	313.33
RS ₄ GT ₂	10.72	332.33
RS ₄ GT ₃	10.94	328.00
RS ₅ GT ₁	9.86	310.00
RS ₅ GT ₂	10.92	289.33
RS ₅ GT ₃	9.92	293.33
RS ₆ GT ₁	10.03	308.33
RS ₆ GT ₂	9.83	288.33
RS ₆ GT ₃	11.94	271.67
RS ₇ GT ₁	10.88	291.67
RS ₇ GT ₂	10.18	290.00
RS ₇ GT ₃	9.84	283.33
CD(P=0.05)	1.59	27.21

4.4.2 Vine length (cm)

It is evident from the Table 4.8 and 4.9 that rootstocks and their interactions with grafting techniques, respectively affected the vine length significantly. Mean comparison of the vine length showed that the longest vine (327.89 cm) was observed in cucumber plants grafted on rootstock Bottle gourd (RS₂) which was statistically at par with plants grafted on rootstocks Pumpkin (RS₃) and Cucumber (RS₄) having vine lengths 327.22 cm

and 324.56 cm, respectively. Grafting techniques did not affect the vine length (cm) significantly. In general grafted plants had significantly longer vines as compared to non-grafted (control). As far as the interaction among rootstocks and grafting techniques is concerned significantly longer vines (350 cm) was recorded in treatment RS₂GT₃ (RS₂= Bottle gourd, GT₃= Splice grafting).

Increased vine length in grafted plants may be due to the increased water and plant nutrient uptake, by the stronger and more extensive root systems of the rootstock. Similar findings recorded by Eslamboly and Deabes (2014) and Khankahdani et al. (2012) who also reported that grafting cucumber and bottle gourd on *Lagenaria* rootstocks resulted in significant increment in vine length.

4.5 Grafting success rate (%)

It is derived from the figures presented in the Table 4.10 and 4.11 that different rootstocks and their interactions with different grafting techniques affected the grafting success rate. Plants grafted on rootstock Bottle gourd (RS₂) recorded the highest success percentage (91.11%) which was significantly higher than all other rootstocks used in the study. Rootstock Ash gourd (RS₇) exhibited minimum (52.22%) grafting success rate. However various grafting techniques applied in the study did not affect grafting success rate.

Table 4.10 Effect of rootstocks and grafting techniques on grafting success rate (%)

Treatment	Grafting success rate (%)
A. Rootstocks	
Summer squash (RS ₁)	70.00
Bottle gourd (RS ₂)	91.11
Pumpkin (RS ₃)	66.67
Cucumber (RS ₄)	73.33
Bitter gourd (RS ₅)	57.78
Luffa (RS ₆)	64.45
Ash gourd (RS ₇)	52.22
CD (P=0.05)	8.07
B. Grafting techniques	
Approach (GT ₁)	68.56
Hole insertion (GT ₂)	65.71
Splice (GT ₃)	69.52
CD (P=0.05)	NS

As far as interaction among rootstocks and grafting techniques is concerned treatment RS₂GT₃ i.e. rootstock Bottle gourd with splice grafting technique recorded maximum grafting success rate (96.67%) closely followed by treatments RS₂GT₂, RS₃GT₃, RS₂GT₁ and RS₄GT₂ with grafting success rate 90%, 90%, 86.67%, and 86.67% respectively. Minimum grafting success rate 53.33% was observed in four treatment combinations i.e. RS₃GT₂, RS₅GT₃, RS₆GT₂ and RS₇GT₃. The successful grafting (compatibility between scion and rootstock) may be due to higher cell division in the scion and rootstock at the graft union site, followed by rapid connection between the vascular bundles of the scion and rootstock and subsequent secondary growth of the scion. Similar trend of results was obtained by Khankahhdani et al. (2012) who observed the greatest graft union percentage on ‘Bottle gourd’ and ‘Shintoza’ rootstocks by using splice grafting technique in watermelon.

Table 4.11 Interaction effect of rootstocks and grafting techniques on grafting success rate (%)

Treatment	Grafting success rate (%)
RS ₁ GT ₁	73.33
RS ₁ GT ₂	70.00
RS ₁ GT ₃	66.67
RS ₂ GT ₁	86.67
RS ₂ GT ₂	90.00
RS ₂ GT ₃	96.67
RS ₃ GT ₁	56.67
RS ₃ GT ₂	53.33
RS ₃ GT ₃	90.00
RS ₄ GT ₁	73.33
RS ₄ GT ₂	86.67
RS ₄ GT ₃	60.00
RS ₅ GT ₁	60.00
RS ₅ GT ₂	60.00
RS ₅ GT ₃	53.33
RS ₆ GT ₁	73.33
RS ₆ GT ₂	53.33
RS ₆ GT ₃	66.67
RS ₇ GT ₁	56.67
RS ₇ GT ₂	46.67
RS ₇ GT ₃	53.33
CD(P=0.05)	20.46

4.6 Quality traits

4.6.1 TSS (°Brix)

TSS is an important quality criterion reflecting concentration of sugars in fruit. The observations recorded for this trait showed significant differences among all the treatments. High total soluble solid contents is desirable for processed products. The data presented in Table 4.12 and 4.13 showed that rootstocks and grafting techniques and their interactions, respectively, significantly affected the TSS.

The highest TSS was recorded in rootstock Pumpkin (RS₃) (2.72°Brix) which was found to be significantly higher than other rootstocks used and was at par with rootstocks Summer squash (RS₁) and Cucumber (RS₄) with TSS 2.71 °Brix and 2.66 °Brix, respectively.

Table 4.12 Effect of rootstocks and grafting techniques on TSS (°Brix).

Treatment	TSS (°Brix)
A. Rootstocks	
Summer squash (RS ₁)	2.71
Bottle gourd (RS ₂)	2.33
Pumpkin (RS ₃)	2.72
Cucumber (RS ₄)	2.66
Bitter gourd (RS ₅)	2.57
Luffa (RS ₆)	2.46
Ash gourd (RS ₇)	2.11
CD (P=0.05)	0.14
B. Grafting techniques	
Approach (GT ₁)	2.21
Hole (GT ₂)	2.80
Splice (GT ₃)	2.51
CD (P=0.05)	0.09
C. Control vs Others	
Control (Non-grafted)	2.80
Others	2.51
CD (P=0.05)	0.18

Grafting techniques also affected TSS significantly. Significantly higher TSS of 2.80 °Brix was found in hole insertion grafting technique (GT₂) as compared to splice and approach grafting techniques.

Non-grafted plants (control) resulted in TSS of 2.80 °Brix which was significantly higher than the average for other grafted combinations (2.51 °Brix).

The data presented in Table 4.13 indicated that the interactions between rootstocks and grafting techniques significantly influenced the TSS. Maximum TSS of 3.60 °Brix was observed in treatment RS₄GT₂ (RS₄= Cucumber, GT₂= Hole insertion grafting) which was statistically at par with treatment RS₁GT₂ (RS₁= Summer squash, GT₂= Hole insertion grafting) with TSS of 3.57 °Brix. However TSS in both the treatments was significantly higher than TSS recorded in all other treatments. Similar findings were observed by Davis et al. (2008) and Chao and Yen (2013) who reported that the different type of rootstock alters the quality attributes of the scion fruit.

Table 4.13 Interaction effect of rootstocks and grafting techniques on TSS (° Brix)

Treatment	TSS (°Brix)
RS ₁ GT ₁	2.07
RS ₁ GT ₂	3.57
RS ₁ GT ₃	2.50
RS ₂ GT ₁	2.43
RS ₂ GT ₂	1.83
RS ₂ GT ₃	2.73
RS ₃ GT ₁	2.60
RS ₃ GT ₂	3.20
RS ₃ GT ₃	2.37
RS ₄ GT ₁	1.83
RS ₄ GT ₂	3.60
RS ₄ GT ₃	2.53
RS ₅ GT ₁	2.83
RS ₅ GT ₂	2.40
RS ₅ GT ₃	2.47
RS ₆ GT ₁	1.97
RS ₆ GT ₂	2.50
RS ₆ GT ₃	2.90
RS ₇ GT ₁	1.77
RS ₇ GT ₂	2.47
RS ₇ GT ₃	2.10
Control	2.80
CD(P=0.05)	0.25

4.6.2 Shelf life (days)

The different rootstocks and grafting techniques used had no significant effect on shelf life of parthenocarpic cucumber.



Plate 8: General view of the research trial at Vegetable Research Farm, CSKHPKV, Palampur



Plate 9a: Flowering stage of scion Kian grafted on seven rootstocks with different grafting techniques



Plate 9b: Flowering stage of scion Kian grafted on seven rootstocks with different grafting techniques



Plate 9c: Flowering stage of scion Kian grafted on seven rootstocks with different grafting techniques



Seedling stage



Flowering stage



Fruit bearing stage



Final harvest

Plate 10: Different stages of growth and development of the best treatment (RS₂GT₃) i.e scion Kian grafted on rootstock bottle gourd using splice grafting technique.

5. SUMMARY AND CONCLUSION

The present investigation entitled “Effect of rootstocks and grafting techniques on horticultural traits and gummy stem blight in parthenocarpic cucumber” was conducted at Vegetable Research Farm, Department of Vegetable Science and Floriculture, CSKHPKV, Palampur (Himachal Pradesh) in a modified naturally ventilated quonset polyhouse during summer-kharif season 2018. The treatments comprised of seven cucurbit rootstocks of local varieties (i.e. bottle gourd, summer squash, pumpkin, ash gourd, bitter gourd, luffa and cucumber), scion parthenocarpic variety Kian and three grafting techniques i.e. approach, splice and hole insertion. The experimental design consisted of a Randomized Block Design with three replications. The study tested if horticultural traits and could be improved and problem of gummy stem blight could be resolved by different grafting techniques since the grafting has been successful in reducing soil and seed borne diseases and improving nutrient and water uptake. The seedlings were grafted on different rootstocks at the cotyledon stage with cucumber variety Kian as a scion using three grafting techniques i.e. approach, hole insertion and splice. The scion attached to the rootstock was fused tightly by a grafting clip or with an ordinary self-adhesive transparent tape to ensure a good vascular contact and successful healing of the grafted components. After grafting, the plants were transferred immediately to the healing chamber for post-graft care for five to seven days to ensure a complete graft union. After the graft was firmly established the silicon/plastic clips and the tapes were removed from the graft union. The grafted seedlings then were transplanted to the soil. Fertigation was given thrice a week by applying liquid fertilizers (19:19:19) @ 2g/m² after third week of transplanting. The observations were recorded on five randomly selected plants for various characters such as days to first flowering, days to first fruit set, days to first harvest, grafting success percent, number of marketable fruits per plant, average fruit weight, marketable fruit yield per square meter, fruit length, fruit width, harvest duration, vine length, internodal length, TSS, shelf-life and percent incidence of *Didymella bryoniae*. Data was statistically analysed using standard procedures of analysis of variance (ANOVA).

All the rootstocks under investigation were found to be resistant to gummy stem blight fungal disease caused by fungus *Didymella bryoniae*.

The rootstocks used resulted in significant effect on various characters. Minimum number of days to first flower (18.82 days), days to first fruit set (26.59 days), days to first

harvest (34.78 days), maximum grafting success per cent (91.11%), maximum number of marketable fruits per plant (15.38), maximum marketable fruit yield per plant (2.28 kg), maximum marketable fruit yield per square meter (11.39 kg/m²), maximum fruit width (4.31 cm) maximum harvest duration (48.38 days), and maximum vine length (327.89 cm) was observed in rootstock bottle gourd (RS₂). The highest values for average fruit weight (149.08 g) and fruit length (16.10 cm) were observed in scion Kian grafted on rootstock summer squash. Plants grafted on rootstock pumpkin resulted in the highest TSS of 2.72 °Brix. Rootstock bitter gourd resulted in minimum internodal length (10.23 cm). The obtained results showed that among all the seven rootstocks, bottle gourd rootstock had high compatibility with parthenocarpic cucumber.

The use of different grafting techniques also had a significant effect on various characters. The splice grafting technique was found to be superior over the hole insertion and approach grafting in six characters studied in the present investigation. Plants grafted using splice grafting technique resulted in minimum number of days to first flowering (19.85 days), days to first fruit set (27.11 days), days to first harvest (36.01 days) and maximum number of marketable fruits per plant (14.22), marketable fruit yield per plant (2.05 kg) and marketable fruit yield per square meter (10.26 kg/m²). The minimum value of internodal length (10.47 cm) was observed using approach grafting technique. Maximum TSS of 2.80°Brix was observed using hole insertion grafting technique. No significant effect of grafting techniques was observed in characters like grafting success per cent, average fruit weight, fruit length, fruit width, harvest duration and vine length in parthenocarpic cucumber.

Most of the characters under investigation were significantly influenced by interaction effect of rootstocks and grafting techniques. The data obtained from the present study revealed that the treatment RS₅GT₃ (RS₅= Bitter gourd and GT₃= Splice grafting) resulted in minimum number of days to first flower (16.17 days), days to first fruit set (24 days) and days to first harvest (32.89 days). The interaction effect of rootstocks and scion in treatment RS₂GT₃ (RS₂= Bottle gourd GT₃= Splice grafting) resulted in the highest grafting success per cent (96.67%), maximum number of marketable fruits per plant (16.35), marketable fruit yield per plant (2.53 kg), marketable fruit yield per square meter (12.66 kg/m²) and maximum vine length (350 cm). Plants grafted on rootstock summer squash using splice grafting technique (RS₁GT₃) resulted in the highest average fruit weight (160.06 g) and longest fruit length (17.25cm). Minimum internodal length (9.83 cm) was observed in treatment RS₆GT₂ (RS₆= Luffa, GT₂= Hole insertion grafting) and the highest TSS of

(3.60°Brix) was observed in treatment RS₄GT₂ (RS₄= Cucumber, GT₂= Hole insertion grafting). The interaction effect of rootstocks and grafting techniques had no significant effects on fruit width and harvest duration.

Conclusion

From the present study it is concluded that rootstocks and grafting techniques play a remarkable role in affecting growth, development and quality of the cucumber. Different rootstocks used in the experiment were screened in vitro for resistance reaction to gummy stem blight, a serious disease caused by fungus *Didymella bryoniae*. All the rootstocks screened showed resistance to the fungal pathogen. Rootstock and scion compatibility is crucial for getting desired results in grafted plants. Local varieties of different cucurbits were used for grafting a popular parthenocarpic cucumber hybrid Kian. Bottle gourd rootstock was found as one of the best rootstocks for grafting and it recorded higher plant growth and yield. Evaluation of characters based on grafting techniques revealed that splice grafting technique was the easiest method and had the higher success rate of grafted plants. Therefore, it is inferred from the study that bottle gourd is best compatible rootstock along with splice grafting technique for securing high yield under protected conditions.

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APPENDICES

Appendix 1. Mean weekly meteorological data at Palampur (30th April to 28th October 2018)

Standard Week No.	Date (2018)	Temperature (°C)		Rainfall (mm)	Relative Humidity- I (%)	Relative Humidity-II (%)	Sunshine (hours)
		Maximum	Minimum				
18	30A-6 May	28.29	17.64	45.8	55.71	53	8.0
19	7-13 May	26.86	15.64	46.9	63.43	57.71	6.3
20	15-20 May	29.89	16.96	0	48	31	6.5
21	21-27 May	32.89	19.43	0	28.14	20	8.07
22	28 May-3 June	32.65	19.07	10	55.71	38.57	7.43
23	4-10 June	30.64	20.64	18	75.71	58.71	5.29
24	11-17 June	30.28	20	33.2	60.29	66.71	6.14
25	18-24 June	29.5	19.14	31.2	55.57	50.29	6.14
26	25 June-1 July	28.29	19.86	139.2	81.86	74.86	4.21
27	2-8 July	26.21	19	161.5	89.14	83.85	3.79
28	9-15 July	28.18	20.29	297.2	93.43	85.71	3.43
29	16-22 July	28.21	20.14	174	93.14	86	4.43
30	23-29 July	26.29	19.71	264.2	98.29	83.71	1.86
31	30 July-5 Aug	27.28	19.71	96.6	90.71	83.86	4.29
32	6-12 Aug	24.39	19.86	154.8	97	92.86	0.5
33	13-19 Aug	26.57	19.78	278.8	96.28	87.57	2.36
34	20-26 Aug	26	19.57	220.8	92.57	86.42	2.29
35	27 Aug-2 Sep	26.93	19.79	176.6	90.43	87	5.14
36	3-9 Sep	26.5	19.5	78.4	77.89	85.43	2.5
37	10-16 Sep	26.21	17.36	105	87.71	85.29	3.07
38	17-23 Sep	25.87	15.93	145.2	83.57	79.91	7.5
39	24-30 Sep	23.93	15.07	138	84.86	76.43	5.57
40	1-7 Oct	26.64	14	2	68.86	52.86	8.93
41	8-14 Oct	25.64	12.39	2	72	48.43	7.57
42	15-21 Oct	25.21	11.93	0	81.14	61.71	9.5
43	22-28 Oct	23.57	10.14	0	52.57	42	9.5

Appendix II. Experimental layout plan

R-1	R-2	R-3
RS ₇ GT ₁	RS ₄ GT ₁	RS ₂ GT ₁
RS ₅ GT ₃	RS ₆ GT ₂	RS ₆ GT ₃
RS ₇ GT ₂	RS ₆ GT ₁	RS ₇ GT ₃
RS ₂ GT ₂	RS ₂ GT ₂	RS ₃ GT ₃
RS ₇ GT ₃	RS ₇ GT ₂	Control
RS ₆ GT ₁	RS ₅ GT ₃	RS ₄ GT ₂
RS ₅ GT ₁	RS ₄ GT ₃	RS ₃ GT ₁
RS ₁ GT ₂	RS ₅ GT ₁	RS ₄ GT ₃
RS ₄ GT ₂	RS ₄ GT ₂	RS ₇ GT ₂
RS ₄ GT ₁	RS ₁ GT ₂	RS ₁ GT ₁
RS ₁ GT ₃	RS ₅ GT ₂	RS ₂ GT ₃
Control	RS ₃ GT ₃	RS ₆ GT ₂
RS ₆ GT ₂	RS ₂ GT ₁	RS ₆ GT ₁
RS ₅ GT ₂	RS ₇ GT ₁	RS ₂ GT ₂
RS ₃ GT ₂	RS ₃ GT ₂	RS ₁ GT ₂
RS ₁ GT ₁	RS ₂ GT ₃	RS ₄ GT ₁
RS ₃ GT ₃	RS ₆ GT ₃	RS ₃ GT ₂
RS ₄ GT ₃	RS ₇ GT ₃	RS ₇ GT ₁
RS ₃ GT ₁	Control	RS ₅ GT ₃
RS ₂ GT ₃	RS ₁ GT ₃	RS ₅ GT ₁
RS ₂ GT ₁	RS ₃ GT ₁	RS ₁ GT ₃
RS ₆ GT ₃	RS ₁ GT ₁	RS ₅ GT ₂

Brief Biodata of student

Name : Anjali
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Academic Qualifications:

Examination passed	Year	School/Board/University	Marks (%)	Division	Major Subjects
10 th	2010	Aadhunik Public School Sidhbari Dharamshala	83.60	First	English, Maths, Science, Social Science, Hindi
10+2	2012	Aadhunik Public School Sidhbari Dharamshala	68	First	Maths, Biology, Chemistry, Physics, English
B.Sc (Hons.) Agriculture	2017	CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur	75.60	First	All subjects under B.Sc (Hons.) Agriculture Elective (Horticulture)
M.Sc (Agriculture)	2019	CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur	79	First	Major Discipline: Vegetable Science Minor Discipline: Plant Pathology