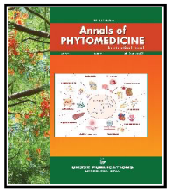
Annals of Phytomedicine 13(2): 1102-1113, 2024

DOI: http://dx.doi.org/10.54085/ap.2024.13.2.114

Annals of Phytomedicine: An International Journal
http://www.ukaazpublications.com/publications/index.php

Print ISSN : 2278-9839 Online ISSN : 2393-9885



Original Article : Open Access

Effect of different rootstocks on yield traits and quality of Bitter gourd (*Momordica charantia* L.)

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Article Info

Article history
Received 10 July 2024
Revised 29 August 2024
Accepted 30 August 2024
Published Online 30 December 2024

Keywords
Grafted plants
Yield traits
Quality
Bitter gourd
Momordica charantia L.

Abstract

The experiment was conducted during 2022-23 to study the effect of grafting technique with different rootstocks on yield, its attributes and quality of bitter gourd (*Momordica charantia* L.) by comparing grafted bitter gourd plants with non-grafted (intact) plants under field conditions. The bitter gourd cultivars, *viz*., Palee F1 and Green long were grafted onto three cucurbitaceous rootstocks by adopting wedge grafting method. At 15 days old seedlings as bitter gourd scions grafted with pumpkin (*Cucurbita moschata*) and sponge gourd (*Luffa cylindrica*) rootstocks. The result revealed that, the grafted plants had better yield and quality than the non-grafted plants (check). Highest number of fruits number (28.02) and fruit yield per vine (3.55 kg/vine) were observed in Palee F_1 scion grafted onto 'pumpkin (*Cucurbita moschata*) rootstock than other graft combinations and non-grafted plants. Total number of pickings (16.48), number of fruits per vine (22.66), average fruit weight (175.95 g), fruit length (23.20 cm) and fruit yield per vine (3.99 kg), in evaluation were also superior in Palee F_1 scion grafted onto 'pumpkin (*Cucurbita moschata*) rootstock. Grafting has positive influence on fruit yield and quality of bitter gourd as well. Grafting increased 42.61% of fruit yield of bitter gourd in T_5 (pumpkin rootstock with bitter gourd scion hybrid) when compared to that of T_1 (bitter gourd ungrafted hybrid-Palee). With respect to quality traits among different graft combinations, T_5 (pumpkin rootstock with bitter gourd scion hybrid-Palee) showed superior performance for ascorbic acid and T_1 (Bitter gourd ungrafted hybrid-Palee) had maximum iron content. The differences recorded for growth and yield of the tested cultivars might be due to different growth characteristics, graft affinity and compatibility. This evidence indicates that grafting bitter gourd scions onto specific rootstock significantly influences yield without deterioration in the fruit quality.

1. Introduction

Bitter gourd, *Momordica charantia* L. is a dicot vine species also known as karela, balsam pear, or bitter melon, belongs to the family Cucurbitaceae and native to tropical and subtropical parts of Africa and Asia. It is known as 'the mainstream food of the 21st century' for several multifarious health benefits owing promising biological properties (Mukherjee *et al*., 2012; Fang and Ng, 2016). Consequently, it is used for both medicinal and food purposes (Morton, 1967; Gao *et al*., 2019). It is also known as vegetable insulin, having an insulin-like compound (p-insulin or polypeptide-p) which lowers the blood sugar level effectively (Joseph and Jini, 2013; Deshaware *et al*., 2018) and been used for the treatment of gout, dysmenorrhea, eczema, jaundice, piles, leprosy, psoriasis, scabies, rheumatism, and pneumonia (Bailey *et al*., 1986; Jia *et al*., 2017). Bitter gourd being rich in all the essential vitamins and minerals, especially vitamins A, B_1, B_2, C and iron, its regular use can prevent hypertension, eye complications, neuritis, and defective metabolism of carbohydrates. Several medicinal properties of the bitter gourd have been studied by various researchers (Neeraja Prabhakar, 2022; Raghuwanshi *et al*., 2022) such as antidiabetic, antiulcerogenic, antimutagenic, antioxidant, antitumor, antilipolytic, analgesic, abortifacient, antiviral, hypoglycemic and immunomodulatory. The *in vitro* studies revealed that the bitter gourd leaf extracts have broad-spectrum antimicrobial activity and proteins (α-monorcharin and β-monorcharin) which have inhibitory effect against HIV virus.

Grafting technique is eco-friendly for sustainable vegetable production and by using resistant rootstock; it reduces dependency on agrochemicals (Rivard *et al.,* 2008). To induce resistance against low and high temperatures, grafts were generally used (Venema, 2008). Grafting increases the yield and induces biotic and abiotic stress tolerance, *viz.,* flooding, drought, and salinity. Grafting as a technology

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for the commercial production of vegetables was later on adopted by many countries in Europe, Middle East, Northern Africa, Central America, and other parts of Asia (Kubota *et al.,* 2008). Many crops are benefitted for enhanced yield and quality through grafting technology. Hamed *et al*. (2012) reported that in watermelon grafts, a late flowering of about one week was observed, which in turn resulted in an equal postponement in fruit maturity. Noor *et al.* (2019) stated that when cucumber grafted on four cucurbit rootstocks, *viz*., ridge gourd, bitter gourd, pumpkin and bottle gourd, flowering started at 33rd day in bottle gourd, luffa and bitter gourd while pumpkin started flowering on 34th day in splice grafting technique. Hole insertion grafting method took maximum number of days for flowering. The non-grafted cucumber cv. Kalaam F_1 showed flowers 60 days after sowing. Tamil selvi and Pugalendi (2017) stated that grafted bitter gourd tend to produce higher female and lower male flowers compared to non-grafted plants. Hoyos (2001) stated that grafting had no effect on the quality, taste, size and shape of the fruit. Yamasaki *et al.* (1994) reported that fruit weight of watermelon grafted on bottle gourd was higher (7.40 kg) when compared to non grafted plants. Ruiz *et al.* (1996) in *Cucumis melo* grafted onto *Cucurbita maxima* × *C. moschata* hybrids. Camacho *et al.* (2009) observed that average fruit weight was considerably influenced by grafting. Hamed *et al*. (2012) reported higher fruit weight (7.00 kg) in watermelon grafted onto bottle gourd rootstock by tongue approach grafting method compared to non grafted watermelons (4.20 kg). Mohamed *et al.* (2012) studied impact of grafting on watermelon growth, fruit yield and quality. Dong *et al.* (2013) studied the effects of wild luffa rootstocks on fruit quality and photosynthetic physiology of bitter gourd. Savsatlý and Karatas (2021) reported that grafting significantly increased the dry matter ratio and extract yield in the bitter gourd fruits and the ash content in young, mature and old leaves. Keeping the above in view, the present research was formulated to investigate on the yield and quality of bitter gourd grafted seedlings.

2. Materials and Methods

2.1 Experimental site

The present investigation was carried out during Summer at PG Research Block, College of Horticulture, Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, Telangana, which is situated at an altitude of 536 m above mean sea level on 78°.40' East longitude and 17° 32' North latitude.

2.2 Root stocks and scions

The two bitter gourd cultivars (Palee F_1 and Green long) were selected, out of which one is a private hybrid, *viz*., Palee F_1 from East West Seeds, Philippines, which is suitable for early and long duration harvest and widely cultivated F_1 hybrid in Telangana, India. Fruits are medium long with moderate, but rather thick spines which result in less damage during transport. Green long, an open pollinated variety of bitter gourd. Fruits are dark green, spiny, 10-12 cm long, suitable for both summer and monsoon sowing. The most commonly used rootstocks for bitter gourd are Luffa (*Luffa* spp.), fig leaf gourd (*Cucurbita ficifolia)* and pumpkin (*Cucurbita moschata*) showing good vigour and compatibility. Based on various reports the rootstocks, *viz.,* pumpkin (*Cucurbita moschata*), bottle gourd (*Lagenaria siceraria*), and sponge gourd (*Luffa cylindrica*) were used as root stocks and grafted with the before mentioned two bitter gourd scions.

2.3 Grafting

Grafting was performed in 4 to 7 days old seedlings. The grafting method adopted in this experiment is wedge grafting. When the diameter of scion is narrower than rootstock, wedge grafting is easy to perform so sowing dates are adjusted accordingly.

2.4 Methods

The field experiment was laid out in Randomized Block Design with 8 treatments and 3 replications. Treatment details were T_1-Bitter gourd hybrid ungrafted, T_2-Bitter gourd OPV ungrafted, T_3-Bottle gourd root stock with Bitter gourd Hybrid scion, T_4-Bottle gourd root stock with Bitter gourd OPV scion, T_5-Pumpkin rootstock with Bitter gourd Hybrid scion, T_6-Pumpkin rootstock with Bitter gourd OPV scion, T_7-Sponge gourd rootstock with Bitter gourd Hybrid scion and T_8-Sponge gourd root stock with Bitter gourd OPV scion were tried and the observations were recorded in respect to growth, yield and quality parameters.

3. Results

3.1 Yield and yield attributes

The analysis of variance showed significant differences for various traits studied in the presented research on grafted bitter gourd revealing presence of genetic variation in the material studied.

3.1.1 Number of pickings

The data on number of pickings per vine is shown in Tables 1and 2. The significantly highest number of pickings per vine (Figure 1) (16.47) was observed in T_5 (Pumpkin root stock with Bitter gourd scion Hybrid-Palee). The significantly lowest value (6.77) for this trait was observed in T_4 (Bottle gourd rootstock with bitter gourd scion OPV-Green long) which was at par with T_3 (Bottle gourd root stock with Bitter gourd scion Hybrid-Palee) (7.44), T_8 (Sponge gourd rootstock with Bitter gourd scion OPV-Green long) (8.30) and T_2 (Bitter gourd ungrafted OPV-Green long) (8.33). Among the three hybrid scion grafts, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly highest value (16.47) and T_3 (Bottle gourd rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly lowest value (7.44).

Out of three OPV Scion grafts, T_6(Pumpkin rootstock with bitter gourd scion OPV-Green long) recorded significantly highest value (10.87) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV-Green long) recorded significantly lowest value (6.77). Treatment, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded 46.35% more number of pickings when compared to T_1 (Bitter gourd ungrafted Hybrid-Palee). T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded 42.96% more number of pickings when compared to T_2 (Bitter gourd ungrafted OPV-Green long). Total number of harvests is an important character contributing to higher yield in Bitter gourd. More number of harvests directly indicates the yield potential of the crop. In general, the grafts had a greater number of harvests than nongrafted due to the rootstock nature. In this study, for the number of harvests trait, the graft combinations T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) followed by T_7 (Sponge gourd rootstock with Bitter gourd scion Hybrid-Palee), respectively, recorded a greater number of harvests.

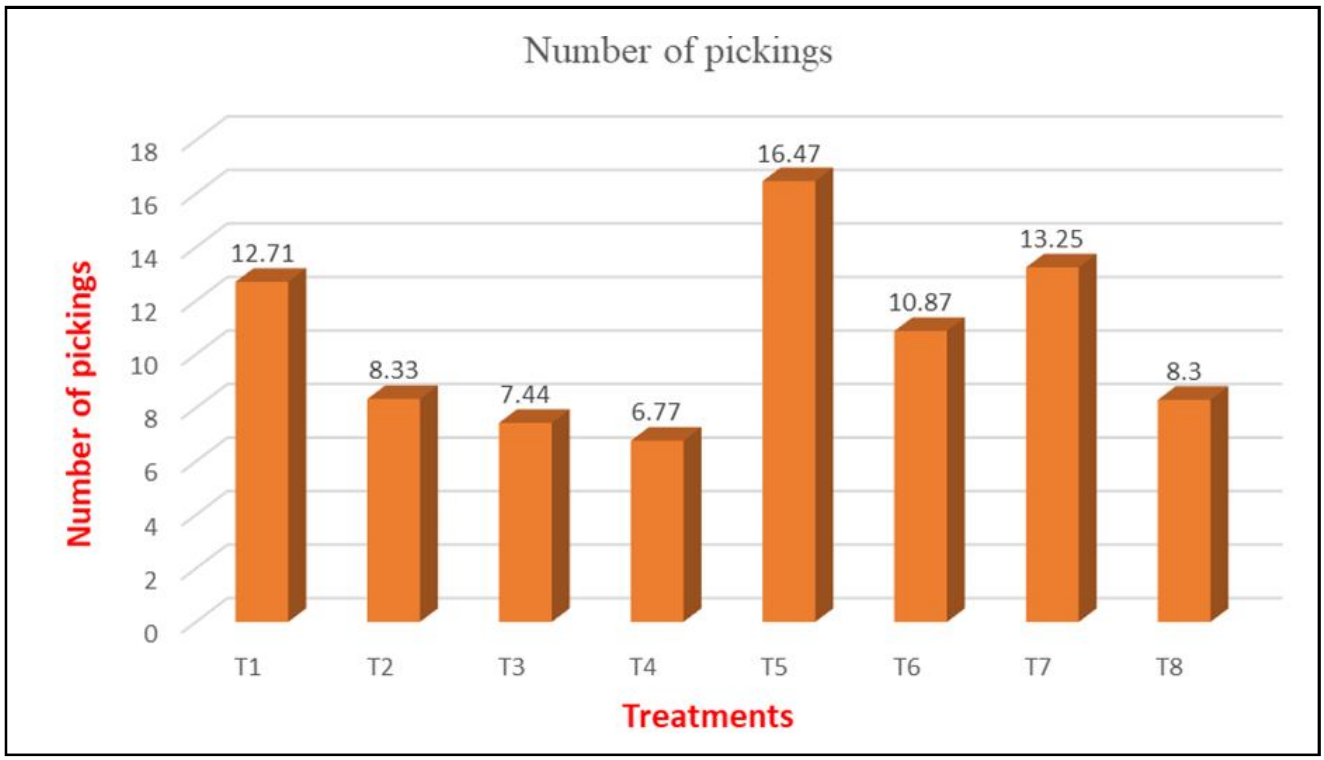

Figure 1: Performance of various grafts of Bitter gourd on number of pickings.

Table 1: Performance of various grafts of Bitter gourd on number of pickings, number of fruits per vine, fruit length (cm), fruit girth (mm) and average fruit weight (g)

Treatments	Number of pickings	Number of fruits per vine	Fruit length (cm)	Fruit girth (mm)	Average fruit weight (g)
T1-Bitter gourd ungrafted (Hybrid)	12.71	18.35	19.78	45.21	157.33
T2-Bitter gourd ungrafted (Open pollinated variety)	8.33	14.20	10.91	34.98	53.67
T3-Bottle gourd root stock with Bitter gourd scion (Hybrid)	7.44	11.18	16.57	43.24	86.20
T4-Bottle gourd root stock with Bitter gourd scion (Open pollinated variety)	6.77	8.44	8.83	33.72	41.26
T5-Pumpkin root stock with Bitter gourd scion (Hybrid)	16.47	22.66	23.20	44.87	175.95
T6-Pumpkin root stock with Bitter gourd scion (Open pollinated variety)	10.87	18.27	12.23	34.07	70.56
T7-Sponge gourd root stock with Bitter gourd scion (Hybrid)	13.25	18.18	19.06	43.31	141.16
T8-Sponge gourd root stock with Bitter gourd scion (Open pollinated variety)	8.30	12.93	10.18	32.04	51.26
SE(m)	0.26	0.46	0.43	1.04	3.00
CD at 5%	0.77	1.38	1.34	3.15	9.12
CV (%)	4.19	5.09	5.08	4.63	5.36

3.1.2 Number of fruits per vine

Number of fruits per vine was ranged from 8.44 to 22.66 among the treatment (Figure 2) and the significantly highest number of fruits per vine (22.66) was observed in T_5 (Pumpkin root stock with bitter gourd scion Hybrid-Palee), while it was significantly lowest (8.44) in T_4 (Bottle gourd root stock with Bitter gourd scion OPV-Green long). Among three hybrid scion grafts, T_5(Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly highest value (22.66) and T_3 (Bottle gourd rootstock with Bitter gourd scion

Hybrid-Palee) recorded significantly lowest value (11.18). Out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV- Green long) recorded significantly highest value (18.27) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV-Green long) recorded lowest value (8.44).

Treatment, T_5 (Pumpkin rootstock with Bitter gourd scion hybrid) recorded 23.48 % higher number of fruits when compared to T_1 (Palee F_1 hybrid ungrafted). T_6 (Pumpkin rootstock with Bitter gourd scion OPV) recorded 28.59 % higher fruit length when compared to T_2 (Green long OPV ungrafted).

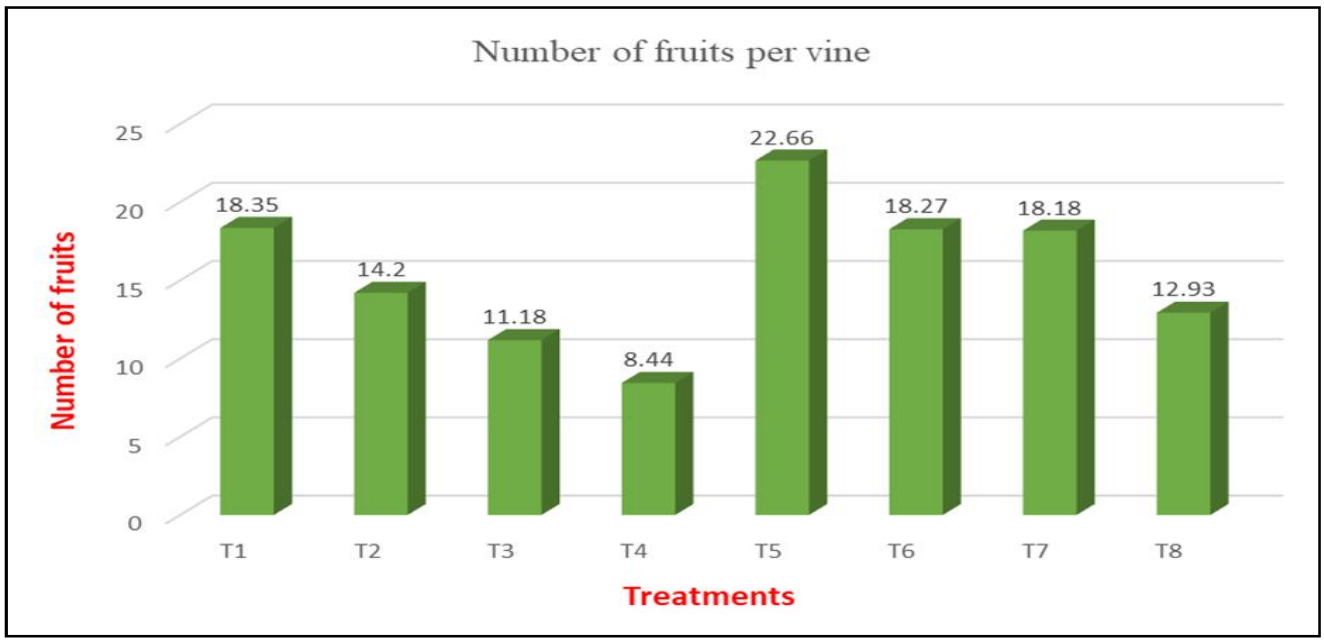

Figure 2: Performance of various grafts of Bitter gourd on number of fruits per vine.

3.1.3 Fruit length (cm)

The mean values for fruit length were ranging from 8.83 to 23.20 cm (Figure 3). Among all the treatments, T_5 (Pumpkin root stock with Bitter gourd scion Hybrid-Palee) recorded significantly highest fruit length of 23.20 cm and T_4 (Bottle gourd root stock with Bitter gourd scion OPV-Green long) recorded the significantly lowest fruit length of 8.83 cm. Among three hybrid scion grafts, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly highest value of 23.20 cm and T_3 (Bottle gourd rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly lowest value of 16.57. Out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV- Green long) recorded significantly highest value of 12.23 cm and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV- Green long) recorded significantly lowest value of 8.83 cm. T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded 21.72 % higher fruit length when compared to T_1 (Bitter gourd ungrafted Hybrid-Palee). T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded 12.09 % higher fruit length when compared to T_2 (Bitter gourd ungrafted OPV-Green long).

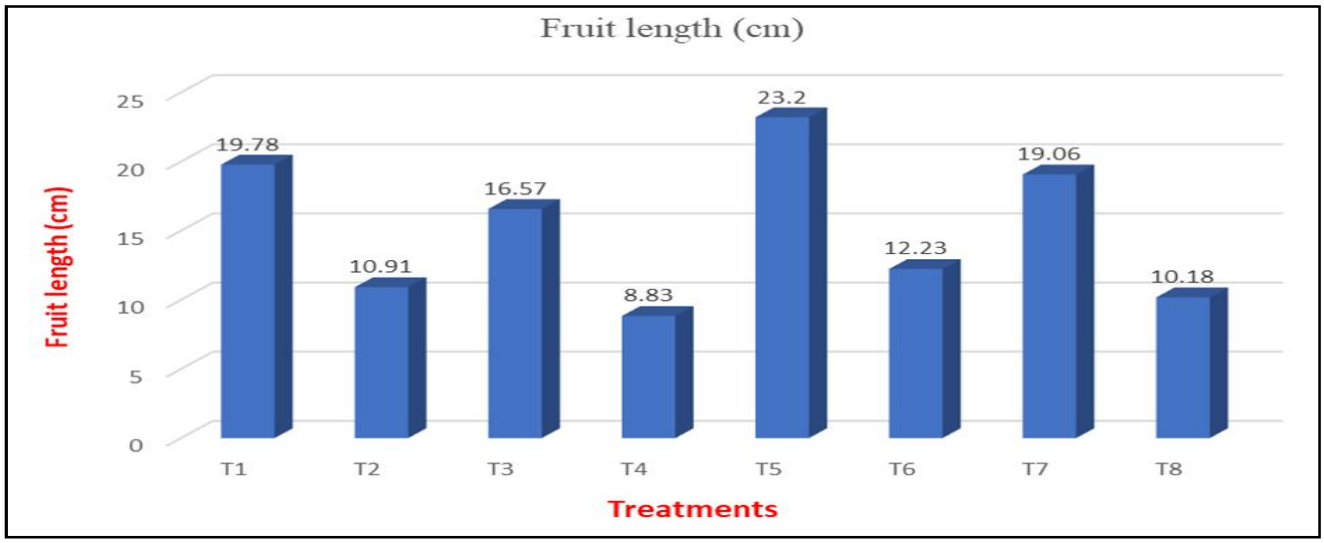

Figure 3: Performance of various grafts of Bitter gourd for fruit length (cm).

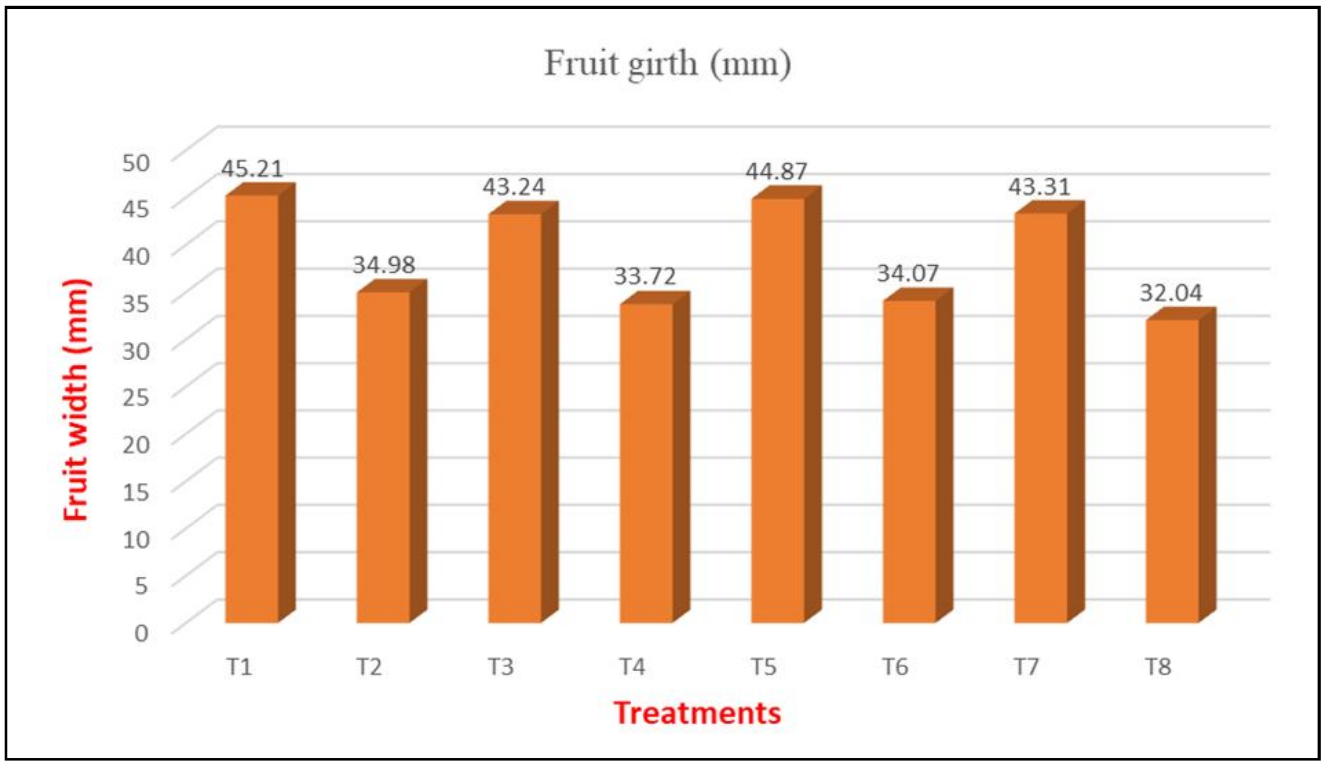

Figure 4: Performance of various grafts of Bitter gourd for fruit girth (mm).

3.1.4 Fruit girth (mm)

Among all the treatments, the performance for fruit girth varied from 32.04 mm to 45.21 mm (Figure 4). The results revealed that the highest mean value (45.21 mm) for fruit girth was observed in T_1 (Bitter gourd ungrafted Hybrid-Palee) which is at par with T_5 (Pumpkin root stock with Bitter gourd scion Hybrid-Palee) (44.87 mm) and the significantly lowest fruit girth (32.04 mm) by T_8 (Sponge gourd root stock with Bitter gourd scion OPV-Palee) which was at par with T_4 (Bottle gourd root stock with Bitter gourd scion OPV-Palee) (33.72 mm). However, Fruit girth was recorded higher in ungrafts, when compared to that of grafts. In case of fruit length and fruit girth, the graft T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) followed by T_6 (Pumpkin rootstock with Bitter gourd scion OPV) registered higher values compared to other graft combinations. The yield contributing characters, *viz*., fruit length, girth and weight were higher in grafted plants. This result is in agreement with Khankahdani *et al*. (2012) and Islam *et al*. (2013) in Watermelon.

3.1.5 Average fruit weight (g)

The fruit weight is the direct indicator of yield potential of any genotype (Figure 5). It ranged between 41.26 g and 175.95 g. Among all the treatment combinations, the significantly highest fruit weight was recorded as 175.95 g in T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) and the significantly lowest weight (41.26 g) was recorded in T_4 (Bottle gourd rootstock with Bitter gourd scion OPV-Green long). The data on individual fruit weight indicated that there was a significant difference among the graft combinations and nongrafted plants or scions. Among the three hybrid scion grafts, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly highest value (175.95 g) and T_3 (Bottle gourd rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly lowest value (86.20 g). Out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded significantly highest value (70.56 g) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV- Green long) recorded lowest value (41.26 g). Treatment, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded 11.61 % higher fruit length when compared to T_1 (Bitter gourd ungrafted Hybrid-Palee). T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded 22.09 % higher fruit length when compared to T_2 (Biter gourd ungrafted OPV- Green long).

3.1.6 Fruit yield per plant (kg)

Fruit yield per plant was ranged from 0.35 kg to 3.99 kg (Figure 6). Among all the treatments, the highest fruit yield per vine was recorded as 3.99 kg in T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) and the lowest fruit yield of 0.31 kg was recorded in T_3 (Bottle gourd root stock with Bitter gourd scion OPV-Green long). The data on fruit yield per vine indicated that there were significant differences among the graft combinations and non-grafted plants or scions. Among the three hybrid scion grafts, T_5 (Pumpkin rootstock with Bitter gourd scion hybrid) recorded significantly highest value (3.99 kg) and T_3 (Bottle gourd rootstock with Bitter gourd scion Hybrid) recorded the significantly lowest value (0.96 kg). Out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV) recorded significantly highest value (1.29 kg) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV) recorded lowest value (0.35 kg). Treatment, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid) recorded 42.80 % higher fruit yield when compared to T_1 (Bitter gourd ungrafted Hybrid-Palee). T_6 (Pumpkin rootstock with Bitter gourd scion OPV) recorded 58.20 % higher fruit yield compared to T_2 (Bitter gourd ungrafted OPV-Green long).

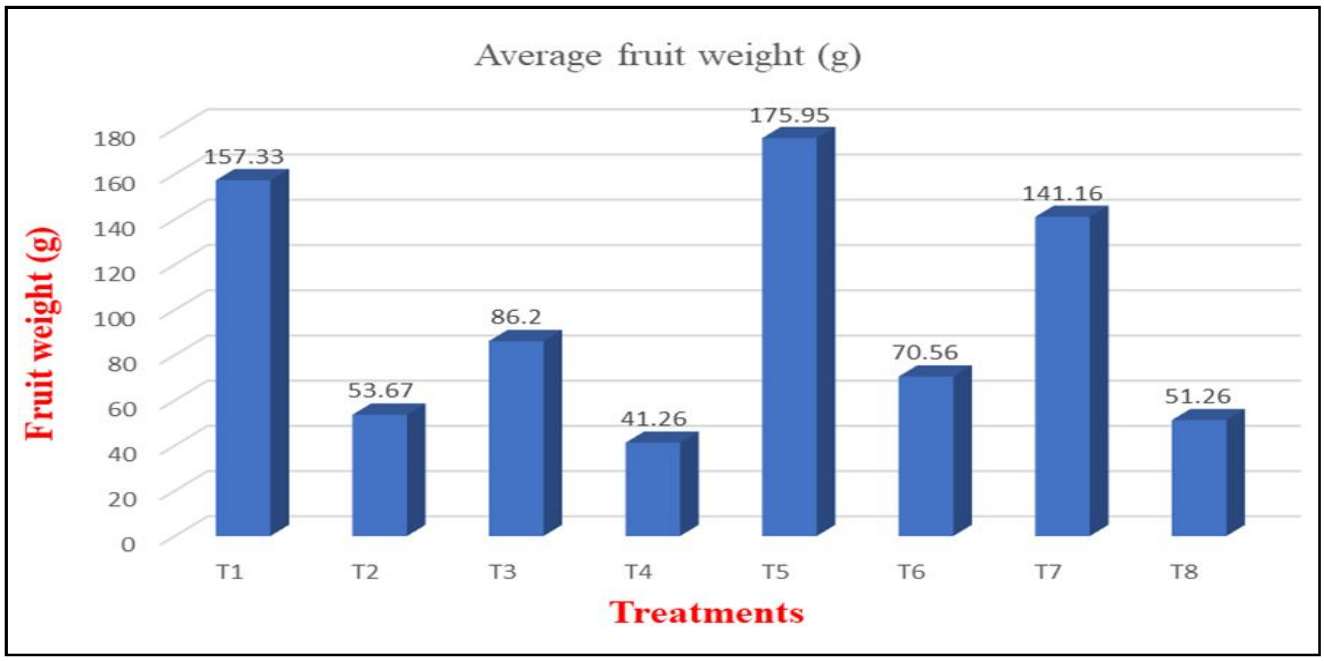

Figure 5: Performance of various grafts of Bitter gourd for average fruit weight (g).

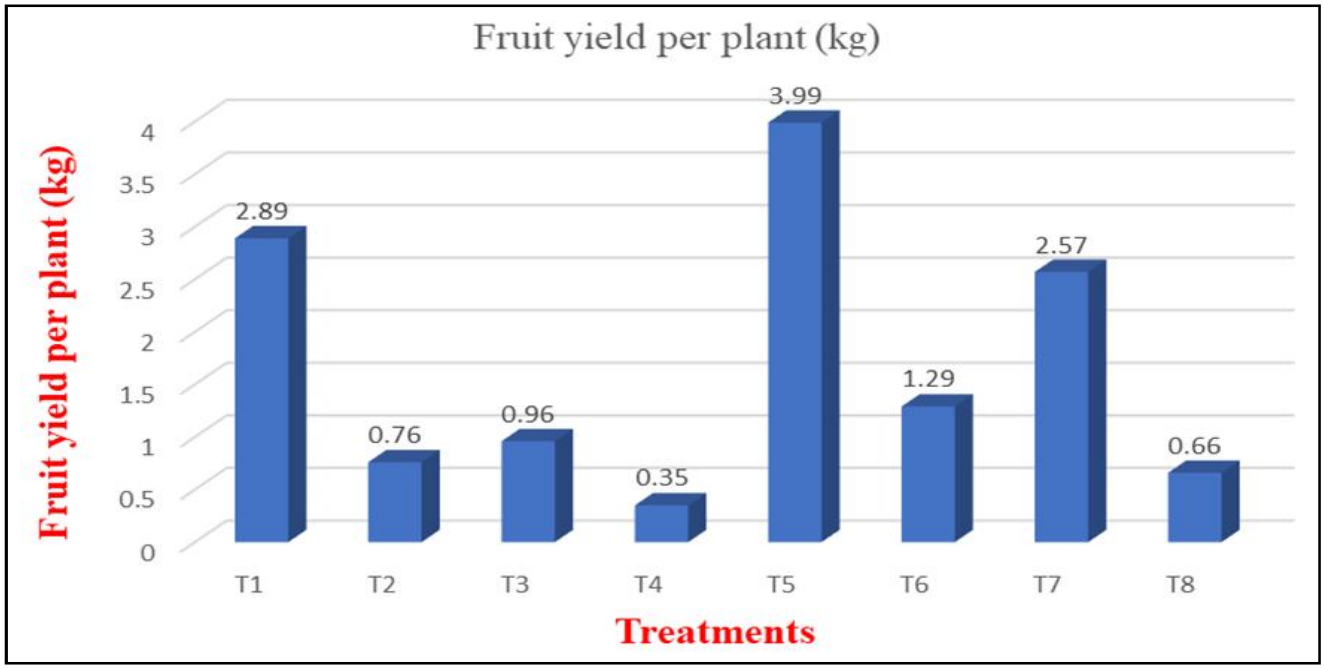

Figure 6: Performance of various grafts of Bitter gourd for fruit yield per plant (kg).

3.1.7 Fruit yield per hectare (t)

Fruit yield per hectare was ranged between 4.64 t to 53.16 t (Figure 7). Among all the treatments, the significantly highest fruit yield per hectare was recorded as 53.16 t in T_5 (Pumpkin root stock with Bitter gourd scion Hybrid-Palee) and the significantly lowest fruit yield per ha (4.64 t) was recorded in T_4 (Bottle gourd root stock with Bitter gourd scion OPV-Green long). The data on fruit yield per hectare indicated that there were significant differences among the graft combinations and nongrafted plants or scions.

Among the three hybrid scion grafts, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly highest value (53.16 t) for fruit yield per ha and T_3 (Bottle gourd rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly lowest value (12.84 t).

Out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded significantly highest value (17.17 t) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV-Green long) recorded lowest value (4.64). Treatment, T_5 (Pumpkin rootstock with Bitter gourd scion hybrid) recorded 42.61

% higher fruit yield compared to T_1 (Palee F_1 hybrid ungrafted). T_6 (Pumpkin rootstock with Bitter gourd scion OPV) recorded 56.78 % higher fruit yield compared to T_2 (Bitter gourd ungrafted OPV-Green long).

Table 2: Performance of various grafts of Bitter gourd for fruit yield per plant (kg), fruit yield per ha (t), ascorbic acid (mg/100 g) and iron content (mg/100 g) in fruits

Treatments	Fruit yield per plant (kg)	Fruit yield per ha (t)	Ascorbic acid (mg/ 100 g)	Iron content (mg /100 g)
T_1-Bitter gourd ungrafted (Hybrid)	2.89	38.49	102.23	1.89
T_2 -Bitter gourd ungrafted (Open pollinated variety)	0.76	10.16	94.39	1.71
T_3 -Bottle gourd root stock with Bitter gourd scion (Hybrid)	0.96	12.84	84.93	1.32
T_4 -Bottle gourd root stock with Bitter gourd scion (Open pollinated variety)	0.35	4.64	68.42	1.24
T_5 -Pumpkin root stock with Bitter gourd scion (Hybrid)	3.99	53.16	107.28	1.76
T_6 -Pumpkin root stock with Bitter gourd scion (Open pollinated variety)	1.29	17.17	96.89	1.56
T_7 -Sponge gourd root stock with Bitter gourd scion (Hybrid)	2.56	34.21	102.54	1.60
T_8 -Sponge gourd root stock with Bitter gourd scion (Open pollinated variety)	0.66	8.83	94.94	1.35
SE (m)	0.08	1.25	1.78	0.04
CD at 5%	0.23	3.79	5.45	0.12
CV (%)	7.88	9.64	3.31	4.39

3.2 Quality traits

From the nutrient point of view, quality is considered as an important factor in any vegetable crop. Bitter gourd is a powerful nutrient dense crop composed of a complex array of beneficial compounds. These include bioactive chemicals, vitamins, minerals and antioxidants which all contribute to its remarkable versatility in treating a wide range of illnesses. The fruits contain high amounts of vitamin C, vitamin A, vitamin E, vitamins B_1, B_2 and B_3, as well as vitamin B_9. The fruit is also rich in minerals including potassium, calcium, zinc, magnesium, phosphorus and iron, and is a good source of dietary fibre. Researchers found that Bitter melon is having full of antioxidants such as carotenoids, including alpha and beta-carotene, lycopene and zeaxanthin (Rodriguez *et al*., 1976).

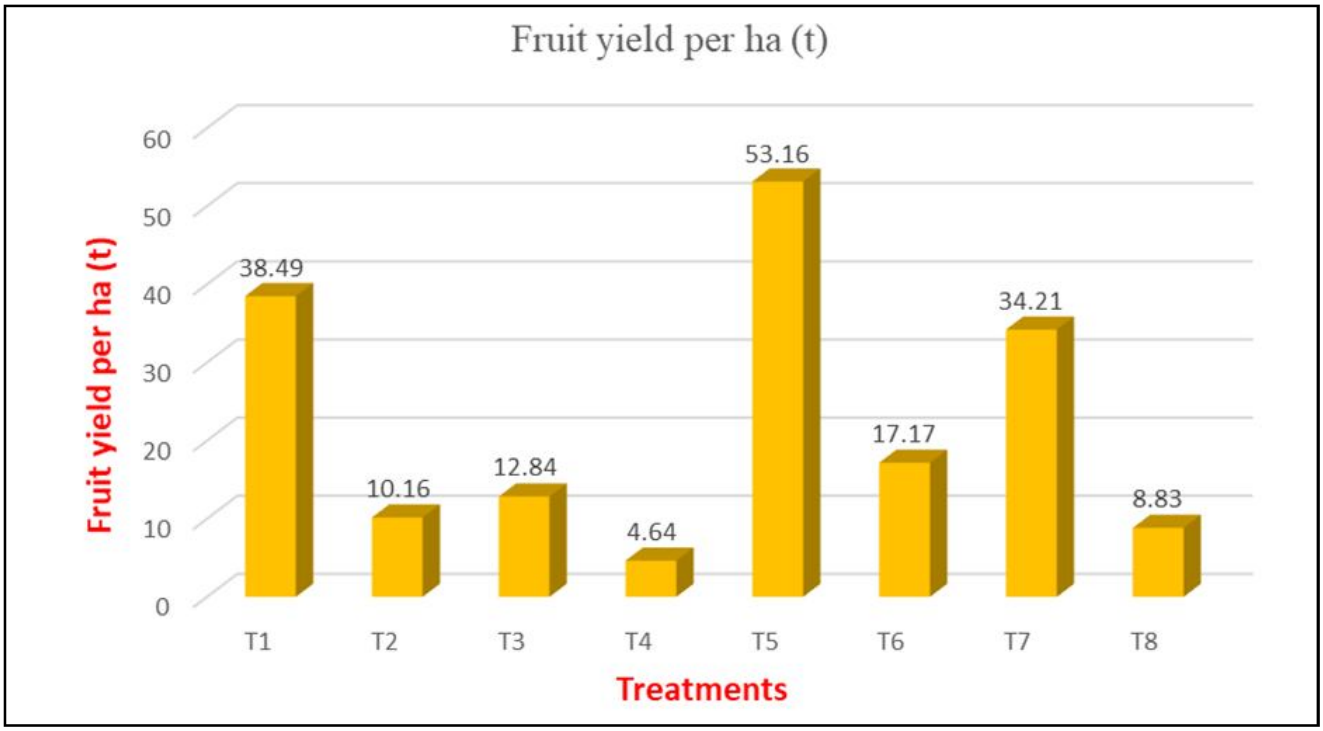

Figure 7: Performance of various grafts of Bitter gourd for fruit yield per ha (t).

3.2.1 Vitamin C (mg/100 g)

Vitamin C also known as ascorbic acid, which is a water soluble vitamin and a powerful antioxidant which is found in variable quantities in vegetables. Generally, higher ascorbic acid content would increase the nutritive value of the fruits, which could help better retention of colour and flavour (Sasikumar, 1999). The ascorbic acid content was ranging from 68.42 to 107.28 mg per 100 g for different graft combinations (Figure 8). Among all the treatment combinations, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded the significantly highest ascorbic acid content of 107.28 which was at par with T_7 (Sponge gourd root stock with Bitter gourd scion Hybrid-Palee) (102.54) and T_1 (Bitter gourd ungrafted Hybrid-Palee) (102.23) and the lowest ascorbic acid (68.42 mg /100 g) was recorded in T_4 (Bottle gourd root stock with Bitter gourd scion OPV-Green long). In case of Bitter gourd scions, the higher ascorbic acid content of 102.23 and 94.39 mg /100 g was recorded by Palee F_1 and Green long, respectively. Among the three hybrid scion grafts, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid) recorded the significantly highest value (107.28 mg/100 g) for vitamin C which was at par with T_7 (Sponge gourd root stock with Bitter gourd scion Hybrid) (102.54 mg/100 g) and T_3 (Bottle gourd rootstock with Bitter gourd scion Hybrid-Palee) recorded the significantly lowest value (84.93 mg/100 g). Out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded the significantly highest value (96.89 mg/100 g) which was at par with T_8 (Sponge gourd rootstock with Bitter gourd scion OPV- Green long) (94.94 mg/100 g) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV- Green long) recorded lowest value (68.42 mg/100 g).

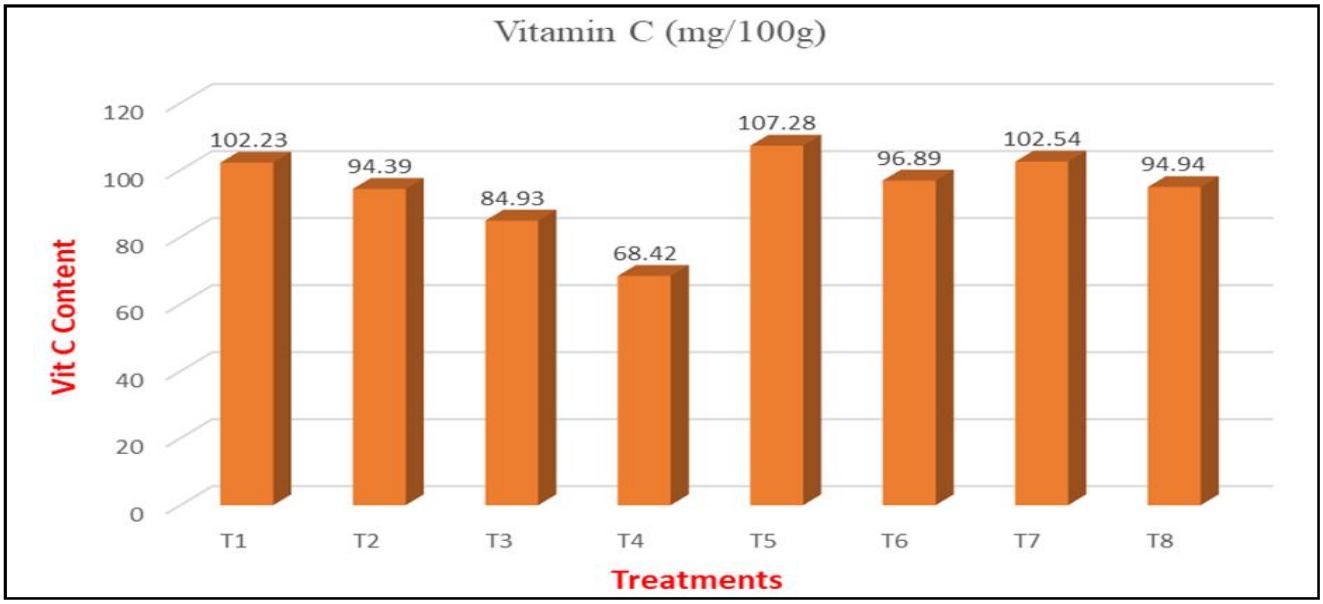

Figure 8: Performance of various grafts of Bitter gourd for ascorbic acid (mg/100 g) in fruits.

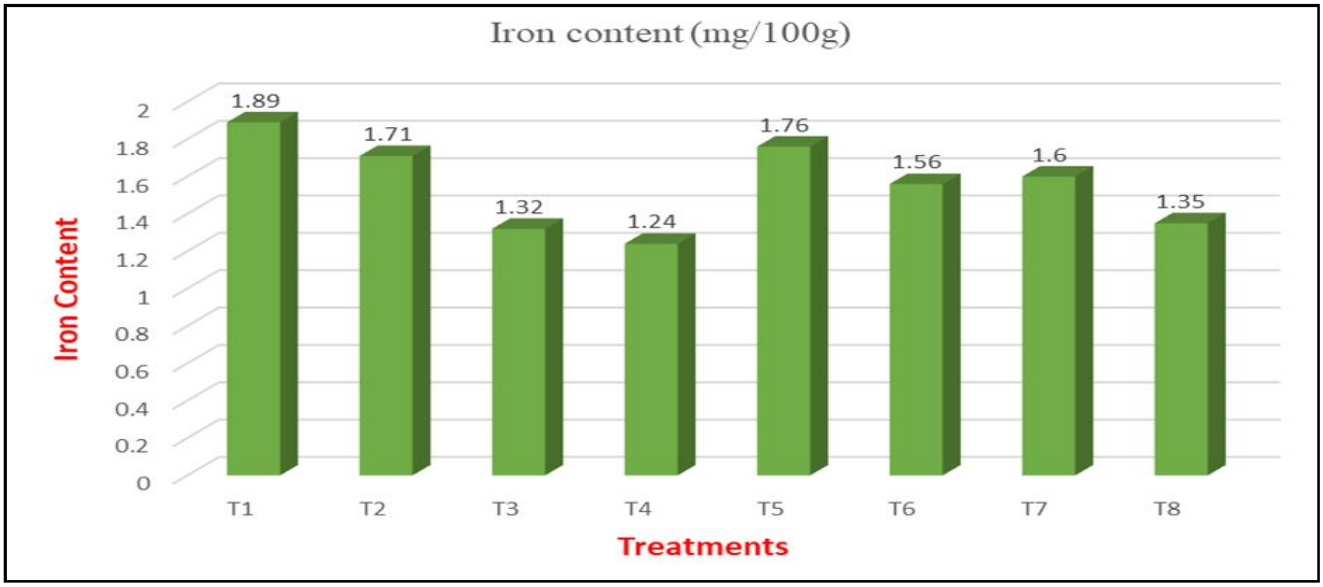

Figure 9: Performance of various grafts of Bitter gourd for iron content (mg/100 g) in fruits.

3.2.2 Iron content (mg/100 g)

Iron content is also an important parameter and among the graft combinations, the iron content ranged from 1.24 to 1.76 mg/100 g (Figure 9). T_5 (Pumpkin rootstock with Bitter gourd scion hybrid) registered high level of iron content (1.76 mg/100 g), followed by Palee F_1 grafted onto Sponge gourd (*Luffa cylindrica*) rootstock (1.60 mg/100 g), while the green long grafted onto Bottle gourd (*Lagenaria siceraria*) was found to have the lowest iron content (1.24). Among the two scions, Palee F_1 recorded the highest iron content (1.89) and green long recorded 1.79 mg/100 g, respectively. Among the three hybrid scion grafts and ungrafted Hybrid scion, T_1(Bitter gourd ungrafted Hybrid-Palee) recorded highest value (1.89 mg/100 g) and T_3 (Bottle gourd rootstock with Bitter gourd scion Hybrid-Palee) recorded lowest value (1.32 mg/100 g). Out of three OPV scion grafts and ungrafted OPV scion, T_2 (Bitter gourd ungrafted OPV-Green long) recorded highest value (1.71 mg/100 g) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV) recorded significantly lowest value (1.24 mg/100 g). However, iron content was recorded higher in ungrafts when compared to that of grafts.

4. Discussion

Bitter gourd is known as 'the mainstream food of the 21st century' for several multifarious health benefits owing promising biological properties (Mukherjee *et al*., 2012; Fang and Ng, 2016). The field experiment was conducted in randomized block design (RBD) with 8 treatments and 3 replications for the presented study. The analysis of variance showed significant differences for various traits studied in the presented research on grafted Bitter gourd revealing presence of genetic variation in the material studied.

The data on number of pickings per vine is concerned, out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV- Green long) recorded significantly highest value (10.87) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV-Green long) recorded significantly lowest value (6.77). Treatment, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded 46.35% number of pickings when compared to T_1 (Bitter gourd ungrafted Hybrid-Palee). T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded 42.96% number of pickings when compared to T_2 (Bitter gourd ungrafted OPV-Green long). Number of fruits produced by any kind of vegetable is a direct indicator of high yield. Higher the fruit number more will be the yield. The higher fruit number was observed in T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid), followed by T_7 (Sponge gourd rootstock with Bitter gourd scion Hybrid) than nongrafted plants. This might be due to vigorous root system rootstock results in enhanced nutrient uptake. These results coincide with those obtained by Nisini *et al*. (2002) in muskmelon, Yetisir and Sari (2003); Khankahdani *et al*. (2012) in watermelon, Rouphael *et al*. (2008) and Huang *et al*. (2010) in cucumber. Kohatsu *et al*. (2013) reported that the rootstock 'Shelper' provided 31.2% and 43.2% increase in the number of marketable fruits and 35.5% and 39.5% in the yield, relative to nongrafted plants and cucumber grafted onto Green-stripped cushaw squash, respectively. According to Khryanin (2007), cytokinin can induce feminization in various plant species. Zhou *et al*. (2007) studied cucumber grafted onto *Cucurbita ficifolia* found that grafted plants had twice the level of cytokinin.

Out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV- Green long) recorded significantly highest value of 12.23 cm and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV- Green long) recorded significantly lowest value of 8.83 cm. T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded 21.72% higher fruit length when compared to T_1 (Bitter gourd ungrafted Hybrid-Palee). T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded 12.09% higher fruit length when compared to T_2 (Bitter gourd ungrafted OPV-Green long). Fruit girth was recorded higher in ungrafts when compared to that of grafts. In case of fruit length and fruit girth, the graft T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) followed by T_6 (Pumpkin rootstock with Bitter gourd scion OPV) registered higher values compared to other graft combinations. The yield contributing characters, *viz*., fruit length, girth and weight were higher in grafted plants. This result is in agreement with Khankahdani *et al*. (2012) and Islam *et al*. (2013) in watermelon.

Mean fruit weight is yet another yield contributing component. High values of mean fruit weight were recorded in the graft combination, T_5 (Pumpkin rootstock with Bitter gourd scion hybrid), whereas among the scions, high values of mean performance were registered by the Hybrid-Palee F_1. This finding falls in line with that of Yetisir and Sari (2003), Passam *et al*. (2005), Alan *et al*. (2007), Rouphael *et al*. (2008), Heidari *et al*. (2012), Camacho *et al*. (2009) and Khankahdani *et al*. (2012) in watermelon. Fruit size of watermelon grafted to rootstock having vigorous root systems was often significantly increased compared to fruit from intact plants (Mohamed *et al*., 2012).

In the present study, higher fruit yield was obtained by T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) compared to other graft combinations and scions. This might be due to different factors such as superior interaction between rootstock and scion enabling good supply of endogenous hormones (Salehi *et al*., 2010), increased efficiency of water and nutrient consumption (Akbari Cheshmemanesh *et al*., 2003; Salehi *et al*., 2010) and enhanced growth and yield (Sherly, 2010; Aloni *et al*., 2010). It may also be due to increased tolerance to salinity (He *et al*., 2009; Huang *et al*., 2009; Huang *et al*., 2010) and pest and disease (Miguel *et al*., 2004; Cohen *et al*., 2005). Pulgar *et al*. (2000) found that grafting had influence on absorption and translocation of phosphorus, nitrogen, magnesium and calcium. Therefore, improved nutrient uptake resulting in increased photosynthesis and these conditions might have allowed the grafted plants to produce higher yield, sometimes with improved fruit quality (He *et al*., 2009). Similar trends of increased fruit yield in grafted plants were also reported by Salam *et al*. (2002), Colla *et al*. (2006), Huitron *et al*. (2010), Khankahdani *et al*. (2012), Mohamed *et al*. (2012) and Islam *et al*. (2013). Among the three hybrid scion grafts, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly highest value (53.16 t) for fruit yield per ha and T_3 (Bottle gourd rootstock with Bitter gourd scion Hybrid-Palee) recorded significantly lowest value (12.84 t). Out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV- Green long) recorded significantly highest value (17.17 t) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV-Green long) recorded lowest value (4.64). Treatment, T_5 (Pumpkin rootstock with Bitter gourd scion hybrid) recorded 42.61 % higher fruit yield compared to T_1 (Palee F_1 hybrid ungrafted). T_6 (Pumpkin rootstock with Bitter gourd scion OPV) recorded 56.78 % higher fruit yield compared to T_2 (Bitter gourd ungrafted OPV-Green long). Possible mechanism for increased crop productivity might be due to increased

water and nutrient uptake by vigorous rootstock improved stomatal conductance thereby increased crop growth (Ruiz *et al*., 1996; Leonardi and Giuffrida, 2006), controlled uptake, synthesis and translocation of water, mineral and plant hormones (Lee and Oda, 2002) and enhanced photosynthesis (He *et al*., 2009).

The Bitter gourd fruits contain high amounts of vitamin C, vitamin A, vitamin E, vitamin B_1, B_2 and B_3, as well as vitamin B_9. Researchers found that Bitter melon is having full of antioxidants such as carotenoids, including alpha and beta-carotene, lycopene and zeaxanthin (Rodriguez *et al*., 1976; Saidaiah Pidigam *et al*., 2022). Out of three OPV scion grafts, T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded the significantly highest value (96.89 mg/100 g) which was at par with T_8 (Sponge gourd rootstock with Bitter gourd scion OPV-Green long) (94.94 mg/100 g) and T_4 (Bottle gourd rootstock with Bitter gourd scion OPV-Green long) recorded lowest value (68.42 mg/100 g). Treatment, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) recorded 4.93 % higher vitamin C when compared to T_1 (Bitter gourd ungrafted Hybrid-Palee). T_6 (Pumpkin rootstock with Bitter gourd scion OPV-Green long) recorded 2.64 % higher vitamin C when compared to T_2 (Biter gourd ungrafted OPV-Green long). Vitamin C also known as Ascorbic acid which is a nutritionally important character and higher contents were observed in the grafts Palee F_1 grafted onto pumpkin rootstock and green long grafted onto pumpkin rootstock than their respective scions. But, statistically no significant difference was found. Zhu *et al*. (2006) and Sherly (2010) reported an increase in ascorbic acid content with grafting.

Use of rootstock also gives rise to problem in terms of excessive vegetative growth of scion and poor quality produce on wrong selection of wild species as rootstock where it had steroid alkaloid in the roots translocated to scion and turn the fruit Bitter (Mochizuki and Yamakawa, 1979). Grafting may affect various quality aspects of vegetables. The rootstock/scion combinations should therefore be carefully selected for specific climatic and geographic conditions. Appropriate selection of rootstock can help to control soil borne diseases and also increase yield and quality. Among the six different graft combinations, Palee F_1 grafted onto Pumpkin (*Cucurbita moschata*) rootstock was found to be the best and showed superiority for all the important traits studied in the evaluation. It could, therefore, be concluded that the graft, Palee F_1 grafted onto pumpkin (*Cucurbita moschata*) rootstock may be used for further research work. Since, it is a preliminary study; further research work should be carried out to know about the agronomic characters like fertilizer schedule, spacing, irrigation frequency, *etc*.

5. Conclusion

The observations on grafting study revealed that Palee F_1 grafted onto sponge gourd rootstock recorded the highest values and grafting was adjudged as the best one among the 8 treatments, in relation to yield and yield contributing characters, *viz*., total number of pickings (16.48), number of fruits per vine (22.66), fruit weight (175.95 g), fruit length (23.20 cm) and fruit yield per vine (3.99 kg), in evaluation. Grafting found to be influenced on fruit yield and quality of Bitter gourd as well. Grafting increased 42.61 % of fruit yield of Bitter gourd in T_5 (Pumpkin rootstock with Bitter gourd scion hybrid), when compared to that of T_1 (Bitter gourd ungrafted Hybrid-Palee). With respect to quality traits among different graft combinations, T_5 (Pumpkin rootstock with Bitter gourd scion Hybrid-Palee) showed superior performance for ascorbic acid and T_1 (Bitter gourd ungrafted Hybrid-Palee) had maximum iron content.

Acknowledgements

The first author expresses gratitude to Sri Konda Laxman Telangana State Horticultural University for provision of facilities to conduct the presented research.

Conflict of interest

The authors declare no conflicts of interest relevant to this article.

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Citation **A. Pranitha, B. Neeraja Prabhakar, Veena Joshi, P. Saidaiah and P. Praneeth (2024). Effect of different rootstocks on yield traits and quality of Bitter gourd (*Momordica charantia* L.). Ann. Phytomed., 13(2):1102-1113. http://dx.doi.org/10.54085/ap.2024.13.2.114.**