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Evaluation of Different Rootstocks and Grafting Techniques on Graft Union Percent, Yield and Yield Components of Watermelon CV. 'Crimson Sweet'

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Abstract: In order to comparison the effect of different rootstocks and grafting techniques on graft union percent, yield and yield components of Watermelon cv. 'Crimson sweet' was performed an experiment in two phases (greenhouse and field). Greenhouse phase was in CRD as factorial with 5 replications and field phase was in RCBD with 3 replications. In greenhouse phase first factor was grafting technique (hole insertion, splice and tongue-approach grafting) and second factor was rootstock type consist 'Bottle gourd' (*Lagenaria siceraria*), 'Shintoza' (*Cucurbita maxima* × *C. moschata*) and 'Pumpkin' (*C. maxima*). After grafting in controllable conditions, grafted plants was transferred to main field and direct seeding was performed as control treatment. Results showed that the greatest union percent was in splice grafting and the least in hole insertion grafting. Union percent in 'Bottle gourd' and 'Shintoza' rootstocks were higher than 'Pumpkin'. Evaluation of interaction between two factors showed that using of 'Bottle gourd' and 'Shintoza' rootstocks and splice grafting had the highest graft union percent. Evaluation of field characters showed that splice grafting on 'Bottle gourd' rootstock had better potential than other techniques and rootstocks in the conditions of this study.

Key words: Grafting technique · Gourd rootstocks · Watermelon grafting

INTRODUCTION

Watermelon (*Citrullus vulgaris* or *C. lanatus*), Cucurbitaceae, is native of warm regions of Africa and in the sixteenth century was brought to Europe and then was transferred from Europe to America and its growing was begun. Between various cultivated Watermelon cultivars in Iran, 'Crimson sweet' has very economical value and has been allocated very land under cultivation and production. This cultivar was bred in the year 1963 and it has round-oval shaped fruit with dark green band in light ground rind. Saberi *et al*. [1] in evaluation the effect of salinity on yield and yield components of 'Charleston gray', 'Crimson sweet' and 'Sugar baby' cultivars found that 'Charleston gray' and 'Crimson sweet' cultivars had higher tolerant threshold to salinity and recommend them for the regions with 8 ds/m soil and water salinity. The first evidence of grafting in vegetables has been recorded in the book in relation to fifth century A.C in China. Grafting advantages in vegetables are consist: resistant to diseases specially soil-born diseases (*Fusarium*, Bacterial and *Verticillium* wilt) and elimination of Methyl bromide for soil disinfectant; resistant to knot-root nematodes; resistant induction from 'Bottle gourd' to scions of gourd genus against red-cobweb mite; transition of resistant to some viruses to scion; using of vigorous root system; resistant to cold and warm; enhancement of nutritive absorption; scion growth regulation; enhancement of size, yield and fruit quality [2]. Using of resistant gourd rootstocks to disease has been led to double production of Watermelon in southeastern of United State of America [3]. Inter-genus grafting is customary in many fruity vegetables such as 'Cucumber' on 'Pumpkin' or 'Watermelon' on 'Bottle gourd' [4]. Grafting in vegetables was begun in the year 1920 for controlling of soil-born diseases and at present is

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customary technique in Asia and a part of Europe and Middle East. It has been reported that grafting and rootstock type affect pH, flavor, color, carotenoids content and fruit texture in vegetables. Although there are some reports based upon reduction of fruit quality in using of grafting in vegetables. Extant differences in results of these reports may be caused by various environmental conditions, used rootstock type and interaction between rootstock and scion [5]. In using of rootstock for Watermelon must be used the plant of Cucurbitaceae family which are resistant to desirable diseases, are compatible to scion and have good growth vigor and as well as do not make any loss in fruit quality [6]. In grafting of Watermelon usually are used 'Watermelon' (*Citrullus lanatus*), 'Winter squash' (*Cucurbita moschata*), 'Pumpkin' (*C. maxima*), 'Shintoza' (*C. moschata* × *C. maxima*) and 'Bottle gourd' (*Lagenaria siceraria*). Recently the rootstock namely 'Ferro' that is similar 'Shintoza' and hybrid between 'Winter squash' and 'Pumpkin' (*C. moschata* × *C. maxima*) and the rootstock namely 'Plops' that is the type of 'Bottle gourd' had been many usage as rootstock in Cucurbitaceae family crops.

Tongue-approach grafting is one of the grafting techniques in Watermelon which the rootstock and scion while are on itself roots are grafted together. After confidence of graft place union, scion and rootstock are cut below and above of graft place, respectively. Hole insertion grafting is one of the other grafting technique in Watermelon which in this technique rootstock is cut from above of cotyledons and is made a hole in cutting place and the scion (consist cotyledons and hypocotyl axis) is placed into hole. Splice grafting also is other type of grafting in vegetables which in this technique is cut a 45° cutting in scion and rootstock as inversion and grafting place is fasten by a clip. Grafting operation commercially is done by trained persons. Recently has been made grafted machines for this purpose [7].

In an experiment, scion of Watermelon cv. 'Sugar baby' was grafted on two rootstocks consist 'Shintoza Camel' (the inter-specific hybrid of gourd) and 'Macis' (the type of 'Bottle gourd') by splice grafting technique. For more evaluations Watermelon also was grafted on itself rootstock. Watermelon seedy plants were considered as control. Grafted plants were transplanted to main field 25-40 days after grafting. Results showed Watermelon yield on 'Shintoza Camel' rootstock was more than 'Macis' rootstock and on itself rootstock as well. In viewpoint of produced fruit number, Watermelon on itself rootstock had no significant difference with other both rootstocks and control. The greatest fruit weight was observed in grafted plants but had no significant difference with grafted plants on Watermelon rootstock. These results show that used rootstock type can be effective on enhancement of fruit yield. Success of Watermelon grafting on gourd rootstocks was 40% more than on itself rootstock. Severe infection of non-grafted plants and a little infection of grafted plants to cobweb mite showed that Watermelon grafting on gourd can be induce resistant to this pest in scion [3].

Low fruit quality consist reduction of TSS, increase of yellow-colored bands in fruit flesh, peel thickness, unsavory flavor, undesirable texture and reduction of fruit firmness also have been reported in grafted Watermelons [8, 9]. On the other hand, positive effects of grafting in Watermelon consist of increase of fruit firmness; TSS and lycopene also have been reported [10]. Yetisir *et al*. [11] reported that rootstock has very influence on Watermelon quality (TSS, firmness, peel thickness and fruit shape) but is depend on used rootstock type. Whereas Miguel *et al*. [6] observed no significant difference in TSS content of Watermelon fruits grafted on the gourd rootstock derived 'Pumpkin' and 'Winter squash' (Inter-specific hybridization) compared to control. Perkins-Veazie *et al*. [12] showed that grafting in Watermelon is leading to increase of Lycopene and total carotenoids till 20% and Amino-acids specially Citrolin till 35%. Lam *et al*. [4] in comparison of grafted plants of two seedless Watermelon cultivars on 'Shintoza' rootstock and non-grafted plants found that fruit number in grafted plants significantly were more than non-grafted plants but fruit weight average on non-grafted plants were more than grafted plants.

Some plants among some plants of Cucurbitaceae family have special strategy against diseases and unfavorable environmental conditions. Phenols, Tannins, Lignin, Phenolic acids and Flavenoeids are among secondary metabolites which have several functions in plant. Among these functions can be mentioned to enzyme activity, plant growth, fruit quality and graft compatibility and resistant against pathogens. These compounds exist in root, stem, vegetative and generative buds, woody parts, leaves, phloem tissue and even in pollens. Phenols can be used for evaluation of resistant to fungi and viruses. High concentrations of phenols in plant can be prevented from germination of fungi spores and their spreading. In this relation, Evrenosoglu *et al*. [13] evaluated three plant groups such as gourd rootstock, grafted Watermelon on gourd and seedy

Watermelon in viewpoint of leaf phenolic materials. They found that phenolic materials in leaf's rootstocks were more than leaf of grafted Watermelon on gourd. Phenolic materials in leaf of seedy Watermelons (non-grafted) were less than others. Pulgar *et al*. [14] in evaluation of mineral elements grafted 'Early Star' cultivar on three gourd rootstocks and considered seedy Watermelon plants as control. Used rootstocks had more absorption ability and transportation of nitrogen that increased nitrogen metabolism in grafted plants compared to control. Bekhradi *et al*. [15] in evaluation the effects of different gourd rootstocks on growth and yield of Watermelon cv. 'Charleston gray' and also its influence on blossom end rot disease found that vegetative characters affected by grafting and using of different rootstocks but had no significant influence on fruit quality. The greatest and the least Watermelon yield obtained on 'Ferro' and 'Summer squash' (*Cucurbita pepo*) rootstocks respectively. The results showed that grafting had no influence on blossom end rot disease in Watermelon cv. 'Charleston gray'. Moradipour *et al*. [16] in evaluation the effect of different gourd rootstocks on plant permanency and some vegetative characters of two greenhouse Cucumber cultivars found that permanency percent of grafted plants on 'Shintoza' rootstock was more than 'Bottle gourd' rootstock. Chouka and Jebari [17] in evaluation the effects of grafting on vegetative growth, root development, yield and fruit quality of Watermelon cv. 'Sugar baby' on three rootstocks such as 'Rjich' (Tunisian local Watermelon), 'RS841' (*Cucurbita moschata* × *C. maxima*) and 'Bottle gourd' found that 'RS841' rootstock in fruit quality, fruit number and weight average, yield, early flowering, root dry weight, internode length and leaf area was better than other rootstocks. 'Bottle gourd' rootstock in fruit number and early flowering was better than 'Rjich' and seedy Watermelons.

MATERIALS AND METHODS

In order to comparison the effect of different rootstocks and grafting techniques on graft union percent, yield and yield components of Watermelon cv. 'Crimson sweet' was carried out an experiment in completely randomized design as factorial arrangement in greenhouse. First factor was grafting techniques consist hole insertion, splice and tongue-approach grafting and second factor was rootstock type consist 'Bottle gourd' (*Lagenaria siceraria*), 'Shintoza' (*Cucurbita maxima* × *C. moschata*) and 'Pumpkin' (*C. maxima*) in five replications. Rootstock seeds were sown in 72 cells culture tray containing peat moss as every other one and Watermelon seeds (scion) also were sown in culture tray or basin in relation to grafting technique. After grafting operation, grafted plants were placed in dark environment with 22-25°C temperature and 70-80% relative humidity and then graft union percent were evaluated. Then grafted plants were transplanted to main field. Direct seeding also was done in main field as control (regional common). Used statistical design in main field was randomized complete block design with six treatments and three replications. Each plot was consist 4 rows with 10 m long (2.5 m mound and 0.5 m stream) and distance of plants on rows was 70 cm. For elimination of marginal effects, sampling for evaluation of characters was performed from middle rows. In this study were evaluated the characters such as graft union percent, day to flowering, yield, harvestable fruit number, fruit weight, main stem length and number of lateral stem. Finally, data was analyzed by MSTAT-C software and the means were compared by Tukey's test.

RESULTS AND DISCUSSION

Greenhouse Phase: Vegetative growth rate in 'Pumpkin' rootstock was very faster than two other rootstocks and vegetative growth rate in 'Shintoza' rootstock was less than 'Bottle gourd' rootstock which this subject led to difficulty in production of grafted plant in fast-grow rootstocks. In using of hole insertion and splice grafting techniques, rootstock seeds were sown as every other one in culture trays and in tongue-approach grafting as every other two so that number of sown seeds were 36 seeds in hole insertion and splice grafting techniques and 24 seeds in tongue-approach grafting technique in each culture tray. The greatest graft union percent was 43.2% in splice grafting and the least was 4.1% in hole insertion grafting. There is significant difference between three grafting techniques in 1% level according to Tukey's test (Table 1).

Comparison of used rootstocks showed that graft union percent were the greatest on 'Bottle gourd' rootstock (36%) and the least on 'Pumpkin' rootstock (6.4%) and was observed significant difference between rootstocks in 1% level of Tukey's test. Evaluation the interaction between rootstock type and grafting technique showed that the greatest graft union percent was observed on 'Bottle gourd' and 'Shintoza' rootstocks by using splice grafting technique (75.4 and 41.5% respectively). There is no graft union percent on 'Pumpkin' rootstock by using hole insertion grafting

Table 1: Comparison the effect of grafting techniques, rootstocks and interaction between them on graft union percent

	Grafting technique			
Rootstock	Hole insertion	Splice	Tongue-approach	Mean
'Bottle gourd'	†6.8^{c}	75.4^{a}	25.8^{bc}	††36.0^{A}
'Shintoza'	5.4^{c}	41.5^{b}	15.7^{bc}	20.9^{B}
'Pumpkin'	0.0^{c}	12.8^{bc}	6.4^{c}	6.4^{C}
Mean	††4.1^{C}	43.2^{A}	16.0^{B}	

†Means with small letters, followed by similar letters are not significantly different at the 1% level according to Tukey's test (HSD)

††In below row or right column, means with capital, followed by similar letters are not significantly different at the 1% level according to Tukey's test (HSD)

technique (Table 1). Moradipour *et al*. [16] in comparison of 'Bottle gourd' and 'Shintoza' rootstocks for greenhouse Cucumber noticed the superiority of 'Shintoza' rootstock than 'Bottle gourd'. This is not according to the present study that because of difference between used genuses as scion is justifiable. In 'Pumpkin' rootstock because of quick growth and become thick and hollow of stem not made available the possibility of scion and rootstock joining so that to this reason all scions on this rootstock dried in hole insertion grafting technique. In this study 'Pumpkin' was unsuitable rootstock. In relation to done evaluations in the present study, can be claim that each used grafting technique have own special virtues and faults. If the necessary conditions be supplied for each technique in the grafting time, each technique may be confirming itself efficiency. In this relation, hole insertion grafting because of needless to graft clip is very economical but preserving conditions of grafted transplants is very sensitive for graft place union. In the other both grafting techniques the production costs increase because of using of graft clip but there is the possibility of more transplant production because of less sensitiveness to environmental conditions. Anyhow in tongue-approach grafting technique the grafting operation was more difficult because of to be brittle of scion and rootstock tissues and to be co-diameter of scion and rootstock is necessary. Therefore determination of careful time of scion and rootstock sowing is the most important problems in tongue-approach grafting technique.

Field Phase: After finishing of greenhouse phase, grafted transplants of splice and tongue-approach grafting techniques on 'Shintoza' and 'Bottle gourd' rootstocks became reedy for transplanting to main field. Heap direct seeding was done as control and Watermelon seedy transplant also was used as a treatment. Therefore totally were evaluated 6 treatments in field phase.

Length of Main Stem: Mean comparison of main stem length by Tukey's test showed that the longest main stem was observed in grafted Watermelons on 'Bottle gourd' by splice grafting technique (180 cm) and the shortest main stem in seedy Watermelons (103 cm). Main stem length in grafted plants was more than seedy and transplant Watermelons and had significant difference (Table 2). Group comparison results of treatments showed that main stem length in grafted Watermelons by splice grafting technique (173 cm) was more than tongue-approach grafting technique (148 cm) and had significant difference together in 1% level. Comparison of rootstock type showed that main stem length in produced Watermelon on 'Bottle gourd' rootstock (170 cm) was more than 'Shintoza' rootstock (151 cm) and had significant difference together in 1% level (Table 3).

Lateral Stem Number: The greatest lateral stem number was observed in seedy Watermelons (12 stem) and the least in grafted Watermelons. There is no significant difference between seedy Watermelons and other treatments but grafted transplants had no significant difference together (Table 2). Group comparison results of treatments showed that lateral stem number in grafted Watermelons by splice grafting technique (5 stem) was more than tongue-approach grafting technique (4 stem) but had no significant difference together. Comparison of rootstock type showed that lateral stem number in produced Watermelon on 'Bottle gourd' rootstock (4 stem) was less than 'Shintoza' rootstock (5 stem) but had no significant difference together (Table 3).

Day to Flowering: Mean comparison of day to flowering by Tukey's test showed that the greatest day to flowering was observed in grafted Watermelons and the least in seedy and transplant Watermelons. In other words, seedy plants produced the flower earlier than grafted plants. In this relation there is no significant difference between

Table 2: Comparison of different types of Watermelon plant based on evaluated characters

Plant type	Character						
	Main stem length (cm)	Lateral stem No.	Day to flowering	Fruit number	Shape index	Fruit weight (kg)	Fruit yield (kg/plant)
Seedy plant	†103[d]	12[a]	36[b]	1.0[e]	1.01[d]	4.2[c]	4.37[e]
Transplant	107[d]	9[b]	33[b]	1.2[c]	1.08[c]	4.9[c]	5.63[d]
'Shintoza' rootstock Splice grafting	166[ab]	5[c]	42[a]	1.8[b]	1.16[ab]	6.7[ab]	11.97[b]
'Bottle gourd' rootstock Splice grafting	180[a]	5[c]	44[a]	2.6[a]	1.19[a]	5.2[bc]	13.60[a]
'Shintoza' rootstock Tongue-approach grafting	136[c]	5[c]	43[a]	1.9[b]	1.12[b]	5.6[abc]	10.67[c]
'Bottle gourd' rootstock Tongue-approach grafting	159[b]	4[c]	42[a]	1.8[b]	1.14[b]	7.0[a]	12.17[b]

†Means in each column, followed by similar letters are not significantly different at the 5% level according to Tukey's test (HSD)

Table 3: Group Comparisons between treatments

Character	Comparison			
	Grafting technique		Rootstock type	
	Splice	Tongue-approach	'Shintoza'	'Bottle gourd'
Main stem length (cm)	173**	14 8**	151**	170**
Lateral stem No.	5ns	4ns	5ns	4ns
Day to flowering	43ns	42ns	42ns	43ns
Fruit No.	2.20**	1.80**	1.85**	2.20**
Shape index	1.18**	1.13**	1.14**	1.16*
Fruit weight (g)	5.95ns	6.30ns	6.15ns	6.10ns
Yield (kg/plant)	12.78**	11.42**	11.32**	12.88**

ns, *, **: Not significant, significant in 5% and 1%, respectively

grafted plants types but had significant difference to seedy and transplant Watermelons (Table 2). Contrary to obtained results in the present study, Chouka and Jebari [17] observed early flowering in 'RS841' (hybrid like 'Shintoza') and 'Bottle gourd' rootstocks so that flowering in seedy Watermelons was observed later than grafted Watermelons. Group comparison results of treatments showed that number of day to flowering in grafted Watermelons by tongue-approach grafting (42 days) was less than splice technique (43 days) but had no significant difference together. Comparison of rootstock type showed that number of day to flowering in produced Watermelon on 'Shintoza' rootstock (42 days) was less than 'Bottle gourd' rootstock (43 days) but had no significant difference together (Table 3).

Harvestable Fruit Number: The greatest fruit number was observed in grafted Watermelons on 'Bottle gourd' rootstock by splice grafting (2.6 fruits) and the least in seedy Watermelons (1.0 fruit). Number of fruit in grafted plants was more than seedy and transplant Watermelons and had significant difference together (Table 2). Group comparison results of treatments showed that the number of fruit in grafted Watermelons by splice grafting (2.2 fruits) was more than tongue-approach technique (1.8 fruits) and had significant difference together in 1% level. Comparison of rootstock type showed that number of fruit in produced Watermelon on 'Bottle gourd' rootstock (2.2 fruits) was more than 'Shintoza' rootstock (1.8 fruits) and had significant difference together in 1% level (Table 3). Chouka and Jebari [17] also obtained the greatest fruit number of Watermelon cv. 'Sugar baby' on 'RS841' and 'Bottle gourd' rootstocks.

Fruit Shape Index: The greatest fruit shape index (fruit length/diameter ratio) was observed in fruits of grafted Watermelons on 'Bottle gourd' by splice grafting technique (1.19) and the least in seedy Watermelons (1.01). Fruit shape index in grafted plants was more than seedy and transplant Watermelons and there is significant difference between them. The produced fruits from grafted plants were longer than the fruits of seedy and transplant Watermelons (Table 2). Group comparison results of treatments showed that the fruit shape index of grafted Watermelons by splice grafting (1.18) was more than tongue-approach technique (1.13) and had significant difference together in 1% level. Comparison of rootstock type showed that fruit shape index in produced Watermelons on 'Bottle gourd' rootstock (1.16) was more than 'Shintoza' rootstock (1.14) and had significant difference together in 5% level (Table 3).

Fruit Weight Average: Mean comparison of fruit weight by Tukey's test showed that the greatest fruit weight was observed in grafted Watermelons on 'Bottle gourd' rootstock by tongue-approach grafting technique (7.00 kg) and the least in seedy and transplant Watermelons (4.20 and 4.90 kg respectively). Fruit weight in grafted plants was more than seedy and transplant Watermelons and there is significant difference between them (Table 2). Group comparison results of treatments showed that fruit weight in grafted Watermelons by tongue-approach grafting (6.30 kg) was more than splice grafting technique (5.95 kg) but had no significant difference together. Comparison of rootstock type showed that fruit weight in produced Watermelon on 'Shintoza' rootstock (6.15 kg) was more than 'Bottle gourd' rootstock (6.10 kg) but had no significant difference together (Table 3). Chouka and Jebari [17] also obtained the greatest fruit weight in grafted 'Sugar baby' Watermelon on 'RS841' (hybrid like 'Shintoza') which is according to obtained results in the present study. In them results also there was no significant difference between rootstocks in viewpoint of fruit weight average.

Fruit Yield in Plant: The greatest fruit yield in plant was observed in grafted Watermelons on 'Bottle gourd' rootstock by splice grafting technique (13.60 kg/plant) and the least in seedy Watermelons (4.37 kg/plant). Fruit yield in grafted plants was more than seedy and transplant Watermelons and there is significant difference between them (Table 2). Group comparison results of treatments showed that fruit yield in grafted Watermelons by splice grafting technique (12.78 kg/plant) was more than tongue-approach grafting technique (11.42 kg/plant) and there was significant difference between them in 1% level. Comparison of rootstock type showed that fruit yield in produced Watermelon on 'Bottle gourd' rootstock (12.88 kg/plant) was more than 'Shintoza' rootstock (11.32 kg/plant) and there was significant difference between them in 1% level (Table 3). Chouka and Jebari [17] obtained the greatest fruit yield in grafted 'Sugar baby' Watermelon on 'RS841' (hybrid like 'Shintoza'). In their results 'Bottle gourd' rootstock there was in next level of fruit yield.

CONCLUSION

Total obtained results showed that splice grafting technique and using of 'Bottle gourd' rootstock had better potential than other techniques and rootstocks in conditions of this study. Meanwhile in comparison of 'Bottle gourd' and 'Shintoza' rootstocks, superiority of 'Bottle gourd' rootstock than 'Shintoza' rootstock encourage because of easier availability of 'Bottle gourd' seed and needless to imports.

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