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EVALUATION OF DIFFERENT ROOTSTOCKS FOR IMPROVING GROWTH AND YIELD OF WATERMELON

M. M. R. SALIM[1], M. A. RAHMAN[2], K. K. SARKER[3]
B. AHMED[4] AND A. K. M. QUAMRUZZAMAN[5]

Abstract

Grafting method of propagation is a standard practice in developed countries to increase plant tolerance to several biotic and abiotic stresses and to improve fruit yield of watermelon. The technique is still remained unexplored especially for watermelon cultivation in Bangladesh. Hence, an experiment was conducted at the research field of Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur during late winter to early summer season of 2020-21 to find out the suitable rootstock as a grafting agent compatible better with watermelon and to study the effect of such rootstocks on the growth, yield and sweetness of watermelon. The seedlings of watermelon (*Citrullus lanatus*) cv. Black Jumbo F_1 was grafted onto four different rootstocks namely, Bottle gourd, Sweet gourd, Ash gourd and Snake gourd using the single cotyledon hole insertion method. The result indicated that grafting improved growth and development of watermelon influencing the length of main stem and numbers of lateral stems. Grafted plant showed significantly lower prevalence of plant wilting in watermelon over non-grafted plants. As such, the plant survival at fruit maturity stage (70 Days after planting) was higher in grafted treatments than non-grafted treatment. The result indicated that grafting of watermelon onto bottle gourd and sweet gourd rootstock significantly influenced vegetative and reproductive growth, decreased the wilt disease, which ultimately contributed to higher numbers of fruit/plant, greater fruit size and higher yield. However, fruit quality in terms of TSS was statistically similar under different grafting and non-grafting treatments. Grafting of water melon onto bottle gourd or sweet gourd could be suggested as an alternative effective method to control plant wilting and improve growth and yield of watermelon.

Keywords: Watermelon, Rootstock, Scion, Grafting, *Fusarium* wilt, Yield

Introduction

Watermelon (*Citrullus lanatus*) is a popular fruit crop in Bangladesh especially during the–summer season. In 2019-2020, about 255,000 metric tons of watermelon was produced from 12,140 hectares of land in the country with an average yield of 21.0 t/ha (BBS, 2020). The crop, watermelon is known as highly susceptible to soil borne diseases especially *Fusarium* wilt causing drastic yield reduction worldwide (Taylor *et al*., 2008).

[1]Principal Scientific Officer (Horticulture), PRC & RARS, Ishordi, [2]Chief Scientific Officer, Soil & Water management Section, HRC, Bangladesh Agricultural Research Institute (BARI), Gazipur, [3]Irrigation and Water Management Division, BARI [4&5]Olericulture Division, HRC, Gazipur.

The technique of grafting in watermelon (*Citrullus lanatus*) onto different root-stocks proved to be a standard production practice in Japan for the management of *Fusarium* wilt. The grafted watermelons also showed higher water use efficiency compared to non-grafted plant under water deficit condition (Rouphael *et al.*, 2008). The benefit of using grafted watermelon seedlings has been increasingly popularized to address production challenges with the ban of the broad-spectrum soil fumigant like Methyl Bromide (Davis *et al*., 2008). Thus, the technique is described as an alternative to soil fumigate Methyl Bromide in controlling *Fusarium* wilt in watermelon (Miguel *et al*., 2004, Yetisir *et al*., 2007). Generally, the outbreak of wilting occurs during the late production stage after spending all the production costs involved in melon production (Taylor *et al*., 2008) and thus the growers face serious loss. Grafting of watermelon onto other cucurbitaceous crops tends to reduce the damage caused by several soil-borne pathogens (Louws *et al*., 2010) resulted in higher yield. The technique also increased the plant tolerance to biotic stress such as viral, fungal and bacterial infection (Rivero *et al*., 2003; Edelstein *et al.*, 2004; Cohen *et al*., 2007). The use of watermelon seedlings grafted on Cucurbita and Lagenaria rootstocks have an acquired resistance to soil borne diseases and thus suggested by several other researchers to achieve higher productivity of watermelon (Miguel *et al.*, 2004; Boughalleb *et al.*, 2008). The use of resistant rootstock to susceptible scions prevents the primary sources of infection resulting in reduced disease incidence (Davis *et al*., 2008) having better growth and yield of water melon. Now a days, the use of resistant rootstock to protect the susceptible scions from pest and diseases and to ensure sustainable production are the common practices in developed countries but rare in Bangladesh. Therefore, the present experiment was undertaken to find out the suitable rootstock as a grafting agent compatible better with watermelon and to study the effect of such rootstocks on the growth, yield and sweetness of watermelon.

Materials and Methods

Study site, weather and soil characteristics

The experiment was carried out at the research field of Olriculture Division, Horticulture Research Centre, Bangladesh Agricultural Research Institute, Gazipur (latitude: 23.988^{o} N, longitude: 90.407^{o} E, at 8.4 m above sea level) during late winter to early summer season of 2020-21. The soil of experimental site belongs to the Agro-Ecological Zone (AEZ)-28 namely Madhupur Tract. The soil was clay loam in texture with an average field capacity of 29.7% and mean bulk density was 1.49 and 1.65 g/cm^3 at the surface (0-15cm) and subsurface (15-30cm) layers, respectively. The fertility status of the soil reported to be medium level in general. The experimental area is characterized by moderately monsoon rainfall, high humidity, high temperature during March to June and heavy rainfall (about 80% of the total rainfall) during June to September. In general, the site having scanty rainfall, low humidity, low temperature, short day and clear sunshine during October to March. During the cropping period of 2020-21 the experimental area was completely rain free from the months of January to March and had showers of rain in April and May but had heavy rain in June (Fig 2). The mean data of maximum and minimum temperature, pan evaporation, relative humidity, sun shine hour and monthly rainfall were recorded during the crop growing period from the Meteorological Station located about 350 m apart from the experimental field and the relevant data are presented in Figure 1 and 2.

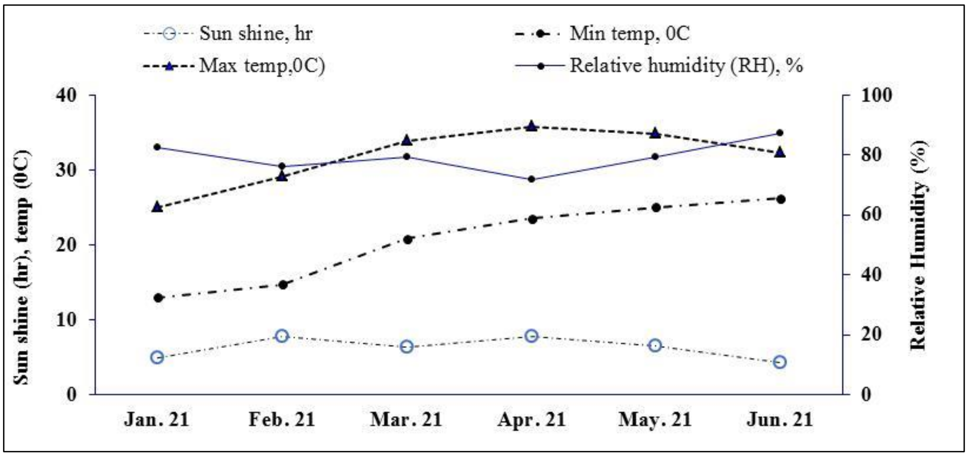

Fig. 1. Mean maximum and minimum air temperature (ºC), relative humidity (RH %) and sun shine (hrs) during the crop growing season in 2020-21.

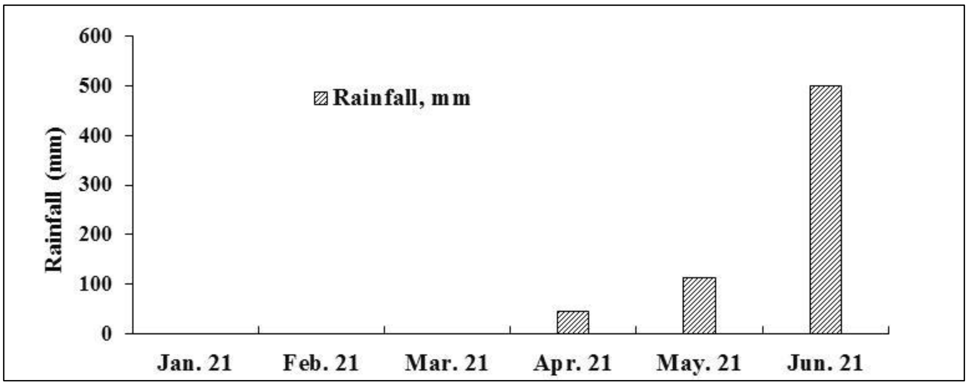

Fig. 2: Monthly rainfall during the crop growing season in 2020-21.

Raising seedlings of scion and rootstocks and grafting method

Seeds of scion (Black Jumbo F_1 watermelon) were sown in small size plastic pots filled with mixture of soil and decomposed cow-dung (l:1) during the first week of February 2021. After a couple of days, the seeds of different rootstocks were sown in the similar pot and media as mentioned above. Two seeds were sown in each pot; water was applied in each day to maintain the soil moisture level near to field capacity that was favorable for seed germination. About 90% seeds were germinated and after germination, one healthy seedling was allowed to grow in each pot. A total of one hundred seedlings of each root stock and 500 seedlings of scion were grown. Two weeks old seedlings of scion were grafted carefully onto the rootstocks on 16 February, 2021 using the hole insertion method (Fig 3). The true leaf, apical meristem and the axillary buds were removed from the topmost growing point of the root stocks. Due care was taken to remove all the apical meristem and buds to prevent future shoot growth of the root stock. A pointed probe was used to create a hole on the top of the root-stock from where the apical part was removed. At the same time, cuttings of scions were made below the cotyledon at 45° angle on two sides to form a wedge (Fig 3d). Then the cutting of scion was inserted into the hole of root stock just after removing the probe. The diameter of scion cutting was similar to diameter of vascular bundle of root stock thus no any grafting clip was required to hold the two plants together. Water was applied as mist to the grafted plants and they were placed in the healing chamber for 7 days. Non-grafted 'Black Jumbo' seedlings were grown in same place and condition as grafted plants.

Experimental design, treatments, land preparation and transplanting

The grafted plants of 'Black Jumbo' F_1 watermelon along with non-grafted plants were used as the test crops. Four different rootstocks such as Bottle gourd, Sweet gourd, Ash gourd and Snake gourd were tested. The land was cross ploughed by chisel and rotavator to ensure the well tilth soil condition. Then beds were formed with the size of 16 m x 2 m, which was considered as unit plot. The experiment was laid out in randomized complete block design replicating three times. Each replication consists of 5 beds where the root stock treatments were randomly distributed. Thirty days old seedlings were transplanted in each bed digging small pits in two rows 1.2m apart in the middle of beds. Due care was taken during transplanting so that the entire soil ball with seedling was removed from the pots without braking of soil ball. The seedlings were placed into the pit in such a depth thus the base of seedlings remained at the soil surface level.

Agronomic management and data collection

The main land was fertilized with decomposed cow-dung @ 5 t/ha prior to final land preparation. The fertilizers @ N_{80} P_{40} K_{60} S_{20} Zn_4 and $B_{1.5}$ kg/ha, were applied in the forms of urea, triple super phosphate, muriate of potash, gypsum, zinc oxide and boric acid, respectively (BARC, 2018). All fertilizers including half of urea and muriate of potash were uniformly applied in the field during final land preparation and the rest half of N and K fertilizers were applied as banding at 30 DAP (days after planting). The early crop growing period was rain free, thus, irrigation water was applied at a regular interval of 7 days starting from the day of transplanting. The crop was weeded only once at 20 DAP and thereafter weeding was not required due to rapid growth of vines covering the ground. Sex pheromone trap was used for controlling fruit fly. All the agronomic practices including irrigation, weeding and top dressing were conducted uniformly in all plots. Five sample plants were randomly selected from the middle of each plot and tagged for data collection. Length of the main stem was measured from the root collar level to the tip and branch length was measured from the base of the first node to the tip. The total number of branches, nodes formed on the main stem was counted and internode length of the middle node was measured. All the measurements were taken from the tagged plants at fruit maturity stage. The number of fruits per plant was recorded at fruit maturity stage. The watermelon fruit was considered as matured and harvestable when the 3 tendrils adjacent to the fruit had dried. The harvested fruits from the tagged plants were weighed separately at each time of harvest to determine the yield per plant and to estimate yield/ha. The recorded data on different characters was statistically analyzed using Statistix10.

Fig. 3a. Root-stock seedling

Fig.3b. Removal of apical meristem of Root-stock

Fig. 3c. Use of probe to create a hole in the top of the root-stock

Fig. 3d. Cutting of scion at 45° angle

Fig. 3e. Scion insertion into the rootstock.

Fig. 3f. Grafted seedling

Fig. 3. Different steps of grafting following hole insertion method.

Results and Discussion

Vegetative growth and plant survival

The growth and development of watermelon plants (cultivar- Black Jumbo) varied due to different rootstocks used as grafting agent (Table 1). The length of main stem of watermelon plant was the shortest (2.19 m) in non-grafted plants (BJ) and the plants grafted onto bottle gourd (BG + BJ) resulted in the longest main stem (2.95 m) at fruiting stage (70 DAP), which was significantly higher over rest of the treatments. Other watermelon plants grafted onto Sweet gourd (StG + BJ), Ash gourd (AG + BJ) and Snake gourd (SG + BJ) had statistically similar length in main stem but significantly higher than non-grafted control (BJ). Similarly, the number of lateral stems was the maximum (6.96) in plants grafted with bottle gourd (BG + BJ) which was significantly higher over rest of the treatments. Ash gourd and snake gourd grafted plants exhibited similar performance as was observed in non-grafted control (BJ). Grafting of water melon onto bottle gourd showed vigorous plant growth and development in terms of higher length of main stem and maximum number of lateral stems.

The onset of flowering was earlier in non-grafted plants both for male (46.8 DAP) and female (47.4 DAP) flower. Flowering was delayed in grafted plants compared to control and grafting with four different root stocks resulted in statistically similar numbers of days to male flowering. Female flower appeared 10-12 days earlier in non-grafted plants (BJ) and all the grafted plants resulted in statistically similar days to first female flowering (Table1). The maximum number of male flower per plant (39.2) as well as the minimum number of female flower (16.3) was recorded in non-grafted BJ plants. The lowest number of male flower (26.27/plant) was observed from SG which was identical to AG grafted plants. On the other hand, the highest number of female flower (24.52/plant) was observed from bottle gourd grafted plants (BG + BJ), which was significantly higher over rest of the treatments. The rest of the grafted plants showed identical number of female flowers which were significantly higher over non-grafted control (BJ). Thus, grafting of watermelon contributed to increase the number of female flower significantly over non-grafted plants.

The appearance of plant wilting varied significantly due to use of different rootstocks (Fig.4). At 15 DAP, 6.6 plants out of 16 died and the wilting damage continued till 45 DAP under non-grafted (BJ) water melon plants (Fig. 4). Grafting onto different rootstocks resulted in significant reduction of wilting damage in watermelon compared to control. However, periodical data exhibits the variation among the rootstock treatments in controlling wilting damage of water melon plants. The BG grafted plants showed the best result in controlling wilting followed by StG and AG as revealed from plant survival rate observed at 70 DAP (Table 1). During fruiting stage (70 DAP) the plant survival varied from 58.7% in control (BJ) to 78.7% in treatment grafted onto bottle gourd (BG + BJ). Grafting of water melon onto sweet gourd (StG + BJ) resulted in the second highest plant survival (73.5%) followed by (AG+BJ) and (StG + BJ). Similar findings were reported by Salam *et al*. (2002), Yetisir *et al*. (2007), Taylor *et al.* (2008) and Mohammed *et al.* (2012). Better plant growth in grafted watermelon compared to non-grafted plant was reported in several other studies (Yetisir *et al*., 2006; Boughalleb *et al.*, 2008; Mohammed *et al.*, 2012). More extensive root growth of bottle gourd rootstock due to augmented endogenous hormone production (Zijlstra *et al*., 1994) and enhanced uptake of nutrients (Huang *et al.*, 2016) might have contributed to more growth and elongation of main stems with higher number of lateral stems of grafted watermelon.

Yield and quality of water melon

Grafted watermelon plants produced higher numbers of female flowers and less male flowers comparing to non-grafted plants which resulted in higher sex ratio (Female/Male) and thus finally contributed to higher fruits/plant and higher yield (Table 1 and Table 2). The maximum number of fruits/plant (3.88) was recorded from bottle gourd grafted plants (BG+BJ) followed by sweet gourd grafted (StG+BJ) but these were statistically similar. Watermelon plant grafted onto ash gourd (AG+BJ) and snake gourd (SG+BJ) produced statistically similar numbers of fruit/plant which was higher than non-grafted plant (BJ) but less than (BG+BJ) and (StG+BJ) (Table 2). Similar kind of result of watermelon under grafting was reported by Salam *et al* (2002). Moreover, there were significant differences in fruit length, fruit circumference and fruit yield of watermelon among the rootstocks used as grafting agent in present study (Table 2). The grafting treatment (BG + BJ) gave the highest fruit length (39.71 cm) and maximum fruit circumference (56.25 cm) followed by (StG + BJ), (AG + BJ) and (SG + BJ). On the other hand, non-grafted plants resulted in significantly the lowest fruit length, fruit circumference and fruit yield. The maximum yield (17.85 kg plant^{-1} equivalent to 44.63 t ha^{-1}) was obtained when watermelon was grafted onto bottle gourd, which was statistically identical to sweet gourd grafted plants (StG+BJ) (Table 2). Ash gourd and snake gourd grafted plants of watermelon also produced significantly higher yields over non-grafted control. The grafted watermelon plant onto snake gourd, ash gourd, sweet gourd and bottle gourd contributed to yield increase of 28, 33, 53 and 74%, respectively, over the non-grafted plant. Plant growth and development was favoured by grafting resulted in more fruit set and bigger fruit size which finally contributed to higher yield compared to control. However, bottle gourd grafted watermelon plants were found superior to all other grafted plants followed by sweet gourd grafted watermelon plant. Rouphael *et al.* (2008) reported that both total fruit yield and marketable fruit yield were significantly higher in grafted watermelon than non-grafted plant. Luis Romero *et al.* (1997) also observed significant fruit yield improvement in response to grafted plant than respective non-grafted melon plants (*Cucumis melo* L.). Alan *et al.* (2007) reported that grafting improved growth and yield of water melon without any harmful effect on fruit quality. Present study revealed that the rootstocks like bottle gourd and sweet gourd were found to be more effective grafting agents in improving growth and yield of watermelon. The fruit quality measured as sweetness (TSS) of the fruits from grafted plant was almost similar to the fruit of non-grafted watermelon plant. In particular, the TSS of fruits of non-grafted plants was 11.2%, while for grafted plants it varied from 10.5 to 10.8% but such tiny variation was statistically non-significant. This result is in agreement with the findings of Alan *et al* (2007).

Table-1. Growth and flowering behavior of watermelon grafted onto different root stocks

Treatment	Length of main stem (m)	No. of lateral stems	Days to 1st male flower	Days to 1st female flower	No. of male flower/plant	No. of female flower/plant	Plant Survival (%) 70 DAP
Control (BJ)	2.19 c	5.51 c	46.8 b	47.4 b	39.24 a	16.28 c	58.7 b
BG + BJ	2.95 a	6.96 a	53.3 a	58.8 a	35.33 b	24.52 a	76.8 a
StG + BJ	2.55 b	6.39 b	53.5 a	61.9 a	32.13 b	20.82 b	73.5 a
AG + BJ	2.59 b	5.83 c	52.2 a	62.8 a	28.14 c	20.80 b	71.8 a
SG + BJ	2.49 b	5.69 c	54.8 a	60.2 a	26.27 c	19.62 b	74.7 a
CV%	11.38	7.39	6.59	7.15	9.26	8.53	8.76
Sig. Level	*	*	**	**	**	**	**

T_1= Control (BJ = Black Jumbo, Watermelon F_1), AG= Ash Gourd, StG = Sweet gourd, BG= Bottle gourd, SG = Snake gourd, *Significanct at P≤0.05, **Significanct at P≤0.01

Table-2. Yield and yield contributing characters of watermelon grafted with different root stocks

Treatment	Fruit length (cm)	Fruit circum-ference (cm)	Fruits /plant	Fruit wt. (kg/Fruit)	Sweetness TSS (%)	Yield (kg/ plant)	Yield (t/ha)
Control (BJ)	26.85 c	39.61 c	3.08 c	3.98	11.2	10.24 c	25.61 c
BG + BJ	39.71 a	56.25 a	3.88 a	4.03	10.8	17.85 a	44.63 a
StG + BJ	34.45 b	53.88 a	3.48 ab	4.12	10.7	15.68 ab	39.30 ab
AG + BJ	30.60 b	42.81 b	3.23 b	4.09	10.5	13.26 b	34.05 b
SG + BJ	31.08 b	45.54 b	3.27 b	4.03	10.5	13.12 b	32.80 b
CV%	3.68	4.46	8.13	6.55	7.22	12.55	12.54
Sig. Level	**	**	**	NS	NS	**	*

T_1= Control (BJ = Black Jumbo, Watermelon F_1), AG= Ash Gourd, StG = Sweet Gourd, BG= Bottle gourd, SG = Snake gourd, *Significanct at P≤0.05, **Significanct at P≤0.01.

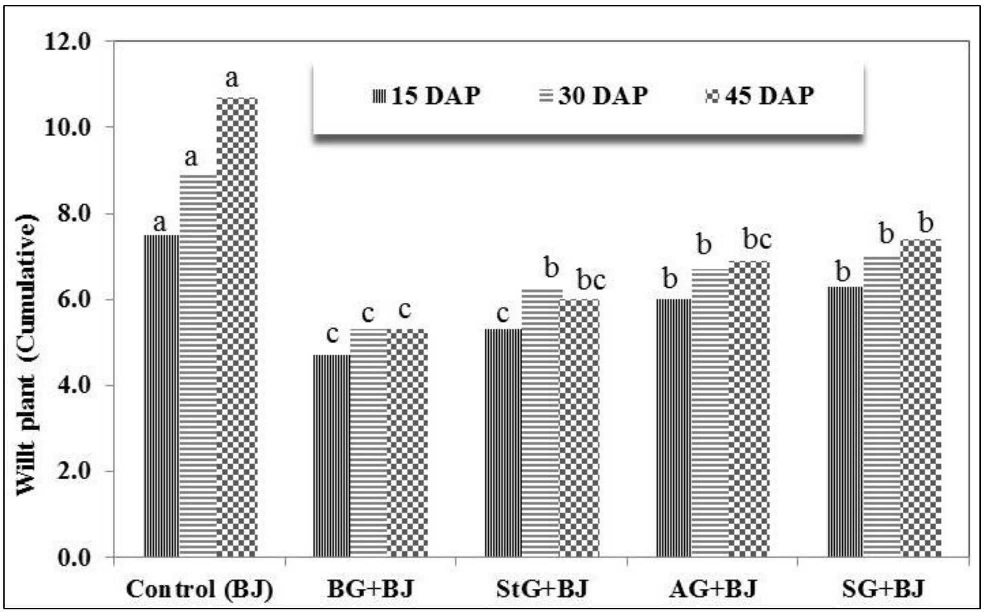

Fig. 4: Plant wilting (No.) at different stages under root stock-scion combinations

BJ = Black Jambo (F_1), BG = Bottle Gourd, StG = Sweet Gourd, AG = Ash Gourd, SG = Snake Gourd, DAP = Days after planting; Lettering on the basis of LSD value at 5% level of significance

Conclusion

Grafting is an effective tool generally used in propagation of fruits crops to improve yield and quality but the technique is rarely used for watermelon in Bangladesh. The present research demonstrated that grafting has the potentials in improving growth, development and finally fruit yield of watermelon. Among the four different root stocks, bottle gourd was found to be the superior grafting agent followed by sweet gourd. Thus, the grafting technique of watermelon onto bottle gourd or sweet gourd could be promoted at grower’s level for controlling wilting, getting better growth and higher fruit yield.

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References

Alan, O., N. Zdemir and Y. Nen. 2007. Effect of grafting on water melon plant growth, yield and quality. *J. of Agronomy*. **6**: 362-365.

BARC, 2018. Bangladesh Agricultural Research Council (BARC). Fertilizer Recommendation Guide (FRG), Farmgate, Dhaka 1215.

BBS 2020. Yearbook of Agricultural Statistics-2019. Bangladesh Bureau of Statistics. Bangladesh. Ministry of planning, Government of Peoples Republic of Bangladesh, Dhaka. p. 274

Boughalleb, N., M. Mhamdi, B. El Assadi, Z. El Bourgi, N. Tarchoun, and M. S. Romdhani. 2008. Resistance evaluation of grafted watermelon (*Citrullus lanatus* L.) against *Fusarium* wilt and *Fusarium* crown and root rot. Asian J. Plant Pathol. **2(1):** 24-29.

Cohen, R., Y. Burger and C. Horev. 2007. Introducing grafted Cucurbits to modern agriculture: The Israeli experience. Plant Dis. **91:** 916-923.

Davis, A.R., P. V. Perkins, Y. Sakata, S. G. López, J. V. Maroto, S. G. Lee, Y. C. Huh, A. Miguel, S. R. King, R. Cohen and Y. M. Lee. 2008. Cucurbit grafting. Critical Rev. Plant Sci. **27:** 50-74.

Edelstein, M., Y. Burger, C. Horev, A. Porat, A. Meir and R. Cohen. 2004. Assessing the effect of genetic and anatomic variation of *cucurbita* rootstocks on vigour, survival and yield of grafted melon. J. Hortic. Sci. Biotechnol., **79 (3):** 370-374.

Huang, Y., L. Zhao, Q. Kong, F. Cheng, M. Niu, J. Xie, and Z. Bie. 2016.Comprehensive mineral nutrition analysis of watermelon grafted onto two different rootstocks. Horticultural Plant Journal, **2(2):** 105-113.

Louws, F. J., C. L. Rivard and C. Kubota. 2010. Grafting fruiting vegetables to manage soil borne pathogens, foliar pathogens, arthropods and weeds. Scientia Horticulturae, **127:** 127-146.

Miguel, A., J. V. Maroto, A. S. Bautista, C. Baixauli, V. Cebolla, B. Pascual, S. Lopez and J. L. Guardiola. 2004. The grafting of triploid watermelon is an advantageous alternative to soil fumigation by methyl bromide for control of *Fusarium* wilt. Sci. Hortic., **103:** 9-17.,

Mohammed, F.H., K. E. A. El-Hamed, M. W. M. Elwan and M. A. N. E. Hussien. 2012. Impact of grafting on watermelon growth, fruit yield and quality. Veg. Crops Res. Bulletin **76:** 99-118.

Rivero, R.M., J.M. Ruiz and L. Romero. 2003. Role of grafting in horticultural plants under stress conditions. Food Agric., **1 (1):** 70-74.

Romero, L., A. Belakbir, L. Ragala and J. M. Ruiz.1997. Response of Plant Yield and Leaf Pigments to Saline Conditions: Effectiveness of Different Root stocks in Melon Plants (Cucumis melo L.). *Soil* Sci. *Plant Nu tr.*, **43 (4):** 855-862.

Rouphael, Y., M. Cardarelli and G. Colla. 2008. Yield, mineral composition, water relations, and water use efficiency of grafted mini-watermelon plants under deficit irrigation. Hort Sci. **43:** 730-736.

Salam, M.A., A.S.M.H. Masum, S. S. Chowdhury, M. Dhar, M.A. Saddeque and M.R. Islam. 2002. Growth and yield of watermelon as influenced by grafting. *J. Biol. Sci.* **2(5):** 298-299.

Taylor, M., B. Bruton, W. Fish and W. Roberts. 2008. Cost benefit analyses of using grafted watermelon transplants for *Fusarium* wilt disease control. Acta Hort. **782:** 343-350.

Yetisir, H., M. Caliskan, and M. Sakar, 2006. Some physiological and growth responses of watermelon [C*itrullus lanatus* (Thunb.) Matsum. and Nakai] grafted onto *Lagenaria siceraria* to flooding. Environmental and Experimental Botany. **58 (1-3):** 1-8.

Yetisir, H., S. Kurt, N. Sari and F. M. Tok. 2007. Rootstock potential of Turkish Lagenaria siceraria germplasm for watermelon: Plant growth, graft compatibility, and resistance to Fusarium. Turk J. Agric. **31:** 381-388.

Zijlstra, S., S.P.C. Groot and J. Jansen. 1994. Genetic variation of rootstocks for growth and production in cucumber; possibilities for improving the root system by plant breeding. Sci. Hort. **56:** 185-186.