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Bioscience Research

Print ISSN: 1811-9506 Online ISSN: 2218-3973

Journal by Innovative Scientific Information & Services Network

RESEARCH ARTICLE BIOSCIENCE RESEARCH, 2019 16(3): 3241-3250. **OPEN ACCESS**

Performance of different rootstocks and cultivars on growth and quality components of grafted Tomato

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This experiment was carried out to study the performance of tomato cultivars (Salar, and Sandal) grafted on various rootstocks (Mocow; *Solanum nigrum*, Brinjal; *Solanum melongena*, and Chili; *Capsicum annuum*) at National Agricultural Research Centre Islamabad, Pakistan during the cropping season 2016 using experimental design Complete Randomized Design (CRD) with two factors having 6 treatments replicated three times. The analysis of experimental results revealed that maximum number of days to 1st flowering, plant height, total soluble solid, fruit dry matter content and disease incidence were recorded in chilli rootstock while more number of flower plant^{-1}, and maximum stem diameter were recorded in Mocow rootstock. Maximum number of fruits plant^{-1}, pH and graft take success were recorded in brinjal rootstock. Regarding cultivars, maximum number of days to 1st flowering, plant height, stem diameter, fruit dry matter content and disease incidence were recorded in sandal cultivar while maximum number of flower plant^{-1}, fruits plant $^{-1}$, total soluble solids, pH and graft take success were recorded in Salar cultivar. Interactive effect of cultivar and rootstock revealed that maximum number of days to 1st flowering, plant height, TSS, fruit dry weight matter content, with minimum number of flowers plant^{-1}, stem diameter and fruit juice pH were recorded when sandal cultivar was grafted onto chilli rootstock. Furthermore, minimum number of fruits plant^{-1} and total soluble solids were recorded when sandal cultivar was grafted onto brinjal rootstock. From the present research findings it could be concluded that salar cultivar grafted on brinjal rootstock has a potential for enhancing maximum yield and graft take success.

Keywords: Cultivars, Tomato, Graft incompatibility, Biotic and Abiotic resistance, Quality

INTRODUCTION

Use of grafted seedlings became a widespread agricultural practice in many parts of the world (Pogonyi et al., 2005). Grafting is an important technique for vegetable production (Lee, 2003). In the Mediterranean, where land use is very intensive and continuous cropping is a common practice, vegetable grafting is considered an innovative technique and is in increasing demand by farmers (Khah et al., 2006).Tomato (*Solanum lycopersicum* L.) is an important vegetable consumed worldwide. World production of fresh tomato for 2009 was about 141 million tons planted on 4.5 million hectares in 144 countries (FAO, 2013). From 1990 and 2004 global consumption of tomatoes increased approximately 4.5% each year (Aherne, 2009). In Pakistan tomato is consumed in diverse ways,

including raw, as an ingredient in many dishes, sauces, salads and drinks. Tomato producers often face production problems related to soil-borne diseases and abiotic stresses that can reduce the yield and quality of fruit (King et al., 2010). A number of methods are available to control soil-borne diseases, including: host resistance, crop rotation, organic amendments, solarization, chemical fumigants and biological control (Schafer, 1999). Grafting onto resistant rootstock has the potential to address concerns about chemical use while decreasing production limitations (Kaskavalci et al., 2009). Grafted vegetable plants were first used in Japan in late 1920^{s} in cucurbits to minimize soil borne diseases. Mostly, it is used on vegetables crops in solanaceae and cucurbitaceae families. In Mediterranean countries, grafting is widely used because of continuous cropping in production (Khah et al., 2006). In tomatoes production, grafting with vigorous and specific rootstocks help to control nematodes .Grafting is used to control soil-borne diseases such as *fusarium wilt* and *verticillium wilt* (Louws et al., 2010). Other advantages includes better tolerance to thermal stress (Rivero et al., 2003), salt tolerance and abiotic stresses (Schwarz et al., 2010). Plants form callus at the graft interface enables water flow from the rootstock to the scion when the callus develops vascular bundles (Moore, 1984). Insufficient connection of vascular bundles between the scion and the rootstock decreases the water flow (Ruiz et al., 1997). Furthermore, graft incompatibility can induce undergrowth or overgrowth of the scion, which can lead to decreased water and nutrient flow through the graft union and cause wilting of the plant. Physiological incompatibility may also occur as a result of lacking cellular recognition, wounding responses, presence of growth regulators, or incompatibility toxins (Davis et al., 2008). The success or failure of grafting depends on various factors including taxonomy, environment, availability of oxygen and water, physiological stage of rootstock/scion, herbicide toxicity, the skill of the grafter and graft incompatibility (Andrews and Marquez, 1993). In plants, the more closely related rootstock-scion are, the better the chances for the graft to be successful (Copes and Oliver, 1970). A successful graft begins a sequence of events during the healing process including: callus proliferation from rootstock and scion, callus bridge formation, vascular differentiation and production of secondary xylem and phloem (Andrew and Marquez, 1993, Kawaguchi et al., 2008). The normal growth of a grafted plant may be interrupted at any stage of development due to incompatibility between scion and rootstock. Incompatibility could be directly related to undergrowth or overgrowth of the scion relative to the rootstock (Lee, 2007).

MATERIALS AND METHODS

Experimental site and Design

This experiment was conducted at National Agricultural Research Centre Islamabad, Pakistan under (shade house) condition during March-July, 2016. The performance of two tomato hybrids was evaluated for their grafting on different rootstock. Three different rootstocks were used for the grafting (mocow, brinjal and Chilli pepper). The experiment was laid out in Complete Randomized Design (CRD) with two factor factorial arrangement having three replication as prescribed by Basit et al., (2019a). Factor A included different rootstocks such as pepper (*Capsicum frutescens*), mocow (*Solanum nigram*), and brinjal (*Solanum melongena*) while factor B comprised of tomato hybrids (sandal and salar).

Planting materials and grafting

Nursery of tomato cultivars (Salar and Sandal) were raised for scion purpose. For rootstocks, the nursery of brinjal (*Solanum melongena)* and pepper (*Capsicum frutescens*) were raised. While mocow (*Solanum nigram*) rootstock collected from different areas. Many tools (Scissor, Plastic bags, Knife and blades, Grafting clips, Clingfilm plastic sheet and Pots) were used for grafting.

Salar and sandal cultivars at the stage of 2-3 true leaves were used as scion and grafted onto pepper, moccow and brinjal rootstocks using the cleft procedure (Lee, 1994). A total of 3 plants for each combination of scion and rootstocks were grafted. The grafted saplings were kept for 5 days in a shade house with extreme day and night temperatures of 31 and 16 ºC, respectively. Then the grafted plants were acclimatized outside of the shade house before transplantation.

Determination of plants' morphological yield and quality variables

Different morphological variables, yield and yield components were recorded. Number of days to flowering was counted from the date of sowing till initiation of first flower. Plant height and stem diameter were recorded at first harvest from the base of plant (2 inches above soil surface) using digital caliper as well as number of days taken to

first flowering were counted after transplanting. Similarly fresh fruit weight at each harvest was measured with electronic balance, for stem diameter Vernier caliper was used (Basit *et al*., 2019b). Hand refractometer was used for total soluble solids and fruit juice pH was determined using pH meter.

To check rate of plants infested among different cultivars of tomato on different rootstocks the following formula is used:

$$\text{Plants infested (\%)} = \text{No. of plants infected} / \text{total no. of plants grafted} \times 100$$

To check rate of success of grafting among different cultivars of tomato on different rootstocks the following formula was used:

$$\text{Graft success (\%)} = (\text{No. of plants graft take success}) / (\text{Total no. of plants grafted}) \times 100$$

Statistical Analysis

The collected data were analyzed using CRD with two factorial through the statistical package "Statistix 8.1" as describe by Jandel Scientific (1991) and Basit et al., (2018). Means separation along with the treatment were done by using LSD (least significant difference) at 0.05 level of significance.

RESULTS ANDDISCUSSION

Days to first flowering, Number of flowers & Fruits plant^{-1}, Plant height and Stem diameter

The data regarding number of days to first flowering, number of flower plant^{-1}, number of fruits plant^{-1}, plant height and stem diameter is given in Table 1.The interactive response of rootstock and cultivar indicated that maximum number of days to first flowering were found in sandal cultivar grafted onto chilli rootstock, while minimum numbers of days to first flowering were found in salar cultivar grafted onto brinjal rootstock. Similarly, the interactive response of rootstocks and cultivars regarding the number of flowers plant^{-1} indicated that maximum value of number of flowers plant^{-1} were observed in cultivar salar when grafted onto mocow rootstock as compared to sandal cultivar grafted on chilli rootstock. Interactive response of rootstock and cultivar indicates that more number of fruits plant^{-1} were found in salar cultivar grafted onto brinjal rootstock, while minimum number of fruits plant^{-1} were observed in sandal cultivar grafted onto brinjal .The interactive response of rootstock and cultivar indicated that maximum plant height was found in sandal cultivar grafted onto chilli rootstock while minimum plant height was found in salar cultivar grafted onto mocow rootstock. The interactive response of rootstock and cultivar indicated that maximum value of stem diameter were observed in sandal cultivar grafted onto mocow rootstock, while minimum value of stem diameter were found in salar cultivar grafted onto brinjal rootstock (Figure 1).

Our results are supported with findings of Matsuzoe et al., (1994) who reported that plants grafted on different rootstocks were different from non-grafted plants in terms of days to 1st flowering, days to 1st fruit maturity and days to fruit set. Ibrahim (1996) studied that grafted plants took maximum days to flowering as compared to non-grafted plants. Delayed flowering, fruit setting and fruit maturity is a common phenomenon due to grafting of the scion. It is because the normal time of plant growth both the vegetative and reproductive stage are under the stress of graft wound, which hinders the translocation of photo assimilates for growth and development. Furthermore when graft union is successful after some time period, then the flow of nutrients is started and physiological processes occurs, therefore it takes more days to flowering as compared to normal flowering of these cultivars. Our results are similar with Coggins and Lesley (1968) who studied that changes in number of flowers were recorded when grafting operation was practiced in vegetables. Grafting was found in favors of sweet potato with respect to flowering and it also affected flowering in tomato, pepper and eggplant as well. More number of flowers recorded in mocow rootstock due to that reason as compare to chilli, mocow rootstock has deep root systems which have greater impact number of branches and leaves, that provide the plant with more nutrients and hence more flower bud development occurs. Our results are similar with Marsic and Osvald (2004) who studied that a good result of grafting was observed when 'Beaufort' was used as a rootstock and 'Monroe' cultivar was used as scion. In that grafted combination, the total fruit yield per plant

Table 1; Days to first flowering, flowers plant^{-1}, fruits plant^{-1}, Plant height (cm) and Stem diameter (mm) of tomato as affected by grafting tomato cultivars (sandal and salar) on different rootstocks (chilli, mocow and brinjal).

Treatments	Days to first flowering	No. of flowers plant^{-1}	No. of fruits plant^{-1}	Plant height (cm)	Stem Diameter (mm)
Rootstocks (RS)					
Chilli	47.50 a	61.08 c	11.50 b	196.00 a	0.62 b
Mocow	46.50 a	71.61 a	12.67 a	189.33 b	0.67 a
Brinjal	44.67 b	66.89 b	12.77 a	195.00 a	0.64 b
LSD≤0.05	1.83	3.10	0.82	4.84	0.03
Tomato cultivars (C)					
Sandal	47.22 a	63.03 b	12.05 b	197.56 a	0.66 a
Salar	45.22 b	70.48 a	12.57 a	189.33 b	0.63 b
LSD≤0.05	1.36	3.01	0.47	2.87	0.02
Interaction					
RS x C	Fig.1a	Fig 1b	Fig 1c	Fig 1d	Fig 1e
Level of significance	*	*	*	*	*

Means in the same category followed by different letter are significantly different at 5% level of significance. "*" represent significant differences at p<0.05. RS= rootstock, C= cultivars.

Table 2. TSS (Brix^{0}), Fruit juice pH, Fruit dry matter content (g), Disease incidence (%) and Graft takes success (%) of tomato as affected by grafting tomato cultivars (sandal and salar) on different rootstocks (chilli, mocow and brinjal).

Treatments	TSS (^{o}Brix)	Fruit juice pH	Fruit dry matter content (g)	Disease incidence (%)	Graft takes success (%)
Rootstocks (RS)					
Chilli	4.86 a	4.74b	30.98 a	33.50 a	66.50 c
Mocow	4.83 ab	4.71b	25.17 b	27.77 b	72.83 b
Brinjal	4.74 b	5.01a	30.22 a	17.00 c	82.67 a
LSD ≤0.05	0.03	0.04	4.19	2.38	2.31
Tomato cultivars (C)					
Sandal	4.79 b	4.69 b	30.18 a	27.33 a	72.33 b
Salar	4.83 a	4.94 a	27.39 b	24.44 b	75.67 a
LSD≤0.05	0.04	0.04	2.29	0.71	0.76
Interaction					
RS x C	Fig 1f	Fig 2a	Fig 2b	Fig 2c	Fig 2d
Level of significance	*	*	*	*	*

Means in the same category followed by different letter are significantly different at 5% level of significance. "*" represent significant differences at p≤0.05. RS= rootstock, C= cultivars

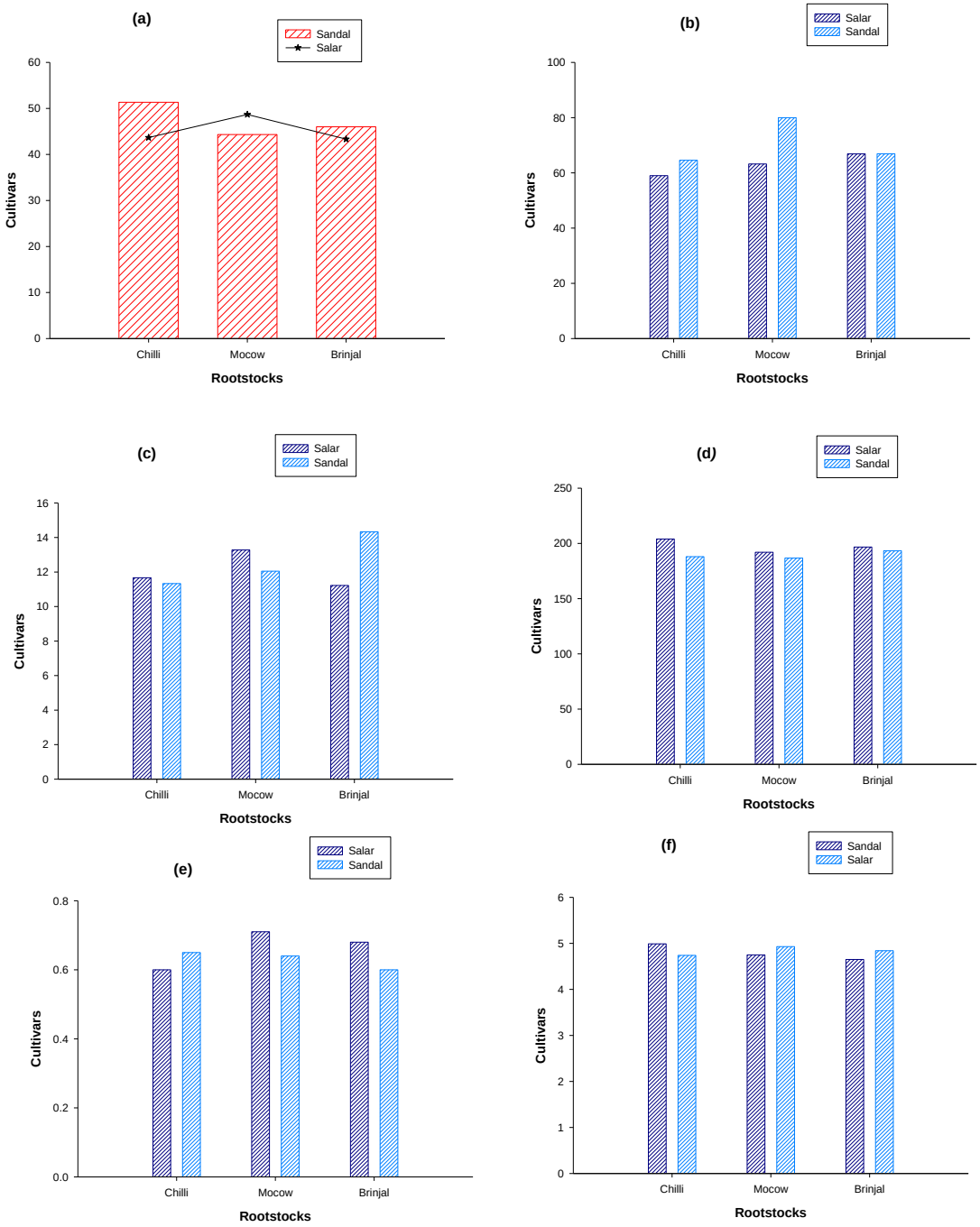

Figure 1. No. of days to first flowering, No. of flowers plant^{-1}, No. of fruits plant^{-1}, Plant height, Stem diameter and Total soluble solid as influenced by interaction between different tomato cultivars grafted on various rootstocks.

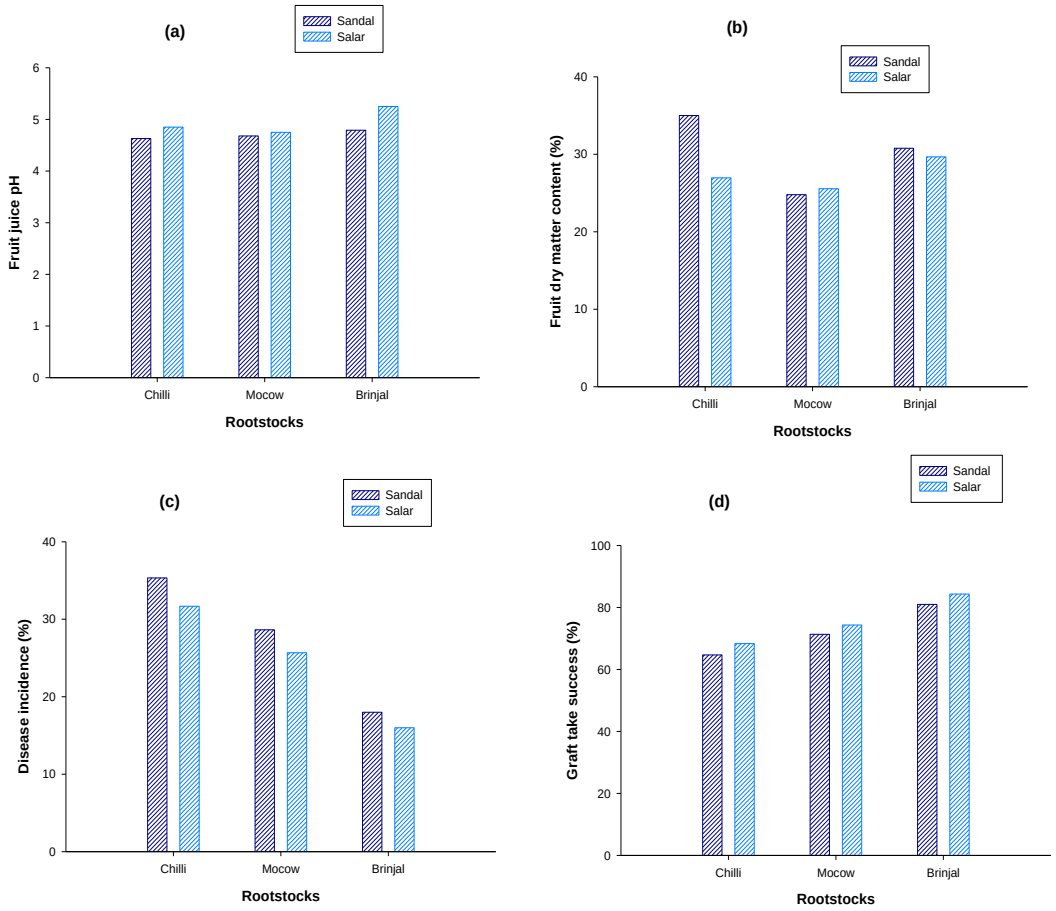

Figure 2. Fruit juice pH, fruit dry matter content, disease incidence and graft take success of tomato as influenced by interaction between different tomato cultivars grafted on various rootstocks

increased significantly in comparison with that of the non-grafted plants or when 'PG3' was used as rootstock.

As brinjal have deep root system therefore it provide the plant with more essential nutrients and it also have a bushy structure with more branches and leaves that leads to more production of photo assimilates and therefore more leaves (source) formation improves the sink (flowering and fruit set). Ioannou et al., (2002) studied that plant height was significantly affected due to grafting under shade house conditions. Whereas in the field condition the “big red” cultivar grafted onto “heman” tomato cultivar resulted in maximum height than the control plants. Our results are similar with Lee (1994) who studied that grafted plants were taller and more vigorous than non-grafted plants. It might be due to grafting, translocation of minerals, vitamins, plant growth regulators and carbohydrates slow down initially at the time of grafting. Which decreased the translocation of auxin (hormone produced in meristematic tissues responsible for plant height and roots development) into the rootstock, and is present in more quantity in the apical meristems that causes increase in plant growth and height as compared to normal plants. Our results are in similarity with Ioannou et al., (2002) and Lee (1994) who studied that grafted plants were more strong and taller than non-grafted ones and had a bigger central stem diameter. The grafted plants like brinjal have deep root system, and when it is used as a rootstock it takes more nutrients from soil transferring them to different plant parts. Hence causes vigorous growth in terms of stem diameter and plant height (Table 1).

Total soluble solid, Fruit juice pH, Dry matter content, Disease incidence and Graft take success

Data regarding total soluble solid, fruit juice pH, dry matter content, disease incidence and graft take success is given in Table 2. The interactive response of rootstock and cultivar indicated that maximum total soluble solids were noted in sandal cultivar grafted onto chilli rootstock. Whereas, minimum total soluble solids were found in sandal cultivar grafted onto brinjal rootstock (Figure 1). The interactive response of rootstock and cultivar indicated that the highest fruit juice pH were found in Salar cultivar grafted onto brinjal rootstock, while minimum fruit pH were found in sandal cultivar grafted onto chilli rootstock. The interactive response of rootstock and cultivar indicated that highest dry matter content were found in sandal cultivar grafted onto chilli rootstock while minimum dry weight matter were found in salar cultivar grafted onto mocow rootstock. Maximum disease incidence was observed in chilli rootstock, while minimum disease incidence was observed in brinjal rootstock. Similarly in cultivars, the maximum disease incidence was observed in sandal cultivar, while minimum disease incidence was observed in salar cultivar. In rootstocks, the maximum graft take success percentage was observed in brinjal rootstock, while minimum graft take plant success percentage was observed in chilli rootstock. Similarly in cultivars, the maximum graft take success percentage was observed in salar cultivar, while minimum graft take success percentage was observed in sandal cultivar (Figure 2).

As the results indicated that the total soluble solids (^{o}Brix) was found maximum when sandal cultivar was grafted onto chilli rootstock. Leoni et al. (1990) studied that fruit qualitative characteristics showed significant differences in terms of total soluble solids, fruit juice pH, and concentration of lycopene. However, fruit acidity in grafted plants cultivated in the open field was higher. Therefore, the above results are in agreement with others researchers who studied that fruit descriptive and qualitative characteristics were affected by grafting. Similarly in terms of quality traits Salar cultivar was more prominent as compared to sandal cultivar of tomato. Our studies are in line with Leoni et al., (1990) who reported that grafting had a significant effects on fruit pH, total soluble solids and lycopene concentration and firmness. Fruit acidity in grafted plants (Big red x Heman), cultivated in field conditions was greater than (Big red x Primavera) self-grafted plants. The dry matter content has been significantly increased. Paratore and Romano (2001) reported that the dry matter content in grafted tomato seedlings ('Beaufort x Rita') was higher than the non-grafted tomato seedlings. Ali (1994) reported that fruit dry weight matter is qualitative parameter. It is because in grafted plants the accumulation of dry matter is higher than non-grafted. The lower success of the tube grafts could be associated with desiccation, therefore in order to increase the graft success a misting chamber could be used to maintain high relative humidity and low level of ambient light. Kawaguchi et al., (2008) studied that important point in grafting is having good graft compatibility and graft union that depends on the compatibility of rootstock and scion. Through cleft grafting method, graft take success rates of 100 % were obtained when eggplant rootstock was used, similarly when SM_3 rootstock was used, 70 % graft take success was observed. When the interspecific hybrid *Solanum Melongena X Solanum Incanum* were used as a rootstock and scion 80 % graft take success was found.

CONCLUSION

From this study we concluded that "Sandal" cultivar grafted on chilli rootstock gave maximum plant height, number of days to first flowering and "Salar" cultivar grafted on "mocow" rootstock resulted in maximum number of flowers plant^{-1} while "Salar" cultivar grafted on "brinjal" rootstock gave maximum number of fruits plant^{-1}, pH, and percent graft take success. Therefore on the basis of results it is recommended that "Salar" cultivar should be grafted onto "brinjal" rootstocks for achieving better production.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

ACKNOWLEGEMENT

We are very thankful to National Agricultural Research Centre, Islamabad-Pakistan, for providing space and labor to carry this project and specially the whole staff of HRI for their kind supervision and providing valuable resources.

AUTHOR CONTRIBUTIONS

Conceived and designed the experiments: IA and IU, Performed the experiments: IU and AB. Analyzed the data: IA, IU, AB & IU. Contributed materials/ analysis/ tools: RUK, MA, IU, SJ, HW,

IHK. Wrote the paper: AB & IU. Reviewed the manuscript: AB. All authors read and approved the final version.

REFERENCES

Aganon C.P., Mateo L.G., Cacho D., Bala D.A. & Aganon T.M. 2002. Enhancing off- season production through grafted tomato technology. Philipp. J. Crop Sci., 27: 3-9.

Aherne. 2009. Grafting raises the salt tolerance of tomato through limiting the transport of sodium and chloride to the shoot. J. Experi. Bot., 56: 703-712.

Alexopoulos A.A., Kondylis A. & Passam H. C. 2007. Fruit yield and quality of watermelon in relation to grafting. J. Food Agric. Envirt., 5(1): 178-179.

Andrews P.K. & Marquez C.S. 1993. Graft incompatibility. Horticultural Reviews. 15:183-232.

Ashita, E. (ed.). 1927, Grafting of watermelons (in Japanese). Korea (Chosun) Agr. Nwsl., 1:9.

Basit A., Shah K., Rahman M.U., Xing L., Zuo X., Han M., Alam N., Khan F., Ahmed I. & Khalid M.A. 2018. Salicylic acid an emerging growth and flower inducing hormone in marigold (*Tagetes sp.* L.). Pure and Appl. Biol. (PAB). 7(4): 1301-1308.

Basit A., Ayaz S., Rab A., Ullah I., Shah S.T., Ahmad I., Ullah I. & Khalid M.A. 2019a. Effect of stevia (*Stevia Rebaudiana* L.) leaf extract on the quality and shelf life of lemon (*Citrus limon* L.). Pure and Appl. Bio. 8(2): 1456-1468.

Basit A., Inayat U., Shah S.T., Ullah I., Alam N. & S.A.Q. Gilani. 2019b. Effect of Media Amendments on Invivo Root and Shoot Organogenesis of Stevia (*Stevia Rebaudiana*). Int. J. Biosci., 14(4): 55-63.

Bolarin A., Perkins-Veazie I. & Hassell P. 2008. The effectiveness of grafting to improve tomato fruit quality. Scientia Horti., 125: 211-217.

Branthome F.B., Sanchez-Bel P., Estan M.T., Martinez-Rodriguez M.M., Moyano E., Morales B., Campos J.F., Garcia-Abellan J.O., Egea M.I., Fernandez-Garcia N., Romojaro F. & Bolarin M.C. 2010. The effectiveness of grafting to improve tomato fruit quality. Scientia Horti., pp: 211-217.

Coggins C.W. & Lesley J.W. 1968. Attempt to improve flower bud retention and development in tomatoes with grafts, nutrition and growth regulators. Hort. Sci., 3: 237-238.

Copes, D.L. & Oliver D.M. 1970. The relationship between graft compatibility and wood specific gravity. J. Forestry., 68: 726.

Cushman. 2008. Grafting raises the salt tolerance of tomato through limiting the transport of sodium and chloride to the shoot. J. Experimental Bot., 56:703-712

Davis A.R. & Veazie P.P. 2008. Grafting Effects on Vegetable Quality. Hort. Sci., 43(6): 1670-1672.

Davis A.R., Perkins-Veazie P., Hassell R.L. & King S.R. 2008. Grafting effects on vegetable quality. Hort. Sci., 43(6): 1670-1672.

Estan M.T., Martinez-Rodriguez M. M., Perez-Alfocea F., Flowers T. J. & M.C. 1982. Use of rootstocks in solanaceous fruit-vegetable production in Japan. 15: 175-179.

FAO. 2013. Production yearbook, Agricultural Statistics Series. FAO, Rome. Vol. 52.

Flores F.B., Sanchez-Bel P., Estan M.T., Martinez-Rodriguez M.M., Moyano E., Morales B., Campos J.F., Garcia-Abellan J.O., Egea M.I., Fernandez-Garcia N., Romojaro F. & Bolarin M.C. 2010. The effectiveness of grafting to improve tomato fruit quality. Sci. Horti. 125: 211-217.

Gioia F.D. & Signore A. 2013. Grafting improves tomato salinity tolerance through sodium partitioning within the shoot. Hort. Sci., 48(7): 855-862.

GOP. 2012. Fruit vegetable and condiment statistics of Pakistan, government of Pakistan, Islamabad.

Hanna H.Y. 2012. Producing a grafted and a non-grafted Tomato plant from the same seedling. Hort Technol., 22(1): 72-76.

Hassell R.L., Memmott F. & Liere D.G. 2008. Grafting methods for watermelon production. Hort Sci. 43: 1677-1679.

Ibrahim M., Munira M.K., Kabir M.S., Islam A.K.M.S. & Miah M.M.U. 2001. Seed

germination and graft compatibility of wild *Solanum* as rootstock of tomato. J. Biol. Sci., 1: 701-703.

Ioannou N., Ioannou M. & Hadjiparaskevas K. 2002. Evaluation of watermelon rootstocks for off-season production in heated greenhouses. Acta Hort. 579: 501-506.

Itagi T. 1992. Status of transplant production systems in Japan and new grafting technics (in Korean). Symp. Protected Hort. Hort. Expt. Sta., Rural Development Admin., Suwon, Republic of Korea. Pp: 32-67.

Ito T. 1992. Present state of transplant production practices in Japanese hortic. Industry., pp. 65-82.

Joe S.R., Davis A. R., Zhang X. & Crosby K. 2010. Genetics, breeding and selection of rootstocks for Solanaceae and Cucurbitaceae. Sci. Hort., 127: 106-111.

Kacjan-Marsic N. & Osvald J. 2004. The influence of grafting on yield of two tomato cultivars (*Lycopersicon esculentum* Mill.) grown in a plastic house. Acta Agric. Slovenica., 83: 243-249.

Kaskawalci N., Bhandari K., Siddique K.H.M. & Nayyar H. 2009. Food crops face rising temperatures: An overview of responses, adaptive mechanisms and approaches to improve heat tolerance. Cogent Food Agric., 2: 113-380.

Kawaguchi M., Taji A., Backhouse, D. & Oda M. 2008. Anatomy and physiology of graft incompatibility in solanaceous plants. J. Hort. Sci. Biotech., 83: 581-588.

Khah E.M., Kakava E., Mavromatis A., Chachalis D. & Goulas C. 2006. Effect of grafting on growth and yield of tomato (*Lycopersicon esculentum* Mill.) in greenhouse and open-field. J. Appl. Hort., 8(1): 3-7.

King S.R., Davis A.R., Zhang X. & Crosby K. 2010. Genetics, breeding and selection of rootstocks for Solanaceae and Cucurbitaceae. Scientia Horti., 127: 106-111.

Kurata K. & Kozai T. (eds.). Trans- plant production system. Kluwer Academic Pub-lishers, Yokohama, Japan.

Lee J.M. & Oda M. 2003. Grafting of herbaceous vegetable and ornamental crops. Horticultural reviews. 11: 61-124.

Lee J.M. & Oda M. 2003. Grafting of herbaceous vegetable and ornamental crops. Hortic. Rev. 28: 61–124.

Lee J.M. 1994. Cultivation of grafted vegetables. I. Current status, grafting methods, and benefits. Hort. Sci., 29: 235-239.

Lee J.M. 2003. Advances in vegetable grafting. Chronic. Hort., 43: 13-19.

Lee J.M., Bang H.J. & Ham H.S. 1998. Grafting of vegetables. J. Japan. Soc. Hort. Sci. 67(6): 1098-1104.

Lee S.G. 2007. Production of high quality vegetable seedling grafts. *Act Hort.* 729: 169-174.

Leoni S., Grudina R., Cadinu M., Madeddu B. & Garletti M.C. 1990. The influence of four rootstocks on some melon hybrids and a cultivar in greenhouse. Acta Hort., 287: 127-134.

Liu H.Y., Zhu Z.J., Lu G.H. & Qian Q.Q. 2003. Study on relationship between physiological changes and chilling tolerance in grafted watermelon seedlings under low temperature stress. Sci. Agri. Sin., 36: 1325-1329.

Louws F., Rivard C.L. & Kubota C. 2010. Grafting fruiting vegetables to manage soilborne pathogens, foliar pathogens, arthropods and weeds. Sci. Hort., 127: 127-146.

Maršić N.K. & Osvald J. 2004. The influence of grafting on yield of two tomato cultivars (*Lycopersicon esculentum* Mill.) grown in a plastic house. Acta. Agric. slovenica., 83(2): 243-249.

Matsuzoe N., Ali M., Okubo H. & Fujieda K. 1994a. Growth behavior of tomato plants grafted on wild relatives of *Solanum melongena*. J. Jpn. Soc. Hort. Sci., 59(2): 358-359.

Matsuzoe N., Nakamura H., Okubo H. & Fujieda K. 1993a. Growth and yield of tomato plants grafted on Solanum rootstocks. J. Jpn. Soc. Hortic. Sci., 61: 847-855.

Moore R. 1984a. A model for graft compatability-incompatability in higher plants. Amer. J. Bot., 71: 752-758.

Moore R. 1984b. The role of direct cellular contact in the formation of compatible autografts in Sedum telephoides. Ann. Bot., 54: 127-133.

Mudge K., Janick J., Scofield S. & Goldschmidt E.E. 2009. A history of grafting. Hort. Rev. 35: 437-495.

Pogonyi A., Pek Z., Helyes L. & Lugasi A. 2005. Effect of grafting on the tomato's yield, quality and main fruit components in spring forcing. Acta Elimentaria., 34: 453-462.

Rivard C.L. & Louws F.J. 2008. Grafting to Manage Soilborne Diseases in Heirloom Tomato Production. Hort. Sci., 43(7): 2104-2111.

Riverio R.M., Ruiz J.M. & Romero L. 2003. Can grafting in tomato plants strengthen

resistance to thermal stress? J. Sci. Food Agric., 83: 1315-1319.

Rivero R.M., Ruiz J.M., Sanchez E. & Romero L. 2003. Does grafting provide tomato plants an advantage against H_2O_2 production under conditions of thermal shock. Physiological Plantarum. 117: 44-50.

Romano D. & Paratore A. 2001. Effects of grafting on tomato and eggplant. *Acta Hort*., 559: 149-153.

Ruiz J.M., Belakbir A., Lo´pez-Cantarero I. & Romero L. 1997. Leaf-macronutrient content and yield in grafted, melon plants. A model to evaluate the influence of rootstock genotype. Scientia Hort. 71: 227-234

Schafer M., Mashayekhi K., Dadkhah A. & Tavallaee F.Z. 1999. Effects of grafting on yield and quality characters of tomato fruit (*Lycopersicum esculentum* Mill.). I.J.A.C.S., 4(16): 1184-1187.

Schwarz D., Rouphael Y., Colla G. & Venema J.H. 2010. Grafting as a tool to improve tolerance of vegetables to abiotic stresses: thermal stress, water stress and organic pollutants. Scientia Horti., 127: 162-171.

Turhan S.F., Huang H.Y., Lin C.H., Tseng M.J. & Chang W.N. 2011. Studies on the graft compatibility of pepper scions grafted onto eggplant rootstocks. Res. Bulletin KDARES., 122: 15-40.

Yasinok K.D.P & West Y.F. 2009. Use of rootstocks in solanaceous fruit-vegetable production in Japan*. J.A.R.Q.* 15: 175-179.

Zhu D.P. & West Y.F. 2003. Grafting increase the salt tolerance of tomato cultivars. Am. J. Infect. Control. 31: 40-42.