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Response of intra and inter specific grafts on plant growth and yield of tomato plants under salinity stress

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Abstract
The experiment was conducted for two consecutive years 2020-21 and 2021-22 in Completely Randomized Design (Factorial concept) consisting thirty treatment combinations with three repetitions. The treatments were comprised of five levels of salinity (0.5, 2.0, 4.0, 6.0, 8.0 DS m^{-1}) and six levels of grafts namely GT-7/GT-7 (Non-graft), GT-7/ArkaVikas, GT-7/Abhinav, GT-7/GNRB-1, GT-7/*SuratiRavaiya* (pink) and GT-7/*Solanumtorvum*. The results showed that increasing salinity levels reduced vegetative growth and yield attributes. Whereas plant height, fruit weight, number of fruits plant^{-1} and fruit yield plant^{-1} when irrigated with 0.5 DS m^{-1} level of salinity. Meanwhile grafting treatments reversed these results as they increased values of all recorded items over non-grafted plants under all salinity levels. Finally, the combination of GT-7 grafted on *Solanum thorium* resulted in best for vegetative growth and yield attributes. The maximum plant height, fruit weight, number of fruits plant^{-1} and fruit yield plant^{-1} was observed in *Solanum thorium*rootstocks

Keywords: Tomato, grafts, salinity, growth, yield

Introduction

Tomato (*Solanum lycopersicum* L.) is a major crop of Solanaceae family originated in Peru with diploid chromosome number (2n=2x=24) and grown in more than 170 countries worldwide under varied agro-climatic conditions. It is one of the most widely cultivated crops in the world and an important cash crop for small as well as medium scale farmers. India occupies an area of 8.13 lakh ha with an annual production of 21.19 million tons in tomato, while it is cultivated in 65.53 thousand ha land with a production of 1876.6 thousand tons in Gujarat (Anon., 2020) [4]. The pressure exerted on the agricultural production chains due to the continuous increase in world population will require an increase of 70% in crop production by 2050 (Anon., 2009). Ever increasing demand for good quality land and water resources in the domestic and industrial sectors has already generated enhanced interest in the utilization of salt affected soils (Mann *et al.*, 2020) [28]. Salinity stress is one of the major environmental threats to crop production (Chang *et al.*, 2014) [6]. Salinity affected area is increasing day by day and spreading all over the world. It is estimated that more than 800 million hectare of land are affected with salinity globally and this figure may increase in the coming years (Anon., 2009). In India, the area under salt affected soils is about 6.73 million ha with states of Gujarat (2.23M ha), Uttar Pradesh (1.37M ha), Maharashtra (0.61M ha), West Bengal (0.44M ha) and Rajasthan (0.38M ha) together accounting for almost 75% of saline and sodic soils in the country (Singh, 2018) [43] and the area is likely to increase up to 16.2 million ha by 2050.

Salinity affects plants in two main ways, high concentrations of salts in the soil disturb the capacity of roots to extract water and secondly high concentrations of salts within the plant itself can be toxic resulting in the inhibition of many physiological and biochemical processes such as nutrient uptake and assimilation (Munns *et al.*, 1995 [33]; Hasegawa *et al.*, 2000 [19]; Munns, 2002 [31] as well as Munns and Tester, 2008) [32]. Salinity represents a substantive threat to tomato production (Keatinge *et al.*, 2014) [24]. Most of the commercial cultivars of tomato are considered to be moderately sensitive to salt stress, which affects seed germination, vegetative and reproductive stages of growth (Estan *et al.*, 2009 [14]; Sholi, 2012 [42] and Lim *et al.*, 2016) [27] with the increase in salinity levels in tomato (Jamil *et al.*, 2006) [23] causing considerable reduction in yield (Foolad, 2004) [17] and quality (Zhang *et al.*, 2017). The commercial cultivars of tomato undergo drastic losses due to salts (Jaafar *et al.*, 2018) [22]. Mechanism of salt tolerance may involve osmotic adjustment, maintenance of pressure potential, production of organic solutes and balance between ion accumulations (Shahid *et al.*, 2012) [41].

Numerous breeding and biotechnological attempts have been made to improve the salt tolerance in vegetable crops but grafting has emerged as an alternative with substantial response to alleviate salinity plants (Colla, *et al*., 2010 [11]; Colla *et al*., 2013 [10] and Albacete *et al*., 2015) [1]. Grafting in vegetable has emerged as a promising surgical alternative over relatively slow conventional breeding methods aimed at increasing tolerance to biotic and abiotic stresses (Kumar *et al*., 2018) [25]. Grafting is an environmentally friendly, sustainable and effective method that enables the exploitation of the benefit of resistant genotypes as rootstocks to improve the performance of commercial cultivars (as scion) susceptible to various abiotic stresses. Grafting onto resistant/tolerant rootstocks is known to alleviate the negative effects of abiotic stress factors like salinity by enhancing their enzymatic antioxidant defense system and nutrient use efficiency (Fernandez-Garcia *et al*., 2002 [16] and Santa-Cruz *et al*., 2002) [38]. Therefore, grafting tomato onto resistant/tolerance rootstocks helps to mitigate the harmful effects of salinity through certain adaptive strategies such as salt exclusion or retention, osmotic adjustment, activation of antioxidant defense system, nutrient homeostasis and plant hormonal balances genes expressions led to favorable responses *etc*. The rootstock's root systems architecture specified by root length and density, root hairs and root surface area plays a critical role in ion and water uptake, thus determining salt tolerance of grafted plants (He *et al*., 2009 [20] and Colla *et al*., 2010) [10]. The positive effects of grafting on salt tolerance in a tomato is widely attributed to the restricted the entry of Na^+ and Cl^-ions in epigeous biomass (Lee, 1994 [26] and Fernandez-Garcia *et al*., 2004) [15] and accumulation of more nutrient elements like Ca^{2+} and K^+ in the leaves of grafted plants than the normal ones under saline stress (Al-Harbi *et al*., 2017) [2].

Materials and Methods

The present investigation entitled "Response of Intra and inter specific grafts to salinity stress in tomato (*Solanum lycopersicum* L.)" was carried out at Vegetable Research Farm, Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari during summer and late *Kharif* season of 2020-21 and 2021-22, respectively. The experiment was laid out in Completely Randomized Design (Factorial concept) consisting thirty treatment combinations with three repetitions. The treatments were comprised of five levels of salinity *viz.*, S_1: 0.5 DS m^{-1} (Normal), S_2: 2.0 DS m^{-1}, S_3: DS m^{-1}, S_4: 6.0 DS m^{-1}, S_5: 8.0 DS m^{-1} and six levels of grafts namely G_1: GT-7/GT-7 (Non-graft), G_2: GT-7/ArkaVikas, G_3: GT-7/Abhinav, G_4: GT-7/GNRB-1, G_5: GT-7/*SuratiRavaiya*(pink) and G_6: GT-7/*Solanum thorium*. The present investigation was carried out on Gujarat Tomato 7 (GT-7) variety of tomato and GNRB-1, *SuratiRavaiya* (Pink) and *Solanum thorium* cultivar of brinjal were obtained from Regional Horticultural Research Station, NAU, Navsari and ArkaVikas were procured from Indian Institute of Horticultural Research, Bengaluru.

The experiment was executed in grow bags of 18 x 18.The grow bags were filled with the media [soil: leaf mound: bio compost: 2:1:1 (v/v)] and seedlings were transplanted in bags.Soil (soil physico-chemical properties namely bulk density (g cm^{-1}), field capacity (%), soil pH and electrical conductivity (DS m^{-1}) were analysed prior to filling of grow bag. Gujarat Tomato 7 cultivar, which was used as scion sown on raised bed in NVPH (Naturally Ventilated Polyhouse). Similarly, tomato cultivars namely, ArkaVikas, Abhinav; and brinjal varieties, GNRB-1, *SuratiRavaiya* (Pink) and *Solanum thorium* were sown in plug trays having 98 plugs in a tray. Nutrients as well as water was applied in all plants as and when needed. Grafting was performed using the cleft grafting method. Grafts were transplanted in the grow bags on 9th of February during first season (2020-21) and 13th of October during second season (2021-22). Salinity treatment was imposed after the successful establishment of grafted seedlings in the grow bags as per treatment. The salinity levels of irrigation water were created by diluting sea water and irrigation water (IW) was applied in order to maintain the field capacity of soil.

Results and Discussion

Effects of salinity on growth and yield parameters of tomato

The data depicted in Table.1and 2 revealed significant effect of salinity on plant height, fruit weight, fruit yield plant^{-1} and number of fruits plant^{-1} except leaf area during pooled analysis. Among the different levels of salinity, S_1 (0.5 DS m^{-1}) recorded maximum plant height (117.59cm) at final harvest respectively during pooled analysis. The decline in the vegetative growth observed with increase in salinity levels. This might be due to the soluble salt in saline soils increased the solute suction of the water from plants, by their decreased absorption of nutrients, therefore, plants suffered a deficiency of water even when growth under moist but saline irrigation water. This also reduces availability of soluble essential nutrients for plant growth. The present investigation is in agreement with the findings of Oztekin and Tuzel (2011) [35], Chen and Noriega (2016) [7], Al-Harbi *et al.* (2017) [2], Habibi *et al.* (2021) [18] in tomato; Zhu *et al*. (2008) [47], Huang *et al*. (2009a) [21] in cucumber. The results also showed that S_1 (0.5 DS m^{-1}) level of salinity recorded maximum fruit weight (56.77g), fruit yield plant^{-1} (1885.85g) and number of fruits plant^{-1} (33.49) on pooled analysis. This might be due to plants were able to enhanced translocation of ions from root to foliage and finally to the fruits. Thus, it would have helped in maintaining and increasing photosynthetic activity of plant which was indirectly affects yield attributes. Analogous results were reported by Savvas *et al.* (2011) [40], Voutsela *et al*. (2012) [44], Di Gio *et al.* (2013) [13], Coban *et al*. (2020) [8] and Sanwal *et al.* (2022) [39] in tomato; Penella *et al*. (2017) [36] in pepper; Colla *et al*. (2006a) [9] in muskmelon; Colla *et al*. (2012) [12] and Colla *et al*. (2013) [10] in cucumber.

Effects of grafts on growth and yield parameters of tomato: The data presented in Table 1 and 2 revealed that the different graft combinations significantly influenced on plant height, fruit weight, fruit yield plant^{-1} and number of fruits plant^{-1} except leaf area during pooled analysis. Among them G_6 graft (GT-7/*Solanumthorium*) displayed maximum plant height (122.37cm) at final harvest except leaf area during pooled findings.

Table 1: Effect of salinity and grafting on plant height (cm) and leaf area (cm^2) at final harvest of tomato

Treatments	Plant height (cm)			Leaf area (cm^2)		
	At final harvest					
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Salinity (S)						
S_1	108.96	126.23	117.59	463.68	476.65	470.16
S_2	107.54	125.02	116.28	462.34	473.77	468.05
S_3	106.65	124.27	115.46	461.53	472.02	466.77
S_4	105.36	123.59	114.47	456.34	468.99	462.66
S_5	101.74	117.09	109.41	449.57	467.13	458.35
SEm ±	2.56	3.31	1.88	13.05	10.79	8.47
CD at 5%	NS	NS	5.27	NS	NS	NS
Grafts (G)						
G_1	95.13	116.43	105.78	446.45	456.87	451.66
G_2	101.71	125.83	113.77	458.64	477.19	467.92
G_3	102.93	119.52	111.23	453.01	470.24	461.63
G_4	114.72	127.37	121.05	470.51	484.42	477.47
G_5	105.33	122.01	113.67	449.97	462.95	456.46
G_6	116.47	128.28	122.37	473.55	478.59	476.07
SEm ±	2.81	3.62	2.06	14.30	11.82	9.28
CD at 5%	7.94	NS	5.27	NS	NS	NS
Interaction (S×G)						
SEm ±	27.40	22.80	3.10	31.98	26.44	1.86
CD at 5%	NS	NS	NS	NS	NS	NS
CV (%)	11.12	9.44	10.3	12.07	9.71	10.92
Pooled Interaction						
Source	Y×S	Y×G	Y×S×G	Y×S	Y×G	Y×S×G
SEm ±	10.07	11.03	24.66	11.98	13.12	29.34
CD at 5%	NS	NS	NS	NS	NS	NS

Those results are consistent with the findings of Petran and Hoover (2014) [37], Chen and Noriega (2016) [7] as well as Nimbalkar (2021) [34] in tomato. This increase in plant height might be due to rootstock confer to grafted plants a stronger and vigorous root system which supply plant nutrients to the scion which contributing for more photosynthesis, which positively affected plant growth. The results demonstrated that grafting is a valid strategy for improving the salt tolerance of tomato. The results of current study are parallel to the findings of Balliu *et al.* (2008) [5], Oztekin and Tuzel (2011) [35], Wahb Allah (2014) [45], Al-Harbi *et al.* (2017) [2], Nimbalkar (2021) [34] and Sanwal *et al.* (2022) [39] in tomato.

Table 2: Effect of salinity and grafting on fruit weight (g), number of fruits plant^{-1} and fruit yield plant^{-1} (g) of tomato

Treatments	Fruit weight (g)			Number of fruitsplant^{-1}			Fruit yield plant^{-1} (g)		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Salinity (S)									
S_1	54.22	59.32	56.77	32.76	34.21	33.49	1769.42	2002.28	1885.85
S_2	53.03	58.59	55.81	32.19	33.79	32.99	1701.07	1978.29	1839.68
S_3	51.66	57.90	54.78	31.51	33.51	32.51	1629.31	1956.60	1792.96
S_4	50.39	57.35	53.87	30.56	32.44	31.50	1533.84	1838.36	1686.10
S_5	48.92	53.31	51.11	29.58	31.06	30.32	1452.35	1685.68	1569.01
SEm±	0.46	0.47	0.33	0.81	0.80	0.57	10.06	9.65	21.10
CD at 5%	1.29	1.33	0.92	NS	NS	1.60	28.46	27.31	62.84
Grafts (G)									
G_1	50.57	56.63	53.60	30.82	32.54	31.68	1580.36	1846.07	1713.22
G_2	52.05	57.09	54.57	31.47	33.07	32.27	1626.94	1899.96	1763.45
G_3	51.47	56.95	54.21	31.25	33.00	32.13	1609.50	1874.71	1742.11
G_4	52.29	57.49	54.89	31.58	33.21	32.40	1636.86	1920.82	1778.84
G_5	50.89	56.73	53.81	31.08	32.82	31.95	1596.36	1872.88	1734.62
G_6	52.58	58.88	55.73	31.70	33.37	32.53	1653.17	1939.00	1796.08
SEm±	0.50	0.51	0.36	0.89	0.88	0.63	11.02	10.58	7.64
CD at 5%	1.42	1.45	0.92	NS	NS	NS	31.18	29.91	29.09
Interaction (S×G)									
SEm±	1.12	1.15	0.51	0.81	1.97	0.20	24.65	23.65	32.89
CD at 5%	NS	NS	NS	NS	NS	NS	69.72	66.89	95.09
CV (%)	3.75	3.47	3.61	11.00	10.31	10.65	2.64	2.16	2.38
Pooled Interaction									
Source	Y×S	Y×G	Y×S×G	Y×S	Y×G	Y×S×G	Y×S	Y×G	Y×S×G
SEm±	0.46	0.51	1.13	0.81	0.88	1.98	9.86	10.80	24.15
CD at 5%	NS	NS	NS	NS	NS	NS	27.61	NS	NS

Yanyan *et al*. (2018) [46] in watermelon as well as Zhu *et al*. (2008) [47] in cucumber. The present studies also revealed that GT-7 grafted onto *Solanum thorium* observed maximum fruit weight (55.73g) and fruit yield plant^{-1} (1796.08g) except number of fruits plant^{-1} on pooled analysis basis. The higher fruit yield may be due to effect of grafting directly on plant yield by interactions of the following processes: increase of water and nutrient uptake resulting from the varietal characters, vigorous root system of the rootstock, compatibility of rootstocks, enhanced production of endogenous hormones. Enhancement of scion vigor probably due to the use of vigorous rootstocks which led to improvement of cytokinins and gibberellins content in scion which ultimately increased the fruit load on plant. The joint action of some or all of these processes could explain the higher fruit yield and fruit yield attributes in tomato from grafted plants observed in the current study. The results are in close affinity with the findings of Santa-Cruz *et al.* (2002) [38], Estan *et al.* (2005), Martorana *et al.* (2007) [30], Martinez *et al.* (2008) [29], Albacete *et al.* (2009), Savvas*et al.* (2011) [40], Voutsela *et al*. (2012) [44], Coban *et al*. (2020) [8], in tomato; Penella *et al*. (2017) [36] in pepper; Colla *et al*. (2006a) [9] in muskmelon; Huang *et al*. (2009a) [21], Colla *et al*. (2012) [12] and Colla *et al*. (2013) [10] in cucumber.

Interaction effect of salinity and grafts on growth and yield parameters of tomato: The interaction between different levels of salinity and graft combinations had significant influence on fruit yield plant^{-1}. However, the study revealed maximum fruit yield plant^{-1} (1919.30g) in S_1G_6 combination (0.5 DS m^{-1} with GT-7/*Solanum thorium*) on pooled analysis basis.

All the parameters of growth and yield parameters namely, fruit weight and number of fruits plant^{-1} were found to be non-significant under interaction effect of salinity and grafts (Table 1and 2).

Conclusions

Our study was concerted to the treatment combination 0.5 dSm^{-1} level of salinity with GT-7/*Solanum thorium* was found superior in terms of plant height and yield per plant. From the results of two years study, it can be concluded that lower level of salinity S_1 (0.5 DS m^{-1}) had superior growth parameter (plant height at final harvest) and yield parameters (fruit weight, number of fruits plant^{-1} and fruit yield plant^{-1}). The positive effect of GT-7 grafted onto *Solanum thorium* could invigorate tomato for better performance in terms of all the growth, yield parameters.

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