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Influence of intraspecific and interspecific grafting on phenology, harvesting behaviour and fruit quality of tomato under salinity stress

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Abstract

An experiment was conducted during 2020-21 and 2021-22 at the Vegetable Research Farm, RHRS, Navsari Agricultural University, Navsari, Gujarat, to evaluate the effects of intraspecific and interspecific grafting on phenological, harvesting and fruit-quality traits of tomato under five salinity levels (0.5, 2.0, 4.0, 6.0 and 8.0 dS m⁻¹). Six graft combinations were tested: GT-7 (non-grafted), GT-7/Arka Vikas, GT-7/Abhinav, GT-7/GNRB-1, GT-7/Surati Ravaiya and GT-7/*Solanum torvum*. Salinity had no significant effect on days to 50% flowering, first picking and last picking. However, increasing salinity significantly reduced the number of pickings and lycopene content, while increasing titratable acidity. The maximum pooled number of pickings (13.65) and lycopene content (4.19 mg 100 g⁻¹) were recorded at 0.5 dS m⁻¹. Among graft combinations, GT-7/*S. torvum* recorded the numerically highest pooled values for number of pickings (14.44), TSS (5.27 °Brix), ascorbic acid (14.11 mg 100 g⁻¹), lycopene (4.20 mg 100 g⁻¹) and titratable acidity (0.28%). Interaction effects were non-significant, indicating consistent graft performance across salinity levels. GT-7 grafted onto *S. torvum* improved harvesting duration and fruit quality under saline conditions.

Keywords: Tomato, grafting, rootstock, salinity, fruit quality, *Solanum torvum*

1. Introduction

Tomato (*Solanum lycopersicum* L.) is an important vegetable crop valued for its nutritional, economic and antioxidant properties. Tomato fruits are rich in lycopene, ascorbic acid, carotenoids and soluble solids, which contribute to their nutritional and commercial quality (Palop *et al.*, 2010) [15]. However, salinity is a major constraint to tomato production, particularly in areas where saline soil and irrigation water limit crop productivity. Salt stress causes osmotic and ionic imbalance, restricts water and nutrient uptake, and adversely affects physiological processes and crop performance (Munns and Tester, 2008) [13].

Grafting is an effective approach for improving the tolerance of vegetable crops to abiotic stresses. The use of suitable rootstocks can enhance root vigour, improve water and nutrient uptake and regulate the accumulation of toxic ions under saline conditions (Colla *et al.*, 2010; Albacete *et al.*, 2015; Kumar *et al.*, 2018) [5, 1, 11]. In tomato, both intraspecific and interspecific rootstocks have shown potential for improving plant performance under salinity. In particular, *Solanum torvum* has been reported as a vigorous rootstock capable of improving tomato performance under stressful conditions (Di Gioia *et al.*, 2013; Giuffrida *et al.*, 2014) [17, 10].

Although several studies have examined the response of grafted tomato to salinity, comparative information on the performance of intraspecific and interspecific rootstocks across a graded salinity regime, particularly with respect to harvesting behaviour and fruit-quality attributes, remains limited. Moreover, rootstock performance can vary with scion genotype, salinity level and growing conditions. Therefore, identifying rootstock-scion combinations that maintain fruit quality and harvesting performance under increasing salinity is important for sustainable tomato production in salt-affected areas.

Hence, the present study was undertaken to evaluate the influence of intraspecific and interspecific grafting of tomato scion GT-7 on reproductive phenology, harvesting behaviour and fruit quality attributes under five levels of salinity. The study specifically assessed days to flowering, picking behaviour, total soluble solids, titratable acidity, ascorbic acid and

lycopene content to identify promising graft combinations for tomato production under saline conditions.

2. Materials and Methods

2.1 Experimental Site and Plant Material

The investigation was conducted at the Vegetable Research Farm, Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat, India, during two consecutive cropping cycles: Summer/Late *Kharif* 2020-21 and 2021-22. The experiment was conducted in a factorial completely randomized design (CRD) consisting thirty treatment combinations with three repetitions. The treatments comprised five levels of salinity, viz., S₁: 0.5 dS m⁻¹ (Normal), S₂: 2.0 dS m⁻¹, S₃: 4.0 dS m⁻¹, S₄: 6.0 dS m⁻¹, S₅: 8.0 dS m⁻¹ and six graft combinations namely G₁: GT-7/GT-7 (Non-graft), G₂: GT-7/Arka Vikas, G₃: GT-7/Abhinav, G₄: GT-7/GNRB-1, G₅: GT-7/Surati Ravaiya (pink) and G₆: GT-7/*Solanum torvum*. The experiment was conducted using grow bags filled with soil, leaf mould and bio-compost in a 2:1:1 (v/v) ratio. Salinity was imposed through irrigation water after establishment of the grafted seedlings and irrigation was managed to maintain the required soil moisture condition. The grafted seedlings were prepared using the cleft grafting method.

2.2 Observations Recorded

Phenological and harvesting traits included days to 50% flowering, days to first picking, days to last picking and total number of pickings. Fruit quality attributes were evaluated at the final picking and included:

- **Total soluble solids (TSS):** TSS was determined using a digital hand refractometer and expressed as °Brix.
- **Ascorbic acid content:** Ascorbic acid content was estimated by the 2,6-dichlorophenol indophenol dye titration method described by Ranganna (1999) [17] and expressed as mg 100 g⁻¹ fresh weight.
- **Lycopene content:** Lycopene content was estimated spectrophotometrically following the method of Nagata and Yamashita (1992) [14] and expressed as mg 100 g⁻¹ fresh weight.
- **Titrate acidity:** Titrate acidity was determined

by titration of fruit juice against 0.1 N NaOH, using phenolphthalein as an indicator and expressed as percentage citric acid equivalent.

2.3 Statistical Analysis

Data from individual years were subjected to analysis of variance (ANOVA). The standard error of the mean [SE(m)] and critical difference (CD) at P = 0.05 were calculated. Homogeneity of error variances was tested before conducting pooled analysis of the data across the two experimental seasons.

3. Results and Discussion

3.1 Reproductive Phenology and Harvesting Duration

Salinity levels (S) and graft combinations (G) did not significantly affect days to 50% flowering, days to first picking and days to last picking during either individual year or the pooled analysis (P > 0.05; Table 1 and Table 2). Across all treatments, days to 50% flowering ranged from 30.27 days at G₆ to 33.80 days at G₁ in pooled analysis, while days to first picking ranged from 71.32 days at G₆ to 75.28 days at G₁.

However, the total number of pickings was significantly influenced by both salinity levels and graft combinations (Table 2). Increased salinity led to a progressive reduction in picking numbers. The control treatment (S₁: 0.5 dS m⁻¹) recorded the maximum pooled number of pickings (13.65), which was significantly higher than those recorded under S₄ (12.73) and S₅ (12.10), but did not differ significantly from S₂ and S₃. The reduction in harvest count under elevated salinity (S₅) stems from salt-induced osmotic stress, inhibited water and nutrient uptake, lower net photosynthetic capacity and premature crop senescence (Mitchell *et al.*, 1991) [12].

Among graft combinations, inter-specific graft G₆ (GT-7/*S. torvum*) recorded the highest number of pickings in both individual years (13.25 in 2020-21; 15.63 in 2021-22) and in the pooled analysis (14.44), significantly outperforming the non-grafted control G₁ (11.52). The robust root structure of *S. torvum* maintains water transport and mineral supply under stress conditions, delaying plant decline and extending the cropping period (Di Gioia *et al.*, 2013) [7].

Table 1: Effect of salinity and grafting on days to 50% flowering and days to first picking of tomato

Treatments	Days to 50% flowering			Days to first picking		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Salinity (S)						
S ₁	25.78	36.44	31.11	59.95	85.26	72.61
S ₂	25.72	36.94	31.33	60.56	85.29	72.93
S ₃	26.28	37.22	31.75	60.80	86.20	73.50
S ₄	26.78	37.56	32.17	60.82	86.75	73.79
S ₅	28.94	38.06	33.50	61.47	88.18	74.82
SEm ±	0.86	1.24	0.76	1.13	1.54	0.96
CD at 5%	NS	NS	NS	NS	NS	NS
Grafts (G)						
G ₁	28.60	39.00	33.80	62.15	88.41	75.28
G ₂	26.40	37.07	31.73	60.49	86.29	73.39
G ₃	26.87	37.20	32.03	61.45	86.40	73.93
G ₄	25.60	36.67	31.13	59.37	84.94	72.16
G ₅	28.00	37.73	32.87	62.11	88.10	75.10
G ₆	24.73	35.80	30.27	58.74	83.89	71.32
SEm ±	0.95	1.36	0.83	1.24	1.69	1.05
CD at 5%	NS	NS	NS	NS	NS	NS
Interaction (S×G)						
SEm ±	2.11	3.04	0.41	2.78	3.78	0.72
CD at 5%	NS	NS	NS	NS	NS	NS
CV (%)	13.70	14.13	14.18	7.92	7.58	7.81

Table 2: Effect of salinity and grafting on number of pickings and days to last picking of tomato

Treatments	Number of pickings			Days to last picking		
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Salinity (S)						
S ₁	12.70	14.61	13.65	132.00	148.58	140.29
S ₂	12.43	14.56	13.49	128.28	147.99	138.13
S ₃	12.16	14.24	13.20	126.06	147.45	136.75
S ₄	11.89	13.57	12.73	124.46	146.13	135.29
S ₅	11.52	12.68	12.10	123.47	145.79	134.63
SEm ±	0.45	0.51	0.34	2.43	2.86	1.88
CD at 5%	NS	NS	0.95	NS	NS	NS
Grafts (G)						
G ₁	11.00	12.05	11.52	123.29	142.60	132.95
G ₂	12.34	14.45	13.40	126.52	147.98	137.25
G ₃	11.71	14.06	12.89	126.40	146.14	136.27
G ₄	13.11	14.06	13.58	127.99	150.25	139.12
G ₅	11.43	13.34	12.39	125.50	144.16	134.83
G ₆	13.25	15.63	14.44	131.43	151.99	141.71
SEm ±	0.49	0.56	0.37	2.66	3.14	2.06
CD at 5%	1.39	1.59	0.95	NS	NS	NS
Interaction (S×G)						
SEm ±	1.10	1.26	0.46	5.95	7.01	0.90
CD at 5%	NS	NS	NS	NS	NS	NS
CV (%)	15.66	15.64	15.69	8.12	8.25	8.22

3.2 Fruit Quality Traits

Total Soluble Solids (TSS) and Titratable Acidity

Total soluble solids showed a numerical increasing trend with increasing salinity; however, the differences among salinity levels were non-significant in the pooled analysis (Table 3 and Table 4). The maximum pooled TSS (5.14 °Brix) was recorded under S₅ (8.0 dS m⁻¹). Titratable acidity increased significantly with increasing salinity, with the highest pooled value (0.26%) recorded under S₅ (8.0 dS m⁻¹). Salinity reduces water inflow into developing fruits relative to carbohydrate transport, concentrating soluble sugars, organic acids and sodium/chloride ions within the

mesocarp tissues (Parmar, 2007; Balliu *et al.*, 2008; Di Gioia *et al.*, 2013; Zaki *et al.*, 2015) [16, 3, 7].

Graft combinations significantly influenced TSS and titratable acidity across both years and pooled data. Among graft combinations, G₆ (GT-7/S. *torvum*) recorded the highest pooled TSS (5.27 °Brix) and titratable acidity (0.28%), followed by G₄ and G₂ for TSS, while the non-grafted (G₁) produced the lowest TSS (4.31 °Brix) and titratable acidity (0.19%). Enhanced leaf photosynthetic activity and sugar loading driven by vigorous rootstocks account for elevated fruit TSS in grafted plants (Colla *et al.*, 2006, 2013; Zaki *et al.*, 2015) [4, 20].

Table 3: Effect of salinity and grafting on total soluble solids (°Brix) and titratable acidity (%) of tomato at final picking

Treatments	Total soluble solids (°Brix)			Titrable acidity (%)		
	Final picking					
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Salinity (S)						
S ₁	4.72	4.52	4.62	0.20	0.21	0.21
S ₂	4.77	4.61	4.69	0.22	0.23	0.23
S ₃	4.81	4.67	4.74	0.22	0.25	0.23
S ₄	4.87	5.01	4.94	0.24	0.27	0.25
S ₅	4.91	5.37	5.14	0.26	0.27	0.26
SEm ±	0.05	0.07	0.14	0.008	0.008	0.006
CD at 5%	0.13	0.20	NS	0.021	0.023	0.015
Grafts (G)						
G ₁	4.45	4.17	4.31	0.18	0.20	0.19
G ₂	5.00	4.97	4.99	0.23	0.26	0.25
G ₃	4.69	4.76	4.72	0.22	0.24	0.23
G ₄	5.03	5.15	5.09	0.25	0.26	0.26
G ₅	4.65	4.52	4.59	0.21	0.23	0.22
G ₆	5.09	5.44	5.27	0.27	0.28	0.28
SEm ±	0.05	0.08	0.11	0.008	0.009	0.006
CD at 5%	0.15	0.22	0.31	0.023	0.025	0.015
Interaction (S×G)						
SEm ±	0.11	0.17	0.08	0.018	0.020	0.006
CD at 5%	NS	NS	NS	NS	NS	NS
CV (%)	4.11	6.18	5.25	13.91	13.96	13.95

Ascorbic Acid and Lycopene Content

Ascorbic acid content exhibited a declining trend with

increased salinity (ranging from 13.60 mg 100 g⁻¹ at S₁ to 12.84 mg 100 g⁻¹ at S₅ in pooled analysis), though

differences among salinity regimes were statistically non-significant ($P > 0.05$; Table 3). Accumulation of Cl^- under high salinity interferes with organic acid metabolic pathways, lowering vitamin C levels (Cucci *et al.*, 2000; Amor *et al.*, 2001; Serio *et al.*, 2004) [6, 2, 19]. In contrast, rootstock choices showed significant differences ($p < 0.05$): graft G_6 retained the highest ascorbic acid content ($14.11 \text{ mg } 100 \text{ g}^{-1}$ pooled), outperforming G_1 ($12.20 \text{ mg } 100 \text{ g}^{-1}$). The higher ascorbic acid content observed in grafted plants may be associated with improved plant physiological status under salinity, as reported previously for salt-tolerant rootstocks (Flores *et al.*, 2010; Savvas *et al.*, 2011) [9, 18].

Salinity significantly lowered fruit lycopene content at final picking (Table 4). The highest pooled lycopene content was recorded under S_1 ($4.19 \text{ mg } 100 \text{ g}^{-1}$), whereas S_5 reduced it to $3.84 \text{ mg } 100 \text{ g}^{-1}$. High salt concentrations impair chromoplast differentiation and carotenoid enzymatic pathways (Fernandez-Garcia *et al.*, 2004) [8]. Among graft combinations, G_6 ($4.20 \text{ mg } 100 \text{ g}^{-1}$) and G_4 ($4.19 \text{ mg } 100 \text{ g}^{-1}$) recorded the highest pooled lycopene contents and were significantly higher than the non-grafted control G_1 ($3.61 \text{ mg } 100 \text{ g}^{-1}$). Improved nutrient uptake and higher photosynthetically active radiation utilization efficiency in vigorous rootstocks support carotenoid biosynthesis under abiotic stress (Fernandez-Garcia *et al.*, 2004) [8].

Table 4: Effect of salinity and grafting on ascorbic acid ($\text{mg } 100 \text{ g}^{-1}$) and lycopene contents ($\text{mg } 100 \text{ g}^{-1}$) of tomato at final picking

Treatments	Ascorbic acid content (mg 100 g ⁻¹)			Lycopene content (mg 100 g ⁻¹)		
	Final picking					
	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
Salinity (S)						
S ₁	12.52	14.67	13.60	4.18	4.19	4.19
S ₂	12.35	14.53	13.44	4.07	4.14	4.10
S ₃	12.13	14.24	13.19	3.99	4.07	4.03
S ₄	12.07	14.10	13.09	3.84	4.02	3.93
S ₅	11.90	13.78	12.84	3.72	3.96	3.84
SEm ±	0.36	0.37	0.26	0.12	0.07	0.07
CD at 5%	NS	NS	NS	NS	NS	0.19
Grafts (G)						
G ₁	11.12	13.28	12.20	3.47	3.75	3.61
G ₂	12.56	14.42	13.49	4.11	4.17	4.14
G ₃	11.77	14.26	13.01	3.96	4.08	4.02
G ₄	12.87	14.73	13.80	4.14	4.22	4.19
G ₅	11.67	13.87	12.77	3.92	4.01	3.96
G ₆	13.18	15.03	14.11	4.16	4.26	4.20
SEm ±	0.39	0.41	0.28	0.13	0.07	0.07
CD at 5%	1.11	1.15	0.72	0.36	0.20	0.19
Interaction (S×G)						
SEm ±	0.88	0.91	0.16	0.28	0.16	0.10
CD at 5%	NS	NS	NS	NS	NS	NS
CV (%)	12.48	11.04	11.70	12.36	6.77	9.89

Conclusion

Increasing salinity significantly reduced the number of pickings and lycopene content, whereas titratable acidity increased with increasing salinity. Grafting significantly influenced harvesting performance and several fruit-quality attributes compared with the non-grafted control. Among the graft combinations, GT-7/Solanum torvum recorded the highest pooled values for number of pickings, TSS, ascorbic acid, lycopene and titratable acidity. Although the salinity $\times$ graft interaction was non-significant, the superior overall performance of GT-7/S. torvum across the tested salinity

levels suggests its potential as a suitable rootstock for maintaining tomato harvesting performance and fruit quality under saline conditions.

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