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Grafted tomato (*Solanum lycopersicum*) varieties on wild brinjal (*Solanum melongena*) rootstocks for growth, yield, fruit quality and economics

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ABSTRACT

Grafting is a horticultural technique that involves joining tissues from one plant (scion) with another (rootstock) to create a new plant. Grafting allows the combination of desirable traits from different plants. Therefore, the present study was conducted during the rainy (*kharif*) season of 2022–23 and 2023–24 at Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh to investigate the effects of tomato grafting on wild brinjal rootstocks on tomato yield, quality, and economics of tomato production. The experimental design employed was a randomized block design (RBD). Treatment T_1 (*S. torvum* + Kashi Anupam) performed best for maximum percentage of grafting success (73.83%). The growth parameters recorded include plant height, which measured 39.97 cm at 30 days after transplanting (DAT) and 79.05 cm at 60 DAT, and the number of branches/plant, which averaged 16.80. The minimum number of days to first flowering was observed in treatment T_2 (*Solanum torvum* + Kashi Sharad), with an average of 58.16 days. Yield parameters revealed an average fruit weight of 76.13 g and a yield of 70.40 t/ha. Nutritional quality analysis showed a Vitamin C content of 21.54 mg/100 g and a lycopene content of 11.57 mg/100 g. The economic evaluation resulted in a benefit-cost (B:C) ratio of 3.85, indicating high profitability.

Keywords: B:C ratio, Branches, Grafting, Lycopene, Plant, Technique

Tomato (*Solanum lycopersicum* L.) is the major vegetable crop, grown in many parts of the world and has high economic importance in many countries. It belongs to family solanaceae with chromosome number of 2n = 24. It is a good source of carotenoids, vitamin C and pro-vitamin A with a good antioxidant potential including lycopene, ascorbic acid, phenolics, flavonoids and vitamin E (Sen *et al.* 2018). It is considered as protective food (Waheed *et al.* 2020). In India, tomato is grown in 46.72 thousand-ha area with a production of 34.29 million tonnes (2020–21). In terms of area and tomato production in 2020–21, Andhra Pradesh leads, followed by Madhya Pradesh and Karnataka. Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, Madhya Pradesh, and West Bengal are the main tomato-producing states. Grafting increases yield and improves fruit quality while promoting plant growth and resistance to biotic stresses (King *et al.* 2010). Grafting onto vigorous rootstocks improves root development, leading to increased absorption of nutrients like nitrogen, phosphorus, potassium, and trace elements. Rootstocks are often selected for their ability to tolerate poor soil conditions, salinity, or *p*H extremes, ensuring consistent nutrient availability for the scion. Grafted plants efficiently allocate absorbed nutrients to the fruits, increasing their size, flavour, and nutritional content. Grafting reduces abiotic stresses which often impair fruit development and quality. Improved xylem conductivity in grafted plants ensures efficient water transport to the shoots. They will also prolong harvest time and shelf life (Yasin and Hussen 2015, Bahadur *et al.* 2015). There is limited information regarding plant growth parameters, yield and fruit quality of tomato when grafted on wild eggplant rootstock (Black *et al.* 2003). Therefore, it is important to check the response of tomato grafted on wild brinjal (*Solanum torvum)* rootstock for growth and yield. The species of brinjal (eggplant) commonly used as rootstock for tomato grafting include the following: *Solanum torvum, Solanum icanum, Solanum xanthocarpum, Solanum indicum, Solanum sisymbrifolium, Solanum integrifolium, Solanum aethiopicum* etc. Hence, this experiment was conducted

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with an objective to study the effect of tomato grafting on wild rootstock of brinjal.

MATERIALS AND METHODS

The present study was carried out at Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj, Uttar Pradesh during *kharif* season of 2022–23 and 2022–24 subsequently for 2 year completed. The experiment was laid out in a randomized block design (RBD) with 15 treatments and 3 replications. The seeds of both rootstocks as well as scion were sown in portrays containing sterilized coco peat to avoid the problem of uneven germination. The seeds of rootstock were sown 4 weeks before the scion seeds. The rootstock is essential to the scion in terms of growth and development, flowering and fruiting and fruit set and improved resistance to diseases (Yun *et al.* 2023). The wild species of brinjal took 25–30 days for germination than other rootstocks (Sharma *et al.* 2019). A 4–5 weeks-old seedlings of wild eggplant were used as rootstocks, whereas 3–4 weeks-old tomato seedlings were used as scions.

All the recommended Packages of Practices were adapted to carry out the experiment. The experiment was conducted by using four wild eggplant rootstocks (*Solanum torvum, Solanum violaceum, Solanum xanthocarpum* and *Solanum incanum*), 3 scion cultivars/ hybrids (Kashi Anupam , Kashi Sharad , Kashi Vishesh) and 3 non-grafted tomato plants. The data were analysed statistically with INDOSTAT software. Percentage of grafting success was calculated by using below formula:

$$\text{Percentage of grafting success (\%)} = \frac{\text{No. of grafted ready for transplanting}}{\text{Total no. of plants grafted}} \times 100$$

In the study, the height of randomly chosen plants from each plot was assessed in centimeters using a metre scale. This measurement was taken from ground level to the tip of the shoot at 30 and 60 days after transplanting (DAT). Additionally, the number of branches, emerging from the main shoot, was counted, and the values were averaged. The number of days taken from transplanting to days to 1st flowering in experimental plots was observed and the data was recorded. Average fruit weight of five randomly harvested fruits from individual plants were taken and weighed treatment wise in weighing balance. The fruit yield/ ha was calculated by weighing the total fruit yield per plot. Rangana (1986) proposed a technique for measuring ascorbic acid. Total lycopene content of tomato was determined by the method of Lee (2001). The B:C ratio was calculated as per the cost concept method, viz. the ratio of gross returns and total cost (Latifah *et al*. 2018).

Grafting: The splice method of grafting was carried out when scion and rootstock seedlings attained their respective height and girth. 1.6 mm silicon grafting clips were used for grafting. Grafted plants were placed in the healing chamber to ensure high grafting success. They were kept in healing chambers with a relative humidity of 85–90% and 28–32°C temperature for 10–12 days to allow graft union. The pro trays were irrigated daily for 25 days. The grafted seedlings were transplanted in the main plot 20 days after grafting, when the grafts were at 3–4 true leaf stage (Zhen *et al*. 2022). The observations were recorded for rootstock, scion and grafts combination.

RESULTS AND DISCUSSION

Since the interaction effect is small compared to the average effect and has been found to be significant, the treatment ranking should not change from year to year. Therefore, it can be excluded. For pooled mean analysis, there were significant differences in the data regarding the percentage of success in graft between rootstocks and scions. Among the different grafts, T_1 (*Solanum torvum* + Kashi Anupam) showed maximum percentage of grafting success with 73.83%. Minimum percentage of grafting success was observed in T_5 (*Solanum violaceum* + Kashi Sharad) with 60.93% (Fig. 1). *Solanum torvum* has a high genetic compatibility with tomato (*Kashi Anupam*). Its vascular system aligns well with the tomato scion, leading to efficient graft union formation and better nutrient/water transport. The above findings of the experiment are in agreement and similar results were reported by Sharma *et al*. (2019), Surve (2019), Palanikumar *et al.* (2020), Rinku *et al*. (2020) and Bhandari and Rejmi (2021).

Plant height (cm) at 30 DAT: The data pertaining to plant height (cm) in grafted tomato showed significant differences among grafted treatments studied for two-years, 2022–23 and 2023–24. Among the different treatments, T_1 (*Solanum torvum* + Kashi Anupam) displayed maximum plant height at 30 DAT with 39.97 cm followed by T_{11} (*Solanum incanum* + Kashi Sharad) with 38.34 cm. Minimum plant height at 30 DAT among grafts was observed in T_{12} (*Solanum incanum* + Kashi Vishesh) with 30.99 cm (Fig. 1). Considerable increase in plant height was noticed in most of the grafted plants, that is related to the fact that grafted tomato were vigorous than the non-grafted one (Khah 2011).

Plant height (cm) at 60 DAT: Pooled mean analysis also showed a similar pattern. Since the interaction effect is small compared to the average effect and has been found to be significant, the treatment ranking should not change from year to year. Therefore, it can be excluded. For pooled mean analysis, there were significant differences in the data regarding the plant height in graft between rootstocks and scions. Among the different treatments, T_1 (*Solanum torvum* + Kashi Anupam) displayed maximum plant height at 60 DAT with 79.05 cm and minimum plant height at 60 DAT among different treatments was observed in T_{14} (Kashi Sharad) (non-grafted) with 55.11 cm. Considerable increase in plant height was noticed in most of the grafted plants that is related to the fact that grafted tomato was vigorous than the non-grafted one (Khah 2011).

Number of branches per plant: Pooled mean analysis also showed a similar pattern. Since the interaction effect is small compared to the average effect and has been found

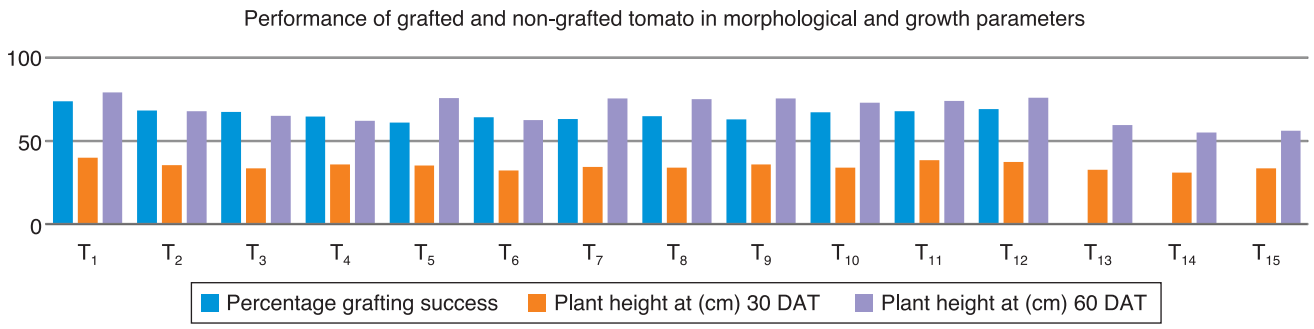

Fig. 1 Performance of tomato varieties grafted on wild brinjal rootstocks for grafting success and plant height.

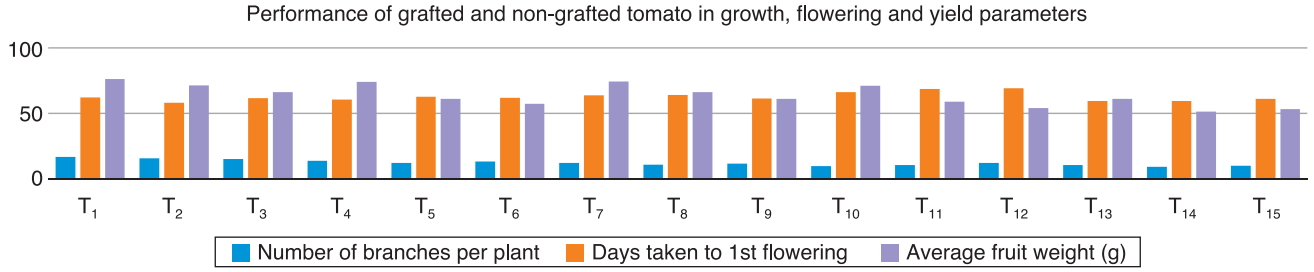

Fig. 2 Performance of tomato varieties grafted on wild brinjal rootstocks for flowering and fruit weight.

to be significant, the treatment ranking should not change from year to year. Therefore, it can be excluded. For pooled mean analysis, there were significant differences in the data regarding the number of branches/plant in graft between rootstocks and scions. Among the different treatments, T_1 (*Solanum torvum* + Kashi Anupam) displayed highest number of branches per plant with 16.80 branches. Minimum number of branches/plant among grafts was observed in T_{14} (Kashi Sharad) (non-grafted) with 9.14 branches (Fig. 2). The number of branches/plant is an important yield contributing factor in tomatoes (Salehi *et al*. 2009). The rootstock's vigorous root system aided scion growth, resulting in greater number of branches in grafted plants (Rathod 2017, Survey *et al.* 2019).

Days taken for 1st flowering: Comparable trends were also revealed by pooled mean analysis. The interaction effect is significant even though it is smaller than the average effect, so the treatment ranking shouldn't fluctuate from year to year. Consequently, it is excludable. When comparing the days taken for 1st flower in a graft, there were notable variations in the data for the pooled mean analysis. Among the different treatments, T_2 (*Solanum torvum* + Kashi Sharad) displayed minimum days taken to 1st flowering with 58.16 days after transplanting. Maximum days taken to 1st flowering among treatments was observed in T_{12} (*Solanum incanum* + Kashi Vishesh) days after transplanting (Fig. 2). *Solanum torvum* influences hormonal balance by promoting the synthesis and transport of flowering-related hormones like gibberellins, auxins, and cytokinins, which induce earlier floral initiation in the scion. Similar findings regarding the time to flowering in grafted tomatoes were reported by Tamilselvi and Pugalendhi (2018), Pugalendhi *et al.* (2021).

Average fruit weight (g): The data pertaining to average fruit weight (g), in grafted tomato showed significant differences among grafted treatments studied for two-years, 2022 and 2023. Comparable trends were also revealed by pooled mean analysis. The interaction effect is significant even though it is smaller than the average effect, so the treatment ranking shouldn't fluctuate from year to year.

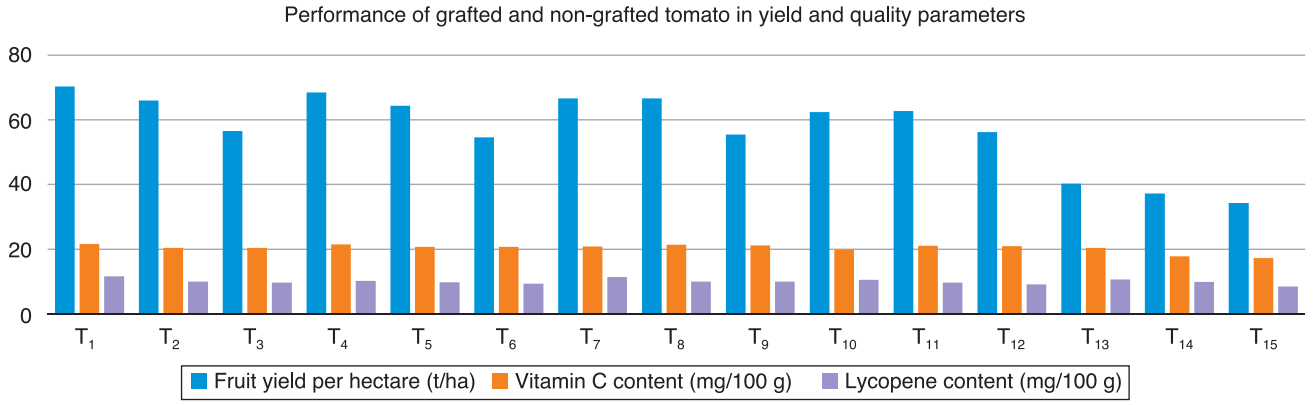

Fig. 3 Performance of tomato varieties grafted on wild brinjal rootstocks for grafting yield and quality parameters.

Table 1 Mean performance of tomato grafted on wild brinjal rootstock (2 year pooled data 2022–23 and 2023–24)

Treatment Notation	Treatment details	Percentage grafting success	Plant height (cm) at		Number of branches/ plant	Days taken to 1st flowering	Average fruit weight (g)	Fruit yield/ ha (t/ha)	Vitamin C Content (mg/100 g)	Lycopene content (mg/100 g)	B:C Ratio
			30 DAT	60 DAT							
T_1	*Solanum torvum* + Kashi Anupam	73.83	39.97	79.05	16.80	62.16	76.13	70.40	21.54	11.57	3.85
T_2	*Solanum torvum* + Kashi Sharad	68.26	35.51	67.75	15.60	58.16	71.13	66.03	20.38	9.99	3.61
T_3	*Solanum torvum* + Kashi Vishesh	67.43	33.64	65.05	15.17	61.5	66.13	56.53	20.38	9.62	3.09
T_4	*Solanum violaceum* + Kashi Anupam	64.59	35.86	62.07	13.67	60.5	73.83	68.50	21.42	10.17	3.75
T_5	*Solanum violaceum* + Kashi Sharad	60.93	35.35	75.74	12.12	62.66	61.05	64.43	20.66	9.715	3.52
T_6	*Solanum violaceum* + Kashi Vishesh	64.19	32.33	62.48	13.20	61.83	57.13	54.63	20.76	9.35	2.99
T_7	*Solanum xanthocarpum* + Kashi Anupam	63.26	34.37	75.46	12.13	63.83	74.29	66.63	20.86	11.36	3.64
T_8	*Solanum xanthocarpum* + Kashi Sharad	64.93	33.97	75.07	10.90	64	66.13	66.66	21.37	9.97	3.64
T_9	*Solanum xanthocarpum* + Kashi Vishesh	63.05	35.91	75.42	11.67	61.16	61.13	55.47	21.09	9.90	3.03
T_{10}	*Solanum incanum* + Kashi Anupam	67.25	33.88	73.01	9.70	66.16	70.90	62.49	19.87	10.46	3.42
T_{11}	*Solanum incanum* +Kashi Sharad	67.92	38.34	73.94	10.65	68.66	58.95	62.82	21.05	9.66	3.43
T_{12}	*Solanum incanum* + Kashi Vishesh	69.08	37.48	75.87	12.17	69	54.00	56.30	20.95	9.06	3.08
T_{13}	Kashi Anupam (non-grafted)	0.00	32.64	59.49	10.47	59.5	60.98	40.23	20.37	10.55	2.94
T_{14}	Kashi Sharad (non-grafted)	0.00	30.99	55.11	9.12	59.33	51.32	37.22	17.77	9.83	2.72
T_{15}	Kashi Vishesh (non-grafted)	0.00	33.64	56.14	10.03	61	53.18	34.28	17.18	8.41	2.50
	'F' Test	S	S	S	S	S	S	S	S	S	
	SEM (±)	4.43	0.40	1.26	0.44	0.35	0.24	2.62	0.72	0.17	
	$CD_{0.05}$	1.54	0.82	2.57	0.89	1.00	0.75	5.37	2.24	0.53	

Consequently, it is excludable. When comparing the average fruit weight in a treatment, there were notable variations in the data for the pooled mean analysis. Among the different treatments, maximum average fruit weight was 76.13 g for T_1 (*Solanum torvum* + Kashi Anupam), and minimum was found to 51.13 g (Fig. 2). T_{15} Kashi Vishesh (non-grafted) as supported by the findings of Ahmed (2014), Kumar *et al.* (2017), Kumar *et al.* (2018), and Yun *et al.* (2023).

Fruit yield/ha (t/ha): The data pertaining to fruit radial diameter, in grafted tomato showed significant differences among grafted treatments studied for two-years, 2022 and 2023. Comparable trends were also revealed by pooled mean analysis. The interaction effect is significant even though it is smaller than the average effect, so the treatment ranking shouldn't fluctuate from year to year. Consequently, it is excludable. When comparing yield/ha in a treatment, there were notable variations in the data for the pooled mean analysis. Among the different treatments, maximum fruit yield/ha was (70.40 t/ha) for T_1 (*Solanum torvum* + Kashi Anupam), and minimum was found to treatment T_{15} (Kashi Vishesh) (non-grafted) (34.28 t/ha) (Fig. 3). Grafted tomato on wild eggplant rootstock had maximum yield/ha than non-grafted plants due to wild brinjal rootstock (*Solanum torvum)* having good root systems ensuring more plant height and vigorous growth, which absorbs more water and nutrients. The scions selected for grafting study are popular varieties/ hybrids of the locality. The higher yield in the grafting might be due to the vigorous root system in the wild rootstock that resulted in improved fruit quantity and quality (Hossain *et al.* 2019, Soe *et al*. 2018, Sharma *et al.* 2019, Yun *et al*. 2023, Moncada *et. al.* 2013).

Vitamin C content (mg/100 g): Pooled mean analysis also showed comparable trends. The treatment ranking should not change from year to year because the interaction effect is significant even though it is smaller than the average effect. It is therefore excludable. There were significant differences in the data for the pooled mean analysis when comparing for ascorbic acid content within a treatment. T_1 (*Solanum torvum* + Kashi Anupam) had the highest ascorbic acid content among the treatments at (21.54 mg/100 g) while minimum was found to T_{15} (Kashi Vishesh) (non-grafted) (17.18 mg/100 g) (Fig. 3). Similar result was also reported by Diwan and Sharma 2021 and Pugalendhi *et al.* 2021.

Lycopene content (mg/100 g): Pooled mean analysis also showed comparable trends. The treatment ranking should not change from year to year because the interaction effect is significant even though it is smaller than the average effect. It is therefore excludable. There were significant differences in the data for the pooled mean analysis when comparing for lycopene content within a treatment. T_1 (*Solanum torvum* + Kashi Anupam) had the highest lycopene content among the treatments at 11.57 mg/100 g, while minimum was found to T_{15} (Kashi Vishesh) (non-grafted) (8.41 mg/100 g) (Fig. 3). Lycopene content can be influenced by grafting, but it is subjected to significant rootstock-scion interaction which indicates that graft combination plays an important role. Similar result was also reported by Sharma *et al.* (2019), Singh *et al.* (2019), Walubengo *et al.* (2022), Pugalendhi *et al.* (2021).

Economics: The data pertaining to benefit cost ratio in grafted tomato showed significant differences among grafted treatments studied for two-years, 2022 and 2023 (Table 3). Among the grafted combination, benefit cost ratio was found to be maximum (3.85) [T_1, (*S. torvum*+ Kashi Anupam)] and minimum was found to (2.50) [T_{15}, (Kashi Vishesh) (non-grafted)].

The present study revealed that grafting of Kashi Anupam tomato hybrid on wild brinjal rootstock *Solanum torvum* significantly increased the percentage grafting success, plant height, number of branches/plant, days taken to 1st flowering, average fruit weight, fruit yield/ha, vitamin C content, lycopene content and benefit-cost ratio. Therefore, using this wild brinjal rootstock in tomato for improving the yield potential and better growth ability with higher graft compatibility would be a potential tool for growing tomatoes.

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