Nepalese Journal of Agricultural Sciences, January, 2025, Volume 28
eISSN 2091-0428; pISSN 2091-041X; esjindex ID = 6279

IMPACT OF *SOLANUM TORVUM* ROOTSTOCKS ON GRAFTED AND NON-GRAFTED TOMATO (*LYCOPERSICON ESCULENTUM* MILL.) CULTIVARS

Susma NEPAL[1], Punam SHRESTHA[1], Choodamani BHATTARAI[2] and Bidur P. CHAULAGAIN[1*]

[1]Himalayan College of Agriculture Sciences and Technology (HICAST), Kirtipur, Nepal

[2]Prime Minister Agricultural Modernization Project (PMAMP), PIU, Bhaktapur, Nepal

***Corresponding Author's email:** bidur@hicast.edu.np

ABSTRACT

This study evaluated the growth, yield, and fruit quality of grafted and non-grafted tomato (Lycopersicon esculentum Mill.) cultivars under protected cultivation. Conducted from March to July 2024 at Bhattarai Shiva Shakti Krishi Farm, Bhaktapur, Nepal, the experiment used two cultivars, Heemsikhar and Srijana, as scions grafted onto Solanum torvum (wild brinjal) rootstock. Four treatments—T1: Grafted Heemsikhar, T2: Control Heemsikhar, T3: Grafted Srijana, and T4: Control Srijana—were put in a randomized complete block design with five replications. Key parameters, including plant growth, fruit yield, and quality traits such as firmness, total soluble solids (TSS), titratable acidity (TA), sugar-acid ratio, and vitamin C content, were assessed. Grafting significantly improved fruit yield, TA, and vitamin C content but had no effect on plant height, stem diameter, fruit firmness, TSS, or sugar-acid ratio. The T3 (Grafted Srijana) treatment yielded the highest fruit weight, with 129.60 g/plant in the first harvest and 121.30 g/plant in the second. T1 (Grafted Heemsikhar) followed, with yields of 112.01 g/plant and 84.60 g/plant at the respective harvests. T3 also recorded the highest TA and vitamin C content, highlighting its potential for enhancing both yield and nutritional quality. These findings provide valuable insights for optimizing tomato cultivation through grafting and offer practical recommendations for improving productivity and fruit quality under protected conditions.

Keywords: Grafting, tomato, wild-brinjal, yield

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.), with a chromosome number of 2n = 24, is one of the most widely cultivated and consumed vegetables globally. In Nepal, it ranks as the third most cultivated vegetable, following cabbage and cauliflower, covering an area of 22,911 hectares, which constitutes 7.9% of the total vegetable cultivation area. The annual production of tomatoes in Nepal is approximately 30,523 metric tons (MoALD, 2023).

Tomatoes are prone to various biotic and abiotic stresses, including soil-borne diseases, temperature fluctuations, variations in relative humidity, light intensity, soil moisture, and nutrient availability. These stressors can limit nutrient uptake, disrupt temperature regulation, and exacerbate soil-borne infections, leading to physiological disorders that negatively impact fruit yield and quality (Lee and Oda, 2002). As a result, grafting has emerged as a promising strategy to improve tomato plant productivity and fruit quality by enhancing plant vigor and increasing tolerance to both biotic and abiotic stresses. This approach is particularly valuable in low-input, sustainable, and organic agricultural systems.

Grafting of herbaceous plants, especially for commercial greenhouse production of selected vegetable crops, is a widely practiced technique. It is typically performed shortly after seed germination, when plants are still small, by grafting the rootstock to enhance specific plant traits. Numerous benefits of grafting have been identified, including improved resilience to extreme temperatures (Rivero et al., 2003; Venema et al., 2008), enhanced nutrient uptake (Colla et al., 2010a), increased endogenous hormone synthesis (Dong et al., 2008), better water-use efficiency (Rouphael et al., 2008), and reduced uptake of persistent organic pollutants from agricultural soils (Otani and Seike, 2007). Additionally, grafting has been shown to improve tolerance to alkaline conditions (Colla et al., 2010b), salinity, flooding (Fernández-García et al., 2004; Yetisir et al., 2006; Martínez-Rodríguez et al., 2008; He et al., 2009), and heavy metal toxicity (Savvas et al., 2010). The robust root system of grafted plants further enhances nutrient and water absorption, surpassing non-grafted plants in efficiency (Lee and Oda, 2002), while providing greater resistance to soil-borne diseases (Ioannou, 2001; Crinò et al., 2007; Morra and Bilotto, 2006).

Furthermore, tomato grafting has been shown to mitigate the effects of salinity (Estan, 2005), soil-borne diseases (Louws et al., 2010), and improve nutrient and water absorption (López-Pérez et al., 2006; El-Shraiy et al., 2011; Voutsela et al., 2012). Grafting also aids in nematode control and enhances tolerance to high temperatures (Rivero et al., 2003), making it an effective approach to improve plant vigor and fruit yield (Barret and Zhao, 2012). However, there is limited research on the effects of grafting methods on tomato plants in Nepal.

This study aims to assess the impact of grafting on tomato growth characteristics, yield performance, and fruit quality, comparing grafted and non-grafted tomato cultivars under field conditions. The results of this study will provide valuable insights into the potential benefits of grafting for enhancing tomato production and will inform horticultural practices in Nepal, especially in low-input agricultural systems.

MATERIALS AND METHODS

The study was conducted at Bhattrai Shiva-Shakti Krishi Farm, located in Suryabinayak-10, Bhaktapur, Nepal, with GPS coordinates approximately 27.6712° N latitude and 85.4370° E longitude. The region has a subtropical highland climate, characterized by distinct seasons and significant solar radiation. The farm receives an annual rainfall averaging around 2596 mm, with the majority occurring during the monsoon season from June to September (Weather and Climate. (2023).

Experimental Design and Treatments

The experiment was structured as a Randomized Complete Block Design (RCBD) with four treatments, each replicated five times. The total experimental plot consisted of 20 plants, with each replication containing four plants. The treatments were as follows shown in table 1.

Table 1. Treatment details

Treatments	Rootstock/ Scion
T1	Grafted Heemsikhar (wild brinjal * Heemsikhar)
T2	Control Heemsikhar
T3	Grafted Srijana (wild brinjal * Srijana)
T4	Control Srijana

The experiment was carried out under a plastic tunnel with a total length of 7.8 meters and a width of 4.26 meters. The seedlings were planted in raised beds, each 2 feet in width and 27 feet in length, raised 1 cm above the ground. A plant-to-plant spacing of 30 cm was maintained, with 60 cm between beds. Experimental units were clearly labeled for treatment identification.

The treatments in this study involved different rootstock-scion combinations to evaluate their impact on tomato plant growth, yield, and fruit quality (Table 1). The tomato variety under experiment were Srijana and Heemsikhar while the rootstock for grafting purpose was Wild Brinjal (*Solanum torvum*). The treatment T1 consisted of grafted Heemsikhar, using wild brinjal (Solanum torvum) as the rootstock and Heemsikhar as the scion. Treatment T2 served as the control for Heemsikhar, where non-grafted Heemsikhar plants were used. Treatment T3 involved grafted Srijana, where wild brinjal was paired with Srijana as the scion. Treatment T4 acted as the control for Srijana, consisting of non-grafted Srijana plants.

Observational Parameters

The following parameters were observed and recorded at 5 and 10 weeks after planting:

1. **Growth Parameters**: Three plants were randomly selected from each replication, excluding the boundary plants, for biometric observations. Plant height was measured using a measuring scale, while stem diameter was recorded 15 cm above the ground using a Vernier caliper, and the data were expressed in centimeters.

2. **Yield**: Yield was evaluated following the first and second harvests. The total fruit weight from each plant was measured and expressed as grams per plant.

3. **Firmness**: Fruit firmness was measured using a digital penetrometer and expressed in kg/cm^2.

4. **Total Soluble Solids (TSS)**: TSS content was determined using a refractometer and expressed in degrees Brix (°Brix).

5. **Titratable Acidity (TA)**: TA was determined by titration with 0.1 N sodium hydroxide (NaOH) using phenolphthalein as an indicator, and results were expressed as percentage citric acid. Acidity percentage was calculated using the following formula: Percentage Acidity= titer value * acidity factor * 100% / volume of aliquot (Majidi et al., 2011).

6. **Sugar-acid ratio (TSS/TA):** The sugar acid ratio of the fruit was calculated by using the given formula: Sugar acid ratio = Brix value / % acidity

7. **Vitamin C content**: **Vitamin C Content**: Total vitamin C content was determined using a volumetric method. The amount of ascorbic acid (mg/100 ml sample) was calculated using the formula:

   0.5mg / V1ml X V2ml / 5ml X 100ML / Wt. of the sample X 100

Where, V1= amount of dye solution consumed by 4% oxalic acid
V2 = amount of dye consumed by working solution (G et al., 2020)

Statistical Analysis
Data analysis was performed using R-Studio and Microsoft Excel. An analysis of variance (ANOVA) was conducted to assess the significance of differences across treatments for all observed parameters.

RESULTS AND DISCUSSION

Impact of Grafting on Plant Height in Tomato Cultivars

The study revealed significant differences in plant height between grafted and non-grafted tomato plants (Table 2). Non-grafted plants consistently exhibited higher plant heights at all stages of growth. Specifically, the control treatment T2 (Heemsikhar) recorded the highest plant height at the 5th week (76.43 cm) and 10th week (144.27 cm) post-transplanting. Similarly, T4 (Control Srijana) showed substantial growth with heights of 73.27 cm at week 5 and 137.98 cm at week 10. In contrast, grafted plants (T1, Grafted Heemsikhar) showed significantly lower plant heights, with values of 36.93 cm at week 5 and 84.55 cm at week 10.

This trend aligns with findings from Khah et al. (2006) and Parajuli (2019), which suggested that non-grafted tomato plants generally exhibit superior growth in terms of plant height. The differences observed in plant height between grafted and non-grafted plants can be attributed to the rootstock-scion interaction. Non-grafted plants benefit from direct nutrient and water supply from their root system, supporting faster initial growth and greater plant height.

Influence of Grafting on Stem Diameter in Tomato Plants
Significant differences in stem diameter were observed between grafted and non-grafted tomato plants (Figure 1). At the 5th week after transplanting, non-grafted plants, particularly T2 (Control Heemsikhar), exhibited the largest stem diameter

at 3.562 cm, followed by T4 (Control Srijana) at 3.074 cm. However, by the 10th week, grafted treatments showed considerable improvements in stem diameter. T3 (Grafted Srijana) recorded the highest diameter at 7.634 cm, closely followed by T1 (Grafted Heemsikhar) at 6.954 cm. The non-grafted treatment T4 (Control Srijana) had a slightly smaller diameter of 6.486 cm.

Table 2. Performance of grafted and non-grafted tomato plants for plant height

Treatments	Height of Plant (cm)	
	5th Week	10th Week
T1 (Grafted Heemsikhar)	36.93 a	84.55 c
T2 (Control Heemsikhar)	76.43 a	144.27 a
T3 (Grafted Srijana)	53.15 b	126.93 b
T4 (Control Srijana)	73.27 a	137.98 a
Mean	59.95	123.43
CV at 5%	5.2	3.7
LSD	4.3	6.4

These findings align with the observations of Parajuli (2019), who reported similar trends in stem diameter between grafted and non-grafted tomato plants. The early growth advantage observed in non-grafted plants can be attributed to direct nutrient absorption and resource allocation, enabling a strong root system and promoting vegetative growth in the initial stages.

However, by the 10th week, grafted plants (T3 and T1) exhibited significant improvement in stem diameter. This suggests that the grafted rootstocks, with their enhanced nutrient uptake, disease resistance, and better tolerance to environmental stressors, began to show their advantages, leading to stronger growth. The larger stem diameters in grafted treatments, especially T3 (Grafted Srijana), may also indicate that the rootstocks provided robust support to the scion as the plants matured. Overall, these results suggest that while grafting may cause a temporary lag in vegetative growth, it ultimately contributes positively to the structural integrity and long-term performance of tomato plants.

Yield Results of Grafted and Non-Grafted Tomato Plants

The yield results clearly favor grafting in terms of fruit production (Table 3). Grafted plants (T3, Grafted Srijana) produced the highest fruit yield, with 129.60 g in the 1st harvest and 121.30 g in the 2nd. Grafted Heemsikhar (T1) also yielded higher than non-grafted plants, with 112.01 g in the 1st harvest and 84.60 g in the

2nd. Non-grafted Heemsikhar (T2, Control) exhibited the lowest yields, with 57.68 g in the 1st harvest and 77.55 g in the 2nd.

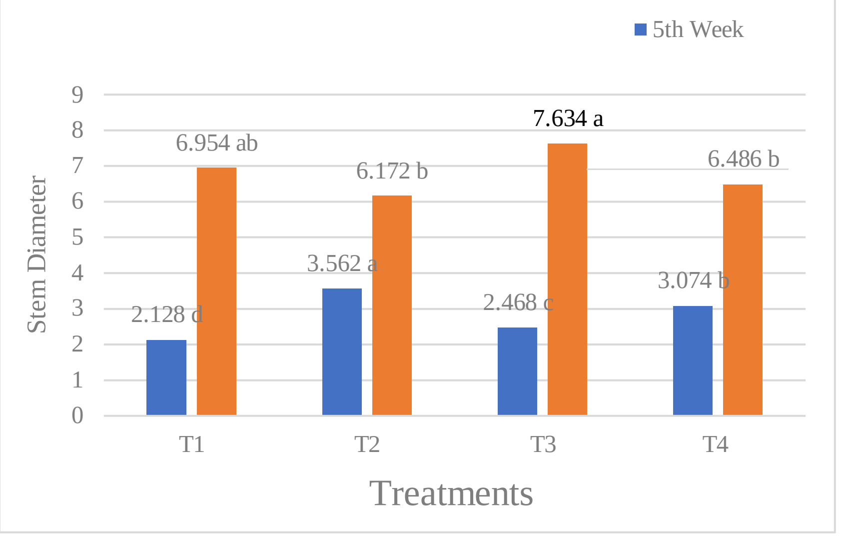

Figure 1. Performance of grafted and non-grafted tomato plants for stem diameter

These findings confirm the positive impact of the 'Wild brinjal' rootstock in enhancing fruit yield, supporting previous studies (Leonardi & Giuffrida, 2006; Rivard & Louws, 2008). The superior root system of the grafted plants, attributed to the 'Wild brinjal' rootstock, contributed to better disease resistance, drought tolerance, and nutrient uptake, leading to higher yields.

Although non-grafted plants showed lower yields, they still produced a reasonable amount of fruit at the second harvest (77.55 g). This suggests that while grafting provides an immediate yield advantage, non-grafted plants remain capable of substantial fruit production.

Impact of Grafting on Tomato Fruit Firmness (kg/cm²)

Grafting did not significantly affect tomato fruit firmness in this study. Non-grafted plants (T2, Control Heemsikhar) had the highest firmness at 3.29 kg/cm², while grafted plants (T1, Grafted Heemsikhar and T3, Grafted Srijana) showed lower firmness values of 2.21 kg/cm² and 2.50 kg/cm², respectively. Interestingly, T4 (Control Srijana) exhibited the lowest firmness at 1.39 kg/cm².

Table 3. Performance of grafted and non-grafted tomato plants for fruit yield

Treatments	Yield (g/plant)	
	1st Harvest	2nd Harvest
T1 (Grafted Heemsikhar)	112.01 a	84.60 b
T2 (Control Heemsikhar)	57.68 b	77.55 b
T3 (Grafted Srijana)	129.60 a	121.30 a
T4 (Control Srijana)	82.88 b	83.00 b
Mean	95.54	91.61
CV at 5%	20.44	25.85
LSD	26.91	32.63

The minimal impact of grafting on firmness can be attributed to several factors, including the complex nature of fruit firmness, which is influenced by genotype, environmental conditions, and harvest maturity. Grafting may not directly affect the biochemical or structural components responsible for firmness, such as cell wall composition or turgor pressure. Additionally, harvest timing and post-harvest handling could contribute to firmness variations, though fruits were harvested at similar stages. These results align with studies by Leoni et al. (1991) and Romano & Paratore (2001), which also found no significant effect of grafting on tomato fruit firmness. While grafting enhances yield and disease resistance, its impact on fruit texture appears minimal. Further studies may explore whether grafting influences firmness under different conditions.

Influence of Grafting on Titratable Acidity in Tomato Fruits

Grafted tomato plants showed higher titratable acidity (TA) than non-grafted ones, with T3 (Grafted Srijana) having the highest TA at 0.073%, followed by T1 (Grafted Heemsikhar) at 0.061%. Non-grafted plants (T2 and T4) had lower acidity levels, ranging from 0.048% to 0.062%. This result aligns with Parajuli (2017), who observed similar findings in grafted tomatoes.

Table 4. Performance of grafted and non-grafted tomato plants for fruit firmness

Treatments	Firmness (kg/cm^2)
T1 (Grafted Heemsikhar)	2.21 a
T2 (Control Heemsikhar)	3.29 a
T3 (Grafted Srijana)	2.50 a
T4 (Control Srijana)	1.39 a
Mean	2.35
CV at 5%	41.70
LSD	1.9

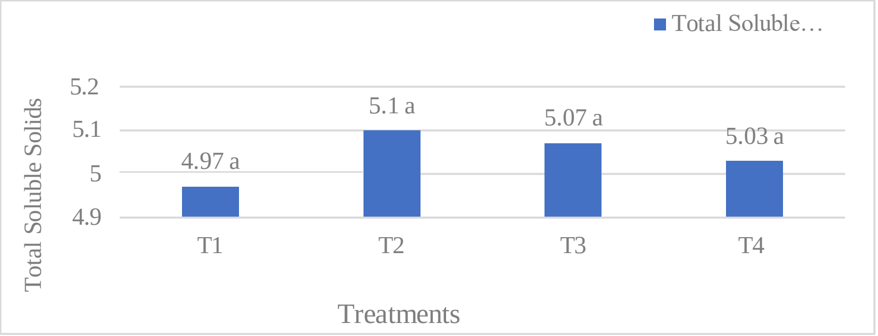

Figure 2. Performance of grafted and non-grafted tomato plants for Total Soluble Solids

Increased acidity can enhance flavor in some cultivars but may be less desirable for consumers preferring milder tomatoes. The higher acidity in grafted plants could be due to the rootstock's impact on nutrient uptake and acid synthesis, particularly the 'Wild brinjal' rootstock. Overall, grafting influences tomato fruit acidity, and the rootstock choice is crucial for both fruit quality and consumer preferences. Further studies are needed to explore the effects of different rootstocks under various environmental conditions

Table 5. Performance of grafted and non-grafted tomato plants for titratable acidity

Treatments	Titratable Acidity (%)
T1 (Grafted Heemsikhar)	0.061 b
T2 (Control Heemsikhar)	0.048 c
T3 (Grafted Srijana)	0.073 a
T4 (Control Srijana)	0.062 b
Mean	0.061
CV at 5%	3.62
LSD	0.004

Impact of Grafting on the TSS/TA Ratio in Tomato Fruits

The TSS/TA ratio, representing the balance between sweetness (TSS) and acidity (TA), was found to be lower in the grafted plants compared to the non-grafted counterparts in this study (Table 6). Specifically, T1 (Grafted Heemsikhar) had a TSS/TA ratio of 82.51, which was significantly higher than T2 (Control Heemsikhar) at 106.51. Similarly, T3 (Grafted Srijana) exhibited a lower TSS/TA ratio (70.02) compared to T4 (Control Srijana) at 81.10. This indicates that grafting may influence the relative concentrations of sugars and acids in tomato

fruits, resulting in a noticeable difference in the sweetness-to-acidity balance. The lower TSS/TA ratio in grafted plants could suggest that grafting, while potentially increasing titratable acidity, may also have a mitigating effect on sugar accumulation, leading to a less pronounced sweetness. This could have a significant impact on the flavor profile of the fruit, as tomatoes with a higher TSS/TA ratio are typically perceived as sweeter, while a lower ratio may indicate a more acidic or tangy taste.
These findings contrast with the studies of Turhan et al. (2011), Mohammed et al. (2012), and Ibrahim et al. (2001), which reported different TSS/TA ratios under similar grafting conditions. The discrepancies in results might be attributed to differences in experimental conditions such as rootstock variety, growing environment, and cultivation practices. Additionally, variations in the scion variety could also contribute to differing TSS/TA ratios in the final fruit.

The reduction in the TSS/TA ratio observed in grafted plants may be a result of complex interactions between the rootstock and scion, particularly in terms of nutrient uptake and metabolic regulation. Given that flavor is a major determinant in tomato quality, understanding the effects of grafting on the TSS/TA ratio will be essential for optimizing tomato varieties for flavor-driven consumer demand.

Table 6. Performance of grafted and non-grafted tomato plants for TSS/TA

Treatments	TSS/TA
T1 (Grafted Heemsikhar)	82.51 b
T2 (Control Heemsikhar)	106.51 a
T3 (Grafted Srijana)	70.02 c
T4 (Control Srijana)	81.10 bc
Mean	85.04
CV at 5%	7.32
LSD	12.43

Effect of Grafting on Vitamin C Content in Tomato Fruits

Grafted tomato plants exhibited significantly higher vitamin C content compared to non-grafted plants. The highest vitamin C content was observed in T3 (Grafted Srijana) at 25.27 mg/100 ml, followed by T1 (Grafted Heemsikhar) at 14.42 mg/100 ml. Non-grafted plants (T2, Control Heemsikhar) showed much lower levels at 7.37 mg/100 ml. This enhancement in vitamin C levels highlights the role of the 'Wild brinjal' rootstock in improving the nutritional quality of tomato fruits, especially in the 'Srijana' scion. This finding is consistent with Mohammed et al. (2009), who reported increased vitamin C content in grafted tomatoes. The improvement is likely due to the rootstock's influence on nutrient uptake, stress tolerance, and the biosynthesis of ascorbic acid. The rootstock may enhance the scion's ability to accumulate and transport nutrients like vitamin C, suggesting improved root-shoot communication or metabolic changes linked to vitamin C synthesis. This enhancement could provide a valuable nutritional advantage, particularly for markets focusing on functional foods and enhanced food quality.

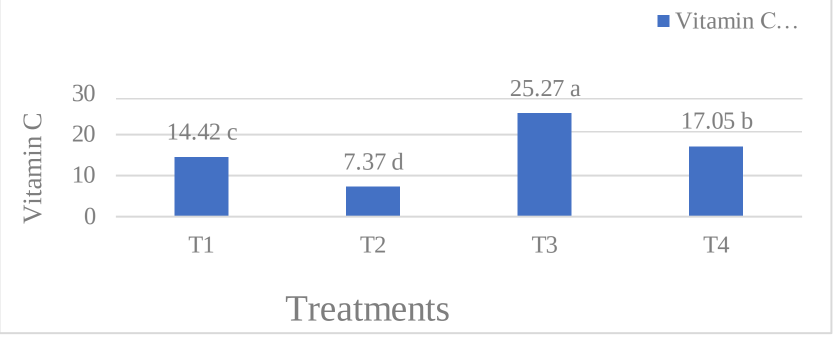

Figure 3. Performance of grafted and non-grafted tomato plants for Vitamin C

CONCLUSION

This study explored the effects of grafting tomato cultivars (Srijana and Heemsikhar) onto wild-brinjal (Solanum torvum) rootstock. The results indicated that grafting significantly enhanced fruit yield and improved certain quality attributes, such as titratable acidity (TA) and vitamin C content. Among the grafted combinations, Grafted Srijana showed the highest yield (121.30 g/plant), increased TA (0.073%), and higher vitamin C content (25.27 mg/100 ml) compared to Grafted Heemsikhar. However, grafting did not have a significant effect on other growth parameters like plant height, stem diameter, or fruit characteristics such as fruit firmness, total soluble solids (TSS), and the sugar-acid ratio. Non-grafted plants exhibited better performance in plant height and TSS content.

In conclusion, grafting with wild-brinjal (Solanum torvum) rootstock resulted in improved yield, titratable acidity, and vitamin C content in both Srijana and Heemsikhar cultivars. Grafted Srijana performed best in terms of yield and fruit quality. However, grafting did not significantly affect other growth parameters or fruit quality traits like firmness and TSS. While grafting demonstrated potential for improving tomato productivity, its impact on flavor and texture was less pronounced. Future research should focus on exploring optimal scion-rootstock combinations and environmental conditions to better understand grafting's influence on tomato fruit quality and sensory attributes.

ACKNOWLEDGEMENTS

We would like to express our sincere gratitude to all individuals and organizations who contributed to the success of this study. Our deepest appreciation goes to Prime Minister Modernization Project (PMAMP), Project Implementation Unit, Bhaktapur and HICAST for their academic, logistics and financial support, which made this research possible. Special thanks to Bhattarai Shiva Shakti Krishi Farm, Bhaktapur, Nepal for providing the field resources and facilities necessary for conducting the experiments. We would also like to acknowledge the contributions of our colleagues and lab members for their guidance, technical assistance, and valuable suggestions throughout the study.

REFERENCES

Colla, G., Cardona Suárez, C.M., Cardarelli, M., Rouphael, Y. (2010a) Improving Nitrogen Use Efficiency in Melon by Grafting. *HortScience* 45, 559–565. https://doi.org/10.21273/hortsci.45.4.559

Colla, G., Rouphael, Y., Cardarelli, M., Salerno, A., Rea, E. (2010b) The effectiveness of grafting to improve alkalinity tolerance in watermelon. *Environ. Exp. Bot.* 68, 283–291. https://doi.org/10.1016/j.envexpbot.2009.12.005

Crinò, P., Lo Bianco, C., Rouphael, Y., Colla, G., Saccardo, F., Paratore, A., (2007) Evaluation of Rootstock Resistance to Fusarium Wilt and Gummy Stem Blight and Effect on Yield and Quality of a Grafted 'Inodorus' Melon. *HortScience* 42, 521–525. https://doi.org/10.21273/hortsci.42.3.521

Dong, H., Niu, Y., Li, W., Zhang, D., (2008) Effects of cotton rootstock on endogenous cytokinins and abscisic acid in xylem sap and leaves in relation to leaf senescence. *J. Exp. Bot.* 59, 1295–1304. https://doi.org/10.1093/jxb/ern035

Estan, M.T., (2005). Grafting raises the salt tolerance of tomato through limiting the transport of sodium and chloride to the shoot. *J. Exp. Bot.* 56, 703–712. https://doi.org/10.1093/jxb/eri027

Fernández-Garcí, N., Martínez, V., Cerdá, A., Carvajal, M., (2004). Fruit quality of grafted tomato plants grown under saline conditions. *J. Hortic. Sci. Biotechnol.* 79, 995–1001. https://doi.org/10.1080/14620316.2004.11511880

Fernández-García, N., Martínez, V., Cerdá, A., Carvajal, M., (2002) Water and nutrient uptake of grafted tomato plants grown under saline conditions. *J. Plant Physiol.* 159, 899–905. https://doi.org/10.1078/0176-1617-00652

Ioannou, N., (2001) Integrating soil solarization with grafting on resistant rootstocks for management of soil-borne pathogens of eggplant. *J. Hortic. Sci. Biotechnol.* 76, 396–401. https://doi.org/10.1080/14620316.2001.11511383

Ibrahim, M., Miruna. K.M., Kabir. M.S., (2001). Seed Germination and Graft Compatibility of Wild Solanum as Rootstock of Tomato. *J. Biol. Sci.* 1: 701–703. https://doi.org/10.3923/jbs.2001.701.703

Lee, J., Oda, M., (2002). Grafting of Herbaceous Vegetable and Ornamental Crops, *Wiley, pp.* 61–124. https://doi.org/10.1002/9780470650851.ch2

Leonardi, C., Giuffrida, F., (2006). Variation of Plant Growth and Macronutrient Uptake in Grafted To- matoes and Eggplants on Three Different Rootstocks. *Eur. J. Hort. Sci.*, 71: 97–101.

Leoni, S., Grudina, R., Cadinu, M., Madeddu, B., Carletti, M.G., (1991). The Influence of Four Rootstocks on Some Melon Hybrids and A Cultivar in Greenhouse. *Acta Hortic*. 127–134. https://doi.org/10.17660/actahortic.1991.287.12

Louws, F.J., Rivard, C.L., Kubota, C., (2010). Grafting fruiting vegetables to manage soilborne pathogens, foliar pathogens, arthropods and weeds. *Sci. Hortic.* 127, 127–146. https://doi.org/10.1016/j.scienta.2010.09.023

Majidi, H., Minaei, S., Almasi, M., Mostofi, Y., (2011). Total Soluble Solids, Titratable Acidity and Repining Index of Tomato in Various Storage Conditions.

MOALD. (2023). *Statistical Information on Nepalese Agriculture* 2078/79 (2021/22). MOALD.

Mohammed, S. M. T., Humidan, M., Boras, M., Abdalla, O. A., (2009). Effect of Grafting Tomato on Different Rootstocks on Growth and Productivity under Glasshouse Conditions. *Asian J. Agric. Res.* 3, 47–54. https://doi.org/10.3923/ajar.2009.47.54

Otani, T., Seike, N., (2007). Rootstock control of fruit dieldrin concentration in grafted cucumber (*Cucumis sativus*). *J. Pestic. Sci*. 32, 235–242. https://doi.org/10.1584/jpestics.g06-49

Parajuli, S., (2017). A Thesis Submitted to the Graduate Faculty of the North Dakota State University of Agriculture and Applied Science.

Rivard, C. L., Louws, F. J., (2008). Grafting to Manage Soil-borne Diseases in Heirloom Tomato Production. *HortScience* 43, 2104–2111. https://doi.org/10.21273/hortsci.43.7.2104

Rivero, R.M., Ruiz, J.M., Sánchez, E., Romero, L., (2003). Does grafting provide tomato plants an advantage against H_2O_2 production under conditions of thermal shock. *Physiol. Plant.* 117, 44–50. https://doi.org/10.1034/j.1399-3054.2003.1170105.x

Romano, D., Paratore, A., (2001). Effects Of Grafting on Tomato and Eggplant. *Acta Hortic*. 149–154. https://doi.org/10.17660/actahortic.2001.559.21

Rouphael, Y., Cardarelli, M., Colla, G., Rea, E., (2008). Yield, Mineral Composition, Water Relations, and Water Use Efficiency of Grafted Mini-Watermelon Plants Under Deficit Irrigation. *HortScience* 43, 730–736. https://doi.org/10.21273/hortsci.43.3.730

Savvas, D., Colla, G., Rouphael, Y., Schwarz, D., (2010). Amelioration of heavy metal and nutrient stress in fruit vegetables by grafting. *Sci. Hortic*. 127, 156–161. https://doi.org/10.1016/j.scienta.2010.09.011

Turhan, A., Ozmen, N., Serbeci, M.S., Seniz, V., (2011). Effects of grafting on different rootstocks on tomato fruit yield and quality. *Hortic. Sci.* 38, 142–149. https://doi.org/10.17221/51/2011-hortsci

Weather and Climate. (2023) Bhaktapur, Bagmati, Nepal Climate. *Weather and Climate*. https://weatherandclimate.com/nepal/bagmati/bhaktapur