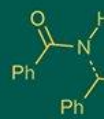


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Performance study of grafted brinjal (*Solanum melongena* L.) for quality parameters

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Abstract

The present study was undertaken during the cropping seasons of 2021-22 and 2022-23 at the All India Coordinated Research Project (AICRP) on Vegetable Crops, Odisha University of Agriculture and Technology (OUAT), Bhubaneswar, Odisha. The experiment was laid out in a Randomized Block Design (RBD) with three replications, involving eight treatments comprising ten graft combinations of brinjal (*Solanum melongena* L.). The comprehensive evaluation of various scion-rootstock combinations across two consecutive seasons clearly demonstrates the pivotal role of grafting in enhancing the nutritional and biochemical quality of brinjal fruits. Among the treatments, graft combinations involving Utkal Tarini and Utkal Anushree scions with either VNR-212 or Sungro-704 rootstocks consistently outperformed non-grafted controls and other grafts across a wide range of parameters. T₆ (Utkal Tarini × VNR-212) excelled in phenolic content and zinc concentration, indicating its superior capacity for antioxidant accumulation and micronutrient translocation. T₄ (Utkal Anushree × VNR-212) recorded the highest anthocyanin, ascorbic acid, and fibre contents, highlighting a strong physiological synergy conducive to flavonoid and structural carbohydrate biosynthesis. Similarly, T₅ (Utkal Anushree × Sungro-704) led in riboflavin and dry matter content, while T₇ (Utkal Tarini × Sungro-704) stood out for its elevated vitamin A levels. These results collectively affirm that the choice of compatible, vigorous scions paired with nutrient-efficient and disease-resilient rootstocks can significantly influence the metabolic efficiency and nutrient density of brinjal fruits. Notably, grafting not only enhanced antioxidant capacity (phenolics, anthocyanins, vitamins C and E) but also improved essential nutrients vitamins (A and B₂) all of which are critical for human health and market value. Therefore, strategic use of grafting, particularly with combinations like Utkal Anushree × VNR-212 and Utkal Tarini × Sungro-704, offers a sustainable and effective approach for improving the nutraceutical quality of brinjal under field conditions.

Keywords: Grafting, scion, rootstock, graft compatibility, vitamin e

Introduction

Use of grafting is a well-established practice in Pomology for tree fruits, its adoption in Olericulture is comparatively recent. Globally, vegetable grafting has become increasingly prevalent in crops like cucurbits, tomato, eggplant, and pepper, where the use of robust, disease-resistant rootstocks helps optimize productivity. Nonetheless, challenges from both biotic and abiotic stresses persist (Buller *et al.*, 2013) [2]. Eggplant, commonly known as brinjal, is a member of the Solanaceae family with a chromosome number of 2n=2x=24 (Choudhary, 2013) [3]. It is believed to have originated in India (Zeven and Zhukovsky, 1975) [18]. Nutritionally, brinjal holds great importance as its fruits contain approximately 6.4% carbohydrates, 1.3% protein, 0.3% fat, and small amounts of essential minerals such as calcium (0.02%), phosphorus (0.02%), and iron (0.0013%). It is also a source of several vitamins including β-carotene (34 mg), riboflavin (0.05 mg), thiamine (0.05 mg), niacin (0.5 mg), and ascorbic acid (0.9 mg) per 100 grams of fruit (Choudhary, 2013) [3]. Brinjal is also noted for its cholesterol-lowering effects, thanks to its high polyunsaturated fatty acid content specifically linoleic and linolenic acids which make up about 65.1% of its pulp and seeds. Glycoalkaloid content in Indian commercial cultivars of brinjal typically measures around 0.37 mg per 100 grams of fruit. Wild brinjal, scientifically known as *Solanum torvum*, is a versatile member of the Solanaceae family, which also encompasses tomatoes, potatoes, and bell peppers.

An important species, *Solanum xanthocarpum* known as yellow-berried nightshade or kantakari is a perennial herbaceous plant native to South and Southeast Asia. It is characterized by its erect or spreading growth habit, adaptability, and consistent medicinal use across indigenous systems of medicine. Likewise, *Solanum incanum*, often referred to as thorn apple or bitter apple, is recognized for its natural resistance to pests and diseases, making it an ideal candidate for use as a rootstock in vegetable grafting. Its fruits are a rich source of vitamin C, thiamine, folic acid, and moisture (Patel *et al.*, 2018) ^[10], enhancing its nutritional and horticultural significance. Although grafting has historically been associated with woody fruit trees, its extension to vegetable crops has gained considerable commercial momentum in recent decades. The practice entered Western agriculture in the early 1990s through the fusion of local scions with imported, disease-resistant rootstocks (Sakata *et al.*, 2007) ^[16]. However, its roots trace back to the development of protected cultivation systems in the late 1950s, which provided an ideal environment for the adoption of grafted vegetable plants. In today's context of organic and sustainable farming, grafting plays a pivotal role in minimizing the reliance on synthetic fertilizers and pesticides (Davis *et al.*, 2008) ^[4]. The continuous use of greenhouse systems often leads to a buildup of soilborne pathogens and nematodes, making vegetable grafting essential for ensuring stable production. Moreover, the strategic selection of compatible and stress-resilient rootstocks offers an effective solution to issues arising from successive cropping and environmental stress, thus enhancing overall productivity and sustainability (Hoyos, 2010) ^[7].

Materials and Methods

The experiment was conducted during the 2021-22 and 2022-23 at AICRP on Vegetable crops, OUAT, Bhubaneswar, Odisha. In the present investigation the design used for analysis of variables were Randomized Block Design (RBD) comprising 3 replications ten graft combinations. Combinations comprised of T₁ (Seedling plants of VNR-212 (Control)); T₂ (*Solanum torvum* x VNR-212); T₃ (*Solanum torvum* x Sungro- 704); T₄ (Utkal Anushree x VNR- 212); T₅ (Utkal Anushree x Sungro- 704); T₆ (Utkal Tarini x VNR- 212); T₇ (Utkal Tarini x Sungro-704) and T₈ (Seedling plants of Sungro- 704 (control)). The successful formation of a compatible graft involves three key processes: adhesion between the rootstock and scion, proliferation of callus cells at the graft junction forming a callus bridge, and vascular differentiation across the graft interface. Consequently, the rootstock and scion were systematically managed in a stepwise manner, as outlined by Mohanta *et al.* (2015) ^[9]. Splice grafting was the method used in experiment to join a scion (desired plant part) onto the stem of a rootstock or intact root piece. Quality parameters like Phenolic content in fruit, Anthocyanin pigment of fruit, Vitamin A content of fruit, Vitamin B₂ content of fruit, Vitamin C content of fruit Ranganna (1986) ^[11], Vitamin E content of fruit were observed. Analysis of Variance was worked out using Fisher and Yates (1967) ^[6]. Extraction: Polyphenols were extracted using 80% ethanol (Blois, 1958) ^[1]. Reagent Addition: 2,2-Diphenyl-1-picrylhydrazyl (DPPH) solution was mixed with the extract. Incubation & Measurement: After incubation for 30 min, absorbance was measured at 517 nm. Calculation:

Polyphenol activity was quantified using a standard curve of gallic acid. Anthocyanin content was estimated using the pH differential method (Giusti and Wrolstad, 2001) ^[15]. Extraction: Fresh fruit samples were homogenized in acidified methanol (1% HCl). Filtration & Dilution: The extract was filtered and diluted with two buffer solutions (pH 1.0 and pH 4.5). Measurement: Absorbance was recorded at 520 nm and 700 nm using a UV-Vis spectrophotometer. Calculation: The anthocyanin concentration was determined using the molar extinction coefficient of cyanidin-3-glucoside. Vitamin A (β-carotene) was determined using high-performance liquid chromatography (HPLC) (Rodriguez-Amaya, 2001) ^[15]. Extraction: Carotenoids were extracted using acetone-hexane solvent. Filtration & Injection: The extract was filtered and injected into an HPLC system. Detection: Carotenoids were detected at 450 nm, and the results were expressed as mg/100g. Vitamin B₂ content was analyzed using fluorometric detection (Bates, 1987). Extraction: Samples were homogenized in an acidic buffer and incubated. Oxidation: The extract was treated with oxidizing agents. Measurement: Fluorescence was measured at excitation 440 nm and emission 525 nm. Vitamin E (α-tocopherol) was analyzed using HPLC with UV detection (Kayden *et al.* 1973) ^[8]. Extraction: Samples were homogenized with ethanol-hexane mixture. Filtration & Injection: The extract was filtered and injected into an HPLC system. Detection: Tocopherol content was quantified at 292 nm.

Results and discussion

1. Phenolic content in fruit, and Anthocyanin pigment of fruit

The phenolic content (mg GAE/100 g fresh weight) and anthocyanin content (mg/100 g fresh weight) of grafted brinjal fruits across pooled means of two year 2021-22 and 2023-24 (Table 1 and figure 1) showed highly significant differences among treatments. For total phenolics, T₆ (Utkal Tarini × VNR-212) recorded the highest pooled value (81.99 mg GAE/100 g), clearly outperforming all other combinations. This enrichment can be attributed to the compatibility between the vigorous scion Utkal Tarini and the nutrient-efficient rootstock VNR-212, which likely improved secondary-metabolite biosynthesis and transport. The next most effective combinations were T₄ (Utkal Anushree × VNR-212, 73.95 mg GAE/100 g), T₇ (Utkal Tarini × Sungro-704, 73.17 mg GAE/100 g), and T₅ (Utkal Anushree × Sungro-704, 72.52 mg GAE/100 g), all significantly superior to non-grafted plants. Among controls, T₈ (Sungro-704 seedlings, 69.54 mg GAE/100 g) marginally exceeded T₁ (VNR-212 seedlings, 68.02 mg GAE/100 g), but both lagged far behind the top grafts. The lowest phenolic levels were recorded in *Solanum torvum*-based grafts T₂ (62.29 mg GAE/100 g) and T₃ (54.88 mg GAE/100 g) suggesting that *Solanum torvum* is less suitable for enhancing this biochemical trait in commercial brinjal cultivars.

Anthocyanin accumulation presented a contrasting pattern. T₄ (Utkal Anushree × VNR-212) displayed the highest pooled value (63.88 mg/100 g), significantly surpassing all other treatments (Table 1 and figure 1). This indicates a strong synergy between the anthocyanin-rich scion Utkal Anushree and the nutrient-acquisitive rootstock VNR-212. T₂ (*Solanum torvum* × VNR-212, 62.39 mg/100 g) and T₅ (Utkal Anushree × Sungro-704, 62.37 mg/100 g) followed,

statistically at par and superior to non-grafted controls. T₇ (Utkal Tarini × Sungro-704) recorded 60.40 mg/100 g, outperforming mid-range combinations such as T₃ (57.72 mg/100 g) and T₆ (57.43 mg/100 g). Although T₆ was the best performer for phenolics, its moderate anthocyanin level indicates that biosynthesis of these antioxidant groups may be independently regulated and strongly influenced by specific scion-rootstock interactions. The non-grafted controls T₈ (54.43 mg/100 g) and T₁ (51.99 mg/100 g) consistently recorded the lowest anthocyanin concentrations. Overall, the results demonstrate that grafting significantly enhances phenolic and anthocyanin quality traits in brinjal, and that performance depends on the compatibility between scion genetics and rootstock physiology. Combinations involving Utkal cultivars with VNR-212 or Sungro-704 emerged as the most promising for nutraceutical improvement under field conditions. These findings support the strategic use of grafting for quality-oriented vegetable production. Similar biochemical shifts following grafting have also been reported by Turhan *et al.* (2011) [17], who observed changes in vitamin C, total sugar, and soluble solids, indicating linked modifications in antioxidant profiles.

1. Vitamin A and Vitamin B₂ content of fruit

The vitamin A content (mg/100 g fresh weight) and riboflavin (vitamin B₂) concentration of brinjal fruits across pooled means of two year 2021-22 and 2023-24 (Table 1 and figure 1)) showed significant treatment variability. For vitamin A, T₇ (Utkal Tarini × Sungro-704) achieved the highest pooled value (0.84 mg/100 g), followed by T₃ (*Solanum torvum* × Sungro-704) with 0.74 mg/100 g. Although numerically lower, the difference between T₇ and T₃ fell below the critical difference, indicating statistical similarity; both were markedly superior to most other graft combinations and the non-grafted controls. T₅ (Utkal Anushree × Sungro-704) formed the next tier with 0.70 mg/100 g, significantly lower than T₇ yet clearly surpassing mid-range treatments. Intermediate values were observed in T₈ (Sungro-704 seedlings, 0.60 mg/100 g) and T₂ (*Solanum torvum* × VNR-212, 0.54 mg/100 g), which were statistically comparable and superior to VNR-212-based controls. The non-grafted control T₁ (VNR-212 seedlings) recorded 0.33 mg/100 g, while T₄ (Utkal Anushree × VNR-212) registered 0.27 mg/100 g. The lowest vitamin A concentration was recorded in T₆ (Utkal Tarini × VNR-212) with 0.21 mg/100 g, significantly inferior to the top-ranked grafts. These findings indicate that carotenoid biosynthesis is strongly governed by scion genotype and its compatibility with specific rootstocks. Sungro-704 rootstock, when paired with either Utkal Tarini or *Solanum torvum* (T₇ and T₃), proved most effective in enhancing vitamin A accumulation, highlighting the importance of strategic grafting for improving micronutrient density in brinjal under field conditions.

For riboflavin (vitamin B₂), T₅ (Utkal Anushree × Sungro-704) recorded the highest pooled content (0.049 mg/100 g), followed by T₆ (Utkal Tarini × VNR-212) and T₇ (Utkal Tarini × Sungro-704), both averaging 0.045 mg/100 g. A mid-range cluster around 0.042 mg/100 g consisted of T₂ (*Solanum torvum* × VNR-212), T₃ (*Solanum torvum* × Sungro-704) and T₈ (Sungro-704 seedlings). The lowest riboflavin level was recorded in the non-grafted control T₁ (0.037 mg/100 g), though this difference was not statistically significant. Together, the results emphasize that grafting can effectively enhance micronutrient profiles in

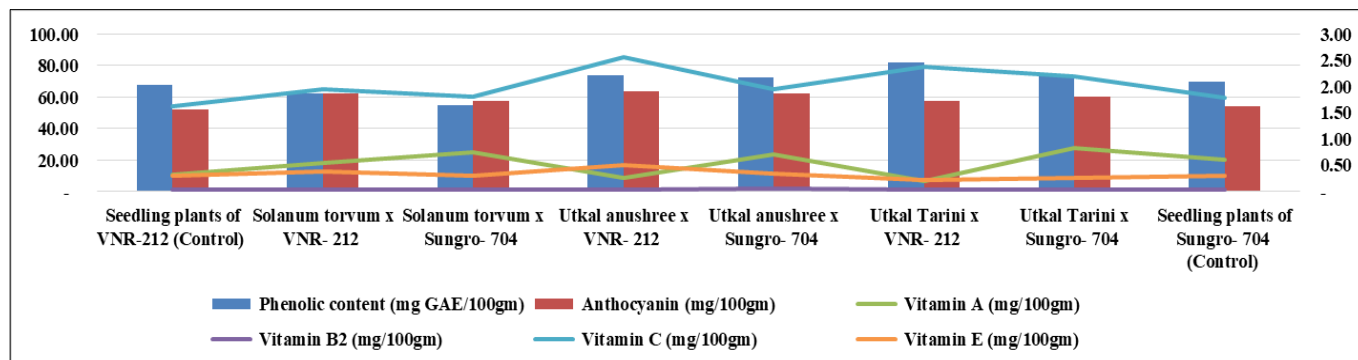
brinjal fruits (Table 1 and figure 1). While vitamin A showed strong treatment discrimination with Sungro-704-based grafts performing best, riboflavin displayed modest yet positive improvements through scion-rootstock combinations, particularly involving Utkal cultivars. These findings align with Rahmatian *et al.* (2014) [13], who also observed higher vitamin A and B₂ levels in grafted plant fruits, suggesting improved nutrient translocation and enhanced carotenoid and flavoprotein biosynthesis.

2. Vitamin C and Vitamin E content of fruit

The ascorbic acid (vitamin C) and tocopherol (vitamin E) contents of brinjal fruits measured across pooled means of two year 2021-22 and 2023-24 (Table 1 and figure 1), showed highly significant variability among treatments. For vitamin C, T₄ (Utkal Anushree × VNR-212) recorded the highest pooled concentration (2.57 mg/100 g), significantly surpassing all other combinations. This substantial enhancement likely results from the strong biochemical compatibility between the metabolically vigorous Utkal Anushree scion and the nutrient-efficient VNR-212 rootstock, which together promote carbon assimilation and antioxidant biosynthesis. T₆ (Utkal Tarini × VNR-212) formed the next tier (2.38 mg/100 g), followed by T₇ (Utkal Tarini × Sungro-704) at 2.19 mg/100 g; both were statistically lower than T₄ yet clearly superior to the non-grafted controls. Mid-range values included T₂ (*Solanum torvum* × VNR-212) and T₅ (Utkal Anushree × Sungro-704) with 1.96 mg/100 g and 1.95 mg/100 g, respectively, exceeding T₃ (*Solanum torvum* × Sungro-704) at 1.81 mg/100 g. Among controls, T₈ (Sungro-704 seedlings) averaged 1.79 mg/100 g, slightly higher than T₁ (VNR-212 seedlings) at 1.63 mg/100 g, but both remained significantly below the high-performing grafts. Overall, the findings indicate that strategic grafting, particularly the pairing of Utkal Anushree or Utkal Tarini with VNR-212, can markedly improve vitamin C accumulation in brinjal fruit. For tocopherol (vitamin E), T₄ (Utkal Anushree × VNR-212) again achieved the highest pooled content (0.50 mg/100 g), significantly exceeding all other treatments by a margin greater than the CD (Table 1 and figure 1). The next numerically highest value was recorded in T₂ (*Solanum torvum* × VNR-212) at 0.38 mg/100 g, although the large difference from T₄ confirmed the latter's pronounced superiority. T₅ (Utkal Anushree × Sungro-704) ranked third at 0.35 mg/100 g and was statistically comparable to T₂. Non-grafted controls (T₁ and T₈) and T₃ clustered around similar concentrations (0.30-0.31 mg/100 g) without significant differences. Lower tocopherol content was recorded in T₇ (0.26 mg/100 g) and T₆ (0.23 mg/100 g), both significantly inferior to T₄. Collectively, the results demonstrate that antioxidant vitamin enrichment in brinjal fruits is strongly governed by scion-rootstock compatibility. T₄ (Utkal Anushree × VNR-212) emerged as the most efficient combination, achieving the highest concentrations of both vitamin C and E across seasons, indicating simultaneous enhancement of water- and lipid-soluble antioxidants. T₆ and T₇ also showed notable vitamin C enrichment, while T₂ contributed substantially to tocopherol levels. These results support the effectiveness of precision grafting for nutraceutical enhancement under field cultivation. Davis *et al.* (2008) [4] similarly reported increased ascorbic acid in grafted tomato fruits, attributing improvements to enhanced antioxidant metabolism through compatible rootstock-scion interactions.

Table 1: Performance of grafted brinjal for various quality parameters

Treatment Details	Phenolic content (mg GAE/100gm)	Anthocyanin (mg/100gm)	Vitamin A (mg/100gm)	Vitamin B2 (mg/100gm)	Vitamin C (mg/100gm)	Vitamin E (mg/100gm)
T ₁ Seedling plants of VNR-212 (Control)	68.02	51.99	0.33	0.04	1.63	0.31
T ₂ <i>Solanum torvum</i> x VNR- 212	62.29	62.39	0.54	0.04	1.96	0.38
T ₃ <i>Solanum torvum</i> x Sungro- 704	54.88	57.72	0.74	0.04	1.81	0.30
T ₄ Utkal anushree x VNR- 212	73.95	63.88	0.27	0.04	2.57	0.50
T ₅ Utkal anushree x Sungro- 704	72.52	62.37	0.70	0.05	1.95	0.35
T ₆ Utkal Tarini x VNR- 212	81.99	57.43	0.21	0.05	2.38	0.23
T ₇ Utkal Tarini x Sungro- 704	73.17	60.40	0.84	0.05	2.19	0.26
T ₈ Seedling plants of Sungro- 704 (Control)	69.54	54.43	0.60	0.04	1.79	0.31
SE. m (±)	0.76	0.75	0.04	-	0.06	0.02
CV (%)	1.90	2.19	12.67	5.22	5.08	11.91
CD (5%)	2.31	2.26	0.12	NS	0.18	0.07

**Fig 1:** Performance of grafted brinjal for various quality parameters

Conclusions

Among the treatments, graft combinations involving Utkal Tarini and Utkal Anushree scions with either VNR-212 or Sungro-704 rootstocks consistently outperformed non-grafted controls and other grafts across a wide range of parameters. T₆ (Utkal Tarini × VNR-212) excelled in phenolic content and zinc concentration, indicating its superior capacity for antioxidant accumulation and micronutrient translocation. T₄ (Utkal Anushree × VNR-212) recorded the highest anthocyanin, ascorbic acid, and fibre contents, highlighting a strong physiological synergy conducive to flavonoid and structural carbohydrate biosynthesis. Similarly, T₅ (Utkal Anushree × Sungro-704) led in riboflavin and dry matter content, while T₇ (Utkal Tarini × Sungro-704) stood out for its elevated vitamin A levels. These results collectively affirm that the choice of compatible, vigorous scions paired with nutrient-efficient and disease-resilient rootstocks can significantly influence the metabolic efficiency and nutrient density of brinjal fruits. Notably, grafting not only enhanced antioxidant capacity (phenolics, anthocyanins, vitamins C and E) but also improved vitamins (A and B₂) all of which are critical for human health and market value. Therefore, strategic use of grafting, particularly with combinations like Utkal Anushree × VNR-212 and Utkal Tarini × Sungro-704, offers a sustainable and effective approach for improving the nutraceutical quality of brinjal under field conditions.

Conflict of interest

The authors declare that they have no conflict of interest.

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