



## Study on the effect of different rootstocks on cane biochemical composition in grape varieties

N A DESHMUKH<sup>1\*</sup>, S D GAT<sup>1</sup>, S R TAKALE<sup>1</sup>, S R SINHASANE<sup>1</sup>, P H NIKUMBHE<sup>1</sup>  
and R G SOMKUWAR<sup>1</sup>

ICAR-National Research Centre for Grapes, Pune, Maharashtra 412 307, India

Received: 8 July 2024; Accepted: 25 March 2025

### ABSTRACT

The present investigation aimed to study the effect of different rootstocks, viz. Dogridge (*V. champini*), 110R (*V. berlandieri* × *V. rupestris*), 140RU (*V. berlandieri* × *V. rupestris*), and 1103P (*V. berlandieri* × *V. rupestris*) on cane biochemical composition, yield and berry quality of new grape varieties, viz. Manjari Medika, Manjari Naveen, Manjari Kishmish along with Thompson Seedless. Experiment was conducted at ICAR-National Research Centre for Grapes, Pune, Maharashtra, during the year 2022–23 and 2023–24. Results showed that cane biochemical content varied significantly among the different rootstock-variety combinations influencing the grapevine fruitfulness, yield and berry quality. Among the rootstock variety combinations, grape variety Manjari Medika grafted on 140RU rootstock exhibited highest levels of carbohydrate (108.05 mg/g), proline (5.07 µmoles/g), and protein (5.90 mg/g) content. However, Manjari Naveen grafted on 110R showed the highest tannin (5.71 mg/g) and phenol (4.43 mg/g) content. Similarly, Manjari Medika × 140RU rootstock exhibit highest fruitfulness (95.74%), yield/vine (18.47 kg) with optimum berry quality, while lowest fruitfulness was recorded in Thompson Seedless × 1103P (81.13%) and minimum yield/vine in Manjari Naveen × Dogridge (8.46 kg), respectively. The study identified a notable linear correlation between yield per vine and cane biochemical, viz. carbohydrates, phenol, tannin, proline and protein. Further, Manjari Medika × 140RU is suggested as promising rootstock-variety combinations for quality grape production at tropical climate of India.

**Keywords:** Biochemical, Cane, Fruitfulness, Grapevine, Rootstock, Yield

Grape (*Vitis vinifera* L.) is as important commercial fruit crops in the world performing better at tropical region of India, where double pruning and single cropping followed. In India, grapevines are grown over an area of 1.62 lakh ha with an average productivity of 21.00 MT/ha from regions, viz. Maharashtra (70.67%), Karnataka (24.49%), Tamil Nadu (1.43%), Andhra Pradesh (1.34%), Madhya Pradesh (1.02%) and Mizoram (0.50%) (Anonymous 2022). During year 2022–23, country exported 2,67,950.39 MT of grapes having total value of Rs. 2,543.42 crores (APEDA 2023). To produce good quality grapes, rootstock is an ultimate choice and in tropical climate of India, use of rootstock is obligatory due to the rising incidence of biotic and abiotic stresses hampering grapevine yield and quality (Jogaiah *et al.* 2021). Further new varieties, viz. Manjari Medika, Manjari Naveen, Manjari Kishmish released for commercial cultivation at tropical climate of India, need suitable rootstock for sustainable quality production.

Different rootstock-variety combinations significantly influence the cane biochemical of grapevine, affecting nutrient uptake, stress tolerance and vine vigor (Toolo 2022). The mature, dark brown canes developed during back pruning decides the grapevine fruitfulness and yield after forward pruning. Thus, information on cane biochemical composition is key to their effective use particularly in new grape varieties. Different cane manipulations (length, thickness, number) and internal biochemicals had a greater effect in regulating production of quality grapes. The optimum level of cane biochemicals (carbohydrate, phenol, tannin, proline, protein) is vital for effective rootstock-variety pairing. As when metabolic needs surpass energy availability, plants maintain cellular functions, growth, and defense mechanisms, supported by carbohydrates (Leao and Oliveira 2023). Additionally, tannins in tree bark protect against microbial and fungal infections due to their antioxidative and antimicrobial properties (Hasler *et al.* 2023). The phenol concentration in canes is crucial for preserving plant structural integrity, while higher proline levels improve defense against biotic and abiotic stresses, enhance berry weight and quality, and serve as a nitrogen source for plant recovery (Burcova *et al.* 2019). Considering

<sup>1</sup>ICAR-National Research Centre for Grapes, Pune, Maharashtra. \*Corresponding author email: [nadeshmukh1981@gmail.com](mailto:nadeshmukh1981@gmail.com)

the above, experiment was conducted to study the effect of different rootstocks on cane biochemical composition, yield and berry quality of new grape varieties, viz. Manjari Medika, Manjari Naveen, Manjari Kishmish along with Thompson Seedless.

## MATERIALS AND METHODS

Experiment was conducted at the research farm of ICAR-National Research Centre for Grapes, Pune, Maharashtra, during 2022–23 and 2023–24 located at an altitude of 559 m amsl. Vineyard was established by planting rootstocks, viz. Dogridge (*V. champini*), 110R (*V. berlandieri* × *V. rupestris*), 140RU (*V. berlandieri* × *V. rupestris*), and 1103P (*V. berlandieri* × *V. rupestris*) in January 2017 (spacing: 2.74 m × 1.52 m). During August 2017, one-season-old hardwood stem cuttings (diameter: 6–8 mm and nodes: 4–5 nos.) of Thompson Seedless, Manjari Medika, Manjari Naveen, and Manjari Kishmish were wedge-grafted onto selected rootstocks and grafted vines were trained on Y-trellis system. Soil of experimental site was well-drained where deep black clay loam had initial pH, 6.2; Electrical conductivity, 0.07 dS/m; Organic carbon, 1.2%; N, 156.8 kg/ha; P, 0.078 kg/ha and K, 3360 kg/ha. The vineyard was drip irrigated based on pan evaporation irrigation schedule and fertilized with dose of 266 kg N (five splits), 177 kg P<sub>2</sub>O<sub>5</sub> (five splits), and 266 kg K<sub>2</sub>O/ha/year (four splits) along with FYM @25 t/ha and micronutrients. Necessary prophylactic plant protection measures were also undertaken during trial. Back pruning was performed in 1<sup>st</sup> week of April and forward pruning in 1<sup>st</sup> week of October in both the years following uniform cultural practices. At forward pruning, 30 shoots/vine having 6–7 buds/shoot were maintained and bunch load was regulated by retaining 40 bunches/vine. Weather data recorded during the fruiting period i.e. October 2022 to March 2023. During the period, air temperature varied from 7.20–38.90°C and daily average ranged between 15.32°C and 31.40°C. Relative humidity ranges from 44.50–82.12% with a mean value of 63.85% (Fig. 1). Similarly, during

October 2023 to March 2024, air temperature ranges from 11.30–40.21°C and daily average varies between 17.86°C and 31.93°C with mean value of 24.90°C. The relative humidity varied in the range of 13.50–80.00% with a mean value of 40.91% (Fig. 2).

At forward pruning, cane samples were collected from five-year-old grafted plants during both the seasons. Three canes from each of eight vines per replication were selected, dried to a constant weight, and ground into a homogenized powder. The powdered samples were sealed in airtight bags and stored at 4°C for biochemical analysis. Cane samples that had been powdered were combined with 10 ml of a 60:40 (v/v) ethanol:water solution. Following homogenization, extractions were subjected to shaker for 30 minutes @80°C with moderate stirring. The mixture was centrifuged at 10,000 rpm for 10 min while cooling before being filtered through a 0.2-micron membrane filter. Finally, the desired biological components were analyzed using cane extracts. Anthrone technique was used to estimate carbohydrates (mg/g) and absorbance was recorded at 630 nm (Hedge and Hofreiter 1962). Using Folin-Ciocalteu reagent, total phenol

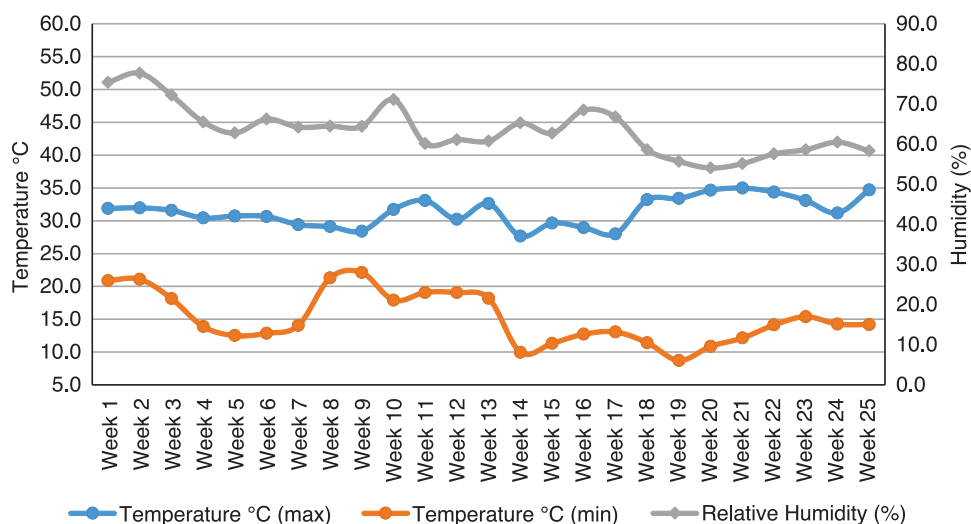


Fig. 1 Weather conditions during the fruiting period i.e. October 2022 to March 2023

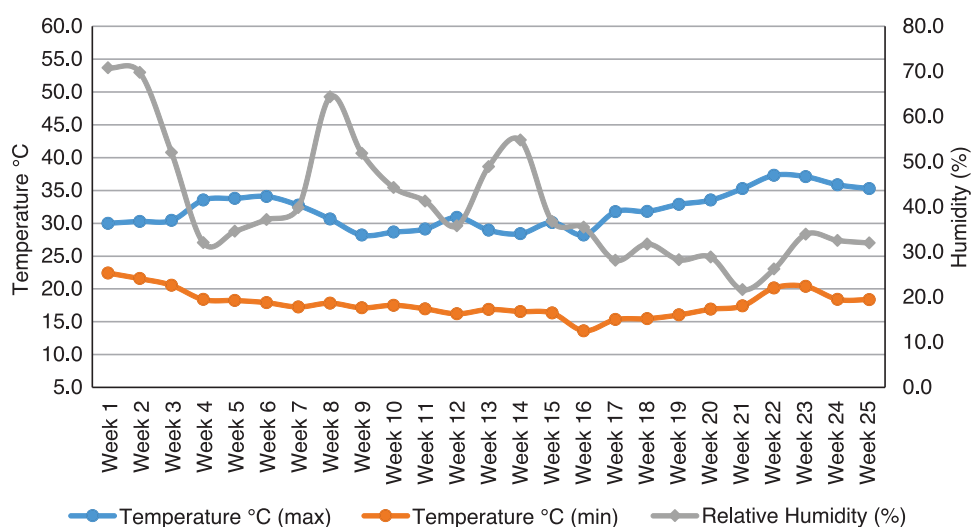


Fig. 2 Weather conditions during the fruiting period i.e. October 2023 to March 2024

(mg/g) and tannin content (mg/g) of canes was estimated and absorbance was recorded at 630 nm and 700 nm (Singleton and Rossi 1965). Proline content ( $\mu\text{moles/g}$ ) was measured calorimetrically and absorbance was recorded at 520 nm (Bates *et al.* 1973). Protein content (mg/g) was estimated using the colorimetric technique and absorbance was recorded at 660 nm (Lowry *et al.* 1951). Yield was calculated by weighing grape bunches from a composite sample of each vine and expressed as kg/vine. Canes were categorized into fruitful and vegetative canes, and the per cent fruitful canes was calculated. Average bunch weight was measured and expressed in g. Berry diameter was measured using Vernier Calipers and expressed in mm. Total soluble solids (TSS) were measured using a handheld digital refractometer, and titratable acidity was determined by titration with 0.1 NaOH using phenolphthalein as an indicator. The experiment was arranged in a factorial randomized block design with two factors: four grape varieties (Thompson Seedless, Manjari Medika, Manjari Naveen, and Manjari Kishmish) and four rootstocks (Dogridge, 110R, 140RU, and 1103P). Each treatment consisted of eight vines, replicated three times. Using SAS system software, version 9.3, significant differences between each variable were determined using analysis of variance (ANOVA) and means of the variables were separated using the Tukey's honest significant difference (HSD) test at  $P < 0.05$  when the F test was significant.

## RESULTS AND DISCUSSION

**Carbohydrate content:** The grapevine cane carbohydrate content showed significant effects that may be attributable to the variety (A), rootstock (B) and their interaction ( $A \times B$ ) (Table 1). Among varieties, canes of Manjari Medika showed the highest carbohydrate content (70.96 mg/g, while lowest carbohydrate content was recorded in Manjari Kishmish (54.50 mg/g). Among rootstocks, 140RU was stood out superior with most carbohydrate content (77.46 mg/g) and the lowest carbohydrate content observed in Dogridge (53.27 mg/g). In interaction ( $A \times B$ ), Manjari Medika vine grafted on 140RU showed the highest carbohydrate content (108.05 mg/g) in canes whereas, Manjari Kishmish vine grafted on Dogridge showed the minimum carbohydrate content (41.28 mg/g). Our experiment has notable effect of different rootstock-scion combinations on cane carbohydrate content. The 140RU rootstock supports better carbohydrate accumulation in the canes, ensuring robust growth and higher yield potential. This might be due to capacity of grapevine shelter for photosynthesis is associated with the transport and capacity of carbohydrates. The similar findings were also reported by Somkuwar *et al.* (2024) and Kose and Celik (2017) that grapevines grafted on 110R and 5C rootstocks had the noteworthy solvent starch contents.

**Phenol content:** The phenol content was significantly differed in the canes of grape varieties (Table 1). Manjari Naveen reported high mean value (4.21 mg/g) and low phenol content was observed in Manjari Kishmish and Thompson Seedless (2.43 mg/g each). The phenol content was not significantly influenced by the rootstocks. However,

Table 1 Carbohydrate (mg/g), Phenol (mg/g) and Tannin (mg/g) content in grapevine canes of different stionic combinations

|             | Rootstock (B)       | Carbohydrate content (mg/g) |                      |                     |                      | Phenol content (mg/g) |                    |                   |                    | Tannin content (mg/g) |          |                    |                    |                   |                    |          |
|-------------|---------------------|-----------------------------|----------------------|---------------------|----------------------|-----------------------|--------------------|-------------------|--------------------|-----------------------|----------|--------------------|--------------------|-------------------|--------------------|----------|
|             |                     | Dogridge                    | 110R                 | 140RU               | 1103P                | Mean(A)               | Dogridge           | 110R              | 140RU              | 1103P                 | Mean (A) | Dogridge           | 110R               | 140RU             | 1103P              | Mean (A) |
| Variety (A) |                     |                             |                      |                     |                      |                       |                    |                   |                    |                       |          |                    |                    |                   |                    |          |
|             | Manjari Medika      | 62.92 <sup>cd</sup>         | 45.30 <sup>ghi</sup> | 108.05 <sup>a</sup> | 67.58 <sup>c</sup>   | 70.96                 | 3.12 <sup>bc</sup> | 3.31 <sup>b</sup> | 3.54 <sup>b</sup>  | 3.47 <sup>b</sup>     | 3.36     | 4.13 <sup>b</sup>  | 4.37 <sup>b</sup>  | 4.68 <sup>b</sup> | 4.56 <sup>b</sup>  | 4.44     |
|             | Manjari Naveen      | 47.21 <sup>fghi</sup>       | 63.18 <sup>cd</sup>  | 65.77 <sup>cd</sup> | 48.15 <sup>fgh</sup> | 56.07                 | 4.12 <sup>a</sup>  | 4.43 <sup>a</sup> | 4.11 <sup>a</sup>  | 4.19 <sup>a</sup>     | 4.21     | 5.42 <sup>a</sup>  | 5.71 <sup>a</sup>  | 5.37 <sup>a</sup> | 5.46 <sup>a</sup>  | 5.49     |
|             | Manjari Kishmish    | 41.28 <sup>i</sup>          | 49.17 <sup>fg</sup>  | 84.53 <sup>b</sup>  | 43.03 <sup>hi</sup>  | 54.50                 | 2.29 <sup>d</sup>  | 2.41 <sup>d</sup> | 2.61 <sup>cd</sup> | 2.40 <sup>d</sup>     | 2.43     | 3.00 <sup>cd</sup> | 3.17 <sup>c</sup>  | 3.43 <sup>c</sup> | 3.16 <sup>c</sup>  | 3.19     |
|             | Thompson Seedless   | 61.68 <sup>de</sup>         | 57.32 <sup>e</sup>   | 51.52 <sup>f</sup>  | 62.97 <sup>cd</sup>  | 58.37                 | 2.33 <sup>d</sup>  | 2.34 <sup>d</sup> | 2.64 <sup>cd</sup> | 2.40 <sup>d</sup>     | 2.43     | 2.83 <sup>cd</sup> | 2.86 <sup>cd</sup> | 2.40 <sup>d</sup> | 2.84 <sup>cd</sup> | 2.73     |
|             | Mean (B)            | 53.27                       | 53.74                | 77.46               | 55.43                |                       | 2.96               | 3.12              | 3.22               | 3.11                  |          | 3.85               | 4.03               | 4.03              | 4.08               | 3.90     |
|             |                     | CD at 5%                    |                      |                     |                      | SE(d)                 | CD at 5%           |                   |                    |                       | SE(d)    | CD at 5%           |                    |                   |                    | SE(d)    |
|             | Variety (A)         | 2.50                        |                      |                     |                      | 1.22                  | 0.24               |                   |                    |                       | 0.11     | 0.18               |                    |                   |                    | 0.19     |
|             | Rootstock (B)       | 2.50                        |                      |                     |                      | 1.22                  | NS                 |                   |                    |                       | 0.11     | 0.37               |                    |                   |                    | 0.74     |
|             | Interaction (A × B) | 5.00                        |                      |                     |                      | 2.43                  | NS                 |                   |                    |                       | 0.23     | 0.18               |                    |                   |                    | 0.38     |

Means followed by different superscript are significantly different at  $P < 0.05$  according to the Tukey's honest significant difference (HSD) test, NS, Non-significant.

rootstock 140RU showed higher mean value (3.22 mg/g). Interaction ( $A \times B$ ) was found non-significant, while Manjari Naveen vine grafted on 110R ( $A \times B$ ) recorded highest phenol content (4.43 mg/g). Rootstocks-variety combination did not differ phenol content significantly, however they might play a role in the scion's ability to produce secondary metabolites. The variation in phenol content may be attributed to distinct genetic makeup of variety, rather than the rootstock (Nemeth *et al.* 2017) and might also depend upon the rootstocks' ability to absorb minerals (Naik *et al.* 2023).

**Tannin content:** Among the grape varieties (Table 1), Manjari Naveen canes exhibited notably highest tannin content (5.49 mg/g) followed by Manjari Medika (4.44 mg/g), whereas Thompson Seedless displayed the lowest tannin content (2.73 mg/g). This variation can be attributed to genetic differences of varieties influencing the activity of enzymes in the phenylpropanoid pathway, such as phenylalanine ammonia-lyase (PAL), leucoanthocyanidin reductase (LAR), and anthocyanidin reductase (ANR), which are key regulators of tannin biosynthesis (Raitanen *et al.* 2020). Interaction ( $A \times B$ ) revealed notable differences, in which Manjari Naveen grafted on 110R recording the highest tannin content (5.71 mg/g) followed by Manjari Naveen grafted on 1103P, while Thompson Seedless grafted on 140RU showing the lowest tannin content (2.40 mg/g). The higher tannin content in Manjari Naveen on 110R and 1103P might be due to the rootstock's ability to enhance nutrient and water uptake, which supports secondary metabolite production (Peiretti and Tassone 2020). Conversely, the lower tannin levels in Thompson Seedless grafted on selected rootstocks could be due to limited resource allocation for secondary metabolites in a variety with inherently low tannin synthesis. These findings suggest that rootstock-scion combinations significantly influence tannin accumulation and could be optimized for improved biotic stress resistance and vineyard productivity.

**Proline content:** Among the grape varieties (Table 2), Thompson canes had the high proline content (3.87  $\mu$ moles/g), at par with Manjari Medika (3.83  $\mu$ moles/g), while Manjari Kishmish canes had lower proline content (2.32  $\mu$ moles/g). Results related to the rootstocks was non-significant, however higher proline content was recorded in Dogridge (3.49  $\mu$ moles/g) followed by 110R (3.35  $\mu$ moles/g) and 140RU (3.28  $\mu$ moles/g). All the selected rootstocks are being salt and drought-tolerant, may be the reason for their identical impact on proline accumulation in this study. In interaction ( $A \times B$ ), distinct rootstocks significantly influenced the proline content in the canes with a more pronounced buildup was observed in Manjari Medika grafted on 140RU (5.07  $\mu$ moles/g) followed by Manjari Naveen grafted on 1103P (4.76  $\mu$ moles/g). This might be due to the stress tolerance exhibited by the above rootstocks as they are derived from parents known for stress resilience. Higher proline levels in canes contribute to defence against both biotic and abiotic stresses, thereby enhancing berry weight and quality and enhances the activity of antioxidant enzymes such as SOD (superoxide dismutase) and POD (peroxidase) (Squillaci *et al.* 2021). These results are in line with the Jogaiah *et al.* (2021).

**Protein content:** The protein content of canes was significantly influenced by both variety and rootstock, as well as their combinations (Table 2). Manjari Medika had the highest protein content (4.75 mg/g) and lowest protein content was observed in Manjari Kishmish (3.22 mg/g). Among the rootstocks, 1103P had the maximum protein content (4.28 mg/g) at par with 140RU (4.19 mg/g), whereas, the minimum was recorded in 110R (2.57 mg/g). In interaction ( $A \times B$ ), Manjari Medika vine grafted on 140RU showed the highest protein content (5.90 mg/g), while the Manjari Kishmish vine grafted on 110R recorded lower protein content (1.70 mg/g). Elevated protein content in canes suggests the plants' adaptability to extreme environmental conditions and its concentration tended to rise alongside cane thickness (Vuerich 2022). In our experiment, rootstocks

Table 2 Proline ( $\mu$ moles/g) and protein (mg/g) content in grapevine canes of different stionic combinations

| Variety (A) \ Rootstock (B) | Proline content (μmoles/g) |                     |                     |                    |         | Protein content (mg/g) |                      |                    |                      |         |
|-----------------------------|----------------------------|---------------------|---------------------|--------------------|---------|------------------------|----------------------|--------------------|----------------------|---------|
|                             | Dogridge                   | 110R                | 140RU               | 1103P              | Mean(A) | Dogridge               | 110R                 | 140RU              | 1103P                | Mean(A) |
| Manjari Medika              | 3.86 <sup>cde</sup>        | 3.20 <sup>fg</sup>  | 5.07 <sup>a</sup>   | 3.18 <sup>fg</sup> | 3.83    | 4.06 <sup>bcde</sup>   | 3.99 <sup>bcde</sup> | 5.90 <sup>a</sup>  | 5.03 <sup>ab</sup>   | 4.75    |
| Manjari Naveen              | 2.75 <sup>g</sup>          | 2.06 <sup>h</sup>   | 3.41 <sup>ef</sup>  | 4.76 <sup>a</sup>  | 3.24    | 3.93 <sup>cde</sup>    | 1.83 <sup>g</sup>    | 4.81 <sup>bc</sup> | 4.27 <sup>bcde</sup> | 3.71    |
| Manjari Kishmish            | 3.34 <sup>efg</sup>        | 4.70 <sup>ab</sup>  | 0.51 <sup>i</sup>   | 0.76 <sup>i</sup>  | 2.32    | 4.87 <sup>bc</sup>     | 1.70 <sup>g</sup>    | 1.77 <sup>g</sup>  | 4.56 <sup>bcd</sup>  | 3.22    |
| Thompson Seedless           | 4.03 <sup>cd</sup>         | 3.43 <sup>def</sup> | 3.85 <sup>cde</sup> | 4.15 <sup>bc</sup> | 3.87    | 3.51 <sup>bcd</sup>    | 2.77 <sup>def</sup>  | 3.29 <sup>f</sup>  | 4.29 <sup>bcde</sup> | 3.46    |
| Mean (B)                    | 3.49                       | 3.35                | 3.28                | 3.14               |         | 4.09                   | 2.57                 | 4.19               | 4.28                 |         |
|                             | CD at 5%                   |                     |                     |                    | SE(d)   | CD at 5%               |                      |                    |                      | SE(d)   |
| Variety (A)                 | 0.27                       |                     |                     |                    | 0.13    | 0.37                   |                      |                    |                      | 0.18    |
| Rootstock (B)               | NS                         |                     |                     |                    | 0.13    | 0.37                   |                      |                    |                      | 0.19    |
| Interaction (A × B)         | 0.55                       |                     |                     |                    | 0.27    | 0.74                   |                      |                    |                      | 0.38    |

Means followed by different superscript are significantly different at  $P < 0.05$  according to the Tukey's honest significant difference (HSD) test, NS, Non-significant.

Table 3 Fruitfulness, yield and berry quality parameters of different stionic combinations

| Parameter                    | Fruitfulness (%)     | Yield (kg/vine)     | Average bunch weight (g) | Berry diameter (mm) | TSS (°Brix)          | Acidity (%)        |
|------------------------------|----------------------|---------------------|--------------------------|---------------------|----------------------|--------------------|
| Variety (A)                  |                      |                     |                          |                     |                      |                    |
| Manjari Kishmish             | 92.72 <sup>a</sup>   | 10.84 <sup>b</sup>  | 273.59 <sup>d</sup>      | 13.83 <sup>d</sup>  | 22.15 <sup>a</sup>   | 0.57 <sup>a</sup>  |
| Manjari Medika               | 93.17 <sup>a</sup>   | 16.93 <sup>a</sup>  | 327.35 <sup>b</sup>      | 17.03 <sup>a</sup>  | 19.90 <sup>c</sup>   | 0.38 <sup>c</sup>  |
| Manjari Naveen               | 92.38 <sup>a</sup>   | 10.39 <sup>c</sup>  | 348.83 <sup>a</sup>      | 16.75 <sup>b</sup>  | 19.88 <sup>c</sup>   | 0.56 <sup>b</sup>  |
| Thompson Seedless            | 90.37 <sup>b</sup>   | 9.71 <sup>d</sup>   | 305.22 <sup>c</sup>      | 16.38 <sup>c</sup>  | 20.35 <sup>b</sup>   | 0.56 <sup>b</sup>  |
| SE(d)                        | 0.56                 | 0.10                | 2.15                     | 0.11                | 0.12                 | 0.00               |
| CD @5%                       | 1.13                 | 0.20                | 4.40                     | 0.23                | 0.25                 | 0.01               |
| Rootstock (B)                |                      |                     |                          |                     |                      |                    |
| 1103P                        | 88.47 <sup>c</sup>   | 12.28 <sup>b</sup>  | 316.29 <sup>b</sup>      | 16.12 <sup>a</sup>  | 20.35 <sup>c</sup>   | 0.51 <sup>b</sup>  |
| 110R                         | 94.22 <sup>a</sup>   | 11.79 <sup>c</sup>  | 299.40 <sup>c</sup>      | 16.06 <sup>a</sup>  | 20.39 <sup>bc</sup>  | 0.53 <sup>a</sup>  |
| 140RU                        | 91.79 <sup>b</sup>   | 12.83 <sup>a</sup>  | 298.64 <sup>c</sup>      | 15.70 <sup>b</sup>  | 20.63 <sup>b</sup>   | 0.51 <sup>b</sup>  |
| Dogridge                     | 94.16 <sup>a</sup>   | 10.98 <sup>d</sup>  | 340.66 <sup>a</sup>      | 16.10 <sup>a</sup>  | 20.91 <sup>a</sup>   | 0.51 <sup>b</sup>  |
| SE(d)                        | 0.56                 | 0.10                | 2.15                     | 0.11                | 0.12                 | 0.00               |
| CD @5%                       | 1.13                 | 0.19                | 4.40                     | 0.23                | 0.25                 | 0.01               |
| Variety (A) × Rootstock (B)  |                      |                     |                          |                     |                      |                    |
| Manjari Kishmish × 1103P     | 89.95 <sup>d</sup>   | 10.32 <sup>h</sup>  | 293.90 <sup>fg</sup>     | 13.87 <sup>g</sup>  | 21.00 <sup>c</sup>   | 0.58 <sup>a</sup>  |
| Manjari Kishmish × 110R      | 95.24 <sup>ab</sup>  | 11.08 <sup>g</sup>  | 270.47 <sup>h</sup>      | 14.44 <sup>f</sup>  | 22.84 <sup>a</sup>   | 0.57 <sup>ab</sup> |
| Manjari Kishmish × 140RU     | 93.60 <sup>abc</sup> | 12.06 <sup>e</sup>  | 257.37 <sup>i</sup>      | 13.20 <sup>h</sup>  | 22.20 <sup>b</sup>   | 0.55 <sup>cd</sup> |
| Manjari Kishmish × Dogridge  | 92.07 <sup>cd</sup>  | 9.91 <sup>i</sup>   | 272.63 <sup>h</sup>      | 13.80 <sup>g</sup>  | 22.56 <sup>ab</sup>  | 0.57 <sup>ab</sup> |
| Manjari Medika × 1103P       | 90.67 <sup>d</sup>   | 17.50 <sup>b</sup>  | 348.27 <sup>c</sup>      | 16.40 <sup>d</sup>  | 19.90 <sup>efg</sup> | 0.38 <sup>g</sup>  |
| Manjari Medika × 110R        | 94.00 <sup>abc</sup> | 15.55 <sup>d</sup>  | 290.53 <sup>g</sup>      | 17.60 <sup>a</sup>  | 19.72 <sup>fg</sup>  | 0.41 <sup>f</sup>  |
| Manjari Medika × 140RU       | 95.74 <sup>a</sup>   | 18.47 <sup>a</sup>  | 301.00 <sup>f</sup>      | 16.50 <sup>d</sup>  | 20.12 <sup>def</sup> | 0.39 <sup>g</sup>  |
| Manjari Medika × Dogridge    | 94.73 <sup>ab</sup>  | 16.22 <sup>c</sup>  | 369.60 <sup>b</sup>      | 17.60 <sup>a</sup>  | 19.86 <sup>efg</sup> | 0.34 <sup>h</sup>  |
| Manjari Naveen × 1103P       | 92.11 <sup>cd</sup>  | 9.93 <sup>h</sup>   | 327.20 <sup>e</sup>      | 17.00 <sup>bc</sup> | 19.90 <sup>efg</sup> | 0.56 <sup>bc</sup> |
| Manjari Naveen × 110R        | 93.29 <sup>bc</sup>  | 11.41 <sup>fg</sup> | 340.13 <sup>cd</sup>     | 16.40 <sup>d</sup>  | 19.40 <sup>g</sup>   | 0.57 <sup>ab</sup> |
| Manjari Naveen × 140 RU      | 89.99 <sup>d</sup>   | 11.78 <sup>ef</sup> | 334.73 <sup>de</sup>     | 16.40 <sup>d</sup>  | 19.90 <sup>efg</sup> | 0.54 <sup>de</sup> |
| Manjari Naveen × Dogridge    | 94.11 <sup>abc</sup> | 8.46 <sup>k</sup>   | 393.27 <sup>a</sup>      | 17.20 <sup>ab</sup> | 20.30 <sup>de</sup>  | 0.55 <sup>cd</sup> |
| Thompson Seedless × 1103P    | 81.13 <sup>e</sup>   | 11.38 <sup>g</sup>  | 295.80 <sup>fg</sup>     | 17.20 <sup>ab</sup> | 20.60 <sup>cd</sup>  | 0.53 <sup>e</sup>  |
| Thompson Seedless × 110R     | 94.33 <sup>abc</sup> | 9.14 <sup>j</sup>   | 296.47 <sup>fg</sup>     | 15.80 <sup>e</sup>  | 19.60 <sup>g</sup>   | 0.58 <sup>a</sup>  |
| Thompson Seedless × 140RU    | 90.28 <sup>d</sup>   | 9.02 <sup>j</sup>   | 301.47 <sup>f</sup>      | 16.70 <sup>cd</sup> | 20.30 <sup>de</sup>  | 0.55 <sup>cd</sup> |
| Thompson Seedless × Dogridge | 93.28 <sup>bc</sup>  | 9.33 <sup>j</sup>   | 327.14 <sup>e</sup>      | 15.80 <sup>e</sup>  | 20.90 <sup>c</sup>   | 0.56 <sup>bc</sup> |
| SE(d)                        | 1.11                 | 0.19                | 4.31                     | 0.22                | 0.25                 | 0.01               |
| CD @5%                       | 2.27                 | 0.39                | 8.80                     | 0.45                | 0.50                 | 0.02               |

Means followed by different superscript are significantly different at  $P < 0.05$  according to the Tukey's honest significant difference (HSD) test.

showed significant affected cane protein content, possibly due to their differing root development patterns, which alter vine growth and affect water and nutrient absorption from the soil (Popova 2021).

**Fruitfulness and yield per vine:** Among the grape varieties (Table 3), Manjari Medika exhibited the highest fruitfulness (93.17%) and yield/vine (16.93 kg), while lowest in Thompson Seedless (90.37% and 9.71 kg), respectively. In rootstocks, 110R had the highest fruitfulness (94.22%), while 1103P recorded lowest (88.47%). The highest yield/vine was recorded in 140RU (12.83 kg), while lowest in Dogridge

(10.98 kg). In interaction (A × B) Manjari Medika × 140RU recorded the highest fruitfulness (95.74%) and yield/vine (18.47 kg), while lowest fruitfulness was recorded in Thompson Seedless × 1103P (81.13%) and lowest yield/vine in Manjari Naveen × Dogridge (8.46 kg). The variation in varieties might be due to varietal behaviour and their genetic makeup. Our experiment has significant effect of different rootstock-variety combinations on grapevine fruitfulness and yield per vine. The highest fruitfulness and yield/vine were recorded in Manjari Medika × 140RU combination might be due to better carbohydrate accumulation in the canes

support better vine growth ensuring higher yield (Kose and Celik 2017 and Somkuwar *et al.* 2024).

**Berry quality:** Among the varieties (Table 3), Manjari Naveen recorded highest bunch weight (348.83 g) and Manjari Medika recorded highest berry diameter (17.03 mm), whereas lowest bunch weight (273.59 g) and berry diameter (13.83 mm) was noticed in Manjari Kishmish. Among the rootstock, Dogridge exhibited highest bunch weight (340.66 g) and 1103P showed the highest berry diameter (16.12 mm), whereas lowest bunch weight (298.64 g) and berry diameter (15.70 mm) was recorded in 140RU. In interaction highest bunch weight was recorded in Manjari Naveen × Dogridge (393.27 g), whereas the lowest was observed in Manjari Kishmish × 140RU (257.37 g). For berry diameter, Manjari Medika × 110R and Dogridge exhibited the highest berry diameter (17.60 mm), while lowest berry diameter was observed in Manjari Kishmish × 140RU (13.20 mm). In quality, Manjari Kishmish exhibited the highest TSS (22.15°B) and acidity (0.57%). Among rootstock Dogridge exhibited the highest TSS (20.91°B), while 1103P had the lowest (20.35°B). In interaction, highest TSS was recorded in Manjari Kishmish × 110R (22.84°B). The lowest acidity was observed in Manjari Medika × Dogridge (0.34%), while highest in Thompson Seedless × 110R and Manjari Kishmish × 1103P (0.58% each). Cane carbohydrate and protein storage lead to greater accumulation of food material for berry development, resulting in larger berry diameters (Nuzzo and Matthews 2005). The variation among the varieties might be due to their distinct genetic makeup (Nemeth *et al.* 2017) and rootstocks' ability to absorb minerals (Naik *et al.* 2023). These findings underline the importance of rootstock-variety combinations in optimizing grape production. Internal biochemical factors, such as carbohydrate and protein storage, as well as proline levels, enhance berry development and quality. The results align with previous studies by Romero *et al.* (2018) in grapevine.

**Correlation studies:** Correlation matrix showed a significant and positive relationship between yield per vine and carbohydrate content (0.59) (Supplementary Table 1). Whereas, tannin was indirectly significant and positively correlated with the phenol (0.97). Phenol, tannin, proline and protein content showed a positive, but non-significant relationship with yield per vine. Similar results have been recorded by Naik *et al.* (2023) in correlation with tannin and phenols (0.96) and Satisha *et al.* (2007) reported a significantly positive correlation between protein and phenol content in canes (0.72). Interestingly there is none of the characteristic which showed negative correlation with the yield per vine. Hence, these all are the most important characteristics contributing towards yield and plant defense mechanisms.

Results showed that cane biochemical content, fruitfulness, yield and berry quality varied significantly among the different rootstock-variety combinations. Grape variety, Manjari Medika grafted on 140RU rootstock exhibited highest levels of cane biochemical along with

higher fruitfulness, yield and optimum berry characteristics. The study also identified a notable linear correlation between yield per vine and cane biochemicals, suggesting their contribution in growth and development of grapevine.

## REFERENCES

- Anonymous. 2022. *Area and Production of Horticulture Crops (2021–22)*. National Horticulture Board. Ministry of Agriculture and Farmers Welfare, Government of India, India.
- APEDA. 2023. [https://apeda.gov.in/apedawebsite/SubHead\\_Products/Grapes.html](https://apeda.gov.in/apedawebsite/SubHead_Products/Grapes.html)
- Bates L S, Waldren R P A and Teare I D. 1973. Rapid determination of free proline for water-stress studies. *Plant and Soil* **39**: 205–07.
- Burcova Z, Kreps F, Schmidt S, Strizincova P, Jablonsky M, Kyselka J, Haz A and Surina I. 2019. Antioxidant activity and the tocopherol and phenol contents of grape residues. *BioResources* **14**(2): 4146–56.
- Hasler G S, Sommerauer L, Schnabel T, Oostingh G J and Schuster A. 2023. Antioxidative and antimicrobial evaluation of bark extracts from common European trees in light of dermal applications. *Antibiotics* **12**(1): 130.
- Hedge J E and Hofreiter B T. 1962. *Carbohydrate Chemistry*, Vol. 17. Whistler R L and Be Miller J N (Eds), Academic Press, New York.
- Jogaiah S, Porika H and Upreti K. 2021. Biochemical and histological basis of graft compatibility in Red Globe grapes (*Vitis vinifera* L.) grafted on different rootstocks. *Modern Concepts and Developments in Agronomy* **9**(2): 896–901.
- Kose B and Celik H. 2017. Phenological changes of shoot carbohydrates and plant growth characteristics in *Vitis Labrusca* L. grape. *Journal of Polymer Science* **61**(1): 257–68.
- Leao P C D S and Oliveira C R S D. 2023. Agronomic performance of table grape cultivars affected by rootstocks in semi-arid conditions. *Bragantia* **82**: 20220176.
- Lowry O H, Rosebrough N J, Farr A L and Randall R J. 1951. Protein measurement with the Folin phenol reagent. *Journal of Biological Chemistry* **193**(1): 265–75.
- Naik S, Tiwari J, Singh B and Sharma D P. 2023. Biochemical attributes of grapes grown at high elevations in Himachal Pradesh. *Grape Insight* **1**(1): 23–31.
- Nemeth G, Molnar Z, Podmaniczky P, Nyitrai-Sardy D, Kallay M, Dunai A and Kocsis L. 2017. Trans-resveratrol content in grape cane and root of different variety-rootstock combinations. *Mitteilungen Klosterneuburg* **67**: 256–64.
- Nuzzo V and Matthews M A. 2005. Berry size and yield paradigms on grapes and wines quality. (In) *International Workshop on Advances in Grapevine and Wine Research* **754**: 423–36.
- Peiretti P G and Tassone S. 2020. Nutritive value of leaves and pruning residues of red and white grapevine (*Vitis vinifera* L.) varieties. *Grapevines at a Glance*, pp. 111–26. Nova Science Publishers, Inc. New York, USA.
- Popova A. 2021. Influence of the biochemical composition of vine canes on cold resistance of buds in different 'Syrah' clones. *Scientific Papers Series B, Horticulture* **1**: 328–33.
- Raitanen J E, Jarvenpaa E, Korpinen R, Makinen S, Hellstrom J, Kilpelainen P, Liimatainen J, Ora A, Tupasela T and Jyske T. 2020. Tannins of conifer bark as nordic piquancy-sustainable preservative and aroma. *Molecules* **25**(3): 567.
- Romero P, Botia P and Navarro J M. 2018. Selecting rootstocks to improve vine performance and vineyard sustainability in deficit irrigated monastrell grapevines under semiarid conditions.

- Agricultural Water Management* **209**: 73–93.
- Satisha J, Ramteke S D and Karibasappa G S. 2007. Physiological and biochemical characterization of grape rootstocks. *South African Journal of Enology and Viticulture* **28**: 163–68.
- Singleton V L and Rossi J A. 1965. Colorimetry of total phenolics with phosphomolybdic-phosphotungstic acid reagents. *American journal of Enology and Viticulture* **16**(3): 144–58.
- Somkuwar R G, Thutte A S, Upadhyay A K, Deshmukh N A and Sharma A K. 2024. Rootstock influences photosynthetic activity, yield, and berry quality in Manjari Naveen grape. *Indian Journal of Horticulture* **81**(1): 43–47.
- Squillaci G, Zannella C, Carbone V, Minasi P, Folliero V, Stelitano D, Cara F L, Galdiero M, Franci G and Morana A. 2021. Grape canes from typical cultivars of campania (southern Italy) as a source of high-value bioactive compounds: Phenolic profile, antioxidant and antimicrobial activities. *Molecules* **26**(9): 2746.
- Toolo K B. 2022. 'Effect of post-harvest summer pruning on carbohydrate reserve status, bud break and fertility of Sultanina H5 in the lower orange river region'. Phd Thesis, Stellenbosch University, Stellenbosch.
- Vuerich M. 2022. *Vitis vinifera* and drought stress: Physiological and anatomical responses. *Anno Accademico* **4**: 34.