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Role of rootstocks in yield and quality of grapes (*Vitis vinifera*) under semi-arid tropics of India: a review

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ABSTRACT

Grape (*Vitis vinifera* L.) cultivation is gaining importance under tropical and subtropical conditions of India by adapting advance crop techniques. The problems of detoriated soil, poor and shortage of water conditions affecting the grape production on own rooted vines. There are a large number of rootstocks available in grape cultivation according to different production constraints. Rootstock not only helps in withstanding vineyard in adverse climatic conditions but also help in improving yield and quality of grapes. The rootstock Dogridge became popular among the grape growers due to its capabilities of overcoming abiotic stresses and better stionic combination. The rootstock suitable for one variety in a given location may not be suitable for the same variety on other location. Hence, choice of rootstock is varied among different cultivars. In view of better yield and quality of grapes, there should have better stock-scion compatibility which imparts high vigour into the scion.

Key Words: Rootstock, Semi arid tropics, Vinryard, Climatic conditions, Abiotic stresses, Stionic combination

Grape (*Vitis vinifera* L.) cultivation gained significance under tropical condition in India, Brazil, Venezuela and Thailand. Varietal adaptability and technological interventions facilitate successful grape growing under tropical conditions (Somkuwar *et al*., 2021). Grapes were an introduction by Mughals in 1300 (Tripathi *et al*., 2018). In India, grapes are mainly consumed as fresh fruit, while small portion is utilized for raisins, juice and wine. The grape production in India is about 31.25 lakh million tonnes from 1.40 lakh ha with a productivity of 21.00 tonnes/ha.

Rootstock has potential to manipulate the vine growth and productivity (Menora *et al*., 2018). In India, maximum grapevine production is on Y-trellis (Sharma *et al*., 2022). Traditionally grape was grown in India on its own roots. However, subsequent deterioration in soil and water, and use of rootstock has become important in semi-arid tropical climate to sustain production and fruit quality. Choice of specific rootstock for establishment of vineyard is difficult due to wider options. *Vitis* species, such as *V. champinii*, *V. rupestris*, *V. berlandierii*, *V. longii*, *V. parviflora*, etc. has capacity to synthesize biochemical constituents modulating scion physiology, root morphology, development and distribution (Somkuwar *et al*., 2012).

To overcome the abiotic stresses like drought and salinity, Dogridge became popular rootstocks among growers, however in long run it induces higher vigour on scion under tropical and subtropical climate which reduces bud fruitfulness (Satisha *et al*., 2010). Thus, 110 R rootstock was recommended for hot semi-arid tropical climate (Somkuwar *et al*., 2006, a). The rootstocks, *viz.* St. George, 110R, 140Ruggeri, 1103 Paulsen and 99R possessed strong drought tolerant root structures compared with SO4 and 5C.

After Dogridge, 1613C and Salt Creek were found relatively salt tolerant under Na_2SO_4 salinity at EC levels of 9.27, 9.07 and 8.34 dS/m. To ease the identification and selection of rootstock considering production constraints. the criteria for selecting rootstocks, *viz.* phylloxera resistance, nematode resistance, adaptability to high pH and low soils pH, adaptability to saline soils, adaptability to wet or poorly drained soils, adaptability to drought came into existence (Reynolds and Wardle, 2001). On the basis of production constraints suitable rootstocks were identified for semi-arid tropical climate (Table 1).

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Table 1. Suitable rootstocks based on different production constraints

Situation/problem	Rootstock
Water shortage	1103 P, 140 Ru, 110-R, 420A, SO4, 99- R, St. George, Dogridge
Soil EC more than 2 m mohs/ cm and water EC more than 1 m mohs/cm	Ramsey, Dogridge, 140 Ru, 99 R, 110 R.
Soil ESP more than 15 per cent and/or water SAR more than 8.	140 Ru, 1613, Ramsey, Dogridge.
Free calcium content of soil is more than 12%	140 Ru, SO 4, 420 A.
Chloride content of water is more than 4 meq/litre	Ramsey, Dogridge B, 140 RU. Teleki 5-C
Poor vigor of the variety without any soil/water problem	Dogridge, St. George, SO 4, 140 RU.
For increased nitrogen, potassium uptake.	Dogridge, St. George, 34 EM, Ramsey.
For increased bud break	1613, B2-56.

In subtropical and tropical climates of India, absence of dormancy period in grapevine creating hurdle in breaking bud dormancy required special management techniques to overcome problems of low bud fertility and higher vigour. If rootstock chooses appropriately, it improves the quality, ensure uniformity and synchronise the bud sprout, ensure fruitfulness and proper grapevine vigour (Satisha *et al*., 2013) which need variety- specific research and long-term studies to monitor the effects of rootstock-scion interaction in vineyard to identify the best combination (Kose *et al*., 2014).

Grapevine is commercially produced at semi- arid tropical climate of India, facing serious problem due frequent drought and soil salinity for which rootstock is an option. In this background, understanding the rootstock-scion synergy for unlocking the productivity potential, besides safeguarding the soil, we discussed herewith the influence of rootstock on grapevine at semi-arid tropical climate of India to give desired stimulus to the productivity and quality.

Stock-scion compatibility

Movement of assimilates in grape vine is associated with growth stage, i.e. budburst to early bloom, roots and permanent woody structures etc vine provide carbon and sugar from stored reserves to new shoots (Zapata *et al*., 2004). According to Mortensen 1972, Dogridge rootstock is compatible with scion cultivars, viz. Norris, Stover, Blue Lake, FES A3-34 and FES A3-60. Chardonnay and P Auxervos grafted on clones of Kober 5-BB, developed symptoms of leaf fall and yellow vein at nursery. Rugerri and Richter rootstock resulted in better healing of grafts union in grapevine cultivars, viz. Halawani, Beiruiti Zaini and Beituni (Abu Qaoud, 1999).

The variety Tas-A-Ganesh and Thompson Seedless on Dogridge rootstock proved better for stionic combination and growth. Similarly, higher graft compatibility rate was reported by Kim *et al*. (2005) in Kyoho grapevines grafted on different rootstocks than Campbell Early in a range between 11 % (Tam-nara/ Rupestris du Lot) and 100 % (Schuyler/ Couderc 3309). The combinations of Jandali with 110R, White-Romi with 140Ru, White-Romi with 216/3 and White-Romi with 41B highly exhibited good compatibility, while Hamadani-Baladi and Zeiny showed lower compatibility (Hamdan and Basheer-Salimia, 2010).

Pusa Urvashi grafted on Dogridge rootstock was found to be most compatible compared to grafted on Salt Creek, 1613 and H-144 rootstocks (Verma *et al*., 2010). In cv. Red Globe, rootstock 140R was found better than 41B (Gargin and Altindisli, 2014). Vrsic *et al*. (2016) observed better compatibility of Welsch Riesling grapevine with 5BB, G251 and G103 rootstocks (80%). Miele and Rizzon (2017) reported that among the fifteen rootstocks Rupestris du Lot, 101-14 Mgt., 3309C, 5BB-K, 161- 49C, 1103P and Isabel were compatible with Cabernet Sauvignon grapevines. Ghule *et al*. (2019) reported better compatibility of grape varieties, viz. Crimson Seedless, Nanasaheb Purple and Manjari Naveen with Dogridge and 1103P rootstocks.

Growth parameters

Rootstock plays an important role in utilizing the reserved food material available in different wine parts, i.e. root, shoot, trunk and fruit and root carbohydrates leads to shoot and root development hence, results into a good flower bud initiation and fruit set. Yield of grape vine is a measure of vegetative vigour contributed by shoot length, shoot diameter and pruning biomass. The yield is positively correlated with the vigour obtained by stionic combination. The high pruning weight results into the maximum fruitfulness in vines due to the higher carbohydrate reserves. The rootstock suitable for one

variety in a given location may not be suitable for the same variety in other location. Similarly, rootstock 420A on cv. Sangiovese Toscano (Basso and Natali, 1981); rootstock Kober 5-BB on cv. Gamay Rouge and Kobber-5BB and 1103P rootstock on cv. Chardonnay imparted higher.

In grape, grafted vines were always more fruitful than own rooted vines (Sommer *et al*., 2001). Gruner Veltliner grape had a higher wood productivity on SO4, K5BB and 5C rootstock than own rooted vines, while highest pruning weight in grape cv. Tas-A-Ganesh and Thompson Seedless on Dogridge rootstock. Thompson Seedless and Dogridge rootstock was a better combination at semi-arid tropical climate compared with own rooted vines Satisha *et al.* (2010). Satisha *et al*. (2013) reported maximum fruitful canes on 110R and own rooted vines, while minimum on Dogridge and St. George rootstock (22.73 and 18.66 %, respectively).

There was significant influence of stock:scion on pruning weight, girth of scion and stock in cv. Thompson Seedless and Tas-A-Ganesh grafted on Dogridge, Salt Creek, 1613-C, 1616-C and St. George rootstock. Similarly, Pusa Urvashi grafted on Dogridge rootstock showed highest shoot length, number of leaves and stock:scion ratio while Pusa Urvashi grafted on 1613 rootstock recorded maximum leaf area Verma *et al*. (2010). Manjuvani (2012) recorded high pruning weight (2.66 kg/vine) and number of canes (45.60) per vine in grafted vine of Thompson Seedless.

Kose *et al*. (2014) found highest shoot length, shoot diameter and internode length in cultivar Merzifon Karasi on 110R, 8B and Rupestris du Lot rootstocks. Somkuwar *et al*. (2014, b) found highest shoot length, internodal length, shoot diameter and leaf area of Thompson Seedless grafted onto Dogridge rootstock as compared with own rooted. Somkuwar *et al*. (2015) found better growth parameters in Fantasy Seedless grafted on Dogridge, followed by 110R rootstock. Cv. Red Globe recorded maximum shoot growth on Freedom rootstock, while maximum leaf area on Salt Creek rootstock Hifny *et al.* (2016). Clingeleffer *et al*. (2019) reported that Chardonnay, Cabernet Sauvignon and Shiraz vines grafted on Ramsey rootstock recorded maximum pruning weight and number of bunches/vine and also suggested to have different rootstocks for each variety to optimise scion performance and fruit composition.

The influence of rootstock on yield and physiological parameters was reported by Elaidy *et al*. (2019) and recommended Salt Creek as the best rootstock for grape cv. Superior Seedless under soil salinity condition. Ghule *et al.* (2019) reported that Dogridge and 1103P rootstock for better performance under semi-arid climate. Marin *et al*. (2019) found that Syrah and Tempranillo grafted on 3309C rootstock had highest vigour. They also noted that rootstocks had a clear effect on vegetative growth for Syrah and Tempranillo wine cultivars.

Shelake *et al*. (2019) reported that Sonaka perform well on Dogridge rootstock. Cabernet Sauvignon recorded maximum pruning weight on Dogridge and 420A rootstock while vines grafted on 3309 rootstock recorded minimum pruning weight as reported by Gautier *et al*. (2020). Ghule *et al*. (2021) found that Red Globe grapevines grafted on Dogridge followed by Salt Creek rootstock proved better for growth parameters. The response of rootstock on growth attributes at hot semi-arid tropical climate of India is depicted in Table 2.

Table 2. Promising scion:stock combination based on growth attributes

Scion:rootstock combination	Reference
Cv. Anab-e-Shahi on Dogridge and 1616	Reddy *et al.,* 1992
Cv. Thompson seedless on 110R	Satisha *et al*. 2013
Cv. Pusa Urvashi grafted on Dogridge	Verma *et al*., 2010
Cv. Thompson Seedless on Dogridge	Somkuwar *et al*., 2014, b
Cv. Fantasy Seedless on Dogridge and 110R	Somkuwar *et al*., 2015
Cv. Sonaka on Dogridge	Shelake *et al*., (2019)

Photosynthetic efficiency

Rootstock influences the photosynthetic efficiency and dry matter partitioning of scion cultivars and modulate yield and quality. In grapevine rootstocks modify leaf gas exchange of scion under non-irrigated conditions, even though vine water status was not altered (Padgett-Johnson *et al*., 2000). Occurrence of drought and salt accumulation in the soil results into leaf scorching thereby affecting the photosynthetic activity of grapevine. The total nutrient availability and source-sink relationship directly affects the photosynthetic efficiency of vine.

The scion specific response of rootstock recorded lower photosynthesis rate in Chardonnay vines grafted on SO4 compared with 1103 P, while Pinot Noir similar rates of assimilation on SO4 and 1103P rootstock (Bica *et al*., 2000). Similarly, Verma *et al*. (2010) recorded highest photosynthetic rate of Pusa Urvashi on Salt Creek rootstock compared with H-144 rootstock. Among ten grape rootstock higher transpiration and photosynthesis were recorded on 1613C and St. George rootstock (Satisha *et al*., 2014). The Promising scion:stock combination based on the photosynthetic efficiency (Table 3).

Table 3. Promising scion:stock combination based on photosynthetic efficiency

Scion:rootstock combination	References
Cv. Pusa Urvashi on Salt Creek	Verma *et al*., 2010
Cv. Sauvignon Blanc on 140Ru and Fercal	Somkuwar *et al*., 2014,a
Cv. Fantasy Seedless on 110R	Somkuwar *et al*., 2015
Cv. Crimson Seedless, Manjari Naveen and Nanasaheb Purple on 1103P and Dogridge	Ghule *et al*., 2019

Sultana grapevines on Freedom rootstock showed highest net CO_2 assimilation and stomatal conductance, while lowered on Harmony rootstock (Morales *et al*., 2014). Similarly, Somkuwar *et al*., (2014,a) observed highest photosynthesis rate in Sauvignon Blanc on 140Ru followed by Fercal, whereas lowest on Salt Creek rootstock. Somkuwar *et al*. (2015) also reported the varied photosynthesis rate among the different stionic combinations ranged from 8.74 to 12.86 μmol/CO_2/cm^2/s. They recorded lowest photosynthesis rate in Fantasy Seedless on 41B rootstock, while 110R rootstock recorded highest photosynthesis rate. The rate of stomatal conductance was highest in Fantasy Seedless grafted on 41B.

According to Siamak, (2018), Asgari–Shahani combination recorded the highest chlorophyll content with maximum photosynthesis efficiency. Grape cultivars, Crimson Seedless, Manjari Naveen and Nanasaheb Purple, grafted on 1103P and Dogridge rootstock recorded higher photosynthetic activities (Ghule *et al*., 2019). Frioni *et al*. (2020) concluded that 1103P can be used to impart resilience of vines to summer drought.

Petiole nutrient

Leaf mineral nutrition varied due to rootstock in Chasselas grapevine (Bovay, 1959). The highest nitrogen and phosphorous in leaves of ten scions varieties grown on St. George rootstock showed higher accumulation of nitrogen in petioles of scion grafted on St. George (Rupesteris du Lot) was also reported by Cook and Lider (1964). The leaf N and K contents were recorded maximum on Kober-5BB rootstock and minimum on Chasselas x Berlandieri 41B and intermediate on Rupestris du Lot, while leaf P was not affected by rootstocks. Similarly, higher leaf nitrogen content in Anab-e-Shahi grafted on Dogridge and potassium content were recorded on St. George rootstock (Bhargava *et al*., 1982).

However, Cabernet Sauvignon grapevines grafted on Arman, Ruperstris Gan No.1 (AXR-1), Rupestris du Lot or 5C- Teleki rootstocks had no effect on partitioning of dry matter in vines. In rootstocks, 1613C had greater affinity for nitrogen, whereas St. George showed higher inflow rate of nitrogen (Williams and Smith, 1991). Red Globe vines grafted on Freedom rootstock had higher level of N, P and K than Harmony and 1613C (Badr, 1994). This might be due to that every rootstock having differential response for nutrient uptake.

There is variety specific differential response of rootstock on scion cultivar. There was an increase in total N from 67%, 77%, 33 % and 8.5 % in Flame Seedless, Red Globe, Thompson Seedless and in Superior Seedless, respectively, on Salt Creek rootstock (Ibacache and Carlos, 2009). The petiole P level was found doubled in all varieties on Salt Creek rootstock. Harmony and 1613C showed higher K levels by at least 60% in cv. Flame Seedless, Red Globe and Thompson Seedless than those on their own rooted vines. Dalbo *et al*. (2011) recommended that rootstock must be considered for nutritional status evaluation and fertilizer recommendation (K and Mg uptake) in grape vine and observed highest K/Mg ratio in cv. Isabella on hybrid rootstocks VR 043-43 and VR 044-4 and lowest K/Mg ratio in own rooted vine.

At critical fruit bud differentiation stage, recorded higher petiole N and K content in Thompson Seedless grafted grapevines compared to own root (Vijaya and Rao, 2015). Rootstocks has dominance in preferential absorption of Mg, Na and Zn, while scion varieties for nutrients like N, P, K, Fe and Cu and suggested that 110R and Dogridge rootstock can be used to limit

the absorption of sodium in cv. Thompson Seedless, Sonaka and Clone 2A (Kalbhor *et al*., 2017). Vijaya *et al.* (2019) recorded higher petiole N content in vines grafted on Dogridge rootstock at full bloom, while effect on increasing petiole K content was recorded with Dogridge at bud differentiation stage. Considerable increase in phosphorus (P) content was recorded in vines grafted on 1103P compared to own rooted vines. Besides rootstocks, Thompson Seedless cultivar recorded higher N and P and Kishmish Chorni recorded higher K content. The Early bud break was observed with 1103P and own rooted vines among rootstocks and with Kishmish Chorni.

Cane physiology

The physiological and biochemical constituents of grape rootstocks varied significantly influencing the scion response to different stresses. Rootstocks of *Vitis berlandierii* × *Vitis rupestris,* group, *viz.* 110R, 1103P, 99R and B2-56, had significantly higher total phenols, flavon-3-ols, flaveonoids, proline and protein content in canes. Which help in reducing the incidence diseases in grape (Cetin *et al*., 2011). Cv. Red Globe recorded higher nitrogen and total carbohydrate content on Dogridge, Salt Creek, Freedom, Harmony and 1103P rootstocks compared with own rooted vines (Rizk-Alla *et al*., 2011).

Similarly, Tas-A-Ganesh grafted on Dogridge rootstock recorded higher accumulation carbohydrate, starch, protein and phenol content in canes of grafted vine as compared with own rooted vines (Somkuwar *et al*., 2013). Merzifon Karasi vines grafted on 5BB and SO4 rootstock recorded highest sugars in root, trunk and shoot, respectively, while vines grafted on 5C and 110R rootstocks recorded maximum carbohydrates and starch content in root, trunk and shoot (Kose *et al*., 2014). Thomson Seedless grapevines grafted onto 110R rootstock recorded higher total phenolic contents and other phenolic derivatives (Somkuwar *et al*., 2014,b).

Satisha *et al*. (2014) recorded highest phenol, protein and proline content in 110R rootstock, while lowest phenol content in St. George was recorded and lowest protein and proline content in 1613C rootstocks. The accumulation of phenolic compounds in these rootstocks may indicate the possible role of phenolic compounds as antioxidants for scavenging the reactive oxygen species generated during abiotic stresses to maintain normal physiological and biochemical processes. Somkuwar *et al*. (2017) found that highest protein and starch content in 110R rootstock, while maximum phenol and carbohydrate content in Dogridge rootstock.

Ulhas *et al*. (2014) observed higher proline content in cv. Merlot grafted on 1103P (1.76 μmol/ml) rootstock, carbohydrate content was higher in Syrah vines grafted on 110R and 1103P rootstocks. Phillips *et al*. (2015) observed significant difference in starch, sugars and total carbohydrate content in cane samples from different regions for various varieties (Merlot, Riesling and Vidal Blanc). The highest cane carbohydrate content (26.36 and 26.31 %) were recorded in Superior Seedless grafted on Salt Creek rootstock and lowest (15.54 and 16.11 %) on own rooted vines for two subsequent seasons Elaidy *et al*. (2019). Goufo *et al*. (2020) analysed the roots, woods, canes, stems, and leaves of grapevines and identified 183 phenolic compounds including 78 stilbenes (23 monomers, 30 dimers, 8 trimers, 16 tetramers, and 1 hexamer), 15 hydroxycinnamic acids, 9 hydroxybenzoic acids, 17 flavan-3-ols (of which 9 are proanthocyanidins), 14 anthocyanins, 8 flavanones, 35 flavonols, 2 flavones, and 5 coumarins.

Biochemical constituents

Rootstock had a significant effect on bunch physical parameters like bunch size, compactness etc. as well as on chemical parameters like total soluble solids and acidity of berries. The rootstock influences titratable acidity in warmer climates but year and soil type may have more impact on titratable acidity than rootstock (Keller *et al*., 2001). Sugar accumulation was significantly lower for vines grafted on 5C rootstock than for the other rootstocks, sugars (Brix) at harvest were similar for all rootstocks while vines grafted on 5C rootstock had lower titratable acidity (Nuzzo and Matthews, 2006).

Somkuwar *et al*. (2013) reported that quality and cane biochemistry changes in relation to cane thickness of own rooted and grafted Tas-A-Ganesh grape, observed that TSS of berries decreased with increase in berry size. Berries on grafted vines recorded lower TSS than on own-rooted vines. The reducing sugars, carbohydrate and phenols were higher in grafted vines. Miele and Rizzon (2017) studied on Cabernet Sauvignon grapevines grafted on 101-14Mgt., 161-49C, 3309C, Rupestris du Lot and Gravesac had high values of density, total soluble solids, pH and sugar:acid ratio and low titratable acidity, which was high with Cabernet Sauvignon grafted on 99R, 110R, Dogridge and 1103P rootstocks.

Sugar profiling

The primary sugars within grape berries are glucose, fructose and sucrose. Sucrose from leaf photosynthesis is transported into berries via phloem although accumulation in berries which was usually started from the veraison stage. During berry ripening, sucrose is converted primarily to glucose and fructose that continue to develop throughout berry ripening (Ribereau-Gayon *et al*., 2000).

Robredo *et al*. (2011) studied the sugar profile in three table grape varieties (Thompson Seedless, Crimson Seedless and Red Globe) and noted that sugar concentrations found in grapes were as fructose, 0.15- 8.74 g /100 g, glucose, 0.19-8.71 g /100 g and sucrose 0.02-0.91 g /100 g. Among sugars, glucose was the most abundant one in early stages and then it decreased until the harvest period, when the amount of fructose and glucose converged to an average of 47% for each sugar. Among different varieties Thomson Seedless recorded highest total sugars.

Organic acid profiling

Tartaric acid content was higher during berry formation and remains fairly stable until berry ripening (veraison). Malic acid accumulates at the end of berry formation and then begins to decline with berry ripening. Although both acids decline during veraison, the loss of tartaric acid is not as rapid and has been associated with increase in berry size. In contrast, degradation of malate is primarily due to metabolites and reduced rate of acid synthesis (Possner and Kliewer, 1985). The organic acid content was used for determining the berry chemical content and harvest intervals. In Thomson Seedless grape, berries tartaric, malic and citric acid were observed maximum with lowest bud load whereas, in Beogradska Besemena cultivar tartaric acid found maximum in lowest bud load while malic and citric acid found maximum with highest bud load (Baiano and Terracone, 2011).

Robredo *et al*. (2011) studied the organic acid profile in three table grape varieties (Thompson Seedless, Crimson Seedless and Red Globe) which varied as tartaric acid (1.28-7.45 g/L), malic acid (0.38-29.92 g /L), citric acid (traces-1.03 g/L). The organic acid profiles among varieties, with Thompson Seedless showing the lowest tartaric/malic acid ratio of 1.19. These differences are an important aspect in terms of overall flavour. Bobeica *et al*. (2015) found that developmental profiles of malic and tartaric acids were slightly affected by the source-sink modulation in Cabernet Sauvignon berries. From veraison to near harvest, the concentrations of malic and tartaric acids were higher, while no significant differences were found at harvest. Tangolar *et al*. (2016) found non-significant differences in tartaric and malic acid concentration for differential bud load.

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