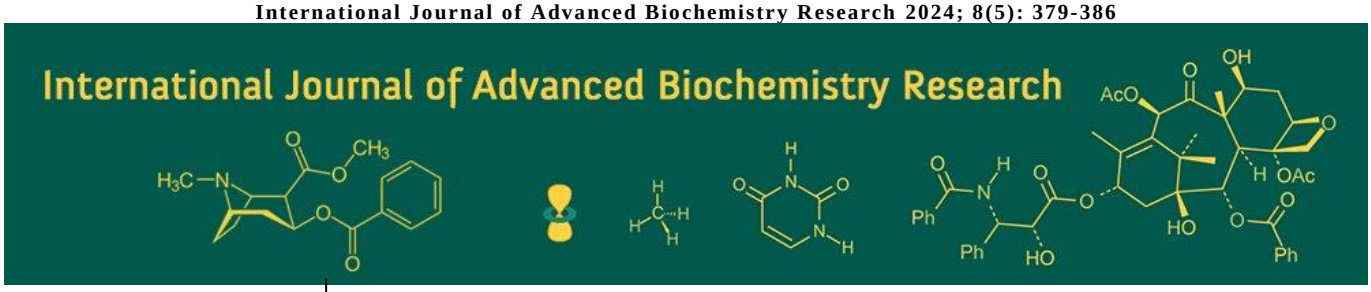

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Influence of varying rootstocks on bio-chemical properties and sensory characteristics of Cabernet Sauvignon wine produced under subtropical climate

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Abstract
The variety, rootstock, climate, soil and aging are some of the factors which determine the quality of wine. Good quality wine examined by smell, balancing components, intensity, depth and finishing. Rootstock-scion interactions induce different responses to grapevine physiology and consequently to wine composition. This study aimed to the effect of eight rootstocks (Dogridge, 110R, 140Ru, 1103P, 101.14MGT, SO4, Fercal and Gravesac) on Cabernet Sauvignon (CS) wine quality. The flavonoid, anthocyanin and DPPH radical scavenging activity was significantly higher in wine from CS/1103P and phenol was highest in wine from CS/Gravesac. The sensory evaluation of CS/140Ru and CS/1103P wine received greater acceptance based on visual, aromatic and palate descriptors. The information generated will be useful in selecting ideal rootstock for Cabernet Sauvignon vine for the production of best quality wines under sub-tropical climate.

Keywords: Grape, wine, biochemical profile, rootstocks, juice

Introduction
The grapevine (*Vitis vinifera* L.), is one of the most extensively grown fruit crops in the world. Globally, fresh fruit accounts for about 27% of this production (Jin *et al*., 2016) [17]. Due to rising worldwide demand and consumption, sparkling wine is the wine market category with the quickest rate of growth, with output having increased by more than 40% in the last ten years. In 2023, global wine production, excluding juices and musts, is estimated at 237.3 mhl and wine consumption is estimated at 221 mhl (OIV, 2024) [24]. In India, about 90% of the table grapes are being cultivated. Presently, grapes are grown in India over an area of 1.71 lakh ha with production of 37.81 lakh MT and productivity of 21.00 MT/ha (APEDA, 2024) [2].

Wine is one of the most popular beverages prepared from grapes through fermentation under the controlled conditions. It comprises phenolic compounds mainly classified into flavonoids and non-flavonoids (Garrido and Borges, 2013; Somkuwar *et al*., 2019) [12, 35]. These compounds are considered to have antioxidant, anti-cancer and anti-inflammatory properties (Arranz *et al*., 2012; Casas *et al*., 2014; Somkuwar *et al*., 2019) [3, 7, 35] and they are also responsible for some of the sensory properties like colour, aroma, flavour, bitterness and astringency in grapes and wine (Del Rio *et al*., 2013; Somkuwar *et al*., 2019) [11, 35]. The success and quality of wine production rely not only on the specific grape varietal but also on the rootstock chosen for cultivation. Rootstocks can also induce differences in the vigor of the rootstock (Winkler *et al*., 1974) [41], which influences the physiology of the vine, yield components, phenology, fruitfulness and berry size, color and composition. The rootstock effect on the vigor and yield components of the Cabernet Sauvignon grapevine cultivated in the Serra Gaucha wine region has been studied (Miele and Rizzon, 2017a) [25, 26]. The selection of rootstocks can have a significant impact on the bio-chemical properties and sensory characteristics of the resulting Cabernet Sauvignon wine (Costacurta *et al*., 2003) [10]. Rootstocks are widely used in viticulture for its resistance to phylloxera, pests and other diseases. It holds tolerant properties towards different abiotic stresses such as adverse soil condition (salinity, alkaline, acidity), also drought and flood situations (Harbertson and

Keller, 2012; Wang, *et al*. 2019) [15, 40]. Effect of rootstock on the scion has been studied regarding its influence on the vine growth, biomass, pruning weight, pH and yield (Keller *et al*. 2012) [15]. The rootstock affects the physiological and biochemical processes such as plant-water relations, the efficiency of uptake and translocation of nutrients, metabolism of plant growth regulators and carbohydrate (Richards, 1983) [31]. The genotype of scion regulates the synthesis of various compounds in the grape, whereas, the rootstock has been observed to regulate genes responsible for carbohydrate metabolism and sugar transport (Cookson and Ollat, 2013) [9]. Rootstock influences the growth, yield and berry composition in grapes (Koundouras, *et al*. 2009, Somkuwar *et al*. 2015) [23, 18, 37]. Rootstock and scion structure can be used to regulate vine growth, phenological period, fruit yield, and the concentrations of bio compounds like phenols, tannins, anthocyanins, and resveratrol, altogether affects quality and taste (Zhang *et al*. 2020) [44]. Furthermore, rootstock also affects grape berry composition by modifying the physiology of scion and the microclimate of the canopy. The changes in berry composition eventually affect the composition and quality of wine produced from it (Cheng, *et al*. 2017; Leeuw *et al*. 2014) [8, 24].

In subtropical and tropical climates of India, absence of dormancy period in grapevine creating hurdle in breaking bud dormancy, so 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) [33] which need variety- specific research and long-term studies to monitor the effects of rootstockscion interaction in vineyard to identify the best combination (Kose *et al*., 2014) [22]. In the above background, an investigation was conducted at ICAR-National Research for Grapes, Pune, India to evaluate the variation in bio-chemical composition and Sensory evaluation of wine produced from Cabernet Sauvignon grafted on different rootstocks, viz, Dogridge, 110R, 140Ru, 1103P, 101.14 MGT, SO4, Fercal and Gravesac.

Materials and Methods

Characterization of Vineyard site and Experimental design: The present research work was carried out at experimental vineyard of ICAR-National Research Centre for Grapes, Pune, Maharashtra, India during the year 2020-21. The vineyard is situated at mid-west Maharashtra state at an altitude of 559 m (18.32° N and 73.51° E) above the sea level with tropical wet and dry climate and the average temperature ranging between 25-35 °C during the peak period of season. Five-year-old Cabernet Sauvignon grafted on eight different rootstocks i.e. Dogridge, 110R, 140 Ruggeri (140Ru), 1103 Paulsen (1103P), SO4, 101.14MGT, Fercal and Gravesac were selected for this study. The vines were planted at a spacing of 2.5 m between rows and 1.2 m between the vines within a row. The row orientation was in the direction of North- South. The vines were trained to mini-Y trellises system. In this region, the vines are pruned twice in a year i.e. double pruning and single cropping pattern is followed for grape cultivation. The experiment was formulated in randomized block design with three replications consisting of ten vines in each replication.

Sample collection and Wine making: *Vitis vinifera* L. cv. Cabernet Sauvignon grapes from eight different rootstocks (collected from triplicate vine rows) were harvested individually with total soluble solids (TSS) between 23-25º Brix. The grapes were destemmed and crushed. The free run juice was treated with 60mg/Litre of SO_2. Grape must and juice was transferred to a 30 Litre stainless steel jacketed fermenter tanks. Before fermentation, all the treatment samples were subjected to cold maceration at <10 °C temperature for 24 hrs. Later, the fermentation was initiated by inoculating the Lalvin EC1118 yeast (Lallemand, France) at 25 g/hl. The fermentation temperature was maintained at 20±2 °C and diammonium phosphate (Laffort, France) at 30 g/hl was added during mid fermentation. The punch-down technique was carried out once per day on all the samples to avoid drying of the cap. The samples were fermented to dryness after 15 days of fermentation, with glucose-fructose levels at <2 g/Litre. The wines were racked, filtered, bottled and stored in 750ml Bordeaux style amber color wine bottles at 16 °C temperature.

Wine and Juice Bio-chemical Analysis

Analysis of enological parameter: The samples of fresh juices and wines from each rootstock were analyzed for titratable acidity, pH, and total soluble solids (TSS). Determination of titratable acidity was conducted by titration with 0.1N NaOH using phenolphthalein as indicator. Besides, titratable acidity was expressed as tartaric aid equivalent. The pH Meter (Model 420, Thermo Orion) was used for measuring the juice and wine pH. Also, juice and wine TSS was determined using the digital hand-held refractometer (0-32% BRIX make ERMA, Japan) with temperature compensated to 20 °C.

Total phenols (TP) content: The total phenolic content in the juice and wine extracts was determined using the modified Folin-Ciocalteu colorimetric method. Briefly, 0.1 mL of diluted samples was mixed with 0.5 ml of Folin-Ciocalteu reagent (diluted 1:2). After 3 min of mixing, 2 ml of 20 % of Na_2CO_3 was added to the mixture. After 90 min incubation at ambient temperature, the absorbance of the supernatant was measured at 630 nm against blank on a spectrophotometer. Gallic acid (GA) was used as standard. The results were expressed as µg of gallic acid equivalent (GAE) per ml of Sample (µg GAE ml^{-1}).

Total flavonoid (TF) content: The total flavonoid content of samples was determined using a modified colorimetric method (Zhishen *et al*., 1999) [45]. Briefly, 1.0 mL of diluted juice and wine extracts was mixed with 1.5 mL of distilled water and, subsequently, with 0.015 mL of 5 % of sodium nitrite solution and allowed to react for 5 min. Next, 0.15 mL of 10 % of aluminium chloride was added and allowed to further react for 6 min before 1 mL of 1 M sodium hydroxide was added. Distilled water was added to bring the final volume of the mixture to 5 mL. The absorbance of the mixture was immediately measured using an UV-VIS spectrophotometer at 510 nm wavelength against a prepared blank. The flavonoid content was determined by a catechin standard curve and expressed as mean (milligrams of catechin equivalents per L of wine -mg L^{-1}) ± SD for the extracts measured in triplicate.

Extractable anthocyanin: The total anthocyanin content was determined using the AOAC pH differential method. Samples were dissolved in 0.2 N potassium chloride buffer at pH 1.0 and in 1.0 sodium acetate buffer at pH 4.5. Absorbance readings at 520 nm and 700 nm in each buffer were performed against distilled as blank. The results were calculated using the following equation.

A = (A520 (pH 1.0) - A700 (pH 1.0)) - (A520 (pH4.5) - A700 (pH 4.5))

Total anthocyanins (mg/L) = A x MW x DF x 103/ε x L, were MW: Molecular weight of predominant anthocyanin (malvidin 3-glucoside), ε: Molar extinction coefficient, DF: Dilution factor, L: Path length of cuvette

DPPH radical scavenging activity: Free radical scavenging activity of crude methanol extract was determined using the 2,2-diphenyl-1-picrylhydrazyl (DPPH) method with some modifications. A methanol solution (100 µL) containing methanol extracts was added to 3.9 ml of freshly prepared DPPH methanol solution. An equal amount of methanol was used as a control. After incubation for 90 min at room temperature in the dark, the absorbance was measured at 515 nm using a spectrophotometer. The results were expressed as µM equivalent Trolox per ml of Sample (µM TE ml^{-1})

Characterization of wine sensory profile

Sensory evaluation was conducted with a trained panel of twelve experienced wine professional tasters. The study was conducted in an odor-free, well-lit room with an ambient temperature of 21 ± 2 °C. These evaluated the visual (color intensity), olfactory (aroma intensity) and taste characteristics (sweetness, acidity, astringency, tannins, bitterness, body, mouthfeel, alcohol and length) and followed by overall quality assessment with Qualitative Descriptive Analysis, recording attributes: one visual, one aromatic and seven taste. All parameters were quantified on a scale with unstructured intensity of 7 points, with minimum anchorage on the left and maximum on the right. The test room comprised individual, white, illuminated booths. Samples were served individually, coded in tasting glasses (ISO) containing 50 mL and at a temperature of 18 ± 2 °C (considered ideal for tasting red wines).

Statistical analyses

Statistical analysis was performed using SAS software 9.3. The difference between cultivars were studied by analyzing the variance. Differences at $p<0.05$ were considered to be statistically significant.

Results and Discussion

The rootstocks used in this experiment have a certain genetic diversity and can therefore influence several physiological and biochemical grapevine aspects, which could have a reflection on wine composition and quality. Indeed, results of studies have shown effect of rootstocks on the grapevine physiology, biochemistry, wine biochemical profile, wine quality and wine sensory characteristics (Somkuwar *et al*. 2014; Miele and Rizzon, 2017; Oliveira *et al*. 2020) [36, 25, 26, 29].

Enological analysis

Results from the analyses of the classic quality parameters of various juices and wines prepared from Cabernet Sauvignon grafted on different rootstocks are presented in Table 1.

Basic TA, pH and sugar analysis: The titratable acidity was higher in CS/Gravesac juice (6.68 g/L) followed by 1103P (6.60 g/L) and Fercal (6.43 g/L) and lower in CS/101.14MGT juice (5.72 g/L). Previous studies have conferred to similar levels of titratable acidity in case of Fercal (Miele and Rizzon, 2019) [27]. The titratable acidity ranged from 3.30 g/L in wines from CS/1103P to 4.35 g/L in wines from CS/Gravesac rootstocks, respectively. The rootstocks CS/110R and CS/140Ru produced a little lower titratable acidity (4.13 g/Lin both) than the CS/Gravesac. Higher total acidity on Gravesac, Fercal and Dogridge may be related to vigor on this rootstock (Miele and Rizzon, 2019) [27]. The pH had a different behavior because higher values found in CS/Dogridge (3.85), CS/Gravesac (3.77), CS/1103P (3.64) juices and lower in CS/110R (3.53), CS/140Ru (3.53) juices. However, pH values ranged from 3.86 to 4.22 in rootstocks CS/Fercal and CS/SO4 wines respectively. Wines from grapevines grafted onto 110R and Gravesac showed higher pH than the wine from grafted grapevines onto and 140Ru and 1103P rootstocks. These differences were probably because the pH indicates the real concentration of H^+ ions that are ionized or dissociated in the solution while titratable acidity estimates the quantity of titratable acids (Miele and Rizzon, 2017) [25, 26]. Rootstocks with *Vitis rupestris* and *Vitis berlandieri* genetic makeup shows a good ability for nutrient uptake (Jogaiah *et al*. 2015) [18] along with low uptake of K concentration (Kodur, 2011) [21]. This was observed significantly in case of 140Ru and 110R reporting of low pH levels in the juice. The ability of the rootstock to absorb the nutrient efficiently is mainly dependent on its fine roots which is often a factor related with its low pH (Kodur, 2011) [21]. Since Dogridge is *Vitis champinii*, it has deep roots and has been observed with high uptake of potassium which results in higher pH in the fruit (Kodur, 2011) [21]. The variations in the nutrient use efficiency of vines induced by rootstocks also affect grape compositions. For example, juice acidity and pH are largely determined by the content of potassium, which precipitates tartrates (Brancadoro *et al*. 1994) [5]. The total soluble solids (TSS) varied from 7.00-9.00º Brix in wine and 22.00-25.00º Brix in grape juice. CS/Gravesac reported 25º Brix which is highest amongst the other rootstocks. Indeed, total soluble solids were significantly affected by the rootstock (Berdeja *et al*. 2014; Miele and Rizzon, 2019) [4, 27]. Although other study shows that there is no effect, or little one, on the total soluble solids of the grape juice. (Wang *et al*. 2019; Wooldridge *et al*. 2010) [40, 42]. However, in this study, the level of pH, acidity and sugar concentrations in juice have differed with its significant rootstock combination affecting the overall quality and composition of wine.

Total Phenols, Flavonoids, anthocyanins and antioxidant activity

To determine the influence of varying rootstocks on biochemical profile of Cabernet Sauvignon, juice and wine samples were analyzed using spectrophotometer and the results are presented in Figure 1.

Total phenol: The total phenol content (TP) of juices of Cabernet Sauvignon with different rootstocks varied from 262.40 to 599.51 µg GAE ml^{-1}. Juice from the vines grafted on CS/101.14MGT presented highest concentrations of phenols (599.51µg/ml) followed by CS/1103P (494.73 µg/ml), whereas it was lowest in juice obtained from CS/110R rootstock (262.40 µg/ml) followed by SO4 (353.51 µg/ml). Similar results were obtained with previous observation found in other studies on same rootstock-scion combinations (Wallis *et al*. 2013; Wallis and Chen, 2012) [38, 39]. In this aspect, CS/101.14MGT had the highest phenolic concentration comparatively indicating an increase response to infection. Such significant similarity has also been previously observed in studies involving high phenolic level found in scion sap of Cabernet Sauvignon grafted on 101.14MGT compared to other rootstocks (Wallis *et al*. 2013) [38]. Research with different scion combination like Chardonnay/101.14MGT observed higher sap levels of caftaric acid (Wallis and Chen, 2012; Wallis *et al*. 2013) [39, 38]. Therefore significant difference have been observed amongst rootstocks in case of the juice. However, occurance of phenolic compound are triggered with several factors like biotic or abiotic stress (Wallis and Chen, 2012) [39]. Hence, further studies on the rate of response with different rootstocks in consecutive vintages will deepen the understanding of scion-rootstock. (Paixao *et al*. 2007) [30]

The total phenol of wines produced from Cabernet Sauvignon with different rootstocks varied from 927.51 to 1902.40 µg GAE ml^{-1}. The maximum phenol concentration was found in wine obtained from the CS/ Gravesac (1902.40 µg/ml), whereas it was minimum in wine obtained from CS/110R rootstock (927.51 µg/ml). The drastic evolution in the concentration of phenols from juice to wine was observed in CS/Gravesac, as several methods used during wine processing significantly affects the final phenolic composition (Burin *et al*., 2010) [6]. All wines were subjected to pre-fermentation maceration was performed for 24 hrs at >10 °C followed by daily punch down during fermentation which might have aided in the overall extraction of phenols from skins in Gravesac thereby increasing the final concentration in wine. The levels of phenols also depend on the maturity and ripeness level correlating with the high TSS obtained in case of Gravesac (25º Brix).

Variation in the overall levels of phenols concentration among the different rootstocks was significant; clearly showed that the rootstock can be one of the main sources of such variation. In the present study also, the accumulation of different phenolic compounds was highest on CS/Gravesac rootstock while it was lowest on CS/110R which were in accordance with the study of Jogaiah *et al*. 2015 [18].

Total flavonoids: Total flavonoid content was significantly varied in juices as well as wines of Cabernet Sauvignon grafted on different rootstocks. Significantly highest amount of total flavonoid was found in juice extracted from CS/1103P (1067.30 mg/L) followed by CS/140Ru and CS/101.14 MGT (1044.52 and 1044.52 mg/L, respectively) compared to all other combinations of rootstocks. The lowest flavonoid content was found in juice from Cabernet Sauvignon vines grafted on Dogridge (462.06 mg/L). In wines Cabernet Sauvignon vines grafted on 1103P, SO4 observed with higher concentrations of flavonoids (4513.25 and 4454.68 mg/L, respectively). Other studies have obtained a similar result in case of 1103P (Oliveira *et al*. 2020) [29]. The wine from Cabernet Sauvignon grapevine grafted on 110R showed lowest flavonoid content (2274.52 mg/L). Flavonoids though present in low concentrations, they are important in wine because of their participation in the co-pigmentation phenomenon with anthocyanins, contribution to intensity and stability of red wine color, taste and also play an important role for their astringency and bitterness (Adams, 2006) [1]. Flavonoids also have aroused considerable interest because of their antioxidant properties and potential benefit to human health (Santos-Buelga and Scalbert, 2000) [32].

Total anthocyanin: The total anthocyanin content was varied from 146.36 mg/L in juice prepared from vines grafted on Gravesec to 277.32 mg/L in juice prepared from vines grafted on 140Ru rootstocks. A significant higher total anthocyanin was occurred in the wines extracted from the vines grafted on 1103P (531.53 mg/L) followed by 140Ru (489.16 mg/L) and 110R (346.65 mg/L). Anthocyanins being the main substances of phenolics group have significant influence on wine characteristics and quality. Anthocyanins are pigments mainly responsible for the wine-red color, which varies according to grape variety, cultural practices and harvest seasons also (Oliveira *et al*. 2020) [29]. The extraction of anthocyanin also depends on the fermentation temperature and maceration techniques (Jackson, 2008) [16]. They may also act as antioxidant that inactivates the free radicals and chelating divalent metal ions, induces upregulation of antioxidant enzymes and plays an important role in reducing age related diseases (Yadav *et al*. 2009) [43].

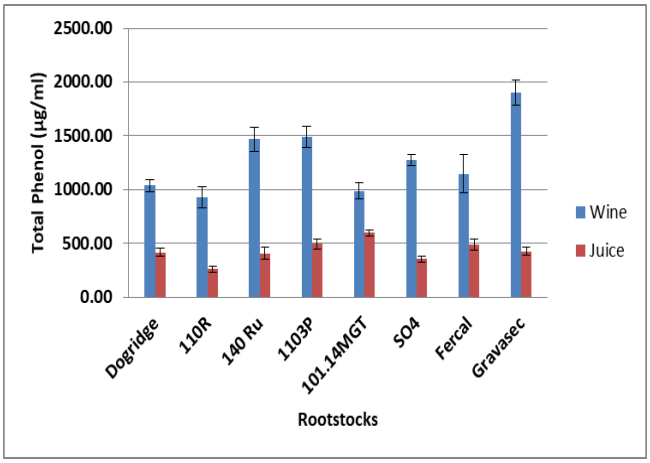
Antioxidant potential: The antioxidant activity values evaluated by the DPPH method ranged from 8.63 to 14.05 µmol TE L^{-1} in juices of Cabernet Sauvignon grafted onto different rootstocks. According to Leeuw *et al*. (2014) [24] Cabernet Sauvignon juice showed highest antioxidant capacity ranged from 5.71 µmol to 7.28 µmol among the four different wine grapes. Similar range was observed in vines grafted on CS/1103P (14.05 µmol) followed by CS/140Ru (13.46 µmol) revealed highest antioxidant activities than that of CS/Gravesac (8.63 µmol) in juice. Association of antioxidant activity in wine found similar to total flavonoids concentration in wines of Cabernet Sauvignon grafted onto different rootstocks. The antioxidant activity was found more than two to three folds in wine samples when compared with juice samples. It was recorded maximum in CS/1103P and minimum in CS/110R (43.07 µmol and 23.89 µmol, respectively). High antioxidant activity observed in CS/1103P could also be driven by relatively higher concentration of the anthocyanin monomers found in 1103P wine as compared to the other rootstocks along with high flavonoid and anthocyanin content. Several studies have observed a correlation between high antioxidant activity and high concentration of anthocyanin monomers, flavonoid content and phenolic compound in wine (Jin *et al*. 2017) [19] and grape juice as well (Burin *et al*. 2010) [6]. Compounds like non-anthocyanin flavonoid are also responsible to elevate the antioxidant activity (Granato *et al*. 2010) [14].

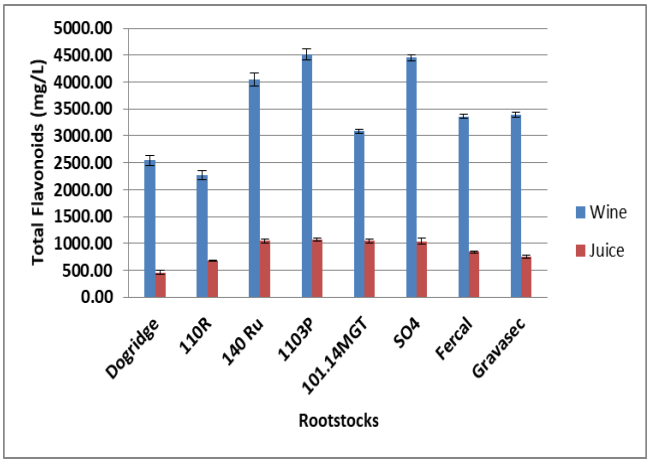
Sensory Evaluation of the wines: The taster scores indicate an influence of rootstock on sensory profile (Figure 2).

Among the 8 attributes based on intensity was evaluated, all the wines were fermented to dryness; hence the intensity of sweetness was at the lowest side of the scale in all the wines of different rootstocks. The aroma intensity was observed to be highest in Gravesac followed by 101.14MGT and Dogridge, whereas lowest aroma intensity was observed in Fercal. The color intensity was scored highest in 1103P (6.90) followed by 140Ru (6.25), 101.14 MGT (6.16), Dogridge (6.16) and Gravesac (6.16). In case of 1103P, it approves with the anthocyanin composition where, 1103P has highest anthocyanin concentration. And lowest scores for color intensity were given to SO4 (3.16), 110R (4.16) and Fercal (4.33). These scores mirrored its lowest anthocyanin levels analyzed especially in 110R followed by SO4 and Fercal, indicating the influence of total anthocyanin on the overall color intensity. Other studies concluded the result of observing high color intensity in combination with high anthocyanin concentration in 1103P (Oliveira *et al*. 2020) [29]. Acidity was perceived higher (>5.25) in Fercal, 140Ru and Gravesac, when compared to SO4 (3.25) and 110R (4.16). Gravesac had the highest rating for tannins followed by 140Ru, 1103P and SO4. High intensity of tannins in Gravesac is a result of the high phenol content, and the same was observed in case of 140Ru, 1103P and SO4 respectively in terms of phenol content. High intensity tannins often have an inclination towards harsher tannins which is often a result with high phenol content. Thereby also correlating with the high level of bitterness found in wine. The scored obtained for the bitterness intensity was quite close, however the level of bitterness was scored highest for Gravesac, followed by 1103P, SO4 and 110R. Astringency is highly correlated with concentration of proanthocyanidins, high phenol and condensed tannins (Oliveira *et al*. 2020) [29]. Wine astringency is related to the quantity and types of tannins present. In particular, the astringency of tannins, which affects palatability, is reported to be related to the formation of complexes with salivary proteins. These may result in a decrease in lubricating properties of saliva and greater friction on mouth surfaces (Gawel *et al*. 2000) [13]. This correlation was observed with 140Ru which received highest score for astringency. Overall high scores for body and mouthfeelness was shared with 140Ru and SO4 respectively. 1103P and 101.14MGT were also scored high after SO4 in mouthfeel attribute. Alcohol intensity was highest in Gravesac. Length attribute is derived by many components responsible for the aftertaste persistence which was highest in 140Ru, 101.14 MGT and 1103P. Highest overall quality rating was given to 140Ru, Gravesac, 1103P and SO4. There were major and minor differences amongst the sensory attributes in different rootstocks. However, sensory evaluation can be correlated with overall composition of anthocyanin, phenols and flavonoids in wine. Overall factors are the key drivers reflecting the effect of the overall composition in wine. However, there was a significant difference between the rootstocks that further affected the resulting composition found in wine and was perceived by the sensory evaluation. Some studies have not found the influence of rootstock on wine composition and overall anthocyanin compounds (Harbertson and Keller, 2012) [15] and on the other hand studies showing difference between rootstocks have also been reported (Oliveira *et al*. 2020; Sivilotti *et al*. 2007; Cheng *et al*. 2017) [29, 34, 8]

Table 1: Effect of rootstocks on TSS, Acidity and pH of Cabernet Sauvignon juice and wine

Rootstocks	Juice			wine	
	TSS (°Brix)	Acidity (g/L)	pH	Acidity (g/L)	pH
Dogridge	23.6d	6.36bc	3.85a	3.60c	4.06bc
110R	24.0cd	5.81de	3.53c	4.13b	4.16ab
140 Ru	24.2bcd	5.88d	3.53c	4.13b	3.97cd
1103P	24.4abc	6.60a	3.64b	3.30e	4.06bc
101.14MGT	24.4abc	5.72e	3.60bc	3.53cd	4.15ab
SO4	24.0	6.27c	3.61bc	3.45d	4.22a
Fercal	24.8ab	6.43b	3.63b	4.05b	3.86d
Gravesac	25.0a	6.68a	3.77a	4.35a	4.20a
LSD @ 0.05	0.658	0.158	0.093	0.148	0.116





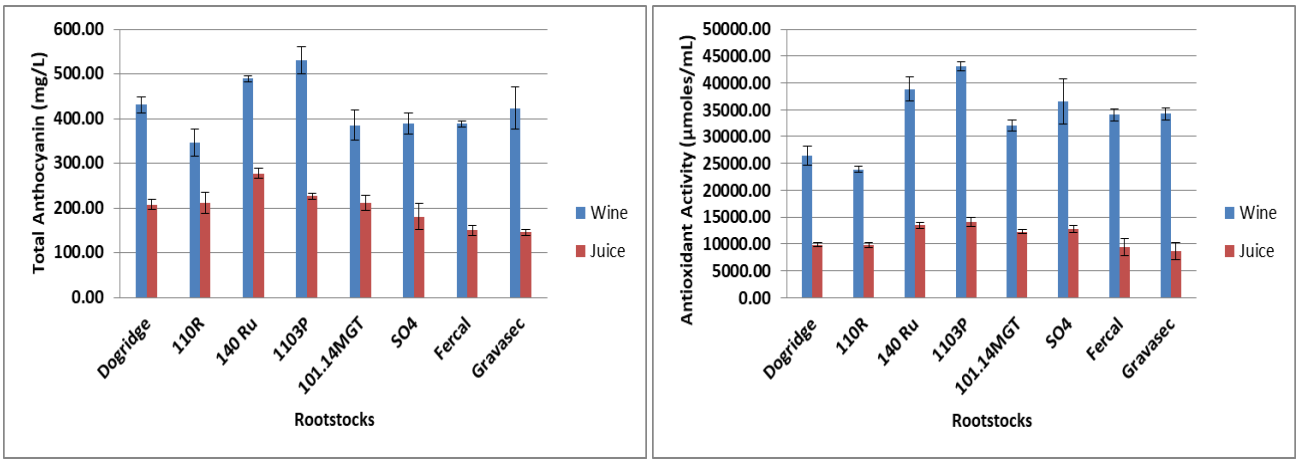


Fig 1: Effect of rootstocks on biochemical composition of Cabernet Sauvignon juice and wine.

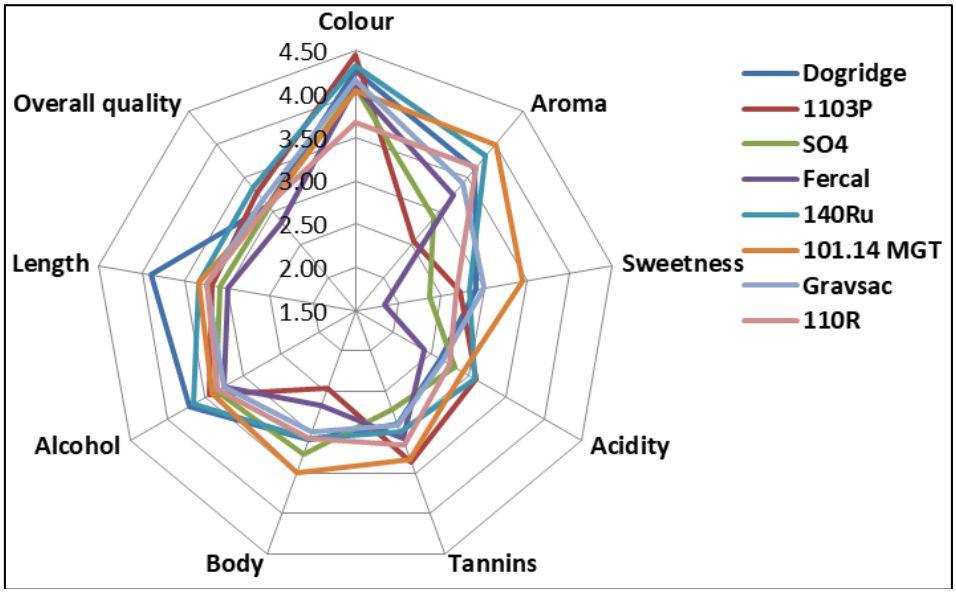


Fig 2: Sensory evaluation Cabernet sauvignon wine prepared from different rootstocks

Summary and Conclusion

Biochemical composition like phenols, flavonoids, total anthocyanin and antioxidant activity were particularly distinguished amongst different rootstocks. Especially Cabernet Sauvignon grafted onto 1103P rootstock, its higher concentration of flavonoids and antioxidant activity in juice and wine. Total phenols were prominent in Gravesac wines which led to high astringency and tannin intensity on the palate. Many biochemical differences were significant with different rootstocks. The phenol concentration was highest in juice of Cabernet Sauvignon grafted onto 101.14MGT rootstock and wines of Cabernet Sauvignon grafted onto Gravesac rootstock. The total anthocyanin content was highest in juice of Cabernet Sauvignon grafted onto 140Ru followed by 1103P rootstocks and wines of Cabernet Sauvignon grafted onto 1103P rootstock. The rootstocks 1103P and 140Ru resulted in the best performance across the all rootstocks evaluated, showing the maximum results in terms of biochemical composition, sensory evaluation in juice and wine. The influence of rootstocks on the effect of aroma constituents and other phenolic compounds needs to be further investigated in consecutive vintages. The information generated will be useful in selecting ideal rootstock for Cabernet Sauvignon vine for the production of best quality wines under sub-tropical climate.

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Conflict of interest:

The authors declare that there are no conflicts of interest associated with this publication.

Ethical approval

This research did not involve any studies with human participants or animals (vertebrates) performed by any of the authors.

Consent to participate: All Authors approve the article for the publication

Consent for publication: We understand that the text and any figures published in the article will be freely available for public. The pictures and text may also appear on other websites or in print, may be translated into other languages or used for commercial purposes.

Availability of data and material: All data generated or analysed during this study are included in this published article (and its supplementary information files).

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