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Rootstock Influences Growth, Yield, Berry Physiochemical and Quality Wine Produced from Cabernet Sauvignon Grown in the Pune Region

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was conducted to study the effect of rootstock on growth, yield, quality, and sensory evaluation of wine made from 'Cabernet Sauvignon' grapes. Among the rootstock's, pruning weight was significantly higher in vines grafted on 110R rootstock. Days for buds sprout

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and days to veraison was early in Gravasec grafted rootstocks, while early days to harvest in Gravasec and SO4 rootstocks. Cabernet Sauvignon vines grafted on 110R rootstock recorded significantly higher fruit yield than other rootstocks studied. Wine composition like volatile acid, total acids and ethanol was higher in vines grafted on 140RU; malic acids in 1103P and colour intensity in SO4 grafted vines. The wine sensory attributes were also positively influenced using different rootstocks, wine prepared from Cabernet Sauvignon grapes grafted on 1103P recorded the highest overall wine quality which was followed by Fercal rootstock.

Keywords: Cabernet sauvignon; grape; rootstock; growth; yield; quality.

1. INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the important fruit crops widely cultivated in different regions. Though the grape is originated from temperate regions, it is performing well under tropical climate in the country where it grows as an evergreen vine without undergoing dormancy. In India, it is grown on an area of about 1.71 lakh hectares with an average production of 37.81 lakh metric tons and productivity of 22.10 MT/ha of grapes annually [1]. However, only about 2% of the total production of grapes is being used for juice and wine purpose [2]. The decline in yield due to the problems associated with soil and water salinity, chlorides in irrigation water and excess levels of sodium in soil and shortage of irrigation water in Maharashtra state alerted the situation. Since then, the use of rootstock to maintain the productivity of grapes under adverse situations has gained popularity [3]. The choice of proper rootstock is becoming difficult due to availability of large number of rootstocks [4]. The performance of rootstock is different under different conditions; hence it is necessary to evaluate rootstock best suited to the environment [5]. Rootstocks is mostly utilized to make a better scion performance under various cultivation condition in viticulture. However, its performance mainly depends on scion cultivars, soil type and climatic conditions [6]. The selection of appropriate rootstock for the scion plays an important role in the growth, fruitfulness, and yield of grapevine scions [7].

In India, it is necessary to use appropriate rootstocks in grapes for profitable production against major abiotic stresses such as soil and water salinity, water scarcity etc. [8]. There is no major issue of the effect of rootstocks on the fruit composition in table grapes except for berry size, TSS, acidity etc., but it is a major concern in wine grapes to produce good quality wines. Due to a lack of knowledge about the influence of rootstocks on fruit composition and other quality parameters (soluble solids, organic acids, and pH), most of the wine cultivars were grafted on Dogridge rootstock which is the choice for table grapes in India [9]. But many scientists concluded that Dogridge rootstock for wine grapes accumulates significantly higher concentrations of potassium in berries which deteriorates the quality of wines in terms of high pH, poor color stability, and high organic acids when grown in warm regions [10,11].

Climate plays a crucial role in grape production [12]. As climate change continues to cause warmer and drier weather, it is having a significant impact on the growth, fruit composition, and early harvest. Grapevine yield and quality are heavily influenced by climate conditions and depend on complex interactions between temperatures, water availability, plant material and viticultural practices [13]. Many farmers have been able to improve fruit yield and quality by using plant material and viticultural practices suited to their local climate. To adapt to higher temperatures, farmers may need to change their planting material and modify their viticultural practices, such as adjusting their harvest dates [14].

Wine is one of the most popular beverages prepared from grapes through fermentation under the controlled conditions. It comprises phenolic compounds mainly classified as flavonoids and non-flavonoids [15]. These compounds are considered to have antioxidant, anti-cancer and anti-inflammatory properties [16,17] and they are also responsible for some of the sensory properties like colour, aroma, flavor, bitterness and astringency in grapes and wine [18]. It is thus necessary to investigate how the rootstock is suitable for a given cultivar and location that affects the plant development, yield and quality. The present study was therefore conducted to study the impact of rootstock on yield and quality in Cabernet Sauvignon wine grape variety.

2. MATERIALS AND METHODS

2.1 Vineyard, Experiment Design, and Vine Management

The study was carried out over three years (2014-15, 2015-16 and 2016-17) in an experimental vineyard located in ICAR-National Research Centre for Grapes, Pune, India (18.32° N latitude, 73.85° E longitude and 559 m altitude). The cultivar 'Cabernet Sauvignon' grafted on eight different rootstocks (Fercal, Dogridge, SO4, 110R, Gravasec, 1103P, 101-14MGT, 140RU) were evaluated in a randomized block design with three replicates represented by five vines per replication. The grape vineyard was four years old, trained onto a mini-Y system of trellises spaced at 2.4×1.2 m accommodating about 3400 vines per hectare.

2.2 Determinations of Berry Physiochemical Parameter

Pruned biomass was measured after fruit pruning (forward pruning) for selected vines and the average was calculated. Days taken for sprouting were recorded from the date of pruning to sprouting of first bud. The first sprouted bud with fully expanded leaf was taken as an indicator to calculate the days taken for sprouting. Days to veraison and days to harvest was calculated from date of fruit pruning for individual vines.

Harvesting was done about 145 days after forward pruning during the month of March. At harvest, soluble solids (Brix), titratable acidity (g L^{-1} tartaric acid) and pH were measured using the juice of pressed berries (100 berries per treatment) collected. Soluble solids (ºBrix) were determined using a handheld refractometer (ERMA, Japan) with temperature compensated to 20ºC. The pH of pure juice of every sample was determined using a pH meter. Titratable acidity was determined by titration with 0.1 N NaOH to a phenolphthalein end point and expressed as g L^{-1} [19]. Also, five vines were selected randomly from each rootstock. Juice recovery (%) was recorded by crushing 1 kg of berries. The observations on the number of berries/bunches, 100 berry weight (g), average bunch weight, yield per vine were recorded at the harvesting.

2.3 Growing Degree Days

Heat units, expressed in growing degree-days (GDD), are frequently used to describe the timing of biological processes.

The basic equation used is GDD = [(T MAX + T MIN) 2]−T BASE, where T_{MAX} and T_{MIN} are daily maximum and minimum air temperature, respectively, and T_{BASE} is the base temperature.

2.4 Wine Preparation and Sensory Evaluation

After harvest, grape bunches were washed with tap running water, rotten and green berries were removed and the de-stemming was done manually. The grape berries, were passed through a stainless-steel presser to prepare must. The must was inoculated with commercial yeast (*Saccharomyces cerevisiae*) with viable cell count, *i.e.* 1.06 × 10^8 mL^{-1}. Fermentation was carried out in 50 L capacity stainless steel tanks at 20-22 °C. During fermentation process, fermenting material was mixed, twice every day. The fermentation was completed in 13 days. The material like skin, seed and yeast lees were separated from the finished wine. The prepared wine bottled properly and stored at 1-2 °C for further analysis. The sensory analysis of Cabernet Sauvignon wines was performed and overall quality at 0 to 9 rating scale, the means was calculated and data were expressed in graphical chart. The wine quality parameters (total acid, malic acid, pH, volatile acid, and ethanol) were recorded on Oeno Foss (FTIR based analyzer). The wine samples were drowned into microtube and centrifuged at 500 rpm for 5 minutes and the readings were recorded.

2.5 Statistical Analysis

The experiment was conducted in Randomized Block Design (RBD) consisting of eight treatments as rootstocks which were replicated three times. Statistical analysis of data collected during studies was carried out by standard method of analysis of variance as described by Panse and Sukhatme [20] and data was analyzed using Statistical Analysis System (SAS) software version 9.3. The standard error of mean (S Em±) was worked out and the critical difference at 5 per cent level of significance was calculated wherever the results were found significant.

3. RESULTS AND DISCUSSION

3.1 Growth Parameters

Non-significant differences were recorded for pruning biomass in Cabernet Sauvignon grafted on different rootstock as indicated by values in Table 1. However, the maximum pruning weight were recorded on 110R (1.00 kg) while minimum pruning weight were recorded in SO4 (0.62 kg) grafted vines. The difference in the pruned biomass among the rootstocks may be due to the difference in the vigor of vine due to higher photo assimilation resulting in higher carbohydrate deposition [21]. The higher pruning weight might be attributed due to more efficiency for the absorption of water and minerals from the root system of rootstocks [22]. The previous study also reported that rootstocks influenced the scion vigor. Rootstocks effects on pruning weight may vary among different scion cultivars [23,11].

Days to bud sprout was early on Gravasec (8.45 days) among all the rootstocks which was followed by SO4 (9.22) and Fercal (9.78) while the rootstock 140RU was late to sprout (11.67 days). Availability of stored food material that has helped to supply for early bud sprout, cultural practices and temperature variation might be a reason for variation in time taken for bud burst [24,25]. These results are in accordance with the earlier reports on the influence of rootstocks on bud break [26] reported that vines grafted on 110R took less time to achieve the maximum percentage of bud break as compared to those grafted on Freedom rootstocks. The biochemical changes and enzyme activities at different stages of bud burst had been investigated by Satisha et al. [27]. The study concluded that the changes in enzyme activities indicated the end of the dormancy period and the beginning of vegetative growth.

The minimum days for veraison were recorded in Gravesec rootstock (101.78) grafted vines whereas, maximum days were recorded in 110R grafted vines (107.00). The interaction between stock and scion affects the root physiology which help in the proper uptake of water and minerals might be resulting into early veraison and harvest. Bunch load is also an important factor for early harvesting Cabernet Sauvignon grafted on 110R rootstock showed higher crop loads among the rootstocks which might be responsible for late harvesting. Similar results were recorded by Donnell et al. [28]. The maximum degree days were recorded in Fercal and 110R (1468.40) grafted vines followed by Dogridge, 1103P, 101.14 MGT and 140RU while, minimum degree days were reported in SO4 and Gravasec (1386.07). Minimum day to harvest was recorded in SO4 and Gravasec (139.89) grafted vines followed by 1103P, 101.14 MGT and 140RU (144.11) however, Fercal took maximum days to harvest (149.00). Koyama et al. [29] reported that BRS Melodia grapevines required growing cycle of 138 days with a yield of 23.85 tons/ ha in the summer season of year 2013, and 121 days and yield of 19.4 tons/ha in the off-season crop during 2014.

3.2 Yield Parameters

Number of bunches/vine, average bunch weight and total yield were significantly affected by rootstocks (Table 2). Maximum number of bunches/vine were recorded in Cabernet Sauvignon grafted on 1103P (71.11) which was at par with SO4 (70.00) and 110R (68.45) rootstocks while the minimum number of bunches/vines were recorded on Dogridge rootstock (50.33). This might be due to the higher carbohydrate reserves of the vine and proper accumulation of source reserve. The highest average bunch weight was observed in vines grafted on 101.14MGT (87.59 g) which was at par with Fercal (86.22 g) while, lowest average bunch weight was recorded in Gravasec (72.03 g). The higher yield/vine was recorded in Cabernet Sauvignon grafted on 110R (6.68 kg) followed by Fercal, 1103P and 140RU rootstocks (6.08, 5.19 and 5.02 kg respectively), while lower yield was recorded in Gravasec grafted vines (4.23 kg). The influence of rootstock on yield has been reported by many previous studies [30,31]. Higher yield is directly related to more stored nutrient material and high pruned biomass of vine. Rootstocks vary in rooting distribution pattern and number of roots, which might affect the pruned biomass and yield components and the yield to pruned biomass ratio [32]. Similar findings were reported by Satisha et al. [33].

The maximum 100 berry weight was recorded in Fercal (95.93 g) whereas it was minimum in 1103P (73.97 g) rootstock. The maximum number of berries/bunches were recorded in Dogridge (106.34) rootstock while minimum in Gravasec (86.89) rootstock.

3.3 Berry Quality Parameters

The basic biochemical composition of Cabernet Sauvignon grafted on different rootstock varied as shown in the results (Table 3). The differences in TSS among the rootstocks were non-significant. The acidity ranged from 5.64-6.33 g/L. The minimum acidity was recorded on SO4 rootstock while the maximum was on 140RU rootstock. Acidity was decreased with the increase in TSS. Similar results were also reported by Thutte et al. [34]. The highest juice pH was recorded in Cabernet Sauvignon grafted on 1103P (3.69) which was at par with SO4, Fercal, Dogridge and Gravasec (3.68, 3.65 and 3.63 respectively) while, minimum on 101.14MGT (3.54) rootstock. The pH value of the grape juice was significantly affected by the rootstock [35]. The maximum juice recovery (64.08 %) was recorded in Dogridge rootstock while minimum juice recovery was recorded in SO4 (53.42 %) rootstock. The volatile acids in grape berries were higher in 1103P (0.13 g/L) while SO4, 110R and Gravasec recorded lower concentrations (0.09 g/L). The maximum the potassium uptake efficiency of vines mainly depends on scion cultivars, rootstock used and soil conditions, some rootstock showed more potash uptake capabilities and increased potassium content of the berries which positively affects the biochemical contents of the berries [36]. Corso et al. [37] It was observed that the rootstock may affect berry ripening by controlling the expression of various genes. The similar results were observed by Somkuwar et al. [26] and [38] in Fantasy Seedless and Manjari Naveen grapevines grafted, both grafted onto Dogridge rootstock.

3.4 Wine Quality Parameters

Significant differences were recorded among the different rootstocks for wine quality parameters studied (Table 4). The wine made from grape berries grafted onto 140RU rootstock recorded the lowest pH (3.76) while the rootstock Fercal recorded higher pH of 4.22. Pan et al. [39] reported that the pH value regulates the degradation of glucose and fructose as the lower the pH values, the slower will be the

Table 1. Vegetative parameters in relation to different rootstocks in Cabernet Sauvignon (pooled means for three years)

Rootstocks	Pruning weight (kg)	Days to bud sprouts	Days to veraison	Degree days	Days to harvest
Fercal	0.85	9.78[d]	106.56[a]	1468.40[a]	149.00[a]
Dogridge	0.64	11.44[ab]	105.33[a]	1431.31[b]	144.22[b]
SO4	0.62	9.22[d]	102.00[b]	1386.07[c]	139.89[c]
110R	1.00	10.78[bc]	107.00[a]	1468.40[a]	148.67[a]
Gravasec	0.70	8.45[e]	101.78[b]	1386.07[c]	139.89[c]
1103P	0.88	10.66[c]	105.55[a]	1431.31[b]	144.11[b]
101.14MGT	0.70	11.66[a]	105.44[a]	1431.31[b]	144.11[b]
140RU	0.76	11.67[a]	105.44[a]	1431.31[b]	144.11 [b]
SEm ±	0.11	0.24	0.56	11.66	0.56
CD at 5%	0.33	0.72	1.70	34.29	1.70
P value	NS	**	**	**	**

**: Significant at P < 0.05, **: Significant at P < 0.01, NS: Non significant*

Table 2. Effect of rootstocks in relation to yield parameters in Cabernet Sauvignon (pooled means for three years)

Rootstocks	No of bunches/vine	Average bunch weight (g)	Yield /vine (kg)	100 berry weight (g)	No of berries/bunch
Fercal	60.44[c]	86.22[ab]	6.08[b]	95.93	98.67
Dogridge	50.33[d]	85.21[b]	4.28[g]	81.50	106.34
SO4	70.00[a]	81.41[c]	4.82[e]	79.08	100.22
110R	68.45[ab]	85.02[b]	6.68[a]	84.84	110.56
Gravasec	59.00[c]	72.03[d]	4.23[g]	82.49	86.89
1103P	71.11[a]	73.45[d]	5.19[c]	73.97	100.33
101.14MGT	51.44[d]	87.59[a]	4.60[f]	86.78	102.33
140RU	62.11[ab]	81.95[c]	5.02[d]	90.54	90.00
SEm ±	2.48	0.63	0.04	7.34	13.65
CD at 5%	7.53	1.92	0.11	22.25	41.40
P Value	**	**	**	NS	NS

**: Significant at P < 0.05, **: Significant at P < 0.01, NS: Non significant*

Table 3. Influence of rootstocks on basic biochemical composition of Cabernet Sauvignon (pooled means for three years)

Rootstocks	TSS (ºBrix)	Acidity (g/L)	Juice pH	Juice recovery (%)	Volatile acid (g/L)
Fercal	23.42	6.04	3.65[ab]	57.27[e]	0.10[bcd]
Dogridge	22.87	6.06	3.63[ab]	64.08[a]	0.12[ab]
SO4	23.16	5.64	3.68[a]	53.42[f]	0.09[cd]
110R	23.92	6.32	3.57[bc]	59.17[cde]	0.09[d]
Gravasec	23.63	5.92	3.63[ab]	58.79[de]	0.09[cd]
1103P	23.20	6.01	3.69[a]	60.24[cd]	0.13[a]
101.14MGT	22.70	5.98	3.54[c]	61.42[bc]	0.11[abcd]
140RU	23.42	6.33	3.57[bc]	62.99[ab]	0.11[abc]
SEm ±	0.31	0.16	0.03	0.83	0.009
CD at 5%	0.93	0.49	0.09	2.52	0.026
P value	NS	NS	*	**	*

**: Significant at P < 0.05, **: Significant at P < 0.01, NS: Non significant*

Table 4. Evaluation of rootstock in relation to wine quality of Cabernet Sauvignon

Rootstocks	pH	Volatile acid (g/L)	Total acid (g/L)	Ethanol (%)	Malic acid (g/L)	Colour intensity (%)
Fercal	4.22	0.24	3.2	10.9	1.1	3.11
Dogridge	3.82	0.27	4.0	11.6	2.0	2.73
SO4	3.82	0.21	3.5	11.1	1.1	3.50
110R	3.86	0.26	4.1	11.0	2.1	1.49
Gravasec	3.87	0.17	3.5	11.3	1.5	2.10
1103P	3.85	0.25	3.9	11.4	2.2	2.23
101.14MGT	3.97	0.29	3.4	11.2	1.3	2.32
140RU	3.76	0.41	4.1	11.7	2.0	2.02
SEm ±	0.07	0.01	0.07	0.10	0.04	0.06
CD at 5%	0.22	0.02	0.21	0.31	0.12	0.17
P value	**	**	**	**	**	**

**: Significant at P < 0.05, **: Significant at P < 0.01, NS: Non significant*

degradation. It also plays a modulating role in wine haze formation, which diminishes or overthrows the commercial value of wine [40]. The concentration of volatile acid was higher in wine made from 140RU (0.41 g/L) followed by 101.14MGT (0.29 g/L) while the rootstock Gravasec recorded the least volatile acids (0.17 g/L). Total acid was higher in 140RU and 110R (4.1 g/L) which was at par with Dogridge (4.0 g/L) and least in Fercal (3.2 g/L). Volatile acid plays an important role in the fermentation process as it delivers information about the degree of improper fermentation processes occurring during winemaking [41] while acids, ethanol and tannins are the primary factors that determine the wine aroma, taste and mouth feel in red wine [42].

The wine made from 140RU rootstock recorded the highest concentration of ethanol (11.7 %) which was at par with Dogridge (11.6 %), 1103P (11.4 %) and Gravasec (11.3 %) while the lower concentration of ethanol was recorded in Fercal (10.9%) grafted vines. The concentration of ethanol (10-14%) was a fundamental requirement for the wine quality as it is linked to sugar content of grape berries, which affect the overall flavor of the wine [43]. However, higher concentration of alcohol decreases astringency and increases the bitterness of wine [44]. Malic acid concentration was higher in wine made from 1103P (2.2 g/L) followed by 110R (2.1 g/L), Dogridge and 140RU (2.0 g/L) while it was less in Fercal and SO4 (1.1 g/L) rootstocks. Color intensity was maximum in SO4 rootstock (3.50%) while minimum was recorded in 110R rootstock (1.49%). During the wine making process, malic acid influences fermentation. Bovo et al. [45] reported that at high concentration of malic acid, all strains of *Saccharomyces* yeasts were positive that enhanced the rate of fermentation process consuming all the sugar.

3.5 Correlation Matrix of Growing Degree Days and Physiological Growth Parameters

The data in Table 5 revealed that the pruning weight showed a strong positive correlation with degree days (0.747) and days to harvest (0.757), indicating that heavier pruning is associated with more heat accumulation and a longer time to harvest. It also has a moderate correlation with days to veraison (0.694), indicated that heavier pruning might also delay the onset of veraison (the onset of ripening). Days to bud sprouts exhibit weaker correlations overall but show moderate positive relationships with days to veraison (0.690) and degree days (0.511), indicating that earlier bud sprouts could be associated with earlier veraison and fewer accumulated degree days. Days to veraison are strongly correlated with degree days (0.969) and days to harvest (0.936). This indicates that the timing of veraison is closely linked with the heat accumulation and the overall length of the growing season. Degree days show very strong positive correlations with days to harvest (0.994). This confirms the importance of heat accumulation in determining the key developmental milestones of the grapevine.

The wine prepared from Cabernet Sauvignon grapes was significantly influenced using different rootstocks (Fig. 1). In terms of overall quality, wine prepared from Cabernet Sauvignon grapes grafted on 1103P rootstocks recorded the highest overall wine quality (8) which was followed by Fercal (7) and SO4 (6) rootstocks whereas the lowest overall wine quality was recorded in wine prepared form Cabernet Sauvignon grapes grafted on 101.14 MGT rootstock (1). Rootstocks significantly influenced the phenolic, biochemical, and sensory parameters of the prepared wine [46,47]. There was very less research carried out which showed the rootstock had a positive effect on the wine

Table 5. Correlation coefficient among physiological growth parameters and degree days

Parameters	Pruning weight (kg)	Days to bud sprouts	Days to veraison	Degree days	Days to harvest
Pruning weight (kg)	1				
Days to bud sprouts	0.131	1			
Days to veraison	0.694	0.690	1		
Degree days	0.747	0.511	0.969	1	
Days to harvest	0.757	0.421	0.936	0.994	1

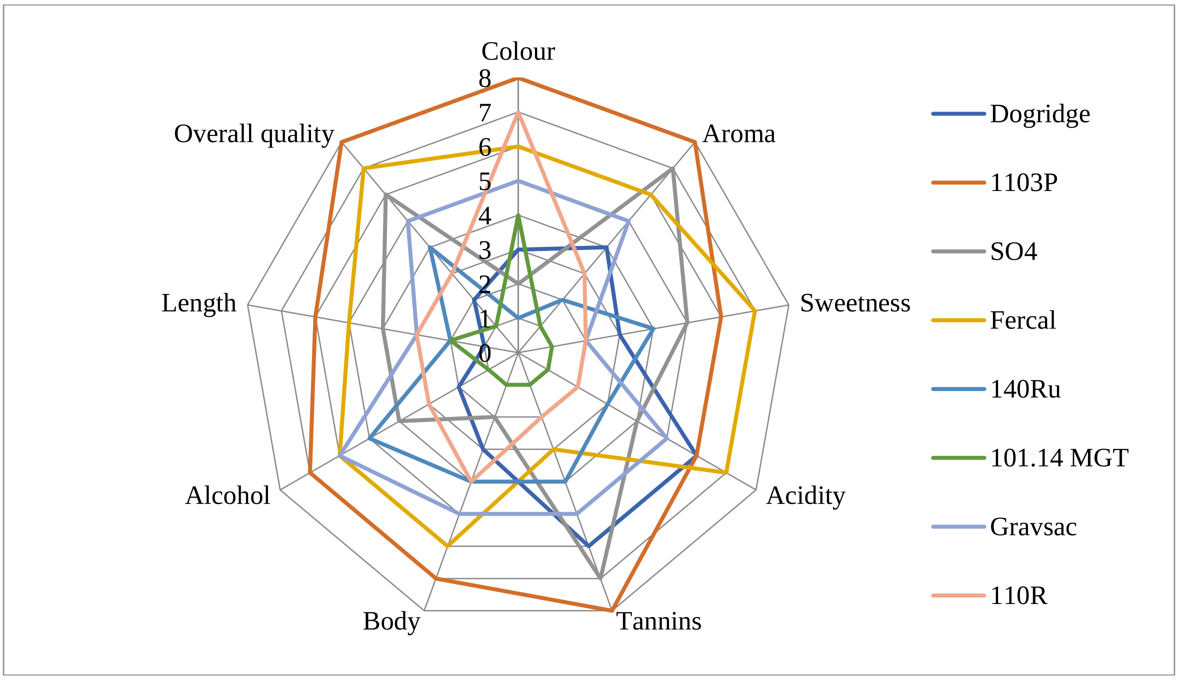

Fig. 1. Sensory attributes of Cabernet Sauvignon grafted on different rootstocks

sensory attributes. The aroma of Cabernet Sauvignon wine was improved when Cabernet Sauvignon grapevines were grafted on the Ruggeri rootstock, compared to those on Salt Creek [48]. Cabernet Sauvignon wine had recorded the highest rating scores when grafted on 161-49 C and 420A MGT rootstocks [49]. As all these experiments were conducted in different environments, soils and climatic conditions in addition vineyard management and wine making procedures might have influenced on the outcomes.

4. CONCLUSION

The experiment evaluated the impact of different rootstocks on the growth, quality, yield, and sensory attributes of wine made from 'Cabernet Sauvignon' grapes. Among the different rootstocks, vines grafted on 110R showed significantly higher pruning weights and fruit yields, with early bud sprout and veraison observed in Gravasec rootstocks. The wine composition varied with rootstock, with higher volatile acids, total acids, and ethanol content in 140RU grafted vines, while malic acids were more prominent in 1103P grafted vines and color intensity was highest in SO4 grafted vines. Sensory evaluation indicated that wine from 1103P grafted vines had the highest overall quality, followed by Fercal rootstock. Thus, rootstock selection is crucial for optimizing the growth, yield, and quality of 'Cabernet Sauvignon' wine.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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