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Influence of degree days on grape phenology, yield and quality of Manjari Naveen grapes grown under semi-arid conditions

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Abstract

Grape (*Vitis vinifera* L.) is one of the most economically important fruit crops in India, with Maharashtra being a significant contributor to the country's grape production. Phenological studies play an important role in understanding grapevine growth and development and the time requirements to plan activities during the season to harvest quality grapes. The main purpose of this research was to evaluate the productivity and phenology of the Manjari Naveen grape variety in a semi-arid region using a double pruning and single cropping system. The study was conducted at ICAR-National Research Centre for Grapes over three years (2020-21, 2021-22 and 2022-23). The Manjari Naveen scions were grafted onto 'Dogridge' rootstocks and trained in the Y trellis system, with a spacing of 9×5 feet. The harvesting was done in 113 days during the 2020-21 fruiting season and the yield was 15.41 ton/ha. In the season 2021-22, the harvesting was done in 119 days and the yield was 17.98 tons/ha. While, during the fruiting season of 2022-23, it took 122 days to mature the grape berries and the yield was 13.28 tons/ha.

Keywords: Manjari Naveen, phenology, climate, degree days, yield, grapes

Introduction

Manjari Naveen is one of the white seedless table grape varieties with mild muscat flavor grown for table purposes. The fruit ripens in 110 to 115 days after forward pruning, which is about 25 to 30 days earlier than present Thompson Seedless. The variety does not require gibberellic acid for bunch elongation and produces uniform berries and clusters and requires minimal thinning. The fruit can be harvested at 16⁰ Brix; hence, quick packing for pre-cooling and cold storage is recommended to maintain its quality. Climate plays a crucial role in grape production (De Orduna *et al.*, 2010) [5]. 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. Many growers have been able to improve yield and quality by using plant material and viticultural practices suited to their local climate. To adapt to higher temperatures, growers may need to change their plant material and modify their viticultural practices, such as adjusting their harvest dates (Van Leeuwen *et al.*, 2019) [18].

The phenology of grapevines tends to occur earlier, impacting sugar and acid levels and ultimately affecting grape quality (Bock *et al.*, 2011) [3]. Heat units, which are also linked to climate change, have been found to delay ripening in berries and to cause a significant reduction in berry quality (Greer and Weedon, 2013) [7]. The total soluble solids, pH, and titratable acidity of berry juice at harvest are affected by the variety and thermal level. The claim that temperature reduces titratable acidity and increases pH is an oversimplification that highlights the risk of generalizations based on indirect evidence, where temperature is confounded with other factors (Sadras *et al.*, 2013) [15]. These changes in grapevine phenology may result in alterations in grape composition, such as early maturity, separation between anthocyanins and sugars, and lower acidity due to increased temperatures (Ramos and de Toda, 2020) [13].

To adapt to changing climates, grape growers can use the phenological diversity of grape varieties as a tool (Wolkovich *et al.*, 2017) ^[20]. Different grapevine cultivars exhibit different temperature requirements to reach key phenological stages. By understanding the temperature requirements of different grapevine varieties using temperature-based phenological modelling, growers can select varieties that are more suited to future warmer conditions. This knowledge can help vine growers adapt to climate change by using grapevine cultivars that are better adapted to changing climates (Parker *et al.*, 2020; Fraga *et al.*, 2016) ^{[12][6]}. Manjari Naveen is a seedless table grape variety with naturally bold berries, loose bunches, and a short-duration variety (Somkuwar *et al.*, 2020) ^[17] being grown in different grape-growing regions in Maharashtra. To understand degree days requirement for table grapes in relation to planning for cultural practices becomes important under semi-arid conditions. The study was therefore planned to know the phenological stages in relation to weather conditions in Manjari Naveen grapes.

Materials and methods

The experiment was conducted at ICAR- National Research Centre for Grapes, Pune during 2020 to 2023. A five-year-old vineyard of Manjari Naveen grafted on Dogridge rootstock was selected for study. The vines were trained to extended Y-Trellis spaced at a 9 x 5 feet distance. The region experiences a tropical wet and dry climate, where double pruning and single cropping are being practiced. The foundation pruning was carried out in April, while fruit pruning was done in October. Pune (18.32°N and 73.51°E) experiences an average temperature ranging from 20 to 28°C, with an annual precipitation of 700 to 750 mm from June to September. The phenological and productive behaviour of Manjari Naveen grapes was evaluated using representative grapevines (n=10) of the experimental area during the period from October 2020 to February 2023. The duration of the main phenological stages and thermal requirement (degree days) from pruning to harvest were determined during the experiment. The vine was consistently adjusted to have 25 to 30 canes per vine during the fruit pruning. Forward pruning was done, leaving a single bud after the knot on the sub-cane, followed by application of hydrogen cyanamide for uniform budburst.

To determine the duration of the phenological stages of Manjari Naveen, five canes per vine were recorded and evaluated through visual observations from the pruning stage (PR) onwards. The stages were considered to have reached 50% bud swell (BS): when the scales were broken and green tissue was visible; sprouting (SP): when the first leaf of the sprout was fully expanded; bunch emergence (BE): when 50% of the shoots presented the inflorescence, with clusters visible. Flowering (FL): when 50% of the flowers were open, with visible flowers; veraison (VE): when 50% of the berries had changed colour and started softening and Harvest (HA): when 100% of the grapes showed intense colour with a proper TSS level. Meteorological data were collected from the weather station, ICAR- National Research Centre for Grapes, Pune (Appendix A, B and C). To characterize the thermal demands of Manjari Naveen grape, the degree day (DD) from pruning to harvest was calculated using the following formula.

$$\text{Degree Days} = (\text{Maximum Temperature} + \text{Minimum Temperature}) / 2 - 10$$

Ten vines were selected to record the observations on number of bunches/vine and average bunch weight was calculated on five bunches on each vine. Berry diameter, berry length and berry weight were measured on 5 bunches and 10 berries of each bunch. Yield/vine and yield/acre were determined on ten vines. The number of berries/bunches was calculated on five bunches of each vine. TSS and acidity were measured by extracting juice from 10 berries from each vine. TSS was measured using a refractometer and acidity was determined by the titration method. Based on the average number of bunches per vine, average weight of bunches, and the number of vines per acre, estimates yield were obtained as per Roberto *et al.* (2012) ^[14]. The physicochemical and productive characteristics of the 'Manjari Naveen' grape are presented as mean values and standard deviations for each variable during the fruit pruning seasons 2020-2021, 2021-2022 and 2022-2023.

Results and discussion

The data recorded on various phenological stages are presented in Fig. 1. The fruits of grape variety Manjari Naveen matured in 113-122 days from fruit pruning. The harvesting stage was passed through different stages called as sub periods e.g. from pruning to bud swelling (PR-BS), pruning to sprouting (PR-SP), pruning to bunch emergence (PR-BE), pruning to flowering (PR-FL), pruning to berry setting (PR-ST), pruning to 8mm (PR-8mm), pruning to 12mm (PR-12mm), pruning to veraison (PR-VA) and pruning to harvest (PR-HA) recorded 8, 10, 13, 35, 39, 59, 79, 87, and 113 days respectively, during the fruit pruning season of 2020-21 (Fig 1a). In the 2021-22 fruit pruning season, the same variety was harvested in 119 days with the durations of the sub-periods from pruning to different stages was 6, 9, 15, 30, 33, 55, 75, 86 and 119 days for PR-BS, PR-SP, PR-BE, PR-FL, PR-ST, PR-8mm, PR-12mm, PR-Veraison and PR-HA, respectively (Fig 1b). During the 2022-23 fruit pruning season, durations of the sub-periods from pruning to different stages were 6, 10, 16, 32, 36, 57, 79, 94 and 122 days for PR-BS, PR-SP, PR-BE, PR-FL, PR-ST, PR-8mm, PR-12mm, PR-Veraison and PR-HA, respectively (Fig 1c).

In viticulture, different grape varieties behave differently in achieving the major growth and developmental stages. Thus, the knowledge of phenological stages in viticulture helps in cultivar selection, manpower and cultural practice scheduling. After the fruit pruning, the increase in temperature results in a higher rate of vegetative growth. Photoperiod and temperature can alter hormone levels, inducing or inhibiting the expression of genes, and leading to the endogenous synthesis of gibberellins, which promote budburst. Extended periods of daylight can stimulate the internal production of gibberellins, which counteract the effects of abscisic acid (ABA) and facilitate budburst. During off-season cropping, grapevines maintain photosynthetically active leaves throughout their growth cycle (Kishino *et al.*, 2019) ^[10]. Consequently, it can be concluded that the shortening of the growth cycle during this period is associated with the timing of vine pruning.

The seasons of 2020-21 and 2021-22 experienced the

highest rainfall from the pruning to sprouting stage. During the 2022-23 season, there was significantly less rainfall recorded during berry development stages, which occur from flowering to veraison, and a dry period of about 112 days. Grapevines require the maximum amount of water during the phenological phase from flowering to fruit set (Winkler, 1974) ^[19], while prolonged droughts can cause delays in the formation of bunches and the harvest of crops. During the fruit pruning season of 2022-23, the variety reported a longer period to attain growth stages and the harvest period was also delayed. During the period of bud sprouting to shoot development, buildup of high humidity can lead to the development of downy mildew, while after the berry setting stage, powdery mildew becomes a major problem in the vineyard. Similarly, during the berry development stages, humidity can impact berry size, sugar development and flavour in the grape berries. Therefore, maintaining a balanced humidity level is crucial to obtain both yield and quality.

Temperature plays a critical role in berry development stages, affecting sugar content, flavour, and ripening. Cool temperatures can slow down the process, potentially leading to a delay in sugar development, while excessive heat may accelerate ripening, leading to over ripeness thereby reducing grape quality. Optimal temperature management is essential for grape quality. The levels of hormones in plants can be influenced by photoperiod and temperature. This is because they can affect the expression of genes that encode enzymes involved in the biosynthesis of plant growth hormones (Kerbaui, 2012) ^[9]. Longer days can trigger the synthesis of gibberellins, which can counter the effects of abscisic acid and promote budburst.

The harvest duration of any grape variety changes with location, soil and weather conditions in that area, canopy management practices followed and rootstock used. The duration of the productive cycle of grapevines depends on factors such as canopy/rootstock combination, plant vigour in the given edaphoclimatic condition and yield (Kishino *et al.*, 2019) ^[10]. The grape variety BRS Clara Seedless grown in a subtropical region has a production cycle of 120 days for the off-season crop (Colombo *et al.*, 2011) ^[4], while the cycle duration could be reduced to 97 days in semi-arid regions due to variations in temperature and climate (Santos *et al.*, 2015) ^[16].

The total degree days requirement from pruning to harvest (PR-HA) during the 2020-21 season was 1645.62. The sub-periods, PR-BS, PR-SP, PR-BE, PR-FL, PR-ST, PR-8mm, PR-12mm and PR-Veraison, had degree days requirements of 83.33, 119.16, 116.38, 507.21, 565.29, 860.93, 1151.76, and 1259.26, respectively. In the 2021-22 season, the total degree days requirement for the cycle was 1679.72. The sub-periods had thermal requirements of 84.50, 140.60, 233.20, 468.58, 524.34, 822.34, 1108.17 and 1222.62, respectively. During the 2022-23 season, the total degree days requirement for the cycle was 1616.60. The sub-periods had thermal requirements of 79.80, 134.30, 226.25, 461.00, 533.10, 750.75, 1019.20 and 1218.60, respectively (Table 1). The temperature in different regions, from temperate to sub-tropical and tropical regions, varies significantly. Subtropical regions have temperatures that are cooler than tropical climates but warmer than temperate zones and winters are generally slightly cool with unpredictable temperatures. Winter conditions can be

unstable and may cause a variation in the accumulation of degree days over several years in the same location. This variation may accelerate or delay the onset of plant development (Hussain *et al.*, 2016) ^[8]. The periods with the highest thermal demand were FL-VE and VE-HA in Manjari Naveen grapes during 2020-2023. Koyama *et al.* (2020) ^[11] also reported degree days requirement of 1744 and 1845 in summer and off-seasonal crop of "BRS Melodia" grape.

The data presented in Table 2 for the season of 2021-22 showed better results in terms of berry weight (3.55 g), berry diameter (17.86 mm), berry length (22.66 mm), bunch weight (418.20 g), yield/vine (18.57 kg) and yield/acre (17.98 ton). In contrast, the 2020-21 season had good TSS (17.84 °Brix) and the lowest acidity (0.54%). The present results indicated the impact of degree days on yield and quality in grapes.

During the cropping season of 2020-21, there was a decrease in the bunch weight, number of bunches/vines, berry length, berry diameter, yield and TSS. This difference was caused by the fact that the vines had to pass through different phases for growth and bear fruit under different weather conditions compared to other crop seasons. According to Anzanello and Souza (2015) ^[2] shoots from off-season crops of table grape cultivars can change the leaf area index, which affects the synthesis and dynamics of carbohydrate reserve storage and consumption in the canes. These changes have a significant impact on the overall mass of the grape bunches. Understanding the phenological and productive behaviour of the vines can be useful in optimizing labour distribution for various management practices such as pruning, harvesting, cultural treatments and the application of phytosanitary products.

Considering the improvement in colour of grapes, vineyards can use defoliation and crop load adjustment techniques (Kishino *et al.*, 2019) ^[10]. The colour of 'BRSI sis' seedless grapes is greatly influenced by the climate, specifically the air temperature. The annual yield of 'BRS Isis' is high, producing 47.7 tons per hectare, which is more than other seedless grape varieties like 'Superior Seedless', 'Thompson Seedless', and 'Crimson Seedless' grown in semi-arid or subtropical regions under annual double cropping systems (Ahmed *et al.*, 2019) ^[1].

Conclusion

The present study examined the growth stages of grapevines and how temperature, humidity and rainfall affected their phenological stages. The variation in temperature could affect the growth stages after fruit pruning in Manjari Naveen grapes. Higher temperatures advanced critical stages like bud break and flowering, ensuring uniformity and optimal fruit set. Adequate rainfall can either boost or slow down grape growth, impacting phenological stages and quality. Manjari Naveen seedless grape recorded a yield of 15.41 ton/ha in 113 days in 2020-21 and 17.98 tons/ha in 119 days in 2021-22. The 2021-22 season showed better results in terms of berry weight (3.55 g), berry diameter (17.86 mm), berry length (22.66 mm), bunch weight (418.20 g), number of bunches/vine (44), number of berries/bunch (125), yield/vine (18.57 kg) and yield/acre (17.98 tons). In contrast, the 2020-21 season had good TSS (17.84 °Brix) and the lowest acidity (0.54%).

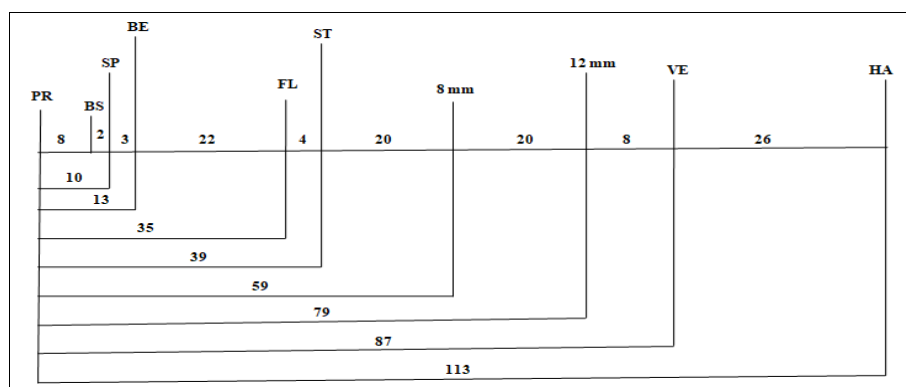
Table 1: Degree Days requirement for each phenological stages of Manjari Naveen grapes, during season 2020-21, 2021-22 and 2022-23 (mean± standard deviation)

Degree Days Requirement (DD)				
Sr. No.	Phenological Period	2020-21	2021-22	2022-23
1	Pruning to Bud swelling	83.33 ± 11.7	84.50 ± 6	79.00 ± 7.1
2	Pruning to bud sprouting	119.16 ± 9.6	140.60 ± 21.1	134.30 ± 12.1
3	Pruning to bunch emergence	116.38 ± 12.8	233.20 ± 30.4	226.25 ± 16.0
4	Pruning to flowering	507.21 ± 66.1	468.58 ± 65.7	461.00 ± 55.5
5	Pruning to berry setting	565.29 ± 79.3	524.34 ± 37.0	533.10 ± 37.7
6	Pruning to 8 mm berry	860.93 ± 60.8	822.34 ± 74.4	750.75 ± 45.6
7	Pruning to 12 mm berry	1151.76 ± 92.8	1108.17 ± 122.4	1019.20 ± 112.5
8	Pruning to veraison	1259.26 ± 189.3	1222.62 ± 74.3	1218.60 ± 171.0
9	Pruning to harvest	1645.62 ± 230.9	1679.72 ± 219	1616.60 ± 114.3

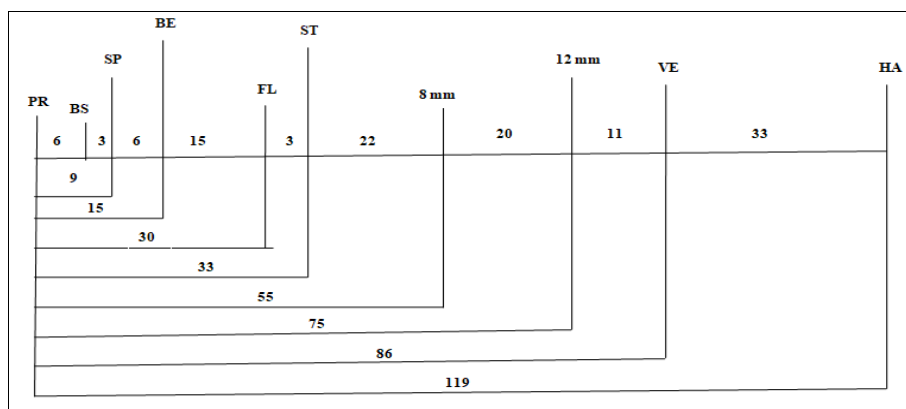
z Temperature-based = 10 °C, y PR-BS: pruning to bud swelling, PR-SP: pruning to sprouting, PR-BE: pruning to bunch emergence, PR-FL: pruning to flowering, PR-ST: pruning to berry setting, PR-8mm: pruning to 8mm, PR-12mm: pruning to 12mm, PR-VA: pruning to veraison, and PR-HA: pruning to harvest.

Table 2: Physical parameters of Manjari Naveen grapes, during season 2020-21, 2021-22 and 2022-23 (mean± standard deviation)

Sr. No.	Physical characteristics	2020-21	2021-22	2022-23
1	Berry weight (g)	3.50 ± 0.5	3.55 ± 0.5	3.40 ± 0.2
2	Berry diameter (mm)	17.84 ± 1.4	17.86 ± 2.3	17.80 ± 2.1
3	Berry length (mm)	22.28 ± 2.5	22.66 ± 3.2	22.50 ± 1.6
4	Bunch weight (g)	386.50 ± 0.1	418.20 ± 29.6	415.60 ± 25.3
5	No of bunches/vine	41.40 ± 5.8	44.40 ± 4.0	33.00 ± 3.6
6	Number of berries/bunches	110.00 ± 7.8	125.00 ± 13.8	120.00 ± 16.8
7	Yield/vine (kg)	15.92 ± 1.3	18.57 ± 1.1	13.72 ± 1.0
8	Yield/acre (ton)	15.41 ± 2.3	17.98 ± 2.3	13.28 ± 1.9
9	TSS (⁰ Brix)	17.84 ± 2.5	17.16 ± 1.6	17.10 ± 1.2
10	Acidity (%)	0.54 ± 0.049	0.55 ± 0.05	0.55 ± 0.05



(A)



(B)

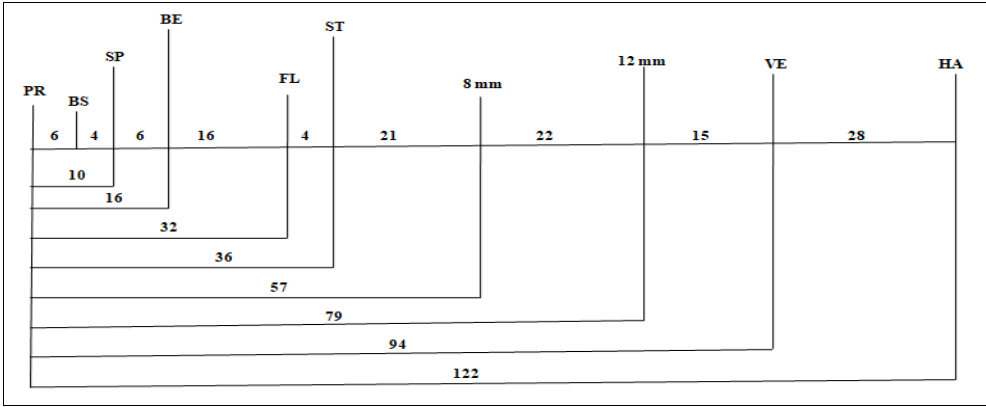
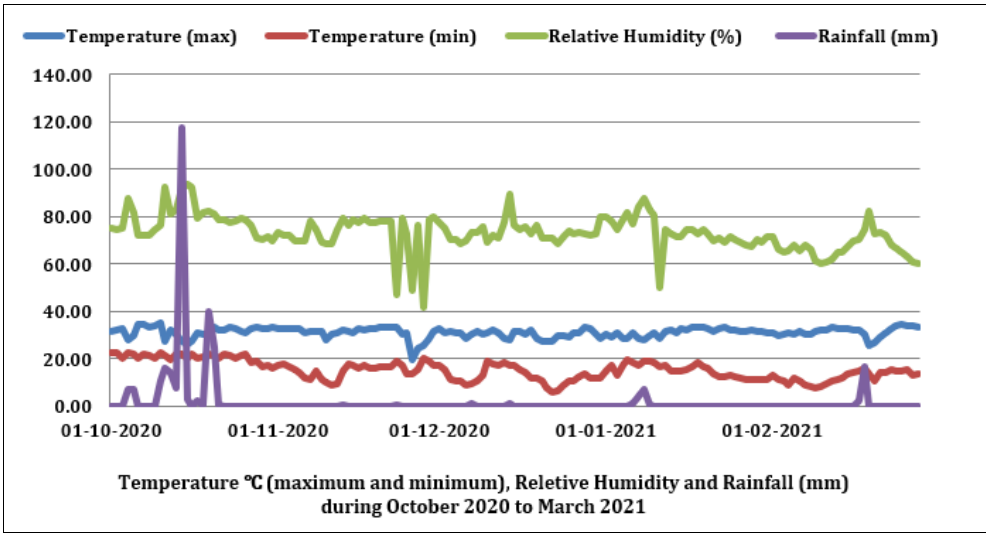
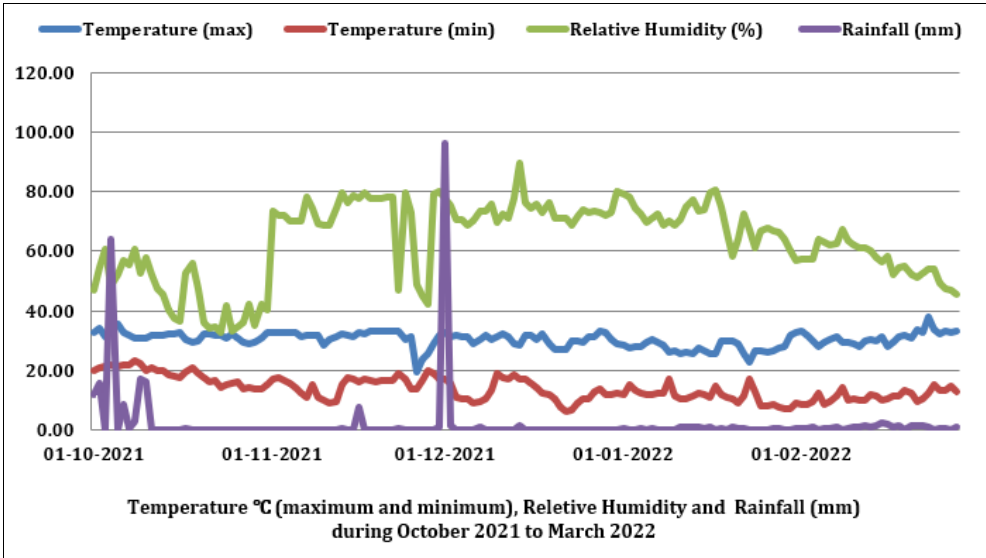


Fig 1: Duration in days of the phenological stages of Manjari Naveen grape in a subtropical region of Maharashtra. (A) 2020-21, (B) 2021-22 and (C) 2022-23. Stages - Pruning (PR), Bud swell (BS), Sprouting (SP), Bunch emergence (BE), Flowering (FL), Berry Setting (ST), Berry size 8 mm (8 mm), Berry size 12 mm (12 mm), Veraison (VE) and Harvest (HA).

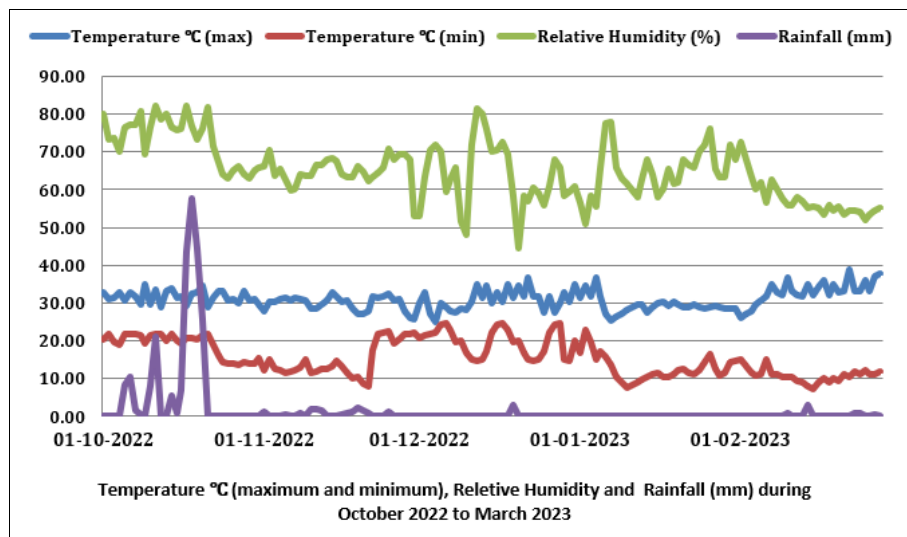
Appendix A



Appendix B



Appendix C



Acknowledgments

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