LAI, photosynthesis and chlorophyll content influences yield and quality of Nanasaheb Purple Seedless grapes under semi-arid condition

Abstract.

Canopy management practices in grapes are crucial for achieving high-quality production. The study was conducted with different treatments of number of leaves above the bunch (10, 12, 14, 16, and >16 leaves). Significant variation was recorded on photosynthetic activity, yield and quality of Nanasaheb Purple Seedless grape variety. The increase inleaf number enhanced total leaf area and photosynthetic capacitywhile,it hadnegative impact on bunch weight, berry sizeand total soluble solids (TSS). Retaining10 leaves above bunch with leaf area of 1980.00 cm^2 /bunch resulted in maximum bunch weight (450.20 g), 50-berry weight (250.13 g) and yield/vine (13.60 kg) while, minimum bunch weight (400.00 g), 50-berry weight (222.30 g) and yield/vine (11.22 kg) were observed by retaining>16 leaves above the bunch. However, retaining 10 leaves above the bunch on a shoot with leaf area/shoot (2475.00 cm^2), leaf area/vine (59400.00 cm^2), leaf area/bunch (1980.00 cm^2) and leaf area/g berry weight (4.36 cm^2/g) were sufficient to obtaingoodquality production in Nanasaheb Purple Seedless grape variety spaced at 9feet X 5 feet distance.

Keywords: leaf area, chlorophyll content, Photosynthetic activity, Yield, Quality

1. Introduction

For successful grape production, canopy management plays acrucial role, which involve training systems that tailored according to the soil type in a particular region, vine vigor, and weather conditions that help to expose maximum leaf area to sunlight, lead to increase yield potential (Somkuwar*et al.*, 2019). In viticulture, balancing leaf area and fruit is critical for accomplishing desired fruit composition. This balance is achieved through canopy management practices, which include techniques to adjust the number of leaves, shoots, and fruits, therefore producing ideal canopy microclimate. The purposeof canopymodifications is to enhance production potential, reducedisease and pest incidence, and facilitate mechanization (Somkuwar*et al.*, 2019). The aim of these practices is to produce high-quality grapes with increased sugar levels (Martinez and Balda, 2013). Furthermore, canopy management helps to maintain the vine's source (leaves): sink (bunch) balance (Moran *et al.*, 2017). Slight changes in canopy microclimates, influenced by alteration in leaf areas, can shorten the grape maturation period (Candar*et al.*, 2020). Falling leaf area can also augment nutrient uptake which helps in grape ripening and enhancing photosynthetic activity of the remaining leaves (Horak *et al.*, 2021). Leaf removal in the maturing stage is common in high-vigor and trained vine canopies (Poni *et al*., 2008). Research indicated proper and timely leaf removal can lead to early maturation or delay maturity of grapes (Poni *et al.*, 2013; Caccavello*et al*., 2017). Fruit exposure to direct sunlight increases its temperature, aiding in malic acid degradation and improving the sugar-acid ratio (Poni *et al*., 2013). In tropical region, grape varieties can achieve sufficient soluble solids required for quality grape production, but this is not applicable in case of color development (Iland and Gago, 2002). Sugar enzyme activity more in the temperature range of 8 to 33°C, differ from those color enzyme activity which required 17 to 26 °C temperature (Iland and Gago, 2002; Sadras*et al.*, 2007). Temperatures above 30°C can inhibit anthocyanin synthesis after the veraison stage (Mori *et al*., 2007). Research on ecophysiology has established the leaf area to fruit ratio as a key viticultural index to define a well-balanced vineyard capable of producing high-quality grapes (Kliewer and Dokoozlian, 2005). The optimal leaf area to fruit ratio is between 0.8 and 1.2 m^2/kg to achieve early maturity and quality (Kliewer and Dokoozlian, 2005). Most of the previous studies have focused on determining the leaf area per unit weight of fruit to maximize sugar concentration, a common indicator of berry ripeness. The optimum leaf area for color development in grapes varies depending on the grape cultivar and specific vineyard conditions. Auzmendi and Holzapfel (2016) reported that the leaf area to fruit weight ratio (ranging from 6 to 12 cm²/g for fresh weight, 8 to 10 cm²/g for total soluble solids concentration, and 9 to 12 cm²/g for anthocyanin content) plays a crucial role in berry composition and color development. To investigate the actual leaf area required to produce quality grapes with good color for export, this study aims to understand the effect of leaf retention above the bunch on leaf area, leaf area index, yield, and quality of Nanasaheb Purple Seedless grapes grafted on Dogridge rootstock under semi-arid conditions.

2. Material and Methods

The study was conductedduring 2023-24at ICAR-National Research Centre for Grapes, Pune. The experimental site located in mid-west Maharashtra at an altitude of 559 meters above MSL (18.32°N, 73.51°E). Nanasaheb Purple Seedless grapevines, grafted on Dogridge rootstocks were planted at a spacing of 9 feet x 5 feet and trained to extended Y-trellis maintaining 0.5 cane/feet^2 (24 canes/vine) on each vine. All the recommendedstandardcultural practices were followed to maintain healthy vine during the period of study. Five treatments with variation in leaf number above the bunch were evaluated as 10, 12, 14, 16, and >16 leaves, with each treatment replicated five times. The experiment was conducted in Randomized Block Design (RBD). LAI and PARwere recorded using LaiPen LP 110 device. LAI was calculated as leaf area per ground area (m²/m²), and PAR, measured in µmol photons $m^{-2}s^{-1}$, quantified the photosynthetic photon flux density (PPFD). Assimilation rate, stomatal conductance, intercellular CO_2, and transpiration rate were measured using an Infra-Red Gas Analyzer (IRGA model Li 6400, LI-COR Biosciences, NE, USA) on fifth to sixthmatured leaves from the shoot tip, between 11 am and 12:30 pm. Leaf area was determined using the linear method (LBK method), with the formula: Leaf area (A) = L x B x K (0.810), and expressed in cm². Total leaf area/shoot, per vine, and per bunch was calculated by multiplying the leaf area of individual leaf by the number of leaves per shoot, shoots per vine, and dividing by the number of bunches per vine, respectively. Average bunch weight was derived from the mean weight of five randomly selected healthy bunches per replication, while, the average weight of 50 berries was calculated and expressed in grams. The number of berries per bunch was averaged from five bunches per treatment. After-maturity, grapes from five vines in each treatment were harvested and weighed to calculate average yield/vine and was expressed in kilograms. Total soluble solids (TSS) were measured with a portable handheld refractometer (Erma Refractometer, Japan) at room temperature, and total acidity (TA) was determined using OenoFoss (FTIR based wine analyzer) and expressed in g/L. Chlorophyll content was estimated by Arnon's (1949) method.

2.1. Statistical Analysis

The data analysis was performed using analysis of variance (ANOVA) following the methodology outlined by Panse and Sukhatme (1995).

3. Result and Discussion

The data recorded on effect of the number of leaves above the bunch on various leaf area parameters are presented in Table 1. The maximum individual leaf areawas recorded in 10 leavesabove the bunch (165.00 cm^2) treatment which was at par with 12 leavesabove the bunch (162.10 cm^2) while, minimum leaf area was recorded in > 16 leaves above the bunch (150.50 cm^2) treatment. As the number of leaves above the bunch increased(from 10to > 16), the leaf area per shoot, per vine, and per bunch was also significantly increased. The leaf area/shoot increased from 2475.00 cm^2 (10 leaves above the bunch)to 3762.5 cm^2 (>16 leavesabove the bunch). Similarly, the leaf area per vine increasedfrom 59400.00 cm^2 to 90300.00 cm^2while, the leaf area per bunch increased from 1980.00 cm^2 to 3225.00 cm^2. The leaf area per gram of berry weight also increased from 4.36 cm^2/g to 8.06 cm^2/g. The optimum leaf number enhanced the overall leaf area, potentially contributing to higher photosynthetic capacity (source) and resource distribution(sink) for grape development.Similar conclusionswere also reportedby Thoke *et al.* (2024).Cataldo et al., (2021) reported maximum leaf area in the control (1.62±0.34) treatment and lowest in the four-leaf removal (1.19±0.43) treatment. The outcomeof the present studyis in agreementwith the findings of Candor *et al.* (2020); Somkuwar*et al.* (2012); Somkuwar*et al.* (2019).Somkuwar*et al.* (2024a and 2024b)suggested that maintaining 12 leavesabove the bunchwith 63820.80cm²in Crimson Seedless and 14 leaf above the bunch with 69312.00cm²leaf area per vine Manjari Kishmish weresufficient for higher yield and better quality grapes.

Bunch characteristics and yield/vineasinfluenced bynumber of leaves above the bunch are presented in Table 2. The average bunch weight decreased from 450.20 g (10 leavesabove the bunch) to 400.10 g (>16 leavesabove the bunch). The same trend was also observed for berry diameter as it decreased from 21.20 mm to 18.30 mm. The number of bunches/vines remained relatively stable, with slight variations, while, the number of berries/bunchindicated non-significant difference across treatments. The 50-berry weight decreased from 250.13 g to 222.30 g and the yield/vine also decreased from 13.60 kg to 11.22 kg. The total soluble solids (TSS) decreased from 19.20 °Brix in 10 leavesabove the bunch to 17.40 °Brix in>16 leavesabove the bunch. However, the acidity levels remained relatively stable, with slight variations. The higher leaf numbers might have reduced TSS, indicating a potential dilution of sugar content in grape berries, which could affect sweetness and overall berry quality. The increase in leaf number which enhanced the total leaf area, but it didnot improve bunch characteristics and yield. In fact, an excessive number of leaves might have negatively impacted both berry quality and yield. Potential of a vine to produce carbohydrates necessary for fruit production and vegetative growth depend on its actual leaf area (Somkuwaret al., 2019). Somkuwar et al. (2024a and 2024b) reported that maintaining12 leaves above the bunch in Crimson Seedless and 14 leaves above the bunch in Manjari Kishmish lead to enhance the productivity and raisin quality. However, excessive leaf retention decreased yield and quality.According to Somkuwaret al. (2019), an optimum leaf area maximizes the rate of photosynthesis, which helps meet the carbohydrate demands of the fruit (bunch). Additionally, Somkuwaret al. (2014) reported 10.09 kg yield/vine in the control group and 12.75 kg in the shoot thinning treatment at the 6-7 leaf stage. Similar resultswerealso reportedbySomkuwar*et al.* (2012) andCandar*et al.* (2020).

Theeffect of varying leaf number on leaf area index (LAI) and photosynthetically active radiation (PAR) are presented in Fig.1. LAI increased from 1.42 in 10 leavesabove the bunch to 2.16 in>16 leavesabove the bunch, demonstratingwidespread leaf coverage. However, PAR decreased from 0.152 µmol photon m^{-2} s^{-1} to 0.098 µmol photon m^{-2} s^{-1}. Higher leaf cover increases shading and reduces light penetration in the canopy, potentially affecting photosynthesis.Somkuwar*et al.* (2024a and 2024b) reported leaf area index (LAI) of Crimson Seedless and Manjari Kishmish increased with the number of leaves above the bunch(1.33 to 2.02 and 1.42 to 1.66 m^2/m^2 respectively) while, PAR value reduced as number of leaves increasedfrom 0.59 to 0.41 and 0.14 to 0.94 µmol photon m^{-2} s^{-1} respectively. Thoke *et al.*, (2024)also reported that the number of leaves per shoots and per vine increased, potentially leaf count. Theleaf area and LAI also increased because of increase in number of leaves pervine which contributes to elevated LAI. Burg *et al.* (2017) reported increased LAI from 1.86 to 2.22 m^2/m^2 in nine different grape varieties.The result of the present study suggests that an increase in leaf density positively correlates with a higher leaf area/ground area. Poni *et al.* (2008) observed that, due to defoliationof leaf (removed about 70% of the shoot leaf area) net carbon exchange rate (NCER) per vine significantlydecreased. This reduction in NCER was linked to a decrease in PAR reaching the vine canopy. Optimizing leaf density to strike a balance between maximizing leaf area for efficient light interception and minimizing shading effects is essential for optimizing crop yield and resource utilization.

Our study also aligns with the finding of Kang *et al*. (2022); Junges*et al*. (2018); Burg *et al*. (2017); Somkuwar*et al*. (2012).

Photosynthetic parameters resulted into decrease in assimilation rate from 13.10 µmol CO_2 m^{-2} s^{-1} in 10 leavesabove the bunch to 10.37 µmol CO_2 m^{-2} s^{-1}in>16 leavesabove the bunch. Slight variation was observedin stomatal conductance. It was increasedfrom14 leaves above the bunch (0.14)to16 leaves above the bunch (0.13) while the stomatal conductance wasagain decreasedin>16 leavesabove the bunch (0.12) treatment.However, intercellular CO_2 and transpiration rate was remained relatively stable. The decrease in the assimilation rate in a greater number of leaves was likely because, beyond a certain point, additional leaves may not contribute effectively to photosynthesis, possibly due to increased shading and reduced light penetration.Possible reason for general decrease in photosynthetic activity could be the increase in total leaf area of canopy (Somkuwar*et al.* 2014). The result of the present study aligns with the findings of our earlier results (Somkuwar*et al*. 2024a and 2024b) where least variation in photosynthetic activities in Crimson Seedless and Manjari Kishmish varietywas recorded after creating different variations of leaves above the bunch. Cataldo*et al*., (2021) also reportednon-significant result in leaf gas exchange parameters between four leaf removal and eight leaf removal during two-year study.

The efficiency of leaf to prepare food through photosynthesis depends upon chlorophyll content of leaf. Thein leaf decrease in chlorophyll a was recorded from 17.50 mg/ml in 10 leavesabove the bunch to 15.64 mg/ml in>16 leavesabove the bunch (Table 4). Chlorophyll b also decreased from 3.85 mg/ml to 3.50 mg/ml, However, total chlorophyll content in leaf of grapevine also recorded similar trends ofdecrease from 21.35 mg/ml to 19.14 mg/ml. Thus, the decrease in chlorophyll content in more leaves indicated reduced chlorophyll synthesis, or increased degradation, potentially affecting photosynthetic efficiency. Petrie *et al*. (2000) reported that leaf removal resulted in an increase in or retention of chlorophyll, which also occurred for the full leaf removal crop treatment.Somkuwar*et al.* (2024a and 2024b) reported that beyond optimum leaf number above the bunch (12 and 14 leaves respectively), chlorophyll content per leaf begin to decrease in Crimson Seedless and Manjari Kishmishgrape variety.

Both positive and negative correlations were observed between the growth and yield parameters in Nanasaheb Purple Seedless grapes (Table 5).Leaf area index was positively correlated withleaf area/vine (0.884), leaf area/bunch (0.998) and leaf area/gram of berry wt. (0.998) highlighting the influence of leaf density on total leaf area. However, the PAR values showed a strong negative correlation in leaf area index (-0.974), increased leaf density reduced light penetration.

4. Conclusion

Optimum leaf area management per vine in any grape variety is an important parameterfor enhancing the yield and quality. Retaining 10-12 leaves above the bunch in Nanasaheb Purple Seedless grape variety provides the best balance, maximizing leaf area and photosynthetic capacity while maintaining desirable bunch weight, berry size, yield/vine, and total soluble solids (TSS). Excessive leaf retention (>16 leaves above the bunch) negatively impacts these quality parameters. Therefore, precise canopy management practices with an optimum leaf area/shoot (2475.00 cm^2), leaf area/vine (59400.00 cm^2), leaf area/bunch (1980.00 cm^2) and leaf area/g berry weight (4.36 cm^2/g) can be achieved by retaining 10 leaves above the bunch for producing high-quality grapes.

References

Auzmendi, I., & Holzapfel, B. P. (2014). Leaf area to fruit weight ratios for maximising grape berry weight, sugar concentration and anthocyanin content during ripening. In *XXIX*

International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): IV 1115 (pp. 127-132).https://doi.org/10.17660/ActaHortic.2016.1115.19

Burg, P., Burgová, J., Mašán, V., &Vachůn, M. (2017). Leaf surface area estimation in different grapes varieties using AM 300 leaf area meter. In *International scientific conference RURAL DEVELOPMENT 2017* (pp. 24-30https://doi.org/10.15544/RD.2017.037

Caccavello, G., Giaccone, M., Scognamiglio, P., Forlani, M. & Basile, B. (2017). Influence of intensity of post-veraison defoliation or shoot trimming on vine physiology, yield components, berry and wine composition in Aglianico grapevines. – Australian Journal of Grape and Wine Research 23: 226-239. doi.org/10.1111/ajgw.12263.https://doi.org/10.1111/ajgw.12263

Candar, S., Bahar, E., &Korkutal, İ. (2020). Impacts of leaf area on the physiological activity and berry maturation of Merlot (Vitis vinifera L.*). Applied Ecology and Environmental Research,***18** (1), 1523-1538. https://doi.org/10.15666/aeer/1801_15231538

Cataldo, E., Salvi, L., Paoli, F., Fucile, M., &Mattii, G.B. (2021). Effects of defoliation at fruit Set on vine physiology and berry composition in cabernet sauvignon grapevines. *Plants*, 10(6), 1183.https://doi.org/10.3390/plants10061183

Iland, P. & Gago, P. (2002). Australia Wines. Styles and Tastes. Campbell town, South Australia. Patrick Iland Wine Promotions.

Junges, A. H., Fontana, D. C., &Lampugnani, C. S. (2019). Relationship between the normalized difference vegetation index and leaf area in vineyards. *Bragantia*, *78*, 297-305.https://doi.org/10.1590/1678-4499.2018168

Kang, Y., Gao, F., Anderson, M., Kustas, W., Nieto, H., Knipper, K., Yang, Y., White, W., Alfieri, J., Torres-Rua, A. & Alsina, M.M., 2022. Evaluation of satellite Leaf Area Index in California vineyards for improving water use estimation. *Irrigation Science*, *40*(4), pp.531-551.https://doi.org/10.1007/s00271-022-00798-8

Kliewer, W.M., &Dokoozlian, N.K. (2005). Leaf area/crop weight ratios of grapevines: Influence on fruit composition and wine quality. *American Journal of Enology and Viticulture*, *56*(2), 170-181.https://doi.org/10.5344/ajev.2005.56.2.170

Martínez de Toda, F., & Balda, P. (2013). Delaying berry ripening through manipulating leaf area to fruit ratio.DOI: https://doi.org/10.5073/vitis.2013.52.171-176

Moran, M. A., Sadras, V. O., & Petrie, P. R. (2017). Late pruning and carry□over effects on phenology, yield components and berry traits in Shiraz. *Australian journal of grape and wine research*, *23*(3), 390-398.https://doi.org/10.1111/ajgw.12298

Petrie, P. R., Trought, M. T., & Howell, G. S. (2000). Influence of leaf ageing, leaf area and crop load on photosynthesis, stomatal conductance and senescence of grapevine (Vitis vinifera L. cv. Pinot noir) leaves. *Vitis-Geilweilerhof-*, ***39***(1), 31-36.https://ojs.openagrar.de/index.php/VITIS/article/view/4601

Poni, S., Bernizzoni, F., &Civardi, S. (2008). The effect of early leaf removal on whole-canopy gas exchange and vine performance of Vitis vinifera L.Sangiovese'. *Vitis-Geilweilerhof-*, ***47***(1): 1.https://doi.org/10.1111/ajgw.12040

Poni, S., Gatti, M., Bernizzoni, F., Civardi, S., Bobeica, N., Magnanini, E., &Palliotti, A. (2013): Late leaf removal aimed at delaying ripening in cv. Sangiovese: physiological assessment and vine performance. – Australian Journal of Grape and Wine Research 19(3): 378-387. doi.org/10.1111/ajgw.12040.https://doi.org/10.1111/ajgw.12040

Sadras, V. O., Stevens, R. M., Pech, J. M., Taylor, E. J., Nicholas, P. R., & McCarthy, M. G. (2007). Quantifying phenotypic plasticity of berry traits using an allometric□type approach: a case study on anthocyanins and sugars in berries of Cabernet Sauvignon. *Australian Journal of Grape and Wine Research*, *13*(2), 72-80.https://doi.org/10.1111/j.1755-0238.2007.tb00237.x

Somkuwar, R. G., Ramteke, S. D., Satisha, J., Bhange, M., &Itroutwar, P. (2014). Effect of canopy management practices during forward pruning on berry development and photosynthesis in Tas-A-Ganesh grapes. *Journal of Horticultural Sciences*, ***9***(1), 18-22.https://doi.org/10.24154/jhs.v9i1.211

Somkuwar, R. G., Ramteke, S. D., Sawant, S. D., &Takawale, P. (2019). Canopy modification influences growth, yield, quality, and powdery mildew incidence in Tas-A-Ganesh grapevine. *International journal of fruit science*, ***19***(4), 437-451.https://doi.org/10.1080/15538362.2018.1555509

Somkuwar, R. G., Taware, P. B., Bondage, D. D., &Nawale, S. (2012). Influence of shoot density on leaf area, yield and quality of Tas-A-Ganesh grapes (Vitis vinifera L.) grafted on Dog Ridge rootstock. *International Research Journal of Plant Science*,**3**(5), 94-99.https://www.interesjournals.org/articles/influence-of-shoot-density-on-leaf-area-yield-and-qualityof-tasaganesh-grapes-vitis-vinifera-l-grafted-ondog-ridge-roots.pdf

Somkuwar, R. G., Kakade, P. B., Dhemre, J. K., Tutthe, A. S., Nikumbhe, P. H., & Deshmukh, N. A. (2024). Leaf Retention Affects Photosynthetic Activity, Leaf Area Index, Yield and Quality of Crimson Seedless Grapes. Journal of Advances in Biology & Biotechnology, 27(9), 123-130.https://doi.org/10.9734/jabb/2024/v27i91281

Somkuwar, R. G., Kakade, P. B., Dhemre, J. K., Gharate, P. S., Deshmukh, N. A., &Nikumbhe, P. H. (2024). Leaf Area Influences Photosynthetic Activities, Raisin

Yield and Quality in Manjari Kishmish Grape Variety. Archives of Current Research International, 24(6), 613-622.https://doi.org/10.9734/acri/2024/v24i6817

Thoke, S., Patil, S. N., Gollagi, S. G., Hipparagi, K., Hiremath, V., Peerajade, D., & Kore, D. (2024). Evaluation of Different Table Grape Varieties in Response to Growth and Physiological Traits during Foundation Bud Pruning. *Journal of Experimental Agriculture International*, *46*(2), 126-140.http://dx.doi.org/10.9734/jeai/2024/v46i22315

Figure 1: Effect of leaves on LAI and PAR of vine in Nanasaheb Purple variety

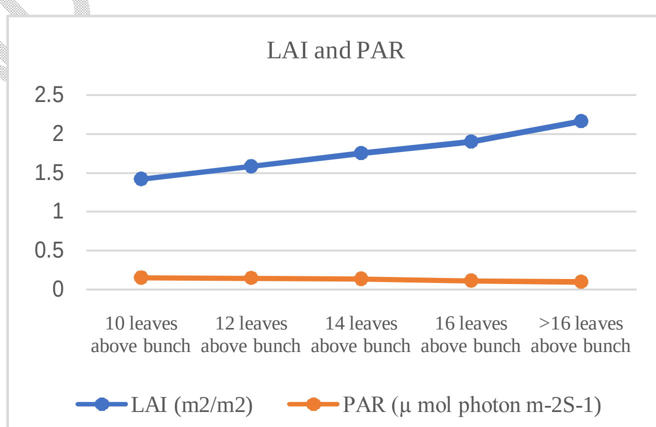

Table 1: Effect of leaves on total leaf area in Nanasaheb Purple variety

Leaf above the bunch	Leaf area/leaf (cm^2)	Leaf area/shoot (cm^2)	Leaf area/vine (cm^2)	Leaf area/bunch (cm^2)	Leaf area/g berry wt. (cm^2/g)
10 leaves above bunch	165.00	2475.00	59,400.00	1980.00	4.36
12 leaves above bunch	162.10	2755.70	66,137.00	2204.60	5.12
14 leaves above bunch	160.50	3049.50	73,190.00	2559.10	6.17
16 leaves above bunch	157.80	3313.80	79,531.50	2840.39	6.92
>16 leaf above bunch	150.50	3762.5	90,300.00	3225.00	8.06
SEm ±	1.09	27.42	658.2	24.00	0.06
CD at 5 %	3.29	82.22	1973.5	71.95	0.18

Table 2: Effect of leaves on bunch characters and yield in Nanasaheb Purple variety

Leaf above the bunch	Av. bunch weight (g)	Berry diameter (mm)	No of bunches/ vine	No of berries/ bunch	50-berry wt. (g)	Yield/vine (kg)	TSS (^{0}Brix)	Acidity (g/L)
10 leaves above bunch	450.20	21.20	30.20	90.00	250.13	13.60	19.20	5.25
12 leaves	430.25	20.40	30.00	89.50	240.36	12.90	18.80	5.20

above bunch								
14 leaves above bunch	415.35	20.00	28.60	90.20	230.25	11.87	18.20	5.30
16 leaves above bunch	410.30	19.50	28.00	90.00	228.00	11.48	17.20	5.25
>16 leaves above bunch	400.10	18.30	28.00	90.00	222.30	11.22	17.40	5.10
SEm ±	2.82	0.13	0.19	NS	1.56	0.08	0.12	0.03
CD at 5 %	8.45	0.40	0.5	NS	4.68	0.24	0.38	0.11

Table 3: Effect of leaves on photosynthetic activities in Nanasaheb Purple variety

Leaf above the bunch	Assimilation rate (µmol CO_2 m^{-2} s^{-1})	Stomatal conductance (mmol CO_2 m^{-2} s^{-1})	Intercellular CO_2 (Ci) (ppm)	Transpiration rate (mmol H_2O m^{-2} s^{-1})
10 leaves above bunch	13.10	0.12	245.50	2.56
leaves above bunch	12.85	0.13	248.15	2.51
14 leaves above bunch	12.55	0.14	245.11	2.53
16 leaves above bunch	12.15	0.13	243.22	2.53

>16 leaves above bunch	10.37	0.12	241.26	2.52
SEm ±	0.08	0.001	NS	NS
CD at 5 %	0.25	0.003	NS	NS

Table 4: Effect of leaves above bunch on chlorophyll content in leaves of Nanasaheb Purple variety

Leaf above the bunch	Chlorophyll a (mg/ml)	Chlorophyll b (mg/ml)	Total chlorophyll (mg/ml)
10 leaves above bunch	17.50	3.85	21.35
12 leaves above bunch	17.15	3.67	20.82
14 leaves above bunch	16.35	3.65	20.00
16 leaves above bunch	16.20	3.53	19.73
>16 leaves above bunch	15.64	3.50	19.14
SEm ±	0.01	0.02	0.13
CD at 5 %	0.33	0.07	0.40

parameters	Leaf area index (m^2/m^2)	PAR (µ mol photon $m^{-2}S^{-1}$)	Leaf area/vine (cm^2)	Leaf area/bunch (cm^2)	Leaf area/gram of berry wt. (cm^2/g)	Total chlorophyll content (mg/ml)	Av. bunch wt. (g)	Yield/vine (kg)
Leaf area index (m^2/m^2)	1							
PAR (µ mol photon $m^{-2}S^{-1}$)	-0.974	1						
Leaf area/vine (cm^2)	0.884	-0.952	1					
Leaf area/bunch (cm^2)	0.998	-0.983	0.892	1				
Leaf area/gram of berry wt. (cm^2/g)	0.998	-0.978	0.880	0.999	1			
Total	-0.984	0.956	-0.827	-0.989	-0.992	1		

chlorophyll content (mg/ml)								
Av. bunch wt. (g)	-0.958	0.912	-0.771	-0.960	-0.968	0.986	1	
Yield/vine (kg)	-0.949	0.933	-0.797	-0.961	-0.966	0.987	0.988	1

Table 5. Correlation coefficients between different growth and yield parameters as influenced by number of leaves maintained above the bunch.