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Leaf Retention Affects Photosynthetic Activity, Leaf Area Index, Yield and Quality of Crimson Seedless Grapes

R. G. Somkuwar [a++], P. B. Kakade [b#*], J. K. Dhemre [b†], A. S. Tutthe [a,b#‡], P. H. Nikumbhe [a,b#‡] and N. A. Deshmukh [a^]

[a] ICAR-National Research Centre for Grapes, Pune, Maharashtra, 412307, India.
[b] Department of Horticulture, PGI, MPKV, Rahuri, Maharashtra, 413722, India.

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 research was conducted at ICAR-National Research Centre for Grapes, Pune during October, 2023 to March, 2024 to investigates the effect of varying leaf retention on leaf area index (LAI), photosynthetic activities, yield and quality of Crimson Seedless grapes grafted on Dogridge rootstock. Five treatments of different numbers of leaves retained on each shoot above the bunch

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[++] Principal Scientist (Horticulture)
[#] PhD. Research Scholar;
[†] Associate Professor;
[‡] Scientist (Horticulture);
^ Senior Scientist (Horticulture);
**Corresponding author: E-mail: pradipkakade1234@gmail.com;*

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(10, 12, 14, 16 and more than 16 leaves) were evaluated. Parameters measured included leaf area, leaf area index, photosynthetically active radiation (PAR), photosynthetic rate, stomatal conductance, chlorophyll content, average bunch weight, berry weight, yield per vine, total soluble solids (TSS) and acidity. The results showed that leaf area per leaf ranged from 140.60 cm^2 in the treatment with more than 16 leaves to 156.40 cm^2 in the 12-leaf treatment. The highest yield per vine (12.89 kg) and optimum berry quality were observed with 12 leaves above the bunch. Increased leaf area improved nutrient assimilation and berry growth but excessive leaf retention led to decreased light penetration and photosynthetic efficiency. These findings suggest that maintaining 12 leaves with 1782.70 cm^2 leaf area above the bunch is optimal for balancing yield (12.89 kg/vine) and berry quality in Crimson Seedless grapes under the tropical conditions.

Keywords: Leaf retention; crimson seedless; berry quality; photosynthetic rate; chlorophyll content.

1. INTRODUCTION

Grape (*Vitis vinifera* L.) is one of the most widely cultivated fruit crops in the world, valued for their versatility and nutritional benefits. It has a significant place in global agriculture and trade. According to the Food and Agriculture Organization (FAO), the global area, production and productivity of grapes was approximately 7.4 million hectares, 77.1 million metric tons and 15 metric tons per hectare in well-managed vineyards [1]. In India, grape is cultivated on an area of about 1.62 lakh hectares with approximately 34.45 Lakh MT of produce under tropical condition (Somkuwar et al., 2024). It is consumed fresh as table grapes, dried to produce raisins, or processed to produce wine, juice, and other products. Crimson Seedless is considered for export to the neighbouring countries. It is a popular coloured grape variety identified for its attractive medium-sized clusters, large dark pink berries, firm and crunchy texture, sweet to neutral taste, and uniform colour. The grape quality required for export is largely depends on canopy management practices like orchard orientation, training, pruning, thinning of berries, bunches and leaf removal practices for quality production [2]. Leaves are powerhouses of photosynthesis, where chlorophyll absorbs light energy to convert carbon dioxide and water into carbohydrates. This essential process not only stimulates plant growth but also supports the critical functions of evapotranspiration. Consequently, understanding leaf area requirement is crucial for physiological and agronomic studies related to plant development [3]. The leaf surface area affects yield and quality of grapevines. It mainly influenced by variety, nutrition, canopy management practices like training and pruning, and finally age of plant [4]. As leaf area index increases photosynthesis rate decreases [5]. Understanding the relative importance of such relationships for vegetation growth and productivity is limited but essential for understanding the responses to CO_2. The concept of leaf area index was first introduced by Watson [6] and defined as the ratio of leaf area to given unit of land area. Somkuwar et al. [7], Burg et al. [4], Somkuwar et al. [2] and Kang et al. [8] studied leaf area index of different grape varieties in each phenophase at different locations. Numerous researchers have also studied the ideal leaf surface area in relation to the quantity of grapes retained on the vine. Total 1.6 and 1.8 square meters of leaf area was required to produce one-kilogram small grapes, while varieties with medium sized to large grapes need between 2.0 and 2.2 square meters of leaf area as reported by Becker et al., 2007. According to Spring and Zufferey [9], 1.0 to 1.2 square metres of leaf area is needed to produce one kilogram of high-quality grape. Fruit size development depends on factors like leaf-fruit ratio, leaf area index, genetics, climate, plant position, branch, tree age, seed count, and nutrient availability [3]. To investigate actual leaf area requirement to produce quality grapes meant for export, this experiment was conducted with the objectives to know the effect of leaf retention above the bunch on leaf area, leaf area index, yield and quality of Crimson Seedless grapes grafted on Dogridge rootstock under semi-arid condition.

2. MATERIALS AND METHODS

The study was conducted at the farm of ICAR-National Research Centre for Grapes, Pune during 2023-24. The experimental site is situated in Mid-West Maharashtra at an altitude of 559 m above mean sea level (18.32°N and 73.51°E). The grape variety Crimson Seedless was grafted on Dogridge rootstocks in August 2017 at a spacing of 9 x 5 feet trained to extended Y-Trellis following all standard recommended cultural practices. After the fruit pruning, the bunch appears on fifth leaf on new growth. Different leaf area per shoot was maintained by altering the number of leaves above the bunch. Five different treatments were evaluated, each corresponding to 10, 12, 14, 16 and > 16 number of leaves above the bunch on each shoot and replicated five times. LAI and PAR was recorded with the help of LaiPen LP 110. (LAI = leaf area/ground area, m^2/m^2) in broadleaf canopies while, photosynthetically active radiation (PAR) is quantified as μmol photons $m^{-2}s^{-1}$, which is a measure of the photosynthetic photon flux density (PPFD). Photosynthetic rate, stomatal conductance and transpiration rate were recorded using Infra-Red Gas Analyzer (IRGA) made in USA (IRGA model Li 6400, LI-COR Biosciences, NE, USA). Matured leaves (fifth to sixth from tip) were used for measuring these parameters. Observations were recorded during bright sunlight at 11.0 am to 12.30 pm. Leaf area was measured by linear method (LBK method) expressed in cm^2. The mathematical relationship for calculation was given as follows;

Leaf area (A) = L x B x K (0.810).

Total leaf area per shoot was calculated by multiplying leaf area per leaf to total number of leaves per shoot. Total leaf area per vine was calculated by multiplying leaf area per shoot to total number of shoots per vine. Total leaf area per bunch was calculated by dividing leaf area per vine to the total number of bunches per vine and was expressed in cm^2. The average bunch weight was calculated by the mean weight of five randomly selected healthy bunches per replication. Fifty berries were selected from five different bunches in each replication, The average weight of 50 berries was calculated and expressed in grams. Number of berries per bunch were calculated from five bunches in each treatment and the average was calculated. After the fruit maturity, the grapes from five vines in each treatment were harvested and weighed using a weighing balance. The average yield/vine was calculated and expressed in kg. TSS was measured using a portable handheld refractometer (Erma Refractometer, Japan). The total acidity (TA) was determined using OenoFoss (FTIR based wine analyzer) and expressed in g/L. Chlorophyll was extracted and estimated by Arnon 's (1949) method.

2.1 Statistical Analysis

The experiment was conducted in Randomized Block Design (RBD) with five treatment and five replication and the data was analysed by standard method of analysis of variance as described by Panse and Sukhatme (1995).

3. RESULTS AND DISCUSSION

The effect of the number of leaves above the bunch on various leaf area parameters are presents in Table 1. The leaf area per leaf ranged from 140.60 cm^2 in T_5 (>16 leaves) to 156.40 cm^2 in T_2 (12 leaves). The leaf area per shoot, vinemand bunch increased progressively with the number of leaves. The highest leaf area per vine (84,364.80 cm^2) and per bunch (2,343.46 cm^2) were observed in T_5 (>16 leaves). This was due to direct correlation between leaf number and total leaf area. The leaf area per gram berry weight also increased with the number of leaves. It was resulted due to enhanced photosynthetic capability and nutrient distribution with more leaves. Thoke et al. [10] reported leaf area of ten different varieties ranging from 183.54 cm^2 in Nanasaheb Purple Seedless to 200.11cm^2 in Thompson Seedless while, Crimson Seedless recorded 188.24 cm^2 at Vijayapura under northern dry zone of Karnataka. This aligns with previous studies of Somkuwar et al. [7]; Burg et al. [4]; Somkuwar et al. [2] and Candor et al. [11] which indicated that increased leaf area can lead to better nutrient assimilation and berry growth.

As shown in Table 2, the average bunch weight was highest in T_2 (360.20 g) while lowest in T_5 (300.50 g). The number of berries per bunch showed slight decrease with more leaves, but the 50-berry weight (148.20 g) and yield per vine was also highest in T_2 (12.89 kg) while, lowest in T_5 (10.81 kg). Total soluble solids (TSS) and acidity showed minimal variation among treatments. This might be due to leaf numbers affected yield parameters, its impact on berry quality was less pronounced. From the study it was concluded that maintaining 12 leaves above the bunch (T_2) is optimal for balancing yield and berry quality. However, Somkuwar et al. [12] reported that shoot thinning (6-7 Leaf stage) and shoot pinching at 10 leaves above bunch increased overall bunch weight (375.60 and 307.80 g), 50- berry weight (184.20 and 172.35 g), TSS (20.20 and 17.66 ^{0} Brix), yield/ vine (12.75 and 12.25 kg) and reduced acidity content (0.52 and 0.53%) respectively in Tas-A-Ganesh grape. Our findings confirm the result obtained by Poni et al. [13], Auzmendi et al. [14], Korkutal et al. [15] and Candor et al. [11].

Table 1. Effect of leaves on total leaf area in Crimson Seedless variety

Leaf above the bunch	Leaf area/leaf	Leaf area/shoot (cm^2)	Leaf area/vine (cm^2)	Leaf area/bunch (cm^2)	Leaf area/gram berry wt. (cm^2/g)
T_1-10 leaves above the bunch	154.00	2310.00	55440.00	1540.00	4.40
T_2-12 leaves above the bunch	156.40	2659.20	63820.80	1782.70	4.96
T_3-14 leaves above the bunch	152.35	2894.64	72366.20	2032.75	5.90
T_4-16 leaves above the bunch	150.25	3155.60	78890.40	2234.85	6.57
T_5->16 leaf above the bunch	140.60	3515.20	84364.80	2343.46	7.81
S Em ±	1.04	25.67	629.8	17.54	0.05
CD (p=0.05)	3.12	76.96	1888	52.61	0.17

Table 2. Effect of leaves on bunch characters, berry quality and yield in Crimson Seedless

Leaf above the bunch	Av. bunch wt. (g)	No of bunches/ vine	No of berries/bunch	50-berry wt. (g)	Yield/vine (kg)	TSS (^{0}Brix)	Acidity (g/L)
T_1-10 leaves above the bunch	350.00	36.00	125.00	140.00	12.60	18.20	5.10
T_2-12 leaves above the bunch	360.20	35.80	122.50	148.20	12.89	18.60	5.10
T_3-14 leaves above the bunch	345.25	35.60	120.00	144.00	12.42	18.10	5.15
T_4-16 leaves above the bunch	340.10	35.30	124.20	136.92	12.00	17.45	5.15
T_5->16 leaf above the bunch	300.50	36.00	123.00	122.15	10.81	17.20	5.12
S Em ±	2.33	NS	0.82	1.00	0.08	0.12	NS
CD (p=0.05)	6.99	NS	2.48	3.00	0.25	0.38	NS

Leaf area index was attributed to inherent varietal character as leaf number and leaf area increases, LAI also increased with the number of leaves with the highest value (2.02 m^2/m^2) in T_5 (Table 3). Conversely, PAR decreased as the number of leaves increased. Denser foliage may reduce light penetration and these impact photosynthetic efficiency as seen by the slight decrease in PAR values with more leaves. Optimal leaf management is crucial for maintaining a balance between sufficient leaf area for photosynthesis and preventing excessive shading that can reduce light availability to lower leaves. Kang et al. [8] reported LAI in the range of 0.8 to 2.4, 1.0 to 4.0 and 0.7 to 4.0 m^2/m^2 in Cabernet Sauvignon, Chardonnay and Pinot Noir grapes respectively. LAI ranging from 1.86 to 2.22 m^2/m^2 in nine different grape varieties was reported by Burg et al. [4]. Thoke et al. [10] found highest leaf area index (3.91 m^2/m^2) in Thompson Seedless while the lowest in Nanasaheb Purple Seedless (3.68 m^2/m^2) and Crimson Seedless (3.87 m^2/m^2) after foundation pruning. Similar results were also reported by Somkuwar et al. [7], Somkuwar et al. [16] and Somkuwar et al. [2].

The assimilation rate, stomatal conductance, intercellular CO_2, and transpiration rate did not vary significantly with the number of leaves. The assimilation rate ranged from 11.20 to 12.10 µmol CO2 m^{-2} s^{-1}, and stomatal conductance remained around 0.11 to 0.14 mmol CO2 m^{-2} s^{-1}. From the results, it was concluded that leaf number affects total leaf area and yield parameters and it has a lesser impact on the intrinsic photosynthetic activities per leaf. Ghule et al. [17] observed that changes in foliar biomass and leaf area influence gas exchange parameters. They reported significant impact of leaf area on the transpiration rate and stomatal conductance in Thompson Seedless, Manjari Medika, and Manjari Kishmish grape varieties. Somkuwar et al. [12] also reported that photosynthetic rates per leaf area can remain stable under different leaf densities.

Table 3. Effect of leaves on berry quality parameters in Crimson Seedless variety

Leaf above the bunch	LAI (m^2/m^2)	PAR (µ mol photon $m^{-2}S^{-1}$)
T_1-10 leaves above the bunch	1.33	0.59
T_2-12 leaves above the bunch	1.53	0.52
T_3-14 leaves above the bunch	1.73	0.50
T_4-16 leaves above the bunch	1.89	0.46
T_5->16 leaf above the bunch	2.02	0.41
S Em±	0.015	0.003
CD (p=0.05)	0.045	0.010

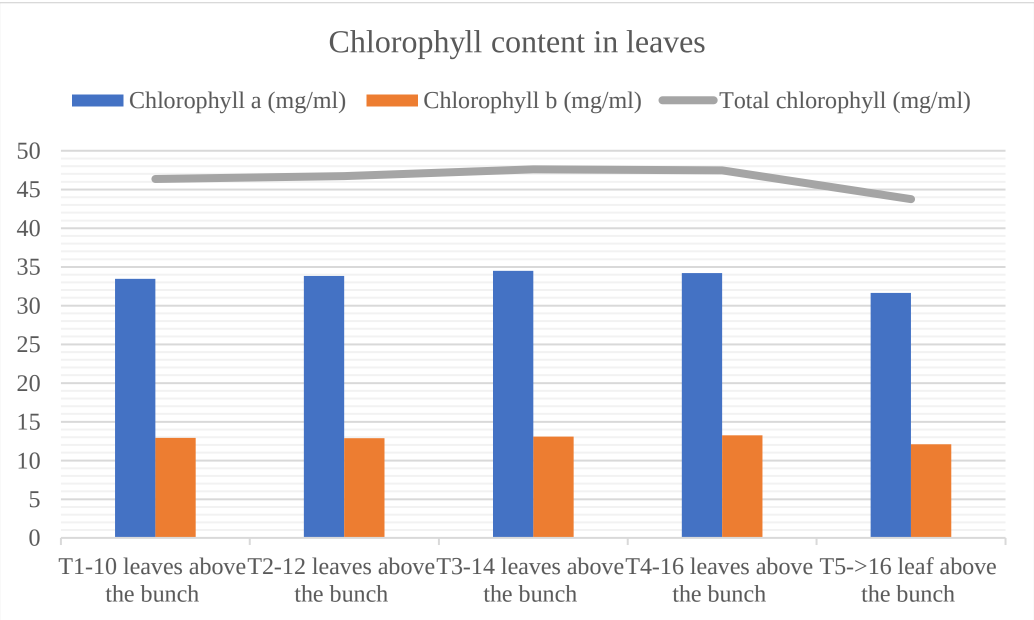

Fig. 1. Effect of leaves on chlorophyll content in leaves of Crimson Seedless

Table 4. Effect of leaves on photosynthetic activities in Crimson Seedless 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 H2O m^{-2} s^{-1})
T_1-10 leaves above the bunch	12.10	0.11	256.20	2.52
T_2-12 leaves above the bunch	12.00	0.12	255.30	2.61
T_3-14 leaves above the bunch	11.55	0.14	252.50	2.58
T_4-16 leaves above the bunch	11.20	0.13	250.62	2.55
T_5->16 leaf above the bunch	12.00	0.11	248.60	2.57
S Em±	0.08	0.001	1.76	0.08
CD (p=0.05)	0.25	0.003	5.29	0.05

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

parameters	Leaf area/leaf	Leaf area/bunch (cm^2)	Leaf area index (m^2/m^2)	PAR (μmol photon m^{-2} s^{-1})	Average bunch weight (g)	Yield/vine (kg)	Total chlorophyll (mg/ml)
Leaf area/leaf	1.000	-0.784	-0.811	0.816	0.998	0.998	0.791
Leaf area/bunch (cm^2)		1.000	0.999	-0.975	-0.745	-0.800	-0.329
Leaf area index (m^2/m^2)			1.000	-0.983	-0.775	-0.826	-0.378
PAR (μmol photon m^{-2} s^{-1})				1.000	0.786	0.831	0.473
Average bunch weight (g)					1.000	0.992	0.822
Yield/vine (kg)						1.000	0.778
Total chlorophyll (mg/ml)							1.000

The chlorophyll content in leaf gives an indication of the efficiency of leaf to prepare food through photosynthesis. Highest total chlorophyll was observed in T_3 and T_4 treatments, with values slightly decreasing in T_5 (Fig. 1) More leaves can increase overall photosynthetic capacity. There may be an optimum leaf number beyond which chlorophyll content per leaf may begin to decrease. Maintaining an appropriate number of leaves can produce maximum chlorophyll content and photosynthetic efficiency without any negative effect. Our results of decreasing chlorophyll content after increasing number of leaves above bunch support the finding of Petrie et al. [18] and Somkuwar et al. [16] who observed that leaf removal led to an increase of chlorophyll content.

Leaf area per leaf was positively correlated with average bunch weight (0.998) and yield/vine (0.998), indicating that larger leaf areas may lead to higher yields and heavier bunches (Table 5). However, it is negatively correlated with leaf area per bunch (-0.784) and leaf area index (-0.811). Leaf area index is highly correlated with leaf area per bunch (0.999), highlighting the influence of leaf density on total leaf area. The PAR values showed a strong negative correlation with leaf area index (-0.983), increased leaf density reduces light penetration. Total chlorophyll content showed moderate positive correlations with leaf area per leaf (0.791) and average bunch weight (0.822), optimal leaf numbers enhance chlorophyll content and photosynthetic efficiency.

The leaf retention above the bunch significantly impacts on leaf area index, yield, and quality of Crimson Seedless grapes. Maintaining 12 leaves above the bunch with individual leaf area of 156.40 cm^2 optimizes both yield (12.89 Kg/vine) spaced at 9 X 5 feet distance and berry quality (18.60 ^{0}Brix TSS) also balancing adequate photosynthetic capacity and efficient nutrient distribution. Excessive leaf retention (>16 leaves) negatively affects light penetration and photosynthetic efficiency, highlighting the importance of proper canopy management. These results provide valuable insights for grape growers aiming to maximize yield and quality through optimal leaf management practices in tropical viticulture.

4. CONCLUSION

Increased leaf area improved nutrient assimilation and berry growth, but excessive leaf retention led to decreased light penetration and photosynthetic efficiency. These findings suggest that maintaining 12 leaves with 1782.70 cm2 leaf area above the bunch is optimal for balancing yield (12.89 kg/vine) and berry quality in Crimson Seedless grapes under the tropical conditions.

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.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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