Leaf area influences photosynthetic activities, raisin yield and quality in Manjari Kishmish grape variety

Abstract

Theideal leaf area is essential for optimizing photosynthesis and resource distribution, which improves bothyield and quality.Leaf retention is a cultural practice that involves maintaining definite number of leaves above the bunch to optimize photosynthetic efficiency and fruit quality. The experiment was conducted at the ICAR-National Research Centre for Grapeswith different treatments of number of leavesabove the bunch (10, 12, 14, 16, and >16 leaves). The parameters measured included leaf area, photosynthetic rate, stomatal conductance, transpiration rate, bunch weight, berry quality, and raisin recovery. The results revealed that retaining 14 leaves above bunchwith leaf area of 1066.33 cm^2resulted in maximumbunch weight (365.00 g), 50-berry weight (123.31 g), yield/vine (23.72 kg) and raisin recovery (26.54 %) while, minimum bunch weight (300.00 g), 50-berry weight (103.48 g), yield/vine (19.20 kg) and raisin recovery (24.35 %) were observed in more than16 leaves above the bunch. However,the leaf area/shoot (2888.00 cm^2), leaf area/vine (69312.00 cm^2), leaf area/bunch (1066.33 cm^2) and leaf area/g berry weight (2.92 cm^2/g) were found sufficient forhigh quality grapeand raisin productionin a vine spaced at 9 X 5 feet distance which was achieved through 14 leaves above the bunch in Manjari Kishmish grape.It is therefore recommended to maintain approximately 14 leaves above the bunch in Manjari Kishmishthat will help to maximize photosynthetic efficiency, enhance leaf area distribution, and support higher yield, raisin and better berry quality.

Keywords: leaf area, LAI, PAR, Photosynthetic activity, Raisin recovery, Yield

Introduction

The grape (*Vitis vinifera* L.) is an important fruit crop grown in India. Basically, it is a temperate fruit crop that has been successfully adapted to the sub-tropical as well as tropical climate and is well known for its various health benefits. Although, India is predominant in grape cultivation, approximately 78% of the total production is used for table purpose, almost 17–20 percent is dried for raisin production, while and the remaining 2% is utilized in the production of juice and wine (Somkuwar et al. 2024a). About 90% production is used for raisin making using Thompson Seedless or its clones (Somkuwar et al., 2019). Manjari Kishmish (clonal selection from Kishmish Rozavis) is becoming popular due to its high raisin recovery (Somkuwar et al., 2024b). To produce quality raisins with internationally and nationally acceptable quality, careful balance of source sink ratio is required (Somkuwar and Ramteke, 2006). Also, cultural practices (nutrient, irrigation and canopy management) play an important role in producing good quality raisin (Somkuwar et al., 2020).Among the several canopy management practices, leaf removalpractice is being followed,as it not only maintains and increase productivity but also has pronounced effect on the distribution of photo assimilates and the source-sink relationship between leaves and fruitsof vineyardwhich adjust balanced between development and yield (Kliewer and Dokoozlian 2005; Somkuwar et al., 2014 and Moran et al., 2017).Leaf removal is a technique that involves the removal of a select number of leaves that cover the fruiting region along shoots (Poni et al., 2006). It is known to directly affect assimilation dynamics. Berry growth and chemical composition can be regulated by manipulating source-sink relationship (Kliewer and Dokoozlian, 2005). Assimilate supply from a source may be increased by increasing leaf: fruit ratio thus, generally leading to larger fruit size in grapes (Petrie et al, 2000). Leaf retention, the practice of maintaining leaves on the vine throughout the growing seasonplays a crucial role in the physiological processes of the grapevine (Somkuwar et al., 2014). The Leaf Area Index

(LAI), which measures the leaf area per unit ground area, is a critical parameter in understanding the canopy structure and its influence on photosynthesis, transpirationand ultimately, the yield and quality of the grape berries (Burg et al., 2017; Munitz et al., 2019; Somkuwar et al., 2020).This study aims to investigate the impact of leaf retention on the leaf area index, yield, and raisin quality of Manjari Kishmish grapes under tropical conditions in Pune region. Understanding these relationships is essential for optimizing viticultural practices to enhance grape quality and production.

Material and Methods

The study was conducted at ICAR-National Research Centre for Grapes, Pune during 2023-24. The experimental site is in mid-west Maharashtra at an altitude of 559 meters above mean sea level (18.32°N, 73.51°E). Manjari Kishmish grapevines, grafted onto Dogridge rootstocks were planted at a spacing of 9 x 5 feet and trained to extended Y-Trellis, 0.5 cane/feet^2 (24 canes/vine) were retained on each vine. All the standard recommended cultural practices were followed to maintain the 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 followed a Randomized Block Design (RBD).Leaf Area Index (LAI) and Photosynthetically Active Radiation (PAR) were recorded using the LaiPen LP 110 device. LAI was calculated as leaf area per ground area (m^2/m^2), and PAR, measured in µmol photons $m^{-2}s^{-1}$, quantified the photosynthetic photon flux density (PPFD). Photosynthetic rate, stomatal conductance, and transpiration rate were measured using an Infra-Red Gas Analyzer (IRGA model Li 6400, LI-COR Biosciences, NE, USA) on matured leaves (fifth to sixth from the 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 cm^2. 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 calculateaverage 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 extracted and estimated by Arnon's (1949) method.

Statistical Analysis

Data analysis was conducted using analysis of variance (ANOVA) as described by Panse and Sukhatme (1995).

Result and discussion

Leaf area per leaf ranged from 115.5 to 165.2 cm^2. The highest leaf area per leaf was recorded in10 leavesabove the bunch (165.2 cm^2) followed by 12 leavesabove the bunch (160.0 cm^2),14 leavesabove the bunch (152.0 cm^2) while, T_4 (16 leavesabove the bunch)and T_5 (>16 leaves above the bunch) observed lower leaf area per leaf (135.5 cm^2 and 115.5 cm^2 respectively). The highest leaf area per shoot and per vine was recorded in 14 leaves above the bunch which was at par with more than 16 leaves above the bunch (with 2888.5 cm^2 and 69312.0 cm^2 and 2887.5 cm^2 and 69300.0 cm^2 respectively)while, 10 leavesabove the bunchrecorded lowest leaf area per shoot and per vine (2478.0 cm^2 and 59472.0 cm^2 respectively).The leaf area per bunch and per gram of berry weight increased with the number of leaves, with highest in more than 16 leaves above the bunch (1082.81 cm^2 and

3.60 cm²/g respectively). The increase in leaf area per shoot and vine with more leaves is due to the direct correlation between the number of leaves and the overall vegetative growth of the vine. However, decrease in leaf area per leaf showed limited resource distribution or reduce efficiency as the leaf number increased. Burg et al. (2017)reported that the leaf surface area in nine grape varieties,showed significant difference in leaf area during developmentwhile, leaf area per vine varied significantly between grape varieties ranging between 20.560 to 26.481 m^2.The results of the present investigation are in close conformity with the findings of Somkuwar et al.(2012); Somkuwar et al. (2019);Candor et al. (2020).

Table 1: Effect of leaves on total leaf area in Manjari Kishmish 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	165.2	2478.00	59472.00	929.25	2.90
T_2-12 leaves above the bunch	160.0	2720.00	65280.00	989.10	2.82
T_3-14 leaves above the bunch	152.0	2888.00	69312.00	1066.33	2.92
T_4-16 leaves above the bunch	135.5	2845.50	68292.00	1004.30	3.00
T_5->16 leaf above the bunch	115.5	2887.50	69300.00	1082.81	3.60
SEm±	1.06	21.96	565.8	8.32	0.02
CD (p=0.05)	3.20	65.85	1696.5	24.94	0.07

The data recorded on variousparameters of bunch and yield are presented in Table 2. The average bunch weight was increased with the number of leaves retained above the bunchwhich ranged from 300.10 to 365.00 g. The maximum bunch weight was recorded in 14 leavesabove bunch treatment (365.0 g) followed by12 leaves above the bunch(350.0 g) while, minimum bunch weight was found in >16 leaves above the bunch (300.10).The number of bunches per vine ranged from 64 to 68 withthe highestnumbers in 16 leavesabove the bunch (68 bunches/vine), while,berries per bunch remained relatively stable across

treatments ranging from 145 to 150. The 50-berry weight ranged from123.31 to 103.48 g with highest in 14-leaves above the bunch(123.31 g) while, the lowest weight was found in >16 leaves above the bunch (103.48 g).However, similar trends were recorded for yield per vine and raisin recovery. Highest yield and raisin recovery were recorded in 14 leaves above the bunch treatment (23.72 kg and 26.54 % respectively) likewise, lower yield/per vine and raisin recovery were recorded in >16 leaves above the bunch (19.20 kg and 24.35 % respectively).Variation in leaf retention above bunch mighthelpedvine to improve its photosynthetic activity, thereby increasing source-sink ratio required for bunch development.Higher leaf numbers (14 leaf above the bunch)favoured to improve bunch weight and yield, likely due to enhanced photosynthetic capacity and nutrient assimilation. Beyond 16 leavesabove the bunch, there was noticeable decrease in both yield and berry qualitywhich might be due to over-shading, competition for resources. Potential of a vine to produce carbohydrate to meet the demands of fruit production and vegetative growth is based on effective leaf area (Somkuwar et al. 2019). The result indicated the importance of maintaining an optimal leaf number for maximizing both yield and quality of grapes.Somkuwar et al., (2019) reported that an increase in leaf area results in high active photosynthesis rate helps to fulfil the demand of carbohydrate in the sink (bunch). Somkuwar *et al.,* (2014) also reported yield/vine ranged from 10.09kg in the control to 12.75kg in shoot thinning treatment at 6-7 leaf stage. These results are in accordance with the findings of Somkuwar *et al.,* 2012 and Candar *et al.,* 2020.

Table 2: Effect of leaves on bunch charactersand yield in Manjari Kishmish.

Leaf above the bunch	Av. bunch wt. (g)	No of bunches/ vine	No of berries/bunch	50-berry wt.(g)	Yield/vine (kg)	Raisin recovery (%)
T_1-10 leaves above the bunch	320.00	64	145	110.34	20.48	25.65
T_2-12 leaves above the bunch	350.00	66	150	116.66	23.10	26.00

T_3-14 leaves above the bunch	365.00	65	148	123.31	23.72	26.54
T_4-16 leaves above the bunch	335.25	68	146	114.81	22.79	24.30
T_5->16 leaf above the bunch	300.10	64	145	103.48	19.20	24.35
SEm±	2.64	0.44	NS	0.88	0.16	0.19
CD (p=0.05)	7.93	1.33	NS	2.65	0.50	0.57

The effect of leaves on berry quality parameter are presented in the Fig.1. The berry diameter and lengthvaried from 13.60 to 15.50 and 17.90 to 18.60 mm respectively. The highestberry diameter and length were recorded in10 leavesabove the bunch (15.50 and 18.60 mm) which was at par with 12 leavesabove the bunch (13.60 and 17.90 mm). However, berry diameter and length were decreased as leaf number increased.The lowest berry diameter and berry length were found in >16 leaves above the bunch (13.60 to 17.90 mm). Total soluble solids were consistent across treatments except for T_5 which was 19.70°Brix.Acidity varied minimally ranging from 5.60 to 5.34 g/L. However, highest acidity was recorded in 12 leavesabove the bunch (5.60g/L) followed by 14 leavesabove the bunch, 10 leavesabove the bunch, 16 leavesabove the bunch and more than 16 leaves above the bunch (5.55g/L,5.50g/L,5.40g/L and 5.34 g/L respectively).The consistency in TSS and slight variations in acidity might be due to leaf number, primarily impacts size rather than sweetness or acidity. Higher leaf numbers potentially improved berry size upto certain point, beyond which reduced size as was resulted in T_5. Maintaining around 12-14 leaves above the bunch appears optimal for balancing berry size and quality. Palliotti *et al.* (2012).demonstrated that mechanical leaf removal post-veraison can delay sugar accumulation in berries, affecting harvest °Brix and wine alcohol content. Cataldo et al. (2021)highlighted that reducing leaf number during berry growth can lead to changes in the growth curve of berries, affecting sugar accumulation and acid levels. The results of the present study are in line with the findings of Somkuwar *et al.,* 2012; Candar *et al.,* 2020.

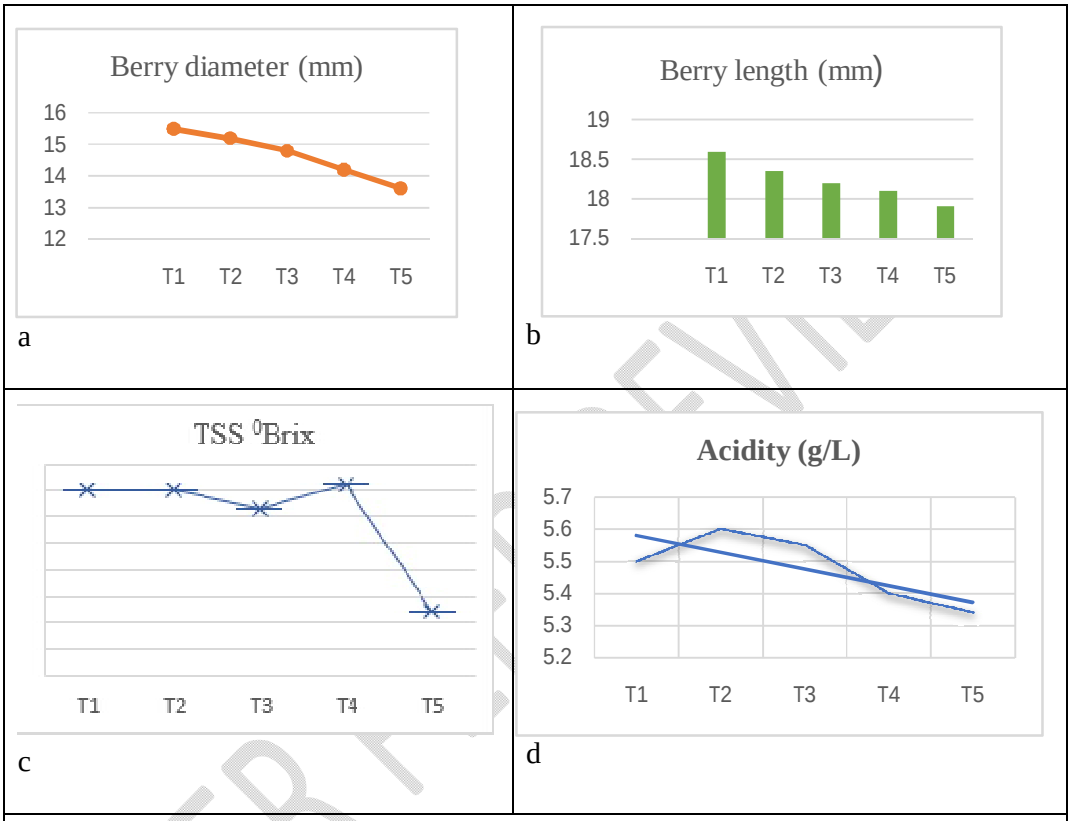

Fig. 1. Effect of leaves on berry quality parameters in Manjari Kishmish variety. Where, T_1-10 leaves above the bunch, T_2-12 leaves above the bunch, T_3-14 leaves above the bunch, T_4-16 leaves above the bunch and T_5-more than16 leaf above the bunch.

The leaf area index (LAI) is critical parameter indicating the leaf area per unit ground area, which directly influences photosynthetic activity and overall plant productivity. The treatments of different leaf numbers above the bunch demonstrated significant effects on LAI. As the number of leaves above bunch increased, there was an increase in LAI. Specifically, the LAI increased progressively from 1.42 at 10 leaves above bunch to 1.66in>16 leaves above bunch. Kang et al. (2022) reportedLAI rangedfrom 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. Burg et al.

(2017) reported LAI ranged 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 per unit ground area. Our study also aligns with the finding of Kang et al. (2022), Junges et al. (2018). Burg et al. (2017), Somkuwar et al. (2012). Photosynthetically active radiation (PAR) represents the portion of the electromagnetic spectrum crucial for photosynthesis. Contrary to LAI, however, as the number of leaves per shoot increased, the PAR values exhibited a declining trend. from 0.140 µmol photon $m^{-2}s^{-1}$ at 10 leaves above bunch to 0.943 µmol photon $m^{-2}s^{-1}$in more than 16 leaves above bunch, the PAR values decreased progressively. Poni et al. (2008) observed that the net carbon exchange rate (NCER) per vine decreased significantly due to defoliation, which removed about 70% of the pre-treatment shoot leaf area. 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.

Table 3: Effect of leaves on LAI and PAR of vine in Manjari Kishmish 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	1.42	0.140
T_2-12 leaves above the bunch	1.56	0.106
T_3-14 leaves above the bunch	1.66	0.100
T_4-16 leaves above the bunch	1.63	0.985
T_5->16 leaf above the bunch	1.66	0.943
SEm±	0.01	0.01
CD (p=0.05)	0.03	0.03

The effects of varying leaf density per shoot on photosynthetic activities are summarized in Table 5. Assimilation rate was key indicator of photosynthetic efficiency, exhibited a slight variation across different leaf densities per shoot. The mean assimilation rates ranged from 11.35 to 10.00 µmol CO_2µmol CO_2 m^{-2} s^{-1}. Although, assimilation rate decreased with increasing leaf density per shoot was observed, the highest assimilation rate was recorded in 12 leaves above bunch, while, lowest assimilation rate was observed in >16 leaves above bunch. From the result it was concluded that an optimal leaf density may exist for maximizing photosynthetic efficiency. Stomatal conductance, which regulates the exchange of CO_2 and water vapor between the leaf and the atmosphere, showed minimal variation among treatments. The values ranged from 0.12 to 0.10 mmol CO_2mmol CO_2 m^{-2} $s^{1.}$ Intercellular CO_2 concentration, indicative of the internal CO_2 concentration within the leaf, remained relatively stable which showed non-significant difference across treatments, with values ranging from 236.10 to 232.10 ppm. Transpiration rate, reflecting the water loss through leaf stomata, showed minor fluctuations across treatments. The values ranged from 2.56 to 2.39 mmol H_2O m^{-2} s^{-1}, with the highest transpiration rate recorded for the treatment with 10 leaves above bunch (2.56mmol H_2O m^{-2} s^{-1}).Ghule *et al.,* (2019)reported that foliar biomass and leaf area was responsible for alteration of gas exchange parameters. They found significant effect of leaf area on transpiration rate and stomatal conductance in Thompson Seedless, Manjari Medika and Manjari Kishmish. Results of the present investigation are also in line with Somkuwar et al. (2014) who reported that canopy manipulation practices had no marked stimulating effect on stomatal conductance. Maximum rate of transpiration (3.05 µmol/m^2/s) was recorded with shoot pinching at 10 leaves above the bunch in Tas-A-Ganesh grapes.

Table 4: Effect of leaves on photosynthetic activities in Manjari Kishmish 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	11.35	0.12	235.60	2.56
T_2-12 leaves above the bunch	11.13	0.11	236.10	2.54
T_3-14 leaves above the bunch	10.50	0.13	233.45	2.50
T_4-16 leaves above the bunch	10.35	0.10	232.10	2.45
T_5->16 leaf above the bunch	10.00	0.10	232.33	2.39
SEm±	0.07	0.001	NS	0.017
CD (p=0.05)	0.21	0.003	NS	0.051

The effect of different leaf number above the bunch on chlorophyll content in plants was also investigated in this study (Fig. 2.). The results illustrated variations in chlorophyll a, chlorophyll b, and total chlorophyll concentrations between different treatments. Chlorophyll a content in leafranged from 29.15 to 25.30 mg/ml among the treatments. The highest chlorophyll a concentration was observed in the treatment with 10 leaves above bunch (29.15 mg/ml), which was at par with the treatment with 12 leaves above the bunch (29.10 mg/ml). As the leaf numbers increased beyond 12 leaves above bunch, there was a gradual decrease in chlorophyll a content, reaching its lowest concentration in >16 leaves above bunch at 25.30 mg/ml. Chlorophyll b content also exhibited a similar trend among the treatments. The treatment with 10 leaves above the bunch showed the highest chlorophyll b concentration (11.21 mg/ml), which was at par with the treatment of12 leaves above bunch (11.10 mg/ml). Subsequent treatments with increasing leaf number per shoot resulted gradual decrease in chlorophyll b content, with the lowest concentration was observed in >16 leaf above bunch treatment (10.00 mg/ml). Similar trend was also observed for total chlorophyll content which combines chlorophyll a and chlorophyll b concentrations. The treatment with 10 leaves above

the bunch resulted highest total chlorophyll concentration (40.36 mg/ml) which was at par with 12 leaves above the bunch (40.20 mg/ml) while, >16 leaf above bunch treatment obtained lowest total chlorophyll concentration (35.30 mg/ml). Petrie et al. (2000) who reported that leaf removal resulted in an increase in, or retention of chlorophyll, which also occurred for the full leaf removal crop treatment.

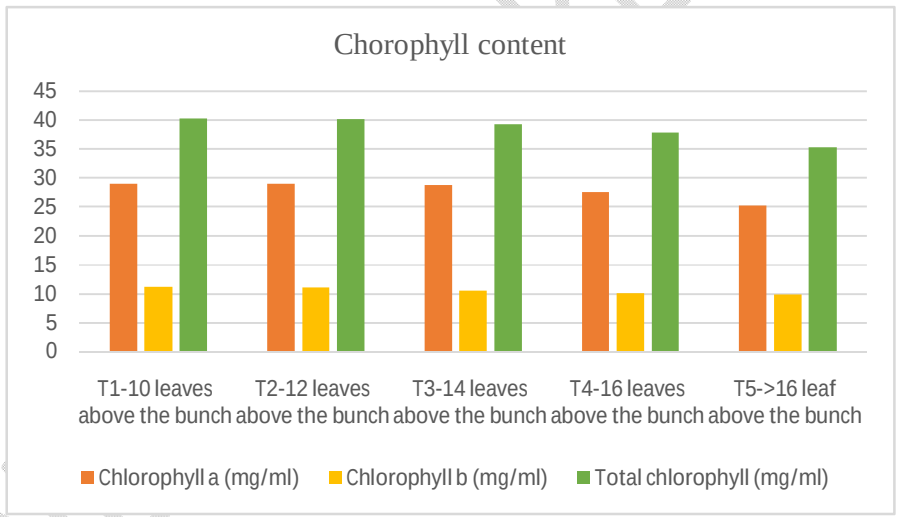

Fig. 2. Effect of leaves on chlorophyll content in leaves of Manjari Kishmish variety

The correlation studies showed positive relations among various parameters within the parameters (Table 6). Leaf area per leaf exhibited a strong positive correlation with total chlorophyll (r = 0.993). while, positive correction with average bunch weight(r = 0.567), yield/vine(r = 0.470) and raisin recovery(r = 0.782)were observed in the present investigation

indicating importance of factors such as leaf morphology, light availability, and chlorophyll content in influencing vine productivity within the vineyard.

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/Vine (cm^2)	Total chlorophyll (mg/ml)	Leaf area index (m^2/m^2)	PAR (µ mol photon $m^{-2}S^{-1}$)	Av. bunch wt. (g)	Yield/vine (kg)	Raisin recovery (%)
Leaf area/leaf	1							
Leaf area/Vine (cm^2)	-0.709	1						
Total chlorophyll (mg/ml)	0.993	-0.642	1					
Leaf area index (m^2/m^2)	-0.709	1.000	-0.645	1				
PAR (µ mol photon $m^{-2}S^{-1}$)	-0.889	0.509	-0.863	0.501	1			
Av. bunch wt (g)	0.567	0.174	0.642	0.170	-0.595	1		
Yield/vine (kg)	0.470	0.237	0.566	0.229	-0.408	0.965	1	
Raisin recovery (%)	0.782	-0.252	0.776	-0.243	-0.957	0.745	0.555	1

Conclusion

Leaf retention significantly affected the yield, raisin recovery and quality of Manjari Kishmish grapes. The optimal leaf number for maximizing yield (23.72 kg/vine) and quality was found to be 14 leaves above the bunch with leaf area of 1066.33 cm^2. Thehighest leaf area, bunch weight, berry size, and overall grape yield was found in 14 leaves above bunch. However, more than 16 leaves, resultedinto decrease in yield and berry quality. The result of the present study highlighted the importance of maintaining an optimal leaf number to enhance photosynthetic efficiency and fruit development.The leaf area/shoot (2888.00 cm^2), leaf area/vine (69312.00 cm^2), leaf area/bunch (1066.33 cm^2) and leaf area/gram berry weight (2.92 cm^2/g) were found sufficient for quality grapeand raisin production (26.54 % raisin recovery), which was achieved through maintaining 14 leaves above the bunch that ensured high-quality grape and raisin production in Manjari Kishmish grape.

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