Influence of pruning severity in the table grape variety 'Karaerik' (*Vitis vinifera* L.)

Nalan Nazan Kalkan[1], Abdurrahim Bozkurt[1], Tevhit Gecim[1], Birol Karadogan[1], Elman Bahar[2] and Ozkan Kaya[1]

[1]Erzincan Horticultural Research Institute
TR-24060 Erzincan
[2]Department of Horticulture, Faculty of Agriculture, Tekirdag Namik Kemal University
TR-59030 Tekirdag
E-Mail: kayaozkan25@hotmail.com

Considering the various cultivating treatments with grapes, especially pruning has a key role influence on the ultimate yield and the cluster quality of a grape variety. In our study, therefore, the table grape variety 'Karaerik' was pruned at four different levels, i. e., 32 (B-32), 40 (B-40), 48 (B-48), and 56 (B-56) buds per vine for three consecutive years (2019, 2020, 2021). Among the four pruning levels, yield, cluster number, cluster weight, maturation index, and pruning weight were the highest in B-56, B-40, and B-48, followed by B-32. The highest berry weight, TSS (°Brix), cluster width, and cluster length were obtained from B-48 vines in all years. Titratable acidity, pH, L*, a*, and b* values were not affected by the pruning levels. Looking at the superior quality of the berries with B-48, especially yield, berry weight, and TSS, as this variety is recommended as table grape, it is advocated that comparatively lower and higher yields obtained with B-32, B-40 and B-56 level may be abandoned.
Keywords: Grapevine, *Vitis vinifera*, pruning levels, yield, 'Karaerik'

Einfluss der Schnittstärke bei der Tafeltraubensorte 'Karaerik' (*Vitis vinifera* L.). Betrachtet man die verschiedenen Kultivierungsmaßnahmen bei Weinreben, so hat insbesondere der Rebschnitt einen entscheidenden Einfluss auf Ertrag und Traubenqualität einer Rebsorte. In unserer Studie wurde daher die Tafeltraubensorte 'Karaerik' in vier verschiedenen Stärken geschnitten, i. e. 32 (B-32), 40 (B-40), 48 (B-48) und 56 (B-56) Knospen pro Rebe in drei aufeinanderfolgenden Jahren (2019, 2020, 2021). Unter den vier Varianten waren Ertrag, Traubenanzahl, Traubengewicht, Reifungsindex und Schnittholzgewicht bei B-56, B-40 und B-48 am höchsten, gefolgt von B-32. Die höchsten Werte für Beerengewicht, TSS (°Brix), Traubenbreite und Traubenlänge wurden in allen Jahren bei B-48-Reben bestimmt. Die titrierbare Säure, der pH-Wert, die L*-, a*- und b*-Werte wurden durch den Schnitt nicht beeinflusst. Betrachtet man die überlegene Qualität der Beeren der Variante B-48, insbesondere Ertrag, Beerengewicht und TSS, da diese Sorte als Tafeltraube empfohlen wird, so wird dafür plädiert, vergleichsweise geringere oder höhere Erträge bei B-32, B-40 und B-56 nicht in Betracht zu ziehen.
Schlagwörter: Weinrebe, *Vitis vinifera*, Schnittstärke, Ertrag, 'Karaerik'

'Karaerik' (*Vitis Vinifera* L.) is the most widely grown grape variety in Erzincan, where it accounts for 95 % of the total area under vine (Kaya and Kose, 2017; Kaya, 2020). The berries of this grape variety are dark black in color, large, and have the appearance of plum fruit (Kalkan et al., 2017). There is a great demand by consumers for the grapes of this variety, which has a special aroma not found in other *V. vinifera* varieties, and a taste between slightly sweet and sour (Karadoğan and Keskin, 2017). It is also widely used in the form of dried pulp, molasses, and vinegar, although it is generally preferred as a table grape by the consumers in the region (Hermosín-Gutiérrez et al., 2020). 'Karaerik' is grown on an area of approximately 900 ha in the region, and considering the amount of production for many years, this rate changes based on years, but is generally 6000 to 6500 tons/year (Köse and Kaya, 2017). In addition, a traditional product called 'Saruç' is produced, for which the berries are dried after walnuts have been put in them (Kalkan et al., 2017). However, Erzincan, which is located in the East of Turkey, is a region with a continental climate and has a very high altitude (1250 to 1650 m, asl) for grape growing (Kaya, 2019). As it is known, the interaction between vine and environment in cold climate conditions often limits the yield, and also the balance between reproductive and vegetative growth for vines plays a key role to sustain high berry quality and production without compromising the health of the grapevine (Sabbatini et al., 2015). In viticulture, the main goal is to achieve high yields per vine without compromising vine health, and a balanced crop load on the vine is a pivotal tool in quality production (Howell, 2001). It has been reported that balance between crop load and vegetative growth improves cluster quality (Smart and Robinson, 1991). Vine balance was defined in the early 1900s by Ravaz (1911) as an annual evaluation of the mass ratio of fruit on the vine to vegetative growth of the vine. In medium vigorous vines, a 5:1 to 10:1 ratio was suggested by some researchers as the optimal value for the Ravaz Index (RI) (Smart and Robinson, 1991). 'Karaerik' variety, being more vigorous in terms of vegetative development, would fall at the high end of the RI suggested for table grape varieties. In vines, a drop in yield also occurs after a few years, as over-crop loading on the vine will result in a decrease in bud yield (Miller et al., 1993). The main reason for this decrease in yield is thought to be related to poor light penetration into the canopy and/or vine allocation and photoassimilate production (Petrie et al., 2000). Over-crop loading also causes source limitation by reduced percentages of soluble solids and/or delayed fruit maturity on clusters of vines (Morris et al., 1984). On the other hand, insufficient bud number on the vine or severe winter pruning results in unbalanced canopy formation as a result of excess carbohydrate encouraging vegetative growth. It has, indeed, been stated that severe pruning of vines caused under-cropping, which caused excessive vegetative growth, reducing cluster number and size, delaying fruit maturity on clusters, compromising cold hardiness of buds or canes, and leading to within-canopy shading of vines (Miller et al., 1993).

Many studies have previously been carried out regarding the phenolic composition, ampelographic properties, nutritional value, physiology, frost tolerance, antioxidant capacity, cold hardiness, and training systems of 'Karaerik' variety, which is very valuable for both the region and Turkey (Kaya et al., 2021). Very little, however, is known with regard to the pruning levels of 'Karaerik' vines, and currently, it is unclear how pruning severity influences the interaction between yield, vegetative growth, and fruit composition in 'Karaerik' grapes grown for fresh consumption. The objective of the present work was to investigate differences between pruning levels of 32 (B-32), 40 (B-40), 48 (B-48), and 56 (B-56) nodes per vine and how they affect vegetative growth, yield, and fruit composition in 'Karaerik' grapes.

Material and methods

Plant material and experimental design

The experiments were conducted in 2019, 2020 and 2021 on own-rooted 'Karaerik' vines (*Vitis vinifera* L.) at a commercial vineyard in Erzincan, Turkey (lat. 039°45´06.54 N; long. 039°21´36.79 W) at an altitude of 1309 m. The vines had been planted in 2002 and trained in a bilateral low cordon training system, with distances of 2.5 m between rows and 2.5 m within rows. In mid-

April, the vines were hand-pruned during the three years of data collection, and nodes on vines were counted during winter pruning. Vineyard pruning treatments were planned according to a 6 x 4 random block split-plot design. The pruning treatments included four levels of pruning, i. e., 32 (B-32), 40 (B-40), 48 (B-48), and 56 (B-56) nodes per vine at dormant pruning. Insect and disease control applications were carried out periodically throughout the season in the vineyard. As base fertilizer 15 kg/ha $MgSO_4$, 5 kg/ha TSP (Triple superphosphate), 6 kg/ha K_2SO_4, 0.6 kg/ha $ZnSO_4$ (Gubretas, Erzincan, Turkey) were applied in autumn close to vine roots with 15 cm depth and with 50 to 60 cm distance. In addition, shortly after pruning or at bud break stage 40 kg/ha of 10-20-20-(N P K) 6AS + 1 Zn (Gubretas, Erzincan, Turkey) fertilizer, at flowering stage 16 kg/ha of 33 % Nitro power (Gubretas, Erzincan, Turkey), and at pea-size of berry stage 18 kg/ha of 33 % Nitro power (Gubretas, Erzincan, Turkey) were applied. Drip irrigation for vines was conducted with two pressure-compensated emitters of 2.4 l/h located at 45 to 50 cm on each side of the vines. At the end of the season the total amount of water given by irrigation application in the vineyard was 138, 145 and 127 mm in 2019, 2020 and 2021, respectively.

Yield, must composition, and cluster characteristics

Six canes per vine (at E-L stage 18-19) were randomly chosen and labeled, and then berry maturity on clusters was measured weekly from veraison (E-L stage 35) (Coombe, 1995) until harvest. At harvest, clusters were collected from the labeled shoots per vine, and also, yield and the total cluster number for each vine were recorded. The clusters for each treatment were weighed immediately after sampling by using an electronic balance to determine the average cluster weight. All berries on clusters were then removed from the peduncle by hand and weighed immediately by using an electronic balance (model C-600-SX; Cobos, Barcelona, Spain) to detect average berry weight. Berries removed from clusters for each application were crushed in plastic bags by hand to extract their juice. For each treatment measurement, 100 berries per replicate and each treatment were randomly sampled. Afterward, the juice of berries was centrifuged at 4000 rpm for nine minutes (Hettich Universal, Berlin, Germany) and utilized for the measurements of maturation index (MI-Brix), titratable acidity (TA), and total soluble solids (TSS). TSS in samples was measured by utilizing a digital refractometer (BRX-242 Erma Inc., Tokyo, Japan). TA and MI were detected by an autotitrator (G20S, Mettler-Toledo, Greifensee, Switzerland), and must samples were analyzed for TA by utilizing 0.1 M sodium hydroxide (Kaya, 2019). In study years, harvest was conducted when TSS reached 16 °Brix, based on typical commercial harvest levels for 'Karaerik' in the region. The pruning weight of 32 (B-32), 40 (B-40), 48 (B-48), and 56 (B-56) nodes per vine or each pruning level replicate was calculated by weighing pruned shoots by utilizing a dynamometer at the time of winter pruning in spring. The weight of dormant cane prunings from each vine for cane weight was determined by dividing pruning weight by the number of canes for each vine. The numerical detection of the colour in berries was conducted with a Minolta CR-300 Chroma Meter (Minolta Corp., Osaka, Japan). Three measurements were carried out around the equatorial belt of each berry in clusters for treatments and the mean value was determined in the data, and then L^*, a^*, and b^* were calculated.

Statistical analysis

Data were separately evaluated for each pruning severity by analysis of variance (ANOVA) with four replications and mean separation was conducted by using LSD multiple comparison test at $p < 0.05$. Analysis was performed with SPSS program version 13.0 (SPSS Inc., Chicago, USA).

Results and Discussion

Since the difference between years was found to be significant in pruning severity treatments with 'Karaerik' vines, the results of all years are shown separately. There were significant differences between the pruning severity treatments, and yield, cluster number, cluster weight, TSS, maturation index, cluster width, cluster length, and pruning weight were affected by pruning severity, except for pH, titratable acidity, L*, a* and b* values (Table 1 and 2). The yield of the vines was significantly affected by the pruning severities and the minimum yield (10.8, 4.3 and 8.9 kg/vine for 2019, 2020, 2021, respectively) was detected in vines bearing cane pruned up to 32 nodes (B-32). Besides, the maximum yield in vines was observed in vines pruned up to 40 (B-40), 48 (B-48) and 56 nodes (B-56), respectively (Tabe 1). The unusually low yields in the second year (2020) of the study were due to late spring frosts that eliminated most of the crop. Yields in B-32, B-40, B-48 and B-56 vines were determined as 4.3, 5.2, 7.1 and 7.0 kg/vine, respectively. Although the spring frost damage affected yield values of 2020, it did not have a negative effect on the yield values of the following year. For 2021, yields of B-32, B-40, B-48 and B-56 vines were determined as 8.9, 15.1, 15.5 and 19.8, respectively. For the years 2019, 2020 and 2021, statistically the total vine yield was the highest in B-56, B-40, and B-48, followed by B-32 (Table 1).

Table 1: Influence of pruning severity on yield, cluster number, cluster weight, berry weight, pH, TSS and titratable acidity of 'Karaerik' vines

Years	Treatments	Yield (kg/vine)	Cluster number (total clusters/vine)	Cluster weight (g)	Berry weight (g)	pH	TSS (°Brix)	Titratable acidity (%)
2019	B-32	10.8 ± 2.9 b	27.7 ± 4.9 b	387.9 ± 46.7b	3.8 ± 0.5 b	3.2 ± 0.1	16.6 ± 0.8 a	0.6 ± 0.0
	B-40	12.3 ± 2.0 ab	31.4 ± 5.7 b	392.9 ± 49.5 ab	3.9 ± 0.6 b	3.2 ± 0.1	16.2 ± 0.9 a	0.7 ± 0.0
	B-48	12.7 ± 1.8 ab	31.8 ± 3.9 b	403.5 ± 61.9 a	4.5 ± 0.4 a	3.2 ± 0.1	16.2 ± 0.9 a	0.7 ± 0.0
	B-56	14.2 ± 2.6 a	37.1 ± 5.2 a	381.8 ± 53.1 b	2.4 ± 0.2 c	3.2 ± 0.1	15.2 ± 0.4 b	0.7 ± 0.0
	p value	***0.068***	***0.008***	***0.069***	***0.001***	***0.907***	***0.004***	***0.799***
2020	B-32	4.3 ± 1.4 b	9.1 ± 2.5 b	485.2 ± 35.36 a	6.3 ± 1.0 b	2.9 ± 0.1	16.7 ± 1.1 a	0.6 ± 0.0
	B-40	5.2 ± 1.7 ab	12.4 ± 3.2 ab	413.4 ± 33.96 b	6.6 ± 0.9 ab	2.8 ± 0.1	16.4 ± 1.3 a	0.6 ± 0.0
	B-48	7.1 ± 2.4 a	14.8 ± 4.0 a	483.8 ± 38.17 a	7.3 ± 1.0 a	2.8 ± 0.2	16.2 ± 0.6 ab	0.6 ± 0.0
	B-56	7.0 ± 2.3 a	16.5 ± 6.7 a	435.5 ± 32.52 b	6.9 ± 0.8 ab	2.9 ± 0.1	15.9 ± 0.8 b	0.6 ± 0.0
	p value	***0.031***	***0.014***	***0.062***	***0.091***	***0.521***	***0.036***	***0.519***
2021	B-32	8.9 ± 3.0 b	20.7 ± 2.6 c	417.0 ± 11.76 b	5.7 ± 0.7 b	3.6 ± 0.1	16.7 ± 1.3 a	0.7 ± 0.0
	B-40	15.1 ± 4.8 a	33.5 ± 2.8 b	435.8 ±15.07 ab	5.6 ± 0.5 b	3.4 ± 0.1	15.8 ± 1.1 ab	0.8 ± 0.0
	B-48	15.5 ± 2.6 a	34.5 ± 1.36 b	456.4 ± 15.75 a	5.9 ± 0.6 a	3.6 ± 0.1	15.7 ± 0.6 ab	0.8 ± 0.0
	B-56	19.8 ± 3.1 a	46.1 ± 1.45 a	426.2 ± 18.43 b	5.6 ± 0.8 b	3.4 ± 0.1	15.5 ± 0.7 b	0.8 ± 0.0
	p value	***0.002***	***0.001***	***0.068***	***0.026***	***0.545***	***0.019***	***0.571***

The linear increase in yield due to increasing shoot number or decreasing pruning severity in vines has been reported by many authors (Lydia and Kurtural, 2013; Kohale et al., 2013; Miele and Antenor, 2013), which is consistent with our results. It has, indeed, been reported in 'Delight grapes that vines pruned with 4 buds on an old shoot (21.93 kg/vine) and 2 buds on an old shoot (16.25 g/vine) resulted in significantly lower yields as compared to 6 buds on an old shoot (27.85 kg/vine). In 'Perlette' grapes, similarly, 14 canes with 5 buds/cane (3.38 kg) and 10 canes with 3 buds/cane (2.56 kg) produced lower yields per vine as compared to 12 canes with 4 buds/cane (3.66 kg) (Thatai et al., 1987). In our results, pruning severity significantly affected the cluster number in all years, and there were significant differences between pruning levels in terms of cluster numbers. Considering our findings, the highest number of clusters were obtained from B-56, while the lowest yield was with B-32 in all years. There was no significant difference between B-40, B-48, and B-56 in 2020, as late spring frosts affected shoots. Chalak (2008) reported that vines at the pruning level of 12 buds/cane bore the maximum number of clusters when compared with vines pruned with 10 buds/cane and 8 buds/cane in 'Cabernet Sauvignon', which is consistent with our results. In 2021, there was more than double the difference in cluster count among B-56 vines (46.1 total clusters/vine) when compared to B-32 vines (20.7 total clusters/vine) (Table 1). These results are in agreement with the results of Velu (2001), the maximum number of clusters was obtained when 5 buds per cane were left in a vine. Striegler et al. (2000) revealed that minimally pruned vines had the highest cluster numbers/vine among the treatments. Except for 2020, B-32 and B-56 treatments had a lower average cluster weight than B-40 and B-48 treatments, with values ranging from 387.9 to 381.8 in 2019 and 417.0 to 426.2 g in 2021, respectively. In 2020, the highest cluster weight was obtained from B-32 and B-48 vines, whereas B-40 and B-56 vines had lower cluster weights (Table 2).

Table 2: Influence of pruning severity on maturation index, cluster width, cluster height, pruning weight, L*, a* and b* of 'Karaerik' vines

Years	Treatments	Maturation index (ratio)	Cluster width (cm)	Cluster length (cm)	Pruning weight (kg)	*L**	*a**	*b**
2019	B-32	25.6 ± 1.6 a	12.0 ± 1.7 b	20.4 ± 2.6 a	1.5 ± 0.3 b	40.3 ± 1.8	-0.7 ± 0.1	-6.7 ± 0.5
	B-40	24.7 ± 2.2 ab	12.5 ± 1.2 b	20.1 ± 2.3 a	1.6 ± 0.5 b	39.1 ± 2.7	-0.6 ± 0.2	-6.4 ± 0.5
	B-48	24.6 ± 1.9 ab	13.5 ± 1.6 a	20.5 ± 1.3 a	2.0 ± 0.5 ab	40.0 ± 2.1	-0.7 ± 0.3	-6.2 ± 0.1
	B-56	22.7 ± 1.5 b	12.8 ± 2.2 ab	18.8 ± 2.1 b	2.3 ± 0.5 a	40.1 ± 1.3	-0.7 ± 0.1	-6.5 ± 0.5
	p value	***0.033***	***0.043***	***0.083***	***0.057***	***0.633***	***0.553***	***0.592***
2020	B-32	27.2 ± 2.7 a	10.1 ± 1.3 b	15.7 ± 1.7 b	1.5 ± 0.3 b	39.5 ± 1.3	-0.6 ± 0.8	-6.0 ± 0.4
	B-40	27.8 ± 2.8 a	11.5 ± 2.1 ab	16.1 ± 3.6 b	1.8 ± 0.5 ab	38.2 ± 2.5	-0.4 ± 0.1	-5.2 ± 0.7
	B-48	26.7 ± 2.9 ab	12.0 ± 1.6 a	17.8 ± 2.0 a	2.2 ± 0.5 a	38.7 ± 0.9	-0.3 ± 0.2	-5.7 ± 0.4
	B-56	25.1 ± 3.6 b	11.5 ± 1.4 ab	16.8 ± 1.8 ab	2.1 ± 0.4 a	38.9 ± 1.1	-0.4 ± 0.2	-5.0 ± 0.7
	p value	***0.056***	***0.058***	***0.070***	***0.045***	***0.528***	***0.645***	***0.612***
2021	B-32	22.7 ± 1.9 a	14.8 ± 1.0 a	19.6 ± 1.8 a	2.3 ± 0.0 b	39.9 ± 0.7	-0.9 ± 0.8	-6.1 ± 0.2
	B-40	20.9 ± 1.3 b	13.2 ± 1.5 bc	19.2 ± 1.4 a	2.6 ± 0.1 b	40.6 ± 0.6	-1.0 ± 0.6	-6.3 ± 0.2
	B-48	20.1 ± 1.5 b	13.9 ± 0.9 bc	19.8 ± 1.0 a	3.0 ± 0.0 ab	40.0 ± 0.6	-1.1 ± 0.5	-6.5 ± 0.2
	B-56	20.3 ± 1.4 ab	12.6 ± 0.7 c	18.4 ± 2.3 b	3.4 ± 0.1 a	40.5 ± 0.5	-1.3 ± 0.4	-6.5 ± 0.5
	p value	***0.067***	***0.003***	***0.092***	***0.014***	***0.673***	***0.568***	***0.524***

Considering the cluster weights of all years, cluster weight was higher in B-48 vines as compared to other pruning treatments. This could be explained by the number of shoots and leaf density on the vine. In the B-56 treatments, the leaves on the shoot may have caused a higher shade when compared to the other pruning treatments. Conversely, although the leaf area is lower in B-32 vines, (even if they are exposed to more sun), B-32 treatments may not have sufficiently fed the clusters due to insufficient shoots and the low number of photosynthesizing leaves. It has, indeed, been reported that the orientation of the canopy to the sun could be correlated with the amount of light intercepted by the canopy, canopy Authors reported that cluster weight increased with decreasing pruning levels (Striegler et al., 2000; Chalak, 2008; Popescu, 2012). Based on the two-year results, however, there was no significant difference between the number of shoots in B-40 and B-48 vines, and this may have caused a significant difference in cluster weights. There were significant differences in berry weight for each pruning level, and the highest berry weight was obtained from B-48 vines in all years (Table 1). It is known that the berry weight decreases with the decrease in pruning severity, and there is an inverse proportion between berry weight and pruning severity (Palanichamy and Singh, 2004). Although this finding is true for B-56 vines, interestingly, in our results, berry weight was higher for B-48 vines than for other pruning severity treatments. It seems quite difficult to interpret these results with our current knowledge, but these findings revealed that the optimal pruning level for the 'Karaerik' grape variety was 48 buds per vine in winter pruning. Pruning severity did not affect pH and titratable acidity, whereas TSS (^{o}Brix) was significantly affected by the pruning levels (Table 1). Although pruning levels seem to be statistically ineffective on acid values, acidity increased with decreasing pruning severity in general. These findings are in agreement with the findings of Avenant (1998), Terence (2008), and Reynolds et al. (2004), who found that pruning had significant effects on TSS and acidity. The maturation index was significantly affected by the pruning levels, and it decreased with increasing pruning severity (Table 2). At the B-56 level, berry quality was reduced, which might be due to the decreased allocation of photosynthesis formed from the fixed leaf area on canes available to the individual cluster. The findings are supported by the results of Pavlov (1998) and Kohale et al. (2013), respectively. The effect of pruning levels on cluster width and length showed significant variation in our study. Both cluster width and cluster length have the higest values in B-48 vines as compared to other pruning levels (Table 2). It was reported that pruning severity did not have a significant effect on length and width of the cluster (Tomer, 1994; Singh et al., 2014) in the case of 'Karaerik' grape variety, pruning levels did affect length and architecture, and the percentage of inner and outer leaves, which is determined by training . width per cluster; however, unlike previously reported, we observed a slight increase in length and width in the clusters. On the other hand, there were significant differences ($p < 0.05$) between treatments in terms of pruning weight in the experiment where different pruning levels were applied. Moreover, with a decrease in the pruning severity, there was an increase in pruning weight, which means that pruning severity is directly related to pruning weight. These findings are consistent with previous works given by Kilby (1999), Poling (2007), and Geller and Kurtural (2013). Color indexes in the berries of grapes are characterized by showing a high correlation with the external visual color of the berries and may be utilized in studies of preservation, maturation, or storage. The effect of pruning levels on the L*, a*, and b* values of berries was found to be insignificant (Table 2). It has been reported that L*, a*, and b* values decrease when the visual color of the berries is more intense (Carrefio and Martinez, 1995). This could be explained by the fact that the berries on the cluster take on a red-violet tint and become darker, but pruning levels did not affect the color values of berries in our results.

Conclusions

There are several remarks to be made regarding the advantages and weaknesses of four different (B-32, B-40, B-48, B-56) pruning levels of canopy structure and cluster characteristics assessment after three years. There were significant differences in yield, cluster number, cluster weight, berry weight, TSS, pruning weight, titratable acidity, maturation index, cluster weight, and length for each vine between pruning levels over the three years. There were no significant differences between pruning levels for titratable acidity, pH, L*, a*, and b* values. Not only reducing the pruning intensity but also increasing the pruning severity reduced the quality parameters of the cluster. These results were not unexpected since a few researchers have indicated that decreasing and increasing pruning severity have a negative effect on yield and cluster characteristics. In general, B-48 vines had a clear advantage over the other pruning-level vines, as both the high grape yield and desired cluster traits were guaranteed by this pruning level.

Author Contributions

NNK and OK designed the study. OK and AB wrote the manuscript and EB and OK interpreted the results. TG and BK were responsible for the performance of the research, collection, data analysis, and interpretation.

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