RESEARCH ARTICLE

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Effects of green pruning and combine microelement applications on bud fruitfulness, vegetative development and cluster characteristics of 'Trakya İlkeren' grape cultivar

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Abstract
Green pruning practices are frequently used in viticulture. These practices provide better light penetration, successful air circulation, prevents air humidity and aids disease control in the grapevine canopy. However, excessive leaf removal inhibits vine growth and good fruit ripening. In this study, the effects of some foliar and canopy management practices on cluster, vegetative growth traits and bud fruitfulness of the following year were investigated. Some green pruning (unproductive shoot removal, leaf removal, shoot tip removal, shoot topping), foliar microelements and green pruning + microlements treatments were applied in 'Trakya İlkeren' grape cultivar. Microelement application increased cluster (382.1 g) and berry weight (4.4 g), berry length (19.7 mm) and width (18.2 mm), cluster length (19.5 cm) and width (13.9 cm), berry volume (3.30 cm3) and berry firmness (7.46 N). The highest maturity index was detected in the control group (23.4). While the most intense L* color value was determined in the green pruning + micro element application, the b* color value was determined in the green pruning application. It was determined that leaf area (211.2 cm2), leaf chlorophyll index (32.75 SPAD), shoot diameter (11.13 mm), shoot length (194.71 cm) and internode length (76.81 mm) increased with microelement application. Among the treatments, the most effective application on bud fruitfulness in the following year was at microelement application (1.34 clusters). The effects of the treatments on the amount of Total soluble solids pH, titratable acid and a* color value were not significant. In this study; green pruning + microelement application was recommended for yield and quality sustainability. According to bud fruitfulness results, the highest cluster numbers per node were obtained from pruning with 4 to 10 buds. It is recommended to prune medium or long to obtain higher yields from this cultivar.

Keywords: Bud fruitfulness, Grapevine, Microelements, Quality, Green pruning

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INTRODUCTION

The ecological conditions (climate and soil characteristics) of the area where the vineyard is established and different cultural processes, including canopy management, are important on the quality of the grape growing (Van Leeuwen et al., 2019; Bettenfeld et al., 2022). When it comes to quality in table grapes, it refers to the combination of the pleasant taste, the original color of the variety, fully ripe berries and the standard structure bunches (Defilippi et al., 2019; Piernas et al., 2022).

During the development period, multiple factors are effective on the grape quality. Green pruning, which involves the removal of shoots, leaves, clusters or fruits during the leafy period of the vines, is as important as yield pruning in order to obtain a consistently high-quality crop in vineyards (Winkler et al., 1974; Palliotti et al., 2014; Conti, 2019). In viticulture, a physiological balance is established between the vegetative and generative development of the vine through pruning procedures. Thanks to this balance, it is possible to obtain grapes of sufficient quality and quantity from the vineyards for many years. In order to fully achieve this goal, winter pruning (dormant pruning), which is one of the pruning methods and is done during the vine's full rest period, that is, when the vine's buds burst and its leaves completely shed, in other words, the vegetation of the vine is green pruning is also applied during the period (Salvi et al., 2021).

Green pruning or summer pruning refers to the processes such as leaf removal, pinching and topping, cluster thinning, removing applied to the vegetative parts and bunches of the vines when they are leafy, that is, during the vegetation period. Korkutal et al. (2022) reported that the application of leaf removal and shoot tip removal in the 'Michele Palieri' grape cultivar increased the berry size and caused a decrease in the yield per vine. Korkutal et al. (2018) reported that shoot tip removal during the berry setting period had a positive effect on the berry characteristics of the 'Merlot' grape variety. The main purposes of green pruning are to improve the product quality, to limit the longitudinal growth of the older branches and shoots of the vine, to ensure that the shoots become mature and lignified, to facilitate air flow in the inner parts of the vine, that is, between the shoots and leaves, and to create the necessary sunlight environment around the clusters (Sadeghian et al., 2015). Green pruning applications contain removing unproductive primary and lateral shoots from the canopy, removing shoot tips, thinning clusters, and removing leaves to allow varying levels of sunlight exposure and air ventilation inside the canopy (Senthilkumar et al., 2015; Ye et al., 2022). Removing basal leaves is one of the most common canopy management practices in vineyards (Dry, 2000; Austin and Wilcox, 2011; Di Profio et al., 2011; Silvestroni et al., 2019; Tarricone et al., 2020). This process is often done during the ripening season to improve berry color and aroma, reduce the effects of diseases if there is shading in the canopy due to excessive leaves (Bledsoe et al., 1988; Percival et al., 1994). Low light penetration in the canopy reduces the formation of primorida in the buds. This is likely mediated by carbon availability and assimilation support for the buds (Keller and Koblet, 1995; Dry, 2000; Lebon et al., 2008; Vasconcelos et al., 2009).

Another important cultural practice in viticulture is soil or leaf fertilization. Plants are living organisms that survive depending on the soil. For this reason, the presence of the required level of nutrients in the soil is very important for the development and survival of plants. Grapevine, which is a cultivated plant, takes certain amounts of macro and micro nutrients from the soil every year, ensuring the continuity of growth, development and productivity for many years. The effects of microelements on the yield of different grapevines have been investigated by many researchers (Morshedi, 2001; Domagała-Świątkiewicz and Gąstoł, 2013; Abd El-Razek et al., 2015; Ashoori et al., 2015; Al-Atrushy, 2019). These nutrients are generally found in agricultural soils (Schreiner et al., 2006; Arrobas et al., 2014; Leibar et al., 2017). However, the amount of these nutrients may not always be the amount required for the plant. If the nutrients needed by the plant are deficient in the soil, there is a decrease in productivity and quality. For this reason, in order to maximize efficiency and quality in production and maintain this level, organic and inorganic fertilizers containing one or more macro and micro nutrients must be applied to the soil or directly to the plant. High yield and quality in plants are directly related to the presence of the necessary nutrients in the plants at the required level, and these micro and macro nutrients must be present in the structure of the plant at the required rate in order to obtain the highest desired yield (Marschner, 1995).

There is more than one factor that affects the fruitfulness of grapevine buds according to the node where the winter buds are located in the nodes of the annual shoots. These factors may be related to genetic structure or external factors. Factors such as the grape variety produced, soil and climate characteristics of the growing area, exposure to sunlight, technical and cultural practices applied to the grapevines also affect the formation of flower primordia in winter buds (Srinivasan and Mullins, 1981; Reynolds and Heuvel, 2009; Keller, 2010; Li Mallet et al., 2016). Between 0 and 4 clusters can form in the primary buds of *Vitis vinifera*'s winter buds, but 4 clusters are rare. The number of inflorescences in the primary bud can generally vary between 1 and 2 clusters. In years when all conditions are as desired in vines (climate, growing conditions, nutrition, etc.), it is normal for some primary buds to have 3 cluster buds. Some primary buds may not even produce a single cluster (Dry, 2000; Clingeleffer, 2010; Keller et al., 2004; Vasconcelos et al., 2009). Winter buds on one-year-old canes are closely related to the grape yield of the vine and therefore the total vineyard area (Sánchez and Dokoozlian, 2005; Ulmer et al., 2020). Since the number of clusters to be formed in vines may vary depending on the location of the winter buds on an old stem, determining the productivity of winter buds in different nodes is important in terms of grape yield from the vines. It is necessary to determine the pruning levels that will provide the highest yield and best quality according to the productivity of the winter buds of grape varieties (Rosner and Cook, 1983; Eltom et al., 2014). Knowing which node of a winter cane has the highest bud productivity aids in both planning the number of buds to leave on the vine during yield pruning and determining the level at which the canes should be prune. Productivity status of the buds located in different nodes; it is detected by applying different methods such as binocular microscope, sectioning of winter buds with a microtome, leaving winter buds in green shoots to grow on vines in the field in summer, counting the number of buds formed by growing cuttings containing single buds in controlled environments outside the field, or counting the buds on long pruned old branches in the field (Antcliff and Webster, 1955; Ferrara and Mazzeo, 2021; Monteiro et al., 2021, 2022; Uray et al., 2023).

In this study; the effects of green pruning and combine microelement applications on shoot development, bud fruitfulness and cluster characteristics were examined in 'Trakya İlkeren' grape cultivar. It is aimed that the results obtained in the study will benefit the development of green pruning applications, the pruning levels of the vines and the continuity of the productivity to be obtained from the vineyards.

MATERIALS AND METHODS

Plant Materials

This research was carried out during 2019-2020 years in the Application and Research Vineyard area of Ondokuz Mayıs University Faculty of Agriculture. The vineyard is located in Samsun province, between 41° 21′ 52″ N latitude and 36° 11′ 29″ E longitude, approximately 195 m above sea level and 2.8 km away from the coast. In the study, 'Trakya İlkeren' grape cultivar was used. It's very early ripening, rounded and with purplish-black colored berries, consumes as table and brine leaf, grafted onto 5C rootstock, given a double-cordon training form, 14 years old, planted at a distance of 3 x 1.5 m, short pruned, and fertilized with 20-20-0 compound fertilizer as standard in March-April.

Soil Properties of the Research Vineyard

The soil of the trial area has a heavy clay structure and its pH was determined to be slightly acidic, unsalted and very slightly calcareous. In addition, it was determined that the phosphorus value of the trial area was low, the potassium value was high and the amount of organic matter was moderate. The soil characteristics of the trial area are given in Table 1.

Table 1. Soil characteristics of the research vineyard (0-30 cm)

Feature	Amount	Content Class
Soil texture	110	Heavy clay
pH	6.16	Slightly acid
% Lime ($CaCO_3$)	0.40	Slightly calcerous
% Total Salt	0.052	Unsalted
Phosphorus (P_2O_5 Kg/da)	4.36	Little
Potassium (K_2O Kg/da)	91.0	More
% Organic Matter	2.98	Middle

Phenological Observations of the Vines

In the study, bud burst (EL 4), full bloom (EL 23), veraison (EL35), maturity (EL 38) and dormant (EL 47) dates were determined according to Lorenz et al. (1995). The dates of bud-burst, flowering, veraison, maturity and dormant periods are given in Table 2.

Table 2. Phenological periods of 'Trakya İlkeren' cultivar

Phenological periods	Start	Finish
Bud-burst (EL 4)	15.04.2020	05.05.2020
Blooming (EL 23)	05.06.2020	20.06.2020
Veraison (EL 35)	20.07.2020	07.08.2020
Maturity (EL 38)	17.08.2020	24.08.2020
Dormant (EL 47)	9.11.2020	10.12.2020

Bud-burst in the buds took place between 15.04.2020-05.05.2020. The flowering period started on 05.06.2020 and was completed on 20.06.2020. Veraison stage took place between 20.07.2020-07.08.2020. The maturation period started on 17.08.2020 and ended on 24.08.2020. It was determined that the vineyards entered a full dormant period on 10.12.2020. Visuals of the phenological periods of the 'Trakya İlkeren' grape cultivar are given in Figure 1.

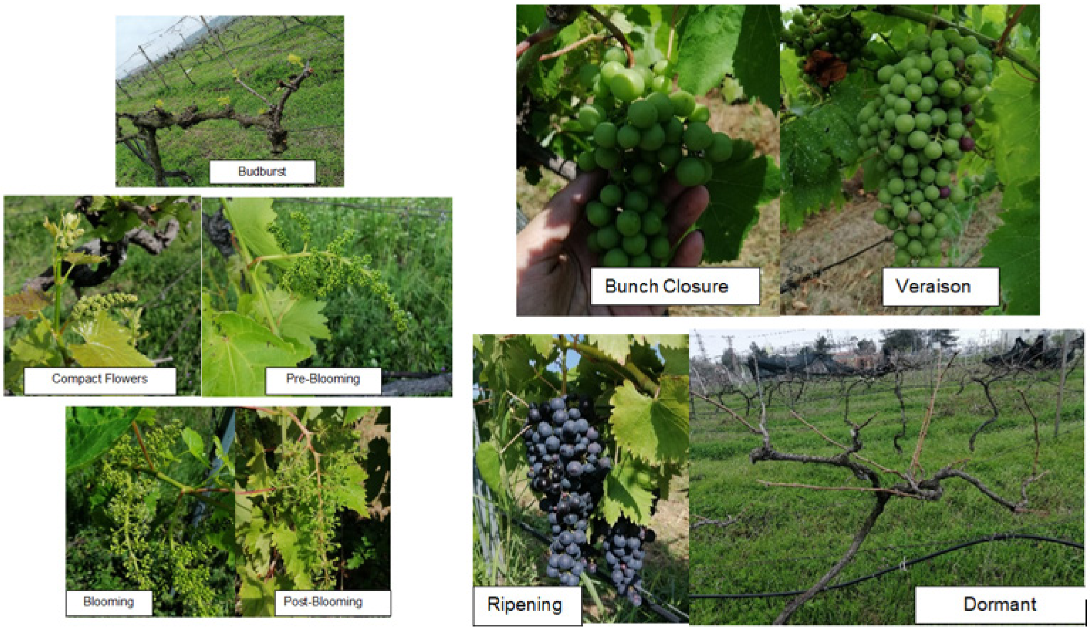

Figure 1. Phenological terms in 'Trakya İlkeren' grape cultivar.

Method

The study was carried out in 4 applications and totally 36 vines were used in all application: Control, combined microelement (ME), green pruning (GP) and green pruning + microelement (GP+ME).

1- Control: In this application, no treatment was applied to the vineyards.

Microelement application: No green pruning was applied to the vines. The combined microelement was applied at compact flowers (EL 15), pre-flowering (EL-22), post-flowering (EL 25) and veraison (EL35) stage. A total of four periods were applied: the compact flowers period (EL 15 stage), before flowering (1 week before blooming), post- flowering (berry set period) and the veraison period. It was applied to the leaves by spraying in liquid form.

2- Microelement application (ME) was applied as at 150 mg/100 L per decare in each period. Composition of combine microelement contents as below;

Water Soluble Copper (Cu-EDTA); 1%,

Water Soluble Iron (Fe-EDTA); 7%,

Water Soluble Manganese (Mn-EDTA); 5%,

Water Soluble Molybdenum (Mo-EDTA); 0.05%,

Water Soluble Zinc (Zn-EDTA); 7%,

Water Soluble Boron (B-EDTA); 1%

3- Green pruning applications (GP): a-removing unproductive shoots that do not have clusters in the early period; b-cutting of the shoot tips before flowering; c-removing leaves at least two leaves at the end of flowering, hard and green berry period and during the veraison period; d-shoot topping was applied when the growth of the shoots stopped and the bottom parts of the shoots started to lignify. a- Unproductive shoot removal: It was applied in the early period by removing all non-cluster shoots. It is the process of removing shoots that reach 15-20 cm in length and do not consist any clusters from the vine. Visuals of the application are given in Figure 2.

b- Leaf removal: The leaves at the bottom of the clusters were manually removed three times, at the end of flowering, during the hard green berry and veraison period. Leaf harvesting was done with at least two leaves in each period. Visuals of the application are given in Figure 3.

c- Shoot tip removal: Tip removal was done before flowering, when the shoots were 40-45 cm. The application was carried out by cutting off 2-3 young leaves from the tip of the shoots. Visuals of the application are given in Figure 4.

d- Shoot topping: It is done in the period when the growth of the shoots stops and the bottom parts of the shoots start to become lignified. In our study, this period coincided with 25.07.2020. The parts of the shoots above the second laying wire were cut by 30 cm and crowning was performed. The tipping process is defined as shortening the tops to a depth of 30-60 cm when the shoots reach a length of 90-100 cm.

4- Green pruning + microelement application (GP+ME): Microelement and green pruning applications were applied together in grapevines. The solution prepared as 150 g/100 L per decare is sprayed in liquid form on the leaves with a back sprayer during the compact cluster period EL-15 (10.05.2020), before flowering EL-22 (29.05.2020), post flowering EL-25 (26.06.2020) and in the veraison period EL-35 (20.07.2020).

Investigated Features

The effects of the applications were determined by examining the following features. The berry and cluster characteristics of the harvested grapes were determined by randomly selecting three clusters per vine from each application, in a total of 108 clusters were used. Yield (kg vine^{-1}), cluster weight (g), cluster length and width (cm), cluster weight (g), internode length (cm), berry weight (g), berry width (mm), berry size (mm), berry volume (cm^3), berry firmness (N), pH, TSS (°Brix), titratable acidity (TA g/L), maturity index (°Brix/TA) were examined in the grape clusters.

Berry Skin Color Measurement

For color measurement, color changes in the berry skin were determined with a CR-400 Minolta brand color measuring device. Color measurements were made on 20 randomly selected berries in the clusters taken from each vine replicate. CIE LAB (L*, a* and b*) values of the samples were measured with the Konika Minolta CR400 (Minolta, Osaka, Japan) color measuring device.

Shoot and Leaf Features

Leaf area (cm^2), leaf SPAD, shoot length (cm), internodes (mm), cane diameter (mm), periderm development of annual shoots (%) were examined as a result of the applications. In order to determine the effects of the treatments on the leaf area, the width and length of a total of 90 leaves in 9 vines belonging to each application were measured with a ruler during the berry and veraison periods. Leaf area was calculated according to the formula Elsner and Jubb (1988).

$LA= [-1.41 + 0.527(W^2) + 0.254(L^2)]$ (LA: leaf area; W: leaf width; L: leaf length).

Leaf SPAD values were determined by measuring 180 sun-exposed, healthy leaves located in the middle part of the shoot (Konica Minolta SPAD-502) in three replicates from each application during the big green pea and veraison periods.

Evaluation of Bud Fruitfulness

Following the treatment year, the effects of the treatments on the bud fruitfulness of the vines compared to the control group were determined in the vineyard after the dormant buds sprouted. For this purpose; during pruning in March, 5 shoots containing 10 buds were left on 3 vines for each treatment. The number of clusters in each node was counted from the base upwards on the newly emerged shoots until May. The clusters were averaged and the average number of clusters per node was determined from basal to upper node.

Statistical analysis

This experiment was conducted in a randomized block design with four treatments, three replication and three vines for each replication. A total of 36 vines were used in all application. To be determine bud fruitfulness; during pruning in March, five shoots containing ten buds were left on three vines for each treatment. The data obtained were subjected to ANOVA test using SPSS 21.0 statistical program and the differences between the averages were compared at the 5% level according to the Duncan's Multiple range test.

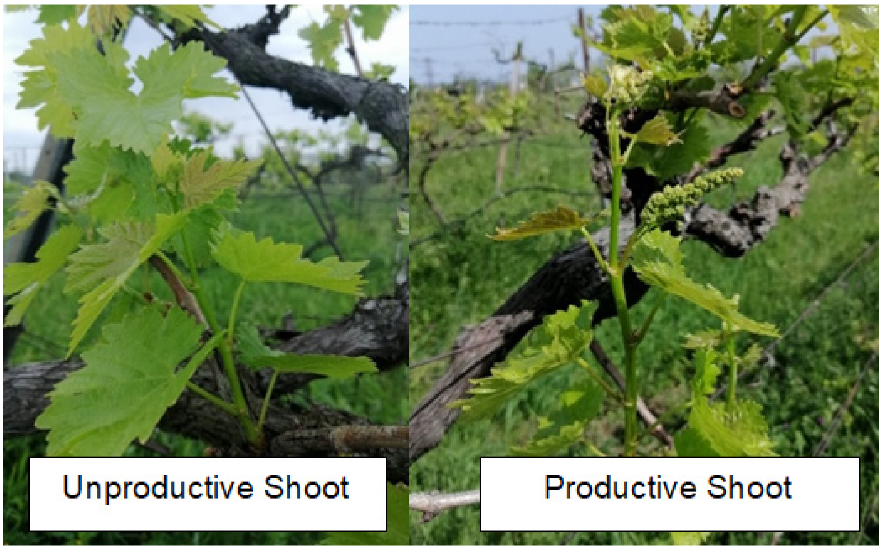

Figure 2. Productive and unproductive shoots

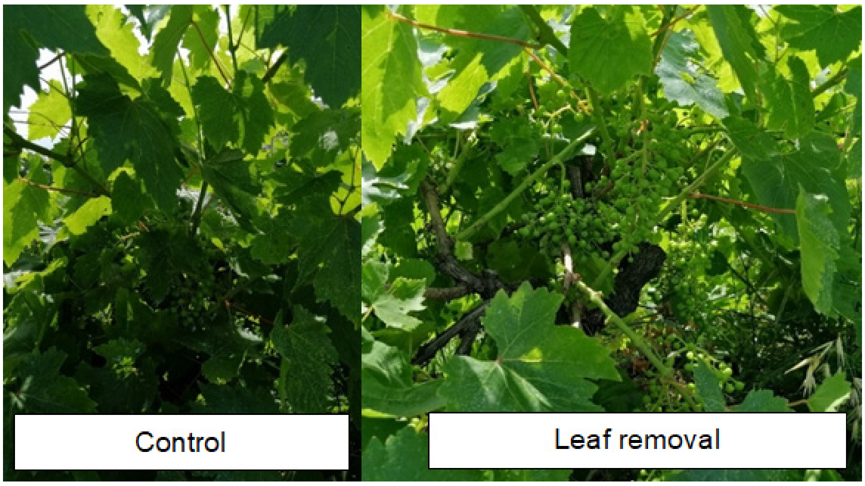

Figure 3. No leaves removed and leaves removed

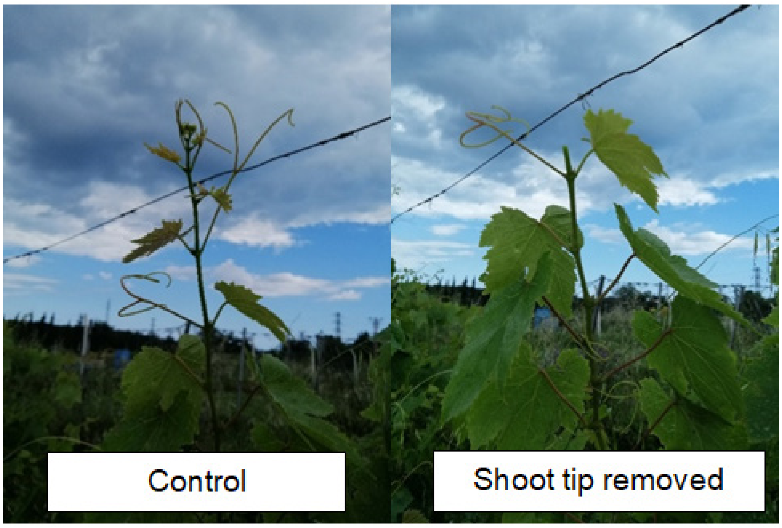

Figure 4. Control and shoot tippping

RESULTS AND DISCUSSION

Green pruning has been making in the summer months for its benefits such as ventilation, light penetration and disease control. On the other hand, it has the opposite effect such as reducing the photosynthetic capacity of the vine, reducing berry color development and delaying berry ripening. The effect of the treatments on cluster and berry characteristics was significant (P≤0.05). The effects of the applications showed significant differences compared to the control group. Among the applications, especially microelement application provided a significant increase in whole clusters and berries (Table 3). In the research, microelement application increased the all cluster and berry features. The highest cluster (382.12 g) and berry weight (4.37 g), vine yield (4516 g), cluster length (19.45 cm) and width (13.90 cm), berry length (19.65 mm) and width (18.17 mm) were obtained from microelement application. On the other hand, microelement when combined with green pruning applications, increased the all cluster and berry features, albeit partially, while the application of green pruning alone decreased the berry weight compared to control group. While the highest cluster weight was obtained in the microelement application with 382.12 g, the lowest cluster weight was obtained in the control group (229.40 g). In the research, it was determined that microelement application increased bunch weight. It was also determined that microelement application had a positive effect on cluster weight when combined with green pruning. The value, which was 266.67 g in the green pruning application, was determined to be 327.91 g in the green pruning + micro element application (Table 3).

Table 3. Effect of green pruning and microlement applications on cluster, berry and yield characteristics

Treatments	Cluster weight (g)	Berry weight (g)	Yield (g^{-1} vine)	Cluster length (cm)	Cluster width (cm)	Berry length (mm)	Berry width (mm)
Control	229.40 d*	4.00 ab	2935.9 b	17.32 c	12.81 b	18.40 b	16.91 c
Green pruning (GP)	266.67 c	3.92 b	3554.5 ab	18.10 bc	12.73 b	17.93 c	16.85 c
Microelement (ME)	382.12 a	4.37 a	4515.5 a	19.45 a	13.90 a	19.65 a	18.17 a
GP+ME	327.91 b	4.10 ab	3825.8 ab	18.82 ab	12.92 b	18.71 b	17.52 b
Standart Errors of The Mean's	6.45	6.50	232.61	0.21	0.08	0.07	0.07
P≤0.05	*	*	*	*	*	*	*

*Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

In this study, green pruning application decreased cluster and berry weight compare to the control vines. Köse et al. (2018) reported that removing fewer leaves increased the cluster and berry weight, TSS and maturity index while removing excessive leaves decreased those parameters in the 'Trakya İlkeren' grapevines. Contrary to the results found in the study, Uslu (1981) found that 25% leaf removal in 'Müşküle' grape increased the berry weight compared to the control and 50% leaf removal. Leaf removal has been reported to increase pH while significantly reducing titratable acidity, TSS, bunch weight, berry size, potassium uptake, and grapevine photosynthesis (Uslu, 1981; Pereira et al., 2006). It has been stated that the removal of leaves showing low photosynthetic activity increases the sugar level in the berry by increasing the light intensity entering the canopy, while it decreases the titratable acidity, pH and K+ levels in the grape juice (Hunter and Visser, 1990). Removing the leaves around the cluster is one of the methods frequently applied in vineyards. In viticulture, leaf removal is done on vines to increase air circulation and light within the canopy. Thus, thanks to the penetration and effectiveness of fungicide sprays, the risk of fungal disease development, especially bunch rot, is reduced (Poni et al., 2006).

Köse et al. (2018) found that removing fewer leaves increased the berry weight in the 'Trakya İlkeren' cultivar. Dardeniz et al. (2018) reported that shoot topping increased berry weight in 'Yalova Çekirdeksizi' cultivar. Contrary to our results found in the study, Uslu (1981) found that 25% leaf removal in 'Müşküle' grape cultivar increased the berry weight compared to the control and 50% leaf removal. And also, Akçay (2013) found that removing fewer leaves increased the berry weight of the 'Sultani Seedless', while removing more leaves decreased it.

Köse et al. (2018) found that removing fewer leaves increased cluster weight, while removing more leaves decreased cluster weight in 'Trakya İlkeren' grape cultivar. Morris et al. (2004) reported that cluster shoot and cluster thinning in 'Aurore', 'Chancellor' and 'Villard Noir' grapes had little effect on cluster weight in all three cultivars. Teker and Altındisli (2021) stated that leaf removal does not significantly affect the yield in the 'Sultani Seedless' grape; however, they reported that 50% leaf removal increased yield compared to 25% leaf removal. Iacono and Sparacio (1999) found that shoot tipping did not affect the yield of 'Cabernet Sauvignon' cultivar.

In the study, the effect of the treatments on berry properties, berry firmness, berry volume and maturity index were found to be statistically significant (P≤0.05). Berry firmness was positively affected by all treatments except the control group. Although all treatments except control vines were in the same group, microelement application gave the highest berry firmness (7.76 N). The berry volume was determined to be the highest (3.30 cm^3) in the grapevines to which microelements were applied. In the conducted studies, Akgül et al. (2007) found that as a result of the application of different zinc (Zn) fertilizers to the foliar at different doses (0.25%, 0.50% and 0%) in the 'Sultani seedless' grape cultivar, the hardest grape berries were obtained at the 0.25% dose level (785 g), while the soft berries were in the control group. Akural (2016), in 'Alphonse Lavallee' cultivar, the highest berry flesh firmness was determined in the leaves taken at berry setting, from the application of top picking from 40 cm of shoots.

TSS content was not found to be significant among the applications, however, the highest TSS was detected in the GP+ME application (17.8%). While there was no significant difference between titratable acidity treatments, the lowest TA was detected in the control group of grapevines (0.78 $g.L^{-1}$). On the other hand, the maturity index showed significant differences between treatments, the highest was determined as control group vines (23.41), and the lowest was determined as GP (20.39) and ME (20.77) applications (Table 4). The effect of green pruning practices on yield and quality varies depending on the structure of the soil, the climate of the growing region and the type of vine grown (Lanyon et al., 2004; Pellegrino et al., 2014; Reynolds, 2022). Arnold and Bledsoe (1990) investigated the effects of leaf removal at different times and at different intensities on the aroma and flavor of the 'Sauvignon Blanc' grape variety. Vasconcelos and Castagnoli (2000), in a study they conducted on the 'Pinot noir' grape variety; They applied different canopy management methods such as shoot topping at the full blooming stage, cutting the axil shoots and removing the leaves in the cluster area. It was determined that topping application increased the fruit set rate, cluster weight, yield per shoot, leaf size and the contribution of main leaves to the total leaf area; it reduces the total yield per vine, pH, leaf area and pruning wood weight. On the other hand; It was determined that leaf removal application four weeks after flowering had no effect on yield components. If the nutrients consumed by the vine every year through pruning and harvesting cannot be replenished, decreases in the yield and quality of grapes are observed from year to year (Schreiner et al., 2006; Schreiner, 2021; Verdenal et al., 2021). An indispensable condition for successful cultivation is to constantly supply the plant with nutrients through fertilization (Bergman, 1992).

Table 4. Effects of green pruning and microlement applications on berry characteristics

Treatments	Berry firmness (N)	Berry volume (cm^3)	TSS (Brix %)	Titratable acidity ($g. L^{-1}$)	pH	Maturity index
Control	6.71 b*	2.65 b	17.3	0.78	2.96	**23.41 a**
Green pruning (GP)	7.21 a	2.72 b	17.6	0.84	2.98	20.39 b
Microelement (ME)	7.46 a	3.30 a	16.8	0.80	2.90	20.77 b
GP+ME	7.35 a	2.81 b	17.8	0.82	3.03	21.48 ab
Standart Errors of the Mean's	0.05	3.57	0.26	0.01	0.03	0.43
P≤0.05	*	*	ns	ns	ns	*

*Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

The berry skin color value has shown significant differences according to applications (Table 5). According to applications, the least L* value was obtained from the ME application (24.76) in the study. The highest L* value was at GP and GP+ME applications (31.34 and 31.36, respectively). Because of the lowest L* value was at ME application; dark skin color berries were given in ME applied vines. The a* value has not show statistical importance between applications. On the other hand, GP application was the highest a* value (8.83) and the lowest was in the control group (4.60). b* value obtaines as negative, and the least b* value was at ME application (-8.41). In the study, chorome and hue color degrees were not showing importance. On the other hand; while chrome value was the highest at GP (11.42), hue value was the highest at ME application (57.82). Compared to the control group, the applications showed that the black color in the berry skin was lightened the most, that is, the brightest berries were obtained from green pruning + micro element application with a value of 31.45, while the micro element application caused an increase in the black color in the berry skin with a value of 24.82. When the data obtained was examined, it was seen that the black color on the berry skin was lightened the most, that is, the brightest berry were obtained from the green pruning + micro element application at 31.45. The value obtained as 28.61 in the control group was determined as 24.82 in the microelement application. As a matter of fact, although it was determined in the study that green pruning increased the L* color value, Köse et al. (2018) reported that removing fewer and more leaves in the 'Trakya İlkeren' grape cultivar decreased the L* color value.

Compared to the control group, the applications showed that the black color in the berry skin was lightened the most, that is, the brightest berries were obtained from green pruning + micro element application with a value of 31.36; while the micro element application caused an increase in the black color in the berry skin with a value of 24.76. As a matter of fact, although it was determined in the study that green pruning increased the L* color value, Köse et al. (2018) reported that removing fewer and more leaves in the Trakya İlkeren grape variety decreased the L* color value. According to results, the applications were affected berry skin color, especially ME application improve 'Trakya İlkeren' skin color. GP application has adversely effect on grape skin color. It is considered that this situation causes the photosynthesis efficiency to decrease as a result of the decrease in the leaf area and chlorophylle content of the grapevine caused by the GP application and therefore the skin color development to be retarded as a result of adversely affecting the synthesis of anthocyanin (Table 5).

Skin color was measured with the help of Konica Minolta CR-400 chromameter (color measuring device). In color measurement, L* (indicates brightness value, L*=0 indicates black, L*=100 indicates white), a* (+a* value indicates red color degree, -a* value indicates green color degree), b* (+b* value indicates green color degree, -b* value indicates blue color degree) and hue° (indicates what color is according to its degree) color values were determined (McGuire, 1992). Sunlight has been a key factor in enhancing fruit color development in colored grape cultivars (Dokoozlian and Kliewer, 1996; Chorti et al., 2010; Shinomiya et al., 2015). Shading of clusters has been shown to reduce total anthocyanin content in grape berry skin (Chorti et al., 2010; Gao and Cahoon, 2015; Guan et al., 2017). Gao and Cahoon (2005) determined that the anthocyanin amount in the berry skin was negatively affected by 95 % cluster shading. On the other hand, many researchers emphasized that microlements improve grape berry color (Delgado et al., 2006; Ananga et al., 2013; Strydom, 2014; Abdel-Salam, 2016; Abou-Zaid and Shaaban, 2019; Chen et al., 2020; Abou El-Nasr et al., 2021).

Table 5. Effect of green pruning and microlement applications on berry skin color values

Treatments	L*	a*	b*	Chrome	Hue angle
Control	28.56 b*	4.60	-6.77 b	8.35	-55.62
Green pruning (GP)	31.34 a	8.83	-5.56 a	11.42	-50.35
Microelement (ME)	24.76 c	5.21	-8.41 c	9.99	-57.82
GP+ME	31.36 a	4.82	-5.86 a	7.66	-50.76
Standart Errors of The Mean's	0.158	1.07	0.10	1.065	0.599
P≤0.05	*	ns	*	ns	ns

*Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

This research has shown that the applications significantly affected the average leaf area and leaf chlorophyll content (P≤0.05). In this research, the lowest average leaf area was obtained from vines with control (159.56 cm^2) and GP (156.76 cm^2) applications, while the highest average leaf area was obtained from ME (211.16 cm^2) applied vines (Figure 5). Similarly, in a study conducted by Poni et al. (2006) on 'Sangiovese' and 'Trebbiano' grape cultivars, the effects of early leaf defoliation were examined. It was determined that fruit set, cluster weight, number of berries per cluster, berry size and cluster compactness decreased with all leaf removal applications.

Leaf is one of the important main organs of the vine. Its primary function is to perform leaf photosynthesis and respiration. Leaf removal is one of the most common summer practices in vineyards aimed at an improvement of cluster microclimates, ripening and reducing fungal disease risks. Leaf removal improves cluster exposure, ventilation and the efficiency of pesticide applications (Guidoni et al., 2008). Leaf removal also provides better light penetration, successful air circulation prevents air humidity and helps with disease control in the grape canopy (Sternad et al., 2015). However, excessive removing of the leaves prevents the growth of the vines and the ripening of the fruits well. For this reason, it should be avoided excessive leaf removing during the growth season (Köse et al., 2018).

Similarly, GP application caused a significantly decrease in leaf chlorophyll content (29.56) than even control vines. The highest leaf chlorophyll content was obtained in ME applied grapevines (32.75). The results obtained from the research showed that the average leaf area and leaf chlorophyll content, which decreased with GP application, increased with the addition of ME to GP application (Figure 6). Al-Atrushy (2019) stated that the application of micronutrients significantly increased leaf area, total chlorophyll content, number of clusters per vine, cluster weight and yield per vine, as well as weight and size of 100 berries, and TSS in 'Mirane' grapevines. On the other hand; the needs of the plant can be met with fertilization during the growing period, or at different stages of the plant's development. In order to fertilize both economically and as needed, plant analyses are important to control the fertilization plan and determine the availability of fertilizer applied to the soil, along with soil analysis (Conradie, 2001; Arrobas et al., 2014).

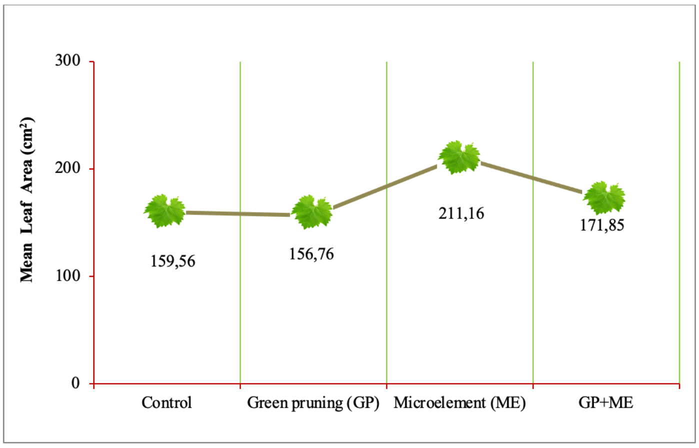

Figure 5. Effect of green pruning and microlement applications on leaf area (cm^2). Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

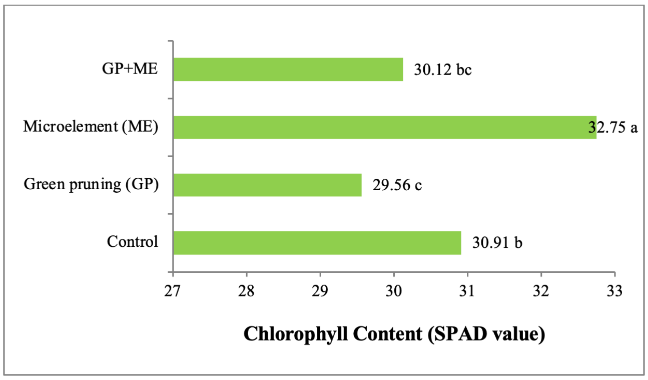

Figure 6. Effect of green pruning and microlement applications on leaf chlorophyll content (SPAD value). Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

Shoot length, cane diameter, internodes and periderm encompassed internodes showed statistically significant differences among foliar treatments (Figures 7, 8, 9 and 10). Among the treatments, microelement application increased shoot length (194.71 cm), cane diameter (11.13 mm) and internode length (76.81 mm). As expected, the lowest shoot growth was observed in GP treated vines. It is seen that microelement application increased shoot growth. Contrary to expectations, ME application delayed periderm development. The highest number of periderm encompassed internodes was found in control vines (7.76). The lowest number of encompassed internodes was obtained from microelement treated vines. A similar result was found by Xu et al. (2020) that the addition of microelements in fertilizer to loquat rootstock seedlings can significantly delay the lignification process of the cambium of grafted vines, which exhibited the greatest improvement in stem thickening.

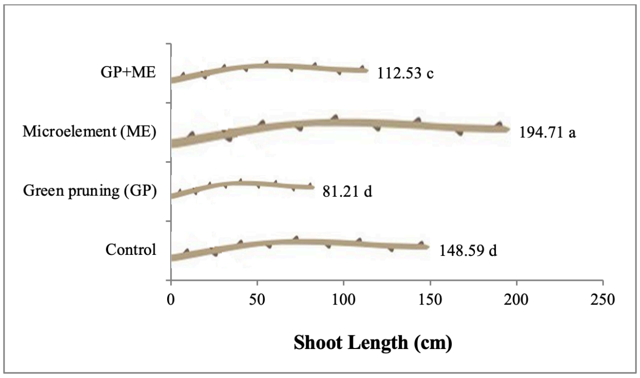

Figure 7. Effects of green pruning and microlement applications on shoot growth. Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

Regular (Caspari et al., 1998) or 90% leaf removal (Chaumont, 1995; Ollat, 1998) reduces photosynthesis. Leaves are also important as a food organ for humans, as the products of photosynthesis produced cannot be fully transported from the leaf to other organs during the day (Downton et al., 1987, Düring, 1988; Roper and Williams, 1989). This study showed that green pruning practices reduced the photosynthetic activities of the plant as it caused a decrease in the average leaf area of the grapevine, a decrease in the chlorophyll index, and a decline in shoot length. As a result, the lack of photosynthetic activity affected the growth and development of grapevines, cluster quality and skin color.

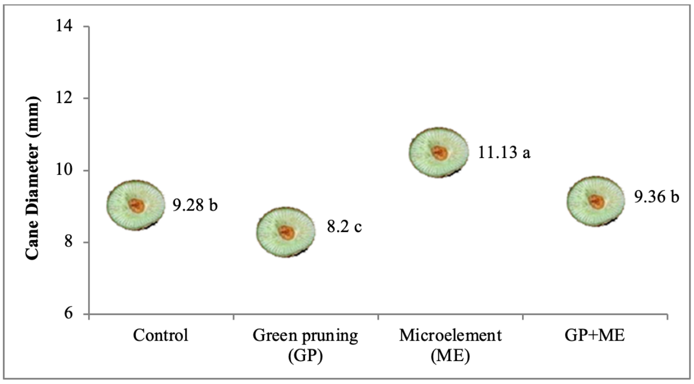

Figure 8. Effects of green pruning and microlement applications on cane diameter. Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

It is known that if grapevines cannot meet the plant nutrients they need during their natural development period, the yield obtained from vineyards will decrease and the quality of the products will be negatively affected. Although the amounts of plant nutrients needed by grapevines vary, in general, grapevines need mainly N, P, K, Mg, Ca, S, B, Mn, Cu, Zn and Mo during the development period (Verdenal et al., 2021; James et al., 2023).

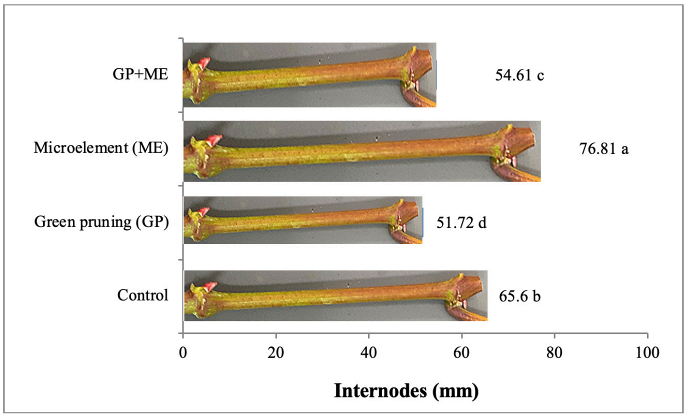

Figure 9. Effects of green pruning and microlement applications on shoot internodes. Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

Applying foliar fertilization is a remarkable method in order to maintain or even increase the growth and yield in micronutrient deficiencies encountered in grapevines (Abd El-Razek et al., 2011; El-Boray et al., 2019; Hosseinabad and Khadivi, 2019), especially during the crop season (Masi and Boselli, 2011; Baldi et al., 2017; Gautier et al., 2018; Kumar and Mohapatra, 2021). In this study, microelement application caused a decrease in lignification which has slowed down periderm development.

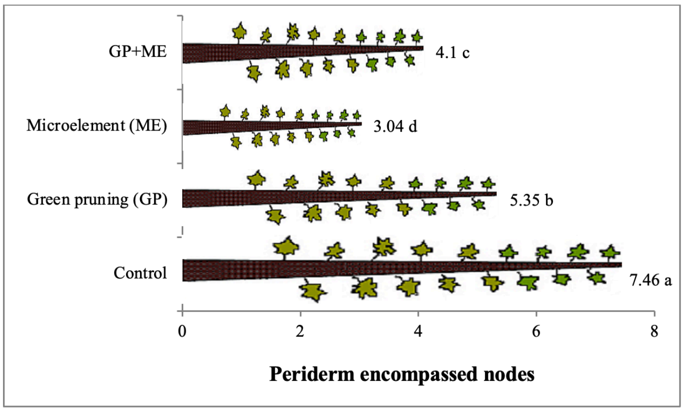

Figure 10. Effect of treatments on shoot development and periderm encompassed nodes. Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

In the study, bud fruitfulness was determined to obtain the effcts of the previous year's applications. It was seen that the applications had a significant effect on the bud fruitfulness in the following year (Figure 11). In the study, the effects of the treatments on the bud fruitfulness in the following year were determined by counting the clusters carried by the shoots formed at the nodes from the bottom in May under vineyard conditions. While the average number of clusters calculated based on the average of 10 nodes in the control group vines was determined to be 1.34 clusters, this ratio was calculated to be 1.15 clusters in the GP application, 1.86 clusters in the ME application and 1.45 clusters in the GP+ME application. As can be seen, while green pruning applications (GP) significantly reduced the bud fruitfulness the following year compared to the control vines, ME application significantly increased the bud fruitfulness. On the other hand, the negative effect of GP application caused a significant increase in bud fruitfulness by adding ME to GP application. In the research, according to bud fruitfulness results, it was evaluated that from 4 to 10 buds can be left during pruning in the 'Trakya İlkeren' grape cultivar depending on the preferred training system, which would be beneficial in terms of total vine yield (Figure 11). As a matter of fact, Çelik (2017) reported that in 'Trakya İlkeren' grape cultivar, 4-8 buds can be left in pruning. In our study, it was determined that the number of clusters per bud increased from the 4th nodes.

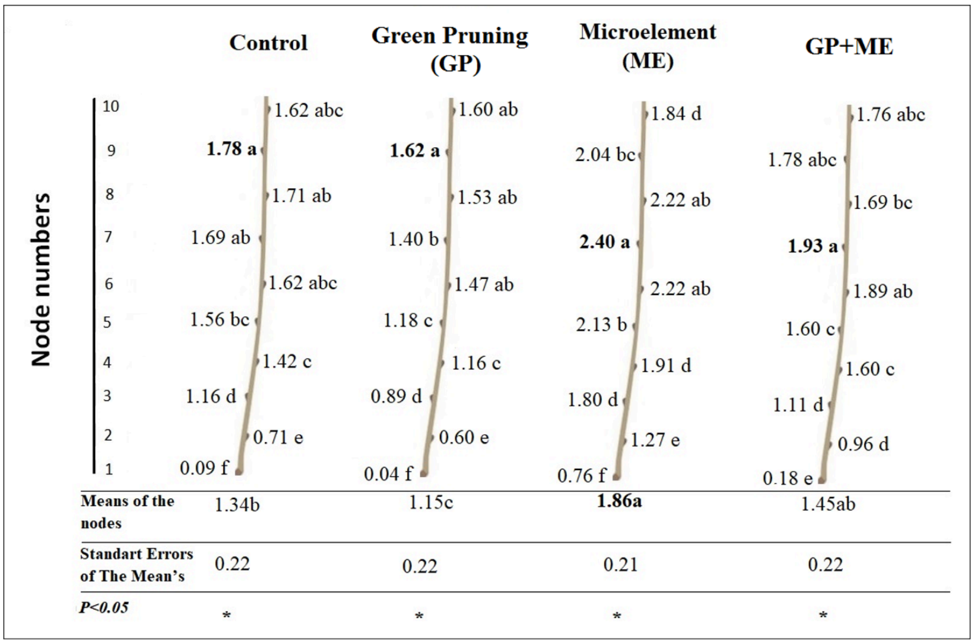

Figure 11. Effect of treatments on the number of clusters formed on the following year's nodes. Means followed by similar letters are not statistically different (P≤0.05) as compared by Duncan's multiple range test.

Several factors may influence bud fruitfulness, such as light, temperature, nutrient and the water status of vineyard (Shikhamany, 1999; Dry, 2000; Mullins et al., 2000). Our study showed that the combined ME application highly affected on bud fruitfulness on grapevines. Especially, when making green pruning application in the vineyards, it should be supported with microelements to prevent decreasing photosynthetic matters. When vineyards show nitrogen, potassium, boron and iron deficiency, it shows a high incidence of bud necrosis and/or low bud fertility (Botelho et al., 2005). Besides, mineral fertilizers have an effect on the growth of shoots, the formation of primordia in winter buds, and leaf covering of clusters. Foliar applications with mineral fertilizers promote the activation of a number of metabolic processes in plants (Aleynikova et al., 2021). For this subject; Mostafa et al. (2017) emphasized that foliar nutrient application (Fulvic acid +Mg + K) gave the highest significant increase in bud burst and fertility, shoot length, leaf surface area, total chlorophyll content, yield/vine, TSS%, total sugars and total anthocyanin content in berry skin while it gave the lowest decrease in acidity compared with that of control vines. Thanks to the green pruning performed during the vegetation period, the incidence of fungal diseases such as Downy mildew, Powdery mildew and *Botrytis cinerea*, which develop rapidly in environments with high relative humidity and in shaded areas, decreases and the contact of the applied fungucides to the inner parts of the vine and the clusters becomes easier (Sholberg et al., 2008, Mahrous and Shalaby 2009; Austin et al., 2011; Almanza-Merchán et al., 2014; de Bem et al., 2015).

CONCLUSION

Although green pruning is one of the most common practices in vineyards, it may have negative effects on the photosynthetic capacity of the grapevine, developmental disorder, yield and quality decline and the productivity of the following year's buds. In this study, the effects of green pruning practices and combined microelement applications on bud fruitfulness, vegetative growth, yield and cluster characteristics of 'Trakya İlkeren' grape cultivar were investigated. It was determined that green pruning practices had negative effects on bud fruitfulness, vegetative growth, yield and bunch characteristics. On the other hand, microelement applications had positive effects on bud fruitfulness. It was determined that supporting green pruning with microelement application will have a mitigating effect on these negative effects. In terms of reducing the negative effects of green pruning practices, it was observed that micro element application contributed positively to the improvement of bud fruitfulness, growth and cluster characteristics. For this reason, it has been observed that microelement application will be beneficial in the period starting from green pruning until veraison in order to reduce the losses of growth and cluster specifications caused by green pruning practices carried out for many purposes such as sun light penetration in canopy, ventilation, control of fungal diseases, berry skin coloration and aroma development in the summer months. When the bud fruitfulness of the following year's is evaluated, it is thought that the highest cluster number per nodes for the 'Trakya İlkeren' cultivar is obtained from pruning with 4 to 10 buds. For this reason, it was concluded that it would be appropriate to perform medium or long pruning and to prefer Lenz Mozer, Guyot or Pergola training systems.

COMPLIANCE WITH ETHICAL STANDARDS

Peer-review

Externally peer-reviewed.

Conflict of interest

This study, which was part of the Fatma Türk's MSc Thesis (YOK Thesis No: 720471/Date: 08.02.2022) is no potential conflict of interest was reported by the author(s).

Author contribution

The contribution of the authors to the present study is equal. All the authors read and approved the final manuscript. All the authors verify that the text, figures, and tables are original and that they have not been published before.

Ethics committee approval

Ethics committee approval is not required.

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Data availability

The data can be available upon the request.

Consent to participate

Not applicable.

Consent for publication

Not applicable.

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