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GA_3 and Hand Thinning Improves Physical, Chemical Characteristics, Yield and Decrease Bunch Compactness of Sultanina Grapevines (*Vitis vinifera* L.)

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Abstract: Nowadays, the Sultanina grapevines H4 strain has become widely cultivated because of its high productivity. However, this Sultanina variety is suffering from clusters with small berries, in addition highly compacted berries, thus negatively affecting the quality of bunch berries. A field experiment was carried out during the two successive seasons on Five years old Sultanina (H4 strain) grapevines grafted onto freedom rootstock grown in a private orchard located in El-Khatatba region, Minufyia Governorate, with coordinates of 30°21′ N 30°49′ E. The investigation was designed to throw light on the effect of hand thinning at levels 0, 25%, and or 50% of cluster shoulders was removed in addition to spray with 0, 20, 30, and 40 ppm GA_3 for berry sizing. In addation, the first application was the hand thinning treatment, which was used on the second and third week of May for the first and the second seasons. The second application was the berry sizing treatment, applied when the berries were at 6–7 mm diameter (on the 3rd and 4th week of May for the first and the second seasons. Results indicated that the total chlorophyll content of leaf decreases when the hand thinning levels or GA_3 concentration increases, while hand thinning and GA_3 treatments were higher than control only concerning pruning weight. Moreover, the results showed that the first level of hand thinning treatments recorded higher values for the cluster weight than the higher level of hand thinning treatments with all the concentrations of GA_3 used for sizing. The highest value was with T2. The overperformance of T2 for the vine yield and the rest of the treatments at the lower level of hand thinning were better than those at the higher level of hand thinning. In conclusion, hand thinning at 50% level and sizing with GA_3 at concentration 30 ppm reduced the cluster compactness and improved the berry weight and firmness. Therefore, it could be recommended to get the most suitable yield and quality of Sultanina grapevines.

Keywords: *Vitis vinifera* L.; H4 strain; quality; shoulders; berry enlargement

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1. Introduction

Grape (*Vitis vinifera* L.) is one of the most important, commercial, popular, favorite, delicious, refreshing, and nourishing fruit crops worldwide [1]. The berries are a good source of sugars, minerals, and vitamins [2] Grape is the third leading fruit crop worldwide, with a harvested area of 6.95 million hectares producing 78.059 million tons annually with an average of 11.23 tons/hectare [3]. In Egypt, it ranks fourth after citrus, mango and olive fruit crops concerning the production area and consumption rates. In the last decade, Grape acreage exhibited a remarkable increase in Egypt, reaching a harvested area of 71,889 hectares, producing 1.586 million tons (22.0665 tons/hectare) [4].

Thompson seedless grape is the most table grape cultivar grown in Egypt for making raisins [5], local consumption, and export. In recent years, the H4 strain has become widely cultivated for both table and dried raisins because of its high yield [6]. However, this strain suffers from producing clusters with high compactness and small berries [7], thus negatively affecting the cluster's quality during the marketing. Overcoming these problems would improve the market price for local consumption and exportation [8].

Plant growth substances play a major role in growth and development [9]. Since grapevines are sprayed with GA_3 at the flowering stage to enhance bunch thinning and berry size in seedless cultivars [10]. Gibberellins (GAs) are the most common reagent used in chemical thinning [10]. The optimum dose and time of application seemed to be beneficial for improving quality [5]. The application of gibberellins also decreases the bunch compactness and improves the berries' quality [2]. Gibberellic acid leads to cell division and enlargement, increases protein biosynthesis, produces new tissues, and promotes the absorption of water and nutrients. GA3 is an effective method in improving Black Magic grape cultivar berries, which could be used in wide range orchards [11]. The addition of gibberellic acid at the concentration of 20 mg/L increased the weight of the cluster and berry, and increased the transportability of the berries [12]. Spraying with GA3 at 15 ppm when cluster 7–12 mm could be recommended for improving berry quality of cultivar 'Parletta' [13]. Pre-flowering gibberellin application can decrease bunch compactness and improve the quality of Syrah grape berries. These findings reflect the potential utility of gibberellin treatments for decreasing cluster compactness and increasing the quality of wine grapes [14]. Thus, the optimum dose and time of application are beneficial for decreasing bunch compactness through thinning effects on Thompson seedless grapevines [15].

Thinning is a common horticultural technique controlling yield and fruit quality [16]. Cluster and berry thinning could be performed through chemical or mechanical approaches [17]. Both methods reduce the number of berries in the compacted cluster, producing loose clusters with suitable appearance and marketability [18]. Additionally, thinning improves the cluster morphology and berry's physical and chemical characteristics of grapevine [19]. Berry numbers were reduced in all thinning treatments. Length, width and weight of berries increased significantly when treated with hand or chemical thinning. GA_3 treatment improved yield and the quality of berries. TSS was improved in all thinning treatments. In general, application of GA_3 and hand thinning along with GA_3 were proposed to improve quality of grapevine berries [20]. Cluster thinning proved to be a useful tool for the successful manipulation of cropload (ratio of leaf area to fruit weight) [21]. Increasing the source-to-sink ratio by berry and cluster thinning at different phenological stages affects the early ripening of grapevines [22–24]. Intense leaf removal and gibberellic acid applied at early flowering can help reducing bunch compactness in Pinot gris and showing it in two training systems. In particular, leaf removal represents a valuable alternative to plant growth regulators [24]. The obtained results clearly demonstrate that applying Sunred® can improve the yield and qualitative parameters of the red table grape variety 'Crimson Seedless', indicating that this biostimulant could be a viable alternative to the most widely used plant growth regulator [25]. GA_3 spraying treatment resulted in lower bunch compactness and improved berry quality in 'Thompson Seedless', while the effects on berry quality observed in 'Sugraone' and 'Crimson Seedless' were not consistent across the trials conducted in different years [26]. The application of 50–100 mg L^{-1} GA_3 prior to grapevine anthesis caused elongation of inflorescences and bunches, and eased cluster compactness in 'Cabernet Franc' and 'Cabernet Sauvignon', and no negative effects were observed on the yield and seed numbers [27]. However, to date, few studies are available regarding the pre-harvest treatment of (H4 strain) with hand thinning and GA_3 foliar spray. Therefore, the principal goal of this work is to improve the yield and fruit quality by detecting the optimum the suitable hand thinning level and detecting the optimum dose and application time of Gibberellic acid its impact on cluster and berry quality. Moreover, overcoming compactness and improving appearance of clusters and berries of Sultanina (H4 strain) grapevines.

2. Materials and Methods

2.1. Plant Materials and Experimental Design

The present study was carried out during the two seasons of 2018, and 2019 on Five-year-old Sultanina (H4 strain) grapevines (*Vitis vinifera* L.) grafted onto freedom rootstock. The shrubs were grown in a private orchard located in El-Khatatba region, Minufyia Governorate, with coordinates of 30°21′ N 30°49′ E. The weather of the experimental region is presented in Figure 1. The tested shrubsshrubs were approximately uniform in vigor and healthy in appearance, grown at 2 × 3 m apart (700 vines/feddan) in sandy soil planted under a drip irrigation system. The cane pruning was trained using a quadrilateral cordon trellis system and supported by the Spanish Parron system. Moreover, the experimental shrubs received the normal agricultural practices, fertigation, and pest control recommended by the Egyptian Ministry of Agriculture.

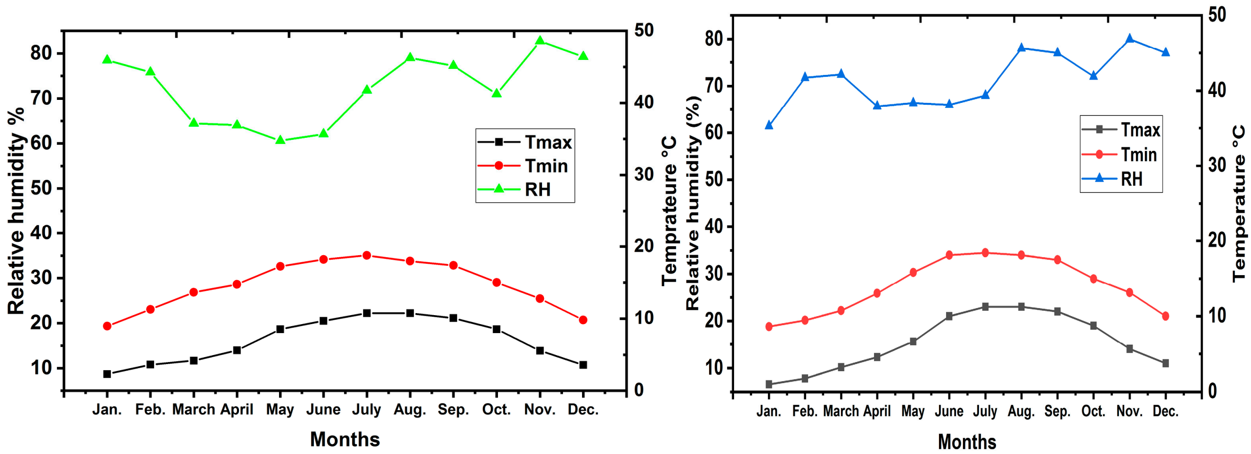


Figure 1. Climatic data of El-Khatatba region-Monthly means of 2018 and 2019.

The objective of this experiment was to improve the growth, yield, and fruit quality of H4 grape by hand thinning and spraying with different Gibberellic acid GA_3 concentrations. Hand thinning and sizing in this experiment were applied to the vineyard during different phonological stages. The hand thinning was used after the fruit set at the 2–4 mm berry diameter stage on the second and third week of May for the first and the second seasons, respectively. Whereas, GA_3 for sizing was applied when the berries were at 6–7 mm diameter on the 3rd and 4th week of May for the first and the second seasons, respectively, and repeated twice four days interval. The sprayed solutions were prepared and diluted with tap water before application on the farm. Triton B emulsifier at a rate of 0.1% was used as a wetting agent during application. Spraying was done until the runoff point using a hand pressure sprayer. The pruning load was adjusted to 120 buds per vine (10 Canes × 12 buds). The experiment was arranged in a randomized complete blocks design in three replicates for each treatment with two shrubs in each replicate. The experiment was applied to 81 homolog shrubs in both seasons of study. This experiment contained nine treatments in three replicates (3 shrubs/replicate) arranged as follows in Table 1:

Table 1. Hand thinning percentage and GA_3 treatments of Sultanina (H4 strain) grapevines.

Treatments No.	Hand Thinning (%)	GA_3 Foliar Spray (ppm)
Control	Without removing any shoulders of the cluster	0.0
T1	25% of cluster shoulders were removed	20
T2	25% of cluster shoulders were removed	30
T3	25% of cluster shoulders were removed	40
T4	50% of cluster shoulders were removed	0.0

Table 1. *Cont.*

Treatments No.	Hand Thinning (%)	GA_3 Foliar Spray (ppm)
T5	50% of cluster shoulders were removed	20
T6	50% of cluster shoulders were removed	30
T7	50% of cluster shoulders were removed	40
T8	50% of cluster shoulders were removed	0.0

2.2. Measurements

To study the responses of shrubs to different treatments in all studied experiments, some parameters were measured as follows:

2.2.1. Leaf Chlorophyll Content (SPAD Units)

Leaf chlorophyll content was taken in June and measured using nondestructive Minolta chlorophyll meter SPAD 502 of the apical 5th leaf [28–30].

2.2.2. Pruning Weight (kg)

Pruning weight is an indicator of vegetative growth and vigor in grapevine, and traditionally, it is manually determined, according to Sabry et al. [30].

2.2.3. Yield and Its Components

At the harvest time of each season, the clusters per vine were recorded. Six clusters/replicate were randomly harvested when the average TSS % attained about 16–17% in the untreated vines and were taken to measure the yield components as follows: The total number of clusters was calculated by counting the clusters at harvest time on each vine. Cluster weight (g) was estimated by the weight of a representative sample of six clusters per replicate. Yield (kg·vine^{-1}), six clusters from each replicate were weighted, and the average cluster weight was multiplied by the number of clusters/vine to calculate the average yield as kg/vine. Total yield ton per feddan, the average yield as tons per feddan, was measured using yield per vine and the number of vines per feddan (700 vines).

2.2.4. Yield Increasing (%)

It was estimated as relative to control treatment as follows:

$$\text{Yield increasing } (\%) = \frac{\text{Total yield} - \text{control yield}}{\text{Control yield}} \times 100$$

2.2.5. Physical Characteristics of Clusters

Actress random samples of 6 bunches per replicate were harvested at ripening when TSS reached about 16–17%. The following characteristics were determined. Average cluster length and cluster width (cm). Compactness coefficient was calculated by dividing the number of the cluster berries by the cluster length as described by Chen [31].

Firmness (kg/cm^2): It was measured using a pressure tester (force-Gouge ModelIGV-O.SA.Shimpo instruments.

2.2.6. Chemical Characteristics of Berries

Total soluble solids (TSS %): It was estimated by the Carlziss hand refractometer. Total titratable acidity (%) was determined by titrating juice against NaOH (0.1 N) using phenolphthalein (ph.ph) as an indicator. The acidity was expressed as tartaric acid (%) according to the method of A.O.A.C. [32]. Total soluble solids/acid ratio was calculated for all the samples by using the following formula: TSS/acid ratio = TSS %/total acidity %.

2.3. Statistical Analyses

The differences between the tested treatment groups and the control group were analyzed in a completely randomized block design according to the method described by

Gomez and Gomez [33]. The obtained data of both seasons were subjected to analysis of variance (ANOVA) using the Co-Stat Computer Software program. The treatment means were compared using Duncan's multiple range test with a probability of 0.05 according to Duncan [34].

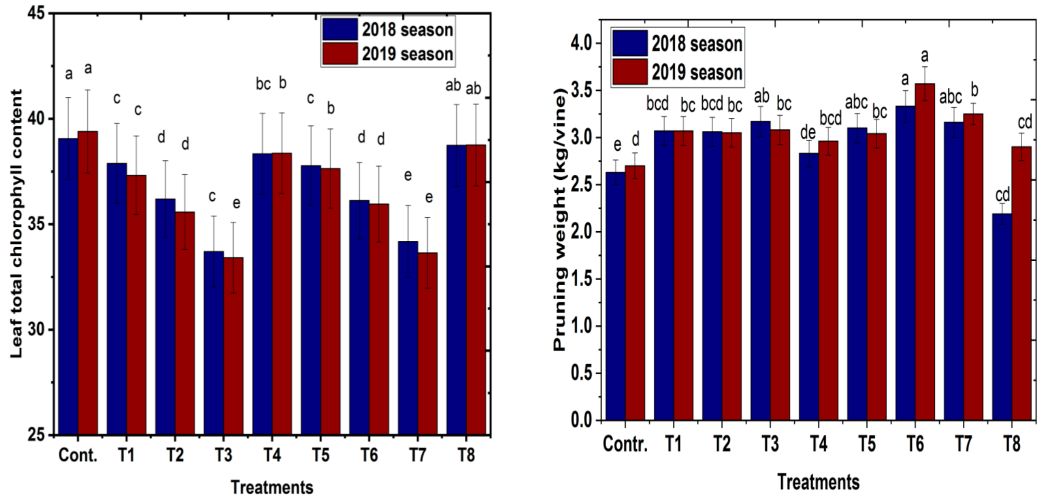
3. Results

This part of the study was conducted to illuminate the effect of hand thinning and GA_3 foliar application for sizing vegetative parameters, yield, and fruit quality of Sultanina grapevines (H4 strain).

3.1. Effect of Hand Thinning and GA_3 Spray for Sizing on Leaf Chlorophyll Content and Pruning Weight

Data presented in Figure 2a,b concerned with leaf chlorophyll content during the 2018 and 2019 seasons. In addition, the pruning weight associated with the application of hand thinning plus GA_3 for sizing compared with control was illustrated. Figure 2a showed that the control vines recorded the highest values of total leaf chlorophyll content as (SPAD) units more than the rest treatments in both seasons. After that, the vines treated with 50% hand thinning without GA_3 application (T8) ranked second. Whereas vines thinned at 25 and 50% hand thinning and sprayed with 40 ppm, GA_3 recorded the lowest significant chlorophyll in both seasons. It could be noticed that the leaf chlorophyll content decreased by increasing the concentration of GA_3 spraying for sizing regardless of the hand thinning levels. The results are in harmony with those of [35] on Black Monukka and Red Globe grapevines. They reported that leaf content of total chlorophyll was significantly increased by thinning of main vegetative shoots treatments compared with untreated vines. The relative increase in complete chlorophyll content observed in shoot thinning may be attributed to the high rate of shoot growth and increased intensity of photosynthesis in leaves. In addition, ref. [36] with Thompson seedless grapevines, found that hand thinning treatments combined with the application of boric acid and girdling gave higher chlorophyll contents values than the control.

According to the pruning wood weight, Figure 2b revealed that vines treated with 50% hand thinning and spraying with 30 ppm GA_3 (T6) recorded the highest values (26.62 and 32.22%) above control in both seasons, respectively. On the other hand, untreated vines (control) recorded the lowest significant pruning wood weight (2.63 and 2.70 kg/vine). In addition, vines treated with 25% hand thinning and sprayed with (20, 30 and 40 ppm GA_3) (T1, T2, and T3) gave intermediate values without significant differences during the two seasons. Moreover, vines treated with 25 or 50% hand thinning without spraying GA3 resulted in less pruning wood weight than those sprayed with GA_3 for sizing. Our results agree with [20] regarding the effect of tested treatments on pruning weight. They reported that Control vines had reduced pruning weights, which is consistent with the literature for white Riesling vines. Moreover, ref. [37] stated that the high pruning weights might not reflect the size and thus capacity of the vines when they carried fruit as significant growth occurred. In addition, Noori et al. [38] reported that Gibberellic acid had played an essential role in increasing vegetative growth, elongating the cells, activating the plant's vital activities, and increasing leaf area and chlorophyll content.



(**a**) (**b**)

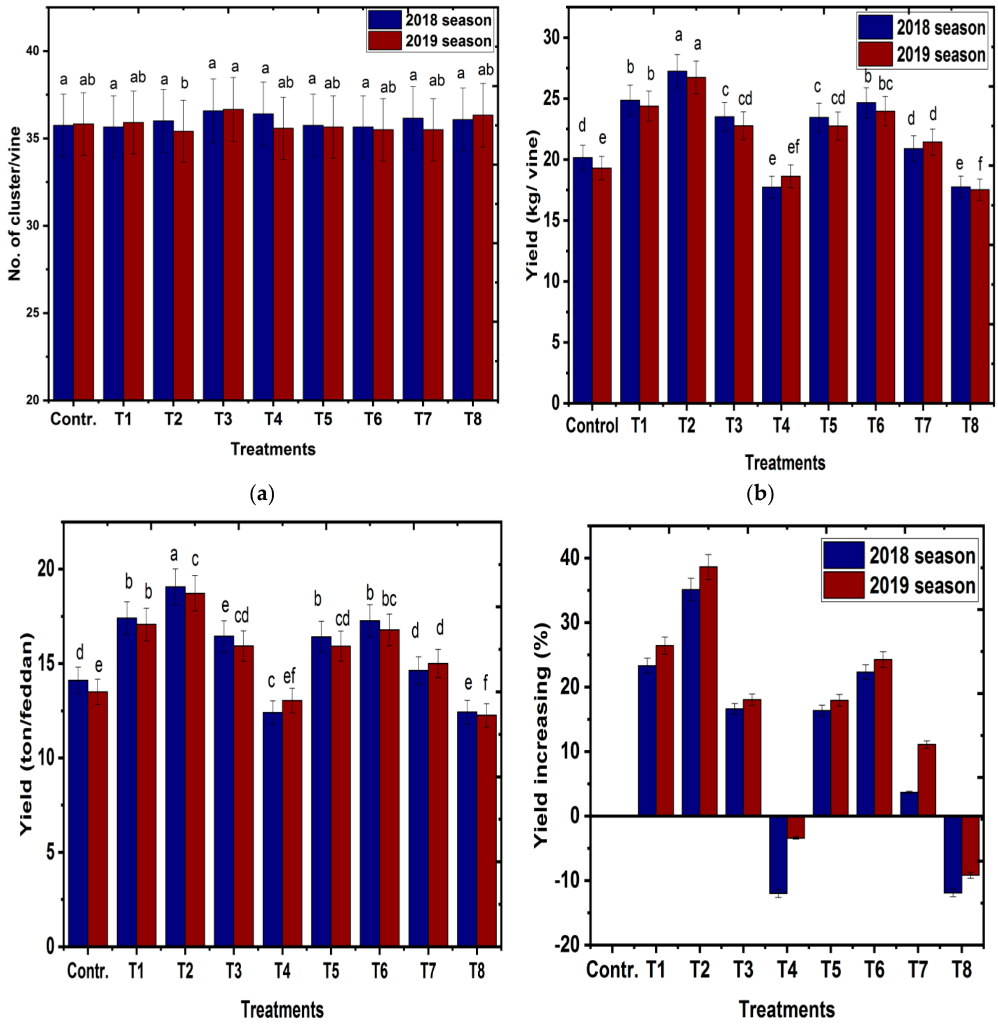
Figure 2. Effect of hand thinning and GA_3 spray sizing on (**a**) leaf chlorophyll content and (**b**) pruning weight of Sultanina grapevines (H4 strain) in 2018 and 2019 seasons. Contr.: without removing any shoulders of the cluster, T1: 25% hand thinning + 20 ppm GA_3 sizing, T2: 25% hand thinning + 30 ppm GA_3 sizing, T3: 25% hand thinning + 40 ppm GA3 sizing, T4: 25% hand thinning without GA_3 sizing, T5: 50% hand thinning + 20 ppm GA_3 sizing, T6: 50% hand thinning + 30 ppm GA_3 sizing, T7: 50% hand thinning + 40 ppm GA_3 sizing and T8: 50% hand thinning without GA_3 sizing. Means in each column followed by the same letter (s) are not significantly different at ($p \leq 0.05$), using Duncan's Multiple Range Test.

3.2. Effect of Hand Thinning and GA_3 for Sizing on Yield and Its Components

The impact of hand thinning and spraying of GA_3 on yield component was illustrated in Figure 3a–d represented by the number of clusters per vine, yield as kilogram per vine, and yield as a ton per feddan, along with the relative yield change compared to control. Regarding the effect on the number of clusters per vine, Figure 3a revealed no significant impact for studied treatments, especially in the first season. The highest number of clusters in the second season resulted from vines treated with 25% hand thinning and sprayed with 40 ppm GA_3 (T3), followed by that treated with 50% hand thinning without spraying GA_3 (T8). On the other hand, the lowest number of clusters was recorded with (T2).

Data presented in Figure 3b is also concerned with hand thinning and spraying GA_3 for sizing on yield as kilogram per vine in two studied seasons. The results show the superiority of (T2), which 25% hand thinning and 30 ppm GA_3 applied concerning yield per vine with 35.12 and 38.84% increment above control in the 2018 and 2019 seasons, respectively. Treatment number one (T1) came in the second order. It yielded about 23.31 and 26.44% increment above control. On the other hand, the lowest yield as kilogram per vine was recorded with 25 and 50% hand thinning without spraying GA_3 for sizing (T4 and T8) with corresponding of (−12.00 and −3.42%) and (−12.35 and −9.18%) decrement under control for first and second seasons, respectively.

According to total yield as a ton per feddan, data in Figure 3c show a similar trend for yield per vine. The highly significant yield per feddan obtained from vines received 25% hand thinning and sprayed with 30 ppm GA_3 (T2), followed by that treated with 25% hand thinning and 20 ppm GA_3 (T1). There are no significant differences between the two hand thinning levels without GA_3 application treatments, which recorded the lowest yield as a ton per feddan in the two study seasons. The total yield per feddan ranged from (19.06 to 12.26 ton/feddan) with (T2) in the first season and (T8) in the second season. The control vines surpassed some treatments concerning total yield as a ton per feddan. The lowest yield was recorded with (T4 and T8) in which the two hand thinning levels were applied without spraying GA_3 for thinning in the two seasons.



(**a**) (**b**)

(**c**) (**d**)

Figure 3. Effect of hand thinning and GA_3 spray sizing on (**a**) the number of clusters/vine, (**b**) yield (kg)/vine, (**c**) yield (ton)/feddan and (**d**) relative yield change compared to control (%) of Sultanina grapevines (H4 strain) in 2018 and 2019 seasons. Control: without removing any shoulders of the cluster, T1: 25% hand thinning + 20 ppm GA3 sizing, T2: 25% hand thinning + 30 ppm GA3 sizing, T3: 25% hand thinning + 40 ppm GA3 sizing, T4: 25% hand thinning without GA3 sizing, T5: 50% hand thinning + 20 ppm GA3 sizing, T6: 50% hand thinning + 30 ppm GA3 sizing, T7: 50% hand thinning + 40 ppm GA3 sizing and T8: 50% hand thinning without GA3 sizing. Means in each column followed by the same letter (s) are not significantly different at ($p \leq 0.05$), using Duncan's Multiple Range Test.

Concerning the relative yield change compared to control, all studied treatments surpassed control except T4 and T8, as shown in Figure 3d. Additionally, the highest relative yield above control (35.14 and 38.60%) was recorded with T2 in 2018 and 2019, respectively. On the other hand, the lowest comparable yield under control (−11.99 and −3.45%) resulted after T4, followed by T8 (−11.88 and −9.20%) in the first and second season, respectively.

The results of our study concerning yield and its component parameters agree with [39] on 'Refosco dal peduncolo rosso grapevine. They reported that reduced cluster weight affected by cluster thinning treatments could be ascribed to the targeted removal of cluster parts during thinning. As expected, cluster thinning achieved significantly decreased the average cluster weight. Similar to results reported for Corot noir grapevine by Sun et al. [40]. Cluster thinning demonstrated a variable impact on yield and yield components.

However, cluster thinning resulted in fewer clusters per vine compared to the control, but the increased average cluster weight had no impact on yield per vine.

As for cluster weight, Figure 4 shows that hand thinning and GA_3 spraying had significant effects in both seasons. The highest cluster weight recorded with vines received 25% hand thinning and 30 ppm GA_3 for sizing (T2), followed by that treated with 25% hand thinning and 20 ppm GA_3 for sizing (T1) during both seasons of study. The lowest cluster weight resulted from vines treated with 50% hand thinning without spraying GA_3 (T8). The cluster weight ranged from (756.71 to 482.37 g) with vines treated with 25% hand thinning plus 30 ppm GA_3 (T2) and 50% hand thinning without GA_3 (T8) sparing in the first and second seasons, respectively. Although the cluster thinning treatments decreased yield, cluster weight increased significantly after applying GA_3 to compensate for the decrease in yield.

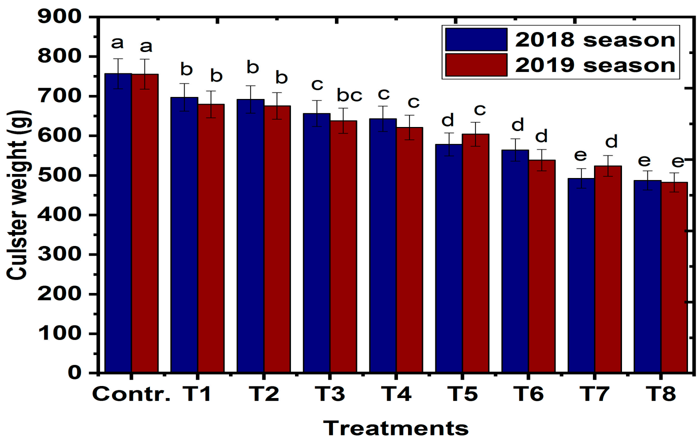


Figure 4. Effect of hand thinning and GA_3 spray sizing on cluster weight during 2018 and 2019 seasons. Contr.: without removing any shoulders of the cluster, T1: 25% hand thinning + 20 ppm GA_3 sizing, T2: 25% hand thinning + 30 ppm GA_3 sizing, T3: 25% hand thinning + 40 ppm GA_3 sizing, T4: 25% hand thinning without GA3 sizing, T5: 50% hand thinning + 20 ppm GA_3 sizing, T6: 50% hand thinning + 30 ppm GA_3 sizing, T7: 50% hand thinning + 40 ppm GA3 sizing and T8: 50% hand thinning without GA_3 sizing. Means in each column followed by the same letter (s) are not significantly different at ($p \leq 0.05$), using Duncan's Multiple Range Test.

These findings agree with Hesamaddin et al. [21] on the 'Yaghouti' grapevine. They proved that cluster weights were directly affected by thinning and GA_3 treatments. Therefore, all thinning treatments followed by GA_3 application increased yield. The obtained results are agree with Gowda et al. [41] who reported that application of GA_3 at early stages of bunch development had a thinning effect of 'Thompson Seedless' grapes. In addition, GA_3 induced cellular enlargement by loosening the cell wall, resulting from enzymatic activities breaking the hydrogen bonds in the cell wall [42].

3.3. Effects of Hand Thinning and GA_3 Spray on Cluster and Berry Quality

3.3.1. Effects of Hand Thinning and GA_3 Spray on Cluster Length, Width, Number of Berries/Cluster, and Compactness

Figure 5a,b did not show significant differences among all treatments and control on cluster length in both seasons. By contrast, the cluster width was significantly affected by treatments. The widest cluster resulted from 50% hand thinning without GA_3 spraying (T8), followed by T7. The results also confirmed that different concentrations of GA_3 for sizing did not show significant differences in individual hand thinning levels in both seasons. The lowest cluster width resulted from control. Figure 5c reveals that control ranked the first order concerning the number of berries per cluster during the two seasons. Moreover, the hand thinning levels affected the number of berries more than GA_3 spraying. In other words, the hand thinning at 25% produced clusters with more berries than that thinned at

50% level regardless of the GA_3 concentrations. The fewest berries per cluster were from T8 and T6 in the 2018 and 2019 seasons. It is evident from the same figure that the number of berries per cluster takes an opposite direction with the cluster width as affected by hand thinning levels and GA_3 spraying for sizing treatments. The thinning treatments directly affected the physical quality parameters such as cluster length, width, and the number of berries/clusters.

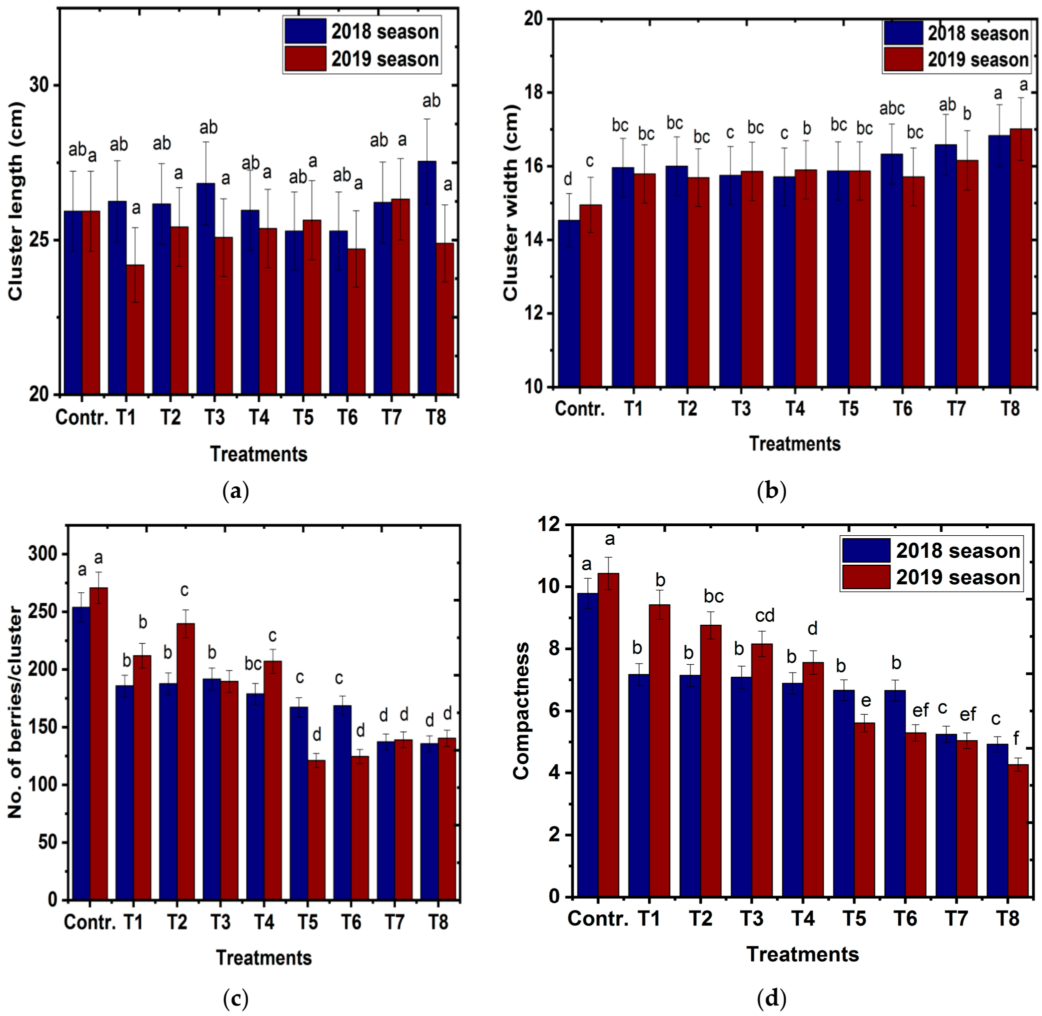


Figure 5. Effect of hand thinning and GA_3 sizing on (**a**) cluster length, (**b**) width, (**c**) No. of berries/cluster and (**d**) compactness of "Sultanina grapevines (H4 strain) in the 2018 and 2019 seasons. Contr. without removing any shoulders of the cluster, T1: 25% hand thinning + 20 ppm GA_3 sizing, T2: 25% hand thinning + 30 ppm GA_3 sizing, T3: 25% hand thinning + 40 ppm GA_3 sizing, T4: 25% hand thinning Without GA_3 sizing, T5: 50% hand thinning + 20 ppm GA_3 sizing, T6: 50% hand thinning + 30 ppm GA_3 sizing, T7: 50% hand thinning + 40 ppm GA_3 sizing and T8: 50% hand thinning Without GA_3 sizing. Means in each column followed by the same letter (s) are not significantly different at ($p \leq 0.05$), using Duncan's Multiple Range Test.

Regarding the compactness as a physical quality criterion, the results in Figure 5d shows that control vines gave the highest compactness in the two seasons. On the other hand, the lowest compactness resulted from 50% hand thinning without spraying GA_3 for sizing (T8). The rest treatments recorded intermediate values between control and T8. Thinning treatments reduced compactness by reducing the number of berries, resulting in a loose cluster with a more suitable appearance. The results from the current study are in the same line as those of Özer and Ergönül [43] on some grape cultivars found that the cluster length decreased at GA_3 and thinning treatments. GA_3 increased berry size alone or combined with berry thinning. Moreover, Radwan et al. [44] reported that using GA_3 at pre-bloom significantly increased the cluster length, whereas using it at full bloom significantly decreased the number of berries per cluster.

3.3.2. Effect of Hand Thinning and GA_3 on Volume and Weight of Berries

The results in Figure 6a–d concerned with the effect of hand thinning and GA_3 spraying on the weight and volume of 100 berries, juice weight, and volume of 100 berries of grapevines (H4 strain) in the 2018 and 2019 seasons.

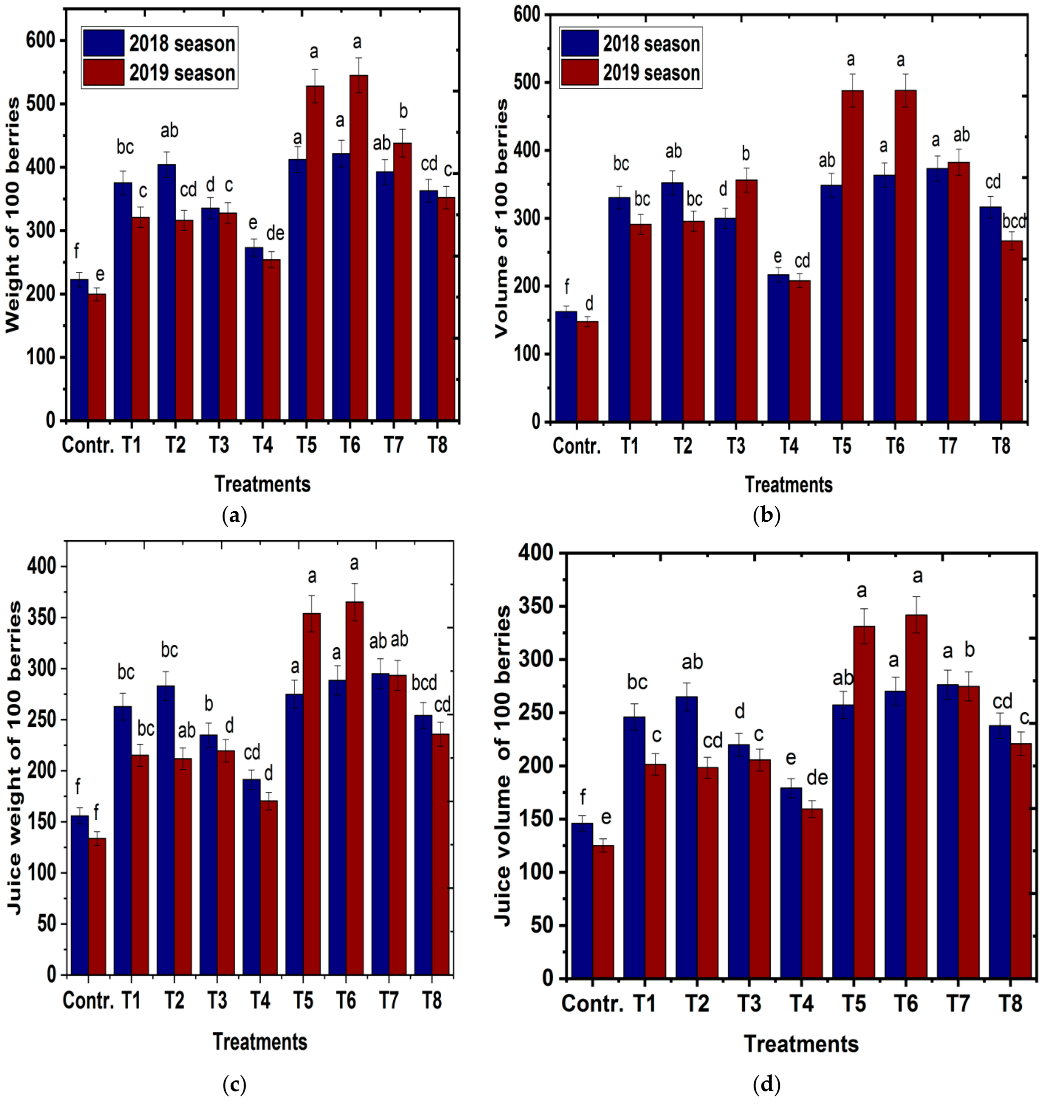


Figure 6. Effect of GA_3 sizing on (**a**) the weight of 100 berries, and (**b**) the volume of 100 berries, (**c**) juice weight of 100 berries, (**d**) juice volume of 100 berries of Sultanina grapevines (H4 strain) in 2018 and 2019. Contr. without removing any shoulders of the cluster, T1: 25% hand thinning + 20 ppm GA_3 sizing, T2: 25% hand thinning + 30 ppm GA_3 sizing, T3: 25% hand thinning + 40 ppm GA_3 sizing, T4: 25% hand thinning Without GA_3 sizing, T5: 50% hand thinning + 20 ppm GA_3 sizing, T6: 50% hand thinning + 30 ppm GA_3 sizing, T7: 50% hand thinning + 40 ppm GA3 sizing and T8: 50% hand thinning without GA_3 sizing. Means in each column followed by the same letter (s) are not significantly different at ($p \leq 0.05$), using Duncan's Multiple Range Test.

Regarding the effect on the weight of 100 berries, Figure 6a 4 showed that vines treated with 50% hand thinning and sprayed with 20, 30 and 40 ppm GA_3 exceeded the rest of the treatments in this respect. The heaviest 100 berries resulted from 50% hand thinning with 30 ppm GA_3 (T6) followed by (T5) without significant differences between them in the two successive seasons. The lightest weights were recorded with untreated vines (control). Similar effects of hand thinning and GA_3 spraying on the volume of 100 berries were observed in Figure 6b. It is clear from the data that 50% of hand thinning practices with spraying gibberellic for sizing surpassed the same practice without GA_3 spraying treatment. In addition, the results proved that the volume of 100 berries always recorded fewer values than the weight of 100 berries for the same treatment even control. Both 25 and 50% hand thinning without spraying GA_3 (T4 and T8) came in the last order before the control and after the rest of the treatments.

According to the effect on juice weight and juice volume of 100 berries, data in Figure 6c,d, also revealed that these parameters take the same trend as the ones mentioned above. In general, all hand thinning treatments with spraying gibberellic for sizing led to an increase in all the studied physical characteristics of 100 berries. Hand thinning at 25 or 50% levels with spraying different concentrations of gibberellic performed higher values than their counterparts without spraying as well as the control. In this respect, the application of GA_3 was reported to be preferable application for increasing berry weight and berry volume. Therefore, spraying of GA_3 at 25 ppm result in a higher 100 berries weight than 20 ppm [45]. In another study, Radwan et al. [44] concluded that spraying of GA_3 30 ppm twice increased berry weight and volume considerably, causing remarkable improvement in berry quality.

3.3.3. Effect of Hand Thinning and GA_3 Spray on Berry Length, Diameter, Shape Index, and Firmness

Figure 7a–d clearly show the effect of hand thinning with the different GA_3 treatments for sizing on berry length, diameter, shape index, and firmness force of (H4 strain) seedless grapevines. The results revealed that 50% hand thinning and 30 ppm GA_3 treatment produced a higher berry length, diameter, and firmness force than the rest treatments. Moreover, Figure 7a proved that 50% hand thinning with 30 ppm GA_3 (T6) significantly increased the berry length, giving the highest value. The same hand thinning and 20 ppm of GA_3 for sizing (T5) ranked second order. On the other hand, the lowest berry length resulted from control in the two seasons. In addition, spraying GA_3 at 30 ppm gave higher berry length than 20 or 40 ppm regardless of hand thinning levels. In addition, data in Figure 7b showed that the berry diameter had the same behavior as berry length. The highest diameter of berry resulted from (T6) followed by (T5, T2, T7, T1, T3, T4, T8, and control) in descending order in both seasons. The berry shape index in Figure 7c showed the same trend of berry diameter without significant differences in the second season. Concerning the effect of hand thinning and GA_3 spraying on the berry firmness, Figure 7d proved the surpassing of T6 and T5 on the rest treatments even control. The highest compression force resulted from 50% hand thinning and sprayed with 30 ppm GA_3. The lowest berry firmness was recorded with control vines in the 2018 and 2019 seasons.

These findings follow those reported in a previous study by Hesamaddin et al. [21], which said that the highest berry length was obtained from mechanically thinned clusters plus GA_3, and the lowest berry length was obtained in control. The highest berries size was caused by thinning, which gave the berries higher space and more nutrient uptake. However, all thinning treatments, enlargement of berries, and increase in berry size might be due to a reduction in berries. Similar results at gibberellin sprayed Flame seedless before bloom was reported by Özer and Ergönül [43]. They found that the crushing resistance of the berries was higher at larger berries with GA_3 and berry thinning applications. The higher resistance to crushing the berries could be attributed to increased berry size with GA_3 and GA_3 plus thinning. The strength of attachment between berry and pedicel is proportional to cellulose content of stem and pedicel increasing with gibberellin dozes.

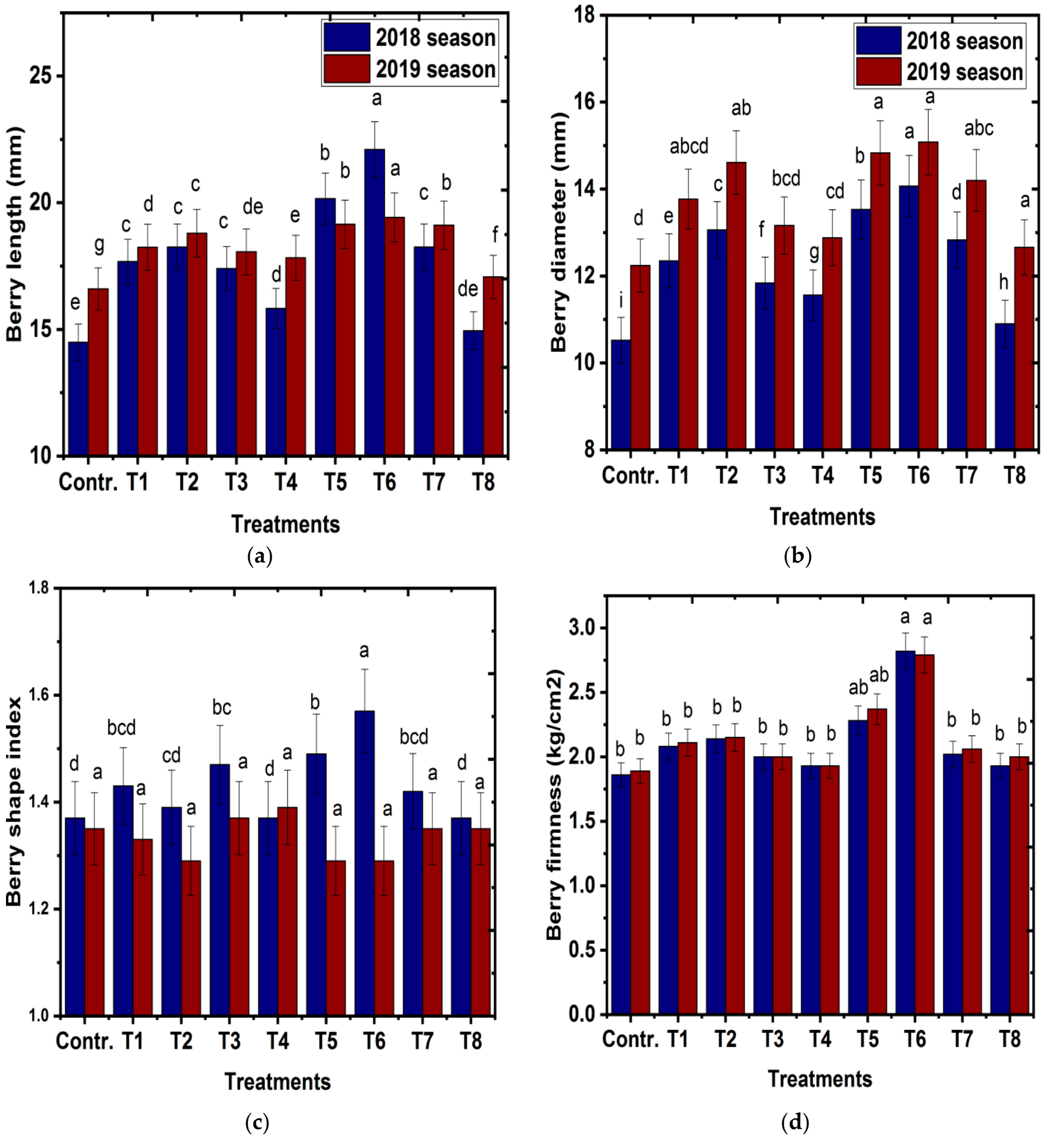


Figure 7. Effect of hand thinning and GA_3 spray sizing on (**a**) berry length, (**b**) berry diameter, (**c**) shape index of and (**d**) berry firmness of Sultanina grapevines (H4 strain) in 2018 and 2019 seasons. Contr. without removing any shoulders of the cluster, T1: 25% hand thinning + 20 ppm GA_3 sizing, T2: 25% hand thinning + 30 ppm GA_3 sizing, T3: 25% hand thinning + 40 ppm GA_3 sizing, T4: 25% hand thinning Without GA_3 sizing, T5: 50% hand thinning + 20 ppm GA3 sizing, T6: 50% hand thinning + 30 ppm GA_3 sizing, T7: 50% hand thinning + 40 ppm GA_3 sizing and T8: 50% hand thinning without GA_3 sizing. Means in each column followed by the same letter (s) are not significantly different at ($p \leq 0.05$), using Duncan's Multiple Range Test.

3.3.4. Hand Thinning and GA_3 Spray on Berry Chemical Characteristics

Figure 8a show that the total soluble solids percentage (TSS %) recorded the highest significantly increasing when clusters were thinned at 50% level without spraying GA_3 (T8). The data also showed that the absent or low concentrations of GA_3 are more effective for increasing TSS percentage with two-hand thing levels. On the other hand, the untreated vines (control) recorded the lowest TSS percentage during the two seasons. Figure 8b proves that acidity is opposite to juice TSS during the two seasons. The most acidic juice resulted from control, whereas the minor acidity was recorded with 25% hand thinning without GA_3 spraying (T4). Both hand thinning levels produced less total acidity % when applied without spraying GA_3 for sizing. However, the two hand thinning levels with spraying 40 ppm GA_3 recorded the most acidic juice compared with the rest treatments except control. According to the TSS/Acidity ratio, the results presented in Figure 8c proved that it looks like the TSS trait. This ratio may be considered as an indicator for grape ripening and harvesting. Data indicated that 25% hand thinning without GA_3 application (T4) ranked the highest significant order, followed by 50% hand thinning without GA_3 application (T8) in the two seasons. Both 25 and 50% hand thinning levels with 20 and 30 ppm GA_3 gave slightly significant TSS/Acid ratio values. In contrast, the high concentration of GA_3 (40 ppm) resulted in lower values without substantial differences between 25 or 50% hand thinning. On the other hand, the lowest TSS/Acid ratio was recorded with control.

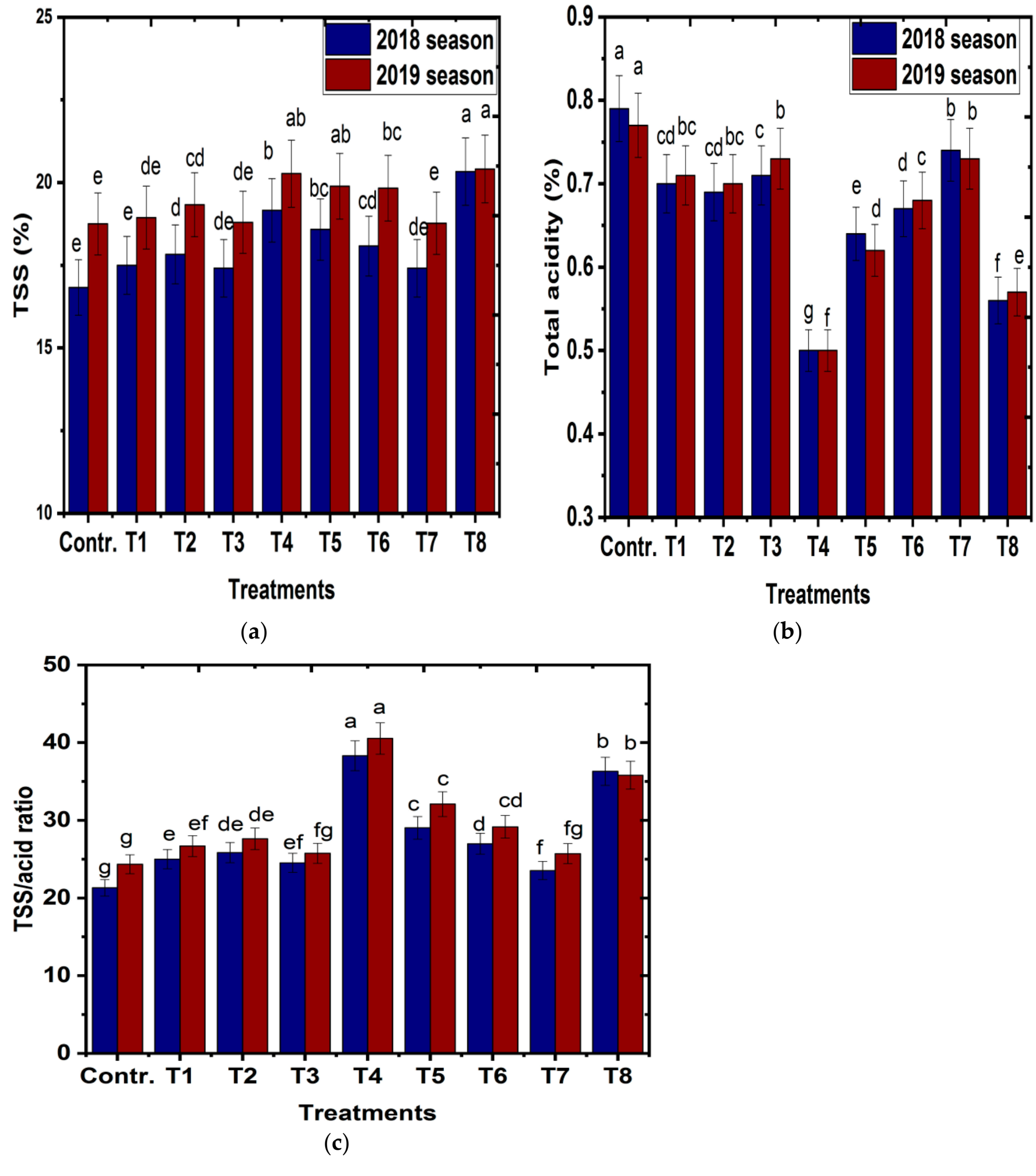


Figure 8. Effect of hand thinning GA_3 sizing on (**a**) TSS, (**b**) acidity, and (**c**) TSS/acidity during 2018 and 2019. Contr. without removing any shoulders of the cluster, T1: 25% hand thinning + 20 ppm GA_3 sizing, T2: 25% hand thinning + 30 ppm GA_3 sizing, T3: 25% hand thinning + 40 ppm GA_3 sizing, T4: 25% hand thinning Without GA_3 sizing, T5: 50% hand thinning + 20 ppm GA_3 sizing, T6: 50% hand thinning + 30 ppm GA_3 sizing, T7: 50% hand thinning + 40 ppm GA_3 sizing and T8: 50% hand thinning without GA_3 sizing. Means in each column followed by the same letter (s) are not significantly different at ($p \leq 0.05$), using Duncan's Multiple Range Test.

Our results agreed with studies of Almanza-merchán et al. [46] on the clonal selection of Riesling × Silvaner grape. They recommended increasing TSS according to the intensity of cluster thinning as an alternative to improve the quality. Clusters thinning resulted in the highest TSS content, considerable total titratable acids values, and technical maturity index. These follow the results obtained by Elgendy et al. [47]. They found that GA_3 at a concentration of 40 ppm improved the berry quality of Thompson Seedless grapevine by increasing TSS and TSS/acid ratio and decreasing acidity.

Tardaguila et al. [48] reported the enhancement of sugar accumulation. Higher sugar concentrations in the fruit at harvest have been seen in the observed increase in Brix caused by the cluster thinning treatments due to the advancement of berry maturation rather than the variation of the sugar accumulation rate. In addition, the titratable acidity showed significantly lower values due to mechanical thinning treatments than the control in Tempranillo and Grenache grapevines.

As a consequence of that, immigration of assimilates from leaves towards berries is enhanced. Similarly, the increase in TSS/acid ratio by thinning in grapes was also observed by Rather et al. [49]. They found that GA_3 spraying after the berry set significantly increased the juice TSS and TSS/acid ratio while decreasing the acidity. Belal [8] reported that berries quality improvement due to cluster thinning and GA_3 foliar application might be due to yield regulation. Removing parts of the clusters leads to a lower yield per leaf area; hereby, the quality will be improved by increasing total soluble solids and decreasing total acidity. Recently, Özer and Ergönül [43] discussed that the increase in TSS after thinning can be explained by the decrease in the number of berries leading to sugar accumulation. Therefore, the spray of GA_3 plus thinning application enhanced of maturity index compared to the control.

4. Conclusions

Hand thinning and GA_3 have been progressively used for enhancing the quality and yield of viticulture production. In this study, the Sultanina (H4 strain) grapevines have grabbed our attention. We attempted to improve the yield and fruit quality of Sultanina (H4 strain) grapevines. Therefore, in this work the main aim was detecting the optimum the suitable hand thinning level and detecting the optimum dose and application time of Gibberellic acid its impact on cluster and berry quality. Moreover, overcoming compactness and improving appearance of clusters and berries of Sultanina (H4 strain) grapevines. As a recommendation treatments on the compactness, chemical and quality features of H4 grape. In the light of the obtained results, it could be concluded that hand thinning of Sultanina (H4 strain) grapevines at 50% level of cluster shoulders removing at 2–4 mm berry diameter and sizing with GA_3 spray at concentration of 30 ppm and repeated twice with 4 days intervals. These treatments reduced the cluster compactness and improved the berry weight and firmness. We observed improved chemical properties of berries such as TSS, TSS/acid ratio. The application of hand thinning 50% of clusters and spray 30 ppm GA_3 for sizing and berry enlargement is recommended for application in Sultanina (H4 strain) vineyards for improving growth, physical and chemical characteristics of clusters and berries under the experimental conditions.

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Abbreviations

Min. temp	minimum temperature
Mean Temp	mean annual temperature
Max: temp	maximum temperature
RH	relative humidity
GA_3	Gibberellic acid
Ppm	Parts per million
T	treatment
g	gram
TSS	Total soluble solids

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