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Article

Effect of Different Seaweed Extracts on Yield, Quality and Physiological Characteristics of the Alphonse Lavallée (*Vitis vinifera* L.) Grape Variety

Osman Doğan * and Kevser Yazar

Department of Horticulture, Faculty of Agriculture, Selcuk University, Konya 42130, Turkey; kyazar@selcuk.edu.tr
* Correspondence: osmandogan@selcuk.edu.tr

Abstract

Grapes are one of the most preferred fruit species in the world. Increasing yield and quality in table grape production has always been the top priority for producers. Producers' interest in biostimulants from sustainable agricultural practices for quality and yield increase is increasing day by day. Seaweed extracts (SWEs), which are among the most preferred biostimulants, are shown as an organic input due to their ecological safety and harmlessness. In this study, *Ecklonia maxima* (Em), *Macrocystis integrifolia* (Mi) and *Ascophyllum nodosum* (An), which are brown SWEs, were applied to the Alphonse Lavallée (AL) grape variety four times via the leaves. As a result of the applications, yield, quality and physiological parameters were examined. As a result of the study, all SWE applied increased yield per vine between 28% and 47%. SWEs improved cluster and berry characteristics and increased phenolic content and antioxidant activity compared to the control. They also contributed to physiological characteristics of the grapevine, such as photosynthetic activity and stomatal conductance. It is thought that SWEs, which are among the sustainable agricultural practices, will improve the yield and quality of grapes not only in organic farming but in all agricultural practices.

Keywords: antioxidant activity; *Ascophyllum nodosum*; *Ecklonia maxima*; *Macrocystis integrifolia*; photosynthetic activity; total phenolic content

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1. Introduction

Grapes are one of the earliest cultivated and most preferred fruit species by humankind on a global scale. Especially in table grape cultivation, increasing yield and quality is of great importance. Grape producers use plant growth regulators to overcome winter cooling and increase berry size and fruit set [1]. New alternatives to these hormones, which are not suitable for organic farming, are being sought every day. Interestingly, SWEs have consistently been known to act like hormones, leading to increases in yields and enhanced plant resilience [2]. In this respect, seaweed can be an alternative to plant growth-promoting hormones.

Many active ingredients have been used in sustainable agriculture practices to be evaluated as biofertilizers and biostimulants. SWE is the most frequently tested of these biostimulants and is an organic product that is both ecologically safe for use and environmentally friendly [3]. Today, there are 221 species of seaweed with commercial value, and they have been used by humans for centuries as food, medicine, biofuel, animal feed and fertilizer [4]. SWEs contain various substances such as auxins, cytokinins, betaines and gibberellins that support plant growth, as well as organic substances such as amino acids, micronutrients and trace elements that can increase product yield and quality [5–8].

In grapevine, application of SWE had positive effects on root development [9,10], mineral nutrient uptake [11], plant growth [12,13], yield [14–16] and grape quality [17,18]. In addition, foliar application of Arthrospira platensis has recently been shown to enhance gas exchange parameters and berry weight in *Vitis vinifera* under both well-watered and water-stressed conditions, supporting its role as a sustainable biostimulant [19]. SWEs have also been studied in many fruit species other than grapes, including mango [20], banana [21], lemon [22], kiwifruit [23], avocado [24], apple [25], peach [26], strawberry [27] and pistachio [28].

It is known that SWEs rich in polysaccharides have an enhancing effect on plant growth [29]. AL-ahbaby [30] reported that SWEs are important for improving the vegetative growth of grapes. Furthermore, SWEs, which contain abundant nutrients and hormones, are known to promote cell division and expansion, contribute to plant physiological and biological processes, increase the efficiency of photosynthesis. In addition, seaweeds are known to act as biostimulants of secondary metabolism, promoting the synthesis of volatile and phenolic compounds [31,32].

In addition to enhancing nutrient utilization, SWEs also increase tolerance to biotic and abiotic stress conditions. This creates a broader group of agricultural biostimulants that can increase yield and quality in both diverse agricultural systems and soil types [33,34]. Furthermore, biostimulants are considered as an affordable climate change mitigation tool for grape producers worldwide [35].

Most herbal biostimulants are prepared from brown algae, the types of which differ depending on their origin [36]. *M. integrifolia*, distributed along the eastern coasts of the North Pacific and the Southern Hemisphere, can reach lengths of up to 50 m. This algin mucus layer is an important source of alginate and is used primarily in the pharmaceutical, cosmetic and food industries [37,38]. *E. maxima* is a brown seaweed species that is dominant in coastal areas of South Africa, with numerous intact and pristine marine protected areas and areas considered to have high biodiversity. South Africa ranks third globally in terms of rich biodiversity, with 80% of its flora being endemic to the country [39]. Of all seaweed-based biostimulant sources, those produced by *A. nodosum* are probably the most extensively studied [40]. *A. nodosum* is a globally abundant SWE and is abundant in northeastern North America and northwestern Europe [41]. *A. nodosum*, a brown seaweed, is one of the biofertilizers extensively used in agriculture [29,36,42,43].

SWE studies generally consist of Ascophyllum nodosum applications. Studies using *E. maxima* and *M. integrifolia* are very few and their effects on yield and quality have not been fully determined. In addition, studies using these three extracts simultaneously are almost non-existent. Therefore, in this study, E. maxima, M. integrifolia and A. nodosum were sprayed separately on the leaves of AL grape variety. As a result of the study, we aimed to provide additive improvement in yield, quality and physiological properties of the AL grape variety of SWE. In addition, we tried to determine whether *E. maxima* and *M. integrifolia* extracts could be an alternative to *A. nodosum*.

2. Materials and Methods

The Alphonse Lavallée (AL) grape variety was used in the study. This variety is 13 years old and grafted onto 1103 Paulsen rootstock. The vineyard used is located at an elevation of 1125 m and is located at 38°02′15.0″ N 32°30′55.7″ E. The distance between vines was 2 m × 3 m. The experiment was designed according to a randomized block design with three replications, each replicate containing 15 vines. The application rows were randomly selected from the vineyard.

In the double-arm training system, 14 heads were left per vine. Short winter pruning was done with 2 buds per head. In addition, 28 buds were left per vine to establish a standard. Shoots growing outside the 28 buds were plucked and cluster thinning was also performed with 1 cluster per shoot. In the study, Ecklonia maxima (Em), Macrocystis integrifolia (Mi) and Ascophyllum nodosum (An), which are organic brown SWE, were applied to the vines four times via leaves before flowering, after flowering and during pea size and veraison periods (Table 1). Applications were planned to be 2.5 mL L^{-1} for each SWE based on reviewing the previous literature [44].

Table 1. Contents of SWE used in the study.

Extract	Organic Matter (%)	Alginic Acid (%)	pH	EC (dS/m)
***E. maxima* (Agrikelp 100 Ekstra)**	5	0.001	4.5–6.5	20
***M. integrifolia* (Alga cifo 3000)**	5	0.02	6–8	40
***A. nodosum* (Algastim)**	10	0.1	6.9–8.1	20

The grapes were harvested on August 28. Among the yield parameters, cluster weight and berry weight were weighed in grams using a precision scale. The length and width of the clusters were measured in cm using a tape measure, while the length and width of the berries were measured in mm using a caliper. In addition to these measurements, soluble solids content (SSC) was calculated as a percentage, and titratable acidity was measured in tartaric acid. pH values were also measured using a pH meter [45]. The effects of treatments on berry skin color (lightness, chroma and hue) were determined using a Minolta (CR 400) colorimeter. Berry detachment force and skin rupture force values were also calculated in Newtons using a manometer (DPS-11; Imada, Northbrook, IL, USA) [44].

2.1. Total Phenolic Content Analysis

Total phenolic content (TPC) of grape juice was calculated using the method developed by Doğan [46]. Firstly, 500 µL of pure foline (FCR (Folin-Ciocalteu solution)) was added to 100 µL of extract. Then, 1500 µL of 20% sodium carbonate solution was added. This prepared solution mixture was completed to 10 mL with pure water and kept in a nucleon (NCI-120) brand shaking incubator (Nükleon, Ankara, Türkiye) until it became homogeneous. After it became homogeneous, this mixture was passed through filter paper and kept in the dark for 2 h. At the end of 2 h, it was read with a Rittun (ultra-3000) brand spectrophotometer (Rittun, Suzhou, China) at a wavelength of 760 nm. Phenolic contents were calculated as µg gallic acid equivalent (µg GAE/100 mL).

2.2. Antioxidant Activity (%DPPH)

Next, 2,2-diphenyl-1-picrylhydrazyl (DPPH) analysis was used to test the antioxidant activity in fruit juice of the AL grape variety. Grape juice mixed with 1/3 methanol was filtered and stored in the dark. Then, the optical density of the mixture of fruit juice extract and control was determined at 517 nm wavelength. A 1/1 ratio of DPPH and methanol was used as the control. Based on the results, %DPPH was calculated using the following formula: %DPPH: [(absorbance of control − absorbance of sample)/absorbance of control] × 100 [46].

2.3. Physiological Analysis

Leaf temperature (LT, in °C), stomatal conductance (gs, in mol m^{-2} s^{-1}) and actual photosynthetic efficiency (PSII) were measured using a LI-COR brand fluorometer device

(LICOR Inc., Lincoln, NE, USA) during the veraison period [47]. PSII, gs and Tleaf measurements were taken on the 4th–6th leaves from the top of the shoot between 9:00 and 11:00 in cloudless conditions during veraison.

2.4. Statistical Analysis

The effects of SWE treatments on the AL grape variety were analyzed using the Duncan multiple comparison test in the SPSS 25 statistical program. The significance level for this test was set at $p < 0.05$ [48,49]. PCA (Principal Component Analysis) and HCA (Hierarchical Cluster Analysis) were also performed using the R software program (version 4.1.1) [50].

3. Results

3.1. Soluble Solids Content, Yield, pH and Titratable Acidity

The effects of different SWEs applied to the AL grape variety on SSC, yield, pH and titratable acidity properties were found to be statistically significant (Figure 1). The highest dry matter ratio was determined in the Em extract application, followed by Mi, An and control, respectively. All seaweed applications increased the SSC ratio compared to the control. When the effects of different SWEs on yield were examined, the highest yield was determined in the An application. As in the SSC amount, all applications increased yield compared to the control. As a result of SWE applications, the highest pH value was determined in the Em application. This application was followed by An, Mi and control, respectively. Titratable acidity values decreased with seaweed applications, unlike other applications. The highest titratable acidity value was determined in the control, followed by An, Mi and Em, respectively.

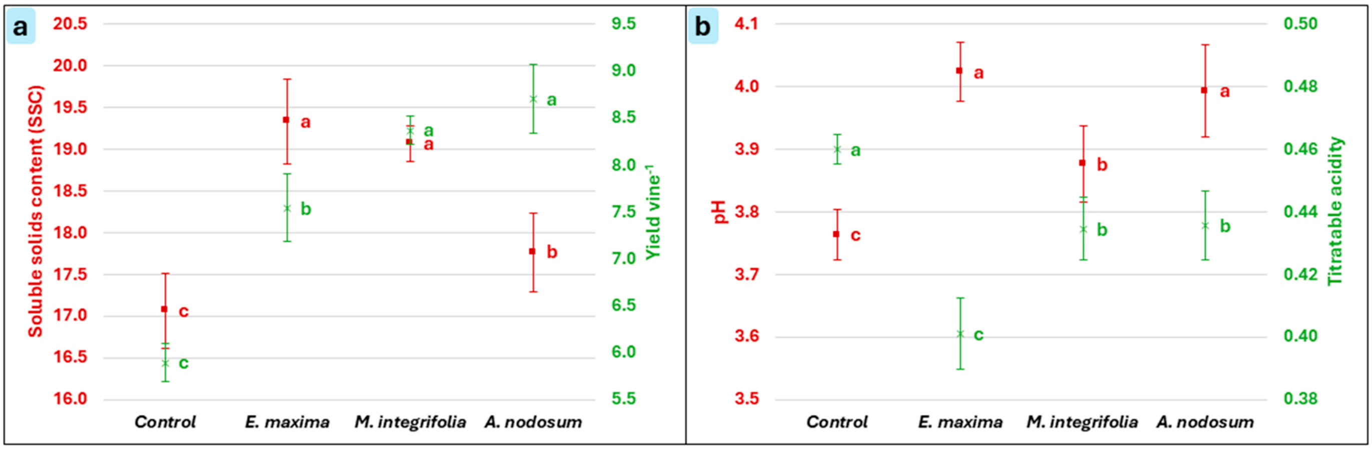

Figure 1. Effects of SWE applications on soluble solids content (**a**), yield (**a**), pH (**b**) and titratable acidity (**b**). Statistically significant ($p < 0.05$) differences are shown with different letters at marked points in the graph. Standard error values are given as double-sided. Means with different letters in the same row and colors were significantly different ($p < 0.05$).

3.2. Cluster Characteristics

The effects of seaweed treatments on cluster weight, cluster length and cluster width of the AL grape variety were statistically significant ($p < 0.05$) (Figure 2a). All SWEs increased cluster length. The highest cluster length was determined in the An extract treatment. This treatment was followed by Em, Mi and control, respectively. Similar results to cluster length were also determined in cluster width. The widest clusters were in the An extract treatment, while the lowest cluster width was in the control. All SWEs also had a positive effect on cluster weight. The heaviest clusters were determined in the An extract treatment. After An treatment, the heaviest clusters were determined in Mi, Em and control, respectively.

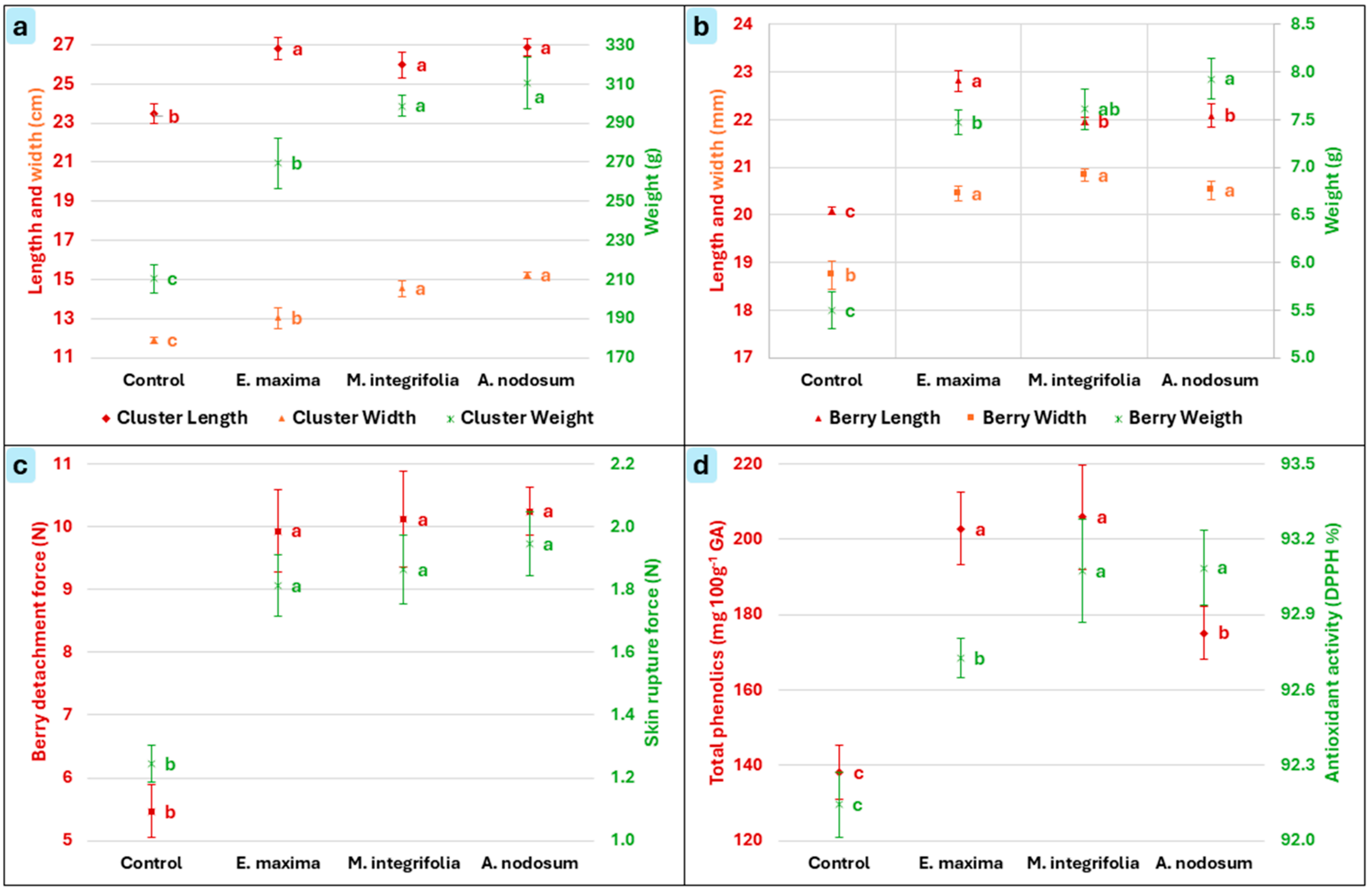

Figure 2. Effects of SWE applications on cluster weight, length and width (**a**), berry weight, length and width (**b**), berry detachment force (**c**), skin rupture force (**c**), total phenolics content (**d**) and antioxidant activity (**d**). Statistically significant ($p < 0.05$) differences are shown with different letters at marked points in the graph. Standard error values are given as two-sided.

3.3. Berry Characteristics

As a result of different SWE applications, statistically significant differences ($p < 0.05$) were determined in the berry length, width and weight of the AL grape variety (Figure 2b). As a result of the applications, the longest berries were in the Em application. Em application was followed by An, Mi and control, respectively. All SWEs increased the cluster length significantly. All SWEs increased berry width compared to the control. The widest berries were determined in the Mi application, while the narrowest berries were in the control. All SWEs also increased berry weight. While the control gave the lowest berry weight result, the heaviest berries were in the An extract application.

3.4. Berry Detachment Force and Skin Rupture Force

SWE applications resulted in significant differences ($p < 0.05$) in berry detachment force and skin rupture force values (Figure 2c). All SWEs applied increased both berry detachment and skin rupture force. The highest resistance in both parameters was determined in the An application, while the lowest resistance was in the control. It was concluded that SWE applications positively affected berry detachment and skin rupture force.

3.5. Total Phenolic Content (μg GAE/100 mL) and Antioxidant Activity (%DPPH)

SWE treatments resulted in statistically significant differences ($p < 0.05$) in total phenolic content and antioxidant activity values (Figure 2d). In our study, the highest phenolic content was determined in the Mi extract application, while the lowest phenolic content was in the control. All SWE applications increased the total phenolic content. Similarly, the highest value in antioxidant activity values was determined in the Mi application. As in the phenolic content, all applications increased the antioxidant activity.

3.6. Color (Lightness, Chroma and Hue) Values

The color scales of the SWE applications on the AL grape variety berries were examined. The effects of SWE on the lightness value were statistically insignificant ($p < 0.05$), while their effects on the chroma and hue values were significant (Table 2). When the chroma values were examined, the highest value was obtained from the control, while the lowest value was determined in the An application. All applications reduced the chroma values compared to the control. Similar data to the chroma value were determined in the hue values; the highest value was in the control, while the lowest value was determined in the An extract application. All applications reduced the hue value.

Table 2. Effect of SWE applications on lightness, chroma and hue values.

	Lightness	**Chroma**	**Hue**
Control	30.14 ± 0.30 a	1.99 ± 0.12 a	312.64 ± 4.63 a
E. maxima	29.00 ± 0.81 a	1.85 ± 0.10 a	285.76 ± 4.74 b
M. intergrifolia	30.40 ± 0.88 a	1.76 ± 0.08 ab	280.25 ± 6.34 b
A. nodosum	30.18 ± 0.99 a	1.56 ± 0.16 b	279.28 ± 7.63 b

Means with different letters in the same column were significantly different ($p < 0.05$).

3.7. Leaf Temperature (LT), Photosynthetic Efficiency (PSII) and Stomatal Conductance (gs)

As a result of our study, the effects of seaweed applications on leaf temperature, photosynthetic efficiency and stomatal conductance in the AL grape variety created statistically significant differences ($p < 0.05$) (Table 3). All applications decreased leaf temperature compared to the control. In photosynthetic efficiency values, the opposite results were obtained from leaf temperature. All SWE applications increased photosynthetic efficiency compared to the control. Stomatal conductance data were also like photosynthetic efficiency. The highest stomatal conductance was determined in the An extract application, while the lowest conductance was determined in the control. All SWE applications increased stomatal conductance. As a result, different SWE applications decreased leaf temperature and increased photosynthetic efficiency and stomatal conductance.

Table 3. Effect of SWE applications on leaf temperature (LT, in °C), photosynthetic efficiency (PSII) and stomatal conductance (gs, in mol m^{-2} s^{-1}).

	LT (°C)	**PSII**	**gs (mol m^{-2} s^{-1})**
Control	26.17 ± 0.30 a	0.32 ± 0.031 c	86.17 ± 7.01 b
E. maxima	24.90 ± 0.04 b	0.47 ± 0.035 b	117.33 ± 4.62 a
M. intergrifolia	25.24 ± 0.48 b	0.46 ± 0.033 b	131.33 ± 12.22 a
A. nodosum	24.85 ± 0.35 b	0.53 ± 0.022 a	132.67 ± 7.02 a

Means with different letters in the same column were significantly different ($p < 0.05$).

3.8. Hierarchical Clustering Analysis (HCA)

Hierarchical Clustering Analysis (HCA) analyzed the similarities and differences of different applications in terms of yield, quality and physiological parameters by grouping them. Red represents the highest value in the image, while blue represents the lowest value, and white represents the intermediate value. The scale values ranged from 1 (red) to −1 (blue). Furthermore, the applications formed five main groups (I, II, III, IV, and V) on the dendrogram (Figure 3). *M. intergrifolia* and *A. nodusum* applications were placed in group A, *E. maxima* application in group B, and the Control application in group C. SSC and Total phenolics were clustered in I cluster; Cluster width, Cluster weight, Antioxidant activity and Stomatal conductance were clustered in II cluster; Berry width, pH, Berry weight, Berry detachment force, Berry length, Skin rupture force, Cluster length, Photosynthetic efficiency were clustered in III cluster; Acidity and Lightness were clustered in IV cluster; and Chrome, Hue and Leaf temperature parameters were clustered in V. Acidity, Chroma, Hue and Leaf temperature parameters had the highest value in the control group. SSC, Berry width, pH and total phenolics parameters had the highest value in the *E. Maxima* application in group B. Cluster width parameter had the highest value in the *A. Nodusum* application in group A, while chroma parameter had the lowest value. Acidity and lightness parameters in group IV were determined to have the lowest value in *E. Maxima* application. This analysis evaluates the effects of different applications on yield, quality and physiological parameters in detail and contributes to the understanding of the effectiveness of the applications.

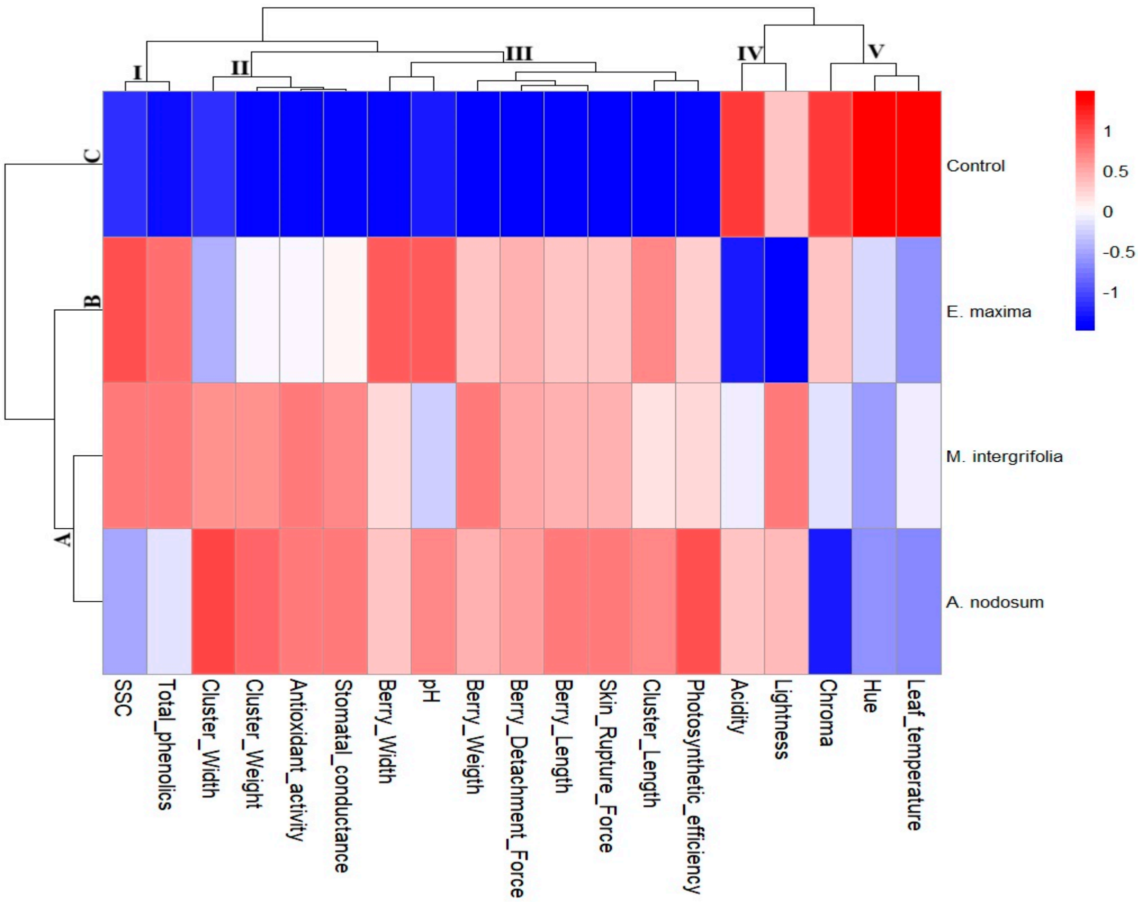

Figure 3. Heat map for the evaluated yield, quality and physiological parameters of the AL grape variety. A, B and C represent the groups of applied SWE. I, II, III, IV and V represent the groups of examined yield, quality and physiological parameters.

3.9. Principal Component Analysis (PCA)

PCA analysis was used to identify variation in the data (Figure 4). PC1 accounted for 71.7% of the variance, while PC2 accounted for 27.37%. In total, these two principal components accounted for 99.07% of the variance. The vectors of variables such as cluster width, cluster weight and photosynthetic efficiency are long and densely seen in the PC1 direction. Cluster width, cluster weight and berry weight parameters show positive correlation with each other. Acidity and SSC parameters are observed to show negative correlation with each other. *A. nodosum* and *M. intergrifera* applications are in the same direction, and it is thought that there is a positive correlation in cluster width, cluster weight, stomatal conductance, berry length, skin rupture force and antioxidant activity parameters. In the *E. maxima* application, berry width and berry detachment force parameters show a positive correlation, while the SSC parameter shows a negative correlation.

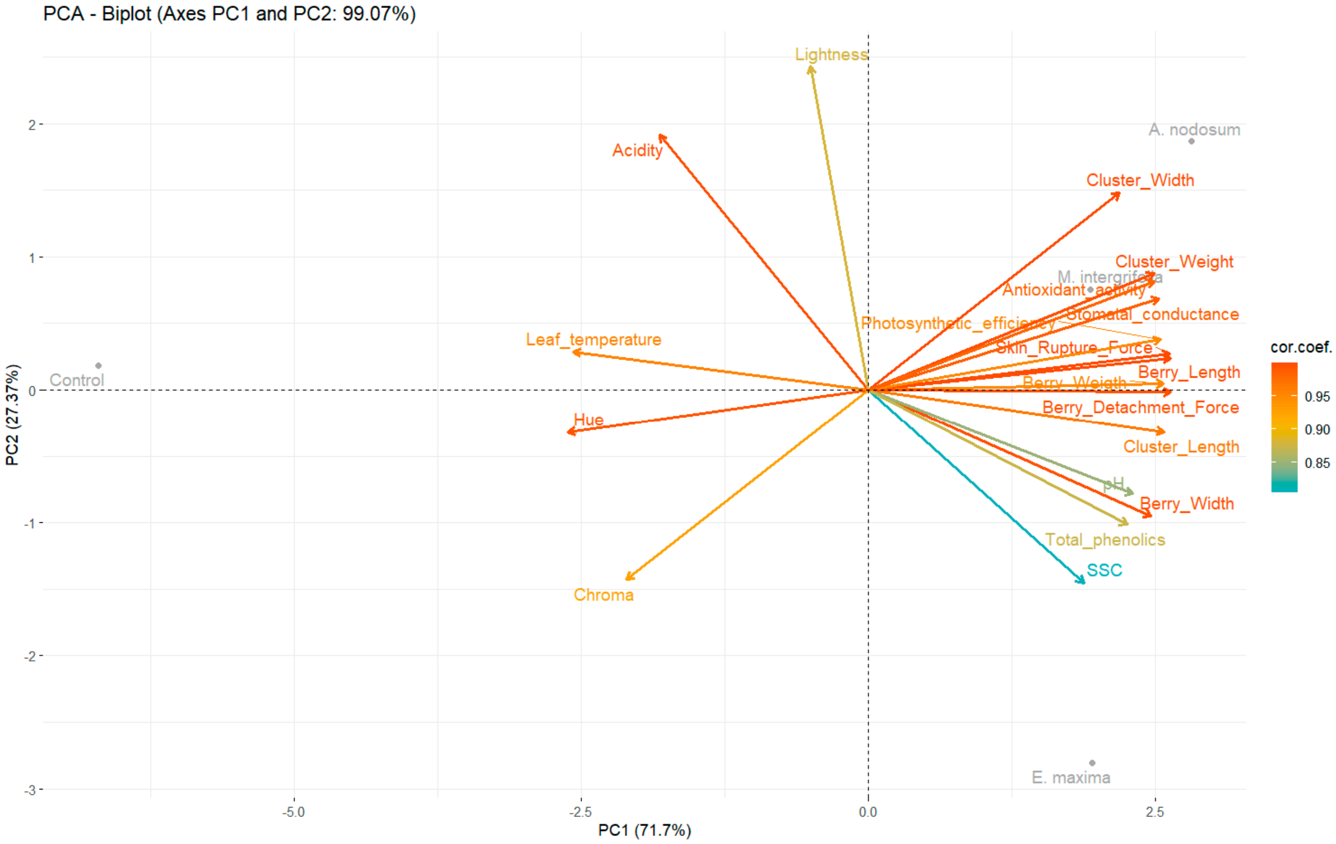

Figure 4. Loading plot of all detected variables included in the PCA (principal component analysis) for yield, quality and physiological parameters in the AL grape variety.

4. Discussion

SWEs applied to plants as fertilizers are mainly obtained from brown algae [36,51]. Although the specific biostimulatory components of SWEs and their mechanism of action are controversial [7], most scientific findings are thought to be due to growth hormones [45], quaternary ammonium compounds [5], microelements [52], carbohydrates [8] vitamins [53] and lipid-based molecules [36]. Therefore, although the composition and mechanisms of action of seaweed are not fully known, they probably work synergistically [6,54,55]. SWEs are known as biostimulants with the capacity to sustainably increase yield and quality by improving plant tolerance and nutrient utilization against abiotic and biotic stresses [33,34]. There are numerous reports on the positive effects of SWEs on yield and grape quality [11,15,56,57]. In our study, all the different SWE applications significantly increased yield, water-soluble dry matter and pH value compared to the control, while decreasing titratable acidity value. El-Sese et al. [16] reported that seaweed applications to the Bez-El-Anza, Thompson Seedless and Red Roomy varieties determined increases in yield and dry matter, while titratable acidity value decreased. In another study, Kara et al. [44] reported increases in water-soluble dry matter and pH values as a result of A nodosum application to the Gök Üzüm and Müşküle grape varieties. In their study, Abo-El-Ez et al. [3] determined an increase in yield with SWE application to the Flame Seedless grape variety. In a different study, it was reported that Ascophyllum nodosum application to the Chasselas Dore variety caused increases in yield [18]. Our study is similar to previous studies in terms of yield and quality parameters.

There are many studies showings that cluster characteristics are improved as a result of seaweed application [17,18,58]. The different SWEs we used increased the cluster weight, length and width of the AL grape variety. El-Sayed et al. [15] obtained similar results to our study by applying SWE to the Early Sweet grape variety. In another study, it was reported that E. maxima SWE was applied to the Thompson Seedless grape variety, increasing the cluster weight [59]. Petoumenou Patris [60] applied A. nodosum, E. maxima and Saccharomyces cerevisiae SWEs to the Crimson Seedless variety. As a result of the applications, all SWEs increased cluster weight and width while causing decreases in cluster length.

SWE applications are known to be a sustainable viticulture practice and improve berry quality [35]. As a result of our study, we found increases in berry weight, length and width compared to the control. SWE have improved berry characteristics in many fruit species including grape [58], apple [61], strawberry [62], kiwifruit [23] and fig [63], similar to our study. In addition, Irani et al. [64] reported that seaweed applications also improved berry characteristics under drought stress conditions. Contrary to ours and many other studies, in some studies SWEs did not affect berry properties [65] or caused decreases in berry weight, length and width compared to the control [66].

In table grape varieties, berry detachment and skin rupture force are important in terms of storage and road resistance. In our study, all SWEs increased berry detachment and skin rupture force compared to the control. Petoumenou Patris [60] applied E maxima, A nodosum and S cerevisiae SWEs to the Crimson Seedless grape variety and increased berry firmness. Again, in studies conducted on apple [67] and cucumber [68], berry firmness increased with SWE application.

Brown seaweeds are used to produce SWEs that are rich in secondary metabolites, including polyphenols and phlorotannins, which are synthesized under stress and help protect cells and cellular components [69]. It has been suggested that SWEs can modulate genetic signals related to secondary metabolite and phenolic biosynthesis [70]. Most reports on seaweed application in viticulture evaluate their effects on grapevine physiology and yield parameters in grapes [11]. However, in recent years, studies on the effects of seaweed applications in viticulture on the synthesis of phenolic compounds have increased [1,31,64,71,72]. In our study, we increased both total phenolic content and antioxidant activity with SWE application. In a study conducted on cherries, it was reported that total phenolic content and antioxidant activity increased similarly to our study [73]. In a study conducted on apples, SWE increased total phenolic content [61]. Similar results to our study were obtained with SWE applications to different grape varieties [64,72,74].

The commercial value of grapes is affected by their appearance, including color [75]. However, low light intensity, high rainfall, relatively low temperature during ripening [76] or high temperatures [77] of the growing region can negatively affect fruit ripening indices such as color development and biosynthesis of primary or secondary metabolites. Grape coloration is associated with anthocyanins, plant pigments responsible for most of the blue, purple and all red hues found in flowers, fruits, some leaves, stems and plant roots [78]. Anthocyanin accumulation in grapes begins during ripening and appears to be regulated, at least in part, by abscisic acid (ABA) [79,80]. In order to improve the internal and external appearance and quality of red colored table grapes experiencing these problems, applications such as abscisic acid [81], methyl jasmonate [82], brassinosteroids [83], 2,4-epibrassinolide [84], oligosaccharides [85], kaolin leaf fertilizer [86] and cyanocobalamin [87] are applied. SWE can be applied as an alternative to these applications to increase the transcription levels of several color-related genes such as PAL, DFR, CHI, F3H, GST, CHS and UFGT [71]. In our study, different SWEs were applied to the colored grape variety AL. Although the effect of seaweed applications on lightness in fruits was not significant, all SWEs decreased chroma and hue values compared to the control. Petoumenou Patris [60] reported that lightness and chroma values increased with *A. nodasum* application to the Crimson Seedless grape variety, while hue values decreased similarly to our study.

The decrease in stomatal conductance (gs) is a possible reduction in stomatal aperture and probably a mechanism to prevent excessive water loss under certain conditions [88]. SWEs, rich in plant hormones, vitamins and amino acids, are known to regulate stomatal conductance and increase water use efficiency [89]. SWEs can improve water regulation by facilitating stomatal opening, thereby increasing water flows and gas exchange [90]. In case of high doses of SWEs, there may be a decrease in net photosynthesis, stomatal conductance (gs) and transpiration rate [91], but it leads to an increase in the number of green leaves and plant height [92]. In case of low concentration application, it increases stomatal conductance (gs) and transpiration rate [93]. In our study, all applied SWEs increased stomatal conductance and photosynthetic efficiency compared to the control and decreased leaf temperature. In other studies, it was reported that seaweed applications had no definite effect on stomatal conductance but decreased stomatal conductance in cherries [73], while stomatal conductance increased in melon, cucumber and tomato [91]. In addition, Popescu Popescu [13] reported that *A. nodosum* application to the Feteasca Alba grape variety positively affected the vegetative growth of the vine stock expressed by leaf area.

5. Conclusions

SWE is one of the most important biostimulants used to increase yield and quality in grapes. Our study is the first study in which these three seaweed extracts were used simultaneously, and their effects on the yield, quality and physiological characteristics of the grapevine were examined simultaneously. As a result of the study, all applied SWEs increased yield per vine by 28% to 47%. SWEs improved cluster and berry properties. All SWEs positively affected the quality parameters total phenolic content and antioxidant activity. It also contributed to physiological properties of the vine such as photosynthetic activity and stomatal conductance. It is thought that *E. maxima* and *M. integrifolia* extracts can be an alternative to the intensively used *A. nodosum*. According to the data obtained from the study, it is thought that the application of SWEs to increase the quality and yield in table grape production can provide improvements in terms of sustainable agricultural practices.

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Conflicts of Interest: The authors declare no conflicts of interest. Additionally, we do not have any conflict of interest with the companies from which we supply products.

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