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ORIGINAL ARTICLE / ORIGINALBEITRAG

Effect of Foliar Spraying of *Ascophyllum nodosum* Extracts on Grape Quality of 'Tarsus Beyazı'

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Abstract
In recent years, studies have shown that seaweed applications could prevent post-harvest berry drops in grapes and allow improvements in cluster and berry quality characteristics. This study was conducted on 'Tarsus Beyazı' grape cultivar, which was grown on its own root and goblet-trained, in the Tarsus district of Mersin Province, Turkey. Although 'Tarsus Beyazı' is an early and well-known cultivar, it does not attract much attention due to its genetic susceptibility to berry drop; however, it is an important grape genetic source. In this study, foliar spraying of seaweed (*Ascophyllum nodosum* [L.] Le Jolis) was applied to the vines of 'Tarsus Beyazı'. After the application, the force to separate the berries from the stalk, berry weight (g), berry width (mm), berry length (mm), cluster width (cm), cluster length (cm), cluster weight (g), titratable acidity (%,TA), total soluble solids (%,TSS), and pH, as well as leaf and berry mineral content, were determined. Based on our results, it was determined that seaweed application had positive effects on the cluster characteristics rather than the berry properties of the 'Tarsus Beyazı'. The difference between application and control grapevines was found to be significant for cluster width and weight. As compared to the control grapevines (11.16 cm), clusters were approximately 9.86% wider in the application grapevines (12.26 cm), and the difference in cluster weight was about 37 g between the mean value of the application (297.40 g) and the control (260.23 g) grapevines. To sum up, the use of seaweeds in 'Tarsus Beyazı' has made it possible to improve grapevine productivity and enhance berry quality, mostly in terms of cluster characteristics.

Keywords Biostimulator · Quality · Table grape · *Vitis vinifera* L. · Wet drop

Introduction

Climate change has a significant effect on modern and traditional viticulture regions worldwide today (Kaya 2019, 2020). It has been reported that some table and profitable wine-producing regions are facing the consequences of extreme weather conditions and the unpredictability of warming trends (Jones et al. 2005; Jones and Webb 2010). Considering the viticulture potential worldwide, this scenario could lead to serious deterioration not only in grape yield, but also in berry and wine quality, and could damage grape production (Jones et al. 2005; Frioni et al. 2019). One of the most relevant components of grape quality for the production of table grapes is berry maturity and quality. Mostly during the summer period, the main vineyard regions of the world are facing a rise in temperature, which strongly affects grape quality and ripening dynamics (Jones and Davis 2000; Tomasi et al. 2011). It has been reported that seaweed-based biostimulants may increase grapevine produc-

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tivity by providing protection against abiotic and biotic factors (Salvi et al. 2019), which plays an important role in the development of environmentally friendly viticulture strategies by reducing the undesirable effects of climate change (Frioni et al. 2018). Most of the previous studies on the effects of foliar application of seaweeds in viticulture have reported their effects in reducing the adverse effects of abiotic and biotic stress, grapevine productivity, and physicochemical components of berry (Frioni et al. 2018; Taskos et al. 2019; Gutiérrez-Gamboa et al. 2020a, b).

For decades, biostimulants have been utilized as a part of the regular management of different table grape cultivars to enhance berry anthocyanin content, to improve copper and other micronutrients absorption, to regulate fruit set, berry growth, and development, or to overcome the effects of inadequate winter chilling (Turan and Köse 2004; Taskos et al. 2019). Biostimulants used in viticulture include various formulations based on different compounds, substances, and other types of products, such as micro- and macronutrients, microorganisms, enzymes, plant growth regulators, trace elements, microalgal extracts, as well as elicitors, which are applied to the leaves or soils to improve their physiological process, productivity, and quality (Gutiérrez-Gamboa et al. 2020a, b). Seaweed extracts, which exhibit growth-stimulating activities and are considered as plant biostimulants, are a category of naturally occurring substances (Goni et al. 2016). Brown seaweeds among them, *Ascophyllum nodosum* (L.) Le Jolis (AN) extracts are widely used in viticulture for their improving effects on crop tolerance to abiotic stresses and growth promotion (Frioni et al. 2019). Previous reports recognize that most of the effects of other biostimulants and seaweed extracts on grapevines contribute not only to the simple contribution of nutrients and chemical compounds but also the modulation of the specific metabolisms of target plants, as previously hypothesized (Khan et al. 2009; Goni et al. 2016). The effects of AN extracts on grapevines have been identified in several published studies, and these were mainly on table grapes, which have evidence of positive effects on productivity (Norrie et al. 2002; Norrie and Keathley 2006). Recently, studies have been increasing due to the effects of seaweed applications on vine physiology and berry quality for different grape varieties in viticulture (Frioni et al. 2018, 2019; Shukla et al. 2019; Taskos et al. 2019; Salvi et al. 2019). However, available information about the effects of the biostimulation through seaweeds to the 'Tarsus Beyazı' grape variety on cluster and berry properties is actually not known and only hypothesized. Therefore, this study aimed to provide an evaluation of the effects of SeaMax, an experimental AN extract, on some cluster and berry characteristics in a 'Tarsus Beyazı' vineyard.

Materials and Methods

Experimental Design and Vineyard Field Conditions

The field study was conducted in an experimental vineyard located in Mersin, Tarsus-Cinköy, Turkey (36°59′.45″ north, latitude; 34°45′37″ west, longitude; 200 m above sea level), during the 2021 season. The vineyard was planted with 'Tarsus Beyazı' (*Vitis vinifera* L.) and grown on their own roots. Row and vine spacing were 3.5 m and 1.75 m, respectively, in an east to west row orientation, resulting in a density of 1663 vines per ha. The vines were spur-pruned in seven to 10 spurs of two to three nodes each and trained to the goblet training system with a trunk height of 40–50 cm. Early spring fertilization for the vineyard (E-L 3, based on the modified Eichhorn-Lorenz system) of 12-12-17 + 2 MgO (N, P, K, and Mg) was uniformly distributed on the soil surface (50 kg N/ha, 110 g per vine). Cultural practices in the vineyard were the same for all treatments and the vineyard soil was managed under conventional tillage management. The irrigation not was applied in the vineyard. When the shoot tips reached ~30 cm in length, shoot pruning was conducted, and standard pest management practices were applied, considering local standards. The climate in the vineyard area is typically Mediterranean, characterized by warm to hot summers and rainy and wet winters. An automatic meteorology station was used to obtain the climate data provided by the Mersin Meteorology General Directorate. The accumulated rainfed and the reference evapotranspiration (ETo) were 65 mm and 37 mm, respectively, during the 2021 growing season (March to September). During this season, average maximum temperature, average temperature, and average minimum temperatures were 34, 30, and 19 °C, respectively. Soil horizons of vineyard show a clay loam texture with the following average characteristics: clay 6.40%; silt 41%; sand 12.6%; organic matter 0.93%; pH (H_2O) 7.59.

Treatments

A commercial fertilizer (Crop Plus, Adama, İzmir, Turkey) based on an AN seaweed extract was applied at three different dosages in an aqueous solution: a low dose at 0.40% (v v^{-1}), a second dose 0.50% (v v^{-1}), and a high dose at 0.60% (v v^{-1}), as well as a control. The solution for treatments was prepared using Tween 20 (Sigma-Aldrich, İzmir, Turkey) as a wetting agent, dissolved in water at a dosage of 1 mL L^{-1}. Control vines were sprayed with distilled water with Tween 20 alone. One treatment of control and the three dosages of the seaweed extract in six different stages of development were conducted for 'Tarsus Beyazı' vines. The first treatment (0.40%—v v^{-1}) was performed as 3rd–4th leaves unfolded (at BBCH 13), and the second treatment

Fig. 1 Seaweed application times according to the BBCH scale: **a** 3rd–4th leaves unfolded (at BBCH 13), **b** first flowerhoods detached from the receptacle stage (at BBCH 60), **c** fruit set (at BBCH 71), **d** berries pea-sized, bunches hang (at BBCH 75), **e** beginning of ripening (at BBCH 81), **f** berries ripe for harvest stages (at BBCH 89)

(0.50%—v v^{-1}) was sprayed in the first flower hoods detached from the receptacle stage (at BBCH 60). The third (0.50%—v v^{-1}), fourth (0.50%—v v^{-1}), fifth (0.60%—v v^{-1}), and sixth treatments (0.60%—v v^{-1}) were applied in fruit set (at BBCH 71), berries pea-sized, bunches hang (at BBCH 75), beginning of ripening (at BBCH 81), berries ripe for harvest stages (at BBCH 89), respectively (Fig. 1). Considering 10 'Tarsus Beyazı' vines per replicate, the foliar applications were conducted in triplicate and were arranged in a complete randomized block design concerning the plot.

Classical Parameters for 'Tarsus Beyazı' Grape

Three shoots per vine before treatment (at E-L stage 19–20) were randomly selected and labeled. Berry maturity was measured weekly from véraison (E-L stage 35) until harvest for treatment and control (Coombe 1995). At harvest, clusters were collected from the labeled shoots per vine for treatment and control. Immediately after sampling, the clusters were placed in plastic bags and brought to the laboratory. Probable total soluble solids (%, OIV 505), berry length (mm; OIV 220), berry width (mm; OIV 221), berry weight (g; OIV 503), cluster length (cm; OIV 202), cluster width (cm; OIV 203), pH and total acidity (%, OIV 506) values in grapes were analyzed according to the methodologies outlined by the International Organisation of Vine and Wine (OIV) (2009). The results of these classical parameters for grapes are stated as the average of three analyses ($n=3$) because treatments were performed in triplicate. The force to separate the berries from the pedicel was determined using the Force Gauge model: FS-5020 device (South Boston, United States).

Analysis of Minerals in Leaf Stalk and Berries

Regarding the leaf stalk mineral analysis, the leaves (50 leaves) on the nodes opposite the first clusters on 1-year shoots were collected together with the leaf stalks at the véraison stage (E-L stage 35). For mineral analysis

Table 1 Effects of the treatment on cluster and berry features and the force to separate the berries from the stalk

Treatment	Berry length (mm)	Berry width (mm)	Berry weight (g)	Cluster length (cm)	Cluster width (cm)	Cluster weight (g)	TSS (%)	TA (%)	pH	FSBS (g)
Control	16.27 ± 0.16	15.70 ± 0.21	2.69 ± 0.20	14.16 ± 0.36	11.16 ± 0.26	260.23 ± 12.44	21.01 ± 0.10	0.72 ± 0.01	3.80 ± 0.02	172.83 ± 3.93
Seaweed	15.38 ± 0.17	15.33 ± 0.26	2.35 ± 0.11	14.80 ± 0.26	12.26 ± 0.27	297.40 ± 13.61	20.06 ± 0.31	0.87 ± 0.01	3.54 ± 0.02	160.80 ± 3.19
P value	0.001	0.271	0.213	0.164	0.006	0.049	0.012	0.001	0.001	0.023

All values in the table represent means ± standard error ($n = 30$)

TSS total soluble solids, *TA* total acidity, *FSBS* the force to separate the berries from the stalk

in berries, 50 berries were randomly selected from clusters of both treatment and control vines after harvest. Samples were oven-dried at 70 °C for 2 days, and then they were ground to pass a 1 mm screen to have a homogenous aliquot for determination of macro- and micro-mineral contents (Kacar and Inal 2008). Minerals of the leaf stalk and berries were determined after wet digesting with an HNO_3-H_2O_2 acid mixture (2:3 v/v) in a microwave oven (speed wave MWS-2 Berghof products + Instruments Harresstr. 1. 72800 Enien, Germany) following a three-step process (first step: 75%, 145 °C, radio-frequency power (RF), for 5 min; second step: 90% RF, 180 °C, for 10 min; and third step: 40% RF, 100 °C, for 10 min) in microwave (Mertens 2005a). The amounts of K, P, Mg, Cu, Zn, Ca, Mn, and Fe minerals of the samples were detected using an Inductively Coupled Plasma spectrophotometer (Perkin-Elmer, Optima 2100 DV, ICP/OES, Shelton, CT 06.484–4794, USA) (Mertens 2005b), and total N was determined according to the micro-Kjeldahl method (Kacar and Inal 2008).

Statistical Analysis

Descriptive statistics for studied variables (characteristics) were presented as mean and standard error of mean. Student t test was used to compare Control and Treatment group means for the studied variables. Statistical significance level was considered as 5% and SPSS (ver: 13) statistical program was used for all statistical computations.

Results and Discussion

Compared to control grapevines, no differences were determined owing to the application of seaweed extract on berry width and weight, instead, berry length was significantly affected by the application. Berry length of grapevines treated with seaweed was higher (~1 mm) due to a reduction not only in the width of berries (0.37 mm) but also in the weight of berries per vine (0.34) (Table 1). The seaweed extract reduced the incidence of berry width and weight, in comparison with the control. Berry width and weight were not affected by the application of the seaweed extract, in accordance with previous findings (Gutiérrez-Gamboa et al. 2019a, b). In previous studies, on the other hand, berry width and length of 'Tarsus Beyazı' were reported to be 18.03 mm and 18.67 mm, respectively, which was higher than the results obtained in our study (İnal 2000; Kiraz 2014). According to the OIV descriptors (e.g., OIV 220, 221, and 503) the berry width, length, and weight values for 'Tarsus Beyazı' in our findings were classified between "short to medium," "narrow to medium," and "small," respectively (OIV 2009). Previous studies have reported the berry weight of 'Tarsus Beyazı' to be 3.50 g (İnal 2000) and 4.28 g (Kiraz 2014). Our results for the berry weight in both control and application showed lower values than the previous study results. These differences are probably due to different ecological conditions, irrigation, or other practices. It has been reported that water deficit stress anticipated the shoot growth slackening of vines, as well as an enhanced berry anthocyanin content and a limited berry weight (van Leeuwen et al. 2009), which confirms our hypothesis.

The width and weight of the cluster were affected by seaweed treatment, although the cluster length did not affect its value. In addition, the cluster length, width, and weight were lower in control (0.64, 1.16, and 37.17 cm than the application of the seaweed extract, respectively); meanwhile, those values increased with the application of the seaweed extract (Table 1). Considering the OIV definition for our results, the cluster length (OIV 202), width (OIV 203), and weight (OIV 502) were between "short to medium," "medium," and "low," respectively (OIV 2009). It was reported that seaweed application in the 'Sultani Çekirdeksiz' grape cultivar increased cluster weight and length, which is consistent with our findings (Norrie et al. 2002). Contrary to our findings, it was reported that foliar application of amino acids and seaweed extract did not cause a significant change in cluster weight and cluster length in the 'Perlette' grape variety compared to the control (Khan et al. 2009). On the other hand, the TSS, TA, and pH content of the berry were affected by extract application. The extract application increased the TA content of the berry, whereas it was caused by a 0.95% and 0.26 decrease in the TSS and pH values of the berry in comparison to the control (Table 1). Based on the OIV's descriptor code 505 and 506, the corresponding percentages for high and medium, low and medium TSS and TA in must were 21.01, 20.06%, and 0.72, 0.87%, respectively (OIV 2009). It has been reported that the amino acid and seaweed extract applied to the leaves at different growth stages of the 'Perlette' grape cultivar increased the SÇKM%, TA%, and pH. These findings were similar to the TA content of our results but were not compatible with TSS and pH values (Khan et al. 2009). Gutiérrez-Gamboa et al. (2019a) reported that a seaweed extract (*A. nodosum*), applied to *V. vinifera* L. cv. 'Tempranillo Blanco' did not affect TSS, TA, and pH in grapes, which is inconsistent with our findings. The reason for this difference in classical measurement parameters between our results and literature may be due to climate and cultivar differences. It has, indeed, been reported that seaweed application to grapevines scarcely affects classical parameters, whereas climatic conditions and grape cultivar in a region widely affect these parameters of berries at harvest (Gutiérrez-Gamboa et al. 2019a). Regarding the force to separate the berries from the stalk (FSBS), seaweed extract had a significant effect on the FSBS values of the berries when compared to the

Table 2 Effects of the treatment on berry and leaf stalk mineral concentrations

Berry samples									
Treatment	*% N*	*% P*	*% K*	*% Ca*	*% Mg*	*Fe (µg g⁻¹)*	*Zn (µg g⁻¹)*	*Mn (µg g⁻¹)*	*Cu (µg g⁻¹)*
Control	0.04 ± 0.01	0.06 ± 0.01	0.71 ± 0.05	0.30 ± 0.05	0.04 ± 0.01	39.11 ± 0.50	–	12.10 ± 0.50	–
Seaweed	0.05 ± 0.01	0.08 ± 0.01	0.78 ± 0.05	0.26 ± 0.05	0.03 ± 0.01	42.20 ± 0.50	–	10.82 ± 0.50	–
P value	0.698	0.072	0.427	0.629	0.293	0.049	–	0.212	–
Leaf stalk samples									
Treatment	*% N*	*% P*	*% K*	*% Ca*	*% Mg*	*Fe (µg g⁻¹)*	*Zn (µg g⁻¹)*	*Mn (µg g⁻¹)*	*Cu (µg g⁻¹)*
Control	1.95 ± 0.20	0.14 ± 0.13	0.92 ± 0.08	3.41 ± 0.41	0.52 ± 0.06	166.11 ± 15.63	113.15 ± 11.37	152.90 ± 13.30	25.69 ± 3.6
Seaweed	1.85 ± 0.9	*0.68 ± 0.071*	1.30 ± 0.16	3.07 ± 0.47	0.53 ± 0.04	171.15 ± 18.12	298.25 ± 30.8	95.42 ± 10.54	*33.89 ± 3.43*
P value	0.592	0.031	0.042	0.618	0.712	0.638	0.021	0.013	0.056

All values in the table represent means ± standard error ($n = 30$)

control. FSBS value in the control was 7.47% higher than in the seaweed extract application (Table 1). 'Tarsus Beyazı' is a sensitive grape variety, and seaweed application partially reduced the FSBS of berries. On the other hand, previous studies reported that the FSBS value of berries of 'Tarsus Beyazı' grown in Adana and Mersin regions was 225.4 and 240.7 g, respectively, whereby our results were considerably lower than these values. Consistent with our findings, it was also determined that amino acid and seaweed extract in the 'Perlette' grape variety reduced berry spilling by 10.6% compared to control vines (Kiraz 2014).

Taking into account the mineral content of the berries, N, P, K, Ca, Mg, and Fe values of control and seaweed application were 0.04–0.05%, 0.06–0.08%, 0.71–0.78%, 0.30–0.26%, 0.04–0.03%, 39.11–42.20 µg/g, and 12.10–10.82 µg/g, respectively. There was a significant difference between control and application in terms of other minerals except for Fe mineral (Table 2). In addition, Zn and Cu minerals could not be determined in the berries in the study. Although foliar applications of seaweed extract have been reported to have various effects on different grape varieties (Abada 2002; Norrie et al. 2002; Abd El-Moniem and Abd-Allah 2008; Khan et al. 2009), studies on the mineral content of berries are limited. This situation restricts the comparison of the results with the literature. However, it is known that seaweed contains various minerals (Fe, Cu, Zn, Co, Mo, Mn, Ni), vitamins, amino acids, and plant growth hormones (IAA, IBA, cytokinins) that cause many beneficial effects on plant growth (Metting et al. 1990; Spinelli et al. 2009; Abdel-Mawgoud et al. 2010). Although seaweed did not have a significant effect on the mineral content of the berries, it partially increases the minerals N, P, K, and Fe compared to the control. On the other hand, seaweed had significant positive effects on the leaf stalk P, K, Zn, and Cu element contents of the vines as compared with control vines. Leaf stalk N, Ca, Fe, and Mg concentrations did not significantly differ between the treatment and control, matching the values supported as adequate in previous studies (Winkler et al. 1974; Poni et al. 2003; Arrobas et al. 2014). It was also reported that the applications of amino acid + seaweed extract (in Perlette) and AN extract did not have a significant effect on the mineral content of the vine leaves ('Sultani Çekirdeksiz') (Norrie et al. 2002; Khan et al. 2009), which is consistent with our findings. Besides, it is known that the most important environmental factors that directly affect the nutrient uptake of leaves are temperature and relative humidity (Fernández et al. 2009). It has been reported that high temperatures may increases solute diffusion of active ingredients and excipients, but decrease solution viscosity, surface tension, and liquefaction point (Ramsey et al. 2005; Fernández et al. 2009). It has been stated that relative humidity may increase uptake efficiency by increasing cuticle hydration and delaying droplet drying (Ramsey et al. 2005). For these reasons, it has been reported that humidifiers can be used successfully in hot and dry areas to increase the uptake efficiency of foliar applications (Ramsey et al. 2005). Considering that Mersin has a warm ecology, significant differences may not have occurred in some minerals since no humidifier was used during the foliar algae application in the study. In general, when the element concentrations of the leaves obtained for our findings are compared with the previously recommended levels (Winkler et al. 1974), it may be stated that most of the macro- and microelements determined in the leaves are at normal levels. However, the mechanism of action of seaweed after foliar application to grapevines is still not fully understood (Gutiérrez-Gamboa and Moreno-Simunovic 2021). Besides, Zn concentration was found to be quite high in the leaves of seaweed-treated vines compared to the control. Seaweed application helped the grapevines to increase the Zn level in the leaf. This increase can be considered notable as Zn is important in the synthesis of the growth regulator IAA, a component involved in many enzymes responsible for pollen and berry formation (Marschner 1995).

Conclusion

Our data indicate that seaweed treatment did not have a positive effect on the physical and chemical properties of the berries; however, it had a positive effect on the cluster properties. The difference between application and control vines was found to be significant for cluster width and weight. It is crucial that future research focuses on determining the potential effect of seaweed on various grape varieties cultivated in different regions, and this is a hypothesis that needs to be explored.

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Author Contribution NK and OK designed the study. HT, MEK, GT, FT, and NO were responsible for the performance of the research and collection. OK and NK interpreted the results and data analysis. OK wrote the manuscript. MEK, GT, FT, and NO determined analysis. All authors have read and agreed to the published version of the manuscript.

Conflict of interest H. Topuz, N. Keskin, M.E. Kiraz, G. Tarım, F. Topuz, N. Ozel, and O. Kaya declare that they have no competing interests.

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