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The Effects od Foliar Application of Humic Substances on Yield, Quality and Mineral Content of Leaves in the Seedless Sultani Grape Variety (Vitis vinifera L.)

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Abstract

Viticulture, which holds a significant place in both the world and our country's agriculture, plays a major role in improving productivity and quality, which also carries great economic value. Fertilization and ensuring that vineyards are nourished to a level that will yield maximum produce are among the foremost practices in this regard. Chemical fertilizers are used intensively in traditional production management, both on the soil and on the leaves. These practices cause pollution of the soil, air, and water resources. This study aims to investigate the effect of foliar application of a humic substance obtained from natural resources. The research was conducted in three replications according to a randomized block design. The humic substance was applied at doses of 0, 0.1%, 0.2%, and 0.3%. According to the results obtained, the effect of foliar application of the humic substance on fresh fruit yield, total soluble solids (TSS), maturity index, and leaf content of K, Ca, Mg, Fe, Zn, Mn, Cu, and B, except for N and P, was found to be statistically significant. By evaluating the effects of all applications, it was concluded that the 0.2% dose yielded the best results, and could be recommended under the conditions of the Aegean Region, Manisa Province, and Alaşehir District.

Keywords: Foliar application, Grapevine, Humic substance, Mineral substances, Quality, *Vitis vinifera* L.

1. Introduction

Grape is an agricultural product which can be utilized in many different ways and is of great importance in terms of human nutrition and health. The multitude of ways in which grapes can be utilized ensures that they are among the products with high economic returns. Thanks to the suitable climate and soil characteristics and high economic returns, viticulture is an agricultural activity carried out in almost every region of Turkey. The Aegean region, particularly Manisa province and the Alaşehir district, holds a leading position in the production of seedless table and raisin grapes. In Turkey, the total vineyard area is 3,722,850 da, with a total production of 3,468,000 tons. The vineyard area is 1,314,418 da in the Aegean region, 871,088 da in Manisa province, and 200,910 da in the Alaşehir district, with production amounts of 1,541,516, 1,139,027, and 261,011 tons, respectively (TUİK, 2025).

The primary goal in grape production is to achieve high yields and quality products. To this end, intensive agricultural activities are carried out, causing damage to the soil and the environment. Due to the deterioration of soil properties, vines are unable to obtain sufficient water, oxygen, and nutrients from the soil, which reduces yield and quality, therefore necessitating the implementation of different plant nutrition strategies. One of these new environmentally friendly feeding management practices is the use of humic substances in the soil and leaves to ensure sustainability in production.

Humic substances (HS) are important components of aquatic and terrestrial ecosystems and constitute a significant reservoir of resistant organic carbon and nitrogen (Roulia, 2024). Humic acids are heterogeneous natural resources with colors ranging from yellow to black, resistant to degradation, and having high molecular weight (Akıncı, 2011). Humic substances have a beneficial effect on soil structure and properties. They improve the buffering, water retention, and cation exchange capacities of soils. Thanks to their active surface areas, they increase their usefulness by binding nutrients through complexation and gelation reactions. At the same time, they reduce the harm of organic pollutants and toxic metals. They facilitate the dissolution and transport of nutrients. They provide benefits as stress relievers by regulating the physiological and metabolic events in plants (Roulia, 2024). Humic acids possess hormone-like activity and stimulate plant growth (Ferrara and Brunetti, 2010). The application of humic substances promotes growth and development in plants through bioactive effects, provides protection against biotic and abiotic stresses, and increases agricultural productivity. In recent years, studies and applications related to the foliar application of humic substances have expanded to many plant groups. Foliar application of humic substances stimulates parameters such as biomass and plant height. At the same time, it increases photosynthetic pigment levels and agricultural productivity. Foliar application supports protection against stress events by increasing the activity of enzymes such as peroxidase, catalase, and phenylalanine ammonia lyase. Foliar application of humic substances also improves fruit quality parameters such as total sugar content, oil, protein, and fiber content (Vioratti Telles de Moura et al., 2023). Humic substances are used by producers to reduce the use of chemical fertilizers and to make more efficient use of nutrients for more sustainable agricultural production (Monda et al., 2021).

Studies have been conducted to determine the effect of foliar application of humic substances on yield, quality, and nutrient content in vineyards and certain other crops, and generally positive results have been obtained. Ferrara and Brunetti (2010) reported that applying humic substances during the full flowering period of the Italia grape variety could lead to a significant increase in qualitative and quantitative parameters in table grapes and the application of humic substances could find a positive application area in organic and sustainable viticulture. In the same grape variety, it was found that two different humic acids extracted from compost and soil could have some positive effects on the overall quality of table grapes (Ferrara and Brunetti, 2008). The effect of foliar application of humic acid and acetic acid on grapevines was studied, and it was noted that both yield and mineral nutrient content were positively affected (Asgharzade and Babaeian, 2012). In another study conducted on grapevines, it was found that foliar application of humic acid could improve the growth, yield, and berry quality characteristics of the vine (Popescu and Popescu, 2018). Studies conducted on cotton, tomatoes, wheat, and strawberries also generally yielded positive results (Tarhan and Karademir, 2019; Öktüren Asri et al., 2016; Aşık et al., 2012; Zydlik and Zydlik, 2023).

The foliar application of humic substances positively affects growth and development parameters, physiological characteristics, and various stress responses in many plant species. However, the effects of humic substances may vary depending on factors such as source, dosage, application timing and frequency, differences in environmental conditions, and plant characteristics. In some studies, soil applications have been found to be more effective, while in others, foliar applications have shown better results. There are studies showing that using both methods together can be more efficient in a complementary manner. Ultimately, foliar application of humic substances can be used as an alternative method for more sustainable production systems in crops with high economic returns (Vioratti Telles de Moura et al., 2023).

In this study, the effects of foliar application of humic substances on fresh fruit yield, certain fresh grape quality parameters, and nutrient content of leaves (N, P, K, Ca, Mg, Fe, Zn, Mn, Cu and B) were investigated under the conditions of Alaşehir district in the Aegean region, where Sultani seedless grape cultivation is intensively practiced. The results obtained may not only guide future studies in the region but also be practically beneficial to producers

2. Materials and Methods

2.1. Experimental materials and study area

The research was conducted in the Yeşilyurt neighborhood of Alaşehir district, Manisa province, which is the highest grape-producing region in Turkey, on the Sultani seedless (*Vitis vinifera* L.) grape variety in a producer's vineyard. The Mediterranean climate prevails in the study area, with an average rainfall of 562 mm and an average temperature of 15.8 °C (Anonymous, 2025). Yeşilyurt neighborhood, where the study was conducted, is located at 28.663° longitude and 38.373° latitude. Its elevation above sea level is 179 meters. Sultani seedless grape is a variety that ripens in mid-season with good yield and development. The cluster is conical in shape, of normal density and medium size (300-400g); the berries are oval-shaped, small (1.2-1.8g), green-yellow in color with a thin skin. Its yield as dried grapes varies between 500-1000 kg/da. Although it is a variety for drying, it is also used as a table grape with some cultural practices (Anonymous, 1990; Yağmur and Ateş, 2013). Observations in Manisa indicate that budbreak occurs in late March-early April, flowering in late May, berry drop in mid-July, and ripening in late August (Yıldırım et al., 2005).

The product named TKİ-Hümas, produced by the Turkish Coal Enterprises Institution, was used as a humic substance source in the study. TKİ-Hümas is a liquid natural organic soil conditioner produced from leonardite and low-quality lignite. Total organic matter: 5%, humic acid + fulvic acid: 12%, water-soluble potassium oxide (K_2O): 3%, pH: 11-13 (Gezgin, 2013).

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The experimental vineyard has a V-shaped training system, with planting distances of 2.90 x 1.80 m. The vines in the vineyard are 25 years old. Generally, raisin production is carried out. In the study, leaf samples taken during the veraison period and grape samples taken during the harvest period formed the material for the research. Soil samples were taken from depths of 0–30 and 30–60 cm before the vines budded, and some physical and chemical properties of the experimental vineyard soil were determined, and the results are shown in Table 1.

Table 1. Some physical and chemical properties of the experimental soil

Soil Characteristics	0-30 cm	Comment	30-60cm	Comment	Literature
pH	5.49	Strong acid	6.20	slightly acid	Kellogg, (1952)
Total Salt (%)	0.11	Salt-free	0.12	Salt-free	Richards,(1954)
$CaCO_3$ (%)	0.88	Very little lime	0.96	Very little lime	Ülgen and Yurtsever, (1995)
Texture, % Saturation	38.72	Loam	40.7	Loam	Ülgen and Yurtsever, (1995)
Organic Matter (%)	0.09	Very little	0.26	Very little	Ülgen and Yurtsever, (1995)
Total N (%)	0.03	Very little	0.04	Very little	Sillanpää, (1990)
Available -P (mg kg^{-1})	35.3	Excessive	26.8	Excessive	Sillanpää, (1990)
Available -K (mg kg^{-1})	237	Enough	193	Enough	Sillanpää, (1990)
Available -Ca (mg kg^{-1})	1311	Enough	5542	Excessive	Sillanpää, (1990)
Available -Mg (mg kg^{-1})	272	Enough	542.6	Excessive	Sillanpää, (1990)
Available -Fe (mg kg^{-1})	11.28	Excessive	6.81	Excessive	Lindsay and Norwell,(1978)
Available -Zn (mg kg^{-1})	2.04	Enough	0.63	little	Sillanpää, (1990)
Available -Mn(mg kg^{-1})	15.89	Enough	3.97	Very little	Sillanpää, (1990)
Available Cu (mg kg^{-1})	8.21	Enough	7.04	Enough	Follet, (1969)

2.1.2. Applications and experimental design

The study was conducted according to a randomized block design in three replications, and the study addressed four application subjects (control 0%, 0.1%, 0.2%, and 0.3% humic substance). In the application, the humic substance was applied separately to each vine by diluting it in equal proportions according to the dose. The application was carried out once during the flowering period in April. The experiment was conducted on a total of 36 vines, with 3 vines per plot. Other cultural practices necessary for the vineyard were applied equally across the experimental plots according to the producer's conditions.

2.1.3. Soil Analysis

In the analysis of the soil samples, the following methods given by the listed literature were used: Texture, water saturation percentage (Richards, 1954), pH and total salt percentage (Richards, 1954), lime (Çağlar, 1949), organic matter (Jackson, 1962), total nitrogen (Bremmer, 1965), available phosphorus (Olsen et al., 1945), xchangeable potassium, calcium and magnesium (Carlson, 1980) and available iron, zinc, manganese, and copper (Lindsay and Norwel, 1978).

2.1.4. Leaf Analyses

Leaf samples were collected during the veraison period to determine the effect of humic substance application on the macro and micro nutrient contents of vine leaves. Leaf samples were collected as whole leaves opposite the first clusters on the lower part of the grapevine shoots (Levy, 1968). The samples brought to the laboratory were cleaned with normal and distilled water, then dried at 65-70°C, ground and prepared for analysis (Kacar and İnal, 2008). In the leaf samples, N was determined using the modified Kjeldahl method (Bremner, 1965), while P, K, Ca, Mg, Na, Fe, Zn, Mn, Cu, and B were determined using the ICP-OES method on the extract obtained by wet ashing (HNO_3 + $HClO_4$; 4:1) (Kacar and İnal, 2008).

2.1.5. Fruit Analyses

The experimental vineyard was harvested at the end of August. Three vines from each plot were harvested and weighed, and the average fresh fruit yield per vine was calculated. Ten clusters were randomly sampled from each harvested plot. The fresh grape samples were brought to the laboratory without delay. From the grape clusters taken from each plot, one hundred grapes were collected from the tip, middle, and bottom sections, and the grapes were pressed to obtain grape juice. In the grape juice, the pH values were determined with a pH meter, the total soluble solids (TSS-Brix) was determined with a hand refractometer, the titratable acidity (%) was determined by titrimetric method (titration of 10 ml portion with 0.1 N NaOH), and the acidity amounts were calculated in terms of tartaric acid (Amerine and Cruess, 1960). The maturity index (%) was obtained by dividing the percentage of Total soluble solids (TSS) by the acid content (g/100ml) (Weaver, 1976).

2.1.6. Statistical Analysis

The data obtained from the study were analyzed using the TAR-IST agricultural statistics package program, and the LSD (0.05,0.01) test was used to compare the means (Açıkgöz et al., 1994).

3. Results and Discussion

The effect of humic substance application on yield and some quality characteristics in the sultani seedless grape variety is shown in Table 2.

Table 2. The effect of humic substance application on yield and some quality characteristics in the sultani seedless grape variety.

Leaf Application Dosages of Humic Substances (%)	Fresh Grape Yield (kg vine^{-1})	Juice pH	Total Soluble solids (TSS) (%)	Titratable acidity (TA) (g Tartaric acid/100 ml)	maturity Index SS/TA
0	11.81	4.32	20.7c	0.45	47.10a
0.1	12.55	4.44	21.2b	0.43	48.99a
0.2	12.94	4.49	21.6a	0.50	43.51b
0.3	13.86	4.35	21.9a	0.53	41.02b
Average	12.79	4.40	21.30	0.48	45,16
LSD	0.507*	ns	0.355*	ns	3.191*

ns: non-significant.

In the study, the fresh fruit yield values of ripe grapes per vine ranged from 11.81 kg to 13.86 kg. The effect of humic substance application on fresh fruit yield was found to be statistically significant. The highest yield was obtained with 0.3% humic acid, while the lowest fresh fruit yield was obtained from the control application (Table 2). In the Italia grape variety, 5 and 20 mg L^{-1} humic acid doses were tested and it was found that these doses significantly increased yield (Ferrara and Brunetti, 2008). In a study investigating the effects of foliar application of humic acid and acetic acid on grape yield and leaf nutrient content, it was emphasized that maximum yield was obtained with a 300 mg kg^{-1} application (Asgharzade and Babaeian, 2012). In two different grape varieties, humic acid was applied to the leaves at doses of 30-40-50 ml L^{-1}, and it was determined that these applications could improve growth, yield, and berry quality characteristics of the vine (Popescu and Popescu, 2018). In studies conducted on other crops such as cotton, wheat, and strawberries, it has been reported that foliar application of humic acid positively affects yield (Tarhan and Karademir, 2019; Delfine et al., 2005; Zydlik and Zydlik, 2023). As seen, foliar application of humic substances generally has a positive effect on yield.
The effect of foliar humic acid applications on the pH value and titratable acidity of grape juice was found to be statistically insignificant. The lowest pH value was obtained in the control (4.32), the highest pH value was obtained with the 0.2% application (4.49), and it decreased again with the 0.3% application. Titratable acidity (TA) was lowest at 0.1% (0.43) and highest at 0.3%, increasing in parallel with the increase in dose. The effect of foliar humic acid application on total soluble solids (TSS) and maturity index was found to be statistically significant. The lowest TSS amounts were found in the control (20.7), and the highest in the 0.3% application (21.9). The maturity index was highest at 0.1% (48.99) and lowest at 0.3% (41.02) (Tables 2,3). In conclusion, the TSS amount showed a parallel increase with the increase in dose with foliar humic substance application, and the 0.2% and 0.3% applications were in the same group. The 0.3% application showed a significant decrease compared to the others. Based on these data, it can be stated that high doses of humic substances may delay maturity. Ferrara and Brunetti (2008) determined in their study on Italian grape varieties that the application of humic acids significantly reduced titratable acidity and increased the °Brix/acid ratio. In two different grape varieties, foliar application of humic acid caused a significant increase in total soluble solids and fruit quality parameters, and it was reported that foliar application of humic acid at a concentration of 40 mL^{-1} could be performed (Popescu and Popescu, 2018). In a study conducted on tomato plants, it was determined that the amount of total soluble solide increased with foliar humic

acid applications, and that a 0.30% humic acid application dose was the most effective dose in terms of tomato's nutritional status and quality (Öktüren Asri et al., 2016). It has been reported that foliar application of humic acid in strawberries resulted in harder, heavier fruits with higher juice content (Zydlik and Zydlik, 2023). As can be seen from the research results, foliar application of humic substances provides positive improvements in quality parameters as well as yield.

3.1. The Effect of Humic Substance Application on the Mineral Contents of Grape Leaves

To determine the effects of foliar application of humic substance on the mineral nutrient content of leaves of the sultani seedless grape variety, samples were taken from all leaves during the veraison period, and the values obtained from the analyses are shown in Tables 3 and 4.

Table 3.The effect of humic substance application on the macro nutrient contents of leaves in the sultani seedless grape variety.

Leaf Application Dosages of Humic Substances (%)	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
0	1.9	0.10	1,15 c	1.37 d	0.33 b
0.1	2.1	0.12	2.45 b	2.23 c	0.38 b
0.2	2.4	0.14	2.65 b	2.82 b	0.48 b
0.3	2.5	0.15	3.73 a	3.68 a	0.78 a
Average	2.2	0.13	2.49	2.52	0.49
LSD	ns	ns	0.960*	0.462*	0.266*

ns: non-significant.

Table 4. The effect of humic substance application on the micro-nutrient content of leaves in the sultani seedless grape variety.

Leaf Application Dosages of Humic Substances (%)	Fe (mg kg^{-1})	Zn (mg kg^{-1})	Mn (mg kg^{-1})	Cu (mg kg^{-1})	B (mg kg^{-1})
0	143 c	48.3 d	47.3 d	5.0 b	24.5 c
0.1	225 b	83.0 c	63.4 c	5.2 b	28.2 c
0.2	253 b	116.0 b	72.8 b	7.0 b	32.4 a
0.3	301 a	157.6 a	81.9 a	10.7 a	33.8 a
Average	238	101.2	66.3	7.0	29.7
LSD	42.667*	30.844*	8.088*	3.289*	3.289*

Foliar applications of humic substances have been found to have a statistically significant effect on other macronutrients (potassium (K), calcium (Ca), and magnesium (Mg)) and micronutrients (iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), and boron (B)), except for nitrogen (N) and phosphorus (P) in the leaf samples. For macronutrients, N, P, K, Ca, and Mg the highest values (2.5%, 0.15%, 3.73%, 3.68%, 0.78%, respectively) were obtained via the 0.3% application, while the lowest values(1.9%, 0.10%, 1.15%, 1.37%, 0.33% respectively) were obtained via the control application. (Table 3). According to Karaman (2012)'s reference values suggested for samples taken in June–July (N: 2.00–2.30%, P: 0.30–0. 40, K: 1.30-1.40%, Ca: 2.0-2.5%, and Mg: 0.25-0.50%), it was observed that foliar applications of humic substances at increasing doses resulted in adequate nutrition levels for grapevines in terms of other macro nutrients except phosphorus. For micronutrients, Fe, Zn, Mn, Cu, and B had the highest values (301 mg kg-1, 157.6 mg kg^{-1}, 81.9 mg kg^{-1}, 10.7 mg kg^{-1}, 33.8 mg kg^{-1}) With a 0.3% application, the lowest values were again obtained with the control application, respectively (143 mg kg^{-1}, 48.3 mg kg^{-1}, 47.3 mg kg^{-1}, 5.0 mg kg^{-1}, 24.5 mg kg^{-1}) (Table 4). According to the reference values suggested by Karaman (2012) for samples taken in June–July (Fe: 60–175, Zn: 25–100, Mn: 30–300, Cu: 5–50, and B: 25–75 mg kg^{-1}), it was determined that the leaves were sufficiently nourished in terms of Fe, Zn, and Mn in all applications. In a study investigating the effects of foliar application of humic acid and acetic acid on grape (*Vitis vinifera* L.) yield and leaf nutrient content, it was determined that foliar applications had a significant effect on the potassium and phosphorus contents of the leaves, with maximum phosphorus and potassium contents achieved with a 300 mg kg^{-1} application (Asgharzade and Babaeian, 2012). The effect of foliar application of humic acid on the nutritional status of tomato plants was investigated, and it was reported that humic acid significantly increased the uptake of N, K, Ca, Mg, Mn, and Cu in tomato plants compared to the control, with the most significant increases generally achieved at a dose of 0.30% (Öktüren Asri et al., 2016). In a study conducted under greenhouse conditions, the effect of foliar humic acid applications on wheat plant, in soils prepared by adding 40% lime and 60 mM NaCl, was determined in terms of dry weight and the amount of nutrients absorbed. It was reported that foliar application of humic acid had a statistically significant effect on the amount of K, Mg, Fe, and Cu absorbed by the plant and that, especially under conditions where plant growth limiting factors were present, foliar application of humic acid could yield positive results in terms of growth (Aşık et al., 2012). Foliar applications of humic substances have shown an increase in both macro and micro nutrients, parallel to the increase in dosage.

4. Conclusion

Grape production is of great importance for Turkish agriculture. Seedless table and raisin grapes are produced, especially in the Aegean region, contributing significantly to the regional and national economy. Efforts to increase yield and quality are crucial for maintaining existing markets. In practices aimed at this purpose, environmental protection and ensuring sustainability in production are essential. In vineyards, foliar fertilization is widely practiced in the region. This study investigated the effect of foliar humic substance applications. According to the results obtained, the applications significantly affected fresh fruit yield, TSS, maturity index parameters, and the K, Ca, Mg, Fe, Zn, Mn, Cu, and B contents of the leaves. Considering all the positive and negative effects, it has been concluded that applying humic substances at a 0.2% dose could be economically viable and therefore recommended.

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Author's Contributions

Both authors contributed equally to this work.

Ethics

There are no ethical issues after the publication of this manuscript.

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