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# Effects of Different Types and Levels of Zinc Sulphate Applications in Vineyards (*Vitis vinifera* L.) in a Semi-arid Environment

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The present study was carried out to determine the effect of soil and foliar applications of different rates of zinc in the vicinity of Alaşehir, one of the most important viticultural centres in the Western Aegean Region where the round seedless grape cultivar (*Vitis vinifera* L.) is widely grown, on productivity and some chemical quality characteristics as well as leaf primary and secondary elements. Zinc was applied to soil and foliage as $ZnSO_4{\cdot}7H_2O$ in the experiment with four replications. One soil application (0–15–30–45 g $ZnSO_4{\cdot}7H_2O$/vine) in addition to foliar application replicated three times (0.0–0.025–0.050–0.10% Zn). Both soil and foliar zinc sulphate ($ZnSO_4{\cdot}7H_2O$) applications increased the amount of fresh grapes per vine.The highest yield was observed at 30 g $ZnSO_4{\cdot}7H_2O$ level per vine in soil application and at the rate of 0.05% Zn in foliar application. Zinc sulphate produced a significant positive effect on the contents of primary and secondary elements (N, P, K, Ca, Mg, Fe, Zn, Mn, Cu) of the leaf (lamina and petiole) with the exception of the leaf petiole manganese content in the soil application and the leaf petiole copper content in the foliar application. Soil and foliar applications of zinc sulphate negatively affected the firmness of the berry flesh. The only fruit quality characteristic positively affected by soil and foliar applications of zinc sulphate was the amount of total soluble solids. Despite the fact that the soil application of zinc sulphate did not have any significant effect on some sugar fractions, the foliar application increased only the fructose and α-glucose significantly. In conclusion, it was established that foliar application of zinc sulphate was slightly more effective on yield as well as some quality characteristics as compared to soil application. Therefore, it was concluded that foliar application could be preferred as it is more economical and easier to apply.

**Key Words: Soil and foliar application, Zinc sulphate, Vineyard, *Vitis vinifera* L., Yield, Primary and secondary elements, Sugar fractions.**

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## INTRODUCTION

Turkey ranks fourth in total vineyard area in the world and sixth among the countries producing fresh grapes. A substantial part of fresh grapes are produced in the Gediz valley in the Aegean Region. Alaşehir location (Manisa), where this experiment was set up, has the largest vineyard area in this region[1].

In a study carried out by Food Agriculture Organization (FAO) of which Turkey is a member, it was reported that zinc deficiency, which is around 30% in world's agricultural areas, was found to be as high as 83% in Turkey[2, 3]. Zinc which is a micronutrient has an important effect on the grape quality because it plays a substantial role in the synthesis of oxcin which is a plant growth hormone and increases the use efficiency of other nutrients. However, a minority of studies were performed to examine the effects of zinc on yield and quality of the grape vineyards in Turkey. Therefore, intensive studies should be conducted to assess the yield and quality losses due to zinc deficiency.

The objective of the present study is to establish the effects of soil and foliar applications of different levels of zinc on the productivity and certain chemical quality characteristics of a round seedless grape cultivar (*Vitis vinifera* L.).

## EXPERIMENTAL

Vegetation trials were carried out in a round seedless grape vineyard (*Vitis vinifera* L.) in Alaşehir vicinity, Manisa, in the Gediz Valley. The climate of the region is semi-arid[4] with hot dry summers and cold wet winters. Average yearly temperature is 19°C and the total amount of annual rainfall is 403 mm. The parent material of the soil consists of limy alluvium deposits. The soils of the region belong to the typic xerofluvent subgroup of the Entisol soil order[5]. Some chemical properties of the soils sampled from the experimental vineyard are shown in Tables 1 and 2.

TABLE-1
SOME CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOILS
PRE-APPLICATION OF ZINC SULPHATE TO THE SOIL
(0–30 cm, 30–60 cm at the soil depth)

| Depth (cm) | pH | Total soluble salt (%) | $CaCO_3$ (%) | Organic matter (%) | Texture | Total N (%) |
|---|---|---|---|---|---|---|
| 0–30 | 7.48 | < 0.030 | 1.35 | 1.55 | Sandy-loam | 0.067 |
| 30–60 | 7.58 | < 0.030 | 1.43 | 0.98 | Sandy-loam | 0.059 |

| Available (mg $kg^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| P | K | Ca | Mg | Na | Fe | Zn | Mn | Cu |
| 6.33 | 100 | 2100 | 240 | 20 | 9.4 | 0.6 | 3.6 | 11.7 |
| 4.30 | 80 | 2100 | 200 | 20 | 8.5 | 0.3 | 3.0 | 6.8 |

TABLE-2
SOME CHEMICAL PROPERTIES OF THE EXPERIMENTAL SOILS PRE-FOLIAR APPLICATION OF ZINC SULPHATE (0–30 CM, 30–60 CM AT THE SOIL DEPTH)

| Depth (cm) | pH | Total soluble salt (%) | $CaCO_3$ (%) | Organic matter (%) | Texture | Total N (%) |
|---|---|---|---|---|---|---|
| 0–30 | 7.55 | < 0.030 | 1.40 | 1.86 | Sandy-loam | 0.067 |
| 30–60 | 7.68 | < 0.030 | 1.90 | 1.28 | Sandy-loam | 0.059 |

| Available (mg $kg^{-1}$) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| P | K | Ca | Mg | Na | Fe | Zn | Mn | Cu |
| 4.60 | 70 | 1860 | 234 | 18 | 7.0 | 0.80 | 5.3 | 10.0 |
| 3.42 | 70 | 1740 | 210 | 18 | 8.0 | 0.67 | 3.8 | 8.5 |

Vegetation trials were set up in the same vine area. Soil application of zinc was made at four levels (0–15–30–45 g/vine) in the form of zinc sulphate ($ZnSO_4 \cdot 7H_2O$). The experiment was set up in a randomized block design with four replications assigning one replication to each group of four vines. As for foliar application, zinc was also applied at four levels (0–0.025–0.050% and 0.10% Zn) in the form of zinc sulphate. The applications were made in randomized complete block design with four replications, one for every four vines. Foliar application of zinc was repeated three times successively once before flowering, once after flowering and once in veraison period. A basal dressing was applied equally to all plots on Feb 18, 2004 as follows: 120 kg N $ha^{-1}$ as ammonium sulphate), 45 kg P $ha^{-1}$ (as triple superphosphate) and 208 kg K $ha^{-1}$ (as potassium sulphate).

On August 29, 2004 each vine was harvested by hand and the fresh fruit yield was determined in kg $vine^{-1}$. The pH, titrable acidity (as tartaric acid ) and brix (the total amount of water-soluble solids) values as well as berry firmness using penetrometry (FHR_1 Japan) with 5 mm diameter were specified in fresh fruit samples[6]. After the fruit samples were lyophilized, sugar fractions were also determined using the gas chromatography method[7].

Leaves were sampled opposite to the first fruit cluster during fruit setting period and then analyzed after being separated as lamina and petiole[8]. The total amount of nitrogen in the leaf samples was measured using the modified Kjeldahl method, phosphorus (P) in wet digested samples with colorimetry, potassium (K), sodium (Na) and calcium (Ca) with flame photometry and magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn) and copper (Cu) using AAS (atomic absorbsion spectrometry)[9]. Genstat package program was used for the evaluation of the results obtained[10].

## RESULTS AND DISCUSSION

**The effect of soil and foliar applications of zinc sulphate on the yield:** In the soil application of zinc sulphate the lowest yield per vine was observed in the control group (12.2 kg of fresh grapes/vine) and the highest yield in the 30 g $ZnSO_4 \cdot 7H_2O$ application (15.4 kg of fresh grapes/vine) (Table-5). In the foliar application of zinc, on the other hand, the lowest grape yield (16.4 kg of fresh grapes/vine ) was determined in the control and 0.025% Zn treatments while the highest yield (17.4 kg of fresh grapes/vine) was observed in the 0.05% Zn treatment (Table-5). Zinc sulphate applications were found to significantly increase the yield in both trials. The positive role played by zinc in boosting the yield is probably associated with the effects of zinc on protein synthesis and growth regulators[11, 12]. The positive effect of soil and foliar applications of zinc as well as applications *via* compound fertilizers enriched with zinc on the yield of various cultivated plants such as grape, fig, wheat, tomato, rice and maize was also established by some researchers[13–18].

**The effect of soil and foliar applications of zinc sulphate on the contents of primary and secondary elements in the leaf (lamina and petiole):** Data related to the effect of the type and level of zinc sulphate applications on primary (N, P, K, Ca and Mg) and secondary elements (Fe, Zn, Mn and Cu) in the leaves (lamina and petiole) are shown in Table-3 and Table-4. Soil application of zinc sulphate significantly increased in the contents of primary elements in both lamina and petiole. This was also true for the foliar application of zinc (except for lamina phosphorus) (Table-3).

The levels of elements such as N, Ca, and Mg determined in the leaf lamina during fruit setting were sufficient according to reference values stated by previous researchers[19–22]. However, a comparison with the reference values given by some other researchers notified P and K insufficiencies[20, 21, 23].

The effects of soil and foliar applications of zinc sulphate on the contents of secondary elements (Fe, Zn, Mn, Cu) in the leaf (lamina and petiole) were also examined and results revealed that these applications had generally significantly increased the contents of Fe, Zn, Mn and Cu in the lamina and petiole (Mn in the soil application and Cu in the foliar application were found to be insignificant in the petiole) (Table-4). When compared with the reference values reported by earlier researchers, the levels of Fe in the lamina and petiole were found to be at adequate levels[21, 22, 24]. The levels of zinc in the lamina and petiole were within the reference ranges reported by some other researchers[25–27]. However, a foliar application of 0.1% Zn caused the Zn in the lamina to reach a toxic level[27]. Results pointed out that the zinc in the leaves (lamina and petiole) increased more in foliar application of zinc sulphate as compared to soil application. This was also confirmed by some researchers[15, 17].

Soil application of zinc sulphate also increased Mn in the leaf lamina, but did not have any significant effect on petiole Mn. In addition, it was established that foliar application of zinc sulphate caused the contents of Mn in not only the lamina but also the petiole to increase to significant extents (Table-4). The levels of Mn determined in the leaf lamina and petiole in all application treatments were found to be at adequate levels when compared with the reference values reported by some researchers[21, 26].

TABLE-3
EFFECT OF SOIL AND FOLIAR ZINC SULPHATE APLICATIONS ON PRIMARY ELEMENTS OF THE LEAF (LAMINA AND PETIOLE)

| Zn | | (%) (dry matter) | | | | | |
|---|---|---|---|---|---|---|---|
| Application | Treatments | N | | P | | K | |
| | | Lamina | Petiole | Lamina | Petiole | Lamina | Petiole |
| SOIL | $Zn_0$ | 2.59 | 0.53 | 0.098 | 0.115 | 0.81 | 1.01 |
| | $Zn_1$ | 2.89 | 0.59 | 0.125 | 0.148 | 0.82 | 1.09 |
| | $Zn_2$ | 2.96 | 0.63 | 0.138 | 0.145 | 0.87 | 1.20 |
| | $Zn_3$ | 2.95 | 0.69 | 0.143 | 0.178 | 0.94 | 1.25 |
| $LSD_{0.05}$ | | 0.23 | 0.11 | 0.031 | 0.034 | 0.09 | 0.13 |
| LEAF | $Zn_0$ | 2.60 | 0.67 | 0.108 | 0.112 | 0.54 | 0.93 |
| | $Zn_1$ | 2.77 | 0.71 | 0.118 | 0.140 | 0.67 | 1.21 |
| | $Zn_2$ | 2.85 | 0.76 | 0.133 | 0.143 | 0.73 | 1.34 |
| | $Zn_3$ | 2.93 | 0.75 | 0.133 | 0.160 | 0.76 | 1.39 |
| $LSD_{0.05}$ | | 0.19 | 0.07 | ns | 0.035 | 0.15 | 0.22 |
| Zn | | (%) (dry matter) | | | | | |
| Application | Treatments | Ca | | Mg | | Na | |
| | | Lamina | Petiole | Lamina | Petiole | Lamina | Petiole |
| SOIL | $Zn_0$ | 2.10 | 1.73 | 0.38 | 0.76 | 0.020 | 0.015 |
| | $Zn_1$ | 2.26 | 1.94 | 0.43 | 0.88 | 0.023 | 0.013 |
| | $Zn_2$ | 2.32 | 2.05 | 0.46 | 0.92 | 0.025 | 0.013 |
| | $Zn_3$ | 2.29 | 1.98 | 0.42 | 0.92 | 0.023 | 0.013 |
| $LSD_{0.05}$ | | 0.14 | 0.21 | 0.05 | 0.09 | ns | ns |
| LEAF | $Zn_0$ | 2.02 | 2.07 | 0.33 | 0.76 | 0.015 | 0.018 |
| | $Zn_1$ | 2.08 | 2.17 | 0.39 | 0.84 | 0.013 | 0.017 |
| | $Zn_2$ | 2.15 | 2.21 | 0.41 | 0.91 | 0.020 | 0.018 |
| | $Zn_3$ | 2.24 | 2.17 | 0.42 | 0.93 | 0.018 | 0.015 |
| $LSD_{0.05}$ | | 0.12 | 0.10 | 0.05 | 0.11 | ns | ns |

ns: non-significant.

Soil application of zinc sulphate had a significant impact on the content of Cu in the leaf lamina and petiole. Foliar application, on the other hand, increased only the level in the leaf lamina, while it had insignificant effect on the content of Cu in the petiole.The levels of Cu determined in both applications were found to be at adequate levels when compared with corresponding reference values reported in other studies[19, 21, 22, 28].

TABLE-4
EFFECT OF SOIL AND FOLIAR ZINC SULPHATE APPLICATIONS ON SECONDARY ELEMENTS OF THE LEAF (LAMINA AND PETIOLE)

| Zn | | mg kg$^{-1}$ | | | |
|---|---|---|---|---|---|
| Application | Treatments | Fe | | Zn | |
| | | Lamina | Petiole | Lamina | Petiole |
| SOIL | $Zn_0$ | 195 | 37.3 | 53.3 | 28.8 |
| | $Zn_1$ | 227 | 43.8 | 70.8 | 32.8 |
| | $Zn_2$ | 266 | 60.0 | 88.5 | 37.8 |
| | $Zn_3$ | 272 | 67.0 | 103.0 | 39.3 |
| $LSD_{0.05}$ | | 67 | 17.4 | 21.9 | 7.5 |
| LEAF | $Zn_0$ | 217 | 39.8 | 74.0 | 30.5 |
| | $Zn_1$ | 258 | 50.0 | 111 | 35.3 |
| | $Zn_2$ | 314 | 61.0 | 204 | 41.8 |
| | $Zn_3$ | 374 | 65.5 | 370 | 55.8 |
| $LSD_{0.05}$ | | 114 | 15.5 | 90 | 15.0 |

| Zn | | mg kg$^{-1}$ | | | |
|---|---|---|---|---|---|
| Appli cation | Treatments | Mn | | Cu | |
| | | Lamina | Petiole | Lamina | Petiole |
| SOIL | $Zn_0$ | 38.3 | 23.0 | 27.3 | 18.0 |
| | $Zn_1$ | 44.0 | 27.5 | 32.8 | 20.8 |
| | $Zn_2$ | 48.5 | 25.5 | 37.8 | 22.8 |
| | $Zn_3$ | 53.0 | 27.5 | 42.8 | 23.5 |
| $LSD_{0.05}$ | | 10.0 | ns | 6.9 | 6.5 |
| LEAF | $Zn_0$ | 47.5 | 21.5 | 28.5 | 41.0 |
| | $Zn_1$ | 68.3 | 29.8 | 32.0 | 39.0 |
| | $Zn_2$ | 78.8 | 36.3 | 36.8 | 33.8 |
| | $Zn_3$ | 78.3 | 38.0 | 38.8 | 40.0 |
| $LSD_{0.05}$ | | 21.0 | 16.1 | 5.1 | ns |

ns: non-significant

The increases obtained in the primary and secondary elements such as N, P, K, Ca, Mg, Fe, Zn, Mn and Cu as a result of foliar and soil applications of zinc sulphate might be attributed to the impact of Zn applications on the photosynthetic activity and the hormonal balance as well as their potentiality of increasing the permeability and stability of the membrane[12, 29].

**The effect of soil and foliar applications of zinc sulphate on some chemical quality characteristics:** Effects of soil and foliar applications of zinc sulphate on the firmness and some chemical characteristics (pH, titrable acidity, total soluble solids and sugar fractions) of the berries were examined (Table-5 and Table-6).

TABLE-5
EFFECT OF SOIL AND FOLIAR ZINC SULPHATE APPLICATIONS ON FRESH FRUIT YIELD AND SOME CHEMICAL QUALITY CHARACTERISTICS

| Zn Application | Treatments | Yield (kg/vine) | Firmness (kg) | pH | Titratable acidity (tartaric acid) (%) | Total soluble solids (%) |
|---|---|---|---|---|---|---|
| SOIL | $Zn_0$ | 12.2 | 0.408 | 2.86 | 0.645 | 16.63 |
| | $Zn_1$ | 13.0 | 0.362 | 3.00 | 0.690 | 17.83 |
| | $Zn_2$ | 15.4 | 0.340 | 3.03 | 0.720 | 19.65 |
| | $Zn_3$ | 15.1 | 0.283 | 2.96 | 0.708 | 18.90 |
| $LSD_{0.05}$ | | 1.9 | 0.057 | ns | ns | 2.09 |
| LEAF | $Zn_0$ | 16.4 | 0.370 | 3.00 | 0.668 | 19.08 |
| | $Zn_1$ | 16.6 | 0.390 | 2.91 | 0.665 | 20.00 |
| | $Zn_2$ | 17.4 | 0.363 | 2.98 | 0.763 | 20.70 |
| | $Zn_3$ | 16.9 | 0.263 | 2.96 | 0.678 | 20.05 |
| $LSD_{0.05}$ | | 0.7 | 0.022 | ns | ns | 0.80 |

ns: non-significant

TABLE-6
EFFECT OF SOIL AND FOLIAR ZINC SULPHATE APPLICATIONS ON SUGAR FRACTIONS OF FRESH FRUIT

| Zn Application | Treatments | Fructose (%) | β-glucose (%) | α-glucose (%) | Sorbitol (%) | Galactose (%) |
|---|---|---|---|---|---|---|
| SOIL | $Zn_0$ | 40.5 | 21.8 | 12.0 | 2.75 | 0.55 |
| | $Zn_1$ | 40.8 | 23.0 | 12.5 | 2.03 | 0.33 |
| | $Zn_2$ | 39.5 | 21.2 | 12.5 | 1.28 | 0.15 |
| | $Zn_3$ | 35.8 | 20.0 | 11.0 | 1.78 | 0.10 |
| $LSD_{0.05}$ | | ns | ns | ns | ns | ns |
| LEAF | $Zn_0$ | 34.3 | 22.0 | 11.0 | 2.00 | 0.83 |
| | $Zn_1$ | 38.8 | 24.3 | 13.0 | 2.50 | 1.83 |
| | $Zn_2$ | 38.3 | 22.5 | 12.5 | 3.00 | 0.08 |
| | $Zn_3$ | 41.0 | 23.0 | 14.3 | 2.75 | 0.10 |
| $LSD_{0.05}$ | | 4.5 | ns | 3.1 | ns | ns |

ns: non-significant

Soil and foliar applications of zinc sulphate had a negative effect on the firmness of the berry flesh. The effect of zinc sulphate on the chemical characteristics was generally insignificant with the exception of the total soluble solids (Table-5).

Soil application of zinc sulphate did not significantly affect sugar fractions (fructose, α-glucose, β-glucose, sorbitol and galactose). Foliar application of zinc sulphate, on the other hand, increased substantially the contents of fructose and α-glucose, which give the grape its taste (Table-6). The relationship between zinc and carbohydrate metabolism has also been confirmed by a number of other researchers[17, 29, 30].

In general, both soil and foliar applications of zinc sulphate increased the yield per vine. The highest yield was obtained at 30 g $ZnSO_4 \cdot 7H_2O$ per vine in the soil application and at the 0.05% Zn level in the foliar application. Soil and foliar applications of zinc sulphate substantially increased the content of some primary (N, P, K, Ca, Mg) and secondary elements (Fe, Zn, Mn, Cu) of the leaf lamina and petiole. However, 0.1% foliar application of Zn caused the Zn level in the leaves to reach a toxic level. Soil and foliar applications of zinc sulphate significantly affected the firmness of berry flesh.

Despite the fact that chemical quality characteristics such as pH and titrable acidity were not affected by zinc applications, the total amount of soluble solids was positively affected. Soil application of zinc sulphate did not have significant positive effect on most of the sugar fractions; however, foliar application caused fructose and α-glucose to increase at a significant level. In conclusion, it was established that foliar applications of zinc sulphate in the vineyards should be given priority in future studies on the ground of the ease of its application and being economical as well as its positive impact on the yield and some quality characteristics. However, it was concluded that the number of applications to be set up during a single vegetation period should also be given careful consideration.

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