

# Effects of the Foliar Application of Magnesium and Zinc on the Yield and Quality of Three Grape Cultivars Grown in the Calcareous Soils of Iran

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## Abstract

A completely randomized factorial block designed experiment was carried out at Maragheh region during 2007-2008 to evaluate the effects of the foliar applications of magnesium (Mg) and zinc (Zn) on the yield and quality of three grape cultivars. Factor one included three levels of Mg (0, 0.40 and 0.80%  $\text{MgSO}_4 \times \text{H}_2\text{O}$ ); Factor two consisted of three levels of Zn (0, 0.20 and 0.40%  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ); and factor three involved three cultivars of grape (*Vitis vinifera* L.) namely 'Sahebi', 'Soltani' and 'Ghezel'. The foliar applications were carried out in two stages, namely, during the enlargement of flower buds and three weeks after the flower petals dropped (late spring). Yield and quality characteristics such as total soluble solids (TSS), juice, pH and acidity were determined. The statistical analyses were performed using MSTATC software and Duncan tests. The analysis of variance demonstrated that the main effects of Mg, Zn and cultivars on yield were statistically significant at 1% level; and the interactive effects of the foliar application of Mg and Zn on the yield were significant at 5% level. The highest yield was obtained with the combined foliar applications of Mg and Zn-fertilizers. 'Ghezel' variety produced the highest yield of 47.11 tons  $\text{ha}^{-1}$  among the three cultivars. The main effects of Mg and Zn foliar application as well as of cultivars were significant. TSS contents were significant at 1% level. The highest pH values were obtained with the foliar application of Mg sulfate at 0.80% and Zn sulfate at 0.40%. Likewise, the main effects of foliar application of Mg and Zn were significant at 1% level in the lowering of juice acidity and K/Mg ratio. Foliar application did not decrease the K/Mg ratio to the desirable level, however in the deficient soils, foliar application was not enough. It means in additional of foliar application, soil application is also necessary for obtaining desirable grape yield and quality.

**Keywords:** grape (*Vitis vinifera* L.) cultivars, yield, quality, K/Mg ratio

## Introduction

Vineyard soils in Iran are primarily calcareous, with a pH above 7.8 and organic matter (OM) of less than 1.00%, and TNV exceeding 10.0%. The overuse of P-fertilizers with P accumulation in soils reduces the availability of the other nutrients below the critical demands in vineyards where the grapes have performed poorly due to the resulting poor uptakes of nutrients, especially magnesium (Mg) and zinc (Zn) (Malakouti *et al.*, 2005). Another problem is the poor management and concern over the quality of the irrigation water. Bicarbonate contents of irrigation waters, especially those of the well waters, are at high levels (Mengel and Kirkby; 1987 Shahabi *et al.*, 2005).

Mg is absorbed by plants as Mg and the amounts of its absorption depend on the available Mg, Soil pH, CEC, %Mg saturation on the CEC and available K and Ca. Mg concentration in grape is about 0.60%. The quantity of Mg taken up by plants is usually less than that of Ca or K. Mg is a primary constituent of chlorophyll, and without chlorophyll photosynthesis would not occur. Mg in chlorophyll accounts for 15 to 20% of the total Mg content of plants. Mg also serves as a structural component in ribosome granules, stabilizing them in the configuration necessary

for protein synthesis. Mg critical level in the arable soils of vineyards is around 750  $\text{mg kg}^{-1}$  according to the ammonium acetate extractant (Malakouti and Rezaei, 2001). It has been observed that growth depressions and visible Mg deficiency symptoms occur if the Mg in the chlorophyll exceeds 20-25% of the total Mg content in plants (Mengel and Kirkby, 1987). This means that through this "inactivation" other metabolic processes which require Mg, including the formation of chloroplasts, is retarded or cannot fully operate. Besides being an integral part of the chlorophyll, Mg is involved in the carboxylase reaction of the photosynthesis, namely, as a coenzyme in the fixation of  $\text{CO}_2$ . During the  $\text{CO}_2$  assimilation, sugar molecules are formed from water and carbon dioxide utilizing solar energy. This is the basic reaction for the synthesis of other plant constituents such as starch, proteins, fat and vitamins. In the case of a low Mg supply in the leaves,  $\text{CO}_2$  fixation is severely inhibited. As a charged divalent cation, Mg is involved in the cation-anion balance, where it is responsible for pH regulation and turgor adjustment of plant cells. About five percent of the Mg is bound to pectate and serves as a structural element of cell walls. The remaining Mg, which is not fixed to structures such as chlorophyll and cell wall, is highly mobile, and it is estimated that about 20% of

all the Mg which has been taken up circulates within the vascular system of xylem and phloem. Because of its high mobility in the phloem, Mg is easily re-translocated from older leaves to places of intensive metabolic activity. This is the reason why visual Mg deficiency symptoms always occur first on the older leaves (Kali, 2002). Leaching of Mg is often a severe problem (35 kg per ha per year) and its deficiency occurs in the northwestern soils of Iran, which are under the cultivation of grape and where high rates of  $\text{NH}_4$  or K-fertilizers are applied (Havlin *et al.*, 2005). Mg is important as a cofactor in most enzyme activating phosphorylation processes, bridging ATP or ADP and the enzyme. These Mg ATP complexes are required in energy transfer processes, e.g. during the synthesis of starch, which is impaired if Mg is in low supply. On the other hand, Mg deficiency also inhibits the degradation of starch in source (older) leaves, which serves as a main energy source in the sinks (growing tissue, storage organs). Since Mg is also involved in the loading and unloading of the phloem through Mg dependent membrane-bound ATPases, both the mobilization and the transportation of carbohydrates to places of high demand are inhibited if the Mg status of the plant is inadequate. This explains why, under Mg deficiency, partitioning of carbohydrates within the plants is dramatically shifted to the disadvantage of the roots. These Mg triggered membrane bound ion pumps are also essential for the uptake of nutrients by root cells. Under Mg deficiency, protein N decreases while non-protein N generally increases in plants. Mg is associated with transfer reactions involving phosphate reactive groups and also is required for maximal activity of almost every phosphorylating enzyme in carbohydrate metabolism. Most reactions involving phosphate transfer from adenosine triphosphate (ATP) require Mg. Since the fundamental process of energy transfer occurs in photosynthesis, glycolysis, the citric acid or Krebs cycle, and respiration, Mg is important throughout plant metabolism (Havlin *et al.*, 2005).

Zn deficiency is widespread in plants and human beings in many countries due to the calcareous nature of soils, high pH, low OM, salt stress, continual droughts, high temperature, high bicarbonates in irrigation water, e.g. irrigation water with  $\text{HCO}_3^-$  concentration of four  $\text{meq l}^{-1} = 244 \text{ mg l}^{-1}$  added to a field crop or an orchard at a rate of 5000  $\text{m}^3$  per hectare per year, the amount of added  $\text{HCO}_3^-$  to soil will exceed one ton per hectare per year (about 1220  $\text{kg ha}^{-1}$ ), and overuse of P-fertilizers and imbalanced application of fertilizers (Malakouti, 2007). Zn is one of the essential elements for plants, and humans, but it is deficient (less than 1.00  $\text{mg kg}^{-1}$  DTPA-extractable Zn) in most calcareous soils and, consequently, in plant and human diets. Zn functions in plants in important ways. It is first of all a component of molecular structure of enzymes, besides being a co-factor in regulating the reactions of many enzymes. It is found as a part of at least four enzymes, including carbonic anhydrase, alcohol dehydrogenase, superoxide desmutase, and RNA polymerase. The enzymes that are known to be activated

by Zn include dehydrogenase, aldoholase, isomerase, transphosphorilase, RNA and DNA polymerase. Zn participates in the plant metabolic processes of protein and carbohydrate transformations. Zn deficiency quickly reduces the rate of activities of carbonic anhydrase. The normal functions of this enzyme accumulating in cytoplasm and chloroplast include fixation of  $\text{CO}_2$  in the photosynthetic processes. Zn also plays a part in the plant nitrogen metabolism. The first possible effect of Zn deficiency would be seen as the reduced levels of RNA cell and ribosome, which in turn halt protein synthesis, leading to the accumulation of free amino acids. Zn is essential for the formation of indole acetic acid (IAA) from tryptophane, one of the necessary ingredients for the synthesis of IAA. This growth factor (IAA) would be indirectly affected by Zn concentrations. High levels of tryptophane in plant leaves low in Zn are possibly due to this synthetic process which is slowed down. The activity of alcohol dehydrogenase (ADH) would be severely reduced due to low Zn levels. This enzyme plays a very important part in the root metabolic activities under stress anaerobic conditions where acetaldehyde is reduced to ethanol. Therefore, under Zn deficiency situation, metabolic activities of anaerobic roots will be disturbed (even under aerobic conditions, formation of ethanol will take place mostly in the meristematic tissue at the tip of the roots). Zn also affects the metabolic reactions of gibberellic acid, whereby such reactions are disturbed under Zn deficiency conditions (Marschner, 1995).

Application of Zn-fertilizers under Zn deficiency conditions has been associated with improved yield and quality of grapes (Malakouti, 2007). Malakouti (2006) in an extensive investigation and analyzing more than 1000 soil and leaf samples of vineyards under different management systems during the past decade (1995-2004) found that in Zn deficient calcareous soils foliar application of Zn improved yield and quality of grapes. He found that the desirable Mg and Zn concentrations, respectively, for grape leaves were 0.60 percent and 35  $\text{mg kg}^{-1}$ , for fresh grapes were 10 and 0.10  $\text{mg kg}^{-1}$  and for raisins were 16 and 0.20  $\text{mg kg}^{-1}$ . He concluded that Mg and Zn deficiencies exist among vineyards (Malakouti, 2006).

In the fertilization practices in the calcareous soils of Iran, Mg has rarely received the same attention as N, P and K. Application of magnesium sulphate to grapes usually increases the sugar content of the grape. This is the main reason why French grape growers use a lot of magnesium sulphate. Despite abundant amounts of Mg in the parent materials of calcareous soils, hidden Mg deficiency exists in grapes. The main reasons for this hidden hunger are the overuse of K-fertilizers and high available Ca. The experimental results revealed that K/Mg ratio is very important for grape quality. An appropriate amount of K/Mg ratio (5.0-7.0) is needed for better grape quality (Malakouti and Rezaei, 2001). Although high levels of K nutrition depress Mg uptake due to a preferential K uptake by plants, increasing K supply affects the Mg content of various plant organs

to varying degrees (Kali, 2002). Moreover, the negative effects of K on the Mg status and yield seem to be confined to the deficiency range of Mg supplied. Increasing K application does not affect grain yields as long as Mg levels in the plant tissue do not fall below the critical threshold values. This shows the importance of an adequate and balanced supply of both nutrients. Kali (2002) reported that along with the application of K-fertilizer, applying magnesium sulphate was fruitful in grape sugar content. Due to the existence of the incompatibility of prices between subsidized N, P, K-fertilizers and unsubsidized Mg and Zn-fertilizers, this study was to investigate the foliar application of Mg and Zn sulphates on the yield and quality of three grape cultivars in Azarbyjan province where the soils usually suffer from Mg and Zn deficiencies.

### Materials and methods

A completely randomized factorial block designed experiment was carried out at Maragheh region during 2007-2008 to evaluate the effects of foliar applications of Mg and Zn on the yield and quality of three grape cultivars. Factor one included three levels of Mg (0, 0.40 and 0.80%  $\text{MgSO}_4 \times \text{H}_2\text{O}$ ); Factor two consisted of three levels of Zn (0, 0.20 and 0.40%  $\text{ZnSO}_4 \cdot 7\text{H}_2\text{O}$ ); and factor three involved three cultivars of grape (*Vitis vinifera* L.), namely, 'Sahebi', 'Soltani' and 'Ghezel'. The foliar applications were carried out in two stages, namely, during the enlargement of flower buds and three weeks after the flower petals dropped (late Spring). Other nutrients were applied uniformly for all the treatments on the basis of soil tests. Yield and quality characteristics such as total soluble solids (TSS), juice, pH and acidity were determined. The statistical analyses were performed using MSTATC software and Duncan test.

### Results and discussion

Results of the soil, water and leaf analyses are shown in Tab. 1, 2 and 3. The experimental data showed that the fertilizer treatments significantly affected the nutrient concentrations in leaves and consequently in dried fruits. There were significant differences in the concentrations of Mg and Zn in grape leaves and grape fruits, mainly due to the foliar application of Mg and Zn-fertilizers (Tab. 3 and 4). The analysis of variance showed that the main effects of Mg, Zn and cultivars on yield were statistically significant

at 1% level and the interactive effects of the foliar application of Mg and Zn on the yield were significant at 5% level. The highest yield (47.11 tons  $\text{ha}^{-1}$ ) was obtained with the combined applications of Mg and Zn (Fig. 1). 'Ghezel' variety produced the highest yield of 47.11 tons  $\text{ha}^{-1}$  among the three cultivars. The main effects of Mg and Zn applica-

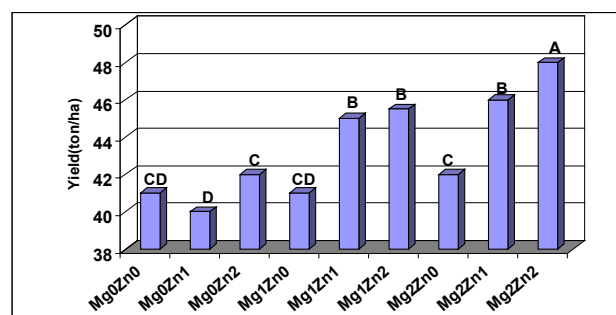


Fig. 1. Effects of foliar application of Mg and Zn on the yield of grapes

tions as well as of cultivars were significant. TSS contents were significant at 1% level. The highest TSS level (15.4%)

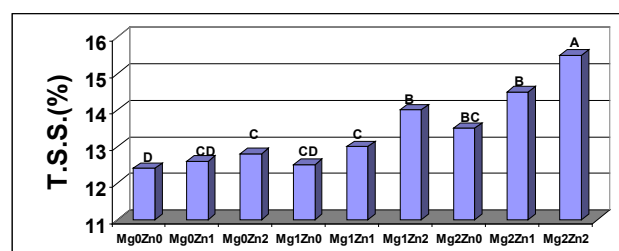


Fig. 2. Effects of foliar application of Mg and Zn on TSS of grapes

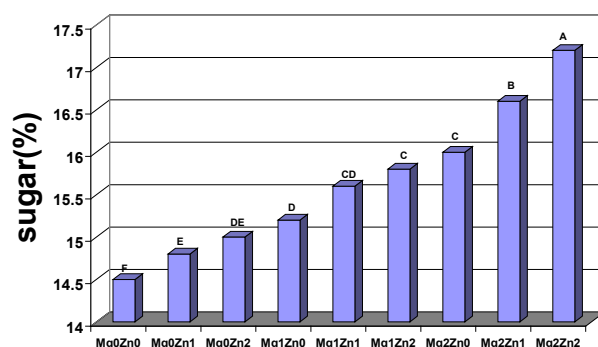


Fig. 3. Effects of Mg and Zn on the sugar percentage in grapes

Tab. 1. Chemical and physical characteristics of the studied soil

Fe $\text{mg kg}^{-1}$	Zn $\text{mg kg}^{-1}$	Mg $\text{mg kg}^{-1}$	OC %	Clay %	Silt %	Sand %	P $\text{mg kg}^{-1}$	K $\text{mg kg}^{-1}$	T.N.V.%	pH	EC $\text{dS/m}$	Depth Cm
4.60	0.35	40	0.56	38	26	36	6.5	160	14	7.9	1.4	0-30
3.20	0.22	30	0.41	36	24	36	4.2	120	15	8.1	1.7	31-60
1.80	0.11	12	0.31	30	22	30	3	110	17	8.1	1.6	61-90

Tab. 2. Chemical analysis of the irrigated water

EC dS/m	pH	Ions in me l <sup>-1</sup>				
		HCO <sub>3</sub> <sup>-</sup>	Cl <sup>-</sup>	SO <sub>4</sub> <sup>=</sup>	Ca <sup>++</sup> +Mg <sup>++</sup>	Na <sup>+</sup>
1.4	7.9	2.6	6.5	5	6	8.2

was obtained with the foliar application of 0.80% Mg and 0.40% Zn solutions. Among the three cultivars, 'Ghezel' produced the highest TSS (Fig. 2). The highest sugar percentage (17.2%) was obtained with the foliar application of 0.80% Mg and 0.40% Zn solutions (Fig. 3). Likewise, the main effects of foliar application of Mg and Zn were significant at 1% level in the lowering of K/Mg ratio, but

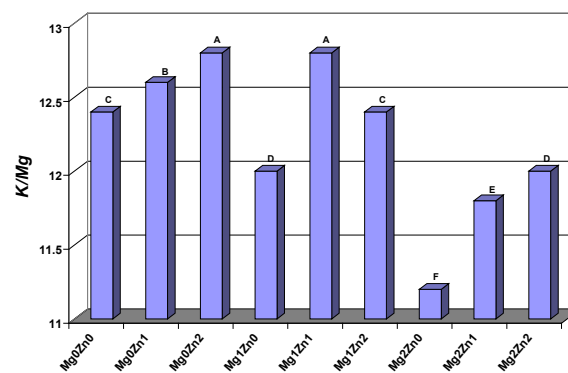


Fig. 4. Effects of Mg and Zn on the ratio of K/Mg in grapes

Tab. 3. Effects of different treatments on grape leaf nutrient concentrations

Treatments	Percentage					mg kg <sup>-1</sup>					
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B	
Mg 0 Zn 0 ‘Sahebi’	1.86 B	0.24 A	1.56 A	3.21AB	0.42 A	46 AB	39 A	8 C	4.8 A	44 A	
Mg 0 Zn 0 ‘Soltani’	1.97B	0.21B	1.52 A	3.20 AB	0.39 A	45 AB	40 A	25 A	5.1A	40 C	
Mg 0 Zn 0 ‘Ghezel’	1.87B	0.21B	1.50 A	3.33 A	0.45 A	46 AB	42 A	25 A	5.0 A	41 B	
Mg 0 Zn 1 ‘Sahebi’	1.98B	0.25 A	1.52 A	3.28 AB	0.42 B	45 AB	40 A	10 C	4.9 A	42 B	
Mg 0 Zn 1 ‘Soltani’	1.96 B	0.22	1.48AB	3.29 AB	0.45 AB	40 B	42 A	15 C	5.0 A	43 B	
Mg 0 Zn 1 ‘Ghezel’	1.87 B	0.20 AB	1.49 AB	3.30 AB	0.43 B	42 B	40 A	27 A	5.1A	44 A	
Mg 0 Zn 2 ‘Sahebi’	1.88 B	0.26 A	1.51A	3.32 A	0.44 AB	45 AB	41A	11C	5.5 A	43 AB	
Mg 0 Zn 2 ‘Soltani’	1.78 B	0.22 AB	1.50 A	3.31AB	0.45 AB	47 A	42 A	17 C	5.2 A	42 AB	
Mg 0 Zn 2 ‘Ghezel’	1.82 B	0.20 B	1.49 A	3.30 AB	0.43 B	48 A	41A	26 A	4.9 A	41AB	
Mg 1 Zn 0 ‘Sahebi’	2.10 A	0.24 A	1.48 AB	3.66 A	0.45 AB	45 AB	39 A	14 C	4.8 A	40 BC	
Mg 1 Zn 0 ‘Soltani’	2.15 A	0.21B	1.47 AB	3.52 A	0.44 AB	47 A	40 A	21B	4.7 A	41BC	
Mg 1 Zn 0 ‘Ghezel’	2.12 A	0.19 B	1.49 A	3.48 A	0.43 B	48 A	42 A	27 A	4.6 A	41B	
Mg 1 Zn 1 ‘Sahebi’	2.15 A	0.23 A	1.44 B	3.36 A	0.42 B	46 AB	41A	13 C	4.5 A	42 AB	
Mg 1 Zn 1 ‘Soltani’	2.17 A	0.21AB	1.45 B	3.42 A	0.45 AB	45 AB	41A	19 B	4.7 A	41AB	
Mg 1 Zn 1 ‘Ghezel’	2.19 A	0.20 AB	1.42 B	3.50 A	0.43 B	46 A	42 A	24	4.9 A	43 AB	
Mg 1 Zn 2 ‘Sahebi’	2.11 A	0.24 A	1.43 B	3.52 A	0.42 B	47 A	41A	14 C	4.6 A	40 A	
Mg 1 Zn 2 ‘Soltani’	2.12 A	0.23 A	1.43 B	3.60 A	0.45 AB	46 A	39 A	21B	4.7 A	41B	
Mg 1 Zn 2 ‘Ghezel’	2.18 A	0.22 AB	1.42 B	3.50 A	0.44 AB	45 AB	40 A	29 A	4.8 A	42 AB	
Mg 2 Zn 0 ‘Sahebi’	2.15 A	0.21AB	1.45 B	3 B	0.46 A	44 B	44 A	18 C	4.5 A	43 AB	
Mg 2 Zn 0 ‘Soltani’	2.21 A	0.22 A	1.41B	3 B	0.48 A	43 B	40 A	17 C	4.4 A	44 A	
Mg 2 Zn 0 ‘Ghezel’	2.23 A	0.23 A	1.42 B	2.6 B	0.48 A	42 B	45 A	17 C	4.3 A	41B	
Mg 2 Zn 1 ‘Sahebi’	2.14 A	0.25 A	1.43 B	2.5 B	0.49 A	43 B	43 A	19 B	4.2 A	42 AB	
Mg 2 Zn 1 ‘Soltani’	2.18 A	0.24 A	1.45 B	2.6 B	0.48 A	42 B	42 A	19 B	4.1 A	42 AB	
Mg 2 Zn 1 ‘Ghezel’	2.18 A	0.23 A	1.46 B	2.5 B	0.51AQ	43 B	41A	25 A	4.2 A	43 AB	
Mg 2 Zn 2 ‘Sahebi’	2.25 A	0.21AB	1.42 B	2.5 B	0.5 A	43 B	42 A	24 A	4.3 A	42 AB	
Mg 2 Zn 2 ‘Soltani’	2.24 A	0.22 A	1.43 B	2.5 B	0.5 A	42 B	44 A	25 A	4.2 A	42 AB	
Mg 2 Zn 2‘Ghezel’	2.21A	0.23 A	1.41B	2.4 B	0.51A	43 B	43 A	24 A	4.3 A	41B	

The average values that are followed by the same letters are significantly the same at 5% level (as tested by multi range Duncan test)

still this ratio was much more than desirable level (5.0-7.0) for the studied cultivars (Fig. 4).

## Conclusions

Results obtained from the experiments indicated that with the increase in the amount of Mg application, the leaf chlorophyll content and hence photosynthesis level

was increased, contributing to a significant increase in the percentages of soluble solids and dry matter. The increase of Mg in chloroplasts had a positive effect on the absorption of K. Leaves with higher content of Mg absorb more K, which contributed to a significant increase in the grape sugar (Mg has a significant role in the formation of ATP and transfer of energy, thereby, facilitating sugar synthesis in the grape fruit. Mg, much similar to Zn, increases the

Tab. 4. Effects of various treatments on dried grape (raisin) concentrations

Treatments	Percentage					mg kg <sup>-1</sup>				
	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	B
Mg 0 Zn 0 'Sahebi'	1.06 B	0.08 A	0.56 A	0.21AB	0.02 B	56 AB	8 A	8 B	2.8 A	24 A
Mg 0 Zn 0 'Soltani'	1.07B	0.01B	0.52 A	0.20 AB	0.09 A	55 AB	8 A	7 C	2.1A	20 C
Mg 0 Zn 0 'Ghezel'	1.17B	0.01B	0.50 A	0.63 A	0.05 AB	56 AB	8 A	7 C	2.0 A	21 B
Mg 0 Zn 1 'Sahebi'	1.08B	0.09 A	0.52 A	0.48 AB	0.02 B	55 AB	8 A	7 C	2.9 A	22 B
Mg 0 Zn 1 'Soltani'	1.06 B	0.02 B	0.48AB	0.49 AB	0.05 AB	50 B	8 A	7 C	2.0 A	23 AB
Mg 0 Zn 1 'Ghezel'	1.07 B	0.02 B	0.49 AB	0.40 AB	0.03 B	52B	8 A	7 C	2.1A	24 A
Mg 0 Zn 2 'Sahebi'	1.08 B	0.06 A	0.51A	0.52 A	0.04 AB	55 AB	8A	8 B	2.5 A	23 AB
Mg 0 Zn 2 'Soltani'	1.08 B	0.02 B	0.50 A	0.51AB	0.05 AB	57 A	8 A	8 B	2.2 A	22 B
Mg 0 Zn 2 'Ghezel'	1.02 B	0.02 B	0.49 AB	0.50 AB	0.03 B	58 A	8A	9 A	2.9 A	21 BC
Mg 1 Zn 0 'Sahebi'	1.00 A	0.08 A	0.48 AB	0.66 A	0.05 AB	55 AB	8 A	7 C	2.8 A	20 C
Mg 1 Zn 0 'Soltani'	1.15 A	0.01B	0.47 AB	0.62 A	0.04 AB	57 A	9 A	7 C	2.7 A	21BC
Mg 1 Zn 0 'Ghezel'	1.12 A	0.04 B	0.49 AB	0.68 A	0.03 B	58 A	9 A	7 C	2.6 A	21B
Mg 1 Zn 1 'Sahebi'	1.15 A	0.08 A	0.44 B	0.66 A	0.02 B	56 AB	9A	8 B	2.5 A	22 B
Mg 1 Zn 1 'Soltani'	1.10 A	0.06AB	0.45 B	0.62 A	0.05 AB	55 AB	9A	8 B	2.7 A	21 BC
Mg 1 Zn 1 'Ghezel'	1.10 A	0.07 AB	0.42 B	0.60 A	0.03 B	56 AB	9 A	8 B	2.9 A	23 AB
Mg 1 Zn 2 'Sahebi'	1.11 A	0.09 A	0.43 B	0.62 A	0.02 B	57 A	9A	9 A	2.6 A	20 C
Mg 1 Zn 2 'Soltani'	1.12 A	0.09 A	0.43 B	0.60 A	0.05 AB	56 A	9 A	9 A	2.7 A	21 BC
Mg 1 Zn 2 'Ghezel'	1.10 A	0.05 AB	0.42 B	0.60 A	0.04 AB	55 AB	9A	10 A	2.8 A	22 B
Mg 2 Zn 0 'Sahebi'	1.15 A	0.05AB	0.45 B	0.42 B	0.06 A	54 B	8 A	7 C	2.5 A	23 AB
Mg 2 Zn 0 'Soltani'	1.21 A	0.09 A	0.41B	0.51 AB	0.08 A	53 B	8 A	7 C	2.4 A	24 A
Mg 2 Zn 0 'Ghezel'	1.23 A	0.09 A	0.42 B	0.6 B	0.08 A	52 B	8 A	7 C	2.3 A	21 BC
Mg 2 Zn 1 'Sahebi'	1.14 A	0.09 A	0.43 B	0.5 B	0.09 A	53 B	8 A	8 B	2.2 A	22 B
Mg 2 Zn 1 'Soltani'	1.18 A	0.08 A	0.45 B	0.6 B	0.08 A	52 B	9 A	8 B	2.1 A	22 AB
Mg 2 Zn 1 'Ghezel'	1.18 A	0.08 A	0.46 B	0.5 B	0.01B	53 B	9A	8 B	2.2 A	23 AB
Mg 2 Zn 2 'Sahebi'	1.05 A	0.06AB	0.42 B	0.5 B	0.1 A	53 B	8 A	9 A	2.3 A	22 B
Mg 2 Zn 2 'Soltani'	1.04 A	0.07 AB	0.43 B	0.5 B	0.1 A	52 B	8 A	9 A	2.2 A	22 B
Mg 2 Zn 2 'Ghezel'	1.01A	0.08 A	0.41B	0.4 B	0.1A	53 B	9 A	10 A	2.3 A	21 BC

\* The average values that are followed by the same letters are significantly the same at 5% level (as tested by multi range Duncan test)

enzymatic activities of fructose-1 and 6- bis phosphatase, causing increased sugar synthesis in the grape). In view to the fact that the levels of Mg in the soils where the experiments have been conducted are low, the foliar application of Mg solution has increased the translocation of synthesized materials of the photosynthesis from the leaf to the grape fruit (Malakouti, 2006).

With the increase in the amount of Zn applied, the sugar content in the three grape cultivars increased significantly, which is a possible result of the increase in the enzymatic activities of fructose-1 and 6- bis phosphatase. On the other hand, the aldolase enzymes will increase along with the sufficient availability of Zn, contributing to an accelerated sugar synthesis. With the increase in the concentration of Zn in leaves of the grape cultivars tested, the level of carbonic anhydrase and net photosynthesis were increased and contributed to an increase in the level of solids content in the syrup obtained from the grapes. With the increase of Zn levels, the amount of P in the leaves of the three grape cultivars decreased, which is mainly due to dilution and their antagonistic effects. Zn, in a probable reaction with R-SH group of the membrane proteins, causes the membrane firmness in cultivars with high zinc

contents, thereby significantly improving their storability characteristics, which correspond with the findings of Marschner (1995) and Malakouti (2006).

Statistical analysis indicated that, in addition to yield increase, the concentration of Mg and Zn in grapes had significantly increased with treatments, which corresponds with the findings of Malakouti *et al.* (2004). Changing the conventional fertilization practices of grape growers (mostly N, P and sometimes K-fertilizers) is very difficult and time consuming and the cost of Mg and Zn sulphate is very high (The fertilizer subsidy is given only to N, P, and K-fertilizers). Therefore, currently, due to economic reasons, the foliar application of Mg and Zn-fertilizers is an appropriate method. Besides, by foliar application, in addition to yield increase, the quality of grapes, especially the sugar percentage, Mg and Zn concentrations in the grape increased, which is important for human health promotion. However, by the foliar application of magnesium sulphate, we could not obtain an appropriate K/Mg ratio (5.0-7.0), which means foliar application of Mg solution by itself was not enough to decrease K/Mg ratio. Therefore, combination of soil and foliar applications are to be recommended. In other words, soil and foliar applications

of magnesium sulphate is necessary for lowering K/Mg ratio in deficient soils.

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