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# Effect of foliar chelated forms spraying on grape yield and mineral status of shoots

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**Abstract:** The aim of this study was to evaluate the foliar chelated forms of Mg and Fe, on grape yield and mineral status of the shoots of vine cultivar Cardinal. Field trials were organized using a random block system with three variants, including a control (Variant I), each replicated three times. Foliar fertilizers were applied at a concentration of 0.5% on four occasions throughout the vegetation period: before and after blooming, during buckshot berry stage, and at the verasion stage. Over the ivestigation of three years, the application of foliar Mg and Fe fertilizers significantly influenced grape yield. The variant treated with Fe (VFe) demonstrated a higher average yield of 14.87 t/ha. Furthermore, a noticeable impact of foliar fertilizers on the concentration of analyzed elements in grapevine shoots was observed. Over the three-year period, the average content of macro elements, including nitrogen, phosphorus, calcium, magnesium, and iron, was higher in the treated variants compared to the control. Additionally, results from shoot tissue analysis confirmed the existence of an antagonistic relationship between magnesium and potassium.

**Key words**: grape; Cardinal; foliar; chelated; shoot; elements

## INTRODUCTION

Foliar fertilization is an important method for improving vegetative growth and production through a better understanding of the physiological behavior of the vine and it is response to various horticultural practices. Foliar fertilization offers numerous advantages, notably its ability to address nutrient deficiencies more rapidly compared to soil application (Fageria et al., 2009). It is versatile, proving effective for both macro and micronutrients, particularly benefiting low-mobile elements in arid soils with limited root growth (Alshaal & El-Ramady, 2017). Additionally, it presents opportunities for integrating nutrient supply with other agrochemicals like herbicides, fungicides, and insecticides, leading to savings in labor, machinery, and energy costs (Gooding & Davies, 1992).

Extensive research indicates that applying chelated fertilizers through foliar spraying reduces the total fertilizer requirement while enhancing fertilizer efficiency. Employing foliar fertilization following soil application proves effective in augmenting trace element levels in crops, thus boosting crop yield and enhancing soil conditions. However, the use of inorganic foliar fertilizers poses challenges in nutrient absorption and mobility within plants. Chelated foliar fertilizers emerge as a solution, enhancing element utilization efficiency, crop yield, and overall quality. (Niu et al., 2021).

Managing and understanding grapevine nutrition can be a daunting task. Mineral nutrients are important to the entire vine as they play vital roles in plant biochemistry. An effective vineyard fertility program is developed from site-based information, including records of fertilizer and irrigation inputs, plant growth assessments, yield data, and plant tissue and soil test results. The significance and intricacy of monitoring vineyard mineral nutrition have grown with the expansion of vineyards into diverse sites and varying scion-rootstock combinations. While tissue analysis remains the predominant laboratory technique for this purpose, effective monitoring demands integration of multiple sources of information. This includes data on soil chemical and physical characteristics, analysis of irrigation water, understanding rootstock and variety requirements, historical fertilizer applications, and observations of vine growth. (Christensen, 2002).

Magnesium (Mg) serves as a vital macronutrient in plants, playing a crucial role in various physiological functions, particularly in photosynthesis. Mg chlorosis can arise from Mg deficiency, elevated soil calcium levels (commonly found in calcareous soils), or a combination of these factors (Gluhić et al., 2009). The plant's uptake of magnesium is further influenced by the antagonistic interaction between calcium and potassium. This was highlighted by Garcia et al. (1999), who observed a notable reduction in magnesium levels in grape berries grown in soils with high calcium content, accompanied by an increase in total acid content. Furthermore, Skinner & Matthews (2006) documented instances of magnesium deficiency in vineyards characterized by low soil pH values and insufficient phosphorus content.

Iron is an essential micronutrient for the growth and development of wine grapes. The application of iron is to ensure the growth of the grapes and to enrich the flavor combination of the grapes (Karimi et al., 2019). Under alkaline soil conditions, application of chelated iron can significantly increase the content of soluble sugar and phenolic acid in grape fruit. Iron (Fe) deficiency is a worldwide problem in fruit production in calcareous or alkaline soils. And about one-third of the total land area contains calcium carbonate (Álvarez-Fernández et al., 2011). Several fruit trees including grapevines can be affected by Fe deficiency in calcareous soils.

The objective of this study was to assess the impact of foliar spraying with magnesium and iron on yield and shoots nutrient composition of Cardinal vine in the Tikvesh region of North Macedonia.

## MATERIAL AND METHODS

### *Test materials and experimental design*

The test was carried out in the Tikvesh region, which is one of the biggest viticulture regions in the North Macedonia (y = 7579308.70; x = 4591465.91). The field trial was carried out during the 2012-2014 period, on grape vines belonging to the Cardinal variety, which is most proven red table grapes early and mostly growing in the Tikvesh region, with average yield from 15 to 20 t/ha.

Field trials has been organised according the method of randomized complete block design, with three replications for each of the fertilization variants plus the control variant. The treated vines were 25 years old, planted at 2.80 x 1.10 m spacing, with a total 3247 vine/ha, with a "2-cordon" pruning system.

The favorable and harmonious climate coupled with dynamic soil and geographic conditions makes this region agro-ecologically suitable for growing many vine varieties with different periods of ripening. The climate in the southern part of the valley is under the influence of a modified Mediterranean climate characterized with long and hot summers, while the northern part of the region is under the influence of a continental climate with mild and wet winters.

The predominant soil type in the region is Rendzinic soil, formed on recent Pliocene sediments. Soil samples were collected during 2012 (before vegetation) and 2014 (after harvest) at three depths. Each soil sample was air-dried, lightly ground and sieved in the accredited laboratory at the Institute of agriculture – Skopje, North Macedonia. Standardized laboratory methods were used to test the basic chemical soil properties: pH value - 1:2,5 (v/v) soil and $H_2O$, with a glass electrode; free $CaCO_3$ by the volumetric method; active lime (CaO) by Drouineau & Galet method; total nitrogen (N) by Tjurin method; available forms of phosphorus ($P_2O_5$) and potassium ($K_2O$) by the AL method, according to Egner-Riehm; available form of magnesium (Mg) by the ammonium acetate solution and available form of iron (Fe) by DTPA.

During the research period, standard commercial agro-technical practices were implemented in the vineyard. Soil tillage and soil fertilization with mineral fertilizers were performed each year in the autumn with 350kg/ha NPK 8-16-24 and during the spring, with 100 kg/ha ammonium nitrate of 33%. Irrigation with furrows was performed 2-3 times during the summer period and plant protection 5-6 times during the vegetation season. The monitored variants are presented in Table 2.

***Data collection and shoots analysis***

✓ Total yield was determined by assessing the number of clusters and their respective weights per vine.

✓ For plant analysis, shoot samples were collected annually post-harvest. The shoots underwent a gentle washing process, followed by drying at room temperature and fine grinding. The analyzed elements (Mg and Fe) in the plant tissue were quantified using the ISP-AES technique subsequent to digestion in a Heating Digester DK 20 with concentrated $HNO_3$ + $H_2O_2$. (Cvetković, 2002).

***Statistical analysis***

The analysis of variance was conducted using SPSS 20.0 software.

## RESULTS AND DISCUSSION

***Effect on grape yield***

The effect of the foliar applications on the grape yield was given in Table 3. It can be inferred that the various types of fertilizers applied exerted a positive influence, evident even in the

**Table 1.** Soil properties

| Depth | pH/ $H_2O$ | $CaCO_3$ | Active lime (CaO) | Total N | Available $P_2O_5$ | Available $K_2O$ | Available Mg | Available Fe |
|---|---|---|---|---|---|---|---|---|
| cm | | % | | | mg/100g soil | | mg/kg | |
| 0-30 | 8.06 | 17.33 | 5.50 | 0.13 | 22.10 | 22.52 | 422.46 | 4.58 |
| ***classification*** | *moderately alkaline* | *high* | *low* | *optimum* | *optimum* | | *optimum* | *medium* |
| 30-50 | 8.09 | 17.28 | 2.00 | 0.11 | 19.22 | 21.46 | 422.73 | 3.95 |
| ***classification*** | *moderately alkaline* | *high* | *low* | *optimum* | *optimum* | | *optimum* | *medium* |
| 50-80 | 8.10 | 18.53 | 3.50 | 0.10 | 16.05 | 19.65 | 448.66 | 3.27 |
| ***classification*** | *moderately alkaline* | *high* | *low* | *optimum* | *optimum* | | *optimum* | *medium* |

*Note: classification according method*

**Table 2**. Foliar treatments applied to grapevines

| Variant | Type of foliar fertilizer | Solution concentration, % | Morning applying during the period |
|---|---|---|---|
| Control | - | - | |
| VMg | Magni mag helat Mg EDTA (1,5 % Mg + 24,14 % $MgK_2$ EDTA + 9,89 % $NH_4NO_3$) | 0.5 | ✓ before blooming;<br>✓ after blooming;<br>✓ buckshot berries;<br>✓ verasion; |
| VFe | Magni fer helat Fe EDTA (3,2 % Fe + 22 % FeK EDTA + 9,18 %.$NH_4Cl$) | | |

initial year of the study, when compared to the control variant. The results indicated that all tested fertilization methods resulted in higher yields than the variant without foliar fertilization (control), which exhibited the lowest average yield at 4.18 kg per vine (13.59 t/ha). Notably, variant VFe demonstrated the highest average yield at 4.58 kg per vine or 14.87 t/ha. As noted by Bozinović (2010), fruit yields are subject to fluctuations from year to year and across vineyards due to varying environmental conditions and management practices, a trend reflected in our findings. Grape yield exhibited significant variability in the third year of the study, notably decreasing compared to preceding years. The adverse impact of excessive precipitation, particularly heavy rainfall in April (135.8 mm) during bud opening and shoot growth, and in September (124.0 mm) during the peak harvest period, warrants attention. Unfavorable weather conditions in May 2014, characterized by hailstorms early in the growing season and an outbreak of Plasmopara viticola, significantly contributed to the diminished grape yield that year, which was markedly lower compared to the two preceding growing seasons (2012/2013). Despite the challenges posed by adverse weather conditions in 2014, foliar application in treated variants demonstrated positive effects on grape yield in these instances. Varietal differences may be attributed to the roles of magnesium and iron in chlorophyll molecules, directly impacting photosynthesis and indirectly enhancing resilience against hail damage and resistance to infections.

Our findings align with those of other researchers who have observed the positive impact of foliar treatments on grape yield and its associated parameters. For instance, Zatloukalová et al. (2011) reported a 3.1-6.7% increase in yields of cv. Riesling italic following repeated foliar applications of 5% solutions of the fertilizers Epso Top (9.65% Mg, 13% S) and Epso combitop (7.8% Mg, 13% S, 4% Mn, and 1% Zn). Similar result was obtained by Al-Atrushy (2019). During the two seasons, author investigates the effect of three concentrations (0, 50 and 100 $mg.L^{-1}$) of micronutrients (Fe, Zn and Mn) and note that the $yield.vine^{-1}$ was significantly increased by increasing micronutrient concentration. Likewise, the highest $yield.vine^{-1}$ was obtained by application of 100 $mg.L^{-1}$ of micronutrient (21.80 and 24.40 $kg.vine^{-1}$) in the two seasons, respectively. According to the research results by Davarkhah & Kavoosi (2017), the application of Ferozinc fertilizer at concentration of 1000 ppm before and after flowering on the table grape cv. Khoshnaw, is recommended to improve the quantitative and qualitative characteristics under irrigation conditions. Noted results showed that the effects of

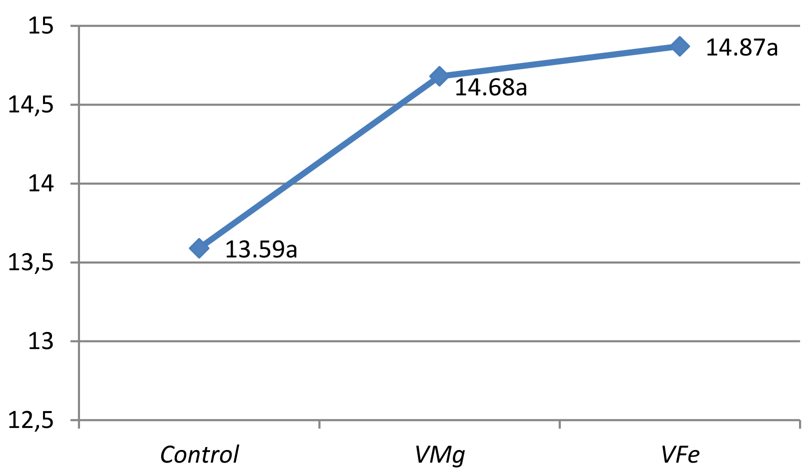


**Figure 1.** Grape yield 2012/2014 (t/ha)

** Significant differences among treatments are denoted by different letters (e.g., a, b, c...).*

Ferozinc fertilizer application were significant ($p \leq 0.01$) on the average of bunch weight, average of fruit weight per bunch, and other parameters. The highest cluster weight (220.222 gr), average fruit weight per cluster (215.887 gr), TSS/TA ratio (31.29), pH (3.68) and vitamin C (2.849 mg/100 cc fruit juice) were obtained in the treatment containing 1000 mg/l Ferozinc fertilizer and both application times (before and after flowering).

***Mineral status of grape shoots***

It is clear from data for mineral status of grape shoots Spraying grapevine plants four times per season with 0.5% solutions of Mg and Fe led to an increase in nitrogen content in the shoots, only (Table 4).

During the research period, treated variants have the significantly higher concentration of nitrogen (1.20 to 1.33 %) compared with control variant (1.10-1.13%). According to the literature sources, the nitrogen content in the shoots varies depending on the variety, the period of sampling, mineral fertilization, soil conditions, etc. The nitrogen content in the shoots is highest at the beginning of the vegetation session (2.25%) and decreasing to the end of the vegetation, when it is 0.7% (Burić & Mijović, 1994). During the research, Licul (1985) states that the nitrogen content of shoots ranges from 0.4 to 1 %. Similar results are noted by Licina (1994) who found 0.46% nitrogen in the vine shoots. The higher content of nitrogen in our research, at all variants compared with Licul and Licina, is probably results of the optimal nutrition of the shoots with nitrogen due to the spring feeding with nitrogen fertilizer through the soil.

The presented results indicate that foliar treatments had no impact on the phosphorus (P) status of the shoots, as all variants exhibited similar concentrations of this macro element throughout the entire period (0.13-0.17%). Our results are not obtained with results by Burić (1979), Dzamić & Nikolić (1994), Licina (1994) and Stojanova (2001), who noted the higher concentration of P. Burić (1979) noted 0.28% P, which is also confirmed by the data from Dzamić & Nikolić (1994), according to which the content of phosphorus in the shoots is 0.31%. During the investigation with foliar treatments with Urea 46% and Magnifert (8:4:8:1+ME) at cv. Chardonnay and Riesling Italian, Stojanova (2001) noted the average content from 0.21 % to 0.39 % of phosphorus at treated variants. Licina (1994), identified significantly higher concentration of phosphorus, from 0.64% at cv. Riesling Italian shoots. The reason for different concentration of this macro element in grape shoot maybe is the type of soil (calcareous type in our investigation) and the level of phosphorus in soil. In most calcareous soils, plants suffer from low availability of nutrients, including phosphorus. Limited availability of P in these soils is also a major limiting factor for plant growth (Samal & Kumar, 2020).

Results for potassium content, confirmed the influence between potassium and magnesium. Concentration of potassium in grape shoots was between 0.45 and 0.52%. The lowest concentration was noted at variant VMg, where magnesium fertilizer significantly decreased K content. The content of this element decreased consistently throughout the research period, likely due to the antagonistic relationships between these elements. The content of potassium in the grapevine shoots usually ranges from 0.3% to 1.2% (Stojanova, 2001), although sometimes different data can be found in the literature, i.e. lower or higher values than stated. So, according to Kozina (1999), potassium content in maturity shoots is between 0.58-0.91%. Markovic et al. (2011) in their three-year study followed the distribution of potassium in grapevine shoots. The results showed that the values of potassium in the shoots, regardless of the year of research, statistically significantly increase in accordance with the amount of applied potassium, of 0.58-1.25 %.

Spraying grapevine plants four times per season with 0.5% Mg solution led to an increase in calcium (Ca) content in the shoots. Interestingly, variant VMg exhibited a significantly higher concentration of this element, ranging from 0.95% to 1.00% Ca throughout the research period. These findings contradict many previous studies that suggest an antagonistic relationship between magnesium and calcium. However, our analyses revealed a significant reduction in the uptake of calcium cations by leaves with an increase in the intensity of plant nutrition with magnesium. This phenomenon may be attributed to the higher concentration of CaCO3 in carbonate soils, where calcium accounts for more than 80% while magnesium comprises only 4%. Additionally, optimal levels of calcium in the analyzed material, even in the control variant, and the process of calcium reutilization in plants (once translocated into the leaves, calcium is practically immobile) may have contributed to these unexpected results. Results for calcium content from this research are similar with results by Stojanova (2001), who reported that grapevine shoots at cv. Riesling Italian content from 0.83 to 1.12 %Ca.

Due to main components of Mg and Fe in the foliar fertilizers used in our research, significant influence of magnesium and iron content as elements in grapevine shoots is obviously (Table 4).

The concentration range is between 0.12 at control variant and 0.17% at variant treated with Mg, which is correspondence with previously results. Vukadinović & Lonćarić (1998), note that magnesium concentration in plants ranges from 0.1% to 1% on average, and with good supply the content ranges from 0.15% to 0.35% in dry matter. Because carbonate soils possess unfavorable physical and chemical properties and magnesium plays a vital role in chlorophyll production, foliar application of magnesium offers significant advantages over root (soil) application (Takacs-Hajos et al., 2007). Foliar spraying with fertilizers containing magnesium is a widespread practice to address nutrient imbalances in grapevines. However, it's worth noting that magnesium doses exceeding those necessary for maximum yield seldom result in further improvements in product quality (Gerendás & Führs, 2013).

The application of Fe chelate during the research period led to a significant increase in iron

**Table 3.** Grape yield

| Year | 2012 | | 2013 | | 2014 | | 2012/2014 | |
|---|---|---|---|---|---|---|---|---|
| Variant | kg/vine | t/ha | kg/vine | t/ha | kg/vine | t/ha | kg/vine | t/ha |
| Control | 4.90 | 15.89$^{a}$ | 4.94 | 16.03$^{a}$ | 2.72 | 8.83$^{a}$ | 4.18 | 13.59$^{a}$ |
| VMg | 5.50 | 17.87$^{a}$ | 5.04 | 16.35$^{a}$ | 3.03 | 9.84$^{a}$ | 4.52 | 14.68$^{a}$ |
| VFe | 5.40 | 17.54$^{a}$ | 5.43 | 17.63$^{a}$ | 2.91 | 9.44$^{a}$ | 4.58 | 14.87$^{a}$ |

** Significant differences among treatments are denoted by different letters (e.g., a, b, c...).*

**Table 4.** Effect of foliar chelated magnesium and iron application on macro and microelements content on grape shoots of cv. Cardinal grapevines at seasons 2012-2014

| Year | 2012 | | | 2013 | | | 2014 | | | 2012/2014 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variant | Control | VMg | VFe | Control | VMg | VFe | Control | VMg | VFe | Control | VMg | VFe |
| Element | | | | | | | | | | | | |
| N (%) | 1.12$^{b}$ | 1.33$^{a}$ | 1.31$^{a}$ | 1.10$^{b}$ | 1.32$^{a}$ | 1.30$^{a}$ | 1.13$^{b}$ | 1.20$^{a}$ | 1.21$^{a}$ | 1.12$^{b}$ | 1.28$^{a}$ | 1.27$^{a}$ |
| P (%) | 0.15$^{a}$ | 0.15$^{a}$ | 0.16$^{a}$ | 0.14$^{a}$ | 0.16$^{a}$ | 0.17$^{a}$ | 0.13$^{a}$ | 0.14$^{a}$ | 0.14$^{a}$ | 0.14$^{a}$ | 0.15$^{a}$ | 0.16$^{a}$ |
| K (%) | 0.57$^{a}$ | 0.4$^{b}$ | 0.5$^{a}$ | 0.50$^{a}$ | 0.41$^{b}$ | 0.50$^{a}$ | 0.45$^{a}$ | 0.47$^{a}$ | 0.49$^{a}$ | 0.51$^{a}$ | 0.45$^{b}$ | 0.52$^{a}$ |
| Ca (%) | 0.93$^{a}$ | 0.95$^{a}$ | 0.89$^{a}$ | 0.91$^{a}$ | 1.00$^{a}$ | 0.81$^{b}$ | 0.93$^{a}$ | 1.00$^{a}$ | 0.94$^{a}$ | 0.92$^{ab}$ | 0.98$^{a}$ | 0.88$^{b}$ |
| Mg (%) | 0.14$^{ab}$ | 0.15$^{a}$ | 0.13$^{b}$ | 0.09$^{c}$ | 0.17$^{a}$ | 0.15$^{b}$ | 0.11$^{c}$ | 0.18$^{a}$ | 0.14$^{b}$ | 0.12$^{c}$ | 0.17$^{a}$ | 0.14$^{b}$ |
| Fe (ppm) | 50.78$^{b}$ | 49.67$^{b}$ | 72.39$^{a}$ | 61.61$^{b}$ | 62.17$^{b}$ | 77.63$^{a}$ | 48.76$^{c}$ | 63.26$^{b}$ | 87.71$^{a}$ | 53.72$^{b}$ | 58.37$^{b}$ | 79.24$^{a}$ |

** Significant differences among treatments are denoted by different letters (e.g., a, b, c...).*

content, which fell within optimal ranges as outlined by Sarić et al. (1991). According to these authors, iron content in plant dry matter typically ranges from 50 to 200 ppm. Our findings align with those of other researchers. For instance, the iron content in grapevine shoots has been reported as 70 ppm by Licina (1994), 196 ppm by Kozina (1999), and in the range of 116 ppm to 130 ppm by Stojanova (2001). Iron deficiency, also known as iron chlorosis, in fruit trees stems from impaired acquisition and utilization of the metal by plants rather than a low level of iron in soils. Consequently, iron fertilizers, whether incorporated into the soil or applied foliarly, are utilized annually to mitigate iron deficiency (Abadía et al., 2011).

## CONCLUSIONS

The application of magnesium and iron sprays had significant effects on the fruit yield and mineral status of grape shoots in cv. Cardinal. Even in the first year of the study, different types of applied fertilizers demonstrated a positive influence compared to the control variant. Results indicated that all tested fertilization methods yielded higher results than the variant without foliar fertilization (control), which had the lowest average yield at 4.18 kg per vine (13.59 t/ha). Notably, variant VFe exhibited the highest average yield of 4.58 kg per vine or 14.87 t/ha. Over the three-year period, the average content of macro elements, such as nitrogen, phosphorus, calcium, magnesium and iron, showed higher levels, indicating the efficacy of the fertilization methods. The spraying grapevine plants four times per season with Mg and Fe, significantly increased content of nitrogen in shoots, only. Results of shoot tissue confirmed antagonistic relation between magnesium and potassium, during the research period.

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