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Macro- and Micronutrient Content in Grapevine Cordons under the Influence of Organic and Mineral Fertilization

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Abstract. The vigour of vine cordons, wood maturation and bud viability are dependent on the nutritional status of the vine during the vegetation season. We analysed the nutrient content of cordons to assess the effect of the fertilization system used in the previous year. We performed fertilization with organic fertilizers (manure in doses of 30, 40 and 50 t / ha) and complex NPK fertilizers of the type (S) + Zn. We determined the content of primary macronutrients (NPK) and secondary macronutrients (Ca and Mg) and some micronutrients (Fe, Cu, Zn, Mn). With organic fertilization, macronutrient content ranges from 0.556 to 0.707% N_{tot}, 1.30 to 2.06% P_2O_5, 0.73 to 1.7% K_2O, the values being positively correlated with the dose of fertilizer. Secondary macronutrients were identified in grape vine cordons in values that range from 2.64 to 2.83% Ca, positively correlated with the dose of fertilizer, and from 1172 to 1010 ppm Mg, the content of which is negatively correlated with the dose of fertilizer. Fe and Cu contents are relatively constant under the influence of organic fertilization, while the values of Mn and Zn increase, depending on the dose of fertilization, ranging from 2.120 to 2.570 ppm Mn and 5.570 to 7.58 ppm Zn. With mineral fertilization, primary macronutrients are present in the wine cordons in quantities of 0.504 to 0.646% N_{tot}, 0.470-1.630% P_2O_5 and 0.570-0.680% K_2O. Values correlate positively with the dose of mineral fertilizers. Secondary macronutrient content ranges from 1.770 to 2.780% Ca, 783.00 to 2119.00 ppm Mg. The content of microelements fluctuates, the values of Fe and Cu being positively correlated with the dose of mineral fertilizers.

Keywords: grapevine cordon, macronutrients, micronutrients, organic and mineral fertilization

INTRODUCTION

Nutrition is a key component in the management of viticulture production, winemaking and sustainable exploitation of viticulture ecosystems, (Dobrei *et al*. 2009, Fourie *et al*. 2007, Grapevine Nutrition, 2006 (26),Romic *et al*. 2012).

Grapevine is a species that has high requirements as to its nutrition medium, its nutritional value proving essential. For a yield of 1 t/acre, IFA World Fertilizer Use Manual (1992) (27, 28) reports a consumption (in pound/acre) of 6.8 N, 2.8 P_2O_5, 12 K_2O, 11.8 Ca, 1.2 Mg, 0.003 B, 0.052 Cu, 0.004 Mn, 0.009 Zn, 0.2 Fe (27, 28).

A great number of studies, performed in different soil and climate conditions, on different varieties, have emphasized the dynamics and the part that micronutrients and macronutrients play in grapevine growth and development and in the quality of wine products, (Conradie 1981, Conradie and Saayman 1989, Dundon *et al.* 1984, Garcia *et al*. 1999, Mathilde Knoll *et al*. 2006, Saayman and Conradie 1982, Usha and Singh 2002).

Elements such as nitrogen, phosphorus, potassium, magnesium, boron, zinc, manganese, iron and copper play an important part in grapevine metabolism for growth processes, fruit development and quality, (Ashley Rachel, 2011).

Primary macronutrients have different contributions: nitrogen acts in vegetative growth and has moderate implications on yield; phosphorus helps in fruiting and potassium is responsible for the quality of the fruit, for the balance in the ratio sugar/acidity and for increasing grapevine resistance to environmental factors. Although grapevine nitrogen requirement is limited, in moderate quantities (100 g N/stock) nitrogen determined an increase in foliar surface, bud density on cordons (leaf number), having positive implications on vegetation and yield, (Bell and Robson 1999, Conradie and Saayman 1989).

Phosphorus is important in grapevine nutrition; it is therefore necessary to provide optimal supply of available phosphorus in the two periods of major consumption: three to four weeks after budburst and after harvest until the leaves fall, a period of approximately four weeks, (CRCV 2006, 26). In this second period of major phosphorus consumption, the influence of this element will play a crucial role in the formation and maturation of buds and cordons.

In what the secondary macronutrients are concerned, calcium is one of the elements with a structural role, it being directly involved in the pectin cellulose structure, while magnesium is a component of chlorophyll, being directly involved in the synthetic activity. The requirements of the cultivated varieties are different from the necessary secondary macronutrients, the ratio K/(Ca+Mg) being important for the nutrition balance, (Capps 1999, Lambert *et al*. 2008, Shaahan *et al*. 1999, Rogiers *et al*. 2000).

The participation of micronutrients in grapevine nutrition has been studied a lot recently, because of their importance in various metabolic processes, enzymatic processes and also processes that determine the quality of viticulture products, (Lai *et al*. 2010, Magalães *et al*. 1985, Toselli *et al*. 2009, Usha and Singh 2002 ,).

The nutritive balance given particularly by the weight of certain micronutrients with a key role (Mg/K, Mg/P and others) is also extremely important for balanced nutrition; various ratios have been described between micro- and macronutrients in grapevine leaves, (Skinner and Matthews 1990).

The studies on the mineral content of grapevine cordons are not very numerous. Most approaches focus on the nutrient content in the petiole in the vegetation period, in the standard phenophases for testing the nutrition status, (Bertoni and Morard 1983, Wolpert *et al.* 2005). Some studies (29, 30) refer to the period of high consumption after harvest until the leaves fall, when most nutriments contribute to the invigoration of the grapevine stock, accumulation of reserve substances in cordons and dormant buds and maturation of the wood in the cordons, which gives better resistance for the period of vegetative break and a good start for the new yield cycle. Other studies and research focused on the mineral content in grapes and must, because of their importance in the quality of must and wine, (Brancadoro *et al*. 1994, Daniela Bertoldi *et al*. 2011).

We believed necessary and interesting to study the accumulation of minerals in grapevine cordons, because, on the one hand nutrients contribute to cordon growth and maturation, formation and development of dormant buds and their quality for a new vegetative cycle. On the other hand, pruning for fruit production and removing cordons is a way to lose a significant quantity of nutriments, which is an important aspect in the count of nutriments in a viticulture agroecosystem.

MATERIAL AND METHODS

The research was conducted at the Tree and grapevine plantation in Timisoara Didactic Station. The physical and chemical characteristics describe a soil with medium fertility, pH_{water} = 6.71, H = 2.76%, P_{mobile} = 110 ppm, K_{mobile} = 301 ppm, Mg = 4275 ppm. Micronutrients are present in average quantities of: 12.46 ppm Fe, 57.09 ppm Cu, 860.00 ppm Mn, 73.44 ppm Zn.

The biologic material was represented by ' Burgund ' variety.

The experimental variants were performed via two types of fertilization: organic and mineral. For the organic fertilization, we used manure (M) in three doses (M_{30}, M_{40} and M_{50} t/ha). Mineral fertilization was supplied by complex NPK fertilizer (S) with zinc [15/15/15(+3+Zn)] applied in doses NPK_{50}, NPK_{100} and NPK_{150} kg active substance/ha.

We studied the mineral content in grapevine cordons at spring pruning for fruit, as a result of organic and mineral fertilization.

The determination of macronutrients and micronutrients was made employing specific laboratory methods: total nitrogen was determined by the method Kjehdal (wet digestion with sulfuric acid followed by distillation); total phosphorus was determined by colorimetric method with ammonium molybdate solution; potassium, calcium and trace elements were determined by the flame photometric method (atomic absorption spectroscopy).

The data obtained were processed with adequate statistic methods. We assessed the influence of fertilizers on the micro- and macronutrients in cordons, the degree of independence of the elements, through multiple correlations, such as the balance ratio between them.

RESULTS AND DISCUSSIONS

The macro- and micronutrient content in mature (lignified) cordons is directly influenced by the type and dose of the fertilizer and by the conditions of nutrition and vegetation. The results we obtained are presented in Tab. 1. The two types of fertilization, organic and mineral, determine a differentiated accumulation of macronutrients and micronutrients in grapevine cordons.

Tab. 1

Macro- and micronutrient content in grapevine cordons, ' Burgund ' variety, under organic and mineral fertilization in the conditions at Timisoara Didactic Station, (average values 2011 – 2012)

Element / Variant	N_{tot}	P_2O_5	K_2O	CaO	Mg	Fe	Cu	Mn	Zn
	(%)	(%)	(%)	(%)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Mt	0.50±0.03	0.47±0.21	0.57±0.17	1.87±0.11	1472.00±188.90	21.43±1.54	1.16±0.11	0.83±0.88	1.46±0.99
M 30t/ha	0.55±0.03	1.09±0.21	0.73±0.17	2.64±0.11	1172.00±188.90	26.54±1.54	2.11±0.11	2.12±0.88	5.57±0.99
M 40t/ha	0.67±0.03	1.42±0.21	1.10±0.17	2.76±0.11	1086.00±188.90	28.22±1.54	2.16±0.11	2.49±0.88	6.82±0.99
M 50 t/ha	0.70±0.03	2.06±0.21	1.70±0.17	2.83±0.11	1010.00±188.90	27.16±1.54	2.11±0.11	2.57±0.88	7.58±0.99
NPK 50 kg a.s./ha	0.51±0.03	0.58±0.21	0.57±0.17	2.07±0.11	783.00±188.90	25.34±1.54	1.72±0.11	1.61±0.88	2.51±0.99
NPK 100 kg a.s./ha	0.54±0.03	0.83±0.21	0.63±0.17	2.53±0.11	1332.00±188.90	31.03±1.54	2.34±0.11	4.88±0.88	5.40±0.99
NPK 150 kg a.s./ha	0.64±0.03	1.36±0.21	0.78±0.17	2.78±0.11	2119.00±188.90	35.61±1.54	2.56±0.11	7.25±0.88	9.74±0.99

Nitrogen was identified in grapevine cordons in quantities ranging from 0.504 % N_{tot} for the control variant and 0.707 % N_{tot} for organic fertilization M_{50} t/ha, tab. 1., fig. 1. With organic fertilization we recorded the accumulation of a larger quantity of nitrogen in cordons (0.556 – 0.707 % N_{tot}) as compared to mineral fertilization (0.516 – 0.646 % N_{tot}). Soil natural fertility ensures the accumulation of a content of 0.541 % N_{tot} in cordons.

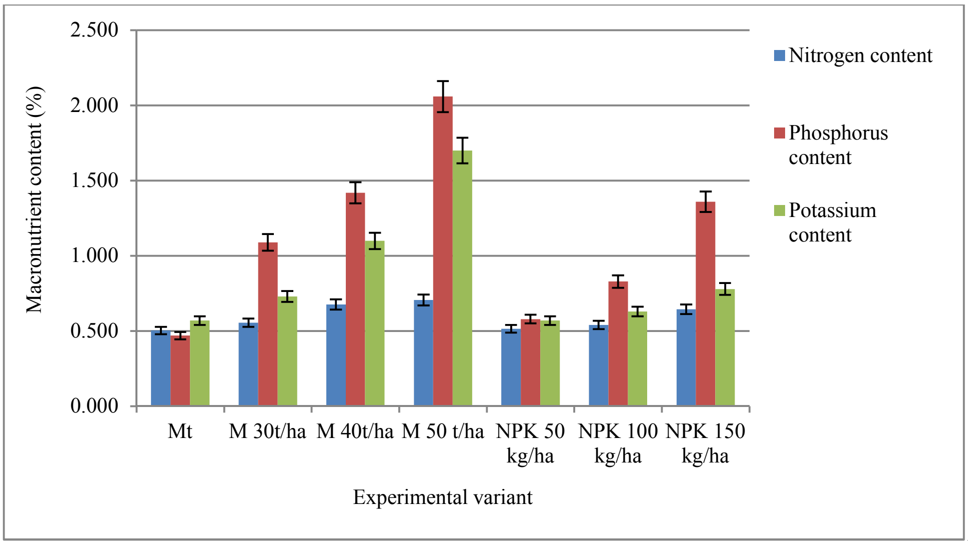

Fig.1. Variation of the macronutrient content in grapevine cordons, ‘ Burgund ’ variety, in relation to the type and dose of fertilizer.

Phosphorus is present in grapevine cordons in quantities ranging from 0.470 % P_2O_5 for the control variant and 2.060% P_2O_5 for the variant fertilized with organic fertilizer of the type M_{50} t/ha. The phosphorus content in cordons is larger in the case of organic fertilization (1.090 – 2.060 % P_2O_5) as compared to mineral fertilization (0.580 – 1.360% P_2O_5). Natural soil fertility ensures the accumulation of phosphorus content of 0.470 % P_2O_5 in the cordons.

Potassium is of major importance for grapevine nutrition. It acts as a biocatalyst and is in antagonistic relations with Ca, Mg and Na, as the presence of these ions in large quantities hinders the absorption of potassium. In autumn, before the leaves fall, potassium migrates from leaves to cordons, where it was identified in quantities ranging from 0.570 % K_2O in conditions of natural soil fertility and 1.700 % K_2O in the cordons in the variant with organic fertilization, M_{50} t/ha. Potassium content is higher in the cordons in organic fertilization variants (0.730 – 1.700 % K_2O) as compared to the cordons in the variants with mineral fertilization (0.570 – 0.780 % K_2O).

Calcium is absorbed by plants in an ionic form (Ca^{2+}), slower than other cations. Together with potassium, it is involved in maintaining the water balance in the cells. It is antagonistic to the ions of Al^{2+}, Mg^{2+}, Zn^{2+}, Fe^{2+}, K^+, Na^+, NH_4^+, fighting their harmful action when they are present in excess.

Calcium content in plants, at foliar level, is between 0.5% and 3%, with the value of 0.5% being considered as critical, (Mangel 1969, 2001).

In grapevine cordons, we identified calcium in quantities ranging from 1.870 % Ca for the control variant and 2.830 % Ca in the case of the variant with organic fertilization M_{50} t/ha, tab. 1, fig. 2.

We identified magnesium in quantities that range from 783.00 ppm Mg in cordons in mineral fertilization NPK 50 kg a.s./ha and 2119.00 ppm Mg in the cordons in mineral fertilization NPK 150 kg a.s./ha, table 1, fig. 2. With organic fertilization, magnesium content in cordons is smaller as compared to the mineral fertilization or to the control variant (1010.00 – 1172.00 ppm Mg), the cordons displaying a higher degree of maturation and lignification, thus having better resistance in winter. In the variant with mineral fertilization, magnesium content is between 783.00 and 2119.00 ppm Mg and in the variant with the natural soil fertility, the control variant, 1771.00 ppm Mg.

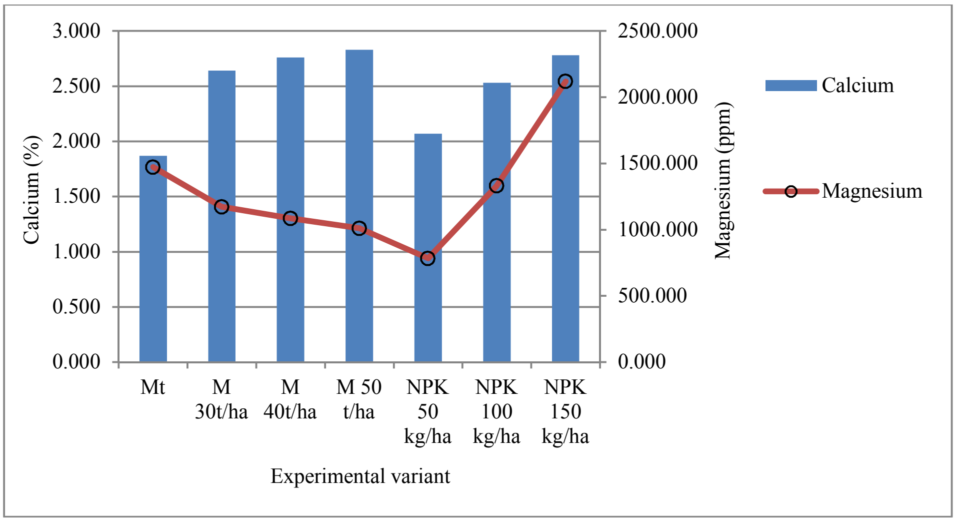

Fig.2. Distribution of Ca and Mg content in grapevine cordons, ‘ Burgund ’ variety, in relation to the type and dose of fertilizer

Iron has major importance in grapevine nutrition. In grapevine cordons, iron was identified in quantities ranging from 25.340 to 35.610 ppm Fe, tab. 1, fig. 3. In the conditions of the natural fertility of the soil, grapevine cordons stored a quantity of iron equal with 21.430 ppm Fe. In the case of organic fertilization, cordons stored iron from 26.540 ppm Fe (in the variant M_{30} t/ha) up to 27.160 ppm Fe (M_{50} t/ha). Mineral fertilization determined iron accumulation in quantities ranging from 25.340 (in the variant NPK_{50}) and 35.610 ppm (in the variant NPK_{150}), higher than the ones in organic fertilization.

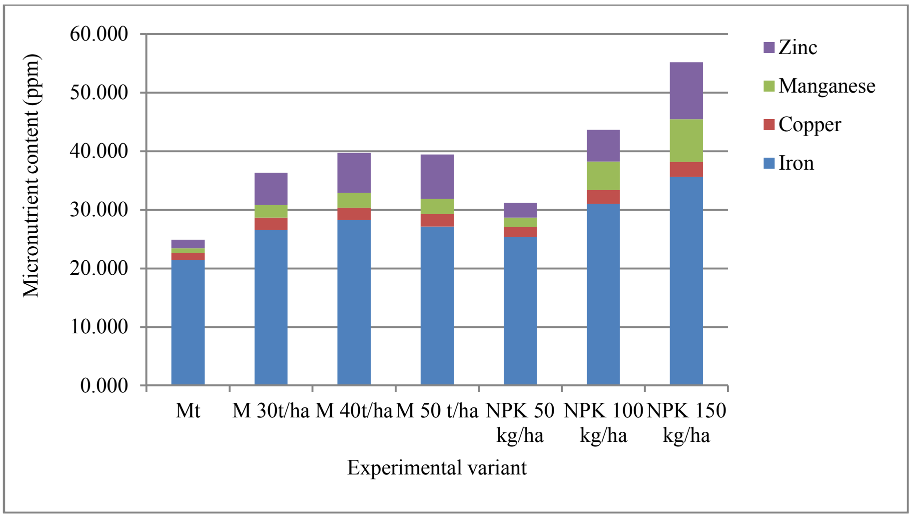

Fig.3. Micronutrient content in grapevine cordons, ‘ Burgund ’ variety, in relation to the type and dose of fertilizer

Copper content is relatively constant in the cordons coming from the variants with organic fertilization, from 2.110 ppm Cu (M_{30} t/ha) to 2.160 ppm Cu (M_{50} t/ha) and it increases from 1.720 ppm Cu (NPK_{50}) to 2.560 ppm Cu (NPK_{150}) in the variants with mineral fertilization. In the control variant (natural soil fertility), the Cu content in the cordons is 1.160 ppm.

Manganese content in grapevine cordons grows proportionally with the dose of fertilizer, within closer limits in the case of organic fertilization, 2.120 ppm Mn (M_{30} t/ha) to 2.570 ppm Mn (M_{50} t/ha), with wider range in the case of mineral fertilization, from 1.610 ppm Mn (NPK_{50}) to 7.250 ppm Mn (NPK_{150}). In the variant without fertilizer, the manganese content in grapevine cordons is 0.830 ppm Mn.

Zinc was determined in the grapevine cordons analysed in quantities between 5.570 ppm Zn (M_{30} t/ha) and 7.580 ppm Zn (M_{50} t/ha) in the case of organic fertilization and 2.510 ppm Zn (NPK_{50}), respectively 9.740 ppm Zn (NPK_{150}) in the case of mineral fertilization. In the variant without added fertilizers (natural soil fertility), zinc accumulated in cordons in a quantity of 1.460 ppm Zn.

The multiple correlation analysis of the content of the elements determined in grapevine cordons led to the identification of some positive correlations with high degree of signification: phosphorus/nitrogen (0.953), phosphorus/potassium (0.927), copper/iron (0.922), manganese/iron (0.969) and zinc/calcium (0.932). The correlation coefficient registered high values also for potassium/nitrogen (0.871), calcium/nitrogen (0.838), calcium/phosphorus (0.866), copper/calcium (0.878), manganese/copper (0.819), zinc/nitrogen (0.821), zinc/phosphorus (0.804), zinc/iron (0.844) and zinc/copper (0.890).

There are also negative correlations between certain elements: magnesium/potassium (-0.326) and manganese/potassium (-0.021), and some elements are weakly correlated or not at all (Tab. 2).

Tab.2

The matrix-table regarding the correlations between the minerals content determined in grapevine cordons, ‘ Burgund ’ variety

Element	N_{tot}	P_2O_5	K_2O	Ca	Mg	Fe	Cu	Mn	Zn
N_{tot}	1.000								
P_2O_5	**0.953**	1.000							
K_2O	0.871	**0.927**	1.000						
Ca	0.838	0.866	0.645	1.000					
Mg	0.092	0.015	-0.236	0.179	1.000				
Fe	0.456	0.403	0.083	0.697	0.601	1.000			
Cu	0.577	0.584	0.285	0.878	0.330	**0.922**	1.000		
Mn	0.336	0.288	-0.021	0.561	0.743	**0.969**	0.819	1.000	
Zn	0.821	0.804	0.536	**0.932**	0.464	0.844	0.890	0.764	1.000

The nutrient content in cordons, the vigour and bud viability are important for scions, for rootstocks, for producing young vines.

All minerals accumulated in cordons constitute a primary resource for the next vegetation cycle. Yet, due to pruning for fruit, approximately 90% of the cordons are removed, and together with them the mineral supply accumulated. These can prove an important source of nutrients in the balance of nutriments in vineyard ecosystems, if they are managed by composting.

CONCLUSIONS

The macro- and micronutrient content in grapevine cordons is directly influenced by the type and dose of fertilizer.

Organic fertilization caused more nitrogen, phosphorus, potassium and calcium to accumulate in grapevine cordons. Magnesium content correlates negatively to the dose of organic fertilizer. In the variants with mineral fertilizer, magnesium is stored in larger quantities in cordons, proportionally with the increase in the fertilizer dose, cordon maturity being more reduced as compared to the variants with organic fertilization.

Zinc has positive correlation with the fertilizer doses, whether organic or mineral, and copper has a relatively low but constant content in all fertilized variants. Manganese is present in larger quantities in the cordons analysed from the variants fertilized with larger doses of complex fertilizers. Iron is the micronutrient with the largest quantities in all variants, in positive correlation with the doses of fertilizer, with higher content in the case of the mineral fertilization as compared to organic fertilization.

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