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THE EFFECT OF ARBUSCULAR MYCORRHIZAL FUNGI ON THE CONTENT OF MACRO AND MICRO ELEMENTS IN GRAPEVINE (*VITIS VINIFERA*, L.) LEAVES

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Abstract

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In a two-year field experiment we used leaf analysis to evaluate the effect of arbuscular mycorrhizal (AM) fungi on the content of some macro elements (N, P, K, Ca, Mg) and micro elements (Zn, Mn, Fe) in grapevine leaves at the beginning of softening/veraison of grape berries. The contents of the individual elements differed which was caused both by the different varieties of Rulandské modré (Pinot Noir) and Frankovka (Blaufränkisch), and by the effect of the conditions of the year (2010, 2011), and by the actual treatment of the experiment (untreated control, mycorrhizal /AM/ plants). In 2010 the contents of all the nutrients in leaves of the variety Rulandské modré (Pinot Noir) were optimal with the exception of the contents of Ca and Mg in 2011 and content of K in 2010. In the mycorrhizal plants in both years only calcium increased significantly (3.50% as against 3.29% and 1.54% as against 1.31%, respectively). The contents of micro elements in the variety Rulandské modré (Pinot Noir) fluctuated irregularly; only the content of Mn was higher in the control treatment in both years. The variety Frankovka (Blaufränkisch) showed a small to great Ca deficit in the leaves in both years; in 2010 also a K deficit and in 2011 a deficit in Mg. The contents of N, K and Mn increased significantly in the mycorrhizal treated plants both in 2010 and in 2011.

grapevine, varieties, arbuscular mycorrhizal fungi, chemical analysis of leaves

Grapevine (*Vitis vinifera*, L.) has been grown on the site for several decades; therefore nutrition requires extraordinary care to ensure a sufficient supply of nutrients in the soil (Ložek, 2010; Krempa *et al.*, 2009). Colonisation of roots with mycorrhizal fungi may influence growth and the health status of host plants which have a better nutrient uptake, better resistance to drought and to heavy metals, and higher resistance to pathogens. Mycorrhizal symbiosis changes the number and spatial arrangement of microorganisms in the rhizosphere (Bennewitz *et al.*, 2008). The mycelium of mycorrhiozal fungi has high demands for assimilates regardless of the growth conditions of the host plant. The hyphae penetrate the primary cortical cells where due to the growth of arbuscules periarbuscular membranes appear and perforation of the plasma membrane of the plant cell does not take place.

Symbiosis with arbuscular mycorrhizal /AM/ fungi is most probably the most widely spread and at the same time the least specific type of mycorrhizal symbiosis. It can be seen in the great majority of cultural plants and that means virtually on all farmed land (Gryndler *et al.*, 2004).

The extensive network of the extra-radical mycelium extending beyond the rhizosphere of the roots enables the plant to take up nutrients from a much larger soil volume, particularly the relatively immovable phosphorus (Linderman *et al.*, 2001). AM fungi are believed to directly affect absorption and assimilation of N (Barea *et al.*, 1987) especially in neutral to moderately alkaline soil (Azcón *et al.*, 2001). Respiration of roots in AM plants is by ca 20% higher than in non-mycorrhizal plants. On carbonaceous soils this increased respiration in mycorrhizal plants may contribute to the acidification of the rhizosphere and to increased solubility of calcium phosphate (Balík *et al.*, 2008).

The objective of the two-year field experiment was to evaluate the effect of arbuscular mycorrhizal (AM) fungi by means of leaf analysis on the content of some macro and micro elements in grapevine leaves at the beginning of softening/veraison of grape berries.

MATERIALS AND METHODS

The field experiment was established in April 2010 with grapevine of the varieties Rulandské modré and Frankovka. Both varieties were grafted on rootstock Kober 125 AA. The spacing of the vineyard was 2.2 × 1 m and was treated by the method of integrated grape and wine production; it was planted on sandy loam of the Mendeleum of the Faculty of Horticulture, Mendel University in Lednice na Moravě. The locality lies in the maize-growing production region in an altitude of 176 m. The region is characterised as warm, sub-region dry with mild winters. The average annual rainfall is 500–600 mm; the average annual temperature is 9 °C. The following agrochemical properties of the soil and contents of available nutrients resulted from soil analyses using the method of Mehlich III: pH – 6.47 (mildly acid); P – 215 ppm (high); K – 465 ppm (high); Ca – 3301 ppm (high); Mg – 311 ppm (good). The K/Mg ratio was 1.5 (good). The soil is not salted and the salt content is 51.2 mg/l.

In the experiment two treatments were used for each of the two varieties.

1. inoculation with arbuscular mycorrhizal fungi using the Symbivit preparation
2. not inoculated (untreated) control.

Each treatment was replicated 4 times (5 shrubs). On 22 April 2010 the root system was inoculated with arbuscular mycorrhizal fungi to a depth of 0.2–0.5 m using a grouting device. The application of compressed air into the soil disturbed the soil profile, aerated the soil and created pores for the subsequently applied preparation. Two punctures were performed in the under-vine strips of the individual shrubs. In the control treatment the punctures were identical only without the application of Symbivit.

Symbivit contained 6 mycorrhizal fungi of the genus *Glomus (G. claroideum, G. etunicatum, G. intraradices, G. geosporum, G. microaggregatum, G. mosseae),* natural clay carriers, biologically decomposable granules of absorption gel, humates, ground rock and extracts from marine organisms.

Leaf samples from the individual treatments were taken for chemical analyses at the beginning of softening of the grape berries. The contents of the specific nutrients were determined from the leaf analyses (N, P, K, Ca, Mg, Zn, Mn, Fe).

The results were processed statistically using analysis of variance followed by testing according to Scheffe (P = 95 %).

RESULTS AND DISCUSSION

a) Variety Rulandské modré

With the exception of the contents of Ca and Mg in 2011 and the K content in 2010, the leaf contents of all the other nutrients corresponded to the content optimal for the stage of softening as reported by Ložek (2010) or were close. While the contents of Ca and Mg in 2010 were optimal (Tab. I), in 2011 (Tab. II) a great deficit of Ca and medium deficit of Mg was found. The K deficit appeared when the contents of Ca and Mg were optimal and *vice versa* and can be explained by the antagonistic relations among these elements. The uptake of nutrients is affected by a number of factors; e.g. soil temperature and humidity, soil reaction, intensity of mineralisation, degree of fertilisation etc., which account for the differences between the years in the contents of the respective macro and micro nutrients (Mengel, Kirkby, 2001).

In the variety Rulandské modré differences among the years (Tabs. I and II) were detected in the contents of all the nutrients. In 2010 (Tab. I) the contents of K and Ca increased significantly only in the mycorrhizal plants. The contents of N and P did not change. Caglar *et al.* (2006) reported that in rootstocks inoculated with mycorrhizal fungi of the

I: *Chemical analysis of leaves in the stage of softening of grape berries – Rulandské modré (2010)*

Treatment No.	Nutrients							
	N	P	K	Ca	Mg	Zn	Mn	Fe
	% in DM					$mg.kg^{-1}$ in DM		
AM	2.28 a	0.25 a	0.92 a	3.50 a	0.30 a	28 a	226 a	246 a
	small surplus	small surplus	small deficit	optimum	optimum	optimum	optimum	optimum
control	2.23 a	0.22 a	0.81 b	3.29 b	0.38 b	35 b	275 b	254 b
	small surplus	small surplus	medium deficit	optimum	optimum	optimum	small surplus	optimum

II: *Chemical analysis of leaves in the stage of softening of grape berries – Rulandské modré (2011)*

Treatment No.	Nutrients							
	N	P	K	Ca	Mg	Zn	Mn	Fe
	% in DM					mg.kg^{-1} in DM		
AM	2.80 b	0.18 b	1.38 c	1.54 c	0.23 c	26 c	159 c	106 b
	medium surplus	optimum	optimum	great deficit	medium deficit	optimum	optimum	optimum
control	2.97 c	0.16 b	1.35 c	1.31 d	0.25 ac	24 c	169 d	90 c
	great surplus	optimum	optimum	great deficit	medium deficit	small deficit	optimum	optimum

Different letters (a, b,..) with each nutrient indicate significant differences among treatments and/or years

Glomus genus leaf analysis revealed a higher content of P in the mycorrhizal treated plants as against the non-mycorrhizal control, but not the contents of N and K. In 2011 (Tab. II) only Ca showed a significant increase in the mycorrhizal treatment.

In 2010 a higher content of all the micro elements was detected in the control plants as against the mycorrhizal plants (Zn, Mn, Fe); however in 2011 only the content of Mn was higher (Tabs. I and II). According to Karagiannidis *et al.* (2007) in experiments where nitrogen fertilisers were applied leaf analysis showed that control plants took up less of the micro elements Zn, Mn and Fe than the mycorrhizal-treated plants; this finding is in accordance with our results.

b) Variety Frankovka

In both years we observed a small to great deficit in Ca in the leaves; in 2010 also a deficit in K was detected and in 2011 a deficit in Mg (Tabs. III a IV). The contents of all the other nutrients corresponded to the content optimal for the stage of softening as reported by Ložek (2010) or being close to it.

Differences in the contents of the nutrients were detected between the years in the variety Frankovka with the exception of P (Tabs. III and IV). Both in 2010 and 2011 only the contents of N, K and Mn increased insignificantly in the mycorrhizal-treated plants. The Zn content was significantly higher in the mycorrhizal plants only in the second year of the experiment; this is in accordance with the findings of Petgen *et al.* (1998) in their rootstock experiment *(Vitis* sp.*)*. The Fe contents were higher in the control treatment in both years which is contrary to Bavaresco *et al.* (1996) who reported that in mycorrhizal plants the Fe content in leaves of rootstock experiments (3309 C a 41 B) increased.

III: *Chemical analysis of leaves in the stage of softening of grape berries – Frankovka (2010)*

Treatment No.	Nutrients							
	N	P	K	Ca	Mg	Zn	Mn	Fe
	% in DM					mg.kg^{-1} in DM		
AM	2.35 a	0.18 a	1.07 a	2.58 a	0.35 a	34 a	353 a	295 a
	small surplus	optimum	small deficit	small deficit	optimum	optimum	small surplus	small surplus
control	2.12 b	0.19 a	0.87 b	2.82 b	0.34 a	31 a	326 b	306 b
	small surplus	optimum	medium deficit	small deficit	optimum	optimum	small surplus	small surplus

IV: *Chemical analysis of leaves in the stage of softening of grape berries – Frankovka (2011)*

Treatment No.	Nutrients							
	N	P	K	Ca	Mg	Zn	Mn	Fe
	% in DM					mg.kg^{-1} in DM		
AM	2.82 c	0.16 a	1.55 c	1.34 c	0.21 b	33 a	281 c	90 c
	great surplus	optimum	small surplus	great deficit	medium deficit	optimum	small surplus	optimum
control	2.68 d	0.18 a	1.41 d	1.43 d	0.21 b	23 b	152 d	97d
	medium surplus	optimum	small surplus	great deficit	medium deficit	small deficit	optimum	optimum

Different letters (a, b,..) with each nutrient indicate significant differences among treatments and/or years

SUMMARY

In a two-year field experiment with grapevine (*Vitis vinifera*, L.) varieties Rulandské modré and Frankovka we evaluated the effect of inoculation with arbuscular mycorrhizal fungi on the content of some macro and micro elements in the leaves. Two treatments were applied in the experiment: 1) inoculation with arbuscular mycorrhizal fungi, 2) non-inoculated (untreated) control. The AM fungi were inoculated with the granulated preparation Symbivit containing six species of mycorrhizal fungi of the genus *Glomus*. The vineyard was planted on sandy loam soil with a high supply of nutrients (P, K, Ca) on the plots of the Faculty of Horticulture in Lednice, South Moravia. Leaf samples of the individual treatments were taken for chemical analyses at the beginning of the stage of softening of the grape berries.

Differences in the contents of the elements (N, P, K, Ca, Mg, Zn, Mn, Fe) were detected between the varieties and between the years and also significant differences between the two treatments. The contents of the nutrients in the leaves of the variety Rulandské modré corresponded with contents optimal for the stage of softening, with the exception of the content of Ca and Mg in 2011 and the content of K in 2010. In 2010 in the mycorrhizal treatment only the contents of K and Ca increased significantly and in 2011 only the content of Ca. In 2010 the contents of all the micro elements in question (Zn, Mn, Fe) were higher in the controls than in the mycorrhizal-treated plants; in 2011 this was true only for Mn. In both years the variety Frankovka showed a small to great deficit in Ca in the leaves and in 2010 also a K deficit and in 2011 a deficit in Mg. Both in 2010 and 2011 in the mycorrhizal treatment only the contents of N, K and Mn increased significantly; Zn increased only in 2011. In terms of the P content there were no differences between the years and neither between the treatments and the content ranged between 0.16 and 0.19 %. The effect of inoculation with arbuscular mycorrhizal fungi on the content of some macro and micro elements in the leaves was ambiguous and differed particularly in dependence on the variety. Further research in this field is necessary.

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