VINE PLANT CHLOROSIS ON UNSTRUCTURED CALCAREOUS SOILS AND LEAF Ca, Mg and K CONTENT

Mirjana HERAK ĆUSTIĆ[1] – David GLUHIĆ[2] – Lepomir ČOGA[1] – Marko PETEK[1] – Ivan GOŠĆAK[3]

[1] Department of Plant Nutrition, Faculty of Agriculture, University of Zagreb, Svetošimunska cesta 25, HR-10000 Zagreb, Croatia, mcustic@agr.hr
[2] Institute for Agriculture and Tourism, Poreč, Croatia
[3] Student, Faculty of Agriculture, University of Zagreb, Croatia

Abstract: Excess calcium in expressly carbonate soils (up to 40 % CaO) in the Plešivica sub-region causes soil bicarbonates accumulation and ion antagonism, thereby disturbing uptake of nutrients, notably Mg and micronutrients. Deficit of some elements results in chlorosis and physiological disorders, which often depress yield and wine quality. Research results show significant differences in soil reaction and $CaCO_3$ and CaO content between investigated soils of the Plešivica vine-growing region. Soil lime content influenced ion antagonism between Ca, Mg and K in vine plants. Magnesium uptake was probably depressed by Ca excess. Soil chemical properties were not the only reason for chlorosis occurrence. Chlorosis is a consequence of grapevine cultivation on inadequate rootstocks and also on unstructured soils of heavy mechanical composition.

Keywords: active lime, grapevine, chlorosis, leaf Mg, Ca, K content

Introduction

The food chain involves agricultural production and its inputs, processing, distribution and consumption of food and so agricultural production has an impact upon the environment (Husti, 2006). Soils are conditionally renewable natural resources and their sustainable use is possible with proper agrotechnics (tillage and fertilization), moisture regime regulation, recycling of plant residues and prevention of soil degradation and pollution (Varallay, 2007). In vineyards, agricultural inputs depend more than elsewhere on soil properties and fertilization. Because of the very sensitive and sophisticated grapevine production, especially if planted on inadequate rootstocks and under inadequate agro-technics, chlorosis and physiological disorders, as indicators of ion antagonism, are most commonly observed in calcareous soils. Calcareous soils are characterized by carbonate contents, by high pH and thereby also high HCO_3^- concentrations in soil solution (Mengel and Kirkby, 2001). All this favours formation of HCO_3^- ions, which cause disturbances in the uptake of nutrients and different types of chlorosis (Imas, 2000; Ksouri et al., 2005). All this often depresses yield and wine quality (Herak Ćustić at al., 2007). Calcium makes up more than 80 % of calcareous soils and exchangeable Mg only 4 %, which leads to Mg chlorosis (Hagin and Tucker, 1982). Garcia et al. (1999) report that high content of Ca in the soil influences ion antagonism between Ca, Mg and K in the vine plant. Because of unfavourable soil physical and chemical properties and very important role of Mg in the central atom of chlorophyll and also as activator of numerous enzymes in the plant, Mg-foliar fertilization has the advantage over uptake through roots (Takacs et al., 2007). Most soils of the Plešivica wine-growing region are alkaline, of heavy mechanical composition and low air capacity. The research objective was to determine the soil reaction, $CaCO_3$ and CaO in the soil and Ca, Mg and K content in the plant in 4 vineyards planted on SO4 rootstock.

Materials and methods

Field investigations were carried out in 2005 and 2006 in the Plešivica vine-growing region in Croatia. The trial was set up on vitisol (rendzina on marl.) Soils are of heavy mechanical composition, with low air capacity, alkaline and calcareous. In 2005, chlorosis was evaluated visually and vineyards were divided into zones of chlorotic and non-chlorotic plants. In the same year, physical and chemical properties were determined and 82 soil samples from vineyards of 25 wine producers were taken. According to soil active lime content, all soils were divided into 3 types: with low, medium and high lime content (20, 25, 30 % CaO, respectively). Four vineyards (cv. Sauvignon blanc) planted on SO4 rootstock (unresistant to high active lime content) and calcareous soils (Borička, Klemenka, Veselnica, Šipkovica) were selected for investigations in 2006. Soil reaction, $CaCO_3$ and CaO content in soil and Mg, Ca and K content in vine plants were determined. Soil reaction was measured in H_2O and 1 MKCl (soil suspension 1:2.5 /10g soil + 25 ml H_20 or 1 MKCl) on a pH-meter with combined electrode. Active lime content was determined according to Galet, and total lime content on Scheibler calcimeter (JDPZ, 1966). Leaf potassium content was determined using a flame-photometer, while Mg and Ca in the plant by AAS. Statistical data analyses were performed using the SAS 8.2 System (1999-2000).

Results and discussion

Preliminary investigations done in 2005 revealed that the soils under study were unstructured calcareous soils (silty clay loam, silty loam) with a high proportion of fine silt, susceptible to compaction and of very low air capacity (0.2.-3.5 %). Also, in 49 % of 82 investigated soil samples from 25 wine producers, between 25 and 40% CaO was found (Jakovčić, 2006). All this can certainly have a limiting effect on vine growing, so selection of chlorotic and non-chlorotic vine plants was made for further research work on 4 selected vineyard locations (Borička, Klemenka, Veselnica, Šipkovica). According to the soil active lime content, all soils were divided into 3 types: with low, medium and high lime content (20, 25, 30 % CaO, respectively). It was found in 2006 that the research location had a significant influence on all the soil parameters measured (soil reaction, $CaCO_3$ and CaO contents) whereas the zone of chlorotic plants and their interactions had no significant effect (Table 1). The average soil reaction value in water was 7.8, and in 1 M KCl 7.7, which indicates alkaline soils. The recorded $CaCO_3$ values and, which is particularly important, levels of active lime (CaO) on particular locations show its significantly lower amount in Šipkovica compared to other locations. Veselnica and Borička locations had approximately identical amounts of active lime (Table 2). Soil lime content (low, medium or high) had no significant effect on potassium and magnesium contents, while a significant difference was recorded in plant calcium contents (Table 3). It is interesting to note that significantly higher Ca values were determined in soils with low and high lime contents compared to soil with medium lime supply. Ratios between calcium and magnesium (Ca/Mg) ions also show that soils with low and high lime contents had a much higher ratio (9.5) compared to soil with medium lime content (5.9). Higher ratio between potassium and magnesium (K/Mg) ions was also determined in soil with low and high lime content (3.8) compared to soil with medium lime content (3.3). Contrary to that, lower ratios between potassium and calcium (K/Ca) ions were determined on soils with low and high lime content (0.4) than in soil with medium lime content (0.6).

Table 1. Results of ANOVA for pH (H_2O), pH (KCl), $CaCO_3$ and CaO in 2006

Source of variability	Element	pH (H_2O)	pH (KCl)	$CaCO_3$	CaO
Location	(A)	***	***	***	***
Chlorosis zone	(B)	n.s	n.s	n.s	n.s
A × B		n.s	n.s	n.s	n.s
Average value		7.79	7.70	33.66	25.82
Coefficient of		1.2 %	0.8 %	10.8 %	11.1 %

Table 2. Soil reaction, $CaCO_3$ and CaO content as influenced by location in 2006

Treatment	pH (H_2O)	pH (KCl)	$CaCO_3$ (%)	CaO (%)
Veselnica	7.88a	7.74a	39.7a	29.6a
Klemenka	7.72b	7.65b	39.3a	26.5b
Boričko	7.82a	7.75a	33.9b	28.4a
Šipkovica	7.77b	7.68b	22.0c	18.8c
Sig.	***	***	***	***
LSD (0.05)	0.06	0.03	2.09	1.64

Table 3. Content of Mg, Ca, and K (%) in vine leaf as influenced by active lime in 2006

Treatment	Mg	Ca	K
LL [1]	0.32	3.07 a	1.19
ML [2]	0.35	2.07 b	1.17
HL [3]	0.30	2.85 a	1.15
Significance	n.s.	***	n.s.
LSD (0.05)	0.09	0.44	0.23

[1] LL - low lime (~ 20 % active lime)
[2] ML - medium lime (~ 25 % active lime)
[3] HL - high lime (~ 30 % active lime)

According to Bergmann (1992), these results point to the importance of interactions between mineral elements, and also indicate that cation competition may play a major role and that Mg uptake can be greatly depressed by excess of other cations, which are taken up at high rates and may compete with Mg^{+2} for the negatively charged cytosol. This competition can lead to Mg deficiency in plants. Not only the uptake, but also the translocation of Mg from the roots to the upper plant parts can be restricted by K^+ and Ca^{+2}. Thus, the increased plant calcium content found in our investigations could have, as reported also by other authors (Garcia at al., 1999), influenced its adverse ratio to magnesium. Thereby, along with other already mentioned adverse soil conditions, cause chloroses, but also confirm the fact that moderate amount of a particular ion in soil is optimal for nutrient uptake. Viticulturalists try to solve the problem of high lime contents by adequate selection of rootstock such as 41 B or 140 R. This was not, however, the case in these investigations where rootstock SO4 was used which tolerates only about 17 % of active lime. In view of all the mentioned facts and a relatively large number of unknowns about the uptake and translocation of particular ions through the plant, it is possible, in accord with Bavaresco et al. (2005), that chlorotic leaves had higher macronutrient levels than green leaves and that their concentrations did not correlate with chlorosis occurrence.

Conclusions

Effects of soil reaction and soil lime content on studied locations had a significant influence on the incidence of grapevine chlorosis, notably Mg chlorosis. It is assumed that the high Ca content had an antagonistic effect upon the uptake and translocation of Mg ions through the plant. Besides excess Ca, occurrence of chlorosis was also significantly influenced by adverse soil physical properties and very low air capacity, but also by the selection of rootstock (SO4) not tolerant to high lime levels. Hence, we recommend mineral fertilization using a vibrational 2-row subsoiler with pneumatic fertilizer device for depth fertilization, and two foliar applications (every 10 days) of Mg early in spring as soon as the leaf area is sufficiently developed.

Acknowledgements

Support of the Ministry of Agriculture, Forestry and Water Management is gratefully acknowledged. The authors thank the wine producers of the Plešivica vine-growing region for their cooperation.

References

Bavaresco L. – Presutto P. – Civardi S.: 2005. VR 043-43: A lime-susceptible rootstock. American Journal of Enology & Viticulture. 56: 2. 192 – 195.

Bergman W.: 1992. Nutritional disorders of plants. Gustav Fischer Verlag Jena , Stuttgart, New York. 345.

Garcia M. – Daverede C. – Gallego P. – Toumi M.: 1999. Effect of various potassium-calcium ratios on cation nutrition of grape grown hydroponically. Journal of Plant Nutrition, 22. 417-425.

Hagin J. – Tucker B.: 1982. Fertilization of dryland and irrigated soils. Springer Verlag, New York, USA.

Herak Ćustić M. – Gluhić D. – Petek M. – Čoga L. – Slunjski S.: 2007. Yield and grape quality of cv. Sauvignon white on calcareous soils of the Plesivica wine region. XV. International Symposium GESCO, Poreč, Croatia. Comptes rendus proceedings, 1. 462-472.

Husti I.: 2006. The mail elements of sustainable food chain management. Cereal Research Communication, 35: 2. 573-576.

Imas P.: 2000. Integrated nutrient management for sustaining crop yields in calcareous soils.GAU-PRII-IPI National Symposium on Balanced Nutrition of Groundnut and Other Field Crops Grown in Calcareous Soils of India, Junagadh, India.

Jakovčić M.: 2007. Biljno hranidbeni kapacitet tala Plešivičke vinske ceste. Zagreb. Diplomski rad.

JDPZ.: 1966. Priručnik za ispitivanje zemljišta. Knjiga I. Kemijske metode ispitivanja zemljišta. Beograd.

Ksouri R. – Gharsalli M. – Lachaal M.: 2005. Physiological responses of Tunisian grapevine varieties to bicarbonate-induced iron deficiency. Journal of Plant Physiology, 162. 335-341.

Mengel K. – Kirkby E.A.: 2001. Principles of Plant Nutrition. Kluwer Academic Publishers. London.

SAS: 1999-2000. System for Wine Release 8.02, SAS Institute Inc.

Takacs-Hajos M. – Szabo L. – Racz I. – Mathe A. – Szoke E.: 2007. The effect of Mg-leaf fertilization on quality parameters of some horticultural species. Cereal Research Communications, 35. 2. 1181-1184.

Varallay Gy.: 2007. Soil resilience (Is soil a renewable natural resource?). Cereal Research Communications, 35. 2. 1277-1280.