Boron Status of Table Grape (*Vitis Vinifera* L.) Grown on Sandy and Calcareous Soils Received Irrigation from Blend Water

Mahmoud Kamh [1*] and Hebat-Allah Anwar[1]

ABSTRACT

The present study aimed to evaluate B status of grape (*Vitis vinifera* L.) received drip irrigation from blend water source (Neil Rever water mixed with agriculture drainage). Some plots in two farms representing sandy non-calcareous and calcareous soils were selected. Soil samples were collected at three intervals of 0 – 90 cm depth at the beginning of the season and analyzed for hot water extractable-B, organic matter (OM), soil salinity (EC_e), and $CaCO_3$ content. B was measured in the applied compost and monitored in irrigation water, petioles, and leaves of the growing grape.

Results indicated that the estimated B input per year was 1.87 kg B ha^{-1}from the irrigation water and the applied organic compost. The hot water extractable-B was higher in the calcareous than that in the sandy soil and tended to increase with soil depth in both soils with higher magnitude in the calcareous soil profile. Regardless soil type, extractable-B was correlated with $CaCO_3$ content. Consequently, average of B concentration in petioles of grape grown on calcareous soil was 64.4 ±11.6 at flowering which increased to 84.5 ±8.5 mg B kg^{-1} DM at veraison stage compared to values those did not exceed 58.7 at both stages in sandy soil. Monitoring of B in leaves clearly showed accumulation with time where the highest B concentration was observed at the post harvest stage with an average of 120.7 ±17.0 mg B kg^{-1}DM in the old and 123.3 ±13.4 in the young leaves of grape grown on the calcareous soil.

Regardless of the soil type, significant positive relationship was obtained between B concentration in the old leaves and hot water extractable-B from soil at flowering and veraison stages. The predicted critical B concentration in soil was 2.3 at flowering and 1.8 mg kg^{-1} soil at the veraison stage. The high temperature during the veraison stage is expected to enhance the transpiration, water uptake, and B uptake and concentration in leaves and, therefore, the critical level of B in soil should be kept at lower level than that at flowering.

Key words: boron, grape, calcareous soil, blend water.

INTRODUCTION

Grown plants acquire their boron (B) requirements during the growing season from the soil solution (soluble B) which is in equilibrium with the soil solid phase. B in soil solution exists mainly as undissociated boric acid H_3BO_3 (Raven, 1980), which is mostly taken up passively by plant roots (Brown and Shelp, 1997). The adsorbing surfaces that highly affect B equilibrium in soil are: organic matter content (Yermiyahu et al., 1988; Raza et al., 2002; Shafiq et al., 2008), $CaCO_3$ content (El-Seewy and El-Malky, 1979; Goldberg and Foster, 1991), clay and type of the clay minerals (Goldberg et al., 1993), and iron and aluminum oxides (Goldberg et al, 1993; Peak et al., 2003) at specific pHs (Gupta, 1993; Goldberg, 1997; Goldberg et al., 2005). Other factors such ionic strength, and moisture content are also affecting the extent of boron adsorption in soil (Goldberg et. al., 2005; Communar and Keren, 2008).

Compared to other nutrient elements, the range between B deficiency and toxicity in plants is narrow (Marschner, 1995). As a result, excessive and deficient of B could be occurred during the same season (Mortvedt and Woodruff, 1993). B deficiency is common on light textured soils (Sarkar et al., 2008), and has been observed in more than 80 countries (Shorrocks, 1997). On the other hand, B toxicity is observed on alkaline soils mostly in arid and semi-arid regions (Goldberg 1997; Nable, et al., 1997; Yermiyahu et al., 2008; McDonald et al., 2010), especially when fresh water (low in B) for irrigation is limited and other sources such as ground or blend water (high in B) used for irrigation (Tanaka and Fujiwara 2007, Yermiyahu et al., 2008).

In Egypt, lack of fresh water for agriculture expansion forces the use of brackish water (drainage, mixed, or underground) for irrigation (Mahmoud and Aboushal,2007; ElGamal and Zaki, 2017). The limitation of its use in irrigation is established mainly on its content of salts. Mixed and drainage water contain higher B concentrations than fresh water (Seyam and Regab, 2005). They reported concentrations of B ranged between 0.06 to 0.13 mg L^{-1} in canals received fresh water from Nile River, between 0.11 to 0.17 mg L^{-1} in canals received mixed water, and between 0.21 to 0.54 mg L^{-1} in drainage water. On the other hand, in Egyptian agriculture there is a little information about B status in soil and crops. This led to absence of scientific information that can be used for managing soils and crops with respect to B. Therefore, the aim of this study was to evaluate B status in grape grown on sandy and

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[1] Soil and Water Science Department, Faculty of Agriculture, El-Shatby, Alexandria University, Egypt.

[*] Corresponding author: mahmoud.kamh@alexu.edu.eg

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calcareous soils received irrigation from blend water (Nile River mixed with drainage water).

MATERIALS AND METHODS

Site description:

Tow farms receiving irrigation water from El-Nasr canal (proportionally mixed water from Nile River and agricultural drainage water) were selected. These were Roda and Maghrabi farms located in Nubaria region, Al-Bohiera governorate, Egypt. Roda and Maghrabi farms are located 70 and 80 Km southwest Alexandria city, respectively**.** Some plots were randomly selected from each farm (10 plots from Roda and 6 from Maghrabi). Both farms are cultivating different cultivars of grape (*Vitis vinifera* L.) and using drip irrigation system. Average of the main soil properties of the selected plots at 0.0 – 0.9 m soil depth are shown in Table 1. Roda is highly calcareous soil with higher salinity and organic matter content compared to Maghrabi soil which is mostly sandy non-calcareous.

Nubaria region, where the two farms are located, is considered to have a desert climate; the annual rainfall ranges between 0.0 to 21 mm/year between November and February. The least amount of rainfall occurs during June to September and the most precipitation falls in December. Temperature ranges between 12 -18 °C in winters and 25 – 36 °C in summer. Relative humidity ranges between 10% in December to 60% in summer.

Soil samples:

Soil samples were randomly collected from the selected plots (10 and 15 ha each plot) of both farms. Samples were collected at the beginning of the season from 9 different locations in each plot. Soil Uger was used to obtain the samples at three depths; 0.0 - 0.3, 0.3 - 0.6, and from 0.6 - 0.9 m from the soil surface. Each 3 samples were mixed according to the depth to form one composite sample, so that 3 samples at each depth were used to represent the plot. The collected soil samples were air-dried and crushed to pass a 2 mm sieve then analyzed for some soil characteristics and boron. Electrical conductivity (EC) and soluble cations and anions were measured in the saturated soil paste extracts as described by Rhoades (1982). The soil pH was measured in 1:2.5 soil:water suspension (McLean, 1982). Soil organic carbon was estimated by the wet-oxidation method of Walkley and Black (Nelson and Sommers, 1982). Available boron was extracted by hot water; the most widely used method developed by Berger and Truog (1939). The complex formed between carmine and H_3BO_3 in concentrated H_2SO_4 media was measured by spectrophotometer at wavelength 585 (Hatcher and Wilcox, 1950).

Water samples:

Water samples were collected from the branch of El-Nasr canal at the entrance of each farm at different times during the season. A clean glass bottle was filed with irrigation water from the canal and closed well with the stopper. Water samples obtained from the irrigation source were analyzed for pH, EC, cations, anions, and boron concentrations. pH and EC were measured immediately (at the same day of collection) using pH and EC meters, and B was determined by spectrophotometric carmine method.

Plant Samples:

To evaluate the boron status in grape, petioles of the leaves opposite to the first cluster (100 petioles) were randomly collected from each plot at flowering, and at veraison stages. Also, to monitor B concentration in leaves through the season, old and young leaves samples (100 leaves) were also randomly collected from each plot at flowering, veraison, and post harvest stages. The collected plant tissue samples were washed in the laboratory (at the same day of collection) with distilled water followed by diluted acid HCl 0.1 N, and then by distilled water different times. Samples were dried firstly on tissue paper then packed in paper bags. Tissue samples were then dried in a forced-air oven at 72 °C until constant weight. After oven drying, samples were ground and subsamples weighing 2 g were ashed at 500 °C for 6 h. The ash was dissolved in dilute hydrochloric/nitric acid mixture and filtered (Campbell and Plank, 1998). The concentration of B was measured by the carmine method.

RERSULTS

Boron in irrigation water and applied organic compost:

As shown in Table 1, irrigation water salinity (Electrical conductivity, EC) ranged between 0.72 and 0.9 dSm^{-1} (460 – 580 mg L^{-1}), with an average of 0.8 dSm^{-1} and the calculated SAR varied between 3.09 and 4.38. The concentration of B in the irrigation water ranged between 0.18 and 0.5 mg L^{-1}. Taking the average of B in El-Nasr canal (Table 1) and water requirement of grapes in Nubaria region (4800 m^3 ha^{-1} $year^{-1}$), the input of B is predicted to be 1.68 kg B ha^{-1} $year^{-1}$ through the irrigation water.

Organic compost was applied to grape during the winter at rate of 9.6 ton ha^{-1}. The analysis of the applied compost (Table 2) showed that The compost had C:N ratio of 22:1. The total B concentration was 19.9 mg B kg^{-1} compost, so that the total input of B through compost is 0.19 kg B ha^{-1}. It is highly expected that B content in the applied compost is largely restricted to the surface soil layer where it was applied as mulching.

Also, such amount of B is not readily or completely available to plants.

Soil properties and hot water extractable-B:

The total $CaCO_3$ content ranged between 9.8 and 23.7 % with an average of 15.6 % at soil depth 0.0 – 0.15 m in Roda farm (considered calcareous soil) (Fig. 1A) compared to 4.4 and 7.3 % with an average of 5.2 % in Maghrabi farm (considered non-calcareous) (Fig. 2A). The average of $CaCO_3$ content was increased to 18.4% and to 5.7% at soil depth 0.6 - 0.9 m in Roda and Magrabi farm, respectively. Organic matter (OM) content was higher on the selected plots of Roda farm compared to Maghrabi farm (Fig 1B and 2B), especially at the surface soil layer (0.0 – 0.15 m). OM ranged from 1.8 to 4.3 % with an average of 2.9% ±0.8 on Roda farm compared to 2.6 to 1.5 % with an average of 2.3% ±0.2 on Maghrabi farm. In both farms, OM content was higher in the surface soil layer (0.0 – 0.15 m) than that in the layers below.

Table 1. Main soil properties of the selected plots from Roda farm (calcareous soil) and Maghrabi farm (sandy non-calcareous soil)

Farm	pH	EC	$CaCO_3$	OM	N	P	K
		dSm^{-1}	-------%-------			------mg kg^{-1}soil------	
Roda	7.7	3.3	17.3	2.4	81.9	46.8	425
	(0.1)	(2.1)	(4.5)	(0.8)	(9.3)	(10.5)	(20.6)
Maghrabi	7.7	2.0	4.6	2.0	66	16.7	177.6
	(0.2)	(1.0)	(1.7)	(0.2)	(12.6)	(4.3)	(20.8)

Values between brackets represent standard deviation.

Table 2. Chemical characteristics of irrigation water of El-Nasr canal, Nubaria

pH	EC	Ca^{2+}	Mg^{2+}	Na^+	K^+	CO_3^{2-}	HCO_3^-	Cl^-	B
	dSm^{-1}				----------------------------meqL^{-1}--------------------------				mgL^{-1}
7.7	0.8	2.8	1.6	4.0	0.4	0.0	3.4	3.6	0.35
(0.13)	(0.09)	(0.20)	(0.08)	(0.18)	(0.02)	(0.00)	(0.10)	(0.20)	(0.14)

Values between brackets represent standard deviation.

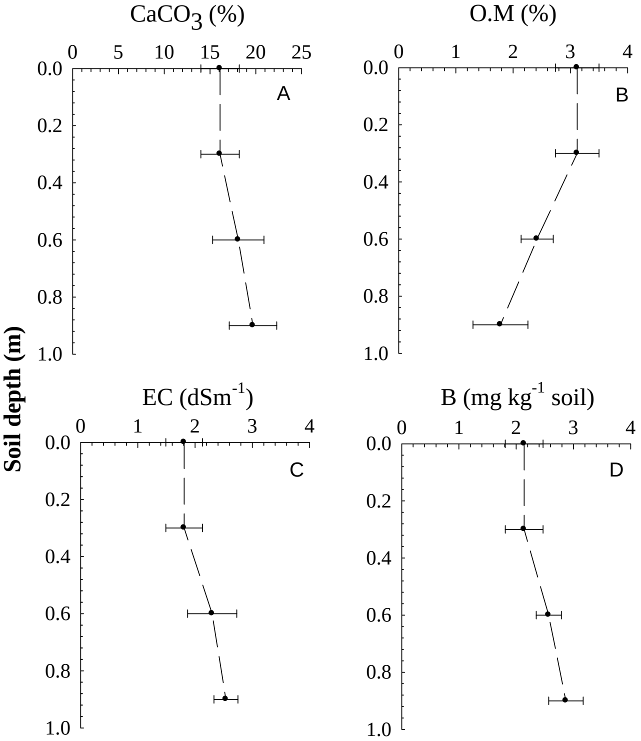

Fig. 1. The distribution of total $CaCO_3$ content (A), organic matter (B), soil salinity (C), and hot water extractable-B (D) with soil depth of the calcareous soil (Roda farm)

For both soils, pH was slightly changed according to soil depth with no specific trend. EC of the soil paste extract (EC_e) varied between 0.97 and 3.67 dSm^{-1} in the calcareous soil (Roda farm) with an average of 2.9 ±0.1.2 in the soil surface layer (0 – 0.15 m) which increased to 3.2 ±1.5 dSm^{-1} at 0.6 to 0.9 m (fig 1C). In the sandy soil (Maghrabi farm), the ECe ranged between 0.81 and 3.2 dSm^{-1} with an average of 2.3 ±1.1 dSm^{-1} in the surface soil layer which, in contrast to the calcareous soil, showed reduction with soil depth (Fig. 2 C).

Hot water extractable-B was higher in the calcareous than that in the sandy soil received the same irrigation water from El-Nasr canal (Fig. 1D and 2D). Extractable-B averaged 2.6 ±0.4 at the surface soil layer which increased with soil depth (0.6 to 0.9 m) to 3.4 ±0.9 mg B kg^{-1} soil in the calcareous soil (Fig 2D). The comparative value of B in the sandy soil (Fig. 2D) was 1.9 ±0.8 and 2.2 ±0.5 mg B kg^{-1} soil, respectively. Regardless soil type, hot water extractable-B was correlated with $CaCO_3$ content at the different soil depths (Fig. 3).

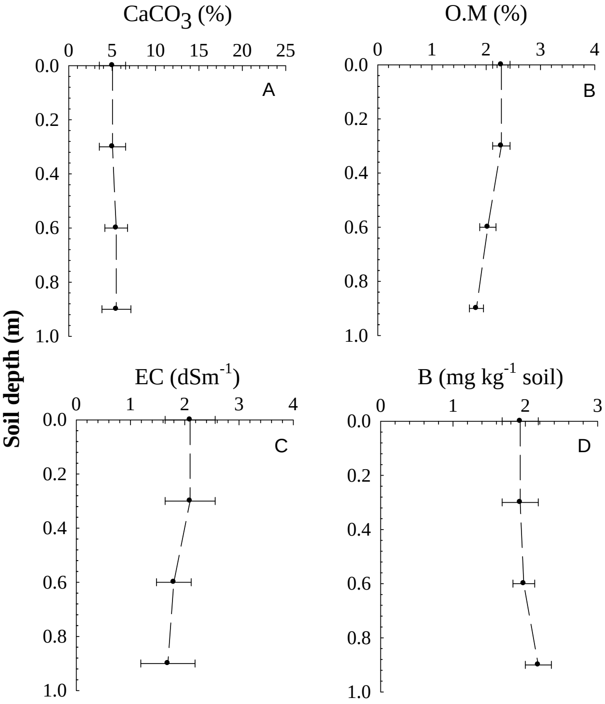

Fig. 2. The distribution of total $CaCO_3$ content (A), organic matter (B), soil salinity (C), and hot water extractable-B (D) with soil depth of the sandy soil (Maghrabi farm)

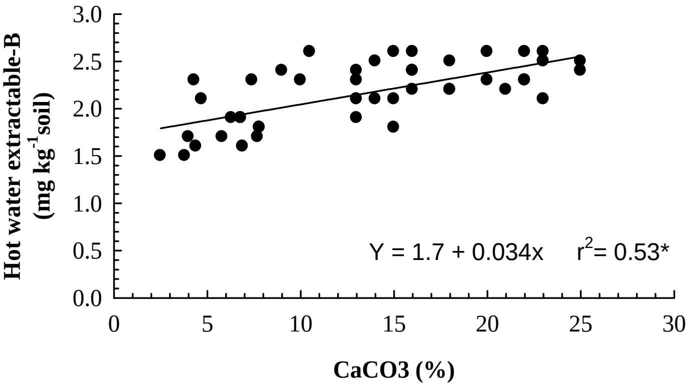

Fig. 3. Relationship between the concentration of hot water extractable-B in soil and the $CaCO_3$ % in both sandy and calcareous soils

Boron concentration in grape petioles and leaves:

Nutrient management guideline for grape is largely based on petioles analysis at bloom to fruit set and at veraison growth stages. The concentration of B in petioles and in leaves (old and young) is shown in Fig. 3. B concentration in petioles of grape grown on the calcareous soil at flowering (Fig. 3A), varied between 55.6 to 85.8 according to plots, and averaged 64.4 ±11.6 mg B kg^{-1} D.M. At the veraison stage, the B concentration varied between 72.2 and 97.7 and averaged 84.5 ±8.5 mg kg^{-1}D.M. The comparative values were much lower in selected plots of grape grown in the sandy soil (Fig. 3B). At flowering and veraison stages B concentration did not exceed 58 mg B kg^{-1}D.M. It is evident that B tended to accumulate in grape petioles through the season. The higher B concentration measured at veraison stage can be explained by the higher temperature.

Monitoring of B status in grape during the season in old and youngest fully developed leaves of grapes grown in the calcareous soil showed also significant increase from flowering to veraison to post harvest. The highest B concentration was found at the post harvest stage with an average of 120.7 ±17.0 and 123.3 ±23.4 mg B kg^{-1} D.M in the old and young leaves, respectively (Fig. 3A). On the other hand, Grape grown on the sandy soil showed insignificant difference in B concentration between flowering and veraison stages (Fig. 3B). However, the highest B concentration in leaves was obtained at post harvest stage (95.3 ±10.1 and 67.7 ±9.6 mg B kg^{-1} D.M in the old and young leaves, respectively).

DISCUSSION

B concentrations in agricultural drainage water varied according to the B leached from agricultural soils (Youssef, 2003). The measured B (Table 1) was higher than that reported by Seyam and Regab (2005) for canals received mixed water in Egypt (0.11 - 0.17 mg L^{-1}). The variation in the measured pH, EC, and B as well as other properties (Table 1) seems to be dependent on the mixing ratio at the pump station; where there was no specific trained between summer and winter values (individual measurements are not shown).

Grape has been classified as moderate sensitive to salinity and sensitive to excess B (Maas, 1990). Irrigation water containing 0.3 mg B L^{-1} can be considered safe for sensitive plants (Keren and Bingham, 1985) and greater than 1 mg B L^{-1} may lead to B toxicity in grape (Peacock and Christensen, 2005). Regardless of soil properties and leaching fraction, the water of El-Nasr canal (Table 1) can be considered suitable for irrigation grapes. On the other hand, when soil-B level is high and irrigation water contains additional B (1.68 kg B ha^{-1} year^{-1}, as calculated in this study) buildup of B in the root zone can be occurred (Nable et al., 1997). Also, the compost applied at the rate 9.6 ton ha^{-1} to the grape is responsible for additional 0.19 kg B ha^{-1} year^{-1}. As both soils receive irrigation water from El-Naser canal and located in the same region, the B input through irrigation water was nearly similar and other environmental factors could be excluded.

Hot water extractable-B was found to be increased with $CaCO_3$ content in soil (Fig. 3) indicating its role in buffering B at high concentration as well as reducing B leaching from soil as both $CaCO_3$ and boron increased with soil depth (Fig. 1 A and D). Continued irrigation with B laden water will increase B than the adsorption capacity of the soil under the current management practices and cause a possible reduction in crop yield (James et al., 1982). On the other hand, the leaching of salts and B through soil profile is dependent also on the amount of water used for irrigation (Ayers and Westcot, 1985). On the calcareous soil (Roda farm) iron chlorosis associated with the high level of soil bicarbonate is one of the main discords (Mengel and Kirkby, 2001; Covarrubias and Rombola, 2013). This was observed on grape leaves during spring (low temperature), and limited irrigation water quantity and frequency and might resulted in more accumulation of B in the root zone. It is highly expected that B leaching was much less under calcareous soil conditions led to build up B in soil and to increase with depth (Fig. 1). Such pattern of increasing B concentration with soil depth and accumulation to toxic level was also found by Ryan et al. (1998), due to limited precipitation rate.

In agreement with (Yermiyahu and Ben-gal, 2006), B concentration in grape petioles and leaves increased with time during the season (Fig. 4). The Calcareous soil with its higher available B than sandy soil showed higher concentrations of B in petioles and in leaves of grape. Establishing a critical concentration from a relation between shoot dry matter and B concentration in the plant was not available in the present work. Based on the fact that B was accumulated in leaves through the season (Fig. 4), there was a positive relationship between B concentrations in the old leaves and soil available B (Fig. 5). In other words, on both soils, B concentration in old leaves of grape was related mostly to the available B in soil (0.0 – 0.30 m depth). This reflected the impotence of soil B test in managing the nutrient.

Taking B critical level in old leaves of grape at 80 mg B kg^{-1} dry matter, the predicted soil B critical level became 2.3 at flowering and 1.8 mg kg^{-1} soil at veraison stages (Fig. 5). The flowering period takes 45 days during April and May at which the temperature ranged between 20 and 25 °C, while during the 21 days veraison stage the temperature ranges between 30 and 35 °C (June). As B uptake by a particular species is determined by B supply and the transpiration rate (Goldbach, 1997; Hu and Brown, 1997), the high temperature during the veraison and post harvest stages is expected to enhance the transpiration, water uptake, and B uptake and concentration in petioles and leaves. Under such conditions, the critical level of B in soil should be kept at its lower margin (1.8 mg B kg^{-1} soil). Applying excess water to leach B is suggested for reclaiming high B soils to satisfactory levels (Ayers and Westcot, 1985). But, on the calcareous soil, care should be taken with grape at the flowering stage. Application of water in excess of plant requirement in such case will increase iron chlorosis. Therefore, the most suitable stage to leach excess B is the post harvest stage. This can maintain suitable soil B level for the new season. Another agronomic management practice is the application of the organic compost. The continuous application of the organic compost on Roda farm (9.6 ton ha^{-1}year^{-1}) resulted in an increase of organic matter content in soil to about 4% in some plots. This can lead to more accumulation of B in soil (applied in- or adsorbed on-composted organic matter) with time and buffer the soil solution at high B concentration. Changing the agronomic practices to free-B potassium humate (5 Kg) instead of organic compost from year to year can help in reducing B accumulation in soil.

CONCLUSION

Boron concentration in soil and in grape was higher in the calcareous soil than in the sandy soil received the same mixed water from El-Nasr canal in Nubaria region, Egypt. Hot water extractable-B from soil was increased with soil depth and positively correlated with $CaCO_3$ content. B concentration in petioles and leaves of grape tended to accumulate with time during the season. Regardless soil type, there was a positive relationship between B concentrations in old leaves and the hot water extractable-B from the surface soil layer (0.0 – 0.30 m depth) suggesting a critical B concentration in soil of 2.3 and 1.8 mg B kg^{-1} soil at flowering and veraison stages, respectively. Results of the present study can be considered as a n early warning for high B status for grape grown on the calcareous soil.

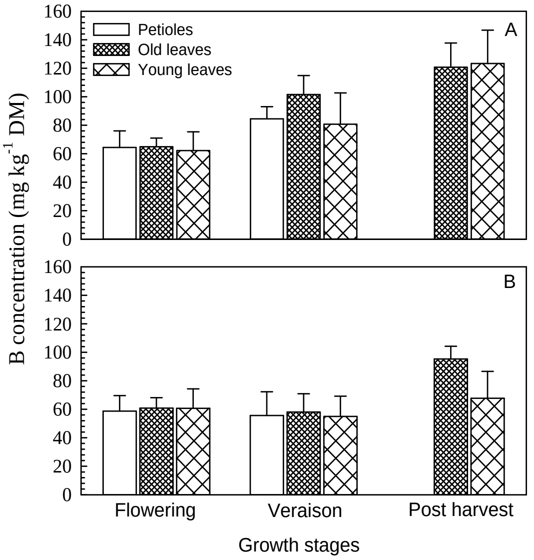

Fig. 4. Boron concentration in petioles, old and young leaves of grape grown on the calcareous (A) and on sandy (B) soils at flowering, veraison, and post harvest stages

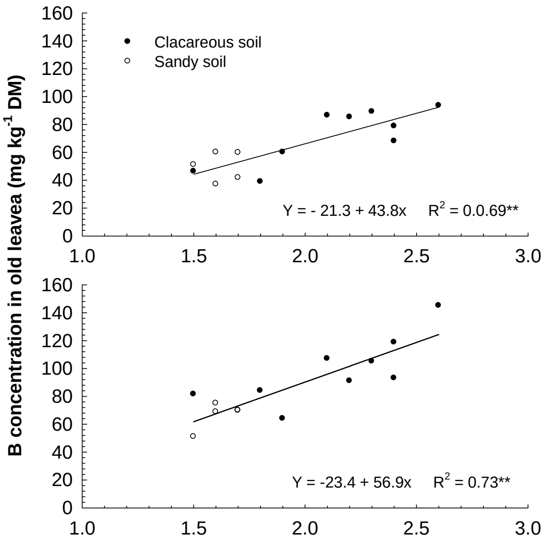

Fig. 5. Relationship between boron concentration in old leaves of grape and hot water extractable-B from the surface soil layer (0.0 – 0.30 m) at flowering (A) and veraison (B) stages

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الملخص العربي

تقييم حالة البورون في عنب المائدة النامى في أرض رملية وجيرية ويروى بمياه مختلطة

محمود قمح، هبة الله أنور

تهدف هذه الدراسة الى تقييم عنصر البورون فى أشجار عنب المائدة والذى يروى بمياه مختلطة (مياه النيل + مياه الصرف الزراعى). وقد تم فى هذه الدراسة أختيار بعض القطاعات فى مزرعتين أحدهما تمثل أرض جيرية والأخرى تمثل أرض رملية فى منطقة النوبارية. وقد تم جمع عينات التربة على ثلاثة أعماق حتى عمق ٠,٩ متر عند بداية موسم النمو. وتم تقدير عنصر البورون ومحتوى التربة من المادة العضوية (OM) وكربونات الكالسيوم ($CaCO_3$) وملوحة التربة (EC). كذلك تم تقدير تركيز البورون فى السماد العضوى المضاف وفى مياه الرى وأعناق وأوراق أشجار العنب.

وأوضحت الدراسة أن مدخلات البورون تقدر بـ ١,٨٧ كجم/هكتار/سنة من مياه الرى والكمبوست المضاف. وقد وجد أن تركيز البورون المستخلص بالماء الساخن (المتاح) أعلي فى الأرض الجيرية مقارنة بالرملية ويزداد مع العمق فى كلا منهما ولكن بدرجة أكبر فى التربة الجيرية. وبغض النظر عن نوع التربة، وجد أن البورون المستخلص يتناسب مع محتوى التربة من كربونات الكالسيوم. ونتيجة لذلك وجدت تركيزات أعلي من البورون فى أعناق أوراق وأوراق نبات العنب النامى فى الأرض الجيرية. وكان متوسط تركيزات البورون فى الأعناق ٦٤,٤ فى مرحلة التزهير والتى ازدادت الى ٨٤,٥ مجم/كجم مادة جافة فى مرحلة نزول الماء هذا بالمقارنة بقيم لم تتعدى ٥٨,٧ فى كلا المرحلتين فى الأرض الرملية. وقد أوضحت نتائج تتبع البورون فى الأوراق أن تركيزات البورون تراكمت مع الوقت خلال الموسم ووصلت أقصاها فى مرحلة ما بعد الحصاد بتركيزات وصلت الى ١٢٠,٧ و ١٢٣,٣ مجم/كجم مادة جافة فى الأوراق القديمة والحديثة على التوالى.

وجدت علاقة إرتباط معنوية بين تركيز البورون فى الأوراق القديمة وتركيز البورون المستخلص بالماء الساخن من الطبقة السطحية (0.0 – 0.3 m). وكان تركيز البورون الحرج فى التربة المتنبأ به هو ٢,٣ مجم/كجم تربة فى مرحلة التزهير و ١,٨ مجم/كجم تربة فى مرحلة نزول الماء. ويفسر ذلك بأن أرتفاع درجة حرارة الجو فى مرحلة نزول الماء مقارنة بمرحلة التزهير تؤدى الى زيادة معدل البخر نتح و أمتصاص الماء وكذلك إمتصاص البورون. ولذا يجب أدارة العنصر بطرقة تسمح بالحفاظ على مستوى البورون فى التربة عند المستويات الأقل عند المراحل التالية لمرحلة التزهير.