ACTA Acta Sci. Pol., Hortorum Cultus 3(2) 2004, 123-129

EFFECT OF BORON FERTILIZATION ON VIGOR, YIELDING AND FRUIT QUALITY OF 'JERSEY' HIGHBUSH BLUEBERRY

Paweł Wójcik
Instytut Sadownictwa i Kwiaciarstwa w Skierniewicach

Abstract. The aim of the study was to examine response of 'Jersey' highbush blueberry to boron (B) fertilization. The experiment was carried out in 2002-2003 at a private plantation in Central Poland on mature blueberries planted on a sandy loam soil with pH 4.1, low organic matter status, and medium available B content. Blueberries were supplied with B by foliar applications or broadcasting. Foliar B sprays were done in the spring or the fall. Spring B sprays were performed at the beginning of blooming, at petal fall, and 3 and 6 weeks after the ending of flowering. In each spring spray treatment, B was used at a rate of 0.2 kg ha^{-1}. Fall B spray was done 5 weeks after fruit harvest using 0.8 kg B ha^{-1}. Soil B was applied at the stage of bud break at a rate of 2 kg ha^{-1}. Blueberries unfertilized with B served as control. The results showed that soil B application and spring B sprays increased B status in flowers and leaves. However, B fertilization, regardless of application mode, had no effect on plant vigor, the number of flowers per cane, fruit set, mean fruit weight, berry firmness, and yielding. Berries of blueberries sprayed with B in the spring had increased soluble solids concentrations. It is concluded that: (i) B fertilizer requirements of 'Jersey' highbush blueberry are low, and (ii) at hot water extractable B concentration in a soil below 0.37 mg kg^{-1} and/or at B status in leaves of current season shoots below 37 mg kg^{-1}, spring B sprays should be applied in blueberry culture to increase soluble solids concentration in fruit.

Key words: highbush blueberry, boron, soil application, foliar application

INTRODUCTION

Highbush blueberry is cultivated in Poland on the area of ca. 300 ha with fruit yields ranging from 800 to 1300 tons annually [Smolarz 2003]. However, many growers have been interested in the establishment of blueberry plantations because of high fruit prices at fresh market and low costs of management and plant protection [Pliszka 2002]. Moreover, since 1 May 2004 Polish producers can export fruits without any tariff walls

Corresponding author – Adres do korespondencji: Paweł Wójcik, Instytut Sadownictwa i Kwiaciarstwa, ul. Pomologiczna 18, 96-100 Skierniewice, e-mail: pwojcik@insad.pl

to European countries in which fruit prices are higher in comparison to those occurring at domestic market. For this reason it is predicted a dynamic increase in blueberry production in Poland.

Blueberries evolved under acidic soil conditions where availability of many nutrients (mainly macroelements) is restricted [Hanson and Hancock 1996]. Therefore, many fertilization practices common to tree fruit production are not appropriate for blueberries. Proper management of nutrition is particularly important in blueberry culture because this species is most frequently grown on sandy soils that are prone to leaching.

Boron (B) is essential microelement required for optimal growth and development of higher plants [Marschner 1995]. It has been reported that under B deficiency conditions blueberry shoot tips die, terminal leaves develop a mottled chlorosis and cupping, and flower and vegetative buds may fail to open on severely affected plants [Gough 1996, Hanson and Hancock 1996]. Plant B deficiency signs occur most frequently on course-textured soils poor in organic matter [Gupta 1979, Shorrocks 1997]. Such soils predominate in Poland. It is estimated that approximately 70% of the agricultural land in Poland has low B status [Grześkowiak 1996]. Thus, we had predicted that on light soils with low organic matter levels available B content can be factor limiting blueberry productivity. Therefore, the aim of the study was to examine the vegetative and the generative responses of highbush blueberries grown on a sandy soil to B fertilization.

MATERIALS AND METHODS

The experiment was carried out in 2002-2003 at a private plantation in Central Poland on mature 'Jersey' highbush blueberries (*Vaccinium corymbosum* L.) planted on a sandy loam soil (Albic Luvisols) at a spacing of 3 × 1 m (3333 bushes ha^{-1}). Some physico-chemical properties of the soil are given in table 1. Soil sample for analysis was taken in 2001 from a layer of 0-20 cm along bush rows. Soil pH was determined potentiometrically in 1 : 2.5 soil/1 M KCl suspensions; contents of particles of sand, silt, and clay by aerometric method according to the procedure by Casagrande and Prószyński [Ostrowska et al. 1991]; organic matter by the chromic and titration procedure [Allison 1965]; exchangeable potassium (K), magnesium (Mg) and calcium (Ca) by means of 1 M NH_4-acetate solution [Ostrowska et al. 1991]; and available phosphorus (P) and B by Ca-lactate solution (pH 3.5) and hot water, respectively [Berger and Truog 1944, Ostrowska et al. 1991]. Phosphorus, K, Mg, Ca, and B were determined by inductively coupled plasma spectroscopy (Thermo Jarrell Ash, Franklin, USA).

Table 1. Some physico-chemical properties of the soil
Tabela 1. Fizykochemiczne właściwości gleby

Sand Piasek	Silt Pył	Clay Części spławialne	Organic C C organiczny	pH	Exchangeable Wymienny			Available Dostępny	
					K	Mg	Ca	P	B
	%		$g\ kg^{-1}$		cmol(+) kg^{-1}			mg kg^{-1}	
72	18	10	23	4.1	5.9	4.4	29.1	58	0.37

During period of the study the area between bush rows was grassed and along rows sawdust was spread over a 1m strip. In each year, fresh sawdust was added periodically in order to keep a 10 cm thick mulch. Plants were fertilized with nitrogen (N) and K. Nitrogen was applied as ammonium sulphate on the entire plantation area at a rate of 100 kg ha^{-1} divided into two equal doses; one was used at the stage of bud burst and others 5 weeks later. Potassium was applied after harvest at a rate of 80 kg ha^{-1} as K-sulphate. Protection against pathogens and pests was performed according to the standard recommendations for commercial blueberry plantations [Olszak and Bielenin 1999].

In the study the efficiency of foliar B sprays versus soil B application was examined. Foliar B sprays were done in the spring or the fall. Spring B sprays were performed on the same plants at the beginning of blooming, at petal fall, and 3 and 6 weeks after the ending of flowering. In each spring spray treatment, B was used at a rate of 0.2 kg ha^{-1} at 300-500 L of water. Fall B spray was done 5 weeks after harvest using 0.8 kg B ha^{-1} at ca. 500 L of water Spring and fall B sprays were done to the point of drip using a handgun sprayer. Soil B was applied at the stage of bud break at a rate of 2 kg ha^{-1}. Boron was applied as Borvit material (8% B as boric acid). Blueberries untreated with B served as control. The experiment was conducted using a randomised complete block design with three replications. Each experimental plot consisted of 10 bushes.

The following measurements and observations were performed: (i) soil available B content was determined only on the plots where B broadcasting was applied and on the control plots. Soil samples were taken at petal fall, and 40 and 80 days after the ending of flowering, along bush row from a depth of 0-30 cm. Composite soil sample from each plot comprised of 5 subsamples. Soil samples were air dried, ground with a wooden roller to pass a 1-mm sieve and then homogenized. Soil B was extracted by hot water according to the procedure described by Berger and Truog [1944] and determined by inductively-coupled plasma spectroscopy; (ii) plant vigor was estimated based on the number and length of current season shoots per cane after ending of plant growth on 7 randomly selected canes per plot; (iii) leaf B concentration was determined in the first week of fruit picking on a 50-leaf sample per plot. Leaves were collected from the middle portion of one-year-old shoots longer than 20 cm. Leaves were rinsed deionized water, dried in a forced-draft oven at 75°C, ground to pass through a 0.84-mm stainless steel screen, ashed in a muffle furnace at 480°C for 12 h., and dissolved in 0.5% HCl. Boron was determined by inductively-coupled plasma spectroscopy; (iv) flower B status was determined at full blooming on a 60-flower sample per plot at the same way as leaf B content; (v) the number of flowers and berries per cane was counted on 5 randomly selected canes per plot; (vi) fruit yield was measured separately for each plot. Only marketable fruit with completely blue skin without signs of decay and mechanical injuries were picked; (vii) main berry weight was calculated on a 100-fruit sample per plot; (viii) fruit firmness was estimated on 30 fruit of similar size by slightly pressing fruit between the thumb and forefinger on a scale from 1 (very soft) to 9 (very firm) and; (ix) soluble solids concentration of fruit was determined by an Abbe refractometer in the homogenate of 300 fruit per plot.

Analyses of variance were performed separately for each growing season. Differences between means were evaluated by Duncan's Multiple Range Test at $P \le 0.05$. Data of the number of flowers and berries per cane were transformed according to $y = \log(x)$.

RESULTS AND DISCUSSION

Hot water-soluble B contents in the soil on the control plots were lower than 0.45 mg kg^{-1} proposed by Wójcik [2003] as the critical value for fruit crops (tab. 2). However, no visual B deficiency symptoms were observed. Soil B contents were comparable within growing season and between the studied years (tab. 2). Regardless of sampling date, B broadcasting increased soil B status above 0.45 mg kg^{-1} (tab. 2).

Table 2. Effect of soil boron application on hot water-extractable boron concentration in the soil
Tabela 2. Wpływ nawożenia doglebowego borem na zawartość boru w glebie ekstrahowanego gorącą wodą

Treatment Zabieg	Boron concentration Zawartość boru (mg kg^{-1})					
	2002			2003		
	petal fall opadanie płatków kwiatowych	40 days after petal fall 40 dni po kwitnieniu	80 days after petal fall 80 dni po kwitnieniu	petal fall opadanie płatków kwiatowych	40 days after petal fall 40 dni po kwitnieniu	80 days after petal fall 80 dni po kwitnieniu
Soil B application Nawożenie doglebowe borem	0.56b	0.53b	0.52b	0.59b	0.55b	0.57b
Control Kontrola	0.37a	0.35a	0.37a	0.36a	0.35a	0.35a

Means within column with the same letter are not significantly different by Duncan's Multiple Range Test at $P \leq 0.05$.
Średnie w kolumnie oznaczone tą samą literą nie różnią się istotnie według testu t-Duncana przy poziomie istotności $P \leq 0,05$.

Table 3. Effect of boron fertilization on leaf and flower B concentrations of 'Jersey' highbush blueberries
Tabela 3. Wpływ nawożenia borem na zawartość boru w liściach i kwiatach borówki wysokiej odmiany Jersey

Treatment Zabieg	Boron concentration, mg kg^{-1} dw Zawartość boru, mg kg^{-1} s.m.			
	leaves – liście		flowers – kwiaty	
	2002	2003	2002	2003
Spring B sprays Wiosenne opryski borem	53.6b	38.5b	48.5b	39.5b
Fall B spray Jesienny oprysk borem	37.9a	28.6a	32.3a	29.1a
Soil B application Doglebowe nawożenie borem	54.1b	40.2b	48.2b	39.1b
Control Kontrola	37.1a	27.8a	30.1a	28.2a

Means within column with the same letter are not significantly different by Duncan's Multiple Range Test at $P \leq 0.05$.
Średnie w kolumnie oznaczone tą samą literą nie różnią się istotnie według testu t-Duncana przy poziomie istotności $P \leq 0,05$.

The number and length of current season shoots per cane of 'Jersey' blueberries were not influenced by B fertilization averaging 78.6 and 458 cm in 2002, and 78.8 and 481 cm in 2003, respectively. This indicates that B fertilization of blueberries had no effect on the strength and growth character.

Blueberry leaf B concentrations on the control plots were within optimal range of 25–70 mg kg^{-1} proposed by Hanson and Hancock [1996] (tab. 3). However, Woodbridge and Drew [1960] found considerable differences in the severity of B deficiency signs among blueberry cultivars. Therefore, they claimed that B needs of highbush blueberry are cultivar-dependent. Hanson [2000] reported that 'Jersey' blueberry leaf B concentration as low as 15 mg kg^{-1} DW was sufficient for optimal growth and fruiting. This indicates that among blueberry varieties, B requirements of 'Jersey' cultivar are particularly low. In our experiment spring B sprays and soil B application increased blueberry leaf B concentrations (tab. 3). Above-mentioned B treatments enhanced flower B status as well (tab. 3). A lack of impact of fall B sprays on leaf and flower B contents probably resulted from restricted B retranslocation from leaves to wood and/or its movement to the growing tissues in the following season. According to Brown and Hu [1996] sorbitol-rich species are able to move B in phloem. Thus, a lack/low mobility of foliar-applied B in phloem of highbush blueberry may result from insufficient amount of sorbitol. Regardless of reason of a lack of B retranslocation in *Vaccinium corymbosum*, it seems that fall B sprays can not be recommended in culture of this species to improve B nutrition in the following rowing season.

Table 4. Effect of boron fertilization on 'Jersey' blueberry yielding, mean berry weight and soluble solids concentration in fruit
Tabela 4. Wpływ nawożenia borem na plonowanie borówki wysokiej odmiany Jersey, średnią masę owocu oraz zawartość ekstraktu refraktometrycznego w owocach

Treatment Zabieg	Marketable fruit yield, kg $bush^{-1}$ Plon handlowy kg $krzak^{-1}$		Mean berry weight Średnia masa owocu g		Soluble solids concentration Ekstrakt %	
	2002	2003	2002	2003	2002	2003
Spring B sprays Wiosenne opryski borem	3.4a	3.2a	1.43a	1.42a	14.1b	14.2b
Foliar B spray Jesienny oprysk borem	3.1a	3.3a	1.39a	1.39a	13.2a	13.5a
Soil B application Doglebowe nawożenie borem	3.2a	3.1a	1.42a	1.38a	13.2a	13.2a
Control Kontrola	3.2a	3.1a	1.39a	1.40a	13.4a	13.3a

Means within column with the same letter are not significantly different by Duncan's Multiple Range Test at $P \leq 0.05$.
Średnie w kolumnie oznaczone tą samą literą nie różnią się istotnie według testu t-Duncana przy poziomie istotności $P \leq 0,05$.

The number of flowers and berries per cane were not affected by B fertilization and averaged 451 and 333 in 2002, and 459 and 341 in 2003, respectively. No B treatment did affect blueberry yielding (tab. 4). Taking into consideration increased flower B content and a lack of the generative response of blueberries to spring B sprays and soil B application we can conclude that plant B status was not factor limiting productivity. Moreover, increased leaf B status in our experiment did not corresponded with blueberry vigor. For these reasons we can suggest that B needs required for optimal vigor and yielding of 'Jersey' highbush blueberry are low.

Berry firmness did not differ considerably among the studied combinations averaging 6.2 and 6.4 in 2002 and 2003, respectively. Also, mean berry weight was influenced by B fertilization (tab. 4). However, berries of bushes sprayed with B in the spring had increased soluble solids concentration (tab. 4). This effect might result from increased leaf photosynthesis rate. This explanation can be true since it is known that B plays a key role in many physiological processes [Marschner 1995]. On the other hand, it is difficult to explain why soil B application did not increase soluble solids concentration in fruit despite similar effect of this treatment on leaf B content as spring B sprays. We are speculating that physiological role of leaf-applied B in plant tissues may be different from that determining by B took up by roots. However, this hypothesis has not been supported by any research experiment so far.

CONCLUSIONS

The obtained results showed a lack of the vegetative and the generative responses of 'Jersey' highbush blueberries to B fertilization. It was found that fall B sprays were not successful in improving blueberry B nutrition in the following growing season. For this reason fall B sprays should not be recommended in blueberry culture. We conclude that (i) B fertilizer requirements of 'Jersey' highbush blueberry are low, and (ii) at hot water extractable B concentration in a soil below 0.37 mg kg^{-1} and/or at B status in leaves of current season shoots below 37 mg kg^{1-}, spring B sprays should be applied in blueberry culture to increase soluble solids concentration in fruit.

REFERENCES

Allison L. E., 1965. Organic carbon. In: Methods of soil analysis, D. D. Black, J. L. Evans, I. E. White, F. E. Engminger, I. E. Clark (Eds.); American Society of Agronomy, Madison, WI, 1367–1378.

Berger K. C., Truog E., 1944. Boron tests and determination for soil and plants. Soil Sci. 57, 25–36.

Brown P. H., Hu H., 1996. Phloem mobility of boron is species dependent: evidence for phloem mobility in sorbital-rich species. Ann. Bot. 77, 497–505.

Gough R. E., 1996. Blueberries – North and South. J. Small Fruit Viticulture. 4, 106–152.

Grześkowiak A., 1996. Nawozy mineralne we współczesnym rolnictwie. [In:] Nawożenie mineralne roślin uprawnych; R. Czuba (ed.); Zakłady Chemiczne "Police" SA, Police, 17–56.

Gupta U. C., 1979. Boron nutrition of crops. Adv. Agron. 31, 273–307.

Hanson E. J., 2000. Foliar boron sprays do not affect highbush blueberry production. Small Fruit Rev. 1, 35–41.

Hanson E. J., Hancock J. F., 1996. Managing the nutrition of highbush blueberries. Extension Bulletin E-2011. Michigan State University, East Lansing, MI, 1–12.

Marschner H., 1995. Mineral nutrition of higher plants. Academic Press, London.

Olszak E., Bielenin A., 1999. Program ochrony roślin; Agrosan, Sandomierz.

Ostrowska A., Gawliński S., Szczubiałka Z., 1991. Metody analizy i oceny właściwości gleb i roślin; Instytut Ochrony Środowiska, Warszawa.

Pliszka K., 2002. Borówka wysoka. PWRiL, Warszawa.

Shorrocks V. M., 1997. The occurrence and correction of boron deficiency. Plant Soil, 193, 121–148.

Smolarz K., 2003. Uprawa borówki i żurawiny. Hortpress, Warszawa.

Woodbridge C. G., Drew R. H., 1960. A boron deficiency dieback in highbush blueberries. Plant Dis. Rept. 44, 855–857.

Wójcik P., 2003. The importance of boron in apple production. In: Crop management and post-harvest handling of horticultural crops. III. Crop fertilization, nutrition and growth; Dris R., Niskanen R., Jain S. M., Eds. Science Publishers, Inc., Enfield (NH), USA, 77–92.

WPŁYW NAWOŻENIA BOREM NA WZROST, PLONOWANIE ORAZ JAKOŚĆ OWOCÓW BORÓWKI WYSOKIEJ ODMIANY JERSEY

Streszczenie. Celem pracy było zbadanie reakcji borówki wysokiej odmiany 'Jersey' na nawożenie borem. Doświadczenie przeprowadzono w latach 2002–2003 na borówkach posadzonych na glebie piaszczysto-gliniastej mającej pH 4,1, niską zawartość materii organicznej oraz średnią zawartość dostępnego boru. Rośliny zasilano borem w formie nawożenia doglebowego lub pozakorzeniowego. Opryskiwania borem wykonywano wiosną lub jesienią. Wiosenne opryski borem wykonywano na tych samych roślinach w fazie początku kwitnienia, w czasie opadania płatków kwiatowych oraz 3 i 6 tygodni po kwitnieniu. W każdym wiosennym oprysku użyto 0,2 kg $B \cdot ha^{-1}$. Jesienny oprysk borem wykonano 5 tygodni po zbiorze owoców w dawce 0,8 kg $B \cdot ha^{-1}$. Nawożenie doglebowe zastosowano w fazie pękania pąków w dawce 2 $kg \cdot ha^{-1}$. Rośliny nietraktowane borem stanowiły kontrolę. Wyniki wykazały, że doglebowe nawożenie borem oraz wiosenne opryski tym składnikiem zwiększyły zawartość boru w kwiatach i liściach. Jednakże nawożenie borem, niezależnie od sposobu zastosowania, nie miało wpływu na siłę i charakter wzrostu, liczbę kwiatów na pędzie, zawiązywanie owoców, średnią masę owocu, jędrność owoców oraz plonowanie. Owoce roślin opryskiwanych wiosną borem miały podwyższoną zawartość ekstraktu refraktometrycznego. Wnioskuje się, że: (1) potrzeby nawozowe borówki wysokiej odmiany 'Jersey' w odniesieniu do boru są niskie, oraz (2) przy zawartości boru w glebie poniżej 0,37 $mg \cdot kg^{-1}$ i/lub przy poziomie boru w liściach poniżej 37 $mg \cdot kg^{-1}$, wskazane jest wiosenne opryskiwanie borówki wysokiej borem w celu zwiększenia zawartości ekstraktu w owocach.

Słowa kluczowe: borówka wysoka, bor, nawożenie doglebowe, nawożenie pozakorzeniowe

Zaakceptowano do druku – Accepted for print: 20.09.2004