The influence of fertilizers on *Vaccinium macrocarpon* Ait. growth and yielding 1. Phenophases, plant morphology and yielding

Aneta Świeczkowska, Zdzisław Kawecki

University of Warmia and Mazury, 10–957 Olsztyn, ul. Prawocheńskiego 21

Vidmantas Stanys

Lithuanian Institute of Horticulture, LT-4335 Babtai, Lithuania E-mail: institutas@lsdi.lt

Four large cranberry cultivars were grown in artificially prepared peat solum obtained from highmoor peatbog. Nitrogen and potassium fertilizers were applied at 10 and 20 kg of each element per hectare. Nitrogen was applied as ammonium sulphate and potassium as potassium sulphate in equal doses during the leaf-bud break, hook stage, fruit set and bud formation. Plant phenophases, the number of fruit-bearing shoots per 1 square meter, the number of flowers per 1 fruit-bearing shoot, the number of set berries per 1 fruit-bearing shoot and the volume of the yield were investigated.

It was revealed that the American cultivars of the large cranberry may be successfully grown on artificially prepared peat solum obtained from highmoor peatbog. In the climatic conditions of north-eastern Poland, flowers of the earliest cultivar 'Ben Lear' were damaged by spring frosts. Nitrogen and potassium fertilization did not affect significantly the course of phenophases and plant morphology, but had a positive effect on yielding. The most favourable dose was 10 kg N and 10 kg K, particularly for cv. 'Pilgrim' and 'Stevens'.

Key words: large cranberry, nutrition, cultivars, phenophases, plant morphology, yielding

INTRODUCTION

In the last few years, particularly in the USA and Canada but also in Europe, a growing interest in large cranberry cultivation has been observed. The high dietary value of berries, their taste and healing properties cause an increase in the growing area of this plant. According to Soczek and Scholtz [12], Kaczmarczyk and Zbieć [4] and Kawecki et al. [5], cranberries are a valuable raw material in food processing industry due to the content of organic acids, a low content of nitrogen compounds and the content of pectins. As Sękowski [9] reports, cranberries contain compounds that may increase the effect of antibiotics and sulphonamides. According to Stang [13], in the USA part of collected cranberries is used as a semifinished product for production of various pharmaceuticals and cosmetics.

According to the research by Soczek, Scholtz [12], Kaczmarczyk and Zbieć [4] and Smolarz [11], the growing of cranberry both by amateurs and for the needs of food industry is not difficult, provided the

proper acid soil is chosen and water that does not contain calcium and magnesium cations is supplied to water the plants.

The objective of the study was to determine the possibilities of large cranberry cultivation on peat solum obtained from highmoor peatbog with additional differentiated nitrogen and potassium nutrition.

MATERIAL AND METHODS

The experiment on cultivars and nutrition of large cranberry (*Vaccinium macrocarpon* Ait.) was set in artificially prepared solum in the Experimental Garden of the University of Warmia and Mazury. On a flat area, 30 meters from a lake, a 30 cm surface layer of mineral soil was removed and the area was covered with milled highmoor horticultural peat AURA, pH 3.5–4.5 (in H_2O). The external edges were covered with PE film in order to separate the solum from adjacent soil. After soil packing, the rooted seedlings of cv. 'Ben Lear', 'Pilgrim', 'Searles', 'Stevens' were planted at a spacing 25 × 25 cm. On all the surface the Mis-3 fertilizing mixture was applied after planting seedlings in spring 1995. Additionally, macro- and microelements were added into the solum (part A and B) [8, 14]. A mixture of greenhouse and peat substrate fertilisers is composed from two parts of constituents. Part A contains the following macroelements: N – 10.2%, P_2O_5 – 8.1%, K_2O – 15.3%, MgO – 6.1%. Part B: Fe – 7.2%, Mn – 2.6%, Cu – 8.7%, Zn – 0.6%, B – 1.8%, Mo – 0.2%.

Components of part A: ammonium, salt petre, concentrated superhosphate, potassium sulphate, magnesium sulphate. Components of part B: ferrous sulphate, manganous sulphate, copper sulphate, zinc sulphate, 7-amonium molybdate, boron acid. After planting, all the plantation was covered with a 2 cm sand layer. In 1996 and 1997 the plants were fertilized similarly as in 1995.

In April 1998, solum pH was 4.5 in 1n KCl. The content of available forms of elements was as follows: P_2O_5 – 265 mg, K_2O – 41 mg, Mg – 32.9 mg/100 g of soil. In the same month, the study on 2 factors was set (factor 1 – cultivars, factor 2 – nitrogen and potassium nutrition). The experiment was organized in randomized split-plot design with 6 replicates. The plot covered the area of 1.5 m^2. Each plot was separated from the adjacent plot with a 30 cm deep rigid plastic barrier.

On the plot, 3 experimental variants were applied: control (without nutrition), nitrogen and potassium nutrition (10 kg N and 10 kg K per hectare), nitrogen and potassium nutrition (20 kg N and 20 kg K per hectare). Nitrogen was applied as ammonium sulphate $(NH_4)_2SO_4$, and potassium as potassium sulphate. Topdressing was applied in 4 equal doses during the leaf-bud break, hook stage, fruit set and bud formation.

Weeds were removed manually. Berries were collected manually during the stage of technological ripeness.

The phenophases and morphology were analysed in the study. The length of fruit-bearing shoots, the number of fruit-bearing shoots per 1 square meter, the number of flowers per 1 fruit-bearing shoot, the number of set berries per 1 fruit-bearing shoot and the volume of yield were examined. The quality of berries (size, mass, the number of seeds) and the chemical composition are presented in Part 2 of the paper.

The results were statistically analysed with the use of the analysis of variance. The T-Tukey test was applied in order to evaluate and compare the mean values at the significance level $p = 0.05$. (Statistica AXXP; SN:AXXP9127977720AR32 CD-KEY: RPBWKCD5L75X6X.)

RESULTS AND DISCUSSION

The beginning of the vegetation of plants depended mainly on the temperatures in spring and it was the same for all the 4 cultivars studied (Table 1). The

Table 1. **Phenophases of the large cranberry during the research**

Cultivars	Beginning of vegetation Close bud	Swollen bud	Cabbage head stage	Bud break	Bud elongation	Roughneck stage	Hook stage	Full blooming	Fruit set	Harvest of berries
1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*
1998										
'Ben Lear'	08.04	10.04	15.04	19.04	29.04	10.05	18.05	02.06	25.06	13.09
'Pilgrim'	08.04	20.04	28.04	02.05	08.05	20.05	01.06	23.06	10.07	26.09
'Searles'	08.04	15.04	23.04	27.04	02.05	15.05	28.05	17.06	02.07	20.09
'Stevens'	08.04	15.04	23.04	27.04	02.05	15.05	28.05	17.06	02.07	20.09

Table 1 (continued)

1	2	3	4	5	6	7	8	9	10	11
1999										
'Ben Lear'	27.03	03.04	10.04	15.04	23.04	05.05	13.05	29.05	20.06	14.09
'Pilgrim'	27.03	16.04	21.04	28.04	02.05	17.05	26.05	10.06	30.06	26.09
'Searles'	27.03	10.04	16.04	23.04	29.04	10.05	20.05	04.06	25.06	21.09
'Stevens'	27.03	10.04	16.04	23.04	29.04	10.05	20.05	04.06	25.06	21.09
2000										
'Ben Lear'	09.04	13.04	15.04	20.04	30.04	11.05	22.05	06.06	30.06	14.09
'Pilgrim'	09.04	17.04	22.04	30.04	12.05	25.05	04.06	28.06	15.07	25.09
'Searles'	09.04	13.04	19.04	25.04	02.05	16.05	31.05	15.06	07.07	20.09
'Stevens'	09.04	13.04	19.04	25.04	02.05	16.05	31.05	15.06	07.07	20.09

stage of the swollen bud depended on the year and cultivar and occurred in the first or second decade of April. This stage was the earliest in cv. 'Ben Lear' and latest in cv. 'Pilgrim'. The following stages of the development up to the roughneck stage occurred at a few days intervals in a similar order.

The beginning of the roughneck stage depended on the cultivar and occurred at the end of the first or second decade of May. Flower buds of cv. 'Ben Lear' suffered from frosts in the first decade of May 2000. The hook and full bloom stages occurred last in cv. 'Pilgrim'. The earliest harvest of ripe berries was obtained from cv. 'Ben Lear', and the latest (at the end of September) from cv. 'Pilgrim'.

During phenologic observations it was found that the earliest cultivar was 'Ben Lear', followed by 'Searless' and 'Stevens', and 'Pilgrim' was the last to ripen. Other authors [2, 10] confirm the results related to the order of the development phases of these cultivars presented in the present paper. Liebster [6] reports that spring daily temperature fluctuations, particularly the temperatures below zero in the period of flower bud formation and blooming are the most dangerous for the large cranberry. During the study, the early blooming cv. 'Ben Lear' suffered from spring frosts in 2000. The yielding of the cultivar was low.

Table 2. **Effect of nitrogen and potassium nutrition on the number of fruit-bearing shoots of the large cranberry per 1 square meter in 1998–2000**

Cultivar	Year	Control	N_{10} K_{10}	N_{20} K_{20}	Mean
		Years × cultivars × nutrition			Years × cultivars
'Ben Lear'	1998	3967a	2850b	3533a	3450b
	1999	1317c	1700b	933c	1317c
	2000	583c	1267c	1133c	994d
'Pilgrim'	1998	4183a	4533a	4367a	4361a
	1999	1450b	1267c	1150c	1289c
	2000	683c	1217c	800c	900d
'Searles'	1998	3417a	3733a	3183a	3444b
	1999	1367c	1633b	1183c	1394c
	2000	817c	1067c	1300c	1061d
'Stevens'	1998	2300b	2867b	3750a	2972b
	1999	1633b	1883b	1850b	1789c
	2000	1300c	1117c	1433b	1283c
$LSD_{0.05}$		1471.98			636.98
		Cultivars × nutrition			Cultivars
'Ben Lear'		1956a	1939a	1866a	1920a
'Pilgrim'		2105a	2339a	2106a	2183a
'Searles'		1867a	2144a	1889a	1967a
'Stevens'		1744a	1956a	2344a	2015a
$LSD_{0.05}$		ns			ns
		Years × nutrition			Years
	1998	3467a	3496a	3708a	3557a
	1999	1442a	1621a	1279a	1447b
	2000	846a	1167a	1167a	1060c
$LSD_{0.05}$		ns			325.22
		Nutrition			
		1918a	2095a	2051a	
$LSD_{0.05}$		ns			

The number of fruit-bearing shoots per square meter depended on the cultivar and nitrogen and potassium nutrition (Table 2). The largest number of these shoots was observed in 1998 (3557 shoots per square meter). The interaction of the differentiated level of nitrogen and potassium nutrition affected significantly the number of fruit-bearing uprights in particular years. Generally, it was observed that nutrition did not differentiate the formation of fruit-bearing shoots.

A decrease in the number of fruit-bearing shoots was observed in the following years. It may have been caused by slow changes in the acidity towards neutral pH, which may have resulted from infiltration of lake water, pH 6.3. Medappo and Dana [7] obtained the best results in the growth of vegetative shoots on the soil pH 4.0–5.0.

Nitrogen and potassium nutrition did not affect the number of flowers, either (Table 3). It varied by cultivar. According to Stang [13], each fruit-bearing shoot should form 1 to 7 flowers. In the study, the number of flowers was quite high – from 3 to 6 per shoot. There were no differences in the number of flowers per shoot in particular years.

The yielding of the large cranberry was very differentiated in the years studied (Table 4). The biggest number of berries was collected in the first two years of study. The year 2000 was the least favourable for yielding. The volume of the yield varied by cultivar. The most high-yielding were cv. 'Pilgrim' (12 tons per hectare on average) and Stevens (11.7 tons per hectare). Despite cultivars, nitrogen and potassium nutrition significantly affected the feature studied. Application of nitrogen and potassium at 10 kg per hectare (converted in pure elements) resulted in the highest yield in c. v. Pilgrim in 1998 (24.7 tons per hectare) and in c. v. Stevens in 1999 (23.3 tons per hectare).

Slightly lower yields were obtained from the plots fertilized with nitrogen and potassium at 20 kg per hectare. After application of these fertilizers, the best fruiting was obtained from cv. 'Stevens' (22.3 tons per hectare) in 1999, whereas the yield of cv. 'Pilgrim' both in 1998 and 1999 remained at the same level and amounted to 17 tons per hectare. A significantly lower yield was obtained from cv. 'Ben Lear'. The mean yield obtained from cv. 'Ben Lear' during all the years studied did not even exceed 10 tons per hectare and in 2000 it amounted only to 0.9 ton per hectare. The lowest yields of the large cranberry were obtained from non-fertilized plots and amounted to 7.9 tons per hectare on average.

In the study by Davenport and Vors [1], differentiation of the doses of nitrogen applied at 10 cultivars did not result in a positive effect on yielding. This element had a more positive impact on the vegetative growth than on the increase in the number of fruits. The results presented in this paper show that the nitrogen dose of 10 kg and the potassium dose of 10 kg caused a better yielding of the cultivars studied. DeMoranville and Da-

Table 3. **Effect of nitrogen and potassium nutrition on the number large cranberry flowers per 1 fruit-bearing shoot in 1998–2000**

Cultivar	Year	Control	N_{10} K_{10}	N_{20} K_{20}	Mean
		Years × cultivars × nutrition			Years × cultivars
'Ben Lear'	1998	4a	3a	3a	3c
	1999	4a	4a	4a	4b
	2000	3a	5a	4a	4b
'Pilgrim'	1998	6a	6a	5a	6a
	1999	4a	5a	4a	4b
	2000	4a	5a	3a	4b
'Searles'	1998	4a	4a	4a	4b
	1999	4a	3a	4a	4b
	2000	5a	4a	4a	4b
'Stevens'	1998	4a	4a	4a	4b
	1999	5a	6a	5a	5ab
	2000	4a	5a	5a	5ab
$LSD_{0.05}$		ns			1.01
		Cultivars × nutrition			Cultivars
'Ben Lear'		4a	4a	4a	4b
'Pilgrim'		5a	5a	4a	5a
'Searles'		4a	4a	4a	4b
'Stevens'		4a	5a	5a	5a
$LSD_{0.05}$		ns			0.45
		Years × nutrition			Years
	1998	5a	4a	4a	4a
	1999	4a	5a	4a	4a
	2000	4a	5a	4a	4a
$LSD_{0.05}$		ns			ns
		Nutrition			
		4a	5a	4a	
$LSD_{0.05}$		ns			

Table 4. **Effect of nitrogen and potassium nutrition on yielding of the large cranberry in 1998–2000 (t/ha)**

Cultivar	Years	Control	N_{10} K_{10}	N_{20} K_{20}	Mean
		Years × cultivars × nutrition			Years × cultivars
'Ben Lear'	1998	5.6c	2.6c	5.2c	4.5c
	1999	6.5c	12.7b	7.3c	8.8b
	2000	1.1c	1.1c	0.4c	0.9c
'Pilgrim'	1998	17.5a	24.7a	17ab	19.7a
	1999	6.6c	10.1b	17.3a	11.3b
	2000	5.1c	7.9c	2.1c	5.0c
'Searles'	1998	7.5c	12.4b	11.0b	10.3b
	1999	10.5b	13.4b	13.5b	12.5b
	2000	4.9c	7.3c	6.7c	6.3c
'Stevens'	1998	5.6c	7.9c	6.7c	6.7c
	1999	20.3a	23.3a	22.3a	22.0a
	2000	3.9c	5.9c	9.6b	6.5c
$LSD_{0.05}$		7.59			4.73
		Cultivars × nutrition			Cultivars
'Ben Lear'		4.4a	5.5a	4.3a	4.7c
'Pilgrim'		9.7a	14.2a	12.1a	12.0a
'Searles'		7.6a	11.0a	10.4a	9.7b
'Stevens'		9.9a	12.4a	12.9a	11.7a
$LSD_{0.05}$		ns			2.11
		Years × nutrition			Years
	1998	9.1a	11.9a	10.0a	10.3b
	1999	11.0a	14.9a	15.1a	13.7a
	2000	3.8a	5.6a	4.7a	4.7c
$LSD_{0.05}$		ns			1.39
		Nutrition			
		7.925b	10.775a	9.925a	
$LSD_{0.05}$		1.3			

venport [3] did not achieve an increase in the yielding of cv. 'Early Black' and 'Howes' after application of low doses of potassium.

CONCLUSIONS

1. The climatic conditions of north-eastern Poland (Olsztyn) were favourable for the normal development and growth of the large cranberry cv. 'Ben Lear', 'Pilgrim', 'Searles', 'Stevens' grown on artificial peat solum obtained from highmoor peatbog.

2. Ground frosts which occurred in Warmia in May 2000 damaged flowers during the hook stage of the early cultivar 'Ben Lear'. The other cultivars, which bloom later, were not damaged by the frosts.

3. The earliest growth and development was observed in cv. 'Ben Lear', followed by 'Searles' and 'Stevens' and the latest in cv. 'Pilgrim'. Ripening of berries of cv. 'Ben Lear' was observed in mid-September, cv. 'Searles' and 'Stevens' on about 20 September and cv. 'Pilgrim' at the end of September. Application of nitrogen and potassium did not have a significant effect on the course of phenophases and plant morphology.

4. The yielding of the cultivars during the 3 years of the study was highly differentiated and depended significantly on the cultivar and the amount of nitrogen and potassium fertilization. The best yielding was achieved by applying 10 kg N and 10 kg K per hectare. 'Pilgrim' and 'Stevens' were the cultivars that showed the highest yielding during the 3 years of the study.

Received
26 April 2003

References

1. Davenport J. R., Vorsa N. Cultivar fruiting and vegetative response to nitrogen fertilizer in cranberry // Journal of the American Society for Horticultural Science. 1999. Vol. 124. N 1. P. 90–93.
2. Demoranville I. E. Fertilizer for Cranberries // Modern Cranberry Cultivation. Univ. of Massachusetts USDA and County Extention, 1987. P. 3–87.
3. DeMoranville C. J., Davenport J. R. Field evaluation of potassium supplements in cranberry production // Journal of the American Society for Horticultural Science. 1994. Vol. 2. N 3. P. 81–87.
4. Karczmarczyk S., Zbieć I. I. Żurawina wielkoowocowa i możliwości jej uprawy w Polsce. Cz. I. Agrotechnika Żurawiny // Zeszyty Naukowe Akademii Rolniczej w Szczecinie, 186 Rolnictwo. 1998. N 69. S. 37–42.
5. Kawecki Z., Łojko R., Pilarek B. Mniej znane rośliny sadownicze i warzywnicze w ziołolecznictwie domowym. ODR Olsztyn, 1999. S. 69–75.
6. Liebster G. Cranberry. Die Kulturpreiselbeere. Top Servis, 8. München, 1972.
7. Medappo K. C., Dana M. N. Influence of pH, calcium, iron and aluminium on the uptake of radiophosphorus by cranberry plants // Proceedings on Soil Science of America. 1968. N 32. P. 381–383.
8. Sadowski A., Nurzyński J., Pacholak E., Smolarz K. Określenie potrzeb nawożenia roślin sadowniczych. Inst. nr 1, 2, 3. Warszawa, 1990.

9. Sękowski B. Pomologia systematyczna // Wyd. Nauk. PWN, Warszawa, 1993. T. II.
10. Smolarz K. Żurawina. Pomologia. Pod red. A. Rejmana. Rozdz. nr 15. PWRiL, Warszawa, 1994. S. 594–602.
11. Smolarz K. Plonowanie kilku odmian żurawiny wielkoowocowej na glebie mineralnej // Uprawa borówki i żurawiny. ISiK, 1999. S. 103–107.
12. Soczek Z., Scholtz R. Uprawa żurawiny na potorfiach. PWRiL, Warszawa, 1970.
13. Stang E. J. The North American Cranberry Industry // Acta Horticulturae. 1993. Vol. 346. P. 284–294.
14. Starck J. R. Uprawa i nawożenie roślin ogrodniczych. PWRiL, Warszawa, 1997.

Aneta Świeczkowska, Zdzisław Kawecki, Vidmantas Stanys

TRĄŠŲ ĮTAKA *VACCINIUM MACROCARPON* Ait. AUGIMUI IR DERĖJIMUI
1. FENOFAZĖS, AUGALŲ MORFOLOGIJA IR DERĖJIMAS

S a n t r a u k a

1998–2000 m. tirtas keturių stambiauogės spanguolės (*Vaccinium macrocarpon* Ait.) veislių *Ben Lear, Pilgrim, Searles, Stevens* augimas. Augalai auginti iš aukštutinių durpių dirbtinai parengtoje dirvoje. Azoto ir kalio trąšos naudotos po 10 ir 20 kg ha^{-1} kiekvieno elemento. Azotas išbertas amonio sulfato, o kalis – kalio sulfato formų lygiomis dozėmis lapinių pumpurų prasiskleidimo, kabliuko (hook stage), užuomazgų mezgimo ir pumpurų susidarymo fazėse. Vertinta augalų fenofazių kaita, generatyvinių ūglių skaičius 1 m^2, žiedų skaičius, tenkantis vienam generatyviniam ūgliui, vaisių skaičius, tenkantis vienam generatyviniam ūgliui, ir derlius.

Parodyta, kad amerikietiškų veislių stambiavaises spanguoles galima sėkmingai auginti iš aukštutinių durpių dirbtinai parengtoje dirvoje. Šiaurės Rytų Lenkijos klimato sąlygomis ankstyviausios veislės *Ben Lear* žiedus pažeisdavo pavasarinės šalnos. Tręšimas azoto ir kalio trąšomis neturėjo įtakos fenofazių eigai bei augalų morfologijai, bet teigiamai veikė derėjimą. Tinkamiausia tręšimo norma buvo 10 kg ha^{-1} N ir 10 kg ha^{-1} K, ypač veislėms *Pilgrim* ir *Stevens*.

Raktažodžiai: augalų morfologija, derėjimas, fenofazės, stambiauogė spanguolė, tręšimas, veislės

Анета Свечковска, Здислав Кавецки, Видмантас Станис

ВЛИЯНИЕ УДОБРЕНИЙ НА РОСТ И УРОЖАЙНОСТЬ *VACCINIUM MACROCARPON* Ait.
1. ФЕНОФАЗЫ, МОРФОЛОГИЯ И УРОЖАЙНОСТЬ РАСТЕНИЙ

Р е з ю м е

В 1998–2000 гг. провели исследования по росту четырех сортов клюквы крупноплодной: *Ben Lear, Pilgrim, Searles, Stevens*. Растения выращивали на почве, искусственно приготовленной из торфа верхового торфяника. Азотное и калийное удобрение внесли в количестве по 10 и 20 кг каждого элемента на гектар. Азот вносили в виде сульфата аммония, а калий – в виде сульфата калия в равных дозах в фазе разрыва листовых почек, фазе крючка (hook stage), фазе завязывания плодов, образования почек. Анализировали фенофазы растений, число плодоносных побегов на 1 $м^2$, число цветов на 1 плодоносном побеге, число завязанных плодов на 1 плодоносном побеге и величину урожая.

Констатировали, что американские сорта клюквы крупноплодной можно успешно выращивать на почве, искусственно приготовленной из торфа верхового торфяника. В климатических условиях северо-восточной Польши цветы самого раннего сорта *Ben Lear* повреждались весенними заморозками. Азотно-калийное удобрение не оказывало влияния на ход фенофаз и морфологию растений, однако способствовало повышению урожая. Лучшая доза удобрений – 10 кг N и 10 кг K, особенно для сортов *Pilgrim* и *Stevens*.

Ключевые слова: клюква крупноплодная, удобрение, сорта, фенофазы, морфология растений, урожайность