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GROWTH, FLOWERING AND YIELDING OF SIX AMERICAN CRANBERRY (*Vaccinium macrocarpon* Ait.) CULTIVARS

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Abstract. *Vaccinium macrocarpon* Ait. – the cranberry of the *Ericaceae* family is cultivated mostly on high peat bogs. In Poland exist a good climatical conditions and considerable acreage of acid soils for cranberry growing. Cranberries can be consumed solely after processing, mostly as juice and sauce. Cranberries are beneficial for the human organism because they are a good source of vitamin A, B_1, B_2 , B_6 and C, flavonoides, organic acids and other substances. Experiments on investigation of 6 cultivars of the American large fruited cranberries were begun in 2004 at the research plantation of Department of Genetics and Horticultural Plant Breeding in Felin, near Lublin. Seedlings were planted out at spacings of 50×50 cm in specialy prepared beds filled with sphagnum peat. During the experiments the following indices were evaluated: growth rhythm, length of horizontal shoots, number of vertical shoots per 1 m^2, number of flowers and berries per 1 m^2 in 4 – fold replications, weight of 100 berries and vitality of pollen. Over two years cultivars 'Pilgrim' and 'Cropper' had the highest yield (average 662 g and 611 g per 1 m^2, respectively). 'Stankavich' had the lowest yields of all 6 cultivars (average 95.5 g). 'Pilgrim' and 'Cropper' had the largest fruit size (average 1.55 g and 1.51 g, respectively), 'Stankavich' the smallest (av. 0.57 g), and 'Le Munion', Nr 20 and 'Stevens' were intermediate in fruit size. Interaction clone × year proved to be important in the case of such characteristics as: annual increment of shoots, number of flowers per 1 m^2, number of berries per 1 m^2 and weight of berries. The number of grains with alieve cytoplasm was the greatest in 'Cropper' and 'Pilgrim' cultivars.

Key words: pollen viability, yielding capacity, *Vaccinium macrocarpon* Ait., vegetation

INTRODUCTION

The cranberry (*Vaccinium macrocarpon* Ait.), a diploid (2n = 2x = 24) species is a slender, creeping, woody, evergreen perennial vine [Vander Kloet 1988] (fot. 1).

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A native North American plant, it is cultivated in the USA and Canada, whereas in Poland grow other vaccinium species: *Vaccinium oxycoccus* and *Vaccinium vitis idaea.* Cranberries contain relatively high levels of vitamin C, cellulose and pectin, and produce anthocyanins and proanthocyanidins (condensed tannins) which have been shown to help prevent urinary tract infections through reduced adhesion of uropathogenic *Escherichia coli* [Leahy et al. 2002]. The anthocyanin content of cranberry is believed to have important therapeutic values, including antitumor, antiulcer, antioxidant, and anti-inflammatory activities [Wang et al. 1999].

Fot. 1. Growth performance of cranberry 'Le Munion' in the fourth year of cultivation
Fot. 1. Rośliny żurawiny odmiany 'Le Munion' w czwartym roku uprawy

The cultural peculiarities of the cranberry are a requirement for acid soils on sites which can be diked and flooded periodically. Flooding is used for winter protection against desiccation, frost protection during the growing season, for facilitating harvest, and for adjusting the ripening season. A thin layer of sand is added to the cranberry bog every three to four seasons, basically to provide a new rooting medium for the old vines.

Cranberry breeding efforts are being focused on early maturing fruit, uniform large size, intense color (total anthocyanin content), keeping quality, high productivity, disease resistance and plant vigor. The greatest emphasis is being placed on productivity and resistance to fruit rot organisms [Hancock 2008]. A large number of flowers per upright with high pollen and egg fertility and insect attractiveness is also essential to heavy fruit production. Most of the cranberry cultivars originated as single vine selections from populations in native bogs, and four these wild vine selections accounted for 91.5% of the total American production area ('Early Black', 'Howes', 'McFarlin', 'Searles') [Janick and Moore 1975]. Cranberry production in all of North America now exceeds 200 000 t annually, on 16 000 ha [Caruso 1997]. The consumption of cranber-

ries is on the rise all over the world and would increase also in Poland, providing their supply from domestic bogs.

The aim of the study was to assess the growth, flowering, yielding and pollen vitality of american cranberry (*Vaccinium macrocarpon* Ait.) in the third and fourth year of cultivation.

MATERIAL AND METHODS

Experiments on testing of the American large fruited cranberries were begun in 2004 at the Felin Research Plantation of University of Life Sciences in Lublin. Six cranberry cultivars including 'Pilgrim', 'Cropper', 'Le Munion', 'Nr 20', 'Stevens' and 'Stankavich' have been brought from Research Institute of Pomology and Floriculture in Skierniewice. Plant material came from traditional breeding.

Stem cuttings were harvested in September 2004 from the field, rooted in peat in a mist chamber, subjected to winter chilling, and grown in pots for two months and placed in the field in spring 2005. The plants were planted out at spacings of 50×50 cm. Size of plot contained 8 plants for each cultivar was 2 m^2. The experiment was set in 4 replications. Plots were established in the specially prepared beds – the layer of 30 cm mineral soil (pH 6.8 in KCl) was removed, powdered with drop-sulphur in dose 0.33 $kg \cdot m^{-2}$ and peat layer consisted of high-bog sphagnum peat (pH 3.5–4.5 in KCl) in dose 200 $dm^3 \cdot m^{-2}$ was applied. In the first two years, no fertilizer was used. From the third year, based on the growth appearance, the ammonium sulphate in dose 5 $g \cdot m^{-2}$ was applied in spring and autumn annually.

During the experiments the following indices were recorded: growth rhythm, length of horizontal shoots, number of vertical shoots per 1 m^2, number of flowers and berries per 1 m^2 in 4-fold replications, weight of 100 berries and vitality of pollen.

Based on the difference in the lenght of horizontaly shoots (10 September vs. 10 April) their growth increment was established. Large fruited cranberries were harvested in the 2nd decade of September.

Pollen viability of 6 cranberry cultivars was measured in 2008 on the base of colour of the grains. One day prior to flowering of each clone were randomly collected 20 flowers and then made microscopic preparations. Slides was coloured with 2% solution of acetocarmin and glicerin (1:1) and investigated by microscope Olympus BX41 under magnification 400×. In any combination (the microscopic slide) were analyzed to 100 tetrads in 10 fields of vision. Pollen tetrads with 3–4 fertile pollen grains were taken as vital. Before analysis, the percentage data of pollen viability were transformed using the Bliss function $Y = \arcsin \sqrt{p}$, where p is the percentage dividing by 100.

Results were analyzed statistically by two-way analysis of variance with use of the Bonferroni test at the significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

Vegetation season of cranberry at the Felin Experimental Station began from 30.03. to 16.04 (tab. 1). This was 1 month earlier than reported Smolarz [1999]. According to this author, vegetation of cranberry generally start in first decade of May. In 2007 cultivars 'Pilgrim' and 'Cropper' started growing as the first (31.03), that is in agreement with the investigations by Ruban and Kurbowicz [1999].

Table 1. Beginning of the vegetation and flowering performance of cranberry in the third and fourth year of cultivation

Tabela 1. Początek wegetacji i przebieg kwitnienia żurawiny w trzecim i czwartym roku uprawy

Cultivar Odmiana	2007			2008		
	beginning of vegetation początek wegetacji	beginning of flowering początek kwitnienia	ending of flowering koniec kwitnienia	beginning of vegetation początek wegetacji	beginning of flowering początek kwitnienia	ending of flowering koniec kwitnienia
Nr 20	12.04	8.06	28.06	10.04	4.06	23.06
Pilgrim	31.03	12.06	3.07	1.04	10.06	1.07
Cropper	31.03	8.06	2.07	30.03	7.06	1.07
Le Munion	7.04	8.06	29.06	5.04	1.06	25.06
Stevens	6.04	15.06	10.07	1.04	10.06	3.07
Stankavich	16.04	16.06	5.07	10.04	11.06	2.07
Mean Średnia	7.04	11.06	3.07	4.04	7.06	29.06

Flowering season was clone-dependent and lasts from the beginning of second decade of June to the end of June in 2008 or beginning of July in 2007. Over two years, cultivar Nr 20 finished flowering as last. The longest period of flowering in 2007 had cultivar 'Stevens' (25 days) and in 2008 cultivar 'Le Munion' (24 days), which is consistent with the characteristics of these cultivars presented by Ballinghton [2001].

Table 2. Growth of 6 cultivars of large fruited cranberry

Tabela 2. Wzrost 6 odmian żurawiny wielkoowocowej

Cultivar Odmiana	2007		2008	
	number of runners per plant liczba długopędów na roślinie	annual increment of shoots, cm roczny przyrost długopędów, cm	number of runners per plant liczba długopędów na roślinie	annual increment of shoots, cm roczny przyrost długopędów, cm
Nr 20	8.0 a *	41.0 b*	15.6 abc*	75.4 d*
Pilgrim	11.4 b	31.5 c	18.0 abc	90.6 b
Cropper	8.0 a	20.3 d	13.8 bc	69.0 ed
Le Munion	12.4 b	51.8 a	19.1 ab	95.5 b
Stevens	9.1 a	14.4 d	13.0 c	64.2 e
Stankavich	12.7 b	27.5 c	20.5 a	102.4 a
Mean Średnia	10.3 *ab*	31.1 *c*	16.6 *abc*	82.8 *c*

*The means followed by the same letters do not differ at $\alpha = 0.05$

Średnie oznaczone tymi samymi literami nie różnią się istotnie przy $\alpha = 0,05$

Observations on the growth appearance indicated that 'Stankavich' produced the highest number of horizontal shoots (average 12.7 in 2007 and 20.5 in 2008). This cultivar had the greatest annual increment in 2008 – 102.4 cm. The shortest increment had 'Stevens' (tab. 2).

For each sample, all erect cranberry shoots and flowers were accounted within a plot of 1m^2 and all fruit was collected. In 2007 and 2008 cultivars 'Pilgrim' (fot. 2) and 'Cropper' produced the highest number of vertical shoots, flowers and berries on area 1 m^2 (tab. 3). Cultivar 'Stevens' was the worst in this regard, however had the highest ratio between numbers of ripe berries and flowers (0.4). As it was emphasized by Yudina and Maksimova [2005], the yield depends on the frequency of fruit setting upon flowering, which is reflected in the index of yield preservation. In their experiment this index averaged 43%, being much greater or smaller in some years. According to Hancock [2008], in cranberry, a high density of short, upright stems with flowers is highly desirable and yielding depends mostly of genetic peculiarities of cultivar and agrotechnics. Recently in USA for a good yield counted 8–10 t per 1 ha.

Table 3. Assesment of the characteristics of cranberry yielding
Tabela 3. Ocena cech plonotwórczych żurawiny

Cultivar Odmiana	2007				2008			
	number of erect shoots per 1 m^2 liczba krótkopędów na 1 m^2	number of flowers per 1 m^2 liczba kwiatów na 1 m^2	number of berries per 1 m^2 liczba owoców na 1 m^2	fruit setting coeffi-cient** współczynnik zawiązywania owoców	number of erect shoots per 1 m^2 liczba krótkopędów na 1 m^2	number of flowers per 1 m^2 liczba kwiatów na 1 m^2	number of berries per 1 m^2 liczba owoców na 1 m^2	fruit setting coeffi-cient** współczynnik zawiązywania owoców
Nr 20	458 d*	522 e*	199 d*	0.38 ab*	498 d*	776 e*	290 e*	0.37 ab*
Pilgrim	660 a	1036 b	350 a	0.33 b	705 a	2005 a	702 a	0.35 bc
Cropper	592 b	1460 a	355 a	0.24 c	632 b	1523 b	456 b	0.30 c
LeMunion	532 c	766 c	255 b	0.33 b	570 c	890 d	320 d	0.36 b
Stevens	204 f	307 g	132 f	0.43 a	253 f	385 g	164 g	0.42 a
Stankavich	286 e	440 f	161 e	0.36 b	320 e	502 f	190 f	0.38 ab
Mean Średnia	455.3 *d*	755.2 *d*	242.0 *c*	0.34 *b*	496.3 *d*	1013.5 *c*	353.6 *c*	0.36 *b*

* Explanations as in Table 2 – Objaśnienia jak w tabeli 2
** The proportion of ripe fruits and flowers – Stosunek liczby dojrzałych owoców i kwiatów

Over two years, cultivars 'Pilgrim' and 'Cropper' had the highest yield (tab. 4). 'Stankavich' had the lowest yields (81 g in 2007 and 110 g per 1 m^2 in 2008) of all 6 cultivars.

The single fruit weight estimated across 2 years averaged 1.21–1.27 g. The highest weight of 100 berries had 'Pilgrim' and 'Cropper'(fot. 3) conversely to 'Stankavich' with the smallest fruits (fot. 4). Kożyczkowska [1999] states that fruit size is a specific characteristic, ie. 'Searles' had the smallest fruit, since it is one of the first cultivars selected from the wild populations, while 'Stevens' and 'Pilgrim' have been released from reciprpcal crossing had the largest fruits. These cultivars also have a larger weight of 100 berries. By DeMoranville [1989] mineral fertilization affects fruit yield, and the impact of fertilization on fruit size may be the next crop year.

Fot. 2 Flowering plant of ‘Pilgrim’ cultivar
Fot. 2. Kwitnąca roślina odmiany ‘Pilgrim’

Fot. 3. Fruits of ‘Cropper’ cultivar (bar = 1 cm)
Fot. 3. Owoce odmiany ‘Cropper’ (skala = 1 cm)

Table 4. Cranberry yielding in Felin near Lublin
Tabela 4. Plonowanie żurawiny w Felinie koło Lublina

Cultivar Odmiana	2007		2008	
	weight of berries – masa owoców		weight of berries – masa owoców	
	g · m^{-2}	100 berries, g 100 owoców, g	g · m^{-2}	100 berries, g 100 owoców, g
Nr 20	219 c*	110 b*	410 cd*	110 c*
Pilgrim	525 a	150 a	800 a	160 a
Cropper	498 a	145 a	725 b	158 a
Le Munion	330 b	130 ab	370 d	140 ab
Stevens	186 c	140 ab	230 e	130 bc
Stankavich	81 d	50 c	110 f	64 d
Mean Średnia	306.5 *b*	120.8 *ab*	440.8 *c*	127.0 *bc*

* Explanations as in Table 2 – Objaśnienia jak w tabeli 2

Fot. 4. Berrying shoot of 'Stankavich' cultivar (bar = 1 cm)
Fot. 4. Pęd owoconośny u odmiany 'Stankavich' (skala = 1 cm)

Two-way analysis of variance showed the high importance of the impact of cultivars on all studied traits (tab. 5). In two years of research, only 100 fruit weight did not differ significantly. Interaction clone × year proved to be important in the case of such characteristics as: annual increment of shoots, number of flowers per 1 m^2, number of berries per 1 m^2 and weight of berries.

In current evaluations average pollen vitality values ranged from 9.88% to 82.12% with an average of all cultivars 43.60%. Cultivar 'Cropper' had the highest number of grains with alive cytoplasm (82.12%) and simultaneously the littlest number of empty

grains (4.02%). Bain [1993] noted that cranberry is self-pollination species but growing a few cultivars on the same plantations may have an good influence on plants yielding.

Table 5. P – value in two – way analysis of variance
Tabela 5. Empiryczne poziomy istotności w dwukierunkowej analizie wariancji

Source of variability Źródło zmienności	Trait – Cecha						
	number of runners per plant liczba długopędów na roślinie	annual increment of shoots roczny przyrost długopędów	number of erect shoots per 1 m^2 liczba krótkopę-dów na 1 m^2	number of flowers per 1 m^2 liczba kwiatów na 1 m^2	number of berries per 1 m^2 liczba owoców na 1 m^2	weight of berries per 1 m^2 plon owoców z 1 m^2	weight of 100 berries masa 100 owoców
Years Lata	$3.94 \cdot 10^{-9}$	$3.87 \cdot 10^{-26}$	$1.02 \cdot 10^{-11}$	$3.63 \cdot 10^{-30}$	$2.45 \cdot 10^{-38}$	$1.42 \cdot 10^{-19}$	0.09
Cultivars Odmiany	$1.13 \cdot 10^{-4}$	$9.89 \cdot 10^{-16}$	$3.47 \cdot 10^{-30}$	$3.97 \cdot 10^{-41}$	$6.35 \cdot 10^{-45}$	$1.38 \cdot 10^{-28}$	$1{,}09 \cdot 10^{-13}$
Interaction cultivar × year Interakcja odmiana × rok	0.65	$6.60 \cdot 10^{-10}$	0.84	$3.44 \cdot 10^{-30}$	$6.64 \cdot 10^{-36}$	$2.64 \cdot 10^{-14}$	0.34

Table 6. Pollen viability of 6 cranberry cultivars, data from the 2008
Tabela 6. Żywotność pyłku 6 odmian żurawiny, dane z roku 2008

Cultivar – Odmiana	Tetrads – Tetrady		
	●	◘	○
Nr 20	0.67 d*	0.85 b	0.20 d
Pilgrim	0.89 b	0.37 e	0.53 a
Cropper	1.14 a	0.38 e	0.20 d
Le Munion	0.79 c	0.62 d	0.40 b
Stevens	0.31 f	1.03 a	0.40 b
Stankavich	0.44 e	1.03 a	0.27 cd
Mean Średnia	0.72 *d*	0.72 *c*	0.36 *bc*

Explanations – Objaśnienia:
● – tetrads with 3 or 4 viable pollen grains– tetrady z 3 lub 4 żywotnymi ziarnami pyłku
◘ - tetrads with 1–2 viable pollen grains – tetrady z 1–2 żywotnymi ziarnami pyłku
○ – tetrads with inanimate grains – tetrady z nieżywotnym pyłkiem
* Explanations as in Table 2 – Objaśnienia jak w tabeli 2

In addition to the unique flavors for cranberries have been appreciated over the years, recent information on their health benefits promises to contribute significantly to increasing production in the 21st century [Ballington 2001].

After two years studies on phenological characteristics of flowers and fruits, the performance of growing and fruiting, showed that 'Pilgrim' and 'Cropper' are the most promising ones and are recommended to be developed first.

The results of the experiment in Felin since 2004 showed that southeastern part of Poland could be a good region for cranberry production on the undertstanding that the required conditions will be ensured.

CONCLUSIONS

1. Vegetation of the cranberry started on 30 March or early April and flowering lasted 19–25 days according to the cultivars.

2. The number of uprights, flowers and ripe berries per 1m^2 was highest in 'Pilgrim' and 'Cropper' cultivars.

3. Cultivars 'Pilgrim' and 'Cropper' yielded better than the others clones.

4. The proportion between the number of fruit set and the number of flowers varied from 24 to 43% within the tested clones with average 35%.

5. Cultivars 'Pilgrim' and 'Cropper' had the largest fruits, whereas 'Stankavich' the smallest, and cultivars Nr 20, 'Le Munion' and 'Stevens' were intermediate in fruit size.

6. Interaction clone x year proved to be important in the case of such characteristics as: annual increment of shoots, number of flowers per 1 m^2, number of berries per 1 m^2 and weight of berries.

7. Average percentage of viable pollen was 43.60. The number of grains with alive cytoplasm was the greatest in 'Pilgrim' and 'Cropper' cultivars.

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WZROST, KWITNIENIE I OWOCOWANIE SZEŚCIU ODMIAN ŻURAWINY AMERYKAŃSKIEJ (*Vaccinium macrocarpon* Ait.)

Streszczenie. Żurawina wielkoowocowa (*Vaccinium macrocarpon* Ait.) należąca do rodziny wrzosowate (*Ericaceae*) jest uprawiana przede wszystkim na torfowiskach wysokich. W Polsce panują dobre warunki klimatyczne oraz występuje znaczący areał kwaśnych gleb odpowiednich do uprawy żurawiny. Owoce żurawiny nadają się do spożycia wyłącznie po przetworzeniu, głównie w postaci soków i sosów. Żurawina zaliczana jest do roślin leczniczych z uwagi na wysoką zawartość składników odżywczych cennych dla zdrowia człowieka, takich jak: witaminy A, B_1, B_2, B_6 i C, flawonoidy, kwasy organiczne i inne. W 2004 r. na plantacji doświadczalnej Katedry Genetyki i Hodowli Roślin Ogrodniczych w Felinie koło Lublina rozpoczęto badania 6 odmian żurawiny wielkoowocowej. Sadzonki zostały posadzone na specjalnie przygotowanych stanowiskach wypełnionych torfem kwaśnym w rozstawie 50×50 cm. Badano następujące właściwości roślin: dynamika wzrostu, długość pędów poziomych, liczba pędów pionowych, kwiatów i owoców na powierzchni 1 m^2 (w 4 powtórzeniach), masa 100 jagód oraz żywotność pyłku. Podczas dwuletnich badań najlepiej plonowały odmiany 'Pilgrim' i 'Cropper' (średnio 662 g i 611 g z poletka o powierzchni 1 m^2). Najniższy plon zebrano z roślin odmiany 'Stankavich' (średnio 95,5 g). Odmiany 'Pilgrim' i 'Cropper' charakteryzowały się najwyższą średnią masą pojedynczego owocu (odpowiednio 1,55 g i 1,51 g), najdrobniejsze owoce zebrano z roślin odmiany 'Stankavich' (0,57 g), natomiast odmiany 'Cropper', 'Le Munion' i Nr 20 wytwarzały owoce średniej wielkości. Dwuczynnikowa analiza wariancji wykazała wysoką istotność interakcji odmiana × rok w przypadku takich cech, jak: roczny przyrost długopędów, liczba kwiatów i owoców na 1 m^2 oraz plon owoców. Największą liczbę żywotnych ziaren pyłku oszacowano w przypadku odmian 'Cropper' i 'Pilgrim'.

Słowa kluczowe: plonowanie, *Vaccinium macrocarpon* Ait., wegetacja, żywotność pyłku

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