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FRUIT YIELD OF EUROPEAN CRANBERRY (*Oxycoccus palustris* Pers.) IN DIFFERENT PLANT COMMUNITIES OF PEATLANDS (NORTHERN WIELKOPOLSKA, POLAND)

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Abstract

The aim of this study was to determine fruit yield of *Oxycoccus palustris* under the climatic and habitat conditions of northern Wielkopolska (the Greater Poland region), depending on the type of occupied plant community. Total fruit number and fruit weight as well as average cranberry leaf size were determined on 33 plots with an area of 1 m^2, located on 7 peatlands. On the study areas, European cranberry produced crops from 9.2 up to 242.0 g × m^{-2}, which gives 92-2420 kg × ha^{-1}. It has been demonstrated that on the peatlands of northern Wielkopolska *O. palustris* reaches its generative and vegetative optimum in the communities of the class *Scheuchzerio-Caricetea fuscae,* in particular in the community *Sphagno recurvi-Eriophoretum angustifolii*.

Key words: *Oxycoccus palustris*, Ericaceae, growth, crop, peatlands, medicinal plants, plant communities, vegetation

INTRODUCTION

Oxycoccus palustris Pers. is an evergreen shrublet of the family Ericaceae with a wide range of occurrence. It occupies *Sphagnum* bogs of the Northern Hemisphere. As a commercial plant, it plays a special role in the Northern and Eastern Europe area as well as in Siberia. In Russia it is the most important species among all wild growing berry plants (Grochowski, 1976; Boč and Mazing, 1988; Plotnikov and Šmidt, 1988). It is estimated Finland's average annual cranberry crops can be more than 20 million kg (Raatikainen, 1988).

European cranberry fruit is used in the food and pharmaceutical industries. It is an excellent additive to meat as well as juice drinks, jams, jellies, etc., are produced from it. Similarly to American cranberry – *Oxycoccus macrocarpos* (Aiton) Pursh, it contains large amounts of organic acids (including vitamin C) as well as pectins, flavonoids, anthocyanins and other active compounds (Murav'ev and Šatilo, 1973; Jensen et al. 2002; Ehala et al. 2005; Kozłowski et al. 2006). Research on American cranberry shows that species of the genus *Oxycoccus* can be used in the treatment of urinary tract infections as well as in the prevention of heart diseases and ulcer diseases of the digestive system. Cranberry fruit extracts show antibacterial and antifungal activity (e.g. Lai et al. 2000; Rodowski, 2001; Stothers, 2002).

In Poland cranberry resources are limited, though this plant occurs across our whole country. Its stands are concentrated in the northern, southern and eastern parts of Poland: in Pomorze (Pomerania), Warmia and Mazury (Masuria), Górny Śląsk (Upper Silesia), the western Kielce region and the southern part of the Łódź region as well as in Polesie and the Lublin region (Zając and Zając eds. 2001). This species also belongs to shrublets frequently encountered on peat and transitional bogs of Wielkopolska (e.g. Gąbka et al. 2007).

Research on cranberry fruit yield has not been conducted in Poland so far. Information on *Oxycoccus palustris* resources and its fruit yield, as well as on habitat conditions which determine them, come primarily from Russian peatlands (e.g. Šutov, 1985; Nekratova et al. 1986; Čerkasov, 1988; Plotnikov and Šmidt, 1988; Ûdina, 1997; Kurlo-

vič and Kosicyn, 2000). Many authors (e.g. Rajko and Sautin, 1973; Snigirev and Hves'ko, 1978; Alekseeva, 1986; Nekratova et al. 1986; Kopoteva and Kupcova, 1997) point out that the productivity of this species is related to the peatland type and vegetation differentiation, as described according to the approach of the Russian school.

This paper attempts to determine fruit yield of European cranberry under the climatic and habitat conditions of northern Wielkopolska, depending on the type of occupied plant community (according to the Braun-Blanquet approach).

MATERIALS AND METHODS

The field study was carried out in September 2008 on 7 *Sphagnum* bogs located within the area of the city of Piła in northern Wielkopolska (Tab. 1). These were oligotrophic peat bogs (Tab. 1, sites 1-4) or medium fertile transitional bogs developing near humic lakes, advanced in the process of disappearance (sites 5-7). In accordance with the physico-geographical division of Kondracki (2002), these sites are situated in the macroregion of the Southern Pomerania Lakelands and they cover the southern part of the Gwda River valley.

33 study areas of 1 m^2 were established on the investigated peatlands. Plots of this size are commonly used to determine cranberry fruit yield (e.g. Šutov, 1985; Čerkasov, 1988; Kurlovič and Kosicyn, 2000). On each plot, all cranberry fruits were collected and 9 shoots of this species were sampled in a systematic way. The fruits were weighed and counted, and from the shoots one leaf was sampled for the measurement of leaf blade length and width. Additionally, 30 randomly selected fruits from each plot were weighed. A smaller amount of fruits (respectively, 18 and 21) was collected from two plots. In total, 969 fruits were weighed and the length and width of 297 cranberry leaves were measured.

Table 1
The location of peatlands and number of vegetation plots.

No.	Peatlands	Administrative unit	Geographical coordinates	No. of vegetation plots
1	Nameless peatland near Zelgniewo	Kaczory	N 53° 10′ 09″ E 16° 52′ 14″	5
2	Nameless peatland between Skórka and Jeziorki	Piła	N 53° 10′ 19″ E 16° 52′ 12″	7
3	Peatland by W part of lake Czarne near Kaczory	Kaczory	N 53° 07′ 23″ E 16° 54′ 56″	5
4	Peatland near lake Okoniowe	Piła	N 53° 11′ 18″ E 16° 47′ 56″	5
5	Peatland by lake Czarne near Jeziorki	Kaczory	N 53° 08′ 45″ E 16° 51′ 34″	3
6	Peatland Kuźnik Olszowy	Szydłowo	N 53° 12′ 46″ E 16° 43′ 38″	4
7	Peatland Kuźnik Bagienny	Szydłowo	N 53° 12′ 53″ E 16° 43′ 53″	4
	Summary			33

Table 2
Variability of *Oxycoccus palustris* in the investigated peatlands. Median, minimal, maximal value and quartile variability coefficient of cranberry crop and some biometric properties.

Variables	Median	Min.	Max.	V [%]
Total no. of fruits	174	18	829	98.85
Total weight of fruits [g]	47.1	9.2	242.0	152.02
Weight of fruit [g]	0.31	0.01	1.09	67.74
Length of leaf [mm]	9.43	5.63	13.95	27.04
Width of leaf [mm]	4.57	2.59	6.94	22.98

The study areas were set up in separate vegetation patches, at sites of the abundant occurrence of European cranberry as well as in different types of bog phytocoenoses. The designated plots were located at a distance of at least 10 m from each other (usually 20-40 m). A floristic inventory was conducted in each square, determining percentage species cover as well as the cover of the moss layer and total cover of all vascular plants, excluding *Oxycoccus palustris*.

The syntaxonomic classification of cranberry patches within the plots was made based on phytosociological relevés of the phytocoenoses on which the study areas were located. The nomenclature of phytosociological units followed a list of plant communities of Wielkopolska made by B r z e g and W o j t e r s k a (2001).

Statistica 7.1 software (StatSoft, 2005) was used for calculations. In statistical analysis, standard parametric tests were used: Student's test, Cochran-Cox test, Pearson coefficient of correlation, as well as non-parametric tests: gamma test, Mann-Whitney test and Kruskal-Wallis test. The Shapiro-Wilk test was used to assess the normality of variable distribution, whereas the F-test, Lévene's test and Brown-Forsyth test were used to assess the equality of variance in comparable groups. In order to normalise the distribution of the analysed variables, outliers were removed in justified cases (not more than one in a particular group).

RESULTS

Fruiting European cranberry was documented in 6 communities of the transitional and peat bogs. These were phytocoenoses representing the following associations: *Sphagno tenelli-Rhynchosporetum albae* Osvald 1923 nom. invers., *Sphagno recurvi-Eriophoretum angustifolii* Hueck 1925 nom. invers. et nom. mut., *Sphagno apiculati-Caricetum rostratae* Osvald 1923 em. Steffen 1931 (class *Scheuchzerio-Caricetea fuscae*) as well as *Sphagnetum magellanici* (Malcuit 1929) Kästner et Floßner 1933, *Sphagno recurvi-Eriophoretum vaginati* Hueck 1925 nom. invers. and *Ledo-Sphagnetum magellanici* Sukopp 1959 ex Neuhäusl 1969 (class *Oxycocco-Sphagnetea*). On the study areas, the cranberry cover ranged between 10% and 90% (on the average 50%). The cover of other vascular plant species was from 5% up to 80% (on the average 40%). The moss layer was very well-developed, usually with the cover of 80-100% (Fig. 1).

European cranberry showed large variations in fruit weight and leaf size (length and width). A large variability was also observed in fruit yield of this species: total fruit number and weight of fruits collected from the designated areas (Tab. 2). The variability in question was associated with phytosociological differentiation of the communities. In the transitional bog phytocoenoses of the class

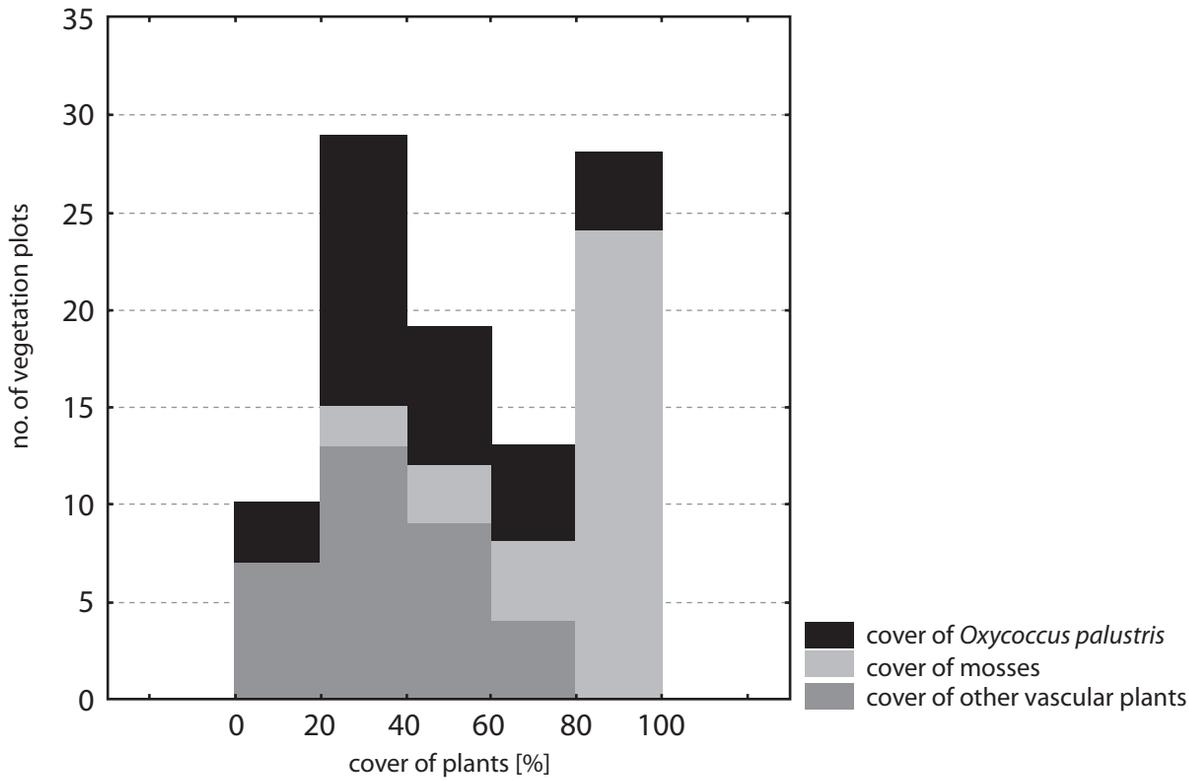

Fig. 1. Differentiation of the cover of *Oxycoccus palustris*, other vascular plants and mosses [%] in vegetation plots of peatlands.

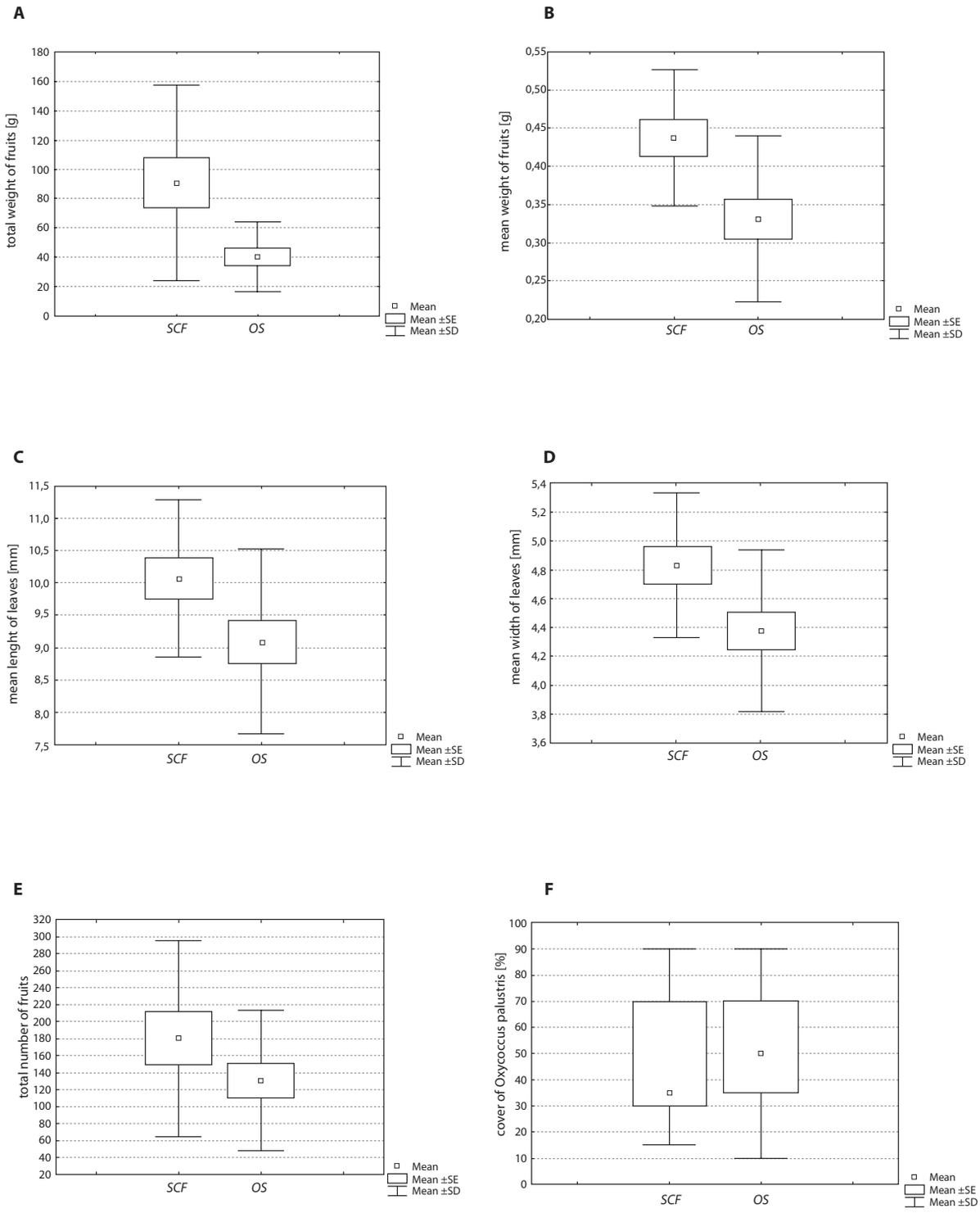

Fig. 2. Differentiation of cranberry crop and some biometric properties in vegetation plots of the phytocoenoses from *Scheuchzerio-Caricetea fuscae* (SCF) and *Oxycocco-Sphagnetea* (OS) classes.
A) Cochran-Cox test: 2.7739; $p < 0.05$; n = 32; B) Student's test: 3.0250; $p < 0.01$; n = 33;
C) Student's test: 2.0936; $p < 0.05$; n = 33; D) Student's test: 2.4366; $p < 0.05$; n = 33;
E) Student's test: 1.3964; N.S.; n = 31; F) Mann-Whitney test: 103.5000; N.S.; n = 33.

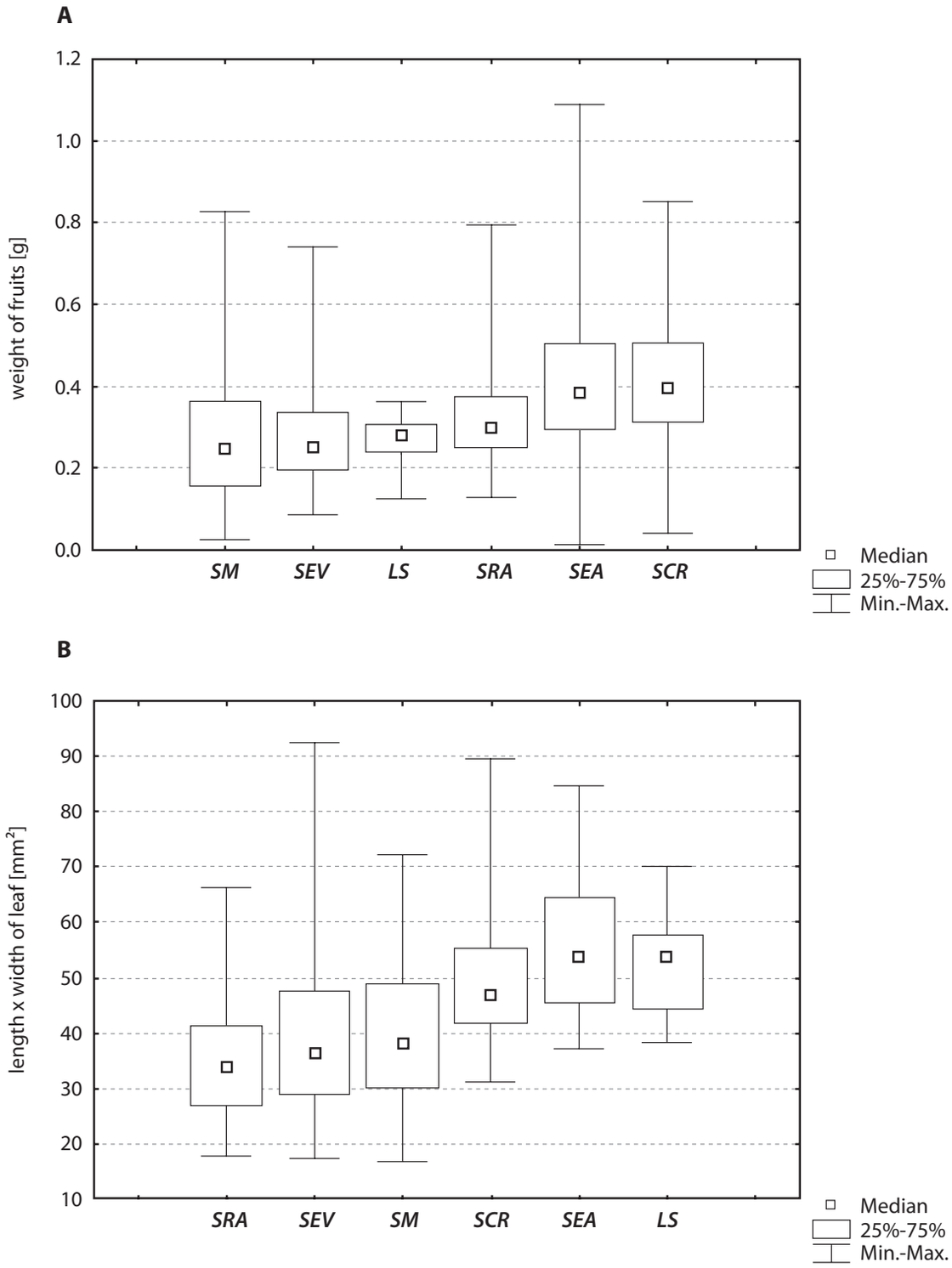

Fig. 3. Differentiation of the weight of fruits (A) and the size of leaves (B) of *Oxycoccus palustris* in phytocoenoses of the *Scheuchzerio-Caricetea fuscae* and *Oxycocco-Sphagnetea* classes.
A) Kruskal-Wallis test: 147.91; $p < 0.001$; n = 969; B) Kruskal-Wallis test: 82.73; $p < 0.001$; n = 297.
Oxycocco-Sphagnetea class: *SM Sphagnetum magellanici*, SEV – *Sphagno recurvi-Eriophoretum vaginati LS – Ledo-Sphagnetum magellanici*; *Scheuchzerio-Caricetea fuscae* class: *SRA – Sphagno tenelli-Rhynchosporetum albae*, *SEA – Sphagno recurvi-Eriophoretum angustifolii*, *SCR – Sphagno-Caricetum rostratae*.

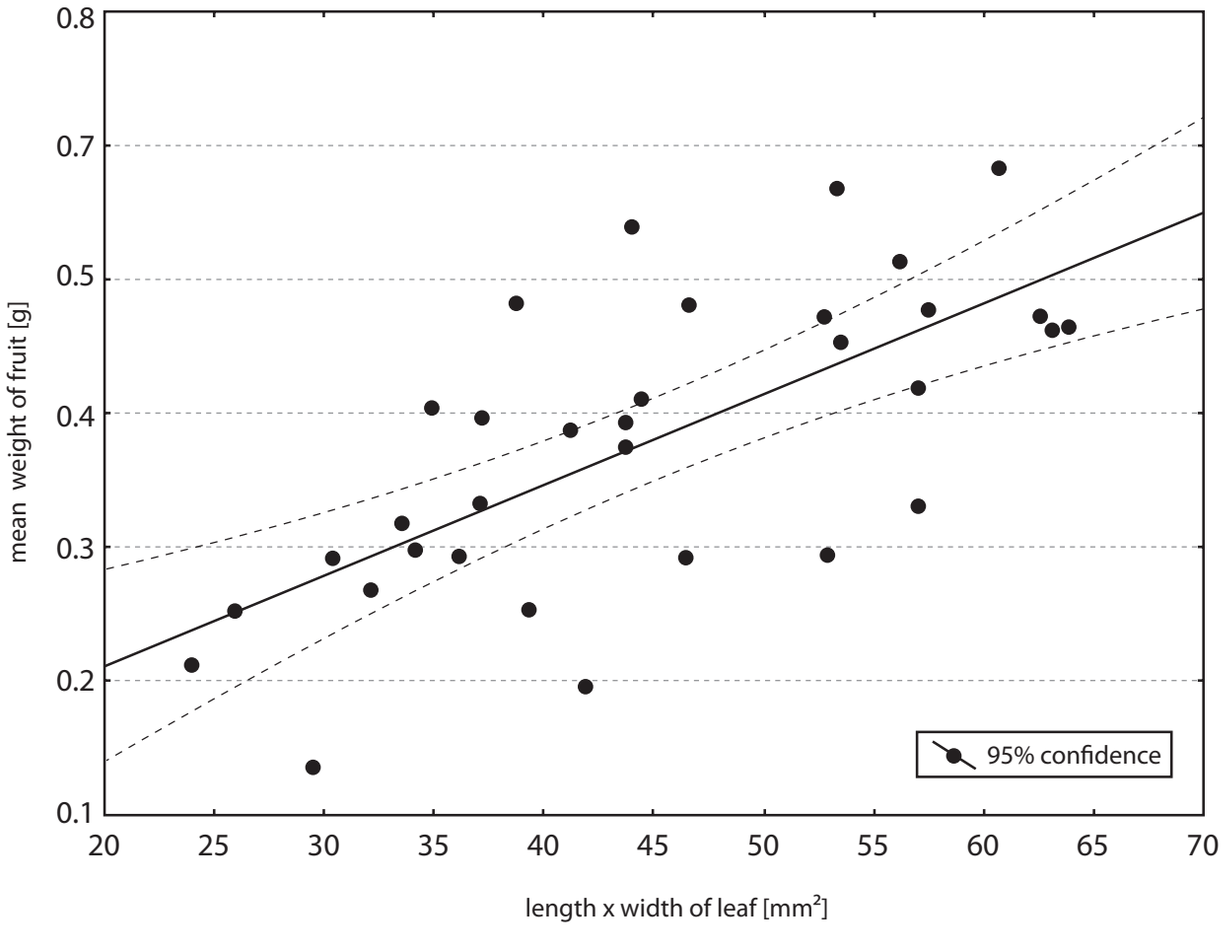

Fig. 4. Correlation between the size of leaves and mean weight of fruits of *Oxycoccus palustris* in vegetation plots. Pearson coefficient of correlation: 0.69; $p < 0.001$; $n = 33$.

Scheuchzerio-Caricetea fuscae, total and average fruit weight, as well as average length and width of cranberry leaf blade, were statistically significantly higher than in the peat bog patches of the class *Oxycocco-Sphagnetea* (Fig. 2). However, in the above-mentioned groups of communities, no significant differences were found as regards total fruit number on the designated areas and the cover of *Oxycoccus palustris* on the patches (Fig. 2). At the plant association level, statistically significant differences were found for such cranberry traits as fruit weight and leaf size (Fig. 3). It should be stressed that the percentage cover of cranberry, as well as of other vascular plants and the moss layer, had no impact on fruit yield of the species concerned (total fruit number and fruit weight as well as average fruit weight). But a clear correlation was found between the average weight of cranberry fruit on the study areas and the average size of its leaves (Fig. 4).

DISCUSSION AND CONCLUSIONS

On the study plots, European cranberry produced crops from 9.2 up to 242.0 g × m^{-2}, which gives 92-2420 kg × ha^{-1}. These are values comparable to the data obtained from Russian, Lithuanian, Belarusian and Ukrainian peatlands (e.g. Rajko and Sautin, 1973; Snigirev and Hves'ko, 1978; Bočarov and Kurlovič, 1988; Boč and Mazing, 1988; Čerkasov, 1988; Ripa, 1988; Krasnov and Orlov, 1996). Fruit yield of cranberry growing in these areas ranges between 3 and 2622 kg × ha^{-1}. Due to changing weather conditions, it is subject to large variations depending on the study year (Šutov, 1985; Alekseeva, 1986; Bočarov and Kurlovič, 1988; Ûdina, 1988; Krasnov and Orlov, 1996).

According to some authors (e.g. Šutov, 1985; Alekseeva, 1986), cranberry fruit yield in the mid-

dle and southern zones of the Russian taiga is more affected by weather conditions than ecophytocenotic factors. However, the water table level (e.g. Bočarov and Kurlovič, 1988; Kurlovič and Kosicyn, 2000) and habitat richness (Ûdina, 1988) also perform an important role. The study presented in this article shows that European cranberry produces better yields (higher total and average fruit weight) in the communities of the transitional bogs than in those of the peat bogs (Fig. 2). *Oxycoccus palustris* fruit reaches the highest weight in the phytocoenoses of the types *Sphagno-Caricetum rostratae* and *Sphagno-Eriophoretum angustifolii* of the order *Scheuchzerietalia palustris* (Fig. 3). Rajko and Sautin (1973) as well as Alekseeva (1986) also indicate higher fruit yields of cranberry occupying mesooligotrophic habitats (transitional bogs) compared to oligotrophic peat bogs.

Oxycoccus palustris is characterised by a wide ecological scale. It is found both on poor oligotrophic peat bogs as well as on medium fertile and fertile types of *Sphagnum* bogs (e.g. Asada, 2000; Bragazza et al. 2005; Navrátilová and Navrátil, 2005; Gąbka and Lamentowicz, 2008). It is considered to be a species characteristic for the class *Oxycocco-Sphagnetea* (Brzeg and Wojterska, 2001) or the order *Sphagnetalia magellanici* (Matuszkiewicz, 2005); thus, from the phytosociological point of view, it has its occurrence optimum in peat bog phytocoenoses. However, our study shows that European cranberry not only produces better yields, but also develops larger leaves in the transitional-bog, not peat-bog, communities (Figs 2, 3). Among the investigated communities of the class *Scheuchzerio-Caricetea fuscae*, cranberry had the lowest fruit yield and luxuriance in the patches with a predominance of *Rhynchospora alba*. These phytocoenoses developed in the complex of peat bogs which had an influence on the poor (oligotrophic) nature of the communities with White Beak-sedge. The luxuriant growth of vegetative and generative organs in *Oxycoccus palustris* growing on the transitional bogs most probably resulted from the greater richness of these habitats compared to the poor and strongly acid peat bogs (Hájek et al. 2002). Additionally, nutrient availability for plants increases in the habitats with the groundwater pH of 6-7 (Rydin and Jeglum, 2006).

European cranberry is characterised by large variations in the morphological features of its vegetative and generative organs (Gugnacka-Fiedor, 1986; Ûdina, 1988; Gronskis and Sniskovskis, 1989). Tetra-, penta- and hexaploid forms of this species are known (Gugnacka-Fiedor, 1983; Ravanko, 1990; Ahokas, 1996; Suda and Lysák, 2001), and they may sometimes occur together even on a very small area of a bog (Suda, 2002). Nevertheless, the presence of different cytotypes in *Oxycoccus palustris* does not explain the morphological variability of this species. In the opinion of Suda and Lysák (2001), tetra-, penta- and hexaploid forms of European cranberry are very difficult to distinguish based both on their morphological features and data on their ecology, phenology and distribution. That is why they relinquished from delineating intraspecific units in *Oxycoccus palustris*. Gugnacka-Fiedor (1986) included plants with fine leaves and fruit in the subspecies *O. palustris* Pers. subsp. *microphyllus* (Lange) Löve et Löve, whereas she distinguished large-leaved and large-fruited forms as a new variety *O. palustris* Pers. subsp. *palustris* var. *macrophyllus* Gug. The positive correlation, found during the study presented in this paper, between average leaf size and average fruit weight on the study areas is interesting in this context (Fig. 4).

It seems that European cranberry forms differing in their leaf and fruit size are habitat-conditioned ecotypes; hence larger fruit and leaves in *Oxycoccus palustris* on the transitional bogs (Figs 2, 3). It should be emphasised that Hagerup (1940) described specimens with shoots which had both fine and large leaves. In turn, Gugnacka-Fiedor (1986) showed that in changed habitat conditions (after the transfer of portions of the population from 4 sites to another bog), the shape and size of cranberry leaves also undergo great changes. Bočarov and Kurlovič (1988) observed on drained peatlands cranberry with smaller, reddish-coloured leaves. An increase in cranberry leaf size was noted by Ûdina (1988) after the application of mineral fertilisation on the bog.

In Central and Eastern Europe a standard research method for studying the vegetation of bog ecosystems is the synecological approach (Matuszkiewicz, 2005). Analysis based on the typological classification of vegetation has enabled us in this study to determine fruit yield of European cranberry depending on the community type in phytosociological terms. It has been demonstrated that on the peatlands of northern Wielkopolska *Oxycoccus palustris* reaches its generative and vegetative optimum in some communities of the class *Scheuchzerio-Caricetea fuscae*.

The relationship between the species composition of bog vegetation and habitat parameters (in particular, groundwater chemistry) and the determination of their effect on the biometric features of cranberry require further detailed research. The results of this type of analysis are being currently processed by the authors. The abovementioned research will allow abiotic requirements of *Oxycoccus palustris* to be identified more precisely and the optimum of this species in phytosociological terms to be determined more accurately.

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Plonowanie żurawiny błotnej (*Oxycoccus palustris* Pers.) w różnych zbiorowiskach roślinnych torfowisk (północna Wielkopolska, Polska)

Streszczenie

Oxycoccus palustris jest jedną z najważniejszych roślin użytkowych rosnących na torfowiskach północnej półkuli. Celem niniejszych badań było określenie plonowania żurawiny błotnej w warunkach klimatyczno-siedliskowych północnej Wielkopolski, w zależności od typu zajmowanego zbiorowiska roślinnego. Określono całkowitą liczbę i masę owoców oraz średnią wielkość liści żurawiny błotnej na 33 poletkach o powierzchni 1 m^2, położonych na 7 torfowiskach. Analizowano występowanie *Oxycoccus palustris* w trzech zbiorowiskach z klasy *Scheuchzerio-Caricetea fuscae* oraz trzech z klasy *Oxycocco-Sphagnetea*. Na wytyczonych powierzchniach żurawina uzyskiwała plon od 9.2 do 242.0 g × m^{-2}, co daje 92-2420 kg × ha^{-1}. Wykazano znaczną zmienność badanych cech omawianego gatunku. Stwierdzono dodatnią korelację między średnią wielkością liści a średnią masą owoców na poletkach. Można sądzić, że opisywane przez innych autorów taksony: *O. palustris* Pers. subsp. *microphyllus* (Lange) Löve et Löve i *O. palustris* Pers. subsp. *palustris* var. *macrophyllus* Gug., to dwa warunkowane siedliskowo ekotypy żurawiny błotnej.Wykazano, że na torfowiskach północnej Wielkopolski *O. palustris* osiąga optimum generatywne i wegetatywne w zbiorowiskach z klasy *Scheuchzerio-Caricetea fuscae,* szczególnie w zbiorowisku *Sphagno recurvi-Eriophoretum angustifolii*.