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YIELD, MORPHOLOGY AND BIOLOGICAL VALUE OF FRUITS OF *Actinidia arguta* AND *Actinidia purpurea* AND SOME OF THEIR HYBRID CULTIVARS GROWN IN NORTH-EASTERN POLAND

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Abstract. *Actinidia arguta* and *Actinidia purpurea* and their hybrid cultivars are species which bear valuable fruits due to their content of valuable bioactive substances and good sensory qualities. This paper presents the yield results from the cultivars' initial 10 years (2000–2009) as well as the morphology and chemical composition of the fruits of some Ukrainian hybrid cultivars of *Actinidia arguta* and *Actinidia purpurea*: 'Figurnaja', 'Kijewskaja Gibrydnaja', 'Kijewskaja Krupnopłodnaja', *Actinidia purpurea*: 'Purpurowaja Sadowaja' and *Actinidia arguta*: 'Sientiabrskaja'. In 2007, the flowers of the tested cultivars were damaged by late spring frost. The lowest yield and the smallest weight, as well as the low stability of morphological features of fruits of the 'Sientiabrskaja' cultivar, indicate its low utility as a commercial crop in north-eastern Poland. However, chemical analyses found high levels of phenolic compounds and vitamin C in the fruit of the cultivar. An analysis of the yield and fruit quality of the other tested cultivars indicated their suitability for cultivation under the climatic conditions of the 6A USDA zone.

Key words: hybrid cultivars, morphology and chemical composition of fruits

INTRODUCTION

Hardy kiwifruit (*Actinidia arguta* (Siebold et. Zucc.) Planch. Ex Miq.) and actinidia charta (*Actinidia purpurea* Rehd. (*A. arguta* var. *purpurea* (Rehd.) C. F. Liang)) belong to the group of *Leiocarpae. Actinidia arguta* is a diploid, tetraploid or hexaploid (2n, 4n, 6n), whereas *A. purpurea* is a diploid (2n). *Actinidia purpurea* is morphologically very similar to *A. arguta.* The aktinidia charta fruit is purple and it ripens considerably sooner than the hardy kiwifruit. In 1981 in the Botany Garden in Kiev (Ukraine), hybrid cultivars of these species were selected [Latocha 2006]. They are valuable ornamental plants and their fruits have a beneficial effect on human health. These plants are

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a rich source of vitamins, especially vitamin C and antioxidants [Krupa and Latocha 2007]. Okamoto and Goto [2005] showed that the fruits of the variety cultivated in Japan have stronger antioxidant properties than kiwi or apples. Depending on the cultivar, fruits of hardy kiwifruit are 3–5 cm long, elliptical and slightly flattened. The skin is delicate, smooth, hairless and green and some cultivars have a red blush [Krupa and Latocha 2008]. The antioxidants present in the fruits enhance the activity of the natural defences of the body and the fruits of some cultivars of hardy kiwifruit have also been highly rated in consumer taste-tests. Particularly emphasised qualities include their sweet nectar flavour and the sweet taste of the pulp [Latocha and Jankowski 2011, Latocha et al. 2011].

Hardy kiwifruit grows in the wild from Siberia to Indonesia at an altitude of 150–3500 m above sea level [Latocha 2006]. Owing to its high resistance to frost, it can be grown in areas where the temperature falls as low as -30°C [Chat 1994]. It starts vegetation early so it may be damaged by late-spring frost [Latocha 2008]. Field experiments conducted in Olsztyn [Kawecki et al. 2001, Kawecki et al. 2004a, Kawecki et al. 2004b, Kawecki and Bieniek 2008] and in central Poland [Latocha 2008, 2010, Marosz 2009] have confirmed that the species can be grown in Poland. Hardy kiwifruit is being introduced as a commercial crop in Canada, Chile, France, New Zealand and the USA [Ferguson 1999, Okamoto and Goto 2005, Williams et al. 2003]. It can also be an interesting crop for producers in north-eastern Europe. There is a 4.5 ha plantation of the crop in Belgium. The largest plantations of hardy kiwifruit in the world are now in Oregon, USA, where one cultivar – 'Ananasnaja' – is grown on over 40 ha [Strik 2005, Strik and Hummer 2006].

The cultivars which are best suited for cultivation on allotments and plantations would be those with relatively large, tasty fruits which are stable and attractive.

The aim of the study was to analyse the yield during the initial ten years of cultivation of three Ukrainian hybrid cultivars of *Actinidia arguta* × *Actinidia purpurea*: 'Figurnaja', 'Kijewskaja Gibrydnaja', 'Kijewskaja Krupnopłodnaja', *Actinidia arguta:* 'Sientiabrskaja' and *Actinidia purpurea:* 'Purpurowaja Sadowaja', as well as the chemical composition of their fruits, during the five years of cultivation (2005–2009) at the Experimental Station of the University of Warmia and Mazury (UWM) in Olsztyn.

MATERIAL AND METHODS

The experiment was set up in autumn, 1996 at the Experimental Station of UWM in Olsztyn. A cultivar of *Actinidia arguta:* 'Sientiabrskaja', a cultivar of *Actinidia purpurea:* 'Purpurowaja Sadowaja' and three Ukrainian hybrid cultivars: 'Figurnaja', 'Kijewskaja Gibrydnaja', 'Kijewskaja Krupnopłodnaja', were planted in A-shaped support frames, spaced at 1.5 × 2 m. One-year plants were brought from the Institute of Pomiculture in Babtai, Lithuania. There were 5 bushes of each cultivar, which were planted next to each other. Each bush constituted an experimental replication. Male bushes 'Bayern Kiwi' (='Weiki' – cultivar of *A. arguta*) were used as pollinators. The male-to-female bush ratio was 1:5. Fertilisation was applied before planting as for all berry plants (40 $t \cdot ha^{-1}$ of manure and 100 $kg \cdot ha^{-1}$ P_2O_5 and K_2O). The plants grew on class IV,

cereal-fodder strong complex soil. It is highly clayey sand with a pH of 6.2–6.8. The plot was weeded manually three times every year during the vegetation period. The creepers were pruned (February/March) to enhance fruit-bearing [Latocha 2006]. The plants were not fertilised or treated with chemical protection agents.

The yield, morphology and chemical composition of the fruits was evaluated in the years 2005–2009. The biological value of the fruits was determined by analysing the content of dry matter, phenolic compounds, total saccharides, monosaccharides, vitamin C and total acidity. The list does not contain results from 2007 due to the lack of fruits caused by the unfavourable weather conditions in the spring. Between the 1st and the 5th of May, the near-ground temperatures were: -6.0°C,-7.1°C,-5.8°C, -3.0°C and -1°C, respectively. Seven days with near-ground frost also occurred in the second decade of May. Temperatures below zero were also recorded on the last two days of that month (-1.4°C and -3.5°C).

Biometric evaluations were based on measurements of the length and width of the fruits and the weight of 100 randomly-selected fruits of each cultivar.

Chemical analysis was performed in three replications. To this end, about 1 kg of fruits of each cultivar was taken. The following were determined:

– dry matter of fruits, by drying at 105°C,
– phenolic compounds – with Folin – Ciolteau reagent (AOAC 9.11 method 1974),
– organic acids, expressed as malic acid, according to standard PN-90/A-75/101/04,
– vitamins C according to standard PN-90/A-75101/11,
– total sugars according to standard PN-90/A-75101/07,
– monosaccharides according to standard PN-90/A-75101/07.

In order to determine the phenolic compounds, 1g of disintegrated sample was subjected to four extraction cycles with 30 cm^3 of 80% methanol. The resulting extracts were filtered and following condensation they were transferred to a volumetric flask. For analysis, 0.25 ml of Folin-Ciocalteau and 0.5 ml of 14% sodium carbonate were added to 0.25 ml of the sample and the flask was filled with distilled water up to the volume of 5ml. Absorbance was measured at the wavelength of 720 nm.

To determine the total acidity, 25 g of product was transferred to a 250 ml beaker and ca. 100 ml of distilled water was added and boiled. The solution was cooled and transferred volumetrically to a 250 ml volumetric flask and left for ca. 15 min. The flask content was filtered through a pleated filter to a dry flask. A conical flask was filled with 10–25 ml of the filtrate and 3–4 drops of phenolphthalein were added. The content was titrated with 0.1 N NaOH at continuous stirring to obtain a pink colour stable for 30 seconds.

In order to determine vitamin C, 10 g of disintegrated sample was transferred volumetrically with 2% oxalic acid to a 100 ml volumetric flask and left in a dark place for 15 min. Next, 5 ml of the sample were taken and 45 ml of 2% oxalic acid was added and titrated with 2,6 dichloroindophenole until the first colour change was obtained.

In order to determine saccharides, 40 g of a mixed sample was weighed in a 250 ml beaker and 100 ml of distilled water was added and boiled. Next, the beaker content was cooled down and volumetrically transferred into a 200 ml volumetric flask. The content was well mixed and 15 min later it was filtered through a pleated filter into a dry flask. Using a pipette, 50 ml of filtrate was transferred to a 200 ml volumetric flask and deprote-

inization was carried out in the following way: 5 ml of Carrez I solution was added, the flask content was mixed and left for 5 min and 5 ml of Carrez II solution was added, the content was then mixed and the flask was refilled with distilled water up to the line. The flask was left for 15 min and the content was filtered through a pleated filter into a dry conical flask.

In order to determine the content of directly-reducing saccharides, 50 ml of the post-deproteinization filtrate was transferred to a 100 ml flask, which was refilled with distilled water up to the line, the content was mixed and the analysis was carried out without a prior inversion.

In order to determine the total sugars, 50 ml of the post-deproteinization filtrate was transferred to a 100 ml volumetric flask and subjected to inversion which was carried out in the following way: 5 ml of concentrated hydrochloric acid was added and a thermometer was inserted in the flask. The flask was then placed in a hot water bath and the content was heated to 68–70°C and such a temperature was maintained for 5 min. The flask with the content was then quickly cooled down to 20°C under a stream of cold water and the flask solution was neutralised with a 20% solution of sodium hydroxide in the presence of methyl orange as an indicator. The flask was refilled with distilled water up to the line and such a solution was used for further determinations.

The results were statistically analysed with the arithmetic average from three simultaneous determinations. The results of the fruit yield, morphology and chemical analyses for each year were subjected to a single-factor variance analysis. As there were no fruits in 2007 and chemical analysis of the 'Sientiabrskaja' cultivar was not performed in 2008, the analysis of year-dependent variation of the physicochemical parameters was not performed. Significant differences were determined by Tukey's HSD test at the level of significance of 0.05 for a field experiment (yield, fruit biometric evaluation) and 0.01 for the laboratory analyses (chemical composition). The calculations were performed with the STATISTICA 9.1 software.

RESULTS AND DISCUSSION

The yield of cultivars of hardy kiwifruits was significantly varied, both between different years and between different cultivars (tab. 1). The first crop was obtained in 2000 (4 years following planting) and they averaged almost 2 kg per bush. 'Purpurowaja Sadowaja' a cultivar of *Actinidia purpurea* yielded the smallest crop in the analysed year, although in subsequent years this cultivar was one of the highest yielding. The highest average yield of 10 kg per plant was achieved in 2005. The average yield in 2006 and 2008 was the same at 5.7 kg per plant. The lowest amount of fruits was picked from the 'Sientiabrskaja' cultivar. In 2008 the cultivar yielded only a few fruits, with the yield amounting to 0.01 kg. The highest yield in study was obtained from the 'Purpurowaja Sadowaja' cultivar (average 10.2 kg). The average yield from the hybrid cultivars ranged from 5 kg for 'Kijewskaja Krupnopłodnaja' to 6.3 kg for 'Figurnaja'.

The fruit weight of each cultivar is shown in table 2. The average weight of a fruit over the years of the study ranged from 3 g for 'Sientiabrskaja' in 2008 to 9.5 g for 'Kijewskaja Krupnopłodnaja' (also in 2008). The average weight of a fruit (6.6 g) in

2005 was higher than in the other years (2006, 2008 and 2009), which made a homogenous group. The statistical analysis carried out in 2009 revealed the existence of only two homogenous groups, differing statistically by the fruit weight. The weight of a fruit of the 'Kijewskaja Krupnopłodnaja' differed statistically from the fruit weight of the other cultivars, which constituted another homogenous group. The most uniform fruit weight in all of the studied years was found for the 'Kijewskaja Gibrydnaja' cultivar.

Table 1. Yielding of *Actinidia* cultivars (kg · plant $^{-1}$) in the years 2000–2009
Tabela 1. Plonowanie odmian aktinidii (kg · roślina $^{-1}$) w latach 2000–2009

Cultivar Odmiana	Yield, kg · plant^{-1} – Plon, kg · roślina^{-1}									
	2000	2001	2002	2003	2004	2005	2006	2008	2009	Mean for cultivar Średnia dla odmiany
Figurnaja	2.15 c*	2.83 b	3.10 c	3.25 b	7.67 d	11.00 c	6.89 d	10.67 d	9.15 d	6.30 d
Kijewskaja Gibrydnaja	2.40 d	3.92 c	4.58 d	4.77 c	3.33 c	13.00 d	4.33 b	4.48 c	5.86 c	5.19 c
Kijewskaja Krupnopłodnaja	3.20 e	4.82 d	2.20 b	9.07 d	2.27 b	9.67 b	6.71 c	2.30 b	4.80 b	5.00 b
Purpurowaja Sadowaja	0.40 a	8.65 e	15.35 e	10.20 e	10.53 e	14.67 e	9.36 e	11.02 e	11.22 e	10.16 d
Sientiabrskaja	1.80 b	0.96 a	0.50 a	0.60 a	1.65 a	2.67 a	1.23 a	0.01 a	0.30 a	1.08 a
Mean of year Średnia dla roku	1.99 a	4.24 b	5.15 c	5.58 d	5.09 c	10.20 f	5.70 d	5.70 d	6.27 e	-

*The values denoted with the same letters are not significantly different at p = 0.05
Średnie oznaczone jednakowymi literami nie różnią się istotnie przy poziomie istotności p = 0,05

Table 2. Mean fruit weight (g) of *Actinidia* cultivars in the years 2005–2009
Tabela 2. Średnia masa 1 owocu (g) odmian aktinidii w latach 2005–2009

Cultivar – Odmiana	The weight of fruit – Masa owocu, g				
	2005	2006	2008	2009	Mean for cultivar Średnia dla odmiany
Figurnaja	6.29 c[1]	4.52 a	5.43 b	5.34 a	5.65 b
Kijewskaja Gibrydnaja	6.32 c	5.92 d	6.34 b	5.07 a	5.91 c
Kijewskaja Krupnopłodnaja	7.92 d	8.37 e	9.55 c	9.36 b	8.80 d
Purpurowaja Sadowaja	5.38 a	5.25 c	4.95 b	4.78 a	5.09 ab
Sientiabrskaja	6.27 b	4.75 b	3.05 a	5.27 a	4.83 a
Mean for year – Średnia dla roku	6.44b	5.76 a	5.86 a	5.96 a	-

[1]For explanation see table 1. Objaśnienia patrz tabela 1

Fruits of the 'Sientiabrskaja' cultivar in the study conducted by Kołbasina [2003] weighed 7–10 g and this cultivar gave a yield of 10–12 kg per plant. The weight of a fruit grown near Moscow was 7.6 g and its height was 2.8 cm. The values achieved in this study were much lower despite the milder weather conditions of North Poland as compared to Moscow. It is possible that the cultivar gives a better yield in the continental climate, which is more stable. Kołbasina [2003] regards the 'Kijewskaja Gibrydnaja' and 'Kijewskaja Krupnopłodnaja' cultivars as more valuable and ones that give a higher yield. The weight of a fruit of the 'Kijewskaja Gibrydnaja' measured in a study conducted by the author was 10–12 g, (length – 3.4 cm and width – 2.5 cm). The yield per bush was 10–18 kg. The average weight of a fruit found in this study was 5.9 g, length – 2.2 cm, width – 1.9 cm and the yield for different years ranged from 4.3 to 13 kg per bush (tab. 2–4). The 'Kijewskaja Krupnopłodnaja' cultivar is regarded by many authors as having a large fruit, with a unit weight of 15 to 25 g [Kawecki et al. 2001, Kołbasina 2003, Kuminow 2003, Metelis 1996]. Kuminow [2003] reports that the yield per plant in Kiev ranged from 16 to 20 kg. The average yield achieved in this study over ten years was 5.5 kg and it was much lower than the value reported above. The unit weight of a fruit found in this study was only half that of plants grown in Kiev. Latocha [2006] regards the 'Purpurowa Sadowaja' cultivar as one with medium-sized fruits with a weight of 8–11 g. According to Kołbasina [2003], fruits grown in Moscow had an average weight of 6.8 g and a length of 2.8 cm. Metelis [1996] reports that when grown in Lithuania, the cultivar gave a yield of 21–28 kg per plant. Its yield in the north of Poland was higher than that of the other cultivars (tab. 1). Latocha [2010] examined several cultivars and genotypes of *Actinidia arguta* × *Actinidia purpurea* in Warsaw in 2007 and obtained only 3.6 to 6.9 kg of berries per plant. According to the author, such a great diversity of yield is caused by genetic factors and by different methods of cultivation, i.e. spacing, type of supporting frame and method of pruning. Data published by Tiyayon and Strik [2003] and Kawecki et al. [2001] indicate that when plants were grown on a T-shaped support frame, at a spacing of 4.6 × 4.6 m, they gave several times higher yield than those grown at the spacing of 1.5 × 2 m on an A-shaped support frame. Fruit size can also be modified by the method of the bush cultivation, the habitat conditions and the number of fruits, regardless of the genetic features or the quality of pollination [Latocha 2010].

The dry matter content was significantly cultivar-dependent. The statistical analysis did not reveal any significant differences with respect to the years of study (tab. 5). Depending on the cultivar, its content ranged from 14.6% in 'Purpurowaja Sadowaja' in 2006 to 25.2% in 'Figurnaja' in 2009. The 'Figurnaja' cultivar formed a homogenous group with the highest average dry matter content (21.8%). A group with the lowest values (16.6–20.7%) consisted of: 'Purpurowaja Sadowaja', 'Kijewskaja Krupnopłodnaja' and 'Sientiabrskaja'. Latocha [2010] also showed that the dry matter content depended significantly on genotype. Its content in fruits of the hardy kiwifruit genotypes under study ranged from 16.8% for 'Jumbo' in 2007 to 25.5% for D11 in 2005.

The content of phenolic compounds in the fruits of the hardy kiwifruit cultivars under study varied significantly from one cultivar to another and from one year of study to another (tab. 5). The highest value was recorded in 2005 (215.2 mg·100 g^{-1}) and the lowest in 2008 (176.3 mg·100 g^{-1}). A significantly higher content of phenolic compounds

than in the other cultivars was found in fruits of 'Sientiabrskaja' (310.7 mg·100 g^{-1}) and the least was in 'Figurnaja' (155.8 mg·100 g^{-1}). Although the 'Kijewskaja Krupnopłodnaja' and 'Purpurowaja Sadowaja' cultivars were in the same homogenous group, the smallest deviations in the content of phenolic compounds for different years were recorded for 'Kijewskaja Krupnopłodnaja' and 'Sientiabrskaja'. Latocha [2010] showed that the fruits of all the genotypes of hardy kiwifruit and hybrid forms contains considerable amounts of phenolic compounds (81.6–339.5 mg GAE (galic acid) per 100 g of fresh matter) and the content is much higher than in fruits of *A. deliciosa* 'Hayward'. The author obtained the highest polyphenol content in fruits of 'D11' in each year. The highest content of the phenolic compounds in this study was found in fruits of 'Sientiabrskaja'.

Table 3. Mean fruit length (cm) of *Actinidia* cultivars in the years 2005–2009
Tabela 3. Średnia wysokość (cm) owocu odmian aktinidii w latach 2005–2009

Cultivar – Odmiana	The length of fruit – Wysokość owocu, cm				
	2005	2006	2008	2009	Mean for cultivar Średnia dla odmiany
Figurnaja	2.66 c[1]	2.10 a	2.19 b	2.31 a	2.31 b
Kijewskaja Gibrydnaja	2.45 a	2.19 a	2.19 b	2.05 b	2.22 a
Kijewskaja Krupnopłodnaja	2.93 d	2.67 c	2.91 c	3.12 c	2.91 c
Purpurowaja Sadowaja	2.59 b	2.34 b	2.23 b	2.23 a	2.35 b
Sientiabrskaja	2.45 a	2.11 a	1.79 a	2.36 a	2.18 a
Mean for year – Średnia dla roku	2.62 c	2.28 a	2.26 a	2.41 b	-

[1]For explanation see table 1. Objaśnienia patrz tabela 1

According to Esti et al. [1998] and Jaeger et al. [2003], the main quality parameters of the fruits of hardy kiwifruit (which determine their acceptance by consumers) include the sugar and acid contents and ratio. A statistical analysis revealed a significant diversity in the sugar content in fruits of the hardy kiwifruit under study, both between the years and between cultivars (tab. 6). The lowest total sugar content was recorded in 2005 and the highest in 2009. The highest total sugar content was recorded in fruits of the 'Figurnaja' cultivar and it was similar in all the years of study. The other cultivars contained significantly less sugar in 2005 than the other years of study. The highest diversity in their content was recorded in the 'Purpurowaja Sadowaja' and 'Sientiabrskaja' cultivars. According to Karczemnaja [1997], the average amount of sugars accumulated in the fruits was 7.3%. In 2004, Kawecki et al. [2004a] found a similar value of the total sugar content (7.5%) in fruits of the cultivars to that reported above, whereas the average values determined in 2005 and 2008 were lower: 5.0% and 6.8%, respectively. The diversity of the total sugar content in fruits of different hardy kiwifruit cultivars between different years of study may have been caused by different weather conditions, especially during the fruit ripening period. Significant differences in interyear yielding and fruit chemical compositions were recorded in 2005 (the largest crop

with the highest vitamin C content and the lowest sugar content). The total rainfall in September 2005, when the fruits were ripening, was higher than in the subsequent years, therefore the amount of sugars accumulated in the fruits was lower. In the analysed year, due to the cooler months of May and June, the plants entered the blooming phase only on 18 June ('Purpurowaja Sadowaja'), 21.06: 'Figurnaja', 23.06: 'Kijewskaja Gibrydnaja' and 'Sientiabrskaja' and 24.06: 'Kijewskaja Krupnopłodnaja', i.e. almost two weeks later than in the other years of study. The blooming period in 2005 was considerably shorter because fruit formation began on 06.07 ('Purpurowaja Sadowaja', 'Figurnaja') 9.06 ('Kijewskaja Gibrydnaja' and 'Figurnaja') and 10.06 ('Kijewskaja Krupnopłodnaja'), i.e. on a similar date as in the preceding and subsequent years. The fruit crop was collected from October 3 in all the cultivars excluding 'Kijewskaja Krupnopłodnaja', whose fruits ripen somewhat later (07.10). In 2006, the fruits of the 'Purpurowaja Sadowaja', 'Figurnaja' and 'Sientiabrskaja' cultivars were harvested from 14 September, the fruit of 'Kijewskaja Gibrydnaja' cultivar was collected from 16 September, while the fruit of 'Kijewskaja Krupnopłodnaja' cultivar ripened only at the beginning of October.

Table 4. Mean width of fruit (cm) of *Actinidia* cultivars in the years 2005–2009
Tabela 4. Średnia szerokość owocu odmian aktinidii w latach 2005–2009

Cultivar – Odmiana	The width of fruit – Szerokość owocu, cm				
	2005	2006	2008	2009	Mean for cultivar Średnia dla odmiany
Figurnaja	2.09 b[1]	1.77 a	1.85 ab	1.78 a	1.86 a
Kijewskaja Gibrydnaja	2.05 b	1.95 b	2.03 b	1.91 a	1.95 b
Kijewskaja Krupnopłodnaja	2.06 b	2.20 c	2.37 c	2.12 b	2.12 c
Purpurowaja Sadowaja	1.80 a	1.88 ab	1.86 ab	1.83 a	1.83 a
Sientiabrskaja	2.29 c	1.80 a	1.58 a	1.85 a	1.87 a
Mean for year – Średnia dla roku	2.06 b	1.92 a	1.94 a	1.90 a	-

[1]For explanation see table 1. Objaśnienia patrz tabela 1

The content of monosaccharides also varied between different years and between different cultivars (tab. 7). The accumulation of monosaccharides in 2005 and 2008 was found to be the highest (3.6% and 3.5%, respectively), unlike that of the total sugars, for which the lowest values were determined in those years. The lowest accumulation of monosaccharides was recorded in 2006. The highest average monosaccharides content was determined in 'Kijewskaja Gibrydnaja' (3.3%), whereas the lowest value was determined in 'Sientiabrskaja' (2.5%). The sugar content in those cultivars varied considerably between the years of study. Kawecki et al. [2001] reported that simple sugars should account for 50–80% of the total sugar content. The content of reducing sugars found by Latocha [2010] in fruits of four cultivars and five genotypes of hardy kiwifruit ranged from 1.7% to 4.9%, with most results in all seasons lying within the range from 2 to 4%, which was confirmed by this study.

Table 5. The content of dry matter and phenolic compounds in the fruits of *Actinidia* cultivars in the years 2005–2009
Tabela 5. Zawartość suchej masy oraz związków fenolowych w owocach odmian aktinidii w latach 2005–2009

Cultivar Odmiana	Dry matter – Sucha masa, %					Phenolic compounds – Związki fenolowe, mg·100 g^{-1}				
	2005	2006	2008	2009	mean for cultivar średnia dla odmiany	2005	2006	2008	2009	mean for cultivar średnia dla odmiany
Figurnaja	21.43 e*	19.96 e	20.71 a	25.25 b	21.84 b	130.80 a	109.91 a	155.80 a	226.72 d	155.81 a
Kijewskaja Gibrydnaja	19.76 d	17.71 d	20.29 a	20.30 ab	19.52 ab	257.50 d	226.72 c	212.14 c	152.20 b	212.15 c
Kijewskaja Krupnopłodnaja	18.60 c	15.60 b	18.38 a	16.77 ab	17.34 a	171.72 b	152.20 b	170.90 b	185.76 c	170.15 b
Purpurowaja Sadowaja	18.23 b	14.56 a	15.50 a	15.80 a	16.02 a	204.05 c	185.76 b	166.56 b	109.91 a	166.57 b
Sientiabrskaja	15.29 a	17.47 c	20.71 a	20.41 ab	18.47 a	311.92 e	310.25 d	-	309.85 e	310.67 d
Mean for year Średnia dla roku	18.66 a	17.47 a	19.12 a	19.71 a	-	215.20 c	196.97 b	176.35 a	196.89 b	-

*The values denoted with the same letters are not significantly different at p = 0.01
Średnie oznaczone jednakowymi literami nie różnią się istotnie przy poziomie istotności p = 0,01

Table 6. The content of total saccharides and monosaccharides in the fruits of *Actinidia* cultivars in the years 2005–2009
Tabela 6. Zawartość cukrów ogółem i cukrów prostych w owocach odmian aktinidiia w latach 2005–2009

Cultivar Odmiana	Total saccharides – Cukry ogółem, %					Monosaccharides – Cukry proste, %				
	2005	2006	2008	2009	mean for cultivar średnia dla odmiany	2005	2006	2008	2009	mean for cultivar średnia dla odmiany
Figurnaja	7.52 e[3]	7.35 b	7.29 c	7.99 b	7.54 e	3.83 d	2.07 b	3.49 b	2.32 c	2.93 c
Kijewskaja Gibrydnaja	5.38 d	7.99 c	7.78 d	7.30 a	7.11 d	4.55 e	2.32 c	3.86 d	2.21 b	3.23 d
Kijewskaja Krupnopłodnaja	4.31 c	7.30 b	6.34 b	7.98 b	6.48 c	3.36 b	2.21 d	2.86 a	2.35 c	2.69 b
Purpurowaja Sadowaja	3.99 b	7.98 c	5.92 a	7.35 a	6.31 b	3.53 c	2.35 c	3.67 c	2.07 a	2.90 c
Sientiabrskaja	3.78 a	6.93 a	-	7.30 a	6.00 a	2.54 a	1.85 a	-	3.24 d	2.54 a
Mean for year Średnia dla roku	4.99 a	7.51 c	6.83 b	7.58 d	-	3.56 d	2.16 a	3.47 c	2.44 b	-

[3] For explanation see table 6 – Objaśnienia patrz tabela 6

Table 7. The content of vitamin C and organic acids in the fruits of *Actinidia* cultivars in the years 2005–2009
Tabela 7. Zawartość witaminy C i kwasów organicznych w owocach odmian aktinidii w latach 2005–2009

Cultivar Odmiana	Vitamin C – Witamina C, mg·100 g^{-1}					Organic acids – Kwasy organiczne, %				
	2005	2006	2008	2009	mean for cultivar średnia dla odmiany	2005	2006	2008	2009	mean for cultivar średnia dla odmiany
Figurnaja	211.79 c[3]	128.93 c	184.94 d	157.41 b	170.77 c	0.82 b	0.56 a	0.75 b	1.03 b	0.79 a
Kijewskaja Gibrydnaja	186.96 b	111.80 b	103.31 b	225.10 c	156.79 b	0.95 a	1.04 c	0.96 c	1.25 c	1.05 c
Kijewskaja Krupnopłodnaja	263.46 e	150.91 e	177.33 c	159.75 b	187.86 d	1.22 c	1.25 d	0.75 b	1.31 c	1.13 d
Purpurowaja Sadowaja	89.93 a	52.44 a	64.48 a	98.97 a	76.45 a	1.42 d	1.31 e	0.52 a	0.56 a	0.96 b
Sientiabrskaja	254.09 d	139.14 d	-	154.25 b	182.49 d	0.95 a	0.89 b	-	0.96 b	0.93 b
Mean for year Średnia dla roku	201.24 d	116.64 a	132.51 b	159.10 c	-	1.07 c	1.01 b	0.75 a	1.02 b	-

[3] For explanation see table 6 – Objaśnienia patrz tabela 6

The content of vitamin C varied between cultivars and between years of study (tab. 7). The lowest values were recorded for fruits of 'Purpurowaja Sadowaja' (76.4 mg·100 g^{-1}) whereas 'Kijewskaja Krupnopłodnaja' and 'Sientiabrskaja' made homogenous group with the highest values (187.9 and 182.5 mg·100 g^{-1}). The highest amounts of vitamin C were accumulated in fruits of the cultivars in 2005 (201.2 mg·100g^{-1}) and the lowest amounts were in 2006 (116.6 mg·100 g^{-1}). A significant effect of the vegetation season on the level of antioxidants (mainly on the level of ascorbate in fruits of high blueberry) was also shown by Łata et al. [2005]. According to Nishyiama et al. [2004], the fruits of different genotypes of *A. arguta* contains highly varied amounts of vitamin C, which range from 37 to 185 mg·100 g^{-1} of fresh matter. Latocha and Krupa [2007] determined the vitamin C content in fruits of several genotypes of *Actinidia arguta* and their results ranged from 33.7 (genotype L1) to 185 mg·100 g^{-1} of fresh matter (D11). The vitamin C content in fruits of several genotypes of hardy kiwifruit, determined by Latocha [2010], ranged from 33.7 to 218.1 mg in 100 g of fresh matter. The author found a higher vitamin C content from year-to-year, which indicates a genetic basis of its high accumulation level. Pietrowa [1987] claims that vitamin C content in hardy kiwi fruits depends to a great extent on the ripening phase during which they are picked and on the cultivar and on the weather conditions during the ripening period. The highest vitamin C content was found in unripe fruits and the lowest in overripe fruits. According to Latocha [2010], most bioactive compounds in hardy kiwifruit (not only vitamin C and polyphenols) have antioxidant properties, which can serve as a measure of their beneficial effect on health.

The accumulation of organic acids varied both between the years of study and between the cultivars (tab. 7). The highest organic acid content, as converted to malic acid content, was recorded in 2005 (1.07%) and the lowest was in 2008 (0.75%). The average acid content did not vary between the years 2006 and 2009 (1.01% and 1.02%). The largest amounts of organic acids were recorded in the fruits of the 'Kijewskaja Krupnopłodnaja' cultivar (1.13%) and the lowest was in 'Figurnaja' (0.79%). According to Karczemnaja [1997], organic acid content in hardy kiwifruit is 1.01%. Kawecki et al. [2001] report that the values range from 0.8 to 1.7%. According to Latocha [2010], the relative concentration of organic acids converted to citric acid in the fruits of the cultivars and genotypes of hardy kiwifruit under study ranged from 0.97% to 1.12%.

Studies carried out by Latocha and Jankowski [2011] showed the good sensory quality and high level of consumer acceptance for fruits of several hybrid forms of *A. arguta* × *A. purpurea*. Latocha [2010] identified the high cross-breeding potential in those two species, especially with respect to a higher proportion of *A. purpurea* in the offspring. This experiment and literature studies have shown that there is a high potential for cultivation of hybrid forms of *A. arguta* × *A. purpurea* in the north-east of Poland, both in home gardens and on commercial plantations.

CONCLUSIONS

1. The yield of cultivars 'Figurnaja', 'Kijewskaja Gibrydnaja', 'Kijewskaja Krupnopłodnaja', 'Purpurowaja Sadowaja' and 'Sientiabrskaja' varied between the years of

study and between the cultivars. The highest average yield was achieved in 2005, whereas the lowest was in the first three years of yielding.

2. The weights of the fruits of the studied cultivars grown in the north-eastern Poland were significantly lower than those given in the scientific literature.

3. The hybrid cultivars of this study produced fruits with higher contents of vitamin C than those quoted in the bibliography.

4. The highest average yield was obtained from the 'Purpurowaja Sadowaja' cultivar; the morphological features of the cultivar fruits were highly stable. The fruits contained the lowest amounts of dry matter and vitamin C.

5. The highest and most stable yield of the cultivars of *Actinidia arguta* × *Actinidia purpurea* was produced by 'Figurnaja'. Its fruits were the smallest and they contained the largest amounts of dry matter and total sugars, but they contained the lowest amount of phenolic compounds.

6. The weight of 'Kijewskaja Gibrydnaja' cultivar fruits was the most uniform and contained a high concentration of phenolic compounds.

7. The average yield of the 'Kijewskaja Krupnopłodnaja' cultivar significantly varied between the years of study. The cultivar fruits contained the highest concentrations of vitamin C, organic acids and weight (which increased with plant age).

8. The lowest yield and the smallest weight, as well as the low stability of morphological features of fruits of the 'Sientiabrskaja' cultivar indicate its low usability as a commercial crop. However, chemical analyses revealed the highest content of phenolic compounds and vitamin C in fruits of the cultivar.

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PLONOWANIE, MORFOLOGIA I WARTOŚĆ BIOLOGICZNA OWOCÓW AKTINIDII OSTROLISTNEJ I PURPUROWEJ ORAZ ICH KILKU ODMIAN MIESZAŃCOWYCH UPRAWIANYCH W WARUNKACH PÓŁNOCNO-WSCHODNIEJ POLSKI

Streszczenie. *Actinidia arguta* i *Actinidia purpurea* oraz ich mieszańce należą do gatunków, których owoce są cenione ze względu na zawartość cennych substancji bioaktywnych oraz dobrą jakość sensoryczną. W pracy przedstawiono wyniki plonowania z pierwszych 10 lat (2000–2009) oraz morfologii i składu chemicznego owoców ukraińskich odmian mieszańcowych aktinidii ostrolistnej i purpurowej: 'Figurnaja', 'Kijewskaja Gibrydnaja', Kijewskaja Krupnopłodnaja', purpurowej: 'Purpurowaja Sadowaja' i ostrolistnej: 'Sietiabrskaja'. W 2007 r. kwiaty badanych odmian zostały uszkodzone przez późno wiosenne przymrozki. Najniższe plony oraz małą stabilność cech morfologicznych wykazano dla odmiany 'Sientiabrskaja', co wskazuje na małą przydatność tej odmiany na plantacje produkcyjne w północno-wschodniej Polsce. Owoce tej odmiany charakteryzowały się jednak najwyższą zawartością witaminy C i związków fenolowych. Analiza wyników plonowania oraz jakości owoców pozostałych badanych odmian aktinidii wskazuje na ich przydatność do uprawy w warunkach klimatycznych strefy 6 USDA.

Słowa kluczowe: odmiany mieszańcowe, morfologie i skład chemiczny owoców

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