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# CONTENT OF MACROELEMENTS IN FRUITS OF UKRAINIAN CULTIVARS OF HARDY KIWIFRUIT AND ACTINIDIA CHARTA DEPENDING ON THE WEATHER CONDITIONS DURING THE PHENOLOGICAL PHASES

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Abstract

*Actinidia arguta* and *Actinidia purpurea* are fruit-bearing vines that have been gaining increased recognition among consumers who expect tasty, natural food produced in an unpolluted environment. The berries of these plants, known as Chinese gooseberries, are smaller than the well-known kiwi fruit, have smooth skin and contain many valuable bioactive substances. The quality of food quality can be characterized, among others, by its content of mineral components, of which many are present in the fruits of these species.

The aim of the study was to determine the response of Ukrainian cultivars of *Actinidia arguta* and *Actinidia purpurea* grown in north-eastern Poland to weather conditions in phenological phases, expressed as a change in the content of macroelements in fruit. A correlation was found between the sum of temperatures and of precipitation in phenological phases in 2006-2011 and the content of macroelements in fruits of the following cultivars: Figurnaja, Kijewskaja Gibrydnaja, Kijewskaja Krupnopłodnaja, Purpurowa Sadowaja and Sientiabrskaja. The research demonstrated that the concentrations of Ca, N, P, Mg and Na in fruit of the examined actinidia cultivars were significantly affected, positively or negatively, by the interaction between the cultivars and meteorological factors in individual phenophases. It was found that the content of macroelements in fruits of cv. Kijewskaja Krupnopłodnaja, Purpurowa Sadowaja and Sientiabrskaja was not significantly dependent on the daily temperatures in any of the examined phenophases. However, these cultivars significantly responded to the content of phosphorus, nitrogen, magnesium and sodium, depending on the sum of precipitation in the two first phenophases. For the culti-

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var Figurnaja, sums of temperatures in the phase from fruit setting to harvest were a factor significantly affecting the magnesium content. On the other hand, the sodium content in fruits of this cultivar was significantly negatively correlated with the sum of temperatures in the phase between the beginning of flowering and fruit setting.

Key words: *Actinidia arguta, Actinidia purpurea*, climate factors, phenology, macroelements, correlation, cultivars, fruits.

**ZAWARTOŚĆ MAKROELEMENTÓW W OWOCACH UKRAIŃSKICH ODMIAN AKTINIDII OSTROLISTNEJ I PURPUROWEJ W ZALEŻNOŚCI OD WARUNKÓW POGODOWYCH W FAZACH FENOLOGICZNYCH**

Abstrakt

Aktinidia ostrolistna i purpurowa należą do owocodajnych pnączy, które w ostatnich latach zyskują coraz większe uznanie konsumentów oczekujących smacznej, naturalnej żywności wyprodukowanej w nieskażonym środowisku. Jagody tych roślin, zwane chińskim agrestem, są mniejsze od dobrze znanego owocu kiwi, mają gładką skórkę, zawierają wiele cennych substancji bioaktywnych. Jakość żywności można scharakteryzować m.in. uwzględniając zawartość składników mineralnych, które są także obecne w owocach tych gatunków.

Celem pracy było określenie zmian zawartości makroelementów w owocach ukraińskich odmian aktinidii ostrolistnej i purpurowej uprawianych w północno-wschodniej Polsce w zależności od warunków pogodowych w fazach fenologicznych. Wykazano korelacje między sumą temperatur i opadów w fazach fenologicznych w latach 2006-2011 a zawartością makroelementów w owocach odmian Figurnaja, Kijewskaja Gibrydnaja, Kijewskaja Krupnopłodnaja, Purpurowa Sadowaja i Sientiabrskaja. Stwierdzono, że koncentracja Ca, N, P, Mg i Na w owocach badanych odmian aktinidii zależała istotnie dodatnio lub ujemnie od współdziałania odmian z czynnikami meteorologicznymi w poszczególnych fenofazach. Zawartość makroelementów w owocach odmian Kijewskaja Krupnopłodnaja, Purpurowa Sadowaja i Sientiabrskaja nie zależała istotnie od sum temperatur dobowych w żadnej z omawianych fenofaz. Odmiany te reagowały natomiast istotnie na zawartość fosforu, azotu, magnezu i sodu w zależności od sum opadów w dwóch pierwszych fenofazach. W przypadku odmiany Figurnaja czynnikiem istotnie dodatnio oddziałującym na zawartość magnezu były sumy temperatur w fazie od zawiązywania owoców do ich zbioru. Zawartość sodu w owocach tej odmiany była istotnie ujemnie skorelowana z sumą temperatur w fazie od początku kwitnienia do zawiązywania owoców.

Słowa kluczowe: *Actinidia arguta, Actinidia purpurea*, czynniki klimatyczne, fenologia, makroelementy, korelacja, odmiany, owoce.

# 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] are relatively young orchard plants. The first selections and varieties of those species emerged as late as in the mid 20$^{th}$ century. Most cultivars of *Actinidia arguta* and *Actinidia purpurea* have been selected or cultivated in China, New Zealand, North America, but also in Europe

(Williams et. al. 2003). In 1981, several varieties of those species were selected in the Botanical Garden in Kiev (Ukraine). Five of those varieties have been cultivated since 1996 in the garden of the University of Warmia and Mazury in Olsztyn (Bieniek 2012a). Starting from this year, a cultivation programme will be carried out in the Warsaw University of Life Sciences (SGGW) to obtain new cultivars with features adapted to the climatic conditions of Poland (Latocha, Krupa 2007). Adaptation of Ukrainian cultivars to the Polish climatic conditions also requires extensive experimental research before they can be recommended for production. As shown by the research carried out to date (Bieniek 2012a, Kawecki et al. 2001, 2004), cultivars selected in Ukraine and Russia are capable of producing fruits of the quality no worse than Chinese actinidia (kiwifruit). Latocha (2010), who examined other varieties of actinidia at the SGGW, found the highest content of most biologically active compounds in fruits of *A. arguta* and *A.purpurea* hybrids, although the content of mineral components was lower in the fruits of those genotypes than in *A. arguta*. As demonstrated by Latocha (2010) and Latocha and Jankowski (2011), actinidia fruits satisfy the requirements of consumers, who expect tasty, natural food produced in an unpolluted environment. According to Danilcenko et al. (2011), quality of food can be also described by its content of macroelements. They are necessary for proper growth and good health of bones and teeth. They ensure electrical transfer and act as cofactors in oxygen transport. Macroelements play an important role in enzymatic reactions, as well as in the protection of cells and lipids in biological membranes (Kang et al. 2007, Ekholma et al. 2007).

The research concerning determination of the mineral composition content of fruits of *Actinidia arguta* and *Actinidia purpurea* and their hybrid forms has been conducted by Bieniek (2012b), Ferguson and Ferguson (2003), Latocha and Krupa (2008), Latocha (2010), Skripczienko and Moroz (2002). These authors recommend fruit of the above species as a rich source of K, Fe, Cu and Mg. Many authors report that the concentration of mineral components in fruit depends on the cultivar, climatic and soil conditions, harvest dates (Milošević, Milošević 2012) and the level of irrigation and fertilization (Jaroszewska 2011). Fluctuations in the content of individual mineral components in fruits in consecutive seasons, found in the research by Latocha (2010) and Bieniek (2012b), can provide evidence for the significant effect of environmental conditions on their accumulation level. The climate in Poland is quite varied both year-to-year and within one year (Olesen et. al. 2007), the fact which can cause differentiation of the mineral composition of fruit. Phenophases are the reflection of plant adjustment to a moderate climate, in which only some seasons favour their growth and development. In some research institutions, phenological observations are treated as a sporadic element of research, and only a few experimental stations have data on the dates of beginning and duration of phenological phases of fruit trees (Licznar-Małańczuk 2004, after Kronenberg 1985). However, observations carried out under specific local geographical conditions indicate very high differences in subsequent years of research as regards the commencement and duration of phenological phases of the flowering period due to the weather conditions (LICZNAR-MAŁAŃCZUK 2004).

The aim of the study was to determine the response of Ukrainian cultivars of *Actinidia arguta* and *Actinidia purpurea* to the weather conditions during the phenophases manifested by a change of the content of macroelements in fruits.

## MATERIAL AND METHODS

The study examined the effect of sums of mean daily temperatures and of precipitation in phenological phases in 2006, 2008, 2009, 2010 and 2011 on the content of macroelements (K, Ca, N, P, Mg, Na) in fruits of Ukrainian cultivars of *Actinidia arguta* and *Actinidia purpurea* and their hybrid forms grown in the garden of the Teaching and Experimental Station of the University of Warmia and Mazury in Olsztyn. The research was carried out on vines of the following cultivars: Sientiabrskaja (*Actinidia arguta* variety), Purpurowaja Sadowaja (*Actinidia purpurea*) and hybrid forms of *Actinidia arguta* and *Actinidia purpurea*: Figurnaja, Kijewskaja Gibrydnaja and Kijewskaja Krupnopłodnaja. Each cultivar was planted in five replications, and each shrub made a replication. Plants were grown in two rows with A-shape supports, in a 1.5 x 2 m spacing. The support was 4 m high. Five vines of the variety Weiki of *Actinidia arguta* were used as pollinators for those cultivars. In 2006-2011, plants were in their tenth to fifteenth years of vegetation. The research results of 2007 were not included because flowers of the examined cultivars were damaged by winter frosts and, consequently, chemical analyses of fruits were impossible. From the establishment of the experiment to the end of 2011, the plants did not require fertilization or chemical protection against diseases and pesticides or additional irrigation during the vegetation period. In the years of the study, 10-cm-thick bedding of bark of coniferous trees was spread around the shrubs. Plants grew on class IV soil of cereal-fodder strong complex. This is a highly loamy sand with the pH 6.85-7.52. The mineral composition of the soil was as follows: N – 9.66, P – 148.84, K – 57.83, Mg – 84.18 mg $kg^{-1}$ d.m.

On the basis of observations in 2006-2011, the following developmental periods were determined for each cultivar: 1) bud swelling, 2) beginning of flowering, 3) fruit setting, 4) fruit harvest.

The period between the bud swelling and the beginning of flowering was the first phenological phase (1-2), the second phase was the period between the beginning of flowering and fruit setting (2-3) and the third was the time between fruit setting and harvest (3-4). In each of those phases, the values of temperatures and precipitation were added up. Tables 1 and 2

Table 1

Mean, minimum and maximum sums of temperatures of 2006-2011 in Olsztyn during phenological phases of Ukrainian cultivars of *Actinidia arguta and Actinidia purpurea*

| Cultivar | ST 1-2 | | | | ST 2-3 | | | | ST 3-4 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | min. | max. | SD | mean | min. | max. | SD | mean | min. | max. | SD |
| Figurnaja | 457.0 | 350.0 | 553.5 | 85.0 | 488.3 | 381.7 | 538.0 | 63.2 | 1361.1 | 1261.3 | 1465.2 | 87.4 |
| Kijewskaja Gibrydnaja | 454.5 | 350.0 | 553.5 | 84.5 | 502.9 | 381.7 | 594.8 | 79.3 | 1365.0 | 1208.2 | 1465.2 | 101.8 |
| Kijewskaja Krupnopłodnaja | 485.4 | 389.4 | 586.3 | 75.0 | 491.1 | 321.4 | 566.4 | 99.4 | 1407.7 | 1223.7 | 1643.1 | 162.3 |
| Purpurowaja Sadowaja | 459.2 | 350.0 | 553.5 | 85.7 | 469.4 | 381.7 | 519.5 | 54.3 | 1346.0 | 1208.2 | 1465.2 | 92.1 |
| Sientiabrskaja | 463.4 | 350.0 | 553.5 | 87.8 | 457.3 | 381.7 | 519.5 | 63.1 | 1353.9 | 1208.2 | 1465.2 | 95.7 |

Explanations:
SD – standard deviation;
ST 1-2 – sums of temperatures in the first phenological phase (the period between the bud swelling and the beginning of flowering);
ST 2-3 – sums of temperatures in the second phenological phase (the period between the beginning of flowering and fruit setting);
ST 3-4 – sums of temperatures in the third phenological phase (the period between fruit setting and harvest.

Table 2

Mean, minimum and maximum sums of precipitation (SP) of 2006-2011 in Olsztyn during phenological phases of Ukrainian cultivars of *Actinidia arguta and Actinidia purpurea*

| Cultivar | SP 1-2 | | | | SP 2-3 | | | | SP 3-4 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | mean | min. | max. | SD | mean | min. | max. | SD | mean | min. | max. | SD |
| Figurnaja | 87.1 | 6.7 | 168.7 | 57.4 | 83.4 | 27.6 | 166.6 | 52.8 | 214.4 | 157.0 | 264.1 | 38.7 |
| Kijewskaja Gibrydnaja | 87.1 | 6.7 | 168.7 | 57.4 | 83.4 | 27.6 | 166.6 | 52.8 | 214.4 | 157.0 | 264.1 | 38.7 |
| Kijewskaja Krupnopłodnaja | 89.5 | 6.7 | 168.2 | 57.7 | 85.7 | 32.4 | 175.9 | 55.9 | 205.6 | 152.3 | 247.5 | 34.5 |
| Purpurowaja Sadowaja | 87.8 | 6.7 | 168.7 | 57.5 | 81.8 | 27.6 | 166.6 | 52.4 | 211.3 | 141.8 | 264.1 | 44.5 |
| Sientiabrskaja | 87.8 | 6.7 | 168.7 | 57.5 | 81.8 | 27.6 | 166.6 | 52.4 | 211.3 | 141.8 | 264.1 | 44.5 |

Key cf. Table 1

present the mean, minimum and maximum values, as well as standard deviation for those meteorological factors. The method of calculating the sum of temperatures expresses the empirical relations between plant development and the amount of heat they received in a given phenophase. It assumes a constant value of sums of temperatures for a specific phase of a given species (MIKKELSEN 1981).

Data originating from the Station of the Institute of Meteorology and Water Management in Olsztyn were used in calculations. Tables 3-8 show the values of the correlation coefficient between thermal conditions and precipitation in established phonological phases and the macroelement content in fruits for each cultivar.

Table 3

Correlation between the potassium content in fruits and the sum of air temperatures and precipitation in 2006-2011 in Olsztyn during phenological phases of Ukrainian cultivars of *Actinidia arguta and actinidia purpurea*

| Factor | Cultivar | | | | |
|---|---|---|---|---|---|
| | Figurnaja | Kijewskaja Gibrydnaja | Kijewskaja Krupnopłodnaja | Purpurowaja Sadowaja | Sientiabrskaja |
| ST 1-2 | -0.252 | 0.211 | -0.134 | 0.079 | -0.365 |
| SP 1-2 | -0.391 | -0.531 | -0.457 | -0.366 | 0.374 |
| ST 2-3 | -0.035 | -0.159 | -0.094 | 0.001 | 0.973 |
| SP 2-3 | 0.546 | 0.608 | 0.633 | 0.757 | 0.845 |
| ST 3-4 | 0.283 | -0.472 | -0.152 | -0.530 | -0.743 |
| SP 3-4 | -0.348 | 0.255 | -0.464 | -0.054 | -0.873 |

Key cf. Table 1

Table 4

Correlation between the calcium content in fruits and the sum of air temperatures and precipitation in 2006-2011 in Olsztyn during phenological phases of Ukrainian cultivars of *Actinidia arguta and Actinidia purpurea*

| Factor | Cultivar | | | | |
|---|---|---|---|---|---|
| | Figurnaja | Kijewskaja Gibrydnaja | Kijewskaja Krupnopłodnaja | Purpurowaja Sadowaja | Sientiabrskaja |
| ST 1-2 | -0.340 | -0.377 | 0.041 | 0.156 | 0.914 |
| SP 1-2 | -0.791 | -0.781 | -0.580 | -0.298 | 0.384 |
| ST 2-3 | -0.557 | -0.682 | -0.214 | -0.599 | -0.532 |
| SP 2-3 | -0.350 | -0.453 | -0.275 | -0.320 | -0.227 |
| ST 3-4 | 0.090 | 0.232 | 0.566 | 0.185 | 0.060 |
| SP 3-4 | 0.612 | 0.929* | 0.764 | 0.760 | 0.280 |

Asterisks indicate correlation coefficient significant at $\alpha$=0.05;
Key cf. Table 1

Table 5

Correlation between the nitrogen content in fruits and the sum of air temperatures and precipitation in 2006-2011 in Olsztyn during phenological phases of Ukrainian cultivars of *Actinidia arguta and Actinidia purpurea*

| Factor | Cultivar | | | | |
|---|---|---|---|---|---|
| | Figurnaja | Kijewskaja Gibrydnaja | Kijewskaja Krupnopłodnaja | Purpurowaja Sadowaja | Sientiabrskaja |
| ST 1-2 | -0.710 | 0.920* | -0.723 | 0.457 | 0.730 |
| SP 1-2 | -0.767 | 0.408 | 0.152 | 0.238 | 1.000* |
| ST 2-3 | -0.272 | 0.440 | 0.551 | 0.583 | 0.573 |
| SP 2-3 | -0.389 | 0.671 | 0.143 | 0.935* | 0.809 |
| ST 3-4 | 0.504 | -0.911* | 0.431 | -0.828 | -0.896 |
| SP 3-4 | 0.507 | 0.042 | -0.622 | -0.433 | -0.776 |

Asterisks indicate correlation coefficient significiant at $\alpha$=0.05;
Key cf. Table 1

Table 6

Correlation between the phosphorus content in fruits and the sum of air temperatures and precipitation in 2006-2011 in Olsztyn during phenological phases of Ukrainian cultivars of *Actinidia arguta and Actinidia purpurea*

| Factor | Cultivar | | | | |
|---|---|---|---|---|---|
| | Figurnaja | Kijewskaja Gibrydnaja | Kijewskaja Krupnopłodnaja | Purpurowaja Sadowaja | Sientiabrskaja |
| ST 1-2 | -0.566 | -0.591 | -0.370 | -0.626 | 0.692 |
| SP 1-2 | -0.518 | -0.402 | -0.904* | -0.396 | 0.007 |
| ST 2-3 | -0.741 | -0.294 | -0.648 | -0.699 | -0.812 |
| SP 2-3 | -0.860 | -0.941* | -0.521 | -0.957* | -0.578 |
| ST 3-4 | 0.484 | 0.667 | 0.527 | 0.919 | 0.433 |
| SP 3-4 | 0.727 | 0.579 | 0.217 | 0.481 | 0.622 |

Asterisks indicate correlation coefficient significiant at $\alpha$=0.05;
Key cf. Table 1

The content of macroelements was determined after fruit harvest at the harvest maturity stage. Chemical analyses were carried out in three replications. Tests were prepared directly after fruit harvest using 0.5 kg of randomly-selected fruits of each cultivar dried at 105°C. The dried material was ground in a laboratory mill. Macroelements in fruits of actinidia were determined after digestion (1 g ground plant material) by wet mineralization ($H_2SO_4$ using a oxidant $H_2O_2$). The mineralized material was transferred to 200 $cm^3$ flasks. The following values were determined in the prepared samples:

- N – by the distillation method;
- P- colorimetrically, by the vanadium-molybdenum method;
- K, Ca, Na – by atomic emission spectroscopy ESA;
- Mg – by atomic absorption spectroscopy ASA.

The analyses were carried out on the basis of certified material CTA--VTL-2. The content of macroelements was determined according to Polish Norms PN-91/R-04014.

The following determination errors were included: N – 3%, P – 4.5%, K – 2%, Ca – 2.8%, Na – 7%, Mg – 1.5%.

Table 7

Correlation between the magnesium content in fruits and the sum of air temperatures and precipitation in 2006-2011 in Olsztyn in phenological phases of Ukrainian cultivars of *Actinidia arguta and Actinidia purpurea*

| Factor | Cultivar | | | | |
|---|---|---|---|---|---|
| | Figurnaja | Kijewskaja Gibrydnaja | Kijewskaja Krupnopłodnaja | Purpurowaja Sadowaja | Sientiabrskaja |
| ST 1-2 | -0.782 | -0.031 | -0.608 | -0.422 | 0.746 |
| SP 1-2 | -0.087 | 0.355 | 0.434 | 0.272 | 1.000* |
| ST 2-3 | 0.021 | 0.193 | 0.218 | -0.013 | 0.553 |
| SP 2-3 | -0.465 | -0.732 | -0.732 | -0.840 | 0.794 |
| ST 3-4 | 0.888* | 0.291 | 0.400 | 0.726 | -0.885 |
| SP 3-4 | -0.451 | 0.240 | -0.308 | -0.074 | -0.760 |

Asterisks indicate correlation coefficient significiant at $\alpha$=0.05;
Key cf. Table 1

Table 8

Correlation between the sodium content in fruits and the sum of air temperatures and precipitation in 2006-2011 in Olsztyn during phenological phases of Ukrainian cultivars of *Actinidia arguta andAactinidia purpurea*

| Factor | Cultivar | | | | |
|---|---|---|---|---|---|
| | Figurnaja | Kijewskaja Gibrydnaja | Kijewskaja Krupnopłodnaja | Purpurowaja Sadowaja | Sientiabrskaja |
| ST 1-2 | -0.787 | -0.826 | -0.417 | -0.637 | -0.983 |
| SP 1-2 | -0.802 | -0.520 | -0.952* | -0.247 | -0.841 |
| ST 2-3 | -0.883* | -0.670 | -0.698 | -0.360 | -0.044 |
| SP 2-3 | -0.470 | -0.788 | -0.435 | -0.531 | -0.367 |
| ST 3-4 | 0.784 | 0.800 | 0.439 | 0.642 | -0.518 |
| SP 3-4 | 0.538 | 0.402 | 0.041 | 0.241 | 0.316 |

Asterisks indicate correlation coefficient significiant at $\alpha$=0.05;
Key cf. Table 1

A detailed list of the macroelements and their content in fruits of the examined actinidia cultivars in individual years of the experiment has been published in BIENIEK (2012b). This study presents the mean content of the discussed elements in fruits of the examined actinidia cultivars in 2006-2011 (Table 9). The significance of differences was calculated using Tukey's HSD test at a level of significance $\alpha$=0.01. In order to determine the relation between the content of macronutrients in fruits and weather conditions in phonological phases, linear correlation were analysed. The significance of the correlation coefficients was set at $\alpha$=0.05. Calculations were performed with Statistica 9.1 software.

Table 9

The mean contents (g kg$^{-1}$ d.m.) of macroelements in fruits of *Actinidia cultivars* in 2006-2011

| Cultivar | K | Ca | N | P | Mg | Na |
|---|---|---|---|---|---|---|
| Figurnaja | 12.31 $^{a}$ | 3.13 $^{a}$ | 9.43 $^{b}$ | 2.99 $^{a}$ | 0.67 $^{b}$ | 0.72 $^{b}$ |
| Kijewskaja Gibrydnaja | 16.57 $^{b}$ | 3.03 $^{a}$ | 8.96 $^{a}$ | 3.03 $^{a}$ | 0.68 $^{b}$ | 0.60 $^{a}$ |
| Kijewskaja Krupnopłodnaja | 18.83 $^{c}$ | 3.51 $^{b}$ | 9.53 $^{b}$ | 3.28 $^{b}$ | 0.61 $^{a}$ | 0.66 $^{ab}$ |
| Purpurowaja Sadowaja | 19.62 $^{d}$ | 3.88 $^{c}$ | 9.90 $^{c}$ | 3.13 $^{ab}$ | 0.73 $^{c}$ | 0.59 $^{a}$ |
| Sientiabrskaja | 16.42 $^{b}$ | 4.86 $^{d}$ | 12.21 $^{d}$ | 4.14 $^{c}$ | 0.81 $^{d}$ | 0.66 $^{ab}$ |

Means followed by the same letters do not differ at $\alpha$=0.01.

## RESULTS AND DISCUSSION

As shown in Table 1, the mean sum of daily temperatures and sum of minimum and maximum temperatures of 2006-2011 in the phase between bud swelling to the beginning of flowering were the highest for Kijewskaja Krupnopłodnaja – the cultivar started vegetation at the latest date. For the other cultivars, in the corresponding phenophase, the value of sums of minimum and maximum temperatures was the same. The lowest mean sum of daily temperatures was observed for cv. Kijewskaja Gibrydnaja, but in the next phenological phase, from the beginning of flowering to fruit setting, this meteorological factor showed a higher value. In addition, the sum of maximum temperatures was the highest for this cultivar, while the sum of minimum temperatures was the same as for other cultivars, except Kijewskaja Krupnopłodnaja. The lowest mean sum of temperatures in the period between fruit setting to harvest was recorded for Purpurowaja Sadowaja. This cultivar was distinguished by the earliest date of fruit ripening (BIENIEK 2012b). The sums of the minimum and maximum temperatures for the cultivars Kijewskaja Gibrydnaja, Purpurowaja Sadowaja and Sientiabrskaja in the examined phenophase showed the same value.

As shown by the analysis of sums of precipitation in individual phases of vegetation of the selected actinidia cultivars in 2006-2011, Kijewskaja Krupnopłodnaja stood out with its varied values of sums of mean precipitation in each of the examined period of development (Table 2). In the first two phenological phases, this value was the highest but in the last one, it was the lowest. The biggest differences, both in the mean sum of precipitation and in sums of minimum and maximum precipitation, were recorded in the phase between fruit setting and harvest. In that phenological phase, Purpurowaja Sadowaja and Sientiabrskaja had the same values of mean sums of precipitations, as well as the minimum and maximum sums of precipitation. Another pair of cultivars with the same properties was composed of Figurnaja and Kijewskaja Gibrydnaja. The cultivar Kijewskaja Krupnopłodna was distinguished by its variable values of the discussed factor.

Based on the data provided in Table 9, it can be claimed that the examined macroelements occur in actinidia fruits in the following, decreasing content: K>N>Ca>P>Mg>Na. Tables 3-8 show values of the correlation coefficient between thermal conditions and precipitation in the determined phenological phases and the content of macrooelements in fruits for each cultivar.

Potassium was the only macroelement for which no significant correlations were found as regards its content in fruits and the other examined factors (Table 3). Positive correlation coefficients for all the examined varieties in the phase between the beginning of flowering and fruit setting may also confirm a favourable relationship between the amount of precipitation in the phenological phase and the content of this element in fruit (Table 3). The highest mean potassium content in 2006-2011 was accumulated by fruit of Purpurowaja Sadowaja (Table 9), for which sums of precipitation in the period between the beginning of flowering and fruit setting had a positive effect on the accumulation of potassium (Table 3). Potassium is the second most important (after nitrogen) macroelement ensuring good growth and yielding of plants. As shown by the yield analysis for this cultivar in 2001-2009, it was also one of the most prolific varieties (Bieniek 2012a). Potassium is also required for obtaining good fruit colour, accumulation of acids and good taste.

Table 4 shows significant positive correlation between the calcium content in fruit from cv. Kijewskaja Gibrydnaja and the sum of precipitation in the phase between fruit setting to harvest. In the examined phenophase, both sums of precipitation and sums of temperatures showed a favourable effect on the growth of calcium content in fruits of all the analysed cultivars. On the other hand, in the phase between the beginning of flowering and fruit setting, sums of temperatures and precipitation had a negative effect on the content of calcium in fruits of all the examined cultivars. In the phase between bud swelling and the beginning of flowering, positive correlation coefficients for both sums of temperature and sums of precipitation were recorded only for Sientiabrskaja. This cultivar was characterized by the highest total content of calcium in fruit. The lowest Ca content was found in fruits of Kijewskaja Gibrydnaja and Figurnaja cultivars (Table 9). Calcium is transferred from fruit to wood. In England, it was found that in the last three weeks before harvest, 20% of calcium was transferred from apples to other plant organs due to dry weather. Stress conditions during plant growth under very dry weather make water with Ca drain away from fruit to leaves. At the same time, low soil moisture reduces Ca availability for plants.

In the current experiment, a significant positive correlation coefficient was found for the interaction between sums of temperatures in the phase between bud swelling and the beginning of flowering and the content of nitrogen in fruits of cultivar Kijewskaja Gibrydnaja (Table 5). As reported by TROMP and OVAA (1971), in spring, just before bud bursting, nitrogen reserves are activated in shoots, which is manifested *inter alia* by intensive protein decomposition. On the other hand, sums of temperature in the phase between fruit setting and harvest had a significant negative effect on the content of this element in fruits of this cultivar. Significant positive values of the correlation coefficient for the content of nitrogen in fruit also confirm the relationship between the sum of precipitation in the phase between bud swelling and the beginning of flowering for cv. Sientiabrskaja, and in the phase between the beginning of flowering and fruit setting for fruits of cv. Purpurowaja Sadowaja. On the other hand, a negative value of the correlation coefficient in the subsequent phenophase, between fruit setting and harvest confirms the negative effect of sums of precipitation on the content of nitrogen in fruits of Kijewskaja Krupnopłodnaja, Purpurowaja Sadowaja and Sientiabrskaja. In addition, during the same phenological phase, the content of nitrogen in fruit was negatively affected by the sums of temperatures, particularly in case of Kijewskaja Gibrydnaja, where the correlation was significant, in fruit of Purpurowaja Sadowaja and Sientiabrskaja, where the effect was weaker. Fruits of the latter cultivar had the highest content of nitrogen (Table 9). Favourable sums of temperatures and precipitation in the first two phenological phases could have a significant effect on the content of this element in fruit of this cultivar, which is confirmed by the positive correlation coefficients (Table 5). Values of all correlation coefficients in these phases were negative only for cv. Figurnaja.

As regards the phosphorus content, significant negative correlations were observed for Kijewskaja Gibrydnaja and Purpurowaja Sadowaja and the sums of precipitation in the phase from the beginning of flowering to fruit setting, and for Kijewska Krupnopłodnaja and the sum of precipitation in the phase between bud swelling and the beginning of flowering (Table 6). Additional correlation coefficients, for all the cultivars, between sums of precipitation and temperatures in the phase between fruit setting to their harvest indicate the favourable effect of the examined meteorological factors on the growth of phosphorus content in fruits. The lowest content of phosphorus was found in fruits of Figurnaja and Kijewskaja Gibrydnaja (Table 9). In this study, correlation coefficients in the first two phenological phases, both for sums of temperatures and precipitation, obtained for these cultivars were all negative, which could have affected the final content of this element in fruit. The highest content of phosphorus was found in fruits of Sientiabrskaja (Table 9). The increase of phosphorus in fruits of this cultivar may have resulted from the favourable course of climatic conditions in the first and in the last phenological phase. Phosphorus affects the formation of flower buds. In the differentiation period, tree buds accumulate significant amounts of organic phosphorus, and a shortage of this element highly reduces the number of flower buds (TAYLOR, GOUBRAN 1975). It is important that the level of phosphorus should be at an optimum level in plant tissues both in the year of fructification and in the preceding year (BOULD, PARFITT 1973). For the above cultivar, the role of phosphorus has not been elucidated. BIENIEK (2012a) demonstrated that Sientiabrskaja is unsuitable for cultivation in climatic conditions of the 6 USDA zone, since it binds the fewest flower buds and produces the lowest yields.

Table 7 demonstrates that the effect of sums of temperatures in the phase between fruit setting and harvest had a highly significant positive influence on the magnesium content in fruit of Figurnaja cultivar, and the sum of precipitation in the phase between bud swelling to the beginning of flowering produced such influence on Sientiabrskaja.

Sientiabrskaja was also the cultivar with the highest content of magnesium in fruits (Table 9). As follows from Table 7, positive values of all correlation coefficients in first two phenological phases were found only for this cultivar. Lower content of magnesium was found in fruits of the hybrid forms of actinidia than in fruits of *Actinidia arguta* or *Actinidia purpurea* (Table 9). However, no significantly negative effect of the sums of temperatures or precipitation on concentration of this element in fruit of the examined cultivars was found in any of the phenological phases (Table 7). As regards the sodium content (Table 8), an opposite, significantly negative relation was found between sums of temperatures in the phase from the beginning of flowering and fruit setting for cv. Figurnaja, and between sums of precipitation in the phase between bud swelling to the beginning of flowering for cv. Kijewskaja Krupnopłodnaja.

HOŁUBOWICZ (1970) demonstrated the role of N, P, Ca and K elements in the regulation of flowering and fruiting. The experiment discussed in this study demonstrated that sums of temperatures and precipitation in the phase between fruit setting and harvest had a positive effect on the development of Ca and P content in fruit of all the examined cultivars.

The influence of temperature and its effect on the growth and development of various species of plants has been analysed in both Polish and foreign literature (CHMIELEWSKI et al. 2004, DRAGAŃSKA et al. 2008, KALBARCZYK 2009, KALBARCZYK, KALBARCZYK 2012, KAWECKI, BIENIEK 2008, LICZNAR- MAŁAŃCZUK

2004, MILOŠEVIĆ, MILOŠEVIĆ 2012, SKOWERA et al. 2007, TAO et al. 2008). SNELGAR et al. (1992) and TIYAYON and STRIK (2004) examined the effect of shading on flowering and fruiting of *Actinidii arguta* Ananasnaja in Oregon (USA). The response of cultivars in terms of the content of macroelements in fruit depending on weather conditions in phenological phases has not been analysed in research publications; therefore it is difficult to refer to literature data. LATOCHA (2010) found that the content of mineral components in fruit depends mainly on the genetic features of the plant. This research demonstrated that the concentration of Ca, N, P, Mg and Na in fruits of Ukrainian cultivars of actinidia significantly depended (positively or negatively) on the relations between cultivars and meteorological factors in specific phenophases.

## CONCLUSIONS

1. The content of mineral components in fruits of cultivars Kijewskaja Krupnopłodnaja, Purpurowa Sadowaja and Sientiabrskaja did not significantly depend on the sums of daily temperatures in any of the phenophases discussed. However, these cultivars responded significantly to the content of phosphorus, nitrogen, magnesium and sodium depending on the sum of precipitation in the first two phenophases.

2. For cv. Figurnaja, the sum of temperatures in the phase from fruit setting to their harvest was a factor significantly influencing the content of magnesium. The content of sodium in fruits of this cultivar was significantly negatively correlated with the sum of temperatures in the phase from the beginning of flowering to fruit setting.

3. The phase between fruit setting and harvest had a favourable effect on the content of calcium and phosphorus in fruits of Ukrainian cultivars of actinidia grown in north-eastern Poland.

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