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Wstępne wyniki oceny wybranych klonów maliny właściwej (*Rubus idaeus* L.) poszerzających zmienność genetyczną pod względem ważnych cech fenotypowych

Preliminary results of the evaluation of selected red raspberry (*Rubus idaeus* L.) clones so as to extend existing genetic variability in terms of important phenotypic features

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W pracy przedstawiono wyniki badań z roku 2019, czyli z pierwszego roku oceny klonów. Celem badań było określenie możliwości poszerzenia zmienności genetycznej maliny właściwej (*Rubus idaeus* L.), istniejącej w zasobach genetycznych Instytutu Ogrodnictwa, pod względem takich cech biologicznych, jak okres dojrzewania, atrakcyjność (wygląd), wielkość i masa owoców, wytwarzanie kolców przez rośliny, siła wzrostu i zdrowotność krzewów. Badaniami objęto najbardziej wartościowe genotypy wyselekcjonowane z populacji 2640 siewek pokolenia F_1, otrzymanych ze skrzyżowania w układzie diallelicznym, wg II metody Griffinga (Griffing, 1956) 10 odmian maliny (‘Canby’, ‘Glen Ample’, ‘Laszka’, ‘Polana’, ‘Polka’, ‘Radziejowa’, ‘Schönemann’, ‘Sokolica’, ‘Veten’ i ‘Willamette’). Uzyskane wyniki badań potwierdziły, że możliwe jest poszerzenie zmienności genetycznej przy zastosowaniu metod hodowli konwencjonalnej, a także połączenie w jednym genotypie takich cech maliny, jak zdolność do wytwarzania wysokiej jakości owoców, wydłużone letnio-jesienne owocowanie i bezkolcowość pędów.

Słowa kluczowe: genotypy maliny czerwonej, hodowla konwencjonalna, hodowla krzyżówkowa, hodowla twórcza maliny, hybrydyzacja, selekcja,

The aim of the study was to determine the possibility of extending the genetic variability of red raspberry (*Rubus idaeus* L.) stock existing in the genetic resources of the Research Institute of Horticulture in terms of such biological characteristics as ripening time, attractiveness (appearance), size and weight of fruit, spine production by plants, growth vigour and health of shrubs. The paper presents the results of research from 2019, i.e. the first year of clone evaluation. The study includes the most valuable genotypes selected from a population of 2640 seedlings of the F_1 generation, obtained from hybridization made in a diallel system, according to the Griffing II method (Griffing, 1956) of 10 cultivars of raspberry (‘Canby’, ‘Glen Ample’, ‘Laszka’, ‘Polana’, ‘Polka’, ‘Radziejowa’, ‘Schönemann’, ‘Sokolica’, ‘Veten’ and ‘Willamette’). The obtained test results confirmed that it is possible to broaden genetic variability using conventional breeding methods, as well as to combine in one genotype such features of raspberry as the ability to produce high quality fruit, extend summer-autumn fruiting and produce spineless shoots.

Key words: conventional breeding, creative raspberry breeding, cross breeding, hybridization, red raspberry genotypes, selection

Introduction

Fruits of raspberry (*Rubus idaeus*), commonly known as red raspberry, are among the most delicious fruits in the world, with very versatile uses. They are excellent for direct consumption and perfect for jams, preserves, juices, and freezing, and make a valuable flavour addition in various products (ice cream, chocolate, candies, teas, etc.). Raspberries contain a wide range of nutrients necessary for the normal functioning of the human body, such as vitamins A, B2 (riboflavin), B3 (niacin), B6, B9 (folic acid), C (ascorbic acid), E and K, and elements such as potassium, magnesium, calcium, sodium, iron, and zinc (Burton-Freeman et al., 2016). The great advantage of raspberries is their low energy value, since 100 g of fresh raspberries provides only 52 kcal. Raspberries also contain ellagic acid (Markowski and Płocharski, 2011), which has antibacterial properties and supports the treatment of common cold and flu. They are also known for their antioxidant and anti-carcinogenic properties, as well as a mitigating effect on free radicals due to the high content of phenolic compounds, including

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anthocyanins and elagitannins (Castilho Maro et al., 2013; Burton-Freeman et al., 2016).

For many years Poland has been the world's leading producer and exporter of fresh, frozen and processed raspberries. In recent years Poland has annually produced approximately 120,000 tonnes of raspberries (in 2019, due to drought, it was only about 75,000 tonnes) (Central Statistical Office, Poland, 2019). Poland (next to Serbia) is therefore the largest producer of this fruit in the world, and the production of raspberries is constantly growing. The area of raspberries grown under high covers (for accelerated or delayed harvest) is increasing rapidly. A large proportion of raspberries produced in Poland come from cultivars bred at the Research Institute of Horticulture. For many years, the primocane (double-cropping) cultivar 'Polka' (Danek and Markowski, 2003; Danek 2012) was particularly valued, as it bears fruit in the summer and autumn. In addition to advantages such as high productivity, good winter hardiness, attractive shape and appearance of fruit, and good fruit flavour, this cultivar also has some disadvantages. These include a high susceptibility of plants and fruit to Raspberry Bushy Dwarf Virus (RBDV), which causes a bushy and stunted growth of plants, uneven ripening and deformation of fruits, also called raspberry fruit decay (Żurawicz and Cieślińska 2005; Tzanetakis et al. 2007; Muster 2008). This virus spreads not only through infected plant material, but also via pollen and infected seeds. It is impossible to control this pathogen on plantations, and losses due to infection are large and incremental (Moore and Hoashi-Erhardt, 2012; Paszko, 2012; Paszko et al., 2018). Another disadvantage of the 'Polka' cultivar are shoots with multiple spines. This trait creates a significant problem with plant maintenance, especially fruit harvesting. The vivid red colour of fruit skin is also considered a disadvantage of the 'Polka' cultivar. As a result, 'Polka' fruits look overripe after a short period of storage, e.g. when displayed on supermarket shelves.

Information available in the professional literature indicates that there are already genotypes of raspberry with different times of fruit ripening, characterized by bright red fruit, low susceptibility to RBDV, different ripening times and spineless shoots (Jones and McGavin, 2004; Moore and Martin, 2008). This means that it is possible to extend the existing genetic variability within the *Rubus idaeus* species by using conventional breeding methods. Thus, it is possible to create new genotypes that combine various desirable biological traits, including those very important for growers and consumers, such as different ripening time, good external and internal quality of fruit, low susceptibility/good tolerance of plants to serious viral diseases, or spine-free shoots, and in this way to enrich the genetic and phenotypic diversity of *Rubus idaeus*.

The aim of the study was to test the hypothesis that cultivars and conventional breeding techniques used in the studies can lead to the extension of the existing genetic variability within the species *Rubus idaeus* and be exploited as a source of genes to create new cultivars of red raspberry. The probability of breeding such innovative genotypes is very high, because the cultivars of raspberry used in the research come from different regions of the world and differ in terms of many biological features, which was confirmed in previous studies, including those carried out in Poland (Żurawicz, 2016a, 2016b, 2017, 2018; Żurawicz et al., 2017, 2018).

Materials and Methods

The plant material used in the study was a population of hybrids (seedlings) of the F_1 generation, obtained in 2014 from the crosses of ten cultivars of *Rubus idaeus* in diallel cross mating design, according to Griffing's method 2 (Griffing, 1956) . The list and a brief description of these cultivars are presented in Table 1, and the crossing scheme in Table 2.

The analysed population of seedlings was grown in an experimental field of the Pomological Orchard of the Research Institute of Horticulture in Skierniewice. This experiment was established in the spring of 2015 in a random block design, in four replicates, with 12 plants per plot, spaced 0.4 m × 2.0 m. In total 2640 seedlings were planted representing 45 hybrid families and created by controlled crossing of parental forms and 10 hybrid families created by selfing of these forms. Plants were maintained during the experiment consistently with the recommendations for commercial plantations of raspberry in Poland.

In 2016-2017, all hybrids (seedlings) and their parental forms were assessed for the following traits: yielding (fruiting type), selected fruit characteristics (appearance, i.e. attractiveness and size), fruit weight, plant growth vigour, plant habit, and presence of spines on shoots.

Based on the assessment of plants in this experiment, we selected seedlings most distinct in terms of the assessed traits, which could extend the genetic variability preserved in the genetic resources

Tabela 1
Table 1

Wykaz oraz krótka charakterystyka odmian użytych w programie krzyżowań
List and brief description of the cultivars used in the crossing program

Nazwa odmiany Cultivar name	Kraj pochodz. Country of the origin	Rodowód Pedigree	Pora dojrzewania Ripening time	Plenność Producti-vity	Wielkość owoców Fruit size	Barwa owoców Fruit colour	Podatność na RBDV RBDV susceptibility	Obecność kolców na pędach Presence of spines on shoots
Canby*	USA	Viking × Lloyd George	dość wczesna quite early	Wysoka high	Średnie medium	żywo czerwone intensive red	Podatna susceptible	+
Glen Ample*	UK	Brak informacji Lack of information	średnio-wczesna medium early	Wysoka high	Duże large	jasno czerwone bright red	mało podatna low susceptible	-
Laszka*	POL	80408 × 80192	Wczesna early	Wysoka high	bardzo duże very large	jasno czerwone bright red	Podatna susceptible	+
Polana**	POL	Heritage × Eva Herbsternte	połowa VIII mid-August	dość wysoka quite high	Średnie medium	żywo czerwone z silnym połyskiem intensive red with high glossiness	mało podatna low susceptible	+
Polka**	POL	Autumn Bliss + Lloyd George + *R. crataeifolius*	VII/VIII	Wysoka high	średnie i duże medium and large	żywo czerwone z silnym połyskiem intensive red with high glossiness	bardzo podatna very susceptible	+
Radziejowa*	POL	92271 × 96221	wczesna (druga połowa VI) Early (second half of June)	dość wysoka quite high	Duże large	żywo czerwone intensive red	Podatna susceptible	+
Schönemann*	GER	Lloyd Georg × Preussen	bardzo późna very late	Wysoka high	bardzo duże very large	ciemno-czerwone dark red	mało podatna low susceptible	+
Sokolica*	POL	96131 × 96221	średnio wczesna medium early	Wysoka high	Duże large	jasno czerwone bright red	Podatna susceptible	+
Veten*	NOR	Asker × Lloyd George	Wczesna early	średnia do wysokiej medium to high	średnie i duże medium and large	czerwone i ciemno czerwone red and dark red	mało podatna low susceptible	+
Willamette*	USA	Lloyd George × Newburgh	Późna late	Wysoka high	Duże large	żywo czerwone intensive red	tolerancyjna tolerant	+

*Objaśnienie: * - odmiana tradycyjna (letnia); ** - odmiana „powtarzająca" (letnio-jesienna)*
*Explanation: * - traditional (summer) cultivar; ** - "repeating" cultivar (summer-autumn)*

Tabela 2
Table 2

Schemat krzyżowania wybranych form rodzicielskich maliny właściwej

Diagram of crossing of selected raspberry parental forms

♀ \ ♂	Canby	Glen Ample	Laszka	Polana	Polka	Radziejowa	Schönemann	Sokolica	Veten	Willamette
Canby	xx	x	x	x	x	x	x	x	x	x
Glen Ample		xx	x	x	x	x	x	x	x	x
Laszka			xx	x	x	x	x	x	x	x
Polana				xx	x	x	x	x	x	x
Polka					xx	x	x	x	x	x
Radziejowa						xx	x	x	x	x
Schönemann							xx	x	x	x
Sokolica								xx	x	x
Veten									xx	x
Willamette										xx

Objaśnienie: ♀ - forma mateczna, ♂ - forma ojcowska; x – krzyżowanie wprost, xx – samozapylenie
Explanation: ♀ - maternal form, ♂ - paternal form; x - straight crossing, xx - selfing

of raspberry at our Institute. In 2017 the selected genotypes were propagated (cloned) and the same was done with their parental forms. In spring 2018 the obtained clones and their parental forms were planted in the collection of clones, in the Pomological Orchard of the Research Institute of Horticulture in Skierniewice. All clones and their parental forms were represented by three plants, planted 0.4 m × 2.5 m apart.

In 2019 plants from the collection of clones were fully fruiting for the first time and assessed in detail. Assessment focused on the following traits:

fruiting type - L-summer (floricane) cultivar, J - autumn (primocane) cultivar, LD - primo-floricane (double-cropping) cultivar (also producing fruit in the apical part of the current year shoots; these fruits can be commercially viable), LDP - late primo-floricane double-cropping cultivar (also producing fruit in the apical part of the current year shoots, but these fruits are formed very late; they do not mature and therefore are not commercially viable);

- fruit appearance (size and attractiveness, including the uniformity and regularity of fruit shape, colour and its uniformity, as well as glossiness) – assessed in a ranking scale from 1 to 9, where 1 is the lowest, and 9 is the highest score for the trait;
- fruit weight - the quotient of the yield and the number of fruits at the end of the second week of harvest (ripening);
- the presence or absence of spines on the shoots;
- shrub height - measurement of the tallest shoot in the shrub;
- shrub health – assessed in a 1 to 3 ranking scale, where 3 is the highest score for the trait (best health status).

Results

The assessment led to the selection of 39 clones which were regarded to have the highest potential to extend the existing genetic variability of red raspberry kept in the genetic resources of the Institute. Their list, numbers and assessment results together with the results of similar evaluation for parental forms are presented in Table 3.

As shown in Table 3, the assessed clones differed significantly in terms of the analysed traits. Nine of these genotypes (23.1% of the clone population) are typical floricane clones (marked with the letter L in Table 3), producing fruit only in the early summer (June/July). A slightly greater number of clones (14; 35.9%) are primocane (J), fruiting in August and September, and sometimes into October. Another 15 clones (38.5%) are primo-floricane genotypes (L-D, summer double-cropping). They form fruit in autumn on the upper part of tall young shoots (current season canes), and due to their height also in early summer of the following year, in the lower part of the same shoots. From a morphological point of view, such genotypes can be called two-level raspberries, because in the first year they bear fruit in the upper part (upper level) of the shoot, and in the second year in the lower part (lower level) of the same shoot. However, six clones from this group were assigned to the subgroup indicated in Table 3 as late primo-floricane (LDP), or Summer-Double-cropping-Late. In these clones, the fruits in the upper part of the young cane are formed in late summer and therefore generally do not ripen. The group of genotypes with this type of growth and fruiting also included four parental cultivars of analysed clones, i.e. 'Veten', 'Canby', 'Laszka' and 'Sokolica', as well as a standard cultivar, 'Przehyba'. From an agrotechnical point of view, the listed cultivars are considered typical floricane cultivars, but they can form flowers and fruits also on the tops of young (current year) canes.

Fruits of the assessed clones generally have good external quality, defined by their attractiveness and size. These features were assessed in a ranking scale 1 to 9, and only clones whose fruit for both features scored at least 6 in the scale during double assessment were considered valuable. The mean weight of harvested fruit is also an important feature. In this respect, clones with the numbers M-52, M-412, M-206, M-378, M-336, M-402 and M-363, with the mean weight of fruit higher than 4 g were distinguished. Fruits produced by clone M-206 were heaviest (mean 6.2 g), and the difference with the mean weight of fruit from its parental cultivar 'Glen Ample' (5.7 g) was significant.

The assessed clones also differed in the number of spines on canes, but only eight genotypes (20.5% of the population of clones) were spine-free (M-217, M-258, M-397, M-271, M-378, M-47 and M-255).

The group of genotypes with spine-free canes included floricane, primocane, primo-floricane, i.e. double-cropping clones, as well as the parental cultivar 'Glen Ample'. Three clones, marked M-341, M-345 and M-311a, were regarded as plants with a low number of spines, and spines were only formed in the lower part of shoots, similar to the parental cultivar 'Canby'.

As expected, the assessed clones also differed in terms of shoot growth vigour. The most vigorous growth was found in typical floricane and primo-floricane clones, and the weakest in primocane

Tabela 3

Table 3

Wykaz i charakterystyka najwartościowszych klonów, potencjalnie poszerzających zmienność genetyczną zasobów genowych maliny właściwej w Instytucie Ogrodnictwa (z uwzględnieniem odmian rodzicielskich / standardowych)

List and characteristics of the most valuable clones, potentially extending the genetic variability of red raspberry genetic resources at the Research Institute of Horticulture (including parental / standard cultivars)

Nr klonu Clone number	Rodowód Pedigree	Typ owocowania Ripening type L, J, L-D, L-D-P*	Cechy owoców (atrakcyjność, wielkość) Fruit characters (atractiveness, size) **			Masa owoców Fruit weight (g) ***	Kolce Spines (+/-)	Wysokość krzewów Shrub height (cm)	Zdrowotność krzewów Shrub healthiness (1–3)****
			15.VI (a, w)	29.VIII (a, w)	20.IX (a, w)				
M-7	Polana × Schönemann	L-D	7, 7	6, 5		3,8	+	135	3
M-104	Canby × Polana	L- D	7, 7		7, 7	3,1	+	115	3
M-52	Polana × Sokolica	J			7, 8	4, 7	+	120	3
M-115	Polka × Radziejowa	L-D	8, 8	7, 7	8,7	2,7	+	150	2
M-42	Polka × Sokolica	J	8,7			3,2	+	115	2,5
M-57	Polka × Sokolica	J	7, 7	8,8	7,7	2,9	+	115	3
M-95	Laszka × Radziejowa	L	8, 8			3,3	+	205	2
M-164	Polka × Radziejowa	L-D	8, 7		8, 8	3,0	+	155	3
M-140	Polka ×Polka	J	7, 7	7, 7	7, 7	3,5	+	60	3
M-217	Polka × Sokolica	L	8, 7	5, 7	6, 6	2,6	-	105	3
M-258	Glen Ample × Sokolica	L	7, 6			3,2	-	235	3
M-412	Glen Ample × Radziejowa	L	7, 7			4,5	+	255	2
M-341	Laszka × Schönemann	L-D-P	8, 7			3,6	+/-	210	3
M-345	Canby × Polana	L-D	9, 7	9, 8	9, 9	3,2	+/-	215	2,5
M-410	Radziejowa × Schönemann	L	7, 7			3,5	+	150	3
M-311a	Glen Ample × Polana	L-D	6, 6			2,8	+/-	180	3
M-397	Canby × Sokolica	L-D-P				2,4	-	225	3
M-271	Laszka × Sokolica	L	6, 6			2,4	-	210	3
M-278	Radziejowa × Sokolica	L	9, 7			3,7	+	115	3
M-198	Radziejowa × Veten	L-D-P	9,7			3,3	+	160	3
M-208	Radziejowa × Veten	L	8, 8			3,6	+	185	3
M-206	Glen Ample × Polka	L-D-P	7, 7			6,2	+	160	2,5
M-293	Polana × Sokolica	J	8, 8	7, 7	7, 6	3,5	+	160	2,5
M-317	Glen Ample ×Polana	L-D	8, 7		8, 8	3,7	+	180	2
M-378	Glen Ample × Polka	J		6, 7	7, 7	4,4	-	155	3
M-336	Polana × Sokolica	J	9, 8		6, 5	4,3	+	110	3
M-388	Radziejowa × Veten	L	8, 9			3,9	+	190	2
M-14	Polana ×Veten	J	7, 8	7, 8	7, 7	3,0	+	140	3
M-402	Laszka ×Polka	L-D-P	8, 8			4,5	+	200	3
M-363	Radziejowa × Sokolica	L-D-P	8, 7			4,2	+	180	3

Explanation:

** - L-summer (floricane) variety, J - autumn (primocane) variety, L-D - summer double-cropping (primo-floricane) variety (having the ability to produce fruit also in the top of the shoots of the first year, these fruits can be a marketable crop), L-D-P - a two- late summer double-cropping variety (having the ability to*

to produce fruit also in the top of the shoots of the first year, but these fruits are formed very late, they do not grow up and therefore do not represent a commercial crop).

*** - a-fruit attractiveness, w-fruit size; assessment using the ranking scale 1-9, where 9 is the highest value of the feature.*

**** - the quotient of the fruit weight at the end of the second week of harvesting (ripening) and the number of fruit*

***** - healthiness of canes using the ranking scale 1-3, where 3 is the highest value of the feature (the highest health status).*

Tabela 3 cd.
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Wykaz i charakterystyka najwartościowszych klonów, potencjalnie poszerzających zmienność genetyczną zasobów genowych maliny właściwej w Instytucie Ogrodnictwa (z uwzględnieniem odmian rodzicielskich / standardowych)

List and characteristics of the most valuable clones, potentially extending the genetic variability of red raspberry genetic resources at the Research Institute of Horticulture (including parental / standard cultivars)

Nr Klonu Clone number	Rodowód Pedigree	Typ owocowania Ripening type L, J, L-D, L-D-P*	Cechy owoców (atrakcyjność, wielkość) Fruit characters (atractiveness, size) **			Masa owoców Fruit weight (g) ***	Kolce Spines (+/-)	Wysokość krzewów Shrub height (cm)	Zdrowotność krzewów Shrub healthiness (1–3)****
			15.VI (a, w)	29.VIII (a, w)	20.IX (a, w)				
M-74	Polka ×Veten	J	8, 8		7, 7	2,9	+	110	3
M-35	Polka ×Veten	L-D	5, 5		7, 8	2,7	-	205	3
M-48	Polka × Sokolica	J	8, 7		7, 6	2,9	+	140	3
M-433	Polka × Schönemann	J	8, 7		7, 7	3,4	+	130	3
M-26	Laszka × Polana	L-D	7, 7	7, 7	8, 7	2,3	+	160	3
M-47	Polka × Sokolica	J	6, 6	7, 6	6, 6	3,6	-	170	3
M-146	Laszka ×Polka	J			7, 7	3,7	+	160	3
M-111	Laszka × Polana	L-D	6, 6	8, 8	7, 8	3,0	+	185	3
M-255	Glen Ample × Polka	J			7, 7	2,5	-	100	3
Średnia dla całej populacji mieszańców			(a) 4,3; (w) 4,3					159	
	Polana	J	7, 6	6, 6	6, 6	3,0	+	125	2,5
	Polka	J	7, 6	6, 6	6,6	3,0	+	95	2
	Veten	L-D-P	7, 7			2,8	+	220	3
	Canby	L-D-P	5, 6			2,4	+/-	250	2,5
	Przehyba	L-D-P	7, 9			4,5	+	225	3
	Laszka	L-D-P	7, 8			3,5	+	225	2,5
	Glen Ample	L	8, 8			5,7	-	225	3
	Heritage	J	7, 7	7, 7	7, 7	4,0	+	100	3
	Poemat	J	7, 7	7, 6	6, 5	3,5	+	150	3
	Sokolica	L-D-P	8, 7			3,8	+	205	3
	Radziejowa	L	7, 7			3,9	+	225	2,5

Objaśnienie:
** - L-odmiana letnia, J - odmiana jesienna, L-D - odmiana letnia dwupiętrowa (mająca zdolność do wytworzenia owoców także w wierzchołkowej części pędu pierwszego roku, owoce te mogą stanowić plon handlowy), L-D-P - odmiana letnia dwupiętrowa późna (mająca zdolność do wytworzenia owoców także w wierzchołkowej części pędu pierwszego roku, ale owoce te powstają bardzo późno, nie dorastają i dlatego nie stanowią plonu handlowego).*
***- a-atrakcyjność owoców, w-wielkość owoców; ocena w skali bonitacyjnej 1-9, w której 9 to najwyższa wartość cechy.*
****- iloraz masy owoców w końcu drugiego tygodnia (dojrzewania) zbiorów i liczby owoców*
***** - zdrowotność krzewów w skali bonitacyjnej 1-3, w której 3 to najwyższa wartość cechy (najwyższa zdrowotność).*

Photo 1. Different size and shape of raspberry fruit.

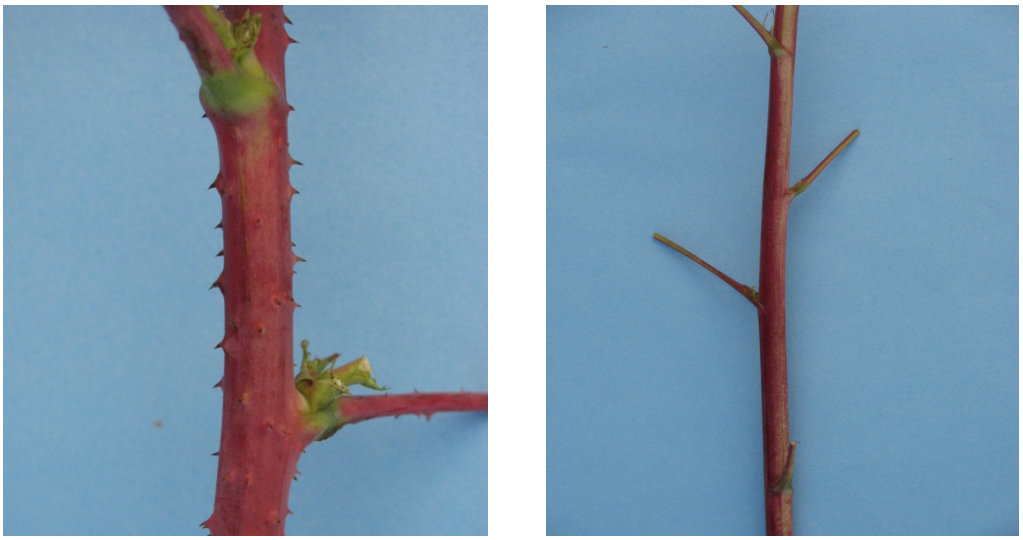

Photo 2. Two types of raspberry canes: spine and spineless.

Photo 3. Differences in the shoot growth vigour.

clones. The mean height of shoots was about 200 cm for floricane and primo-floricane clones, and about 150 cm for primocane clones. Similar growth characteristics were found for parental cultivars, with the least vigorous growth in the primocane 'Polka' cultivar, with the mean height of canes just 95 cm.

The last of the assessed characteristics of the analysed clones was the healthiness of raspberry shoots. For the vast majority of clones (79.5% of their population), the assessed healthiness of shrubs was scored at 3.0 (in a 1 to 3 ranking scale), and no clear symptoms of diseases or pests were observed on the shoots. Moderate healthiness (score 2.0-2.5 in the ranking scale) was found for only eight clones (20.5% of the clone population). Similar scores with respect to this trait were found for the parental forms.

Discussion

The extension of the existing genetic variability within the species *Rubus idaeus* makes sense if it is possible to combine in one genotype multiple biological traits of plants that are important for growers and consumers. In the conducted study, such traits included the type of fruiting of the analysed clones, the attractiveness, size and weight of the fruit, the presence of spines on canes, growth vigour of shrubs and their healthiness. The combination of such traits in one genotype, although quite difficult to achieve, but possible, was previously pointed out by Jennings (1988), Jennings and McNicol (1991) and Daubeny (1996), but they did not conduct detailed research in this area. This difficulty can be easily explained by one of the Mendelian principles stating that traits are inherited independently. The desired combination, especially in perennial

plants, can be achieved in extensive cross-breeding programmes that involve known sources of genes, large seedling populations and are time-consuming, which makes the research costly.

Meanwhile, primocane raspberry cultivars, especially 'Polana' and 'Polka', are the most popular in Poland (Danek, 2002). They both produce good quality fruit but have abundant and quite sharp spines. Plants with spiny canes are very difficult to maintain when they need to be tied to the supporting structure (trellises) and pruned after fruit harvest. Spines also make harvesting difficult, as they can injure the hands of pickers, but they can also damage the fruit when plants are swinging vigorously in wind, as pointed out by Daubeny (1996). This is important in the case of autumn-fruiting raspberries, because plantations of these cultivars are run without trellises preventing shoots from swinging during windy weather. Of note is the fact that nowadays almost all cultivars of blackberries commercially grown in the world are spineless, while the vast majority of red raspberry cultivars have spines. There are some spine-free cultivars, e.g. 'Glen Ample', but their share in commercial production in Poland is still insufficiently high.

Our findings show that a large population of seedlings and selected clones includes genotypes that bear fruit at the same time as the Polish primocane cultivars 'Polka' and 'Polana', or the newest 'Poemat' and 'Polonez', but without spines. Spineless clones, either floricane, primocane or primo-floricane, produce good quality fruit that are attractive in appearance and large, and in this respect they are not inferior to the parental cultivars, which in our research also served as standard cultivars.

Obviously, red raspberry plants should be characterised by vigorous growth and low susceptibility to diseases and pests, but also a high degree of selfing, especially when cultivars are grown in monocultures or under cover for accelerated or delayed harvest (Keep, 1968; Daubeny, 1969, 1971; Redalen, 1976; Colbert and de Oliveira, 1990; Żurawicz, 2016a, 2016b, 2017, 2018; Żurawicz et al., 2018). Although the latter issue was not the subject of our research on clones, relevant studies will be carried out for the most promising clones.

The year 2020 will be the second year of full fruiting of the assessed clones, and it will be possible to verify the results of the assessment obtained in 2019. This will allow for the selection of the clones that offer the best combination of the desired functional traits and thus can expand the existing genetic variability of the raspberry genetic resources at the Research Institute of Horticulture.

Conclusions

1. The efficiency of crossing the parental forms (cultivars) of raspberry used in the presented research is different, but it is possible to create a sufficiently large population of seedlings with different biological traits.
2. It is possible to breed new genotypes, extending the existing genetic variability within the species *Rubus idaeus* by conventional breeding and the use of raspberry cultivars that differ for many biological features.
3. A particularly valuable aspect of new phenotypic forms is the combination of biological features of raspberry in one genotype, such as fruiting in the summer, autumn or autumn -summer, formation of spineless shoots and production of high-quality fruit.

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