

GROWTH, YIELDING AND FRUIT QUALITY OF FOUR PLUM (*Prunus domestica* L.) CULTIVARS UNDER ORGANIC ORCHARD CONDITIONS

Summary

The experiment, conducted in 2004-2013, assessed the possibility of organic production of the fruit of four plum cultivars. The objects studied were trees of the cultivars: 'Herman', 'Cacanska Rana', 'Valjevka' and 'Yellow Afaska', grafted on Myrobalan seedlings. The experiment was established in the spring of 2004 in the Experimental Ecological Orchard in Nowy Dwór-Parcela (central Poland). The trees were grown in accordance with the principles of organic fruit-growing. The plum trees came into bearing fruit in the third year after planting. In the period 2008-2013, the largest amounts of fruit were harvested from the trees of the cultivar 'Herman'. Other cultivars yielded considerably lower. The lowest fruit yields were obtained each year from the trees of the cultivar 'Cacanska Rana'. The highest mean fruit weight was found in the cultivar 'Yellow Afaska'; however, the fruit crops of this cultivar were observed to have the highest proportion of fruit damaged by the plum moth (*Laspeyresia funebrana*) and infected by the brown rot of stone fruits (*Monilinia laxa*, *Monilinia fructigena*). Of the four plum cultivars tested, the most suitable for growing under organic orchard conditions was the cultivar 'Herman', characterized by an early fruit ripening time.

Key words: plum, cultivar, organic fruit production, fruit quality

WZROST, OWOCOWANIE ORAZ JAKOŚĆ OWOCÓW CZTERECH ODMIAN ŚLIWY DOMOWEJ (*Prunus domestica* L.) W WARUNKACH SADU EKOLOGICZNEGO

Streszczenie

W doświadczeniu prowadzonym w latach 2004-2013 oceniano możliwość ekologicznej produkcji owoców czterech odmian śliwy. Przedmiotem badań były drzewa odmian: 'Herman', 'Cacanska Rana', 'Valjevka' i 'Żółta Afaska', szczepione na siewkach ałyczy. Doświadczenie założono wiosną 2004 roku w Ekologicznym Sadzie Doświadczalnym w Nowym Dworze – Parceli (centralna Polska). Drzewa prowadzono zgodnie z zasadami sadownictwa ekologicznego. Śliwy weszły w okres owocowania w piątym roku po posadzeniu. W latach 2008-2013 najwięcej owoców zebrano z drzew odmiany 'Herman'. Pozostałe odmiany plonowały wyraźnie słabiej. Najmniejsze plony zbierano corocznie z drzew odmiany 'Cacanska Rana'. Największą masę miały owoce odmiany 'Żółta Afaska', jednakże w plonie tej odmiany obserwowano największy udział owoców uszkodzonych przez owocówkę śliwkóweczkę (*Laspeyresia funebrana*) i porażonych przez brunatną zgniliznę drzew pestkowych (*Monilinia laxa*, *Monilinia fructigena*). Spośród czterech badanych odmian najbardziej przydatna do sadu ekologicznego okazała się śliwa 'Herman', charakteryzująca się wczesną porą dojrzewania owoców.

Słowa kluczowe: śliwa, odmiana, ekologiczna produkcja owoców, jakość owoców

1. Introduction

The plum is a fruit tree species commonly grown in Poland. The land area under plum orchards is more than 20,000 ha, producing nearly 100 thousand tonnes of fruit per year [1]. Plum trees are grown successfully in commercial orchards under the integrated production system. Growing them in organic orchards, however, causes a lot of difficulties [2-7]. Serious problems are posed by pests and diseases that damage the fruit, reducing its quality. Especially dangerous under organic orchard conditions is the plum moth (*Laspeyresia funebrana*), whose larvae feed inside the plums. During periods of persistent heavy rainfall, a lot of problems are caused by the brown rot of stone fruits (*Monilinia laxa*, *Monilinia fructigena*).

A major role in the organic cultivation of plum trees is played by the selection of cultivars. Trees of the cultivars recommended for organic plum orchards should be resistant or low susceptible to diseases and pests. Also of high importance is the quality of the fruit, i.e. fruit size, skin colour, good flavour, and easy separation of the pulp from the stone [8].

The aim of the experiment was to determine the suitability for organic cultivation of four plum (*P. domestica* L.) cultivars that had proved very valuable in integrated production [9-11]. Under assessment was tree growth and yielding, and fruit quality.

2. Materials and methods

The experiment was established in the spring of 2004 in the Experimental Ecological Orchard in Nowy Dwór-Parcela near Skierniewice, on a sandy-loam podzolic soil with a loamy subsoil, of class IVb rye and potato complex. The average organic matter content was 1.3-1.4%. Four cultivars of *P. domestica* (L.) characterized by good tree health, especially tolerance to the plum pox virus, were chosen.

Brief descriptions of the cultivars studied: '**Herman**' – a dessert variety, notable for good tree productivity and very early ripening time. Its fruit is medium in size, with a broad oval shape. It is covered with a purple-blue skin with a dense blue bloom that lasts long after the harvest. The flesh is whitish yellow, very tasty, easily separating from the stone.

Table 1. The programme of protection of the plum trees in the Experimental Ecological Orchard in Nowy Dwór-Parcela
 Tab. 1. Program ochrony drzew śliwy w Ekologicznym Sadzie Doświadczalnym w Nowym Dworze-Parceli

| Plant protection products | Application times | | | | | |
|--|---|---------------------|--------------|--------------|--|---|
| | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 |
| Miedzian 50 WP (3 kg ha ⁻¹) | 31.03; 28.04; 05.05 -1,5kg ha ⁻¹ | 08.04; 27.04 | 07.04; 20.04 | - | - | - |
| Miedzian Extra 350 SC (3 l ha ⁻¹) | - | - | - | 06.04; 21.04 | 04.04 | 23.04 |
| Treol 770 EC (10l ha ⁻¹) | 01.04 | 10.04 | - | - | 10.04 | 29.04 |
| Promanal 60 EC (15 l ha ⁻¹) | - | - | 12.04 | 06.04 | - | - |
| Bioczoz (15l ha ⁻¹) + horticultural soap (15 l ha ⁻¹) | 27.05; 10.06 | 06.07 | 13.05; 09.06 | - | - | - |
| horticultural soap + denatured alcohol (15 l ha ⁻¹ + 15l ha ⁻¹) | - | - | - | 14.06 | 18.05; 24.05; 29.05; 06.06; 16.06; 28.06 | 12.06; 19.06; 27.06; 02.07; 08.07; 17.07; 22.07; 01.08; 09.08 |
| SpinTor 240 SC (0,8 l ha ⁻¹) | - | 10.06; 18.06; 30.07 | 11.06; 21.06 | 03.06 | 16.06; 29.06 | - |

Source: Own work / Źródło: opracowanie własne

‘Cacanska Rana’ – a dessert variety, medium productive, early ripening. Its fruit is large, ovoid. The skin is originally mauve, but during warm summers it takes on a purple-blue colour in well-ripened fruit. Its entire surface is covered with a dense, light-blue wax coating. The flesh is greenish yellow, quite juicy, tasty, separating very easily from the stone.

‘Valjevka’ – a type of the Common Prune, notable for good tree productivity and late ripening time. Its fruit is suitable for fresh consumption and processing. The plums are average in size and bottle-shaped. Their skin is initially bluish navy-blue, but in well-ripened fruit it is dark navy-blue, covered with an intense grey-blue bloom. The flesh is yellow, very juicy, with a high sugar content, tasty, separating easily from the stone.

‘Yellow Afaska’ – one of the few late varieties of plum, with a bright yellow colour of the skin. Its fruit is suitable for fresh consumption, but can also be used by the processing industry. The fruit is large, oval. The skin is thin, initially green and yellow, and then yellow at full maturity. The flesh is juicy, firm, with a high sugar content, tasty.

The trees, grafted on Myrobalan seedlings, were planted at a spacing of 4.5 x 3.5 m, in four replications, with five trees per plot. For the first two years, the soil in the orchard was maintained in mechanical fallow. In the third year, grass from self-seeding was introduced in the inter-rows, leaving mechanical fallow in the rows. Tree crowns were trained in the form of a spindle. Every year, light sanitary and rejuvenation pruning was performed. From 2007, the trees were irrigated with a drip system. The programme of protection of the plum trees against diseases included 2-3 treatments annually with a copper formulation (Miedzian 50 WG or Miedzian Extra 350 SC). Protection against pests included 1 treatment with the formulation Treol 770 EC or Promanal 60 EC against the red spider mite (*Panonychus ulmi*) and the brown scale (*Parthenolecanium corni*). Aphids were controlled by performing one or several treatments, depending on the severity of infestation, with a mixture of Bioczoz and horticultural soap or horticultural soap and denatured alcohol. In 2009-2012, 1-3 treatments were

performed with the bacterial formulation SpinTor 240 SC against the plum moth (*Laspeyresia funebrana*). The protective treatments that were performed are shown in Table 1.

Under assessment was tree growth vigour, fruit yield, and fruit quality. The thickness of the tree trunk was measured annually in the autumn, in a permanently marked place, at a height of 30 cm above the soil surface. In the first two years after planting, the diameter of the trunk was measured, and from the third year - its circumference. On that basis, the cross-sectional area of the trunk was calculated. After the plum trees had come into fruiting, fruit yields were determined annually, separately for each tree. The times of fruit ripening were recorded. Mean fruit weight was calculated on the basis of a sample of 400 fruit randomly collected from each replication (4 x 100 fruit). Similar samples (4 x 100 fruit) were collected to assess the infestation by the plum moth (*Laspeyresia funebrana*) and infection with the brown rot of stone fruits.

The results were statistically analyzed using analysis of variance in the program Statistica 10. To assess the differences between means, Duncan’s test was used at a significance level of 0.05.

3. Results

3.1. Tree growth and yielding

Trunk cross-sectional area (TCSA) of the four *P. domestica* cultivars is shown in Table 2. Trees of the cultivars: ‘Cacanska Rana’, ‘Valjevka’ and ‘Yellow Afaska’ were characterized by a similar growth vigour, while those of the cultivar ‘Herman’ grew significantly less vigorously than them.

The first plums from the trees of the cultivars ‘Herman’, ‘Cacanska Rana’ and ‘Valjevka’ were collected in the third year after planting, and from the trees of the cultivar ‘Yellow Afaska’ – two years later. The level of yielding of the trees varied over the years of the experiment and depended mainly on the climatic conditions during flowering. In 2007, there were spring frosts that damaged more than 90% of the fruitlets on the plum trees. The result of this was lack of fruiting of the trees of the cultivars ‘Cacanska Rana’ and

'Yellow Afaska', and poor yields of the trees of the other cultivars. In 2010, pollination and fruit setting were not favoured by the windy and rainy weather during flowering. The decrease in fruit yields in the organic orchard in 2010 was also exacerbated by the damage to the fruitlets caused by plum sawflies (*Hoplocampa minuta* and *Hoplocampa flava*). The tree blooming period in 2011 was characterized by frequent and abundant rainfall, which was not conducive to good pollination and the setting of fruit. Under those conditions, the trees of the cultivars 'Herman' and 'Cacanska Rana', characterized by early flowering, did not set fruit at all. Trees of the cultivar 'Valjevka', flowering 2-3 days later, produced isolated fruit, and the crops harvested from the trees of the cultivar 'Yellow Afaska' in 2011 did not exceed 0.6 kg per tree (Table 2). In the year 2012, the most favourable for the cropping of plum trees, the harvested fruit crops ranged, depending on the cultivar, from nearly 2 to more than 9 kg of plums per tree (Table 2). Under the Experimental Ecological Orchard conditions, the most regularly fruiting were the trees of the cultivars 'Herman' and 'Yellow Afaska' (Table 2).

In the period 2008-2013, the trees of these cultivars yielded 25.4 and 22.7 kg of fruit per tree, respectively. The other cultivars yielded significantly lower. Irrespective of the year, the lowest yielding trees were those of the cultivar 'Cacanska Rana' (Table 2).

3.2. Fruit ripening time and fruit quality

The fruit of the earliest cultivar 'Herman' matured in the last ten days of July, and those of the latest cultivar 'Valjevka' about 13 September (Table 3).

The plums of the cultivars under assessment differed in terms of size. The largest ones were produced every year by 'Yellow Afaska', and the smallest – by the cultivar 'Herman' (Table 3). Fruit size was also considerably affected by the weather conditions during fruit setting and ripening in the different years of the experiment. For example, the plums of the cultivar 'Herman' ripening in the last ten days of July were the largest in 2009, and the smallest in 2008. On the other hand, the plums of 'Yellow Afaska' were the most impressive in 2008 and 2009, and the smallest in 2010 (Table 3).

At harvest time, it was found that many of the plums were damaged by disease or pests. The extent of the injuries was different depending on the cultivar and the year of the experiment. The highest percentage of fruit damaged by the plum moth (*Laspeyresia funebrana*) was recorded in 2008 (Table 4). Only the plums of the cultivar 'Herman' were in that year entirely free of larvae of this pest. In 2009-2012, the infestation of plums by this pest was significantly lower. This was contributed to by the use of the formulation SpinTor 240 S.C. The most susceptible to infestation by the plum fruit moth (*Laspeyresia funebrana*) was the cultivar 'Yellow Afaska' (Table 4).

Table 2. Tree growth and yielding of four *P. domestica* cultivars under ecological growth conditions

Tab. 2. Wzrost i plonowanie 4 odmian śliwy domowej (*P. domestica* L.) w warunkach uprawy ekologicznej

| Cultivar | TCSA* [cm ²] 2013 | Yield [kg tree ⁻¹] | | | | | | Total yield 2008-2013 [kg tree ⁻¹] |
|-----------------|-------------------------------------|--------------------------------|-------|-------|-------|-------|-------|--|
| | | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | |
| 'Herman' | 107.0 b | 6.8 a | 3.9 b | 1.0 b | 0.0 c | 9.3 a | 4.4 a | 25.4 a |
| 'Cacanska Rana' | 134.9 a | 1.9 bc | 0.9 c | 0.6 b | 0.0 c | 1.7 c | 1.1 b | 6.1 c |
| 'Valjevka' | 131.3 a | 1.5 c | 3.0 b | 1.0 b | 0.1 b | 6.3 b | 0.0 c | 11.8 b |
| 'Yellow Afaska' | 129.8 a | 2.3 b | 6.7 a | 2.3 a | 0.6 a | 9.2 a | 1.6 b | 22.7 a |

* TCSA – trunk cross-sectional area

Source: Own work / Źródło: opracowanie własne

Table 3. Fruit ripening date and fruit weight of four *P. domestica* cultivars under ecological growth conditions

Tab. 3. Termin dojrzewania i masa owoców 4 odmian śliwy domowej (*P. domestica* L.) w warunkach uprawy ekologicznej

| Cultivar | Fruit ripening date | Fruit weight [g]* | | | | Mean fruit weight |
|-----------------|------------------------|-------------------|--------|--------|--------|----------------------|
| | | 2008 | 2009 | 2010 | 2012 | |
| 'Herman' | 23.07 | 25.6 d | 34.3 c | 30.0 c | 30.3 c | 30.0 d |
| 'Cacanska Rana' | 30.07 | 48.1 b | 53.2 b | 43.8 a | 60.9 b | 51.5 b |
| 'Valjevka' | 13.09 | 33.2 c | 31.6 c | 36.6 b | 32.5 c | 33.5 c |
| 'Yellow Afaska' | 10.09 | 71.1 a | 71.3 a | 46.0 a | 66.2 a | 63.7 a |

* the years 2011 and 2013 have been omitted because not all the cultivars yielded

Source: Own work / Źródło: opracowanie własne

Table 4. Degree of infestation of four *P. domestica* cultivars by larvae of the plum moth in the Experimental Ecological Orchard in Nowy Dwór-Parcela in 2008-2012

Tab. 4. Stopień porażenia owoców 4 odmian śliwy domowej przez owocówkę śliwkówecką w Ekologicznym Sadzie Doświadczalnym w Nowym Dworze-Parceli w latach 2008-2012

| Cultivar | Number of fruits with plum moth larvae [%] * | | | | Mean 2008-2012 |
|-----------------|--|--------|--------|--------|-------------------|
| | 2008 | 2009** | 2010** | 2012** | |
| 'Herman' | 0.0 d | 4.0 ab | 4.0 a | 0.3 b | 2.1 c |
| 'Cacanska Rana' | 5.0 c | 2.0 b | 0.0 b | 0.0 b | 1.8 c |
| 'Valjevka' | 15.0 b | 1.0 b | 0.0 b | 0.0 b | 4.0 b |
| 'Yellow Afaska' | 46.0 a | 6.0 a | 0.0 b | 17.5 a | 17.4 a |

* the years 2011 and 2013 have been omitted because not all the cultivars yielded

** after treatments with SpinTor 240 SC against the plum moth

Source: Own work / Źródło: opracowanie własne

Table 5. Degree of infection of four *P. domestica* cultivars with the brown rot disease in the Experimental Ecological Orchard in Nowy Dwór-Parcela in 2008-2012

Tab. 5. Stopień porażenia owoców 4 odmian śliwy domowej przez brunatną zgniliznę w Ekologicznym Sadzie Doświadczalnym w Nowym Dworze-Parceli w latach 2008-2012

| Cultivar | Number of fruits infected with brown rot [%] * | | | | Mean 2008-2012 |
|-----------------|--|-------|--------|--------|-------------------|
| | 2008 | 2009 | 2010 | 2012 | |
| 'Herman' | 0.0 b | 0.0 b | 9.5 b | 0.0 c | 2.4 c |
| 'Cacanska Rana' | 0.0 b | 0.0 b | 10.0 b | 17.0 b | 6.8 b |
| 'Valjevka' | 0.0 b | 0.0 b | 6.0 b | 0.0 c | 1.5 c |
| 'Yellow Afaska' | 5.0 a | 6.0 a | 75.5 a | 36.0 a | 30.6 a |

* the years 2011 and 2013 have been omitted because not all the cultivars yielded Source: Own work / Źródło: opracowanie własne

In 2008 and 2009, the rainless and sunny weather during the ripening of plums was not favourable to the development of fungal or bacterial infections. Plums of the cultivars: 'Herman', 'Cacanska Rana' and 'Valjevka' were healthy. Some decaying plums were only observed in the crop of the cultivar 'Yellow Afaska' (Table 5). In 2010 and 2012, the severity of infection was much greater due to lower temperatures and abundant rainfall. The highest percentage of decaying fruit was observed in those years in the crop of the cultivar 'Yellow Afaska' (Table 5).

4. Discussion

The growth and yielding of plum trees is affected by many factors, but the most important among them are the cultivar, the rootstock [9, 12] and the climatic and soil conditions [13]. The choice of the cultivar is important for any type of orchard, but especially for organic orchards due to the limited ability to protect trees against diseases and pests [3, 4, 14]. Selecting cultivars for organic cultivation is not easy because no plum genotypes resistant to pests have so far been available, and the number of those resistant to diseases is relatively small [8]. The research undertaken by us is innovative in Polish conditions. For the experiment conducted under ecological orchard conditions we had selected four cultivars of *P. domestica* trees that are recommended in Poland for integrated fruit production [9]. Among the selected cultivars were 'Herman', 'Cacanska Rana', 'Yellow Afaska' and 'Valjevka'. Under organic growth conditions, the cultivar 'Herman' proved to be the most valuable. Although the trees of this cultivar blossomed early, like those of the cultivar 'Cacanska Rana', they were better at setting fruit and yielded more regularly, and in terms of fruit size they were no worse than those grown under the integrated system. In a study by Grzyb et al. [15] the average weight of fruit of the cultivar 'Herman' in integrated production was 29.9 g, whereas in organic cultivation 30.0 g (table 3). Plums of the cultivars 'Cacanska Rana' and 'Valjevka' harvested in an organic orchard were larger than those from integrated production. This was probably related to the low-yielding of the trees of these cultivars. A cultivar found to be yielding fairly regularly under organic orchard conditions was 'Yellow Afaska', but the trees of this cultivar came into bearing fruit two years later than under integrated production conditions, in which the protection of trees was carried out according to the recommendations for integrated cultivation contained in the Programme of Fruit Plant Protection [10].

Climatic conditions are another important factor influencing the fruiting and quality of the fruit of plum trees. Under organic growth conditions, adverse weather conditions in the absence of the traditional protection cause plum

trees to become more affected by diseases and pests. That was the case in 2010, when the windy and rainy weather persisting during bloom time was not only unfavourable to pollination but also contributed to the damage to fruitlets by plum sawflies (*Hoplocampa minuta* and *Hoplocampa flava*). Depending on the cultivar, these pests infested from 26% ('Herman') to over 50% ('Yellow Afaska') of plum fruitlets. According to Rozpara et al. [6], the number of *Hymenoptera* insects captured on one white glue trap did not exceed in 2010 the adopted risk threshold, which at abundant cropping would not have been a problem, but the unfavourable weather conditions during bloom time had contributed to very poor fruit setting, and that is why these pests reduced fruit yields even further. Studies conducted in other countries have shown that the formulation Quassia is highly effective against plum sawflies [16, 3]. Unfortunately, to date, this formulation has not been approved for use in ecological farming in Poland. Apart from sawflies, the plum moth is also a serious pest of plum trees. Wiech [17] reported that the extent of damage it causes is influenced by the weather conditions at the time the moths are flying around and laying eggs. Rozpara et al. [6] demonstrated that the formulation SpinTor 240 SC used in experiments located in the Experimental Ecological Orchard in Nowy Dwór-Parcela reduced to a considerable extent the population of this pest. This is confirmed by the results of our experiment. In 2009-2012, the percentage of plums infested by the plum moth was significantly lower than in 2008, when the formulation was not used. Since 2013, SpinTor 240 SC has not been allowed for use on fruit crops. Weather conditions have an effect on the extent of infection of plum trees with the brown rot of stone fruits. Grabowski [18] reported that infections by fungi of the genus *Monilinia* develop most often on mechanically damaged fruit at moderate temperatures and abundant rainfall. Our results are consistent with the literature. In our experiment, the hot weather during fruit ripening in 2008 and 2009 was not conducive to fungal infections in contrast to the lower temperatures and rainfall in 2010 and 2012. The brown rot of stone fruits was controlled by spraying with copper formulations registered for use in the organic cultivation of plum trees. However, during the years favourable to the development of the disease they were not sufficiently effective, especially for the cultivar 'Yellow Afaska', whose fruits proved to be more susceptible to infection than those of the cultivars 'Herman', 'Cacanska Rana' and 'Valjevka'.

5. Conclusions

1. In terms of fruit production under organic growth conditions, the most valuable proved to be the cultivar 'Herman'.

2. The cultivars 'Cacanska Rana' and 'Valjevka' produced good quality fruit, but were unreliable in yielding.
3. Trees of the cultivar 'Yellow Afaska' yielded regularly, but the quality of the fruit was unsatisfactory as the plums proved to be susceptible to damage by the plum moth and the brown rot of stone fruits.

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7. References

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