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INJURIES TO 'TOPAZ' AND 'PINOVA' APPLES BY PESTS IN AN ORGANIC ORCHARD AND THEIR EFFECT ON FRUIT STORABILITY

Summary

During two storage seasons, in the years 2011/2012 and 2012/2013, a study was conducted in the Experimental Ecological Orchard of the Research Institute of Horticulture in Skierniewice on the extent of pest damage to apples of the cultivars 'Topaz' and 'Pinova' and on the storability of the damaged fruit. The trees of both cultivars were protected with the pesticides permitted in organic production. It was found that, regardless of the cultivar, the injuries to apples were mostly caused by leafrollers and the rosy apple aphid. On the damaged apples, stored for 5 months in a normal cold store, two diseases had occurred – bull`s eye rot (Pezicula spp.) and brown rot (Monilinia fructigena), but very few skin injuries were the spot of disease development. Only on 6.7% of the 'Topaz' apples and on 3.7% of the 'Pinova' apples did the diseases develop in the point of a skin injury. The typical wound disease – the blue mould of apples (Penicillium expansum) was not found on the damaged apples.
***Key words**: organic orchard, apples, cultivars, pest damage, leafrollers, rosy apple aphid, experimentation*

USZKODZENIA JABŁEK `TOPAZ` I `PINOVA` PRZEZ SZKODNIKI W SADZIE EKOLOGICZNYM I ICH WPŁYW NA PRZECHOWYWANIE OWOCÓW

Streszczenie

W ciągu dwóch sezonów przechowalniczych 2011/2012 i 2012/2013 prowadzono w Ekologicznym Sadzie Doświadczalnym Instytutu Ogrodnictwa w Skierniewicach badania nad stopniem uszkodzenia jabłek odmian `Topaz` i `Pinova` przez szkodniki oraz zdolnością przechowalniczą uszkodzonych owoców. Drzewa obu odmian były chronione środkami dozwolonymi w produkcji ekologicznej. Stwierdzono, że niezależnie od odmiany jabłoni uszkodzenia owoców najczęściej powodowały zwójkówki liściowe i mszyca jabłoniowo-babkowa. Na uszkodzonych jabłkach, przechowywanych przez 5 miesięcy w chłodni zwykłej, wystąpiły dwie choroby – gorzka zgnilizna jabłek (Pezicula spp.*) i brunatna zgnilizna jabłek (Monilinia fructigena), jednak nieliczne uszkodzenia skórki owoców były miejscem rozwoju chorób. Tylko na 6,7% owoców odmiany `Topaz` i 3,7% odmiany `Pinova` choroby rozwinęły się w miejscu uszkodzenia skórki. Nie stwierdzono występowania typowej choroby przyrannej – mokrej zgnilizny jabłek (Penicillium expansum).*
***Słowa kluczowe**: sad ekologiczny, jabłka, odmiany, szkodniki, zwójkówki liściowe, mszyca jabłoniowo-babkowa, badania*

1. Introduction

Among organically-grown fruit crops there are small orchards providing fruit for the needs of the grower as well as commercial orchards producing healthy fruit for the broad market. In the commercial production of apples, a very important role is played by the fruit quality characteristics that determine their acceptance by consumers, such as: fruit size, taste, and appearance, including the intensity of blush and lack of skin damage and fruit deformation. The cause of damage to apples, apart from mechanical damage (hailstorms, careless harvesting), are pests which can feed on fruitlets or fruits, thus significantly reducing the marketable yield and making apples look less appealing [1]. Controlling pests in organic apple orchards is very difficult because of a limited number of pesticides allowed for use in the organic production system. Injuries to apples, apart from causing a significant deterioration in their quality, can increase the risk of apple storage diseases because some pathogenic fungi infect fruits only through skin wounds (e.g. *Monilinia fructigena*, *Penicillium expansum*) [2].

The success in organic apple growing is determined mainly by the proper selection of a cultivar characterized by resistance or low susceptibility to diseases. The greatest chances of success have the scab-resistant varieties, especially those of the newer generation, with tasty and attractive fruit (e.g. 'Topaz', 'Rubinola', 'Melfree', 'Enterprise') [3, 4]. Among this group of cultivars, 'Topaz' is the most commonly grown variety in organic orchards in Europe [5]. Studies conducted at the Research Institute of Horticulture in Skierniewice have shown that varieties with low susceptibility to scab (*Venturia inaequalis*) are also suitable for organic orchards, such as 'Pinova', 'Delbard Jubilee', and 'Ligolina' [4]. The cultivars 'Topaz' and 'Pinova' belong to a group of winter varieties, and their fruits are characterized by good internal quality (levels of soluble solids and acids) and can be stored for a long time without decreasing the flesh firmness [6]. However, a disadvantage of these cultivars is their high susceptibility to the bull`s eye rot of apples [7].

The aim of this study was to determine the extent of damage at harvest time to apples of the cultivars 'Topaz' and 'Pinova' caused by various species and groups of pests in an organic orchard, and the effect of these injuries on fruit storability.

2. Material and methods

The study was conducted over two storage seasons – 2011/2012 and 2012/2013 – in the Experimental Ecological Orchard (ESD) of the Research Institute of Horticulture, located in Nowy Dwór-Parcela near Skierniewice. Apple

trees of the cultivars 'Pinova' and 'Topaz' on M.26 rootstock were planted in 2004 at a spacing of 4 m x 2 m. The trees were protected against pests and diseases with the pesticides allowed in organic production. The tree protection programme in the years 2011 and 2012 is given in Table 1.

The apple harvest date was determined on the basis of the starch index. The harvested apples were assessed for damage caused by various pests. The type of damage was determined according to the atlas by Rein [8]. For each cultivar, 400 apples were assessed, counting those with characteristic skin wounds. Then the damaged apples were divided into 5 groups depending on the evidence of feeding characteristic of: the codling moth, leafrollers, beetles and bugs, the apple sawfly, and the rosy apple aphid. Each group consisted of 100 fruits. The apples were placed in a normal cold store at 2°C and relative air humidity of 92%. During the storage period, the apples were inspected once a month; those with spots of rot were separated out, and the causal agent of the disease was identified on the basis of the symptoms. Checks were also made whether the developing spot of rot was at the site of a wound on the skin. Five inspections of the stored apples were carried out, with the assessment ending in March of the following year.
The results obtained were analyzed statistically by R.A. Fischer's analysis of variance. Percentage values were transformed using the Bliss formula. To assess the significance of the differences between means, the Newman-Keuls test was used at a 5% probability level.

3. Results and discussion

3.1. Damage to apples by pests

The assessment of the quality of 'Pinova' and 'Topaz' apples carried out at harvest showed that in both seasons the largest number of fruits were damaged by caterpillars of leafrollers (Tab. 2). Among that group of pests, apples are most frequently damaged by species such as *Pandemis heparana*, *Adoxophyes orana*, and *Spilonota ocellana*. Their caterpillars feed on the skin of fruitlets and ripening fruits, and can cause shallow, extensive wounds in the skin and flesh, or deeper, smaller, closely-spaced holes, often in a place where the apple was covered by a leaf or came into contact with another apple [9, 10]. There were no significant differences in the susceptibility of the tested cultivars to the feeding of leafrollers. On average, for both cultivars and years, this type of damage was shown by 25.4% of the apples harvested. The importance of this group of pests in the reduction of fruit quality has also been pointed out by other researchers [10, 11].

The average number of apples damaged by the rosy apple aphid (*Dysaphis plantaginea*) was 10.0%. As a result of this pest feeding in early spring on flower buds, stalks and fruitlets, the affected apples become smaller and deformed – characteristic convex mounds are formed around the calyx. Badowska-Czubik and Kruczyńska [1] had found that in young apple orchards this species of aphid caused a greater reduction in marketable yield of apples than it did in older orchards. Jönson and Tahir [12] had evaluated several scab-resistant cultivars and found that apples of the cultivar 'Topaz' were severely damaged by aphids.

The extent of the damage to apples caused by the apple sawfly (*Hoplocampa testudinea*) can vary. If a larva of the sawfly eats its way into a small fruitlet as far as the core, that fruitlet does not usually grow and falls off at the time of the June drop. On the other hand, fruitlets with superficial skin damage in the form of narrow corky streaks encircling the fruit (the so-called 'lollipop') remain on the tree and continue to develop [13]. Such symptoms of feeding were seen on the harvested apples, and they were more numerous in 2012 than in 2011 (an average of 7.9%).
Injuries to apples can also be inflicted by beetles (Coleoptera) and bugs (Heteroptera), which puncture the skin or eat out holes in fruitlets and fruits. In this study, the number of apples with such injuries was ranked in the third place, averaging 7.1%.

A big surprise was the small number of apples with injuries characteristic of the codling moth (*Cydia pomonella*). Caterpillars of this species, considered the most dangerous pest in organic orchards [14], eat their way into the fruit as far as the core, leaving on the surface one or two large holes. The likely reason for the low severity of these symptoms (an average of only 1.8% of the apples) was the use of Madex SC, a pesticide permitted in organic farming, which significantly reduces the percentage of fruit damaged by this pest [15]. Moreover, apples which have been severely damaged by larvae of the codling moth in the early stages of fruit development fall off prematurely.

Table 1. The protection programme for 'Topaz' and 'Pinova' apple trees in ESD Nowy Dwór-Parcela in 2011 and 2012
Tab. 1. Program ochrony jabłoni `Topaz` i `Pinova` w ESD Nowy Dwór-Parcela w latach 2011 i 2012

Diseases		**Pests**	
Formulation and dosage	***Date***	***Formulation and dosage***	***Date***
2011			
Miedzian Extra 350 SC 3,0 l/ha	6.04	Promanal 60 EC 2,0%	6.04
Miedzian Extra 350 SC 1,5 l/ha	11.04; 21.04; 29.04	Horticultural potassium soap 2% with the addition of ethyl alcohol 2%	18.05; 13.06; 7.07; 13.07; 20.07; 27.07; 3.08; 10.08
Siarkol Extra 80 WP 8,0 kg/ha	20.05; 14.06; 16.07	Madex SC 250 ml/ha	13.06; 21.06
		SpinTor 480 SC 0,4 l/ha	16.07
2012			
Miedzian Extra 350 SC 3,0 l/ha	4.04	Treol 770 EC 1,5%	10.04
Miedzian Extra 350 SC 1,5 l/ha	17.04	Horticultural potassium soap 2% with the addition of ethyl alcohol 2%	18.05; 24.05; 29.05; 6.06; 16.06; 28.06
Siarkol Extra 80 WP 8,0 kg/ha	17.05; 27.06	Madex SC 250 ml/ha	19.06; 29.06

Source: Own work / Źródło: opracowanie własne

Table 2. Extent of damage to 'Topaz' and 'Pinova' apples by pests (assessment at harvest)
Tab. 2. Uszkodzenia jabłek odmian `Topaz` i `Pinova` przez szkodniki (ocena w trakcie zbioru)

Pest	% of damaged fruits			
	2011		2012	
	`Topaz`	`Pinova`	`Topaz`	`Pinova`
Codling moth *Cydia pomonella*	1,4 ab	3,7 abc	0,5 a	1,7 ab
Rosy apple aphid *Dysaphis plantaginea*	9,8 c	3,9 abc	9,0 c	17,2 d
Leafrollers *Tortricidae*	30,3 f	22,3 de	23,1 e	25,9 ef
Apple sawfly *Hoplocampa testudinea*	3,0 abc	3,4 abc	17,8 d	7,3 abc
Beetles and bugs Coleoptera, Heteroptera	8,0 bc	8,7 c	2,7 abc	9,0 c

Means followed by the same letter are not significantly different at p=0.05

Source: own work / Źródło: opracowanie własne

3.2. Effect of skin damage on the storability of apples

During the storage of apples, only two diseases were found – the bull`s eye rot of apples (*Pezicula* spp.) and the brown rot of apples (*Monilinia fructigena*). The first symptoms of brown rot had already appeared at the beginning of storage (in November), whereas occasional symptoms of bull`s eye rot were seen in December, but most spots of rot developed no earlier than after 3-4 months of storage. It was found that the symptoms of both diseases developed in various locations on the apple, not only around the skin wound. On average, 6.7% of all the wounds on 'Topaz' apples were the sites of disease development, the corresponding percentage for 'Pinova' apples being 3.7%.

The development of diseases in the different groups of apples was as follows:
Rosy apple aphid – the injuries to apples, usually in the form of deformation around the calyx, were not sites for the development of storage diseases.
Apple sawfly – occasionally a spot of brown rot or bull`s eye rot of apples developed on the corky surface of the wound ('lollipop').

The number of apples damaged by other pests, on which the diseases developed at the skin wound, are given in Table 3. The diseases developed more often on apples of the cultivar 'Topaz' than 'Pinova'. On average, for the cultivars and years, brown rot developed on 1% of the apples damaged by beetles and bugs, and bull`s eye rot on 2.5% of such apples. In the case of apples damaged by leafrollers, brown rot and bull`s eye rot developed on 1.8% and 2.0% of those apples, respectively (Tab. 3).

The largest number of rotting apples was found in the group of apples damaged by the codling moth, especially those of the cultivar 'Topaz'. On average, brown rot occurred on 21% of 'Topaz' apples and on 5% of 'Pinova' apples, whereas bull`s eye rot on 11% of 'Topaz' apples and on 5% of 'Pinova' apples.

The both stated storage diseases have a latent nature, which means that the infection of apples occurs in the orchard, and the symptoms of the diseases develop only after some time as the apples ripen in cold storage [2]. The severity of the diseases after 5 months of storing apples in a normal cold store is given in Table 4. In the case of bull`s eye rot, the main sites where the fungi *Pezicula* spp. penetrate the apple fruit are the lenticels, although skin wounds can also be a gateway for the pathogens. However, in our experiments, spots of bull`s eye rot developed mostly on healthy skin, and only sometimes around the wound caused by the codling moth, leafrollers, or beetles and bugs. The severity of the disease was very high, especially in the 2012/2013 season (Tab. 4). Both cultivars are highly susceptible to the bull`s eye rot of apples [3, 7]. In the absence of protection products allowed for use in organic orchards to control bitter rot, apples of these cultivars should not be stored for longer than 4 months, or a thermotherapy needs to be performed [6, 16].

The *Monilinia fructigena*, causal agent of the brown rot of apples, infects the fruit only at the site of skin damaged, even when the wound is very small, e.g. in the form of cracks invisible to the naked eye. However, the severity of this disease on the infected apples was low (Tab. 4). The disease developed mostly at the sites where the codling moth and leafrollers had been feeding, and occasionally also on visually healthy fruit.

Table 3. Number of apples damaged by pests, on which diseases developed in the spot of skin damage (per 100 apples in each group of pests)
Tab. 3. Liczba jabłek uszkodzonych przez wybrane szkodniki, na których choroby rozwinęły się w miejscu uszkodzenia skórki (na 100 sztuk w każdej grupie)

Disease	Beetles and bugs		Leafrollers		Codling moth	
	`Topaz`	`Pinova`	`Topaz`	`Pinova`	`Topaz`	`Pinova`
2011/2012						
Brown rot	1	1	5	1	13	2
Bull`s eye rot	3	2	5	1	13	2
2012/2013						
Brown rot	-	-	0	2	29	8
Bull`s eye rot	-	-	2	0	9	8

Source: own work / Źródło: opracowanie własne

Table 4. Severity of storage diseases (in %) after storing apples in a normal cold store for 5 months
Tab. 4. Nasilenie chorób przechowalniczych (w %) po 5 miesiącach przechowywania jabłek w chłodni zwykłej

Disease	`Topaz`		`Pinova`	
	At skin injury spots	At other spots	At skin injury spots	At other spots
2011/2012				
Brown rot	3,1	0,4	0,7	0,3
Bull`s eye rot	4,0	36,4	2,6	25,0
2012/2013				
Brown rot	5,8	0,6	2,4	0,2
Bull`s eye rot	0,8	64,6	1,6	90,2

Source: own work / Źródło: opracowanie własne

It should be emphasized that not all injuries to the skin of apples were sites of disease development. Many of the damaged apples had kept in good condition for five months. The most likely reason is that those wounds had not been infected by pathogenic fungi in the orchard and at the time of fruit harvest were already 'dry' (healed) and did not constitute a good substrate for the development of fungi. It can be surmised that it is also for this reason that over the two years of the study no evidence was found of the typical wound disease – the blue mould rot caused by the fungus *Penicillium expansum*. Lakshminarayana et al. [17] have shown that the number of spots of blue mould rot was significantly smaller after artificial infection performed 4 days after damaging the fruit than when it was performed immediately after wounding its skin. This indicates that blue mould rot develops during storage primarily as a result of fresh wounds becoming infected during careless harvesting (cut skin, pulled-out stalks).

4. Conclusions

1. The most serious damage to the skin of 'Pinova' and 'Topaz' apples in the organic orchard was caused by leafrollers and the rosy apple aphid.
2. The main disease found on the stored apples was bull`s eye rot (*Pezicula* spp.), followed by brown rot (*Monilinia fructigena*).
3. Injuries to the skin of apples contributed only slightly to the development of storage diseases. Only 6.7% of the wounds on 'Topaz' apples and 3.7% of those on 'Pinova' apples were spots of disease development.
4. There was no evidence of the typical wound disease – the blue mould rot (*Penicillium expansum*) developing on the apples damaged by pests.

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