Incidence of storage diseases on apples of selected cultivars and advanced selections grown with and without fungicide treatments

J. Blažek, J. Kloutvorová, J. Křelinová

Research and Breeding Institute of Pomology, Holovousy, Czech Republic

ABSTRACT: In the course of a 3-year study the natural occurrence of storage diseases in ambient air storage with 1 to 2°C was evaluated on samples of 30 cultivars and advanced selections that were harvested from orchards with and without the use of fungicide treatments. Based upon the frequency of occurrence, bitter rot and grey mould were the most common diseases in this study followed by blue mould and brown rot. Fungicide treatments applied in the orchard with integrated plant protection reduced total fruit rotting with different cultivars two to four times. Significant losses caused by rotting usually took place in the last quarter of the normal storage life of each cultivar, but in the case of samples treated with fungicides it was mostly during the last month. Cultivars Angold, Gala, Florina, Melodie and Meteor proved to be partially resistant to the storage diseases, but the smallest shares of rotted fruits were recorded on apples of Zuzana and Melrose. Still, five advanced selections proved not to be so affected by fruit rotting as Melrose and Zuzana, from which HL 237 and HL 390 were the most remarkable. The majority of selections with resistance to storage diseases as well as Zuzana cv. contain Glockenapfel cv. in their pedigree.

Keywords: apples; storage diseases; cultivars; advanced selections; bitter rot; grey mould; blue mould; brown rot; tolerance; resistance

Bitter rot (*Gloeosporium album*), grey mould (*Botrytis cinerea*), and blue mould (*Penicilium expansum*) are the most damaging parasitic diseases of apple fruits during their storage (Cappelini et al. 1987; Spotts et al. 1999). Bitter rot occurs the most frequently on apples in storage at temperatures between –1 and 4°C (Wilkinson 1943). Incidence of these storage diseases on apples during their keeping in the air storage depends on a range of different factors: cultivar susceptibility, orchard rot history, fruit quality, orchard type, fruit mineral composition (mainly calcium content), fungal inoculum and weather. Among them, sanitary conditions in the orchard are probably the most important, followed by different levels of susceptibility of cultivars (Sholberg et al. 1989; Deell, Prange 1993; Jones et al. 1996; Gessler 1997; Spotts et al. 1999).

In the Czech Republic there have been very suitable conditions for the development of storage diseases on apples in years when rainy weather prevails. In such years, besides normal protection against fungal diseases, two special treatments of fungicides are recommended for susceptible cultivars, one at the beginning of September and the second 10 days before harvest (Lánský, Kneifl 2000; Lánský et al. 2003).

Organically grown apples that were treated with restricted protection against fungal diseases had a higher incidence of storage rots, apple scab (*Venturia inaequalis*) and russeting (Deell, Prange 1993). Apples of three cultivars with resistance or tolerance to scab grown without any fungicide treatments showed final losses between 20 and 30% caused by fruit rotting during storage, whereas apples coming from orchards where conventional plant protection was applied only had losses between 2 and 8% (Blažek et al. 1999). Similarly, the absence of fungicide treatments in the case of cultivars resistant to scab leads to a higher incidence of storage diseases (Belz, Ruess 2001). Several advanced apple selections were detected within the running apple-breeding program at the Research and Breeding Institute of Pomology at Holovousy that had been distinguished by a long storage potential with

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a very low incidence of storage diseases. The aim of this study, which took place in 2002–2005, was to compare the natural occurrence of storage diseases during the long-term storage in a set of chosen selections possessing these characteristics with some standard cultivars grown in the Czech Republic. The intention of this study was to ascertain the cultivars with some resistance to storage diseases that could be proposed for organic growing or as donors for the next level of crosses.

MATERIAL AND METHODS

In the storage study that included three harvest years (2002–2004), 12 apple cultivars grown in the Czech Republic, 7 new cultivars and 11 advanced selections from the apple breeding program of the RBIP at Holovousy were used. The origin of the new cultivars and advanced selections and their estimated maximum storage life are given in Table 1. Fruit samples, consisting of 13 kg plastic boxes, were harvested in the optimum harvest maturity stage of each cultivar or selection from two orchards located in Holovousy. In the first orchard, apples were grown without fungicide treatments, whereas in the second one a standard program of integrated protection aimed mostly at apple scab control was applied. Two standard cultivars: Idared and Šampion were not included in the first orchard.

The location is characterised by an average yearly temperature of 8.1°C, average rainfall about 650 mm and altitude about 300 m. Samples of fruits were stored up to 11 months at 1 to 2°C in ambient air atmosphere reaching mostly the stage when fruits were completely decayed by rotting or senescence. From February all samples were inspected in monthly intervals during which the fruits afflicted by rots were removed, pathogens involved were classified according to their symptoms and the numbers of discarded fruits noted.

For the storage disease identification the following classification was used (Kůdela, Kocourek 2002): Brown rot – *Monilinia fructigena* (Schröt. ex Aderh. et Ruhl.) [*Monilia fructigena* (Pers. ex Pers)], Bitter rot – *Pezicula alba* Guthrie [*Gloeosporium album* (Osterw)], [*Pezicula malicorticis* (H.S. Jackson)], [*Gloeosporium perennans* (Zeller et Childs)], Blue mould – *Penicillium expansum* (Link. Thom) and Grey mould – *Botryotinia fuckeliana* (de Bary ex de Bary), [*Botrytis cinerea* (Pers: Fr)]. Occurrence of the particular storage disease was expressed by the percentage of discarded fruits calculated from the

Table 1. Origin of advanced selections or new cultivars and their maximum storage life

Cultivar or selection	Female	Male	Storage life (days)
Angold	HL A 28/39	Golden Delicious	220
HL 8	Glockenapfel	Šampion	250
HL 189	Jonadel	Rubín	200
HL 212	HL 18	HL 261	230
HL 237	Starkrimson Del.	Glockenapfel	310
HL 322	Clivia	Melrose	180
Hl 390	Bláhova oranžová	Glockenapfel	330
HL 514	HL III 12/30	Rubín	190
HL 851	Zuzana	Idared	240
HL 872	Purdue 1983	Purdue 1690	250
HL 1711	Idared	Discovery	230
HL 2218A	HL 223	TSR29T26	180
Meteor (HL 704A)	Megumi	Melrose	250
Primadela (HL 1529)	Primula	HL 237	160
Rubimeg (HL 319)	Megumi	Rubín	210
Rubinstep (HL 164)	Clivia	Rubín	170
Rucla (HL 251)	Clivia	Rubín	200
Zuzana (HL III 25–34)	Glockenapfel	James Grieve	260

HL A 28/39 = Antonovka o.p., HL III 12/30 = Jonathan × Ontario, HL 18 = Golden Spur × Granny Smith, HL 223 = Starkrimson Del. × Glockenapfel, HL 261 = Golden Delicious × Purdue R7T41, Purdue 1690 = Steele Red × N40R80T119, Purdue 1983 = Purdue 60837 × 669 NJ5, TSR29T26 = Starking Delicious × OR48T84

Table 2. Incidence of rotted fruits with susceptible cultivars 2002–2004

Samples from orchards	Year	Brown rot	Blue mould	Bitter rot and grey mould	Total
Without chemical protection	2002	1.0	9.7	25.7	36.4
	2003	2.9	4.5	43.5	50.9
	2004	0.6	4.1	35.3	40.0
	mean	1.5	6.1	34.8	42.4
LSD at $P < 0.05$		0.9	3.4	5.0	9.1
With chemical protection	2002	0.3	2.9	8.9	12.1
	2003	0.1	1.7	21.3	23.1
	2004	0.3	1.4	16.0	17.7
	mean	0.2	2.0	15.4	17.6
LSD at $P < 0.05$		n.s.	n.s.	3.9	6.3

original number of fruits in each sample. Because of the difficulties in distinguishing bitter rot from grey mould in rotted fruits of the majority of cultivars and the identification of both pathogens using laboratory tests would be very expensive, both diseases were classified into one group.

For a mean survey incidence of storage diseases in the three harvest years and the two variants of orchard protection data from cultivars susceptible to storage diseases were used. These results were tested by analysis of variance. Means were separated by Tukeys "least significance difference" test at $P < 0.05$ (LSD). The differences between cultivars were tested using the occurrence of the fruits inflicted by the diseases in the three years as replications.

RESULTS AND DISCUSSION

Factors influencing occurrence of storage diseases

Bitter rot and grey mould were the most common storage diseases recorded in this study (Table 2). With samples collected from the orchard without chemical protection their mean occurrence on long-term stored apples ranged from 25.7% in 2002 to 43.5% in 2003. With samples taken from the orchard protected by fungicides these values varied in the same years between 8.9 and 21.3%. Using fungicides reduced relatively most significantly the share of rotted fruits by these pathogens in 2002, which was the year with the smallest infection pressure. On the contrary, in the year of the highest infection pressure (2003) applications of fungicides were relatively least effective.

Blue mould was on average the second most frequent cause of apple rot. The mean shares of fruits infected by this pathogen varied between 1.4 to 9.7%. The highest shares of fruits decayed by blue mould were recorded in 2002, while the lowest in 2004.

Brown rot caused by *Monilinia fructigena* was the least frequent storage disease recorded in this study with the maximum of 2.9% of recorded fruits coming from the unprotected orchard in 2003. Application of fungicides in the orchard was the most effective in the control of this disease compared to

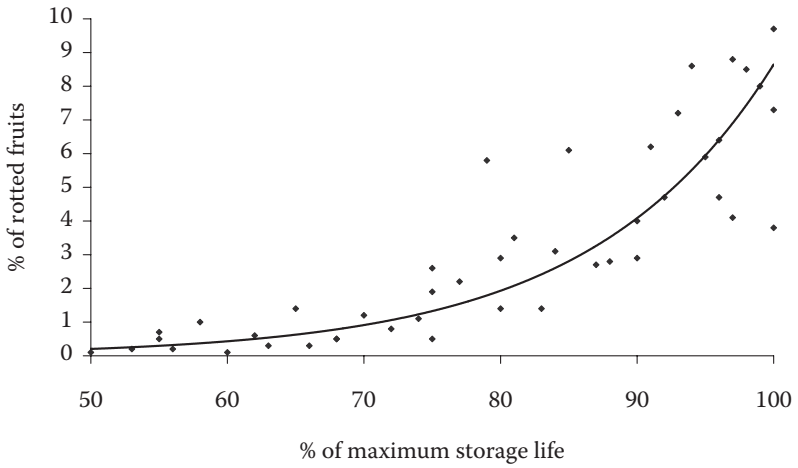

Fig. 1. Impact of storage life (% of maximum storage duration) on the percentage of rotted fruits grown without fungicides

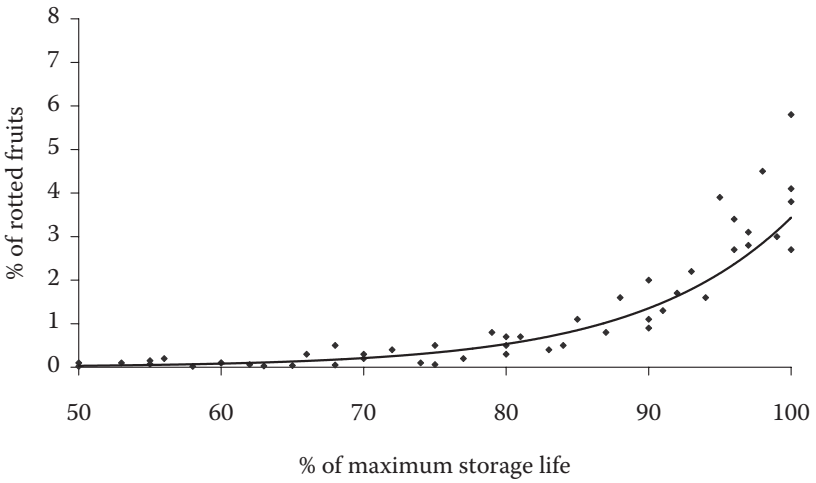

Fig. 2. Impact of storage life (% of maximum storage duration) on the percentage of rotted fruits grown with using fungicides

the other diseases. Brown rot differed from other storage diseases in time of its occurrence. Nearly all apples rotted by this pathogen were recorded in the first inspections, whereas the occurrence of all other diseases was progressively increased with the duration of the storage.

The mean total cumulative share of rotted fruits recorded in this study in samples harvested from the orchard without fungicide application was 42.2%, compared to 17.7% in the samples from the orchard with integrated protection. Both figures are much higher than the data on storage rot occurrence on apples obtained from comparable conditions in other studies (Deell, Prange 1993; Blažek et al. 1999; Darnhoher, Wurm 2005). These discrepancies can be explained by the fact that in this study occurrence of rotting was observed much beyond the usual storage life of particular cultivars. Therefore, in the case of very susceptible cultivars (Lord Lambourne, Jarka and Rubín), nearly all the fruits were destroyed by rotting by the time of the last observations.

A course of rot fruit occurrence during the normal storage life of apple cultivars susceptible to storage diseases based on the observance of samples harvested from the orchard without fungicide applications in 2002–2004 is given in Fig. 1. Shares of rotted apples increased very rapidly towards the end of the normal storage life of the cultivars, reaching on average 8.7% of lost fruits at that stage. However, economically significant losses caused by the occurrence of storage diseases of apples arose only during the last quarter of the storage life.

Samples that were harvested from the orchard with the integrated plant protection had 4.1% of rotted fruits at the end of their storage life on average (Fig. 2). Economically significant losses caused by rotting of

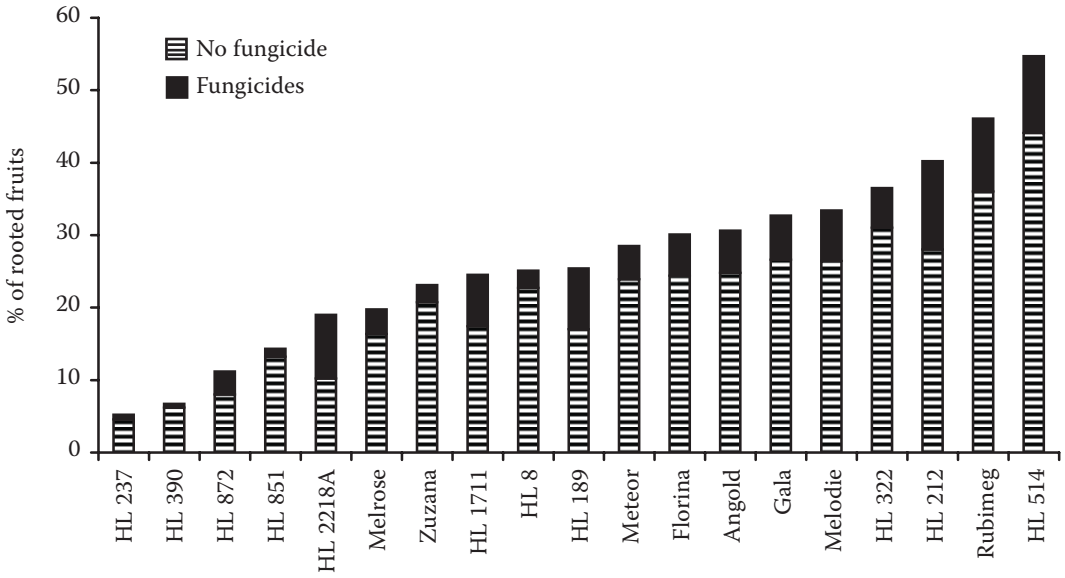

Fig. 3. Advanced selections and cultivars with the least shares of rotted fruits

apples were usually recorded only during the last month of their normal storage life.

Susceptibility of cultivars

Complete results of the evaluation of all cultivars and advanced selections based on samples harvested from the orchard without fungicide application are given in Table 3. Nearly all apples of cultivars Lord Lambourne, Rubín and Jarka were rotted; these three cultivars can be thus classified as the most susceptible to storage diseases. Topaz did not show much better results with the average of more than 90% rotted fruits at the time of the last evaluation in July. However, this cultivar could be classified as a medium susceptible if March results are taken into consideration only. The higher susceptibility of Topaz to bitter rot has already been reported (Darnhoher, Wurm 2005; Palm, Kruse 2005). Cultivars Golden Delicious and Rubinstep with shares of rotted fruits around 80% in the last terms of observations were ranged as cultivars susceptible to storage diseases.

Cultivars Jonagold and Rucla with shares of rotted fruits around 60% in the July term of observations were classified as medium susceptible. Still less susceptible to the diseases were Primadela and Rubimeg with about 40% rotted fruits in the July observations. The following cultivars – Angold, Gala, Florina, Melodie, Meteor and Zuzana proved to be partially resistant to the storage diseases as their shares of rotted

Table 3. Mean share (%) of rotted fruits grown in orchards without chemical protection

Cultivar or selection	Brown rot	Blue mould			Bitter rot and grey mould			Total rotted
		March	May	July	March	May	July	
Angold	2.5	0.0	0.6	2.2	2.4	12.0	20.1	24.8
Gala	0.6	0.2	1.9	5.7	0.5	9.7	20.3	26.6
Golden Delicious	0.4	1.6	3.2	9.5	13.0	36.3	69.9	79.8
Florina	0.9	0.1	1.9	3.0	2.6	13.8	20.5	24.4
HL 8	0.5	0.4	1.8	5.6	2.8	8.0	16.6	22.7
HL 189	1.0	0.0	0.3	1.8	0.0	3.1	14.2	17.0
HL 212	0.3	1.3	3.5	9.0	1.4	7.8	18.7	28.0
HL 237	0.1	0.0	0.1	0.1	0.0	2.0	4.3	4.5
HL 322	2.6	0.3	0.8	3.0	2.0	12.9	25.4	31.0
HL 390	3.0	0.0	0.0	0.4	0.0	0.2	2.8	6.2
HL 514	5.1	0.1	5.0	12.9	4.0	10.7	26.1	44.1
HL 851	0.0	0.2	0.4	1.0	0.4	5.6	12.2	13.2
HL 872	0.2	0.0	0.0	0.3	0.1	1.4	7.5	8.0
HL 1711	1.2	0.0	0.2	2.8	0.3	5.1	13.4	17.4
HL 2218A	0.0	0.0	0.0	0.2	0.0	3.5	10.0	10.2
Jarka	3.4	1.0	7.5	12.5	37.5	59.8	81.9	97.8
Jonagold	1.3	0.0	2.2	5.0	7.0	22.5	52.1	58.4
Lord Lambourne	9.5	2.8	8.1	10.4	64.0	78.9	79.7	99.6
Melodie	3.8	0.6	3.6	6.1	1.6	8.0	16.5	26.4
Melrose	1.7	0.0	0.0	0.67	0.0	1.8	14.0	16.4
Meteor	0.4	0.0	0.0	0.3	2.4	9.5	23.2	23.9
Primadela	0.6	0.9	0.9	2.0	0.2	7.0	40.6	43.2
Rubimeg	0.0	0.0	0.5	4.2	1.1	15.6	31.8	36.0
Rubín	1.8	4.6	14.9	19.0	37.3	69.6	77.9	98.7
Rubinstep	1.1	2.1	7.6	18.5	11.0	37.4	58.7	78.3
Rucla	0.9	0.5	2.8	5.6	3.9	33.3	54.6	61.1
Topaz	0.4	0.0	1.0	8.2	4.6	30.7	82.1	90.7
Zuzana	0.7	0.3	2.7	5.7	2.0	9.4	14.3	20.7
Mean	1.57	0.61	2.55	5.56	7.22	18.41	32.48	39.61
LSD at $P < 0.05$	1.1	1.7	2.2	3.7	5.8	7.2	9.0	10.9

fruit in last evaluations ranged from 20 to 25%. The resistance of Gala to some storage diseases has been already reported (Spotts et al. 1999). The highest level of resistance to the diseases was recorded in cultivar Melrose, which had on average only 16.5% of rotted fruits in the last evaluations. Melrose has been classified as resistant to some storage diseases in previous studies (Denardi et al. 2003).

Regarding blue mould, the most susceptible were Rubín and Rubinstep, but for the later the occurrence of the disease was a problem only beyond the normal storage life of the cultivar. On the other hand, the highest level of resistance to the disease was found in Melrose and Meteor that had only a negligible number of fruits infected by the pathogen.

With respect to brown rot losses of economic significance, the cultivar Lord Lambourne seemed to be the most susceptible to the disease. On the contrary, no single apple destroyed by the disease was recorded in Rubimeg.

An evaluation of samples harvested in the orchard treated with fungicide, which had generally much smaller occurrence of storage diseases, resulted in similar classifications of cultivar susceptibility (Table 4).

Table 4. Mean share (%) of rotted fruits grown in orchards with chemical protection

Cultivar or selection	Brown rot	Blue mould			Bitter rot and grey mould			Total rotted
		March	May	July	March	May	July	
Angold	0.3	0.0	0.0	0.0	0.0	1.0	5.5	5.8
Gala	0.0	0.0	0.0	0.0	0.1	0.5	6.1	6.1
Golden Delicious	0.0	0.0	0.0	0.0	0.4	8.2	25.9	25.9
Florina	0.7	0.0	0.5	0.8	0.0	0.2	4.2	5.7
HL 8	0.0	0.0	0.2	0.4	0.0	0.0	2.0	2.4
HL 189	0.0	0.0	0.0	0.0	0.0	1.7	8.4	8.4
HL 212	0.0	0.0	0.0	1.6	0.0	0.6	10.6	12.2
HL 237	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.7
HL 322	0.0	0.0	0.0	0.2	0.0	1.9	5.3	5.5
HL 390	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.5
HL 514	2.0	0.0	2.1	3.8	0.0	0.0	4.8	10.6
HL 851	0.0	0.0	0.0	0.0	0.0	0.8	1.1	1.1
HL 872	0.0	0.0	0.0	0.0	0.0	0.0	3.2	3.2
HL 1711	0.0	0.0	0.0	0.1	0.0	2.0	7.0	7.1
HL 2218A	0.0	0.0	0.0	0.0	0.0	1.4	8.8	8.8
Idared	0.0	0.0	0.0	0.0	0.2	1.1	8.6	8.6
Jarka	1.7	0.0	1.4	4.9	6.5	25.3	42.0	48.6
Jonagold	0.0	0.0	1.6	3.4	2.0	10.8	17.7	21.1
Lord Lambourne	2.9	1.0	2.8	7.0	17.2	47.7	80.0	89.9
Melodie	0.1	0.0	0.0	0.4	0.3	3.0	6.5	7.0
Melrose	0.0	0.0	0.0	0.0	0.0	0.6	3.4	3.4
Meteor	0.0	0.0	0.0	0.2	0.0	0.5	4.4	4.6
Primadela	0.0	0.0	0.0	0.8	0.6	5.4	28.3	29.1
Rubimeg	0.0	0.0	0.0	0.0	0.1	1.3	10.1	10.1
Rubín	0.0	0.6	4.5	13.0	10.4	33.2	42.9	55.9
Rubinstep	0.0	0.0	0.9	4.8	1.0	12.7	26.6	31.4
Rucla	0.6	0.2	0.4	1.7	0.0	4.0	14.3	16.6
Šampion	0.0	1.5	7.6	12.7	6.0	26.9	43.7	56.4
Topaz	0.0	0.0	0.0	3.0	0.2	9.4	19.0	22.0
Zuzana	0.2	0.0	0.4	1.3	0.0	0.1	0.9	2.4
Mean	0.3	0.11	0.75	2.00	1.5	6.68	14.74	17.04
LSD at $P < 0.05$	0.7	0.4	1.5	2.8	6.9	9.3	11.8	11.0

In this set of cultivars two other cultivars were evaluated – namely Idared, which ranked among partially resistant ones and Šampion, which ranked among cultivars susceptible to all storage diseases including blue mould. Regarding the storage disease control, applications of fungicides were more effective in Golden Delicious, Topaz, Rucla, Rubimeg and especially Zuzana, which had the smallest shares of rotted fruits.

Resistance of advanced selections

From eleven advanced selections bred in RBIP at Holovousy included in this study 5 genotypes were less affected by fruit rotting during storage than cultivars Melrose and Zuzana (Fig. 3). The most remarkable among them were selections HL 237 and HL 390, which had negligible shares of rotted fruits in samples from the orchard without fungicide treatments and practically no incidence of storage diseases in samples from orchards with integrated plant protection. The selection HL 390, however, seemed to be quite susceptible to brown rot. Both selections were distinguished from other apples by very late harvest ripening (the last week of October) and by an extremely long storage life up to 330 days in air storage. Similar characteristics were also typical for HL 851 and HL 8. It may be an interesting link that all these selections, as well as the Zuzana cultivar, contain Glockenapfel cv. in their pedigree.

A very low occurrence of rotted fruits in these selections need not be only a consequence of their resistance but might be also connected with delayed processes of fruit maturity. It is particularly well known that slowing-down fruit maturing during storage using ULO technology has a very strong influence upon the decrease of storage disease occurrence (Hong et al. 1997).

The majority of advanced selections that were partially resistant to storage diseases in this study were characterised by a higher content of acids and by taste with a perception of being more acid than sweet. Their taste was slightly inferior to presently grown cultivars, therefore, they could be proposed only as donors of storage disease resistance for the new crosses in apple breeding programmes. A certain exception in this respect was HL 1711, which usually receives the highest scores for taste; but fruit appearance of the selection is inferior because of poor colouring and flat shape of the ribbed fruits. Selections HL 322, HL 212 and HL 514 had better fruit quality but their resistance to storage diseases was not so remarkable.

CONCLUSIONS

- The present study confirmed considerable differences among cultivars and selections in susceptibility to storage diseases in general as well as in particular cases.
- Bitter rot and grey mould were the most common storage diseases in this study followed by blue mould and brown rot.
- Fungicide treatments applied in the orchard with integrated plant protection reduced fruit rotting two to four times.
- Economically significant losses caused by rotting usually took place in the last quarter or during the last month of the normal storage life of each cultivar.
- Cultivars Angold, Gala, Florina, Melodie and Meteor proved to be partially resistant to the storage diseases, but the smallest shares of rotted fruits were recorded on apples of Zuzana and Melrose cultivars.
- Five advanced selections proved to be less affected by fruit rotting than cv. Melrose and Zuzana, among which HL 237 and HL 390 were the most remarkable. All these selections are proposed for use as donors of resistance in the next level of breeding.

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Výskyt skládkových chorob u jablek vybraných odrůd a perspektivních hybridů vypěstovaných ve výsadbách neošetřovaných a ošetřovaných fungicidy

ABSTRAKT: V průběhu tříletého studia byl hodnocen přirozený výskyt skládkových chorob u vzorků 30 odrůd a perspektivních hybridů, které byly sklizeny ve výsadbách neošetřovaných a ošetřovaných fungicidy, skladovaných v běžném chlazeném atmosférickém skladu. Podle frekvence výskytu byly nejčastějšími chorobami v tomto studiu kruhová hnědá a šedá hniloba, za kterými následovaly modrá a moniliová hniloba. Použití fungicidů ve výsadbě snižovalo u různých odrůd výskyt hnilob plodů dvojnásobně až čtyřnásobně. K významným ztrátám způsobeným hnilobami plodů obvykle docházelo až v poslední čtvrtině délky optimální skladovací doby každé odrůdy, avšak u vzorků z výsadby ošetřované fungicidy to byl nejčastěji až poslední měsíc jejich skladování. Odrůdy Angold, Gala, Florina, Melodie a Meteor se ukázaly být částečně odolné vůči skládkovým chorobám, ale nejmenší podíly shnilých plodů byly zaznamenány u vzorků odrůd Melrose a Zuzana. Ještě méně bylo hnilobami postiženo pět perspektivních hybridů, z nichž nejpozoruhodnější byly HL 237 a HL 390. Většina hybridů odolných vůči skládkovým chorobám a také odrůda Zuzana vznikly při použití odrůdy Zvonkové.

Klíčová slova: jablka; skládkové choroby; odrůdy; perspektivní hybridy; kruhová hnědá hniloba; šedá hniloba; modrá hniloba; moniliová hniloba; tolerance; odolnost

Corresponding author:

Ing. Jan Blažek, CSc., Výzkumný a šlechtitelský ústav ovocnářský Holovousy, s. r. o., Holovousy 1,
508 01 Hořice v Podkrkonoší, Česká republika
tel.: + 420 493 692 821, fax: + 420 493 692 833, e-mail: blazek@vsuo.cz