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Possibilities of brown rot management in organic stone fruit production in Hungary

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Summary In this study, possibilities of environmentally-friendly plant protection against two brown rot species was summarized for organic stone fruit orchards. Symtomps of the two most important brown rot species (*Monilinia fructigena* (Aderh. & Ruhl.) Honey and *Monilinia laxa* (Aderh. & Ruhl.) Honey) were described and then cultivar susceptibility to brown rot was discussed. Several sustainable plant protection methods were selected and discussed in details such as mechanical, agrotehcnical, biological, and other control possibilities (elemental sulphur, lime sulphur and copper).

Key words: brown rot, organic production, stone fruits, *Monilinia* spp.

Introduction

Two old brown rot species can be distinguished in Hungary which are considered to cause the major damage of stone fruit species. One is *Monilinia fructigena* (Aderh. & Ruhl.) Honey, and the other is European brown rot (*Monilinia laxa* (Aderh. & Ruhl.) Honey). The third member of the old brown rot family (*Monilinia fructicola*) is not discussed here as it is not causing yet yield loss in Hungary since it is a quarantine organism in Europe; however, recently it was detected in a commercial fruit market in Budapest (*Pertóczi & Palkovics*, 2006). More details about the environmentally-benign control of *M. fructicola* can be found in a previous review of *Holb* (2004).

The symptoms of *M. fructigena* are manifested mainly on the fruit. It is a wound parasite, therefore, it infects via injuries. Around the wound, growing brown areas form, which finally cover the whole fruit. Later, yellowish conidiophores appear in concentric rings on the rotting areas (*Holb*, 2003). The pathogen infects by conidia. The rotting fruit either falls down or it withers and mummifies on the tree. The mummy overwinters on the tree, and also the infected fruit can overwinter in the storage and they become the inoculum sources of the next year. Its host plants include all pome and stone fruit species. Among the nuts, it attacks only hazelnut.

European brown rot is one of the most dangerous diseases of stone fruits (primarily of sour cherry, sweet cherry and apricot) causing the death of shoots and younger branches. At blooming and fruit set, the shoots begin to wilt and then they suddenly become dry. The dry leaves do not fall down, they stay on the tree during the whole season. A strong infection might also cause the death of woody shoots and older branches. Since the pathogen is a wound parasite, it appears on the fruits at injuries after hail or strong pest damage. Brown rotting of fruits starts and then grey conidiophores appears on their surface. The fruits often mummify and stay on the tree. The primary inoculum sources of the disease are the dead woody parts and the fruit mummies. The disease can also cause significant damages during storage. Its host plants include the stone fruit species.

Cultivars susceptibility

Susceptibility of fruit species and cultivars to brown rot fungi under East-European climate conditions was discussed by *Soltész* (1997), therefore, only some examples are mentioned here (*Table 1*).

In the case of sweet cherry, fruit rot is more important than blossom or twig blights. Most cultivars are susceptible to brown rot. However, the cracking of a fruit is more important for the infection caused by *M. laxa* than cultivar susceptibility. *Ubrizsy* (1965) supposed that the stigma and ovary of a flower produces an antibiotic-like material which prevented infection. This prevention is lost if the weather is rainy for a long period because the wetting of flowers deactivates the antibiotic effect. *Bargioni* (1982) demonstrated that sweet cherry cultivars with thin fruit skin are more susceptible to brown rot than those with thicker fruit skin. Among the sweet cherry cultivars, cv. 'Vega' is very susceptible to blossom blight. More resistant sweet cherry cultivars include cvs. 'Bigarreau Burlat', 'János cseresznye' and 'Valerij Cskalov'. Cultivar 'Germersdorfi' is one of the most sensitive cultivars (Benedek *et al.*, 1990).

In the case of sour cherry, blossom and twig blights are

Table 1 Examples of resistant and susceptible fruit cultivars to brown rot caused by *Monilinia* spp.

Fruit	Host resistance	Plant organ	Cultivar	Reference
apricot	tolerant	blossom, twig	Neptun, Mamaia, Silvana, Sulina, Sirena	*Cociu* cit. *Soltész*, 1997
apricot	high susceptibility	blossom, twig	Budapest, Mandulakajszi	*Szabó*, 1997a
apricot	moderate susceptibility	blossom, twig Polonais	Ceglédi óriás, Liget óriás, *Szabó*, 1997a	
apricot	low susceptibility	blossom, twig	Borsi-féle kései rózsa, Piroska, Pannónia, Ceglédi bíborkajszi, Magyar kajszi, Rakovszky	*Szabó*, 1997a
peach	high susceptibility	fruit	Early, Lord Napier, Michigan, Triumph	*Mohácsy* et al., 1963
peach	high susceptibility	fruit	Shipley	*Koroknai*, 1971
peach	moderate susceptibility	fruit	Alexander, Amsden, Champion, Ford, Győztes, Mayflower	*Koroknai*, 1971
peach	low susceptibility	fruit	Canada, Carman, Elberta, J.H. Hale, Incrotio Pieri, Magyar arany duránci	*Koroknai*, 1971
peach	high susceptibility	fruit	J.H. Hale, Champion	*Soltész*, 1997
plum	high susceptibility	fruit	Bluefre, President, Stanley	*Szabó*, 1997b
plum	moderate susceptibility	fruit	Cacanska najbolja, President	*Szabó*, 1997b
plum	low susceptibility	fruit	Besztercei, Silvia, Tuleu gras	*Szabó*, 1997b
sour cherry	partial resistance	blossom, twig	Csengődi, Akasztói, Cigánymeggy 59	*Apostol*, 1990; *Apostol & Véghelyi*, 1992
sour cherry	low susceptibility	blossom, twig	Lativiszkaja Nizkaja, Nagy Angol, Mocanesti, Ljubszkaja, Sirpotreb, Oblacsinszkaja, Cigánymeggy 3, Maraska Savena, Mettar, Elegija	*Soltész*, 1997

the most important symptoms of brown rot decay. There are some sour cherry cultivars which have a low susceptibility or disease tolerance, such as 'Nagy Angol', 'Mocanesti', 'Oblacsinszkaja', 'Cigánymeggy 3', 'Maraska Savena', 'Mettar' and 'Elegija' (*Soltész*, 1997). Moreover, *Apostol* (1990) and *Apostol & Véghelyi* (1992) revealed that cvs. 'Akasztói' and 'Cigánymeggy 59' were partly resistant to *M. laxa*. Sour cherry cultivars of Pándy type are very susceptible to fruit rot (*Paszternák* et al., 1982). In the domestic cultivar assortment, the Pipacs cultivars (Korai pipacsmeggy, Pipacs 1) show a certain level of resistance. It has been known that cv. 'Csengődi' is highly, though not absolutely resistant to brown rot, therefore it is highly recommended for organic production (*Apostol,* 1990; *Apostol & Véghelyi,* 1992).

In the case of apricot and peach, both fruit rot and blossom blight caused by *M. fructigena* or *M. laxa* can be significant diseases. Susceptibility of cultivars is high if they are late blooming and if the fruit can be injured easily. *Guerriero & Watkins* (1984) classified the level of cultivar susceptibility into 9 grades. In Romania, several apricot cultivars tolerant to brown rot were bred such as 'Neptun', 'Mamaia', 'Silvana', 'Sulina' and 'Sirena' (*Cociu* cit. *Soltész*, 1997). *Szabó* (1997a) classified several apricot cultivars into brown rot susceptibility groups. He evaluated cvs. 'Budapest' and 'Mandulakajszi' as highly, 'Ceglédi óriás', 'Liget óriás' and 'Polonais' as moderately and 'Borsi-féle kései rózsa', 'Piroska', 'Pannónia', 'Ceglédi bíborkajszi', 'Magyar kajszi' and 'Rakovszky' as lowly susceptible to blossom and twig blights caused by *M. laxa*.

In an early Hungarian study, *Mohácsy* et al. (1963) found that peach cvs. 'Early', 'Lord Napier', 'Michigan' and 'Triumph' were very susceptible to infection caused by brown rot fungi. A few years later, *Koroknai* (1971) demonstrated that peach cv. 'Shipley' was highly susceptible, cvs. 'Alexander', 'Champion', 'Ford', and 'Mayflower' were moderately susceptible while 'Canada', 'Carman', 'Elberta', 'J.H. Hale', 'Magyar arany duránci' were lowly susceptible to brown rot. In contrast, *Soltész* (1997) noted that cvs. 'J.H. Hale' and 'Champion' were highly susceptible to infection caused by *Monilinia* spp. Both authors mentioned that most nectarine species are highly susceptible to brown rot and the reason is that peelings of nectarine species can be injured very easily, therefore, ice and insects can cause several wounds on the fruit surface (*Soltész*, 1997). *Adaskaveg* et al. (1991, 1992) noted that resistant peach genotypes had thicker fruit skin and higher phenolic content.

In the case of plum, fruit rot is the most important damage but flower infection can also occur. Such features as vulnerable fruit peeling, long, wet weather periods during fruit maturity and clustering of fruits, are the main factors responsible for susceptibility to brown rot infection (*Soltész*, 1997). *Szabó* (1997b) classified several European plum cultivars into brown rot susceptibility groups. He found that 'Bluefre', 'President' and 'Stanley' are highly, 'Cacanska najbolja' and 'President' are moderately, and 'Besztercei', 'Silvia' and 'Tuleu gras' are lowly susceptible to fruit rot caused by *M. laxa*.

Mechanical and agrotechnical control

The agrotechnical methods recommended as plant protection tools against *Monilinia fructigena* are as follows. The fallen infected fruits should be collected and destroyed or ploughed into the soil where they are decomposed. The infected, mummified fruits should be removed and destroyed during pruning in early spring (Leeuwen *et al.*, 2000, 2002). Winter and summer prunings, fruit thinning and the continuous collection and removal of infected fruits are effective tools in reducing the inoculum sources.

One of the most important control elements against European brown rot is the removal of primary inoculum sources. The mummified fruits should be regularly collected from the tree and from the ground. The blighted twigs and mummified fruits should be removed and destroyed during winter pruning. The mummies should be ploughed into the soil, so that they are destroyed as a result of the soil microbiological processes. Under foggy, humid weather conditions, severe blossom blight occurs. The damage is further increased if the canopy is dense. Therefore, we should aim to reach a less dense canopy, thereby we can significantly reduce the conditions favourable for infection. In the case of sweet and sour cherry, cracking frequently occurs as a result of the imbalanced water supply, which frequently results in fruit rot. This can be prevented by ensuring a balanced water supply. Even if cracking occurs, the damage can be reduced by a quick harvest. It is also known that if sweet cherry trees are covered with rain shields made of polyethylene or other waterproof, light-transmitting material prior to harvest, it will prevent fruit cracking, and therefore, reduce fruit decay by various fungi. *Borve & Stensvand* (2003) demonstrated that fungicide applications were not needed when cherry fruits were covered during rainy periods from bloom until the end of harvest. They concluded that rain shields can be used both as a supplement and a replacement for fungicide applications to reduce fruit decay in sweet cherry. Injuries during harvest should be minimized. The timely harvest can significantly reduce the degree of fruit infection. Before taking the fruits to storage, the infected, rotten fruits should be removed, because they can infect the healthy fruits during storage.

Biological control

In the case of *M. fructigena*, mainly the damage during storage can be reduced by biological control (*Table 2*). *Jenkins* (1968) found that some bacteria can be found in large numbers on rotting fruits and they have a role in destroying the hyphae of *Monilia* spp. Later, it has been revealed that these bacteria inhibit the development of *Monilia* species also via their antibiotics production. In the 1980s, two bacterium species (*Bacillus cereus* and *B. substilis*) were isolated, which are successfully used abroad to prevent the rotting of stored fruit (*Pusey & Wilson*, 1984). The best-known antagonist fungi, such as *Aureobasidium pullulans*, *Epicoccum nigrum* or *Trichoderma* species occur only rarely on fruits infected by *Monilia*. On the other hand, some *Penicillium*, *Cladosporium* and *Mucor* species are frequently present on infected fruits in great numbers besides the *Monilia* species (*Hong* et al., 2000).

Biological control against European brown rot dates back to the 1960s. *Jenkins* (1968) found that some bacteria dissolve and destroy the hyphae of *Monilinia* species. Later, it has been proved that these bacteria also produce a significant amount of antibiotics. After the successful identification of the bacteria (*Bacillus cereus* and *B. substilis*), they have been successfully applied to prevent the fruit rot of stone fruits during storage (*Pusey & Wilson*, 1984). Since the end of the 1980s, Melgarejo and her research group has performed extended research in the field of biological control against *M. laxa*. They have identified several antagonist species such as *Penicillium frequentans* (*Melgarejo* et al., 1989), *Penicillim purpurogenum* (*Larena & Melgarejo*, 1996), and *Epicoccum nigrum* (*Madrigal* et al., 1991). Among the three species, *P. frequentans* and *E. nigrum* seem promising as regards their application in the practice. *Larena* et al. (2003) have produced a stabil bioproduct of *E. nigrum* in laboratory.

Table 2 Some organisms used in biological control against *Monilia* spp.

Target organism	Bioprotection agent
M. laxa, M. fructigena	*Trichoderma viridae*
M. laxa	*Aspergillus flavus, Epicoccum nigrum, Penicillium chrysogenum, P. frequentans, P. purpurogenum*
M. laxa	*Penicillium frequentans*
M. laxa	*Penicillium frequentans*
M. laxa	*Epicoccum nigrum*
M. laxa	*Epicoccum nigrum*
M. laxa	*Metschnikowia pulcherrima* (yeast)
M. fructicola	*Bacillus subtilis* B-3 strain
M. fructicola	*Bacillus subtilis* B-3 strain
M. fructicola	*Bacillus subtilis* B-3 strain
M. fructicola	*Bacillus subtilis* B-192
M. fructicola	*Pseudomonas corrugate* and *P. capacia*

Approved chemical materials

One of the most critical control elements against *M. fructigena* is the control of wounding agents such as insect pests. Efficient control against *Ragholetis cerasi* in the case of sour and sweet cherry; *Grapholita funebrana* in the case of plum (*Deseő* et al., 1971); and *Anarsia lineatella* and *Grapholita molesta* in the case of apricot and peach (*Holb*, 2005) is of special importance. In organic production, copper-containing chemicals can be used against the disease. Control should be started already after bud burst with a high volume spraying. High volume sprays with copper and sulphur reduce the overwintering inoculum sources of brown rot. The period before harvest is critical, because the fruits become more frequently infected at that time.

Control of insect pest is also an essential element of European brown rot control. This means primarily efficient protection against *Ragholetis cerasi* in the case of sweet and sour cherry, against *Grapholita funebrana* in the case of plum, *Anarsia lineatella* and *Grapholita molesta* in the case of apricot and peach.

Fruit cracking has great significance in *M. laxa* infection on sweet and sour cherry. After hail, immediate spraying is necessary in order to prevent infection via the injuries. Three chemical compounds are permitted in Hungarian organic plant protection: elemental sulphur, lime sulphur and copper compounds (*Holb & Veisz*, 2005). Sulphur was the first pesticide used against brown rot diseases. Sulphur was applied in some regions in every 7 or 14 days from blossom until fruit maturity. These control measures were responsible for a substantial reduction in fruit losses, although the results were not satisfactory. Therefore, *Rudolph* (1925) developed a protective spray schedule that has proved relatively effective on apricots. The trees were sprayed with Bordeaux mixtures when the blossoms were at pink bud stage. Where the disease has been severe, two sprays were advised, one at tight cluster stage and one at full bloom. These sprays were phytotoxic to floral parts of the trees. In Hungary, in the early 1920's, *Béla Husz* proved the fungicide activity of Bordeaux mixture against *M. laxa* during bloom (*Berend*, 1957) and his recommendations were used until World War II. In the 1950's, liquid lime sulphur applications were suggested against blossom blight (*Ogawa* et al., 1954). However, authors noted that lime sulphur applications on blossoms may result in severe flower damage. Eradication of incipient fruit infection on cling peaches following rains during the last three weeks before harvest was shown to be possible with ground application of liquid lime-sulfur within 37 hours from the beginning of rain (*Ogawa* et al., 1954). Recently, *Holb & Schnabel* (2005) developed a lime sulphur and a wettable sulphur spray schedule against brown rot blossom blight of sour cherry for organic sour cherry production. Nowadays, copper-containing fungicides are the most frequently used chemicals against the disease in organic production. Control should be started already before bud burst with a high-volume spray. Critical periods are blooming and ripening. It has been known that a 0.2% copper-hydroxide hidroxid (e.g. Cuproxat FW) applied at tight cluster stage in sour cherry and apricot can significantly reduce the risk of brown rot infection. During blooming, the plants are highly sensitive to copper. Special attention should be paid to peach, since copper can cause severe phytotoxicity in it already at the green tip stage.

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