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Monilia spp. the Pathogens of Fruit Plants

Monilia spp. patogenami roślin owocowych

The research of the brown rot diseases of fruit started in Europe over 200 years ago and in North America about 150 years ago. The first authentic description of a brown rot fungus on fruits occurred in 1796, and the author designated it as *Torula fructigena*. The name of a brown rot fungus *Monilia fructigena* was given by Persoon in 1801, from Latin *monile*, a necklace (Honey, 1928; Harrison, 1933 acc. to quoted literature).

The name *Monilia fructigena* is still used for the imperfect stage of the fungus, which produced buff sporodochia on the surface of infected fruit (Honey, 1928; 1936; Wormald, 1954; Byrde and Willetts, 1977). In 1928 Honey proposed the generic name *Monilinia* for the perfect stage of fungi causing the brown rot fruit and included to this genera those species which produced monilioid conidia and pseudosclerotia (Honey, 1928; Byrde and Willetts, 1977). The perfect stage of those fungi belong to the genus *Monilia*, the subdivision *Ascomycotina*, the class *Discomycetes*, the order *Helotiales* and to the family *Sclerotiniaceae*. This stage was found and described in 1883 in Pennsylvania, USA. It was the first record of the perfect stage of any brown rot fungus and it was named *Ciboria fructicola* (Harrison, 1933; Wormald, 1954; Byrde and Willetts, 1977 acc. to quoted literature).

In 1886 the brown rot fungi were divided in view of their specific ability to infect particular species of plants. *Monilia fructigena* (infecting mainly pome fruits), *M. laxa* (infecting apricots) and *M. cinera* (infecting plums and cherries) are distinguished in this manner (Wormald, 1954; Byrde and Willetts, 1977 acc. to quoted literature).

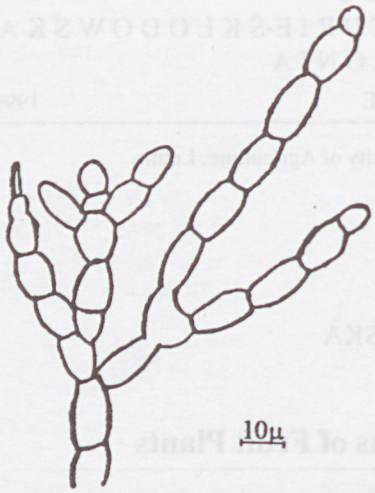

Fig. 1. A conidial chain of the *Monilia* spp. – *Junctoriae* (from Byrde and Willetts, 1977).

Fig. 2. A conidial chain of the *Monilia* spp. – *Disjunctoriae* (x 1000, from Wormald, 1954).

In 1936 Honey suggested a division of the genus *Monilinia* into two groups. The presence or absence of disjunctors in the maturity macroconidia chain was used as a diagnostic character within this genus. The species which did not produce disjunctors, within the fruiting chains were described as a *Junctoriae* group, and the species with disjunctors within the fruiting chains were described as a *Disjunctoriae* group by him (Figs. 1, 2). The disjunctors are small cells, usually 3 to 10 µm, promoting separation and dissemination of the spores (Honey, 1928; 1936; Wormald, 1954; Byrde and Willetts, 1977). The presence of disjunctors was first observed in 1888 by Woronin. Woronin found and described these cells of *Monilia urnula* (*S = vaccini*) (Honey, 1928; 1936; Harrison, 1933; Wormald, 1954; Byrde and Willetts, 1977).

There are about 30 known species fungi causing brown rot, which infected all pome and stone plants, and many other species of *Rosaceae* and *Ericaceae* family. The cultivated apple (*Malus pumila* Mill.), the pear (*Pyrus communis* L), the quince (*Cydonia oblongata* Mill.), the peach and nectarine (*Prunus persica* (L.) Batsch), the apricot (*P. armeniaca* L.), the plum (*P. domestica* L.), the sweet cherry (*P. avium* L.), the cherry (*P. cerasus* L.), the fig (*Ficus carica* L.), the almond (*P. amygdalus* Batch), the bilberry (*Vaccinium myrtillus*), the whimberry (*V.*

vitis-idaea), other species of bilberry (*V. uliginosum, V. stamineum, V. oxycoccos, V. macrocarpon, V. corymbosum*), the rhododendron (*Rhododendron ferrugineum*) and the ledum (*Ledum palustre*) are especially infected by *Monilia* spp. (Wormald, 1954; Gjaerum, 1969; Walker and McLeod, 1970; Byrde and Willetts, 1977; Batra, 1979; 1983; Willets and Harada, 1984). Hazel, medlar, grape, strawberry, blackberry, gourd, persimmon, loquat, hawthorn, tomato and many ornamental trees and shrubs are mentioned as hosts of the brown rot fungi by many authors (Wormald, 1954; Kotte, 1958; Byrde and Willetts, 1977 acc. to quoted literature; Zalewska, 1998).

The species from *Junctoriae* group represented by *Monilinia fructicola* (Wint.) Honey, infected rosaceous fruit, and species from *Disjunctoriae* group as *M. baccarum* (Schröter) Whetzel, *M. ledi* (Nawaschin) Whetzel, *M. oxycocci* (Woronin) Honey, *M. rhododendri* (Fisher) Whetzel, *M. urnula* (Weinmann) Whetzel infected plants from the *Ericaceae* family (Gjaerum, 1969; Batra, 1983).

Particular species of the genus *Monilia* can infect flowers and blossoms, fruitlets, unripe fruit, leaves, peduncles, dwarf shoots, twig and stored fruit. The brown rot fungi caused flower and blossom wilt, cancer of woody tissues and fruit rot (Honey, 1928; 1936; Harrison, 1933; Wormald, 1954; Gjaerum, 1969; Byrde and Willetts, 1977; Batra, 1983; Willetts and Harada, 1984; Siegfried et al., 1990; Rüegg and Siegfried, 1992; 1993; Rüegg, 1995).

The primary infections of blossoms always caused by *M. laxa* and *M. vaccini* occurred in spring. The hot and wet weather is favourable for infection. Under favourable conditions the pathogen overgrows the stames or the stigma to the ovary chamber. Dense conidial tufts (sporodochia), composed of conidiophores and spore chains, develop on the surface of infected organs. Conidia make the source of inoculum for secondary infection to other parts of the same tree, or at the same time, between adjacent shrubs and trees (Wormald, 1954; Byrde and Willetts, 1977; Siegfried et al., 1990; Rüegg and Siegfried, 1993; Rüegg, 1995).

Infection of leaves is uncommon by the fungi from the genus *Monilia*. The leaves, which are young or damaged by insects, are infected by the species from a *Junctoriae* group. On the other hand, the primary infection of quince leaves takes place just after buds opening, that is before florescens, unlike other plants. The pathogen penetrates the flowers, fruits and twings (Siegfried et al., 1990; Rüegg and Siegfried, 1992). The infection of leaves of *Rosaceae* family plants may be heavy, when the mycelium growth occurs from flowers to twigs (Wormald, 1954; Byrde and Willetts, 1977; Batra, 1983; Siegfried et al., 1990). Various species of fungi, from *Disjunctoriae* group, caused the primary infection of leaves too. This

infection is caused by the ascospores. The dissemination at the ascospores is synchronized with the growth of leaves (Gjaerum, 1969; Batra, 1983).

The brown rot and cancers of twigs caused by *Monilia* spp. occurred more frequently than other symptoms of this disease (Byrde and Willetts, 1977; Siegfried et al., 1990; Rüegg and Siegfried, 1992; Rüegg, 1995). The progressive wilt of cuticle (epidermis) and bark cause the sinking of tissues, after that the wounds are formed in this place. Callus is sometimes formed on the margin of wounds and limits the future growth of fungi. Very often gum is observed on the infected twigs. It causes that this disease could be mistaken with the fire blight caused by *Erwinia amylovora* (Burr.) Winslow et al. (Siegfried et al., 1990). When the twigs are infected very heavily, all plant could die (Byrde and Willetts, 1977; Siegfried et al., 1990). Under favourable conditions the fungi formed conidiophores and conidia on the dead twigs of plants.

The brown rot fungi are pathogens reducing the fruit yield. Fruit rot is the most destructive form of the disease. *Monilia* spp. can infect fruit early in spring, just after blossom blight, and afterwards in other phases of developing plants. The mass infection of developing fruit is depended not only on the pathogen inoculum but on weather conditions, during the last two or three weeks before the harvest (Rüegg, 1995). Besides, the susceptibility of ripening fruits to the *Monilia* spp. is increased by biochemical transformations. This transformation causes the increase of sugar content, while the content of acids is lower (Byrde and Willetts, 1977; Willetts et al., 1977). Damage of cuticle caused by heavy rain, hail or insects facilitate the infection of especially soft pome and stones fruits (Siegfried et al., 1990; Rüegg and Siegfried, 1992). The infection of hazel fruits, which have rather hard perycarp is facilitated especially by insects (Moore, 1947). Under favourable conditions, the surface of rot fruits is covered with vegetative mycelium or with sporodochia. The sporodochia are arranged in concentric bands around the source of infection to give a characteristic appearance of the fungi from the *Monilia* genus. Under unfavourable conditions, the sporodochia are not formed, and fruit becomes discoloured, dried, wrinkled and mummies are formed in this way. Mummies hang on branches of trees, or alternatively, mummiefied fruits fall to the ground, where they remain throughout the winter months (Byrde and Willetts, 1977; Siegfried et al., 1990; Rüegg and Siegfried, 1992). The black rot of apple is a characteristic disease symptom caused by the fungi from the genus *Monilia* too. The infected fruits are brown at first but they become black as the rot progresses. The skin of the apple takes on a shiny appearance, the surface is smooth, and mycelium does not form on it. Such fruits appear during storage (Wormald, 1954; Byrde and Willetts, 1977 acc. to quoted literature).

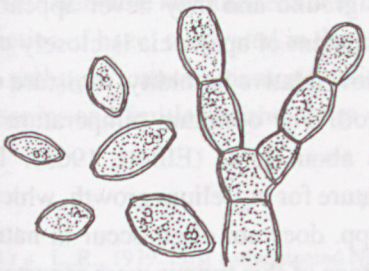

Fig. 3. Conidiophore and conidia of *Monilia coryli* Schellenb. (x 200, from Zalewska, 1998)

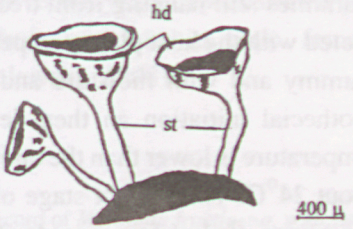

Fig. 4. The perfect stage of the *Monilia* spp., mature apothecia showing head (hd) and stipe (st) (from Byrde and Willetts, 1977)

The brown rot fungi are able to survive in fruit mummies or in infected tissues of trees and shrubs: in peduncles and twig blight and cancers (Byrde and Willetts, 1977; Siegfried et al., 1990; Rüegg, 1995).

The conidian stage (sporodochia) develops on the surface of infected organs in the spring. Macroconidia are the main propagules of the fungi from the genus of *Monilia - Junctoriae* group. The macroconidium is one-celled , smooth, ellipsoid, ovoid or lemon – shaped and colourless when viewed in the light of a microscope (Fig. 3). The size of conidial is variable, it is characteristic of each species, and is influenced by environmental conditions, time and surface when the spordochia are formed (Byrde and Willetts, 1977; Zalewska, 1998).

Morphological structures formed by fungi causing brown rot include microconidia and sclerotia, which are produced on the surface of dropped mummies. The sclerotia are produced in fruit mummies, especially of susceptible host plants, in consequence of the accumulation of inhibitory substances which inhibit mycelial growth in the fruit. This morphological structure is named as pseudosclerotium by some authors, because of the occurrence of host cells in the sclerotium (Honey, 1928; Byrde and Willetts, 1977). Sclerotia do not often form on the agar culture. The factors which cause the formation of sclerotia are not well understood. Some conditions influencing this phenomena are physical and chemical processes, sufficient moisture, temperature or light, and uneven nutrient distribution in the substrate (Byrde and Willetts, 1977; Zalewska, 1998). The sclerotia of the fungi from the

genus *Monilia* obtained from the natural substrate and from agar medium and sclerotia of *Botrytis cinerea* are very similar (Willetts, 1969; Machowicz-Stefaniak, 1998; Zalewska, 1998).

The apothecium is the perfect stage of the fungi from the genus *Monilinia* (Fig. 4). Apothecia develop on fruit mummies on the ground and they never appear on mummies still hanging from trees. The development of apothecia is closely connected with the host plant, temperature, light, low relative humidity, moisture of a mummy and with moisture and pH of the soil. The optimum temperature for apothecial initiation an then development is about 15°C (Elliott, 1965). This temperature is lower than the optimum temperature for mycelium growth, which is about 24°C. The perfect stage of *Monilinia* spp. does not often occur in natural conditions. Only a few records of the perfect stage of this fungus were reported in North America and Australia. The apothecia of *Monilinia* spp. were found in Holland in 1912, in Italy in 1920 and in Russia in 1931 (Byrde and Willetts, 1977 acc. to quoted literature). In Japan numerous ascospores were produced on plants from *Ericaceae* family by nine species of *Monilia* (Batra, 1983). The apothecium has light brown, smooth, slender stips and discs, which are about 1.5 cm across. The inside of the disc is lined with a layer of parallel elongated cells which have ascospores (Wormald, 1954).

The pectolityc enzymes exudated by *Monilia* spp. are significant at the first phase of the brown rot. Then the wall-degrading enzymes: cellulasa, xylanasa, polygalacturonasa, pectin esterasa, pectin lyasa, α-L arabinofuranosa, β-galactosidasa and others are activated (Schellenberg, 1908; Byrde and Willetts, 1977; Willetts et al., 1977; Sharma and Kaul, 1994).

Sometimes the *Monilia* spp. could cause dry mummification of fruits. This mummification results from a comparatively early inhibition of pectolytic activity by oxidized polyphenolic fruit constituents in diseased fruits. The ethylen, which is produced in fruits when they are stored, stimulates the disease process.

Besides the species infecting plants of various taxonomic units, the fungi of *Monilia* genus also include those which infect only one specific species. Leaves and fruits of hawthorn are infected by *Monilia johnsonii* (Ellis and Everhart) Honey. The decay of tip twigs and mummification of blueberry fruits (*Vaccinium vitis-idaea)* are caused by *Monilinia urnula* (Weinmann) Whetzel. The perfect and conidian stages are produced on one plant by this species (Gjaerum, 1969; Batra, 1983).

There are also species which need two species of plant for the full life cycle. These are *M. ledi* (Nowaschin) Whetzel and *M. rhododendri* (Fischer) Whetzel. The conidian stage is produced on blueberry (*Vaccinium* spp.) by this species, whereas ascospores are produced on the fruit of ledum (*Ledum*) and on the fruit of

rhododendron (*Rhododendron*) by *M. ledi* and *M. rhododendri* ,respectively. The perfect stage of this fungi is developed early spring and ascospores infect the shoots of various species of blueberry (*Vaccinium*)(Gjaerum, 1969; Byrde and Willetts, 1977; Batra, 1983; Willetts and Harada, 1984).

Considerable harmfulness of *Monilia coryli* Schellenb. was shown for different varieties of hazel cultivated in the Lublin region in recent years. It was shown that the pathogen causes mummification of hazel fruits and inhabits male, female blossoms and fruitlets without any symptoms (Zalewska, 1998).

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STRESZCZENIE

W pracy omówiono cechy morfologiczne, biologię i szkodliwość grzybów z rodzaju *Monilia*, powodujących brunatną zgniliznę roślin owocowych. W obrębie *Monilia* spp. poznano około 30 gatunków, wśród których największe znaczenie gospodarcze w klimacie umiarkowanym mają *Monilia fructigena* (Pers. ex Pers.) Pers. ex Stendel, *Monilia laxa* (Ehrenb. Ex Pers.) Sacc. et Vogl. i *Monilia coryli* Schellenb. Porażają one głównie kwiatostany, owoce, liście i młode pędy roślin z rodziny *Rosaceae*: jabłoń, grusza, brzoskwinia, nektarynka, wiśnia, czereśnia, śliwa i pigwa. W cyklu rozwojowym tych grzybów dominuje stadium konidialne rozwijające się na porażonych organach, zwłaszcza na zmumifikowanych owocach. Na roślinach z rodziny *Ericaceae* występują gatunki, które oprócz stadium konidialnego wytwarzają powszechnie stadium workowe. Należą do nich między innymi *Monilinia urnula* (Weinmann) Whetzel, *Monilinia ledi* (Nowaschin) Whetzel i *Monilinia rhododendrii* (Fischer), opisane w Japonii. Wśród *Monilia* spp. występuje zdolność do porażania różnych gatunków roślin lub tylko jednego gatunku. Natomiast *M. ledi* i *M. rhododendrii* wymagają dwu różnych gatunków roślin żywicielskich do pełnego cyklu życiowego.

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