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Fruit injury in organic fruit production and its relationship to brown rot caused by *Monilinia* spp.

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Summary: In a two-year Hungarian study, the temporal progress of brown rot incidence and various injury types were studied in organic fruit orchards and the relationship between brown rot and injury types was determined. Results showed that brown rot reached an almost 20% incidence level in both years. Total injury incidence reached up to 5.3 and 19.8% in the two years. In all cases, insect injury incidence was the highest among injury types in most assessment dates. Incidence levels of other injury types (bird injury, mechanical injury and other injury) began to increase, but none of those reached levels >4%. Pearson's correlation coefficients showed that brown rot incidence correlated significantly with the incidence of insect injury. In addition, brown rot incidence and the incidence levels of bird injuries was also significantly correlated. High injury and brown rot incidence levels suggest further improvements on organic fruit protection.

Keywords: *fruit injury, brown rot, insect injury, bird injury, mechanical injury, organic, apple*

Introduction

During the season fruit injury can occur due to various factors, such as codling moth (*Cydia pomonella*) (Xu et al., 2001, Holb, 2003, 2004), oriental fruit moth (*Cydia molesta*) (14), tortrix moths (*Pandemis* and *Adoxophyes* spp.) (Xu et al., 2001), various species of wasps (Lack, 1989), starlings (*Sturnus vulgaris*), blackbirds (*Turdus merula*), and crows (*Corvus* spp.) (Mitterling, 1965, Tobin et al., 1989, Leeuwen et al., 2000, Xu et al., 2001); growth cracks (Xu et al., 2001), and mechanical injury (Xu et al., 2001). Relative importance of injury factor depends on the efficacy of disease and pest management programs. For example, in an organic orchard with a less effective pest management program (Rader et al., 1985; IFOAM, 2000), the importance of the various wounding agents differred markedly from conventional or integrated productions (Holb and Scherm, 2008).

Monilinia fructigena is an important fungal pathogen causing pre- and postharvest fruit rot in pome fruits (Byrde and Willetts, 1977, Holb, 2006, 2009). The pathogen belongs to the group of brown rot fungi which includes two other important species, *M. laxa* and *M. fructicola*. *M. fructigena*, in contrast to *M. laxa* or *M. fructicola*, can infect fruit through fresh or partially healed wounds (Byrde and Willetts, 1977, Xu et al., 2000). So it may egsist a strong relationship between fruit injury and *Monilinia* infection of fruits, especially in organic orchards.

The objectives of this study were to study the temporal progress of brown rot incidence and various injury types in organic fruit orchards and to determine the relationship between brown rot and injury types.

Materials and methods

Orchard sites

In 2014 and 2015, a study was conducted in an organic apple orchard in eastern Hungary. The orchard with soil type of brown forest soil was located in Eperjeske. The orchard consisted of eight apple cultivars, with a distance between rows of 5 m and within a row of 2 m. Trees were planted in 1996 on M26 rootstock. Trees were pruned to spindle shape. Organic production guidelines have been applied since the planting of the orchard and all sprays were applied with a Kertitox 2000 spray machine.

Brown rot and injury assessments

Five trees were assessed every 2-week period from end May until September. Fifty randomly selected fruits were observed on the trees. Mean incidence of brown rot was calculated from the data for each assessment date. All fruits used for brown rot assessment were also assessed for injury. Four injury types were assessed: (i) insect injury, (ii) bird injury; (iii) mechanical injury, and (iv) other injuries. Mean incidence of each injury types was calculated from the data for each assessment date.

Data analyses

Brown rot and injury incidence data were plotted over time to obtain progress curves for each year. Pearson's correlation coefficients were calculated between brown

rot incidence and the various injury incidence levels. This analysis was done separately for years. Genstat 5 Release 4.1 was used for statistical procedure. Linear regression functions were also fitted to determine realtionship between injury incidence and insect injuries.

Results

Brown rot and injury progress

Brown rot developed slowly and reached an almost 20% incidence level in both years (Figures 1 and 2). First brown rot sypmtoms on fruit was assessed in June or July. Total injury incidence reached up to 5.3 and 19.8 % in the two years. In all cases, insect injury incidence was the highest among injury types in all assessment dates. Insect injury incidence followed the progress curve of and brown rot incidence. Incidence levels of other injury types began to increase, but none of those reached levels >4% (Figures 1 and 2). Insect injury was the leading injury type reaching more than 65% contribution to Monilinia infected fruit.

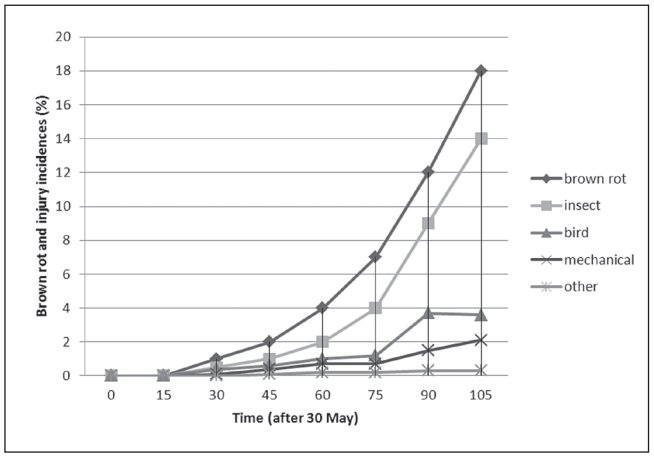

Figure 1. Incidence of brown rot and injry types from 30 May until September (Eperjeske, Hungary, 2014)

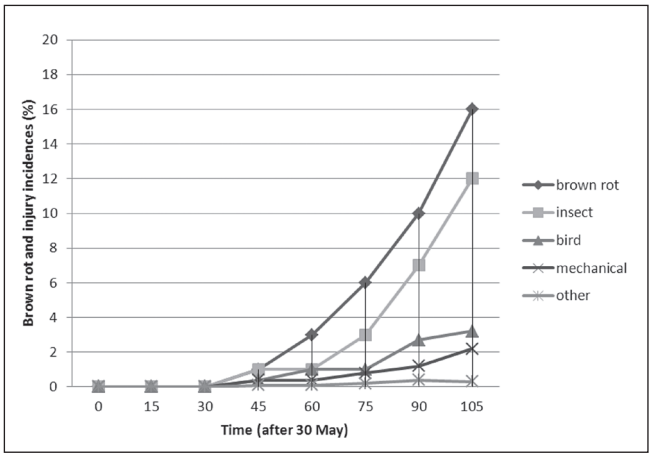

Figure 2. Incidence of brown rot and injry types from 30 May until September (Eperjeske, Hungary, 2015).

Relationships between brown rot and injury types

Pearson's correlation coefficients showed that brown rot incidence correlated significantly with the incidence of insect injury (Table 1). In addition, brown rot incidence and the incidence levels of bird injuries was also significantly correlated. Insect injury had the highest correlation coefficients with brown rot incidence (Table 1).

Table 1. Correlation coefficients (*r*) and probability levels (*P*) between brown rot incidence and various injury types in organic apple orchards (Eperjeske, Hungary, 2014–2015).

Associations	2014		2015	
	r (*P*)		*r* (*P*)	
Brown rot vs. insect injury	0.911	(0.0052)	0.899	(0.0111)
Brown rot vs. bird injury	0.713	(0.0411)	0.701	(0.0467)
Brown rot vs. mechanical injury	0.135	(0.8543)	0.109	(0.8986)

Linear regression analysis between these two variables showed that there was a highly significant ($P < 0.001$) linear relationship between brown rot incidence and insect injury incidence with high R^2 values (Figure 3).

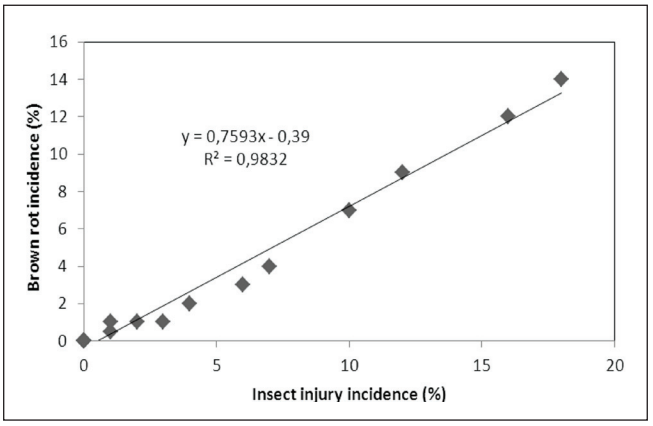

Figure 3. Relationships between overall brown rot incidence and overall insect injury incidence (Eperjeske, Hungary, 2014 and 2015)

Discussion

It is well-known that fruit injury is related to brown rot of apple, but only few studies demonstrated season-long progress data on brown rot and various injury types including relationships among injury types and brown rot development.

Similarly to study of Holb and Scherm (2008), almost all injured fruit was infected with *Monilinia* spp. in this study. This suggest that fruit prevention against injury is essential in brown rot management (Lack, 1989; Holb, 2003, Xu et al., 2001).

Insect injury was the leading injury factor in our study suggesting that insect control in orgainc fruit orchards is an essential factor to reduce *Monilinia* infection. Holb and

Scherm (2008) suggested that this insect control had to focus on codling moth control as majority of insect injury was caused by *Cydia pomonella* in apple or by other moth pests in fruit orchards.

Bird and mechanical injury had lower roles in fruit injury compared to previous studies prepared in Western European countries (e.g. Mitterling, 1965, Tobin et al., 1989, Leeuwen et al., 2000, Xu et al., 2001). This was probably due to more dry conditions in Central Europe and the investigated cultivar were more susceptible to growth crack than cultivars grown here.

Our results clearly showed that an organic orchard was highly depenedent on efficacy of plant protection products. In case of brown rot, both insect and fungal disease controls play an essential role in brown rot management efficacy. Against insects including codling moth, *Bacillus thuringiensis*, granulosis viruses, rotenone, and summer oils are recommended in fruit orchards (Altieri et al., 1983, Wearing, 1993, IFOAM, 2000). For disease management, copper and sulphur as well as some mineral or plant compounds are approved for orchard spray applications. Seeing high brown rot incidence level at harvest, an improtant task is to further improve both insect and frungal disease managements in organic fruit production. A succesful example of this was a development of brown rot management strategy in organic apple production by Holb et al. (2011).

Acknowledgements

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