SCAB CONTROL MANAGEMENT STRATEGIES IN ENVIRONMENTALLY-BENIGN APPLE PRODUCTION SYSTEMS

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Abstract

In this short review, current scab management strategies are interpreted from the aspect of environmentally-benign production. The basic features of plant protection in integrated and organic apple production systems will be shown and their relationships with apple scab epidemiology and management will be presented. Then, all types of control measures such as mechanical, agrotechnical, biological, biotechnical and chemical control will be demonstrated shortly which are approved in integrated and/or in organic scab management programs. In the integrated production system, special attention will be paid to current disease warning systems which will be related to cultivar susceptibility, spraying techniques and timing of spray applications. Finally, future aspects and possible improvements on scab control strategies are interpreted.

Key words: apple scab, Venturia inaequalis, disease management, integrated apple, organic apple, sanitation, scab warning system

Introduction

Both environmental and food-safety concerns have generated a great interest in integrated pest management (Penrose et al. 1994, Cooley and Autio 1997) which is a decision-based process involving coordinated use of multiple tactics for optimizing the control of all classes of pests (insects, pathogens, weeds, vertebrates) in an ecologically and economically sound manner (Prokopy 2003). Biologically/culturally-based tactics reduce pesticide use through alternative practices that replace some, or even all, of the pesticides needed to control a pest. The greater the shift from traditional, chemically-based tactics to biologically/culturally-based tactics,
coupled with strategies that integrate pest management practices, the more advanced the IPM program (MacHardy 2000). Although integrated approach has reduced pesticide use in apple production, there is increasing pressure for further reductions for all classes of pesticides (Zalom 1993, Penrose et al. 1994, 1996, Cooley and Autio 1997, MacHardy 2000, Prokopy 2003). Fungicides comprise the greater proportion of pesticides applied to apples (Bower et al. 1993, Penrose 1995, Holb et al. 2005 b) and the largest proportion of fungicide sprays are applied to control apple scab, caused by *Venturia inaequalis* (MacHardy 1996, 2000, MacHardy et al. 2001). Scab management involves 6–16 fungicide treatments per season, depending on the weather conditions and disease pressure (Köller et al. 1991, Van der Scheer 1992, Beresford and Manktelow 1994, Penrose and Dodds 1994, Manktelow et al. 1996, MacHardy 1996, 2000, MacHardy et al. 2001, Carisse and Dewdney 2002, Holb et al. 2003, 2004, 2005 b, Vincent et al. 2004), which represent up to 90% of the annual fungicide costs in apple production. Therefore, an important objective in integrated orchard management programs is the reduction of primary scab inoculum in order to lessen fungicide use during the growing season (MacHardy 1996).

### Advanced scab management strategies in integrated apple production

The basic disease management practices are cultural practices including cultivar resistance, mechanical, biological and chemical control. Cultivars with partial resistance to scab are known, and there is a potential to reduce the fungicide dose to control scab in orchards planted with these cultivars (Blaise and Gessler 1994). Some of those scab-resistant cultivars are available, but due to their low or middle levels of fruit quality standards, they have not been widely planted or accepted in integrated apple orchards. Cultivars, throughout the selection of several genotypes in orchard plantings, are also used as a management practice. Different genotypes planted in mixed cultivar stands seem to effectively reduce incidence and severity of plant diseases (Mundt 2002, Mundt et al. 2002), including apple scab (Masny and Bielenin 2001, Meszka et al. 2002). Unfortunately, biological products against apple scab are not available; however, there are some good experimental results in this field with *Athelia bombacina* and *Microsphaeropsis ochracea* species (Heye and Andrews 1983, Carisse et al. 2000, Vincent et al. 2004). Nowadays, chemical control relies mainly on DMI and strobilurin fungicides (Köller et al. 1991, Carisse and Pelletier 1994, Köller and Wilcox 2000, Broniarek-Niemiec et al. 2002, Broniarek-Niemiec and Bielenin 2003, Köller et al. 2005). However, there are several examples of reduced activity of these fungicides against apple scab (Parisi et al. 1994, Shirane et al. 1996, Köller et al. 1997, 2004, Köller and Wilcox 2001). This called for developing resistance management strategies, which were critically evaluated and improved by the study of Köller and Wilcox (1999). For the last two decades, great attention has been paid to sanitation practices against apple...

In most advanced scab management strategies, scab warning models are used to control the disease. These models are incorporated into decision-making systems and used as a computer software program such as APPLES CAB (Blaise et al. 1987), SEEM simulator (Seem et al. 1989), VENTEM™ (Butt et al. 1992), RIMpro (Trapman 1994), and WELTE (Aalbers et al. 1998). Their main purpose is to optimize fungicide use by better timings of fungicide sprays. In Figure 1, the fundamentals of these computer programs and their relationships in an advanced scab management are shown. The figure explains that sanitation practices and biological control are used to reduce disease inoculum and scab epidemics. Information on this procedure is incorporated into pathogen submodels of scab warning systems. Computer models calculate the severity of scab infection depending on cultivar resistance, weather variables and information obtained from the pathogen submodels. Then the decision-making module of the computer models gives suggestion on fungicide selection and/or possible fungicide reduction.

The typical scab computer program is centered on a warning system consisting of (1) weather data collecting equipment from which infection periods (mainly Mills’ scab infection periods) can be predicted, (2) strategies to apply fungicides based on the predicted “severity” of the infection periods, and (3) several possibilities (e.g., telephone, printed page, satellite) to notify the grower as quickly as possible of current infection conditions (Fig. 2). This type of scab warning program is designed to improve the efficiency of scheduling fungicides.

The most advanced integrated scab management program has been developed in the United States (MacHardy 1993, 1996, 2000, Sutton et al. 2000). In addition
to the above warning system, two new strategies were developed. These systems were based on the pathogen spores (ascospores) that cause the initial infections, which was measured in autumn as the number of scabbed lesions on 600 shoots. The two systems are as follows:

1) a “scab-risk” action threshold that distinguishes “low-risk”, “moderate-risk” and “high-risk” orchards. The developed system was able to distinguish “high-risk” orchards from “low-risk” orchards which could allow to use tactics for the reduction of early season fungicide dose and application numbers. This resulted in lower fungicide costs and a better application of fungicide-resistance strategies (Fig. 3);

2) a “sanitation” action threshold which could enable the grower to reduce scab-risk action threshold by using orchard sanitation (leaf shredding and urea application in autumn or early spring). The use of sanitation reduces the potential ascospore dose (PAD) and allows a “moderate-risk” orchard to be considered as a “low-risk” orchard, and the grower can use the tactics recommended for a “low-risk” orchard (Fig. 4).
The “sanitation” action threshold improves fungicide efficiency by (1) reducing the fungicide dose in a “low-risk” orchard, (2) employing sanitation practices to economic advantage in a “moderate-risk” orchard, and (3) alerting the grower to prepare for a full-season fungicide schedule in a “high-risk” orchard.

Newly developed scab management decision system in organic apple production

In organic production, the use of synthetic products is not permitted; therefore, scab control in organic apple production relies on copper and sulphur fungicides. Efficacy of these fungicides is lower compared to synthetic fungicides used in integrated apple production. Therefore, scab epidemics are much more severe in organic apple production compared to the integrated one. Moreover, an effective bioproduct against apple scab has not been commercialized yet and the most effective fungicide component (copper) is banned in several Western-European countries, which calls for new alternatives against apple scab. In recent studies (Holb et al. 2004, 2005 a), the role of overwintered conidia was proved in early scab epidemics in organic apple orchards and curative efficacy of lime sulphur against apple scab was verified under field conditions (Holb et al. 2003). These two main findings allowed to construct a theoretical scab warning model against apple scab in organic apple production (Holb et al. 2005 b). The structure of the model is shown in Figure 5. In this model three parameters should be incorporated: 1) $Y_{75}$ as the time for bud closure for cv. ‘Jonagold’, 2) previous year autumn scab incidence (40%) as minimum threshold criterion for overwintering conidia, and 3)
minimum values of AUDPC (Area Under the Disease Progress Curve) and theta (the absolute rate of disease progress) for calculating the present year epidemic intensity until the tree reaches day $Y_{75}$. The effect of spray application can be modelled based on the above factors in order to suppress conidial entrapment as much as possible. If computer calculated AUDPC and theta are lower than the minimum and until mid-October the orchard has a lower level of scab incidence, less than 40%, then no further control is needed against overwintering conidia. However, if computer calculated AUDPC and theta are higher than the minimum and autumn scab incidence is between 40–60% until mid-October then an additional copper or lime sulphur spray should be applied at bud burst next spring. And finally if computer calculated AUDPCs and theta are higher than the minimum and autumn scab incidence is above 60% until mid-October then an additional early fungicide spray combined with winter pruning should be applied in order to suppress infections by overwintered conidia.

**Concluding remark**

In integrated apple orchards, the combination of chemical, cultural and biological control methods in scab management strategies is only the first level of IPM in the Integrated Fruit Protection (IFP). As IPM has four levels (Prokopy 1993, Prokopy et al. 1994, MacHardy 2000), the future objective is to integrate the above scab management strategies into the further levels of IPM in order to harmonise scab management strategies with control of other diseases and pests and with other horticultural management practices such as pruning, irrigation and nutrition supply.

In organic apple orchards, there are still several efficacy problems in the level of scab management strategies too, so further improvements of this level are needed for integrating chemical, cultural and biological control methods in an effective way.

**Literature**


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