Comparison of Scab Warning Systems in Integrated Apple Production

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SUMMARY

In the present study, the suggestions for infection risk and sprays of the most frequently used PC-based scab warning systems (RIMpro and WELTE) and the conventionally used Mills table as a reference were compared in integrated apple production. The efficacy of the spraying programs based on the three different warning systems was evaluated by assessment of apple scab incidences during primary infection periods.

13 and 11 Mills infection periods were detected in 2000 and 2001, respectively, during primary infection periods (from 15 March until 5 June). Taking into consideration the heaviness of Mills infection periods, 11 and 9 sprays were applied in 2000 and 2001, respectively. The two PC-based scab warning systems detected 1-4 less infection periods and suggested 1-3 less sprayings compared to the numbers of infection periods and sprays according to the Mills table. Our results proved that the 9-11 sprays according to the Mills table could be reduced to 7-9 sprays by RIMpro scab warning systems which did not reduce the efficacy and did not increase the symptoms of leaf and fruit scab significantly. The WELTE scab warning systems detected generally one or two more infection periods and suggested one additional spray compared to RIMpro warnings and sprays.

INTRODUCTION

The present trend in crop protection limits the use chemicals by integrating host resistance with agricultural practices and nonchemical applications, and by applying chemicals only when strictly necessary. This approach implies an increase in the level of complexity, and it also imposes on farmers the need for wider and deeper knowledge. At present, warning systems based on simulation models seem to be the best strategy for achieving these goals. They are designated in such a way as to provide farmers with useful information at the right time. Therefore, warning systems are a useful tool in decision-making.

During recent years, warning systems for plant protection have increased in importance (Sigvald, 1997; Mangstl et al., 1998), especially in the context of ‘integrated plant production’ (Berrie et al., 1996). The first simulation models were used for control of potato late blight and soon after for control of apple scab. The first scab simulation models were EPIVEN by Kranz et al. (1973), VISIM by Seem and Sutton (unpublished), and unnamed models by Analytis (1973, 1979). In these simulation models, weather parameters and the amount of inoculum were included in order to forecast disease infection and threshold levels. In the later published models, all major components of the apple scab control were incorporated, including fungicide residue, fungicide efficacy, fungicide activity (protectant, curative, and eradicant activity) pathogen resistance to fungicides, amount of inoculum, and economics. According to these components, models such as APPLESCAB (Blaise et al., 1987) and the SEEM simulator (Seem et al., 1989) consist of several submodels: weather, tree growth, disease development, fungicide residue, management and economics. Nowadays, models have been improved in order to incorporate them into the modern integrated fruit production system. These newly developed PC-based simulators were: VENTEM^{TM}-et (Butt et al., 1992), RIMpro (Trapman, 1993), METY (Boshuisen and Verheyden, 1994), and WELTE (Aalbers et al., 1998). At present, these are the most frequently used PC-based scab warning systems in integrated apple production in Western European countries.

The aim of this paper were (i) to characterise shortly the RIMpro and WELTE PC-based scab warning systems and (ii) to compare the efficacy of these scab warning systems with the Mills table during ascospore infection periods.

MATERIALS AND METHODS

Orchard site and field design

Examinations were carried out in an experimental orchard of the Wageningen University, Institute of Applied Plant Research. In the orchard, cultivar Jonagold trees were planted at a spacing of 3 x 1.25 m and grafted on M9 rootstocks. The orchard has been treated according to the principles of the Dutch Integrated Fruit Production (MBT). Regulations of disease and pest control have been renewed annually in both production systems. Spray schedules have been applied since 1996 (year of settlement).

For the RIMpro, the WELTE scab warning systems and the Mills table, sprays were applied in four treatment replicates according to prediction of scab warning systems in 2000 and 2001 during the primary scab infection periods. Area of each replicate was 100 m^2. Replicates were randomised in a block system in the field. Sprays were applied with an axial- ventilatorred spraying machine (manufacturer EMPASS 2000, Veenendaal, The Netherlands) with a ceramic hollow cone at 1.1-1.2 MPa with a volume of 600 l ha^{-1}. Applied product was 0.05% Chorus (cyprodinil, 50%, Syngenta Crop Production BV, The Netherlands) until 20 April, then from 20 April until the beginning of June, 0.075% Score 10 WP (difenoconazole, 10%, Syngenta Crop Production BV, The Netherlands) was applied.

Scab warning

The disease prediction of two PC-based scab warning systems (RIMpro and WELTE) and the Mills table were compared. The PC-based systems have the following components: (i) a meteorological station with sensors, (ii) a PC, installed with simulation models, (iii) RAM cards, modems. In our experiments, weather parameters were detected with a METY meteorological station (Bodata, Dortrecht, The Netherlands). Data were collected on RAM cards and transported to a PC through a modem every 12 minutes. Collected data were: minimum, maximum and mean temperature (°C), relative humidity (%), rainfall (mm), and leaf wetness (hour). For both PC-based warning systems, amount of primer inoculum, tree phenological stage and characters of fungicides were determined. All data sets were loaded into specific submodels of each PC-based scab warning systems.

In the Mills method, Mills infection periods were calculated according to Mills and LaPlante (1951). Sprays were applied according to the heaviness of infection periods (heavy, moderate, and low).

In the RIMpro scab warning system, the system scores and presents detailed parameters on developing and released ascospores, leaf wetness, rainfall and threshold for a final fungicide application. The system calculates relative infection measures (RIM), which is the simulated number of spores on lesions that infect the host tissues. In our experiment, fungicides were applied when RIM was above the critical threshold (300) according to Trapman (1994).

In the WELTE scab warning system, climatological and several biological factors are integrated into the model in order to calculate infection risk. A threshold value of 100 implies a need for treatment with a curative fungicide. Moreover, the system also provides different infection risks (Hindorf et al., 2000), such as low (30), moderate (60) and severe (100). In our experiments, fungicide sprays were applied according to different infection risks of Hindorf et al. (2000).

Assessment of scab symptoms

Incidence of scab symptoms was assessed in mid-May and mid-June in both years. In May, scab incidence of 4 x 100 leaf clusters was determined in each treatment replicate. In June, scab incidences of 6 x 50 grown leaves and of 5 x 20 fruits were assessed in each treatment replicate.

RESULTS

Forecasting with Mills table and RIMpro and WELTE scab warning systems

Weather conditions were favourable in both years for the development of apple scab in the primary infection periods. In the years of 2000 and 2001, 13 (5 heavy, 6 moderate and 2 low) and 11 (6 heavy, 3 moderate and 2 low) Mills infection periods could be detected, respectively, during the primary scab infection periods (from 15 March until 5 June) (Figure *1A and 2A*).

The number of infection risks detected by the RIMpro scab warning system was smaller than that of the Mills table's data (*Figure 1 and 2*). The RIMpro detected 7 and 9 infection risks between 15 March and 5 June in 2000 and 2001, respectively (*Figure 1B and 2B*).

The WELTE scab warning system detected 10 (7 heavy, 2 moderate and 1 low) and 10 (6 heavy, 2 moderate and 2 low) infection risks in 2000 and 2001, respectively (*Figure 1C and 2C*).

Decision on control using Mills table, the RIMpro and the WELTE scab warning systems

Mills table

Sprays were applied in each infection period after 20 March if the period between the time of infection and the last spraying exceeded 72 hours. Accordingly, we applied 11 and 9 sprays in 2000 and 2001, respectively (*Figure 1A and 2A*). Assessments made in mid-May showed that primary leaf clusters were not infected in the examined years (*Figure 3*). Assessments in June also indicated excellent control, leaf incidence was below 4% and fruit incidence was below 1.5%.

RIMpro scab warning system

The number of sprays applied after 20 March was 7 and 8 in 2000 and 2001, respectively (*Figure 1B and 2B*), which resulted in a significant decrease in the number of sprays compared to the suggestions of the Mills table. However, leaf incidence increased significantly on the RIMpro plots compared to the data of scab incidence on the plots of Mills table (*Figure 3*).

WELTE scab warning system

The number of sprays was 8 in both year (*Figure 1C and 2C*). The control efficacy of WELTE was similar to that of RIMpro. Both leaf and fruit incidences were higher than in the case of control based on Mills table, however, no significant difference was detectable (*Figure 3*).

DISCUSSION

Our results demonstrated that the use of PC-based scab warning systems is a valuable tool in the control of apple scab. The traditional warnings based on the Mills table also save a significant number of sprayings compared to conventional spray schedules. The present study showed that PC-based scab warning systems can further decrease the number of sprays against apple scab during the primary infection season.

The number of sprays could be reduced to a greater extent according to the suggestions of RIMpro system. According to Trapman (1994), the number of sprays according to Mills table could be reduced from 9-10 to 5-6 using the RIMpro during the primary infection periods. Moreover, the efficacy of control decreases from 98% only to 96%. Our results showed that 9-11 sprays applied using Mills table could be reduced to 7-9 using RIMpro system without a significant decrease in the efficacy of control.

The WELTE forecasting system detected more infection periods and suggested one more sprays than the RIMpro system. According to Aalbers et al. (1998) and Creemers (1998) the WELTE scab warning system presents only those infection periods that are biologically important for the host-pathogen interaction. After introducing the model to the Netherlands, fungicide applications were reduced to 50% of the usual spray scheme in 8 out of 13 orchards. The effects on scab control were the same or better than in orchards receiving twice as much fungicide applications. However, the results of this study and of Holb et al. (2003) indicated that, the fungicide sprays could be reduced to 20-25% using WELTE scab warning system compared to spray applications using Mills table without a significant decrease in the efficacy of control.

In sum, the PC-based scab warning systems are of considerable help in the control of apple scab. However, attention must be paid to the fact that these systems can not replace the grower and these systems can be used successfully in orchards where other technological elements (e.g. irrigation, soil cultivation, pruning) are harmonised.

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Figure 1: **Infection risk data of Mills infection periods of apple scab (A) and PC-based scab warning systems (B and C) with spraying dates in 2000 (Randwijk, 15 March - 05 June)**

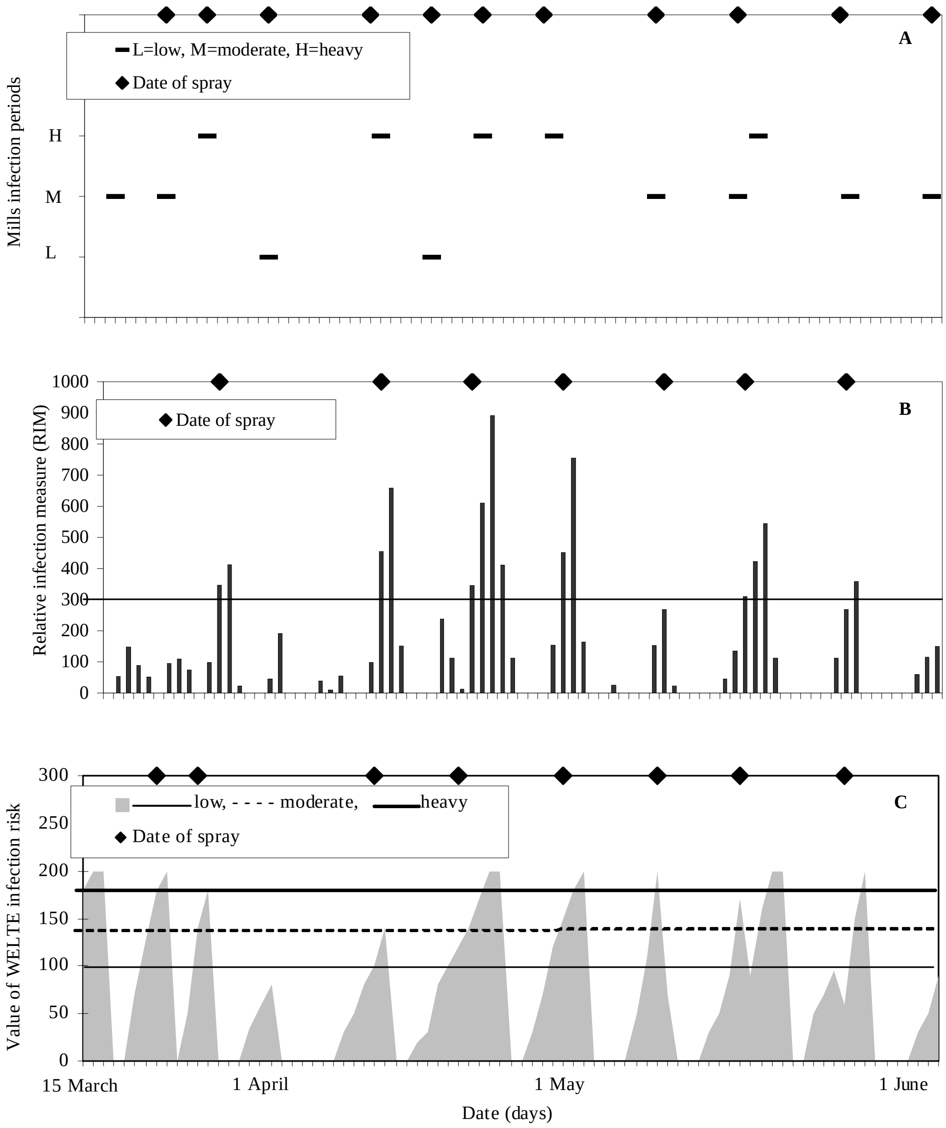


Figure 2: **Infection risk data of Mills infection periods of apple scab (A) and PC-based scab warning systems (B and C) with spraying dates in 2001 (Randwijk, 15 March - 05 June)**

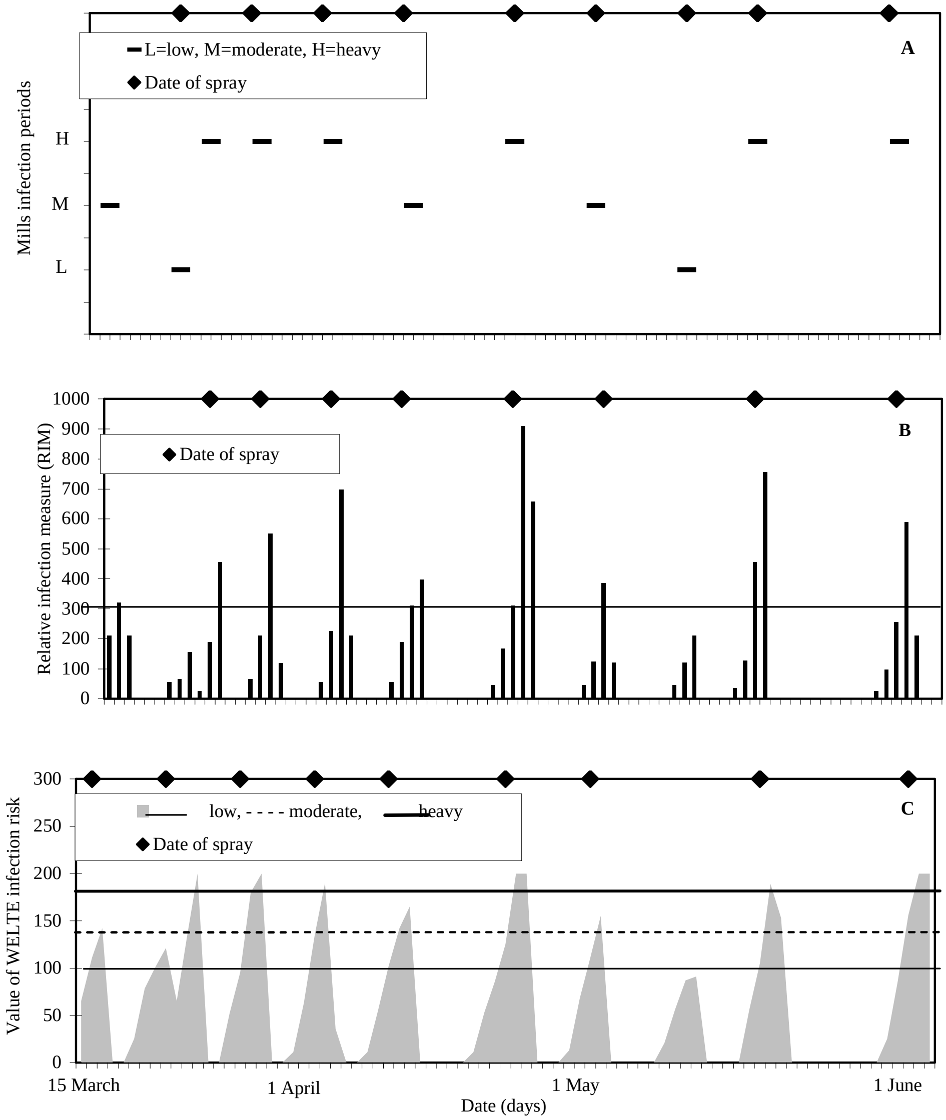
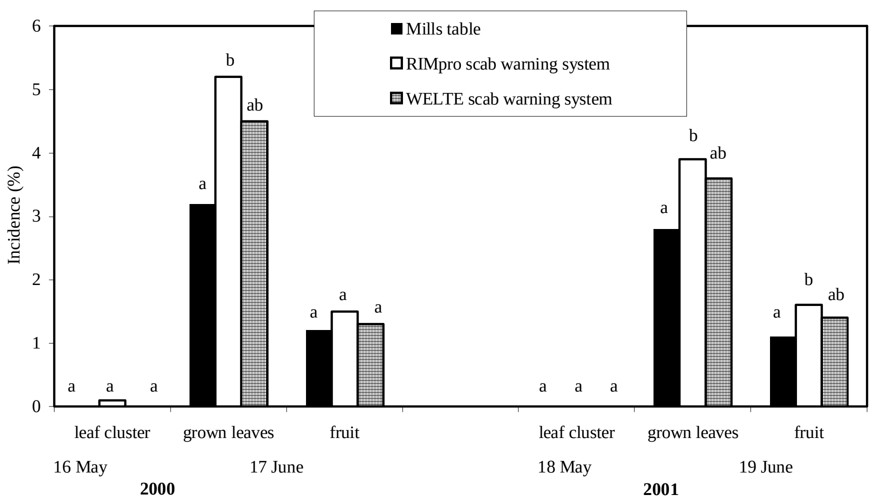


Figure 3: **Scab incidence (%) of primary leaves, grown leaves and fruits in treatments according to Mills table and PC-based warning systems (RIMpro and WELTE) on apple cultivar Jonagold**



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