Designing Strategies to Control Grey Mould in Strawberry Cultivation Using Decision Support Systems

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Abstract

Grey mould is one of the major diseases in strawberry cultivation. Fungicides to control *Botrytis cinerea* are applied frequently during flowering and sometimes at harvest. Reduction of pesticide use is one of the major aims of the Dutch government. Implementation of a Decision Support System (DSS) helps to achieve this goal. Pin point timing of fungicide application can possibly improve the efficacy of the treatment and reduce the number of spray applications. Predicted weather data to forecast infection risks are used by most DSS's. However in strawberry cultivation irrigation is a daily practice. The effect of overhead irrigation on the *Botrytis* infection risk is unknown. This is one of the reasons that strawberry growers infrequently use DSS's. Therefore adaptation of the model to agricultural management is necessary. Under low disease pressure DSS BoWaS controlled *Botrytis* fruit rot 62% better then routine applications of fungicides, with a 50% reduction of fungicide input. Adding an irrigation or a disease pressure sub-routine did not improve the model under low disease pressure. BoWaS based on disease pressure and weather resulted in better control of grey mould then the weather based BoWaS, under high disease pressure. Adding an irrigation rule did not improve the model further. Using the modified BoWaS reduced fungicide input with 36% compared to routine applications with the same efficacy.

INTRODUCTION

Grey mould caused by *Botrytis cinerea* is a major threat to strawberry cultivation in the open field. In conventional strawberry growing, under field conditions several spray applications with fungicides are necessary. Public concern on fungicide use requires reduction of pesticide input in horticultural cultivation.

The risk of infection of the flowers by *B. cinerea* depends on temperature and humidity (Bulger et al., 1997). At the optimum temperature short periods of leaf wetness are sufficient for the fungus to infect flowers. At sub-optimal temperatures prolonged leaf wetness periods are necessary for the fungus to infect strawberries. Pin point timing of fungicide application can possibly improve the efficacy of grey mould control and surely reduce the number of spray applications (Wander et al., 2004). Several Decision Support Systems (DSS) can be used as an aid to control grey mould. Predicted weather data, combined with measured weather data are used by most of these models to forecast *Botrytis* infection risk. However, in strawberry cultivation irrigation is an almost daily practice. The effect of overhead irrigation on the *Botrytis* infection risk is unknown. Generally DSS's predict the infection risk correctly. However sometimes the infection risk was not predicted but did occur. This is considered a risk since no fungicides are registered with a curative mode of action in the Netherlands. Furthermore disease pressure based on inoculum density is not incorporated in the models. These are reasons that Dutch strawberry growers infrequently use DSS's.

The aim of our research was to evaluate additional decision rules dealing with overhead irrigation and disease pressure.

MATERIALS AND METHODS

The experimental site was situated at Vredepeel on a sandy soil with 2.7% organic matter and a pH of 5.1. Cold stored waiting bed plants (cv. 'Elsanta') were planted on May 16th 2006 and May 9th 2007. Each net plot consisted of 20 strawberry plants, in a slightly elevated bed 150 cm wide with two rows 55 cm apart. Strawberry plants were planted 29 cm apart within rows.

To control *Botrytis* in strawberry, plants were sprayed with registered fungicides based on Decision Support Systems (Table 1). Strawberry Actual (treatment D) provided by WeerOnline BV and BoWaS (treatment C) provided by Agrovision BV, which was developed in cooperation with Applied Plant Research were used. Sub-routines dealing with the effect of overhead irrigation (C-I) and/or *Botrytis* disease pressure (C-DP1 and C-DP2) were made. The irrigation sub-routine assumes that farmers irrigate the crop daily, thus lengthening the leaf wetness period. An adjusted infection risk based on temperature and the modified leaf wetness period was then calculated. The disease pressure sub-routine (C-DP1) was calculated in 2006 by estimating sporulation density (modified from Sosa-Alvarez et al., 1995). With high sporulation density the spray interval was shortened with 1 or 2 days. The disease pressure sub-routine (C-DP2) was adjusted in 2007 and was based on previous and predicted infection risks. The spray interval could either be shortened by 3 days or lengthened by 2 days.

The fruits of 20 plants per plot were handpicked twice a week. Fruits were rated class 1, small (<28 mm), class 2, cracked or rotten. Fruits of each quality rating were weighed. Percentage fruit rot caused by *B. cinera* was calculated.

Data were analysed using Genstat 9.0 (Rothampstead Experimental Station, UK). Analysis of variance was applied to the cumulative incidence of *Botrytis* fruit rot and marketable yield. A randomised block design with three replicates was used.

RESULTS AND DISCUSSION

Marketable yield was significantly lower in the untreated control compared to treatments in which grey mould was controlled chemically, except for treatments C-DP1 and D in 2006 (Table 1).

The number of days with high infection risks during flowering and harvest were relatively low in 2006 and high in 2007. The calculated infection risk of both models is based on temperature and leaf wetness adjusted from a model developed in the USA (Bulger et al., 1987). Preharvest *Botrytis* fruit rot is caused by infection of flowers primarily (Jarvis and Borecka, 1968; Mertely et al., 2002). After bloom, environmental factors showed considerably less association with disease incidence than during blooming (Wilcox and Seem, 1994). Emphasis on control should focus on peak bloom (Mertely et al., 2002), a fact which is used in both DSS's. BoWaS uses a dynamic flowering model to calculate infection risk. The threshold for infection risk is lowest at full bloom and higher at the first week of flowering and during harvest. Strawberry Actual uses a fixed threshold of 5%, but infection risk calculated during flowering is higher than during harvest. Differences in susceptibility between flowers (flowering stages) and fruits (Jarvis and Borecka, 1968) are built into both DSS's.

The number of spray applications was less when DSS's were used compared to the number of spray applications according to routine. This is in accordance with Wander et al. (2004). Grey mould control using Strawberry Actual (D) and BoWaS including sub-routines (C-I; C-DP1), were comparable to routine application of fungicides in 2006. Grey mould control based on BoWaS (C) was significantly better than routine applications of fungicides in 2006. In a season with relatively few days with high infection risks fungicide input could be reduced with 50% and this coincided with a 62% better efficacy compared to routine application. However in a season with several days with high infection risk (2007) both BoWaS and Strawberry Actual were less effective than routine application in controlling grey mould. The number of sprays advised by BoWaS was 5 less than in the routine treatment. The spray interval advised or applied was too long under heavy disease pressure. Therefore the spray interval advised should be dependent on infection risk, time since the last fungicide application and disease pressure.

Including a sub-routine for the effect of disease pressure gave no better control of grey mould in 2006 than routine application and was less effective than BoWaS (C).

The number of days during flowering with *Botrytis* infection risk was higher in 2007 than in 2006. DP1 calculates the number of conidia produced within the plot based on weather conditions modified from Sosa Alvarez et al. (1995). Especially in annual waiting bed production of strawberry necrotic leaves are not significant sources of *B. cinerea* inoculum (Boff et al., 2001). Thus inoculum must be mainly produced outside the field proving a constant source of inoculum when circumstances are favourable. Furthermore Blanco et al. (2006) stated that airborne conidial density of *B. cinera* was not significantly correlated with *B. cinera* incidence in flowers. In contrast Xu et al.(2000) found that high inoculum density led to more infection. Sporulation and subsequent dispersal of *B. cinerea* is enhanced by rain fall (Sutton, 1990) and total wetness duration (Sosa-Alvarez et al., 1995), circumstances also favouring infection. It was argued that consecutive days of high infection risk are coincided with high disease pressure. There upon sub-routine C-DP2 was developed. *B. cinera* fruit rot incidence was significantly less after spraying fungicides according to sub-routine (C-DP2) than BoWaS (C), in 2007. Adding the irrigation rule (C-DP2+I) did not improve *B. cinerea* control. Sub-routine BoWaS-DP2 shortens the spray interval compared to the advised spray interval with BoWaS, under high disease pressure, which possibly explains the better efficacy. This finding is in accordance with the observation of Xu et al. (2000), who showed that models using inoculum and weather predicted infection are slightly better than weather based models.

More sprays were advised using the irrigation sub-routine than using BoWaS, but did not lead to a lower percentage of fruit rot in 2006 compared to routine applications (B) and higher than BoWaS (C). Obviously overhead irrigation was applied in the field, but not on a daily basis. Thus leading to an overestimation of the *Botrytis* infection risk in 2006. The sub-routine irrigation was only applied in combination with the sub-routine disease pressure in 2007. The combination of the disease pressure and irrigation rule (C-DP2+I) did not control grey mould better than treatment C-DP2. The effect of overhead irrigation on infection risk should be investigated in more detail.

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Tables

Table 1. The effect of fungicide applications based on Decision Support Systems compared to routine applications on *Botrytis* fruit rot at Vredepeel in 2006.

Code	Treatment	Number of sprays		Marketable Yield (g/pl)		*Botrytis* (%)	
		2006	2007	2006	2007	2006	2007
A	Untreated	0	0	571 b[1]	394 a	4.0 c	17.3 c
B	Routine application	6	11	699 a	534 bc	1.0 b	1.7 a
C	BoWaS	3	6	704 a	570 bcd	0.4 a	3.0 b
C-I	BoWaS + irrigation	6	-	680 a	-	0.9 b	-
C-DP1	BoWaS + Dis. Pres. 1	4	-	633 ab	-	1.2 b	-
C-I+DP2	BoWaS + Irrigation + Dis. Pres. 2	-	9	-	580 cd	-	1.9 a
C-DP2	BoWaS + Dis Pres. 2	-	7	-	576 cd	-	1.7 a
D	Strawberry Actual	6	6	629 ab	520 b	1.0 b	4.4 b

[1] Values followed by different characters are significantly different (P=0.05).