Possibilities of Strawberry Integrated Disease Management in Different Cultivation Systems

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Summary

In the last few years strawberry production in Croatia is constantly increasing. One of the main problems in production are diseases. During two-year trials in strawberry plantations in northern Croatia, the occurrence of diseases was monitored in order to establish the most effective methods of integrated disease management. Trials were performed in three cultivation system: open field, greenhouse and hydroponic. The most frequent disease in all three production systems was gray mould (*Botrytis cinerea*). In open field production, the occurrence of common leaf spot (*Mycosphaerella fragariae*) and leaf scorch (*Diplocarpon earliana*) were also frequently observed, while leaf blotch (*Gnomonia comari*), leaf blight (*Phomopsis obscurans*) and fruit anthracnose (*Colletotrichum* spp.) were only sporadically present. For the control of the most important disease, gray mould, forecast model BOTMAN was implemented. As relatively simple model based on meteorological data, BOTMAN allowed effective, ecologically and economically more acceptable control, based on integrated chemical and biological measures. Meteorological data were obtained from the State Hydrometeorological Department (DHMZ). Results showed no significant difference in intensity of gray mould infection between usual chemical control and BOTMAN-based control. Two-years research on strawberry disease management in Croatia revealed perspective possibilities of integrated strawberry disease management.

Key words

cultivation system; diseases; gray mould; integrated control; strawberry

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Introduction

Strawberry production in Croatia is constantly increasing, especially in the continental region around Zagreb. The cultivation of strawberry represents an attractive option for semi-professional or professional family business, which can be payed off and become profitable in a relatively short period of time. As strawberry is a culture in expansion and relatively new in this region, many problems emerge and affect the stability of yield. One of the main limiting factors for sustaining every-season high yield are strawberry diseases. Besides soil-borne mycoses like Verticillium wilt or Phytophthora crown rot, gray mould is by far economically the most important disease of strawberries in agroecological conditions of northwest Croatia. As it destroys flowers, immature and mature fruits and causes extensive post-harvest rotting, strawberries in this region are usually treated 6-8 times with botriticides. Wrong fungicide application timing, resistance of *B. cinerea* to various active ingredients, inapropriate fungicide usage and witholding period limitations are the main reasons for inefficient and money-consuming gray mould management on strawberries in Croatia. Integrated gray mould management is based on various prediction models, like DSS BoWas - Botrytis Warning Sytem (Bulger et al., 1987), BOTMAN – Botrytis Manager (Shtienberg and Elad, 1997), DSS – Decision Support System (Wander et al., 2004), and BOTEM (Berrie et al., 2002). As temperature and wetness period are crucial factors in gray mould development (Bulger et al., 1987; Wilcox and Seem, 1994; Xu et al, 2000), all above mentioned models are based on measurment of these two parameters. Chemical and biological integrated *Botrytis* management forecast model BOTMAN is developed in Israel and used in tomato and cucumber production. BOTMAN is a model by which potential severity of gray mould outbreak can be calculated on the basis of retrograde and forecast meteorological data. Application of BOTMAN reduced the use of fungicides up to 60 % in trials conducted in Israel (Shtienberg, 2004), but this model did not function well in trials conducted on tomato in Spanish greenhouses (Moyano et al., 2003). The main object of this research is to evaluate effective, ecologically acceptable and more economic integrated gray mould management on strawberries in different production systems on the basis of disease forecast system BOTMAN. Another aim of this research was to determine which leaf and fruit diseases, apart from gray mould (*Botrytis cinerea*) and gray leaf spot (*Mycosphaerella fragariae*), appear on strawberries in different cultivation systems.

Materials and methods

In order to evaluate the occurrence of strawberry diseases in different cultivation systems, part of open field, greenhouse and hydroponic plantations were left untreated in 2004. Open field plantation (cv. Marmolada) and unheated greenhouse (cv. Madeleine) were situated in Velika Gorica, while hydroponic greenhouse (cv. Elsanta) was situated in Samobor. Untreated parts were approximately 50 meters long, with 250 - 300 strawberry plants. Plants were visually inspected every seven days. Only foliar and fruit diseases were monitored. Samples of diseased plant organs with characteristic symptoms were taken to laboratory, where causal organisms were identified. Disease incidence monitoring was based on the number of plants and plant parts (leaves, fruits) with visible symptoms. Disease incidence was classified as "high" if more than 30 % of the plants were infected and leaf area affected, in the cases of leaf diseases, ranged from 4 to 5 according to scales described by Miličević (2001). Disease incidence was classified as "moderate" if the percentage of plants infected was from 5-30 % and leaf area affected, in the cases of leaf diseases, ranged from 2 to 3. Disease incidence was classified as "low" if less than 5 % of the plants was infected and leaf area affected, in the cases of leaf diseases, ranged less than 2. In 2005 a trial was conducted in order to investigate the possibilities of the application of integrated gray mould management on strawberries based on prediction model BOTMAN (Shtienberg and Elad, 1997). Two variants of BOTMAN model were implemented, assigned as BOTMAN 1 and BOTMAN 2. BOTMAN 1 was based on the analysis of seven-days retrograde temperature in the period from 9 am to 9 pm and leaf wetness periods data. Leaf wetness period was measured with instrument Prognozer Zagreb (Cvjetković, 1987). Weekly mean values were calculated for both parameters. Severe gray mould outbreak was expected in the cases when leaves were wet more than seven hours per day and active temperature exceeded 9.5 hours per day. Moderate gray mould outbreak was expected if only one of these criteria was fulfilled. Mild gray mould outbreak or no gray mould outbreak was expected if none of these criteria was fulfilled. BOTMAN 2 was based on the analysis of six forecast meteorological data for the following four days (rain quantity, number of rainy days, maximum and minimum temperature, number of cloudy days and number of days with hot, dry weather). Both variants of BOTMAN model were applied in open field production (cv. Marmolada), while only BOTMAN 1 model was applied in unheated greenhouse production (cv. Madeleine) and hydroponic production (cv. Elsanta). All above mentioned meteorological data necessary for

BOTMAN 2 model were obtained every day from the National Hydrometeorological Department of Croatia (http://www.dhmz.htnet.hr/index.php) in Zagreb. On the basis of calculated parameter values obtained from meteorological data, gray mould development was separated into three risk groups:

1. high risk, severe disease outbreak is expected (risk index ≥ 4.6)
2. moderate risk, moderate disease outbreak is expected (risk index from 2.5 to 4.5)
3. low risk, mild outbreak or no disease outbreak is expected (risk index ≤ 2.4)

Treatment decisions were made every seven days. In the case when intensive disease development was expected, chemical fungicides (listed bellow) were applied, while in the case of predicted moderate disease development biological fungicide Trichodex WP (*Trichoderma harzianum* T-39) was used. In the case of low risk no treatment was done, which is a modification of the original BOTMAN model. A trial was set according to randomised complete block design with four replicates, as recommended by OEPP/EPPO (1997). Each plot was six meters long, with an average of 30 strawberry plants. In order to compare the BOTMAN model with conventional gray mould control, seven fungicide treatments were done in seven to eight days intervals, from the blossom begining to the ripening period (Table 1). Fungicides were applied in following order: dichlofluanid (Euparen WP 50), iprodion (Kidan KS), pyrimethanil (Mythos SC), vinclozolin (Ronilan DF), fludioxonil (Switch 62.3 WG) and fenhexamid (Teldor SC). To compare the BOTMAN model with biological control, part of the trial was treated seven times with biofungicide Trichodex WP in sevet to eight days intervals. Control part was left untreated. Mean value of infected fruits was calculated as a number of diseased fruits on 200 fruits visually inspected. Mean values were compared with Duncan's New MRT, using Agricultural Research Manager 6.1.12. software (Gylling Data Management Inc.).

Results and discussion

The most common disease in all three production systems was gray mould (Table 2). This result confirmed previous yearly observations that gray mould is a disease that occurs every year on strawberries and cause considerable, sometimes even drastic losses. Four leaf mycoses were found in open field production (Table 2). It can be explained by the presence of inocula on strawberry residua, nearby strawberry plantations and the presence of wild host plants from the genus *Fragaria* that can harbour such inocula (*F. vesca*, *F. viridis* and *F. elatior*). No leaf mycosis was detected in hydroponic greenhouse and

Table 1. Schedule and type of treatments applied in variants of BOTMAN model on the basis of the estimated risk of potential gray mould outbreak in different production systems.

Treatment schedule	Open field cultivation- BOTMAN 2			Greenhouse cultivation - BOTMAN 1			Hydroponic cultivation - BOTMAN 1		
	A	B	C	A	B	C	A	B	C
1	+ Dic.	-	-	+ Dic.	-	-	-	+ Tri.	-
2	+ Ipr.	-	-	+ Ipr.	-	-	+ Ipr.	-	-
3	-	+ Tric	-	-	+ Tric	-	-	+ Tri.	-
4	+ Pyr.	-	-	+ Pyr.	-	-	+ Pyr.	-	-
5	+ Flu.	-	-	-	+ Tric	-	-	+ Tri.	-
6	-	-	+	-	-	+	-	-	+
7	+ Fen.	-	-	+ Fen.	-	-	+ Fen.	-	-
Total	5	1	1	4	2	1	3	3	1

A - chemical treatment, B- biological treatment, C - without treatment, Dic - dichlofluanid; Ipr - iprodione; Pyr - pyrimethanil; Flu - fludioxonil; Fen- fenhexamid; Tri - *Trichoderma harzianum*, (+) - treatment with chemical or biological fungicide, (-) - without treatment

Table 2. Diseases occurrence on strawberries in different cultivation systems

Open field cultivation	Unheated greenhouse cultivation	Hydroponic cultivation
Gray mould +++	Gray mould +++	Gray mould +++
Common leaf spot ++	Common leaf spot +	
Leaf scorch ++		
Leaf blotch +		
Leaf blight +		
Fruit antrachnose +		

+++ High incidence; ++ Moderate incidence; + Low incidence

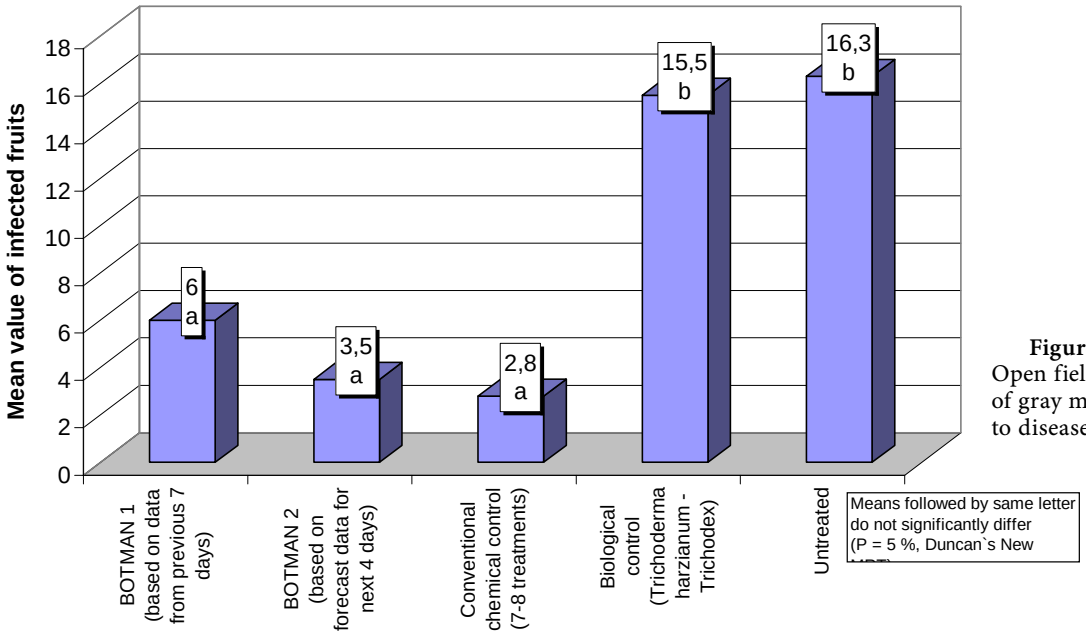

Figure 1.
Open field cultivation – Results of gray mould severty in relation to disease control model

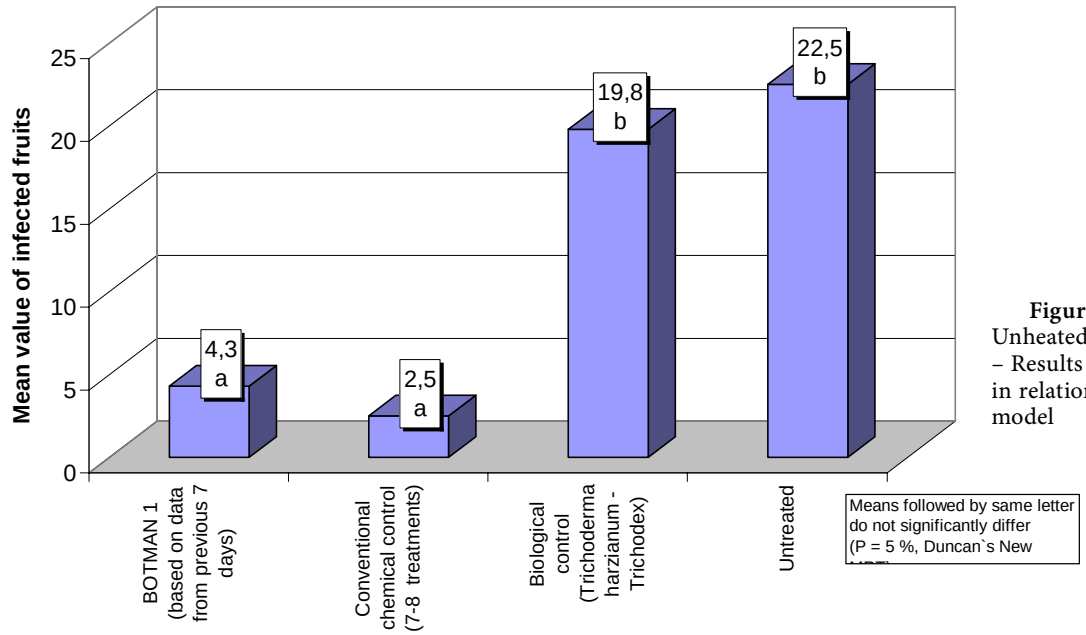

Figure 2.
Unheated greenhouse cultivation – Results of gray mould severty in relation to disease control model

only one, common leaf spot (*M. fragariae*), was found in low incidence in unheated greenhouse (Table 2). As the greenhouse construction is left open during the warm days in May and June, there is a possibility that conidia of *M. fragariae* enter the greenhouse and infect strawberry leaves. Such entrance of inoculum can not happen in a hydroponic greenhouse, as it is closed all the time. Taking into account such occurrence of strawberry diseases in 2004, disease management strategies evaluated in 2005 were focused on gray mould as the most problematic and economically important strawberry disease. To reduce the severity of leaf mycoses, principally eventual common leaf spot severe outbreak, dichlofluanid (Euparen WP 50) was chosen for the first treatment against gray mould, as this fungicide has a side-effect on *Mycosphaerella fragariae* and *Diplocarpon earliana* (Miličević et al., 2002). Both BOTMAN variants, the one based on previous seven days leaf wetness and temperature data and the other based on four-days forecast, were evaluated in open field production (Figure 1). Gray

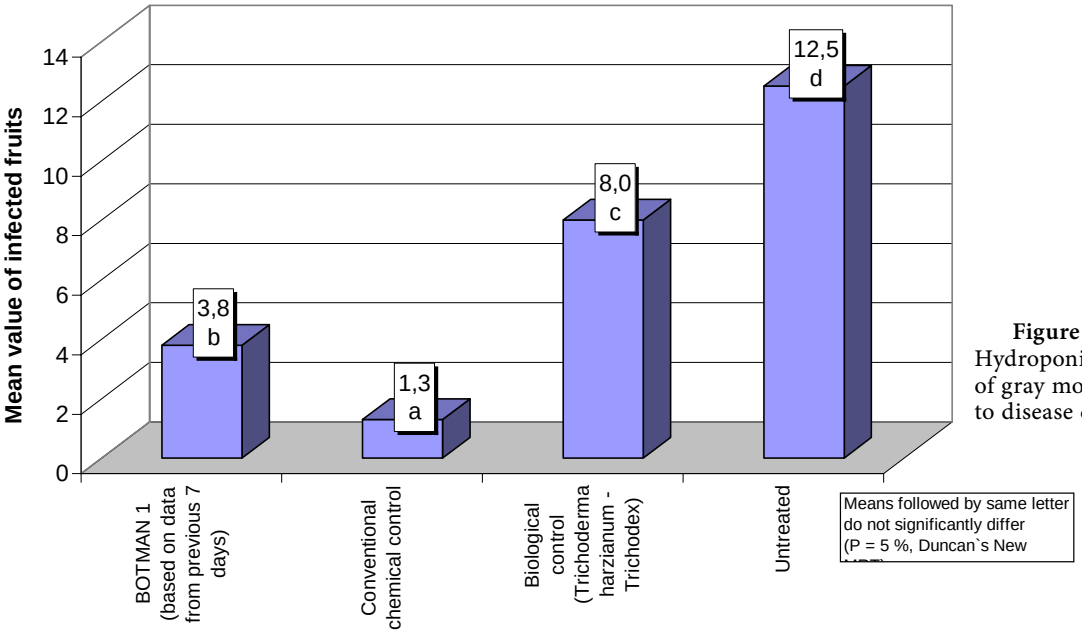

Figure 3.
Hydroponic cultivation – Results of gray mould severty in relation to disease control model

mould severity in open field trial was the lowest where conventional chemical control was applied, but not statistically different in comparison with both BOTMAN variants. Both BOTMAN variants were equally effective in reducing gray mould severity. In both BOTMAN variants there was one chemical treatment less and one treatment with Trichodex instead of a chemical fungicide. These results showed that BOTMAN-based gray mould management in open field production could be equally effective, but more economic, than a routine every-week fungicide strategy. The biological control of gray mould based on seven Trichodex applications was disappointing. Trichodex applications did not reduce disease severity, and it is obvious that *Trichoderma harzianum* T 39 does not function well in conditions of high *B. cinerea* pressure. Similar results with Trichodex were obtained in greenhouse and hydroponic trials; a biological control model was unsatisfying and did not reduce gray mould severity. BOTMAN based gray mould management in the greenhouse trial was statistically equally effective as conventional chemical control (Figure 2). Only variant based on previous seven days (BOTMAN 1) was evaluated in unheated greenhouse and hydroponic greenhouse, as more suitable for closed systems. Comparing it to conventional chemical control, one treatment was omitted and two treatments were done with Trichodex instead of chemical fungicide. Such results showed the perspective of using the BOTMAN model in strawberries as a base for integrated biological-chemical, economically and ecologically more acceptable gray mould control strategy in unheated greenhouses. In hydroponic production, BOTMAN-based control was statistically inferior to conventional chemical control, although the percentage of diseased fruits was relatively low (3.8) in BOTMAN variant (Figure 3). Difference between these two control strategies was only 2.5 % of the fruits infected, which is practically irrelevant in production. Differences in efficacy between conventional chemical control and BOTMAN-based control can be attributed to higher number of chemical fungicide treatments in conventional control; seven compared to only three in BOTMAN-based control. As predicted gray mould development risk was moderate three times, Trichodex was used three times instead of chemical fungicides. A somewhat higher number of diseased fruits could be the consequence of generally lower effectiveness of a biocontrol agent compared to chemical botriticide compounds, although the exact conclusions can not be made.

Conclusions

Six different leaf and fruit mycoses were found to occur on strawberries in strawberry cultivation areas around Zagreb. Gray mould (*Botrytis cinerea*) was the most significant disease in all three cultivation systems. While the incidence of gray mould was high, the incidence of common leaf spot (*Mycosphaerella fragariae*) and leaf scorch (*Diplocarpon earliana*) was moderate in open field production. Leaf blotch (*Gnomonia comari*), leaf blight (*Phomopsis obscurans*) and fruit antrachnose (*Colletotrichum* spp.) were present only sporadically and were found only in open field production. Trial results from all three production systems show that that prediction of gray mould development on the basis of leaf

wetness period and active temperature (9-21°C) duration can be implemented in more economic and ecologically acceptable integrated biological-chemical disease management in strawberry. It is also evident that biological control strategy with only Trichodex (*Trichoderma harzianum* T 39) applications can not satisfactorily reduce losses caused by *B. cinerea*, but this biofungicide can be effectively used in alternation with chemical fungicides, in periods when moderate gray mould outbreak is expected. Gray mould management variant based on previous seven days leaf wetness and temperature data and variant based on 4-days forecast were statistically equally effective in open field production. Results showed the possibility of practical use of BOTMAN warning system in strawberries, but as all disease warning systems, it should be investigated in more locations and over a period of years.

References

Berrie A.M., Harris D.C., Xu X.M. (2002). A potential system for managing *Botrytis* and powdery mildew in main season strawberries. Acta Horticulturae 567: 647-649

Bulger M.A., Ellis M.A., Madden L.V., (1987). Influence of temperature and wetness duration on infection of strawberry flowers by *Botrytis cinerea* and disease incidence of fruit originating from infected flowers. Phytopathology 77: 1225-1230

Cvjetković B., (1987). Novosti u biologiji i prognozi gljive *Venturia inaequalis* (Cooke) Winter. Jugoslovensko savjetovanje o pripremi pesticida. Zbornik radova, Vol.9: 229-238

Miličević T. (2001). Etiology and Epidemiology of Important Fungal Diseases on Strawberry. MSc Thesis, Faculty of Agriculture, University of Zagreb, Croatia

Miličević T., Cvjetković B., Topolovec-Pintarić S. (2002). Dynamics of most important fungal diseases of strawberries in Croatia and suggestions for integrated control. Plant Protection Science, Vol. 38 (Special Issue 2): 689-692

Moyano C., Raposo R., Gomes V., Melgarejo P. (2003). Integrated *Botrytis cinerea* Management in Southeastern Spanish Greenhouses. Journal of Phytopathology 151 (2), 80 - 85

OEPP/EPPO (1997). Gudeline for the efficacy evaluation of plant protection products. *Botrytis cinerea* on strawberry. Vol. 2: 17-19

Shtienberg D., and Elad Y. (1997). Incorporation of weather forecasting to integrated, chemical-biological management of *Botrytis cinerea*. Phytopathology 87: 332-340

Shtineberg D., (2004). Rational management of *Botrytis* - incited diseases: Integration of control measures and use of warning systems. In: Botrytis: Biology, Pathology and Control. Chapter 18: 335-347. Kluwer Academic Publichers, Dordrecht, Netherlands

Wander J., Stensvand A., Creemers P., Berrie, A., Rossi, V., (2004). Testing of DSS to improve the control of *Botrytis cinerea* in strawberries. Acta Horticulturae 649: 241-246

Wilcox W.F., and Seem R.C., (1994). Relationship between strawberry gray mold incidence, environmental variables, and fungicide applications during different periods of the fruiting season. Phytopathology 84: 264-270.

Xu X.M., Harris D.C., Berrie A.M., (2000). Modeling infection of strawberry flowers by *Botrytis cinerea* using field data. Phytopathology 90: 1367-1374

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