Yield loss caused by fruit rot fungi on sweet cherry in Kyustendil region, Bulgaria

Borovinova B.

Institute of Agriculture, 2500 Kyustendil, Bulgaria

Summary: The aim of the study was to determine the incidence of fruit rot caused by several fungal pathogens from 1999 to 2003. The study was conducted in three sweet cherry orchards at the Institute of Agriculture (Kyustendil, Bulgaria). One copper containing fungicide was applied in late autumn and early spring. During the growing seasons, 2–5 sprays were applied against fungal diseases. Trees were not sprayed specifically against fruit rot during the growing season, with the exception of 1999, when a spray of myclobutanil was applied after a long rainy period during the maturity of fruits. In one orchard, two nitrogen fertilization treatments were also prepared. In treatment 1, trees were fertilized with ammonium-nitrate 10 g/m^2 and in the other treatments trees were not. Incidence of the five most important fruit rot pathogens, *Monilinia fructigena, M. laxa, Botritys cinerea, Alternaria alternata* and *Rhizopus stolonifer* was assessed in all orchards. The most severe yield loss (14.80 %) was measured in 1999, when weather conditions were the most favourable for fruit rot development. In this year, brown rots (*M. fructigena* and *M. laxa*) caused the highest damage (9.22 and 4.04 %, respectively) out of all assessed fruit rot pathogens. In all other years, yield loss was significantly lower than in 1999. In 2002, *A. alternata* caused the main fruit rot (4.46%) and all other fungi were less important, while in 2003, *B. cinerea* caused considerable yield loss (2.28 %) compared to all other fruit rot pathogens. Experiments on fertilization showed that nitrogen significantly increased fruit rot damage in 1999, 2001, 2002 and 2003. The effect of nitrogen fertilization was higher in years with rainy periods around harvest (1999 and 2002) compared to more dry years (2000 and 2001). Results were compared with similar studies and biological interpretations of the results are discussed.

Key words: sweet cherry, brown rot, *Monilinia fructigena, M. laxa, Alternaria alternata, Botrytis cinerea*, nitrogen fertilization

Introduction

Kyustendil region is the most ancient fruit-growing region in Bulgaria. In this region, cherry was grown approximately on 2800 ha in the 1960's, and produced more than 30 % of the total cherry production in Bulgaria. During the 1990's, the cherry orchard area was reduced in this region and also in the whole Bulgaria due to the change in the ownership of the orchards. Nowadays, the total area of sweet cherry orchards is about 1600 ha in the Kyustendil region.

In the Kyustendil region, the most important diseases and pest of sweet cherry in the growing season are cherry leaf spot caused by *Blumeriella jaapii* (Rehm) Arx, brown rot caused by *M. laxa* (Aderh. & Ruhl.) Honey and cherry fruit fly *Rhagoletis cerasi* L. (*Borovinova* & *Sredkov*, 1996; 2003). In sweet cherry growing, the ripening period of fruits is short and several diseases and pests cause serious damage during this period. Therefore, it is very difficult to protect fruits against rots around harvest without pesticide residues. During the ripening period of fruits and in storage, fruit rot occurs caused by several fungi such as *Monilinia fructigena* (Aderh. & Ruhl.) Honey, *M. laxa, Botrytis cinerea* Pers. Fr., *Rhizopus stolonifer* (Ehrenb. Fr.) Vuill., *Glomerella cingulata* (Stoneman) Spauld. & H. Schrenk and *Alternaria alternata* (Fr. Fr.) Keissl (*Børve*, et al., 1998, 2000; *Børve & Stensvand*, 2003; *Holb*, 2003). Among these pathogens, *M. fructigena* and *M. laxa* are the most common fruit rot pathogens on stone fruits in Europe (*Paszternák* et al., 1982; *Van Leeuwen* et al., 2000, 2002; *Ruegg & Schwizer*, 2000; *Holb*, 2003, 2004) and in Bulgaria (*Borovinova* & *Sredkov*, 1996).

Brown rot fungi infection on fruits is facilitated by injuries on ripening fruits and fruit-to-fruit contact around harvest time (*Byrde & Willetts*, 1977; *Batra*, 1991; *Michalaides* & *Morgan*, 1997; *Soltész*, 1997; *Børve* et al., 1998, 2000; *Xu* & *Robinson*, 2000; *Holb*, 2003). Most important injuries on fruits are cracking in rainy weather or fruit fly (*Rhagoletis cerasi* L.) damage on ripening fruits around harvest time (*Byrde & Willetts*, 1977; *Batra*, 1991; *Soltész*, 1997; *Hong* et al. 1998; *Holb*, 2004). Susceptibility of a stone fruit to brown rot is increasing if the nutrition supply is not harmonic. The largest negative effect is known when nitrogen fertilization is overloaded in the orchard (*Byrde & Willetts*, 1977; *Batra*, 1991; *Soltész*, 1997).

The aim of this five-year-study was to determine the incidence of fruit rot caused by several fungal pathogens in three sweet cherry orchards. The effect of nitrogen fertilization was also determined on the susceptibility of fruits to fungal rot.

Material and method

Orchard site and experimental layout

The study was conducted in three sweet cherry orchards at the Institute of Agriculture, (Kyustendil, Bulgaria) during five consecutive years from 1999 to 2003. The basic investigations were made in a conventional cherry orchard (orchard 1). The area of the orchard was 20 ha. Additional investigations were made in two other experimental orchards (orchards 2 and 3), which were sweet cherry cultivar collections, each of 21 ha area. The three orchards were maintained in a similar way. Trees were planted in spring of 1991 on a leached ciannamon forest soil in all orchards. Cultivars Van and Bing were grafted on *Prunus mahaleb* rootstock and planted at a distance of 5.7 x 4.5 m in each orchard. All orchards were irrigated by furrow irrigation method once in 1999, 2000, 2001 and 2003.

General spray schedules against diseases from 1999 to 2003 are shown in *Table 1*. Bacterial canker, brown rot and shot hole were controlled by protective treatments with copper containing fungicides in late autumn and early spring. During the growing seasons, cherry leaf spot was controlled by post-infection sprays in orchard 1 and by protective sprays with ergosterol biosynthesis inhibitors and with dodine in orchards 2 and 3. Trees were not sprayed against fruit rot during the growing season, with the exception of 1999, when a spray of Systane 12 E (a.i. myclobutanil) was applied after a long rainy period during the maturity of fruits. Insecticides were applied if necessary.

In one orchard, the influence of nitrogen fertilization on susceptibility of sweet cherry fruits to fungal rot was investigated on trees fertilized with ammonium-nitrate 10 g/m^2 and without fertilization. Three and seven g/m^2 ammonium-nitrate was applied in November and April in each year. Fertilization treatment was made on cv. Van from 1999–2002 and on cv. Bing in 1999 and 2003.

Table 1 General spray schedules against diseases in three sweet cherry orchards from 1999 to 2003 (Kyustendil, Bulgaria)

Date of application	Active ingredient	Product name	Dosage (%)
1999			
26 March	copper hydroxide	Champion WP	0.4
30 April	tebuconazol	Folicur 25 WG	0.075
13 May	dodine	Silit 40	0.1
29 May	miclobutanil	Systane 12 E	0.06
08 June	miclobutanil	Systane 12 E	0.06
07 July	dodine	Efuzin	0.12
17 November	copper hydroxide	Funguran OH	0.35
2000			
23 March	copper hydroxide	Funguran OH	0.4
27 April	tebuconazol	Folicur 25 WG	0.075
22 May	miclobutanil	Systane 12 E	0.06
18 July	dodine	Silit 40	0.1
17 November	copper sulphate	Bordeaux mixture	1
2001			
23 March	copper hydroxide	Funguran OH	0.4
26 April	dodine	Silit 40	0.1
18 May	tebuconazol	Folicur 25 WG	0.075
22 November	copper hydroxide	Funguran OH	0.4
2002			
19 March	copper hydroxide	Funguran OH	0.4
30 April	dodine	Silit 40	0.15
14 May	tebuconazol	Folicur 25 WG	0.075
20 June	tebuconazol	Folicur 25 WG	0.075
25 November	copper hydroxide	Funguran OH	0.4
2003			
26 March	copper hydroxide	Funguran OH	0.4
13 May	tebuconazol	Folicur 25 WG	0.075
29 May	tebuconazol	Folicur 25 WG	0.075
25 November	copper hydroxide	Funguran OH	0.4

Weather monitoring and assessment

Mean daily temperature (°C day^{-1}) and wetness duration (hours) were recorded during critical periods for fruit rot infection in June and July from 1999 to 2003. Days with optimal temperature and wetness duration longer than 5 hours were recorded.

Five trees in four replications were assessed in each orchard and year during harvest. 300-600 fruits were selected randomly from the four sides of each tree. The five most important fruit rot pathogens, *M. fructigena, M. laxa, B. cinerea, A. alternata* and *Rh. stolonifer* were assessed. The fungal pathogens on fruits were identified by morphological characteristics of fungus body and spores according to Gams *et al.* (1987). Fruit rots which can not be identified precisely were rated on separate disease incidence scales, as unidentified or mixed infection. Disease incidence of fruit rot was calculated as the mean of the five-year data set for each fungal pathogen. Incidence was calculated as the number of diseased fruits divided by the total number of counted fruits.

Statistical analyses

Fruit rot incidence data of each pathogen were transformed to *angular* (Y=arcsine $[\%]^{1/2}$) to correct normality before analysis. For each fruit rot data set, significant F-tests ($P < 0.05$) were followed by a Least Significance Difference (LSD)-test for pair-wise comparison of year means using $LSD_{0.05}$ values. The same analysis was performed for evaluating the effect of nitrogen fertilization on incidence of total fruit rot. Statistix 2.1 statistical package was used for all analyses.

Results and discussion

Weather monitoring

During critical periods for fruit rot infection, optimal temperature and duration of wetness > 5 hours were 20, 15, 6, 6, and 9 in June; and 14, 7, 1, 10, and 15 in July in 1999, 2000, 2001, 2002, and 2003, respectively. The most favourable weather conditions were recorded in 1999 for the fruit rot development caused by *M. fructigena, M. laxa, B. cinerea, A. alternata* or *R. stolonifer*. Weather conditions for fruit rot were the less suitable for all other years.

Fruit rot incidence and nitrogen fertilization

The most severe yield loss (14.80 %) caused by fruit rot fungi was measured in 1999 (*Table 2*). Brown rot caused by *M. fructigena* and *M laxa* caused the highest damage (9.22 and 4.04 %, respectively) out of all assessed fruit rot pathogens (*Table 2*). This was due to the fact that weather conditions were favourable for fruit rot on 34 days in June and July. The additional spray against fruit rot was not enough for control of the disease. Moreover, rainy periods occurred during the ripening period and fungicides were not allowed to apply 5–7 seven days before harvest because of fungicide residue in fruits. In 1999, most mature fruits cracked because of the continuous rain at harvest time. Our results are in agreement with those of *Zehr* (1982), *Wilcox* (1990), *Van Leeuwen* et al. (2000, 2002), *Fourie & Holz* (2003ab) and *Holb* (2004) who stated that a more serious brown fruit infection of stone and pome fruits occurred in rainy periods due to fruit cracking and lower effectiveness of fungicides. In all other years, yield loss was significantly lower than in 1999. In 2002 and 2003, fruit rot damage was significantly higher compared to that of 2000 and 2001. In 2002, *A. alternata* caused the main fruit rot (4.46%) and all other fungi were less important while in 2003, *B. cinerea* caused considerable yield loss (2.28 %) compared to all other fruit rot pathogens (*Table 2*).

Comparing the assessed five fungi species in the three sweet cherry orchards from 1999 to 2003, *M. laxa* was the most common brown rot pathogen (*Table 3*). In the second and the third places, *M. fructigena* and *B. cinerea*, respectively, caused considerable yield loss, too. Some fruits were infected with two fungi – mainly with *M. laxa* with *A. alternata* or with *B. cinerea*. 5.57 % out of all rotten fruits was damaged by undefined fungi (*Table 3*).

Table 3 Mean incidence of each fruit rot fungus in percentage of total fruit rot on sweet cherry cv. Van from 1999 to 2003 (Kyustendil, Bulgaria)

Fruit rot fungus	Incidence (%)
Monilinia laxa	40.25
Monilinia fructigena	25.56
Alternaria alternata	16.54
Botrytis cinerea	8.50
Rizoctonia stolonifer	0.91
Undefined[a]	5.57
Mixed infection	2.67
Total	100.00

[a] for explanation, see Table 2

Experiments on nitrogen fertilization showed that nitrogen fertilization significantly increased fruit rot damage in 1999, 2001, 2002 and 2003 (*Table 4*). The effect of nitrogen fertilization was higher in years with rainy periods around harvest (1999 and 2002) compared to more dry years (2000 and 2001). The reason for the increasing fruit rot is that fruits of fertilized cvs. Van and Bing trees were cracked more easily after a rainy period compared to unfertilized trees. Results of the nitrogen fertilization experiment supported the earlier findings of *Byrde & Willetts* (1977) and *Soltész* (1997).

Table 4 Effect of nitrogen fertilization on incidence of total fruit rot (%) on cvs. Van and Bing in a sweet cherry orchard from 1999 to 2003 (Kyustendil, Bulgaria)

Treatments	1999		2000	2001	2002	2003
	Van	Bing	Van	Van	Van	Bing
No fertilization	8.49a	12.43a	0.64	1.35b	7.43a	3.10a
Fertilized with 10 g/m² nitrogen	17.36b	14.88b	0.65	0.67a	12.00b	4.20b
F test[a]	***	*	NS	*	**	*

[a]F-test = *,**,*** significant at P = 0.05, 0.01, 0.001. Because of the back-transformation on brown rot severity data no $LSD_{0.05}$ and SED values are available.

Table 2 Mean incidence of fruit rot pathogens on cv. Van in three sweet cherry orchards from 1999 to 2003 (Kyustendil, Bulgaria)

Year	Monilinia laxa	*Monilinia fructigena*	*Alternaria alternata*	*Botrytis cinerea*	*Rhizopus stolonifer*	Mixed infection	Undefined[a]	Total[b]
1999	4.04b[c]	9.22b	0.11a	0.18a	0.00	1.25	0.00a	14.80c
2000	0.40a	0.00a	0.08a	0.00a	0.00	0.00	0.00a	0.48a
2001	0.34a	0.00a	1.00a	0.00a	0.00	0.00	0.67a	2.01a
2002	0.00a	0.00a	4.46b	0.00a	0.00	0.00	4.10b	8.56b
2003	1.83a	0.00a	0.68a	2.28b	0.91	0.00	0.80a	6.50b
F test[d]	**	***	**	*	NS	NS	**	**

[a] Fruit rot without fruiting bodies of fungi.
[b] Annual yield loss caused by fruit rot pathogens altogether.
[c] Values within columns followed by different letters are significantly different.
[d] F-test = *,**,*** significant at P = 0.05, 0.01, 0.001. Because of the back-transformation on brown rot severity data no $LSD_{0.05}$ and SED values are available.

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