INCIDENCE OF POSTHARVEST ROT OF CRANBERRY (*VACCINIUM MACROCARPON* AIT.) IN LATVIA

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Abstract
The American cranberry (*Vaccinium macrocarpon* Ait.) is a perspective and marketable crop both in Latvia and foreign markets, but berries are affected by rot in storage. The aim of the study was to detect the incidence level of cranberry fruit rot at the beginning of storage period in different places in Latvia. In 2007 - 2011, two hundred sound berries (out of 1000) were randomly collected by hand along a diagonal from five different cranberry plantations from locations all over Latvia. Berries were kept in plastic bags for a month and refrigerated at +7 °C. At the end of November, berries were sorted and rotten berries were separated from the sound ones. Over the period of 2007 - 2011, the incidence of storage rot reached 12 - 15% at the end of November, with an upwards trend observed every year, but the hot and rainy summer of 2010 significantly reduced the quality of fruit in storage, peaking on the average 33% of decayed berries. The incidence of fruit rot varied among the inspected cranberry plantations, but a tendency was observed that older plantations produced more rotting fruit and incidence of the disease was 12 - 50% after a month's storage in the oldest plantation. The application of fungicides during the vegetation season did not affect development of post-harvest rot. Storage rot was a problem in the cranberry samples from all inspected plantations in Latvia, and in future the incidence of fruit rot is expected to increase.
Key words: cranberry, storage rot, shelf-life.

Introduction

In Latvia, the American cranberry (*Vaccinium macrocarpon* Ait.) is a perspective and marketable crop. The same as in North America, the climate in Latvia is appropriate for cranberry growing. American cranberry has been cultivated for fifteen years in Latvia and alongside with plantations enlarging every year, the spreading of diseases, including fruit rot, turns into one of the most important risk factors in cranberry cultivation. In Latvia the first investigations of fruit rot were started in 2006 (Vilka et al., 2009b). Cranberry rot is a disease complex caused by several pathogens in Latvia: *Botrytis cinerea, Allantophomopsis cytisporea, Fusiccocum putrefaciens, Phomopsis vaccinii, Coleophoma empetri, Phyllosticta elongata, Physalospora vaccinii, Pestalotia vaccinii, Gloeosporium minus,* and *Discosia artocreas* (Vilka et al., 2009a).

The harvested cranberry fruit is used in three ways: frozen, processed into juice or other products, and stored as fresh fruit. At storage the storing expenses grow and quality of fruit gets reduced, but it offers an opportunity to use fresh fruit for some months after harvest. Fresh fruit account for about 10% of total North American sales and only some growers store berries until November or December (Charles, 2003; Olatinwo et al., 2004).

The fruit rot is one of the most important problems in cranberry plantations in North America, because it reduces the quality of yield. If in North America cranberries were cultivated without fungicide application, losses due to field rot could reach 50 - 100% (Cranberry diseases, 1995; Johnson - Cicales et al., 2009). Even with application of fungicides, incidence of fruit rot in New Jersey and Massachusetts has ranged from less than 1% up to 15% (Stiles and Oudemans, 1999; Polashock et al., 2009). A lower incidence level of fruit rot was observed in Wisconsin where field rot reached 10 - 40% and fungicides usually were not used to control fruit rot (McManus et al., 2003). The incidence of pre-harvest and post-harvest fruit rot in most of cranberry growing regions is very high, therefore storage time of fruit is short (Charles, 2003).

Incidence of berry rot during storage has been investigated by researchers in different places and different periods of time. In New Jersey in 1976 - 1978, after 4 weeks in storage, incidence of fruit rot was 4.3% if berries were water-harvested (wet method) and immediately removed from field, but for berries harvested by hand (dry method) incidence level reached only 3.2% (Stretch and Ceponis, 1983). In recent years, R.O. Olatinwo et al (Olatinwo et al., 2004) have obtained different results: in Michigan after a month in storage (5 °C), incidence of fruit rot of 'Stevens' varied between 5 - 85% (in 2000) and 3 - 40% (in 2001) in different growing sites. Development of berry rot is influenced by temperature during storage. In Wisconsin, in 1999 – 2000, when berries were harvested by hand and stored at 3.5 °C, after 7.5 weeks the incidence of fruit rot was 16 - 52%, but after storing berries at 6 °C for 6 weeks, the incidence was only 4-6% (Blodgett et al., 2002). The incidence of storage rot depends on water immersion time at harvest. Increased water immersion time (up to 24 hours) has significantly increased the fungal rots (about 6.9%). Hand-picking of berries is an expensive method, but it decreases the possibility that berries might become infected by fungi (Stretch and Ceponis, 1983).

Researchers from Wisconsin have proved the importance of ripening fruit at harvest for prolonging shelf-life in storage. The red berries have a thicker and stronger cuticle and are better covered with wax formation than unripe (white) berries. During wet harvest, the calyx of the red berries may retard the entry of fungi better, so it is important for severity of storage rot. The ripening berries are unsusceptible to infection with causal agent of fruit rot, so these berries will store better (Ozgen et al., 2002).

Incidence of field rot and storage rot can vary among years and locations. Scientists from North America have investigated fruit rot of cranberries for many years, but the reason for variances in the rot incidence level is still unknown (Charles, 2003).

For the competition with American imported berries, Latvian growers have to store berries by fresh (without frozen), how long is possible and profitable. Therefore the present investigation is necessary to detect incidence level of cranberry fruit rot after a month's storage in conditions of the customer's refrigerator.

The study aim was to detect the incidence level of cranberry fruit rot at the beginning of storage in different places in Latvia.

Materials and Methods

Five cranberry plantations from different locations (Talsi, Babite, Alsunga, Rucava and Ape municipality) in Latvia were inspected at harvest (Table). The samples were taken from cultivar 'Stevens'. The trials were carried out in 2007, 2009, 2010, and 2011.

Berries were harvested from 10 th to 17 th of October in 2007, 19 th - 27 th of October in 2009, 4 th - 10 th of October in 2010, and 1 st - 06 th of October in 2011 depending on the ripening time at five different cranberry plantations from all over Latvia.

Two hundred sound berries (out of the total of 1000) were randomly collected by hand along a diagonal in each plantation.

Berries were kept in plastic bags for a month and refrigerated at +7 °C (Forney, 2009). At the end of November (time depended on harvesting), berries were sorted and rotten berries were separated from the

Table

Description of inspected cranberry plantations

Cranberry growing site	Structure of bog	Year of plantation set up	Acreage of plantation (2011), ha	Fungicide use	Provenance of seedling
1. Rucava municipality, farm Purva dzērvenīte	established after peat extraction	1998	13	used since 2009*	USA, Mena
2. Alsunga municipality, farm Stīgas	established after peat extraction	1995	1.5	not used	Belarus (previously USA, Wisconsin)
3. Ape municipality, farm Lienama - Alūksne	established after peat extraction	1997	20	used**	USA, Wisconsin
4. Talsi municipality, farm Piesaule	established after peat extraction	1998	11	not used	National Botanic Garden of Latvia in Salaspils (previously USA)
5. Babīte municipality, farm Strēlnieki	Established on a field (1.5-m layer with sawdust, 30-cm upper layer with peat)	2002	3	not used	Belarus (previously USA, Wisconsin)

* application of copper hydroxide (770 g kg^{-1}; copper equivalent: 500 g kg^{-1}) at the dosage of 4 kg ha^{-1} was carried out at the beginning of bloom (10%) in 2009; copper hydroxide (770 g kg^{-1}; copper equivalent: 500 g kg^{-1}) at the dosage of 4 kg ha^{-1}, was applied at the beginning of bloom (10%), and mixture (1 kg ha^{-1}) of pyraclostrobin, 67 g kg^{-1}, and boscalid, 267 g kg^{-1},- after bloom in 2010 and 2011.

** application of copper hydroxide (770 g kg^{-1}; copper equivalent: 500 g kg^{-1}) at the dosage of 3.5 kg ha^{-1} was carried out at bud elongation in 2007; in 2009, fungicides were not used; copper hydroxide (770 g kg^{-1}; copper equivalent: 500 g kg^{-1}) at the dosage of 3.5 kg ha^{-1} was applied at bud break in 2010; copper hydroxide (770 g kg^{-1}; copper equivalent: 500 g kg^{-1}) at the dosage of 3.5 kg ha^{-1}- at bud elongation in 2011.

sound ones. The rotten berries were kept and used for identification of the causal agent of the storage rot and for further investigations.

The surface of rotted berries was disinfested in 95% ethanol solution (761 g L^{-1}) for 1 - 2 minutes. The piece of berries was put down onto potato-dextrose agar (PDA) for causal agent detection. Plates were incubated at 20 - 25 °C for 3 to 4 weeks (Waller et al., 1998; McManus et al., 2003; Olatinwo et al., 2004). Fungi were identified directly on the isolation plates by comparing morphological characteristics of the spores and spore bearing structures with descriptions in the literature (Cranberry diseases, 1995).

Analysis of the weather conditions in the inspected years showed that in 2011 an excess precipitation level persisted for several months (May to September) in comparison with other years. Weather conditions of the vegetation seasons in 2007, 2009 and 2011 were usual. A considerably higher amount of precipitation was observed in August 2010, when precipitation level exceeded 190% of the average over longterm observations, reaching 147 mm. Specifically high precipitation level was observed in Rucava municipality, where a downpour produced 82 mm (93% from the norm of the month).

The results of the trials were statistically processed with MS Excel for windows and SPSS package. The obtained data were analyzed using descriptive statistics, and significance ($p<0.05$) of the differences between the samples was assessed using ANOVA Single factor.

Results and Discussion

In Latvia, for marketing, berries are stored at the temperature of 2-4 °C in a refrigerator, whereas most of the customers berries store at +7 °C in fridge for consumption of fresh fruit. The incidence of fruit rot in the first month of storage varied by years of inspection. The overall incidence level varied from 35 to 57% at the end of November (Figure 1). Cranberry rot is a disease complex that could can be coused by several pathogens. During our investigations, *Fusiccocum putrefaciens, Coleophoma empetri, Phomopsis vaccinii, Botrytis cinerea, Allantophomopsis cytisporea, Phyllosticta elongate* and *Physalospora vaccinii* were isolated from the rotted berries in storage.

The harvesting time did not influence the level of berry rot by years (differences were not statistically significant), except in 2010, when a substantially higher incidence of the disease was established, reaching 33% ($p = 0.008$).

Nevertheless, a slight increase in the tendency to rot over the trial period was observed. At the end of November 2007 the disease incidence was 12%, and in different cranberry plantations the rot level ranged from 8 to 16% (Fig. 1). After two years (in 2009), the average amount of decayed berries had slightly increased and differences among the incidence level (3 - 32%) in different farms had also increased. The high level of disease incidence in 2010 probably was caused by the weather conditions. In August, when the majority of berries go through an active growing phase, raindrops can easy wound their skin therefore weather is favourable for the development of the causal agent of the fruit rot.

The incidence of cranberry postharvest diseases in Latvia is less to compare with North America. Probably growing conditions are different. Density of upright shoots affects incidence level of fruit rot. Farmers in North America have target to get a high yield and good incomes, therefore berries were taken away unripe and it is the reason for high level of fruit rot in storage in North America.

Usually, harvesting time of cranberries in Latvia is in the middle of October, but in USA the berries are harvested in September or in early October (Olatinwo et al., 2004).

Influence of plantations in Latvia of postharvest diseases is shown in Figure 2. In general, significant differences between the incidence of fruit rot in different cranberry plantations were not observed ($p = 0.643$). In 2010, in comparison with other farms, the tendency for higher incidence of fruit rot (43 - 57%)

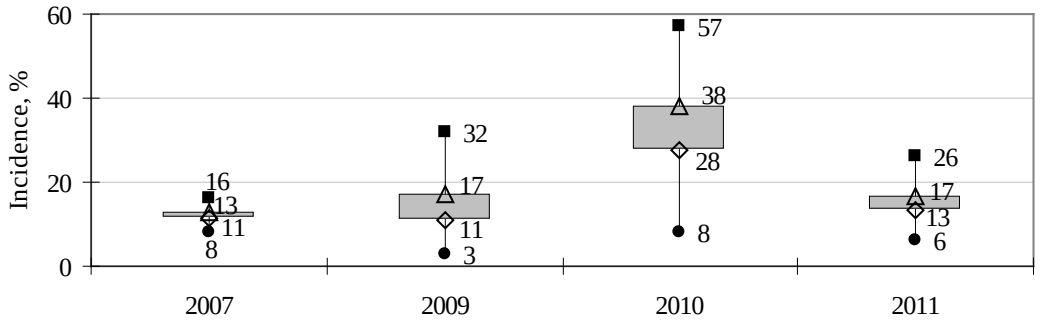

Figure 1. The incidence of fruit rot in storage at the end of November by years.
(◇ $\bar{x}$ - Sx; ■ max.; ● min.; △ $\bar{x}$ + Sx; Sx - standard error).

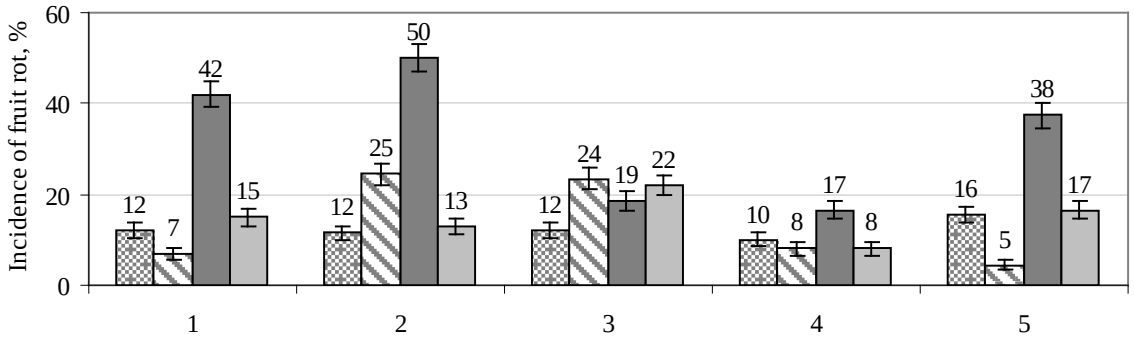

Figure 2. The incidence of fruit rot after a month's (end of November) storage depending on growing site, 2007 – 2011, % (2007; 2009; 2010; 2011; 1- Rucava municipality; 2- Alsunga municipality; 3- Ape municipality; 4-Talsi municipality; 5- Babīte municipality).

was observed in the farm in Alsunga municipality (Number 2) having the oldest cranberry plantations (Fig. 2). The younger farm (in Babīte municipality) will have had to be opposite results. The amount of decayed berries was highly variable by years: from 5% in 2009 to 38% in 2010. The lowest prevalence of what at the end of November was observed in plantations of Talsi municipality (Number 4) reaching an average of 11% in the course of the trial years. It is difficult to explain the prevalence differences among the farms, because the disease development depended on varying, usually unknown factors. Similar results have been obtained in North America. The age of a cranberry plantation in North America can reach up to 100 years, and most of them are use fungicides for fruit rot control, but the level of fruit rot after a month's storage in different growing sites varies (5 - 85% in 2000) (Olatinwo et al., 2004).

The most of inspected cranberry plantations' growers were not applied fungicides for fruit rot control, but only two growers of them take for necessary to use fungicides. In cranberry plantations of Rucava municipality fungicides were applied starting from 2009. For comparison, in 2007, the incidence of fruit rot after a month's storage was 12% in Rucava municipality, but in 2009, after applying copper hydroxide (770 g kg^{-1}; copper equivalent: 500 g kg^{-1}) at the dosage of 4 kg ha^{-1} at beginning of bloom (10%), incidence reached 7 %.

Although the fungicides were used the next years as well, incidence of fruit rot did not decrease any more. In cranberry plantations of Ape municipality fungicides were used for many years, except for 2009, when copper hydroxide (770 g kg^{-1}; copper equivalent: 500 g kg^{-1}) was not applied and the amount of decayed berries in storage increased for times compared to the years 2007 and 2009. Although in the most of inspected plantations weather conditions increased the incidence of fruit rot in storage, but only berries from Ape municipality stored better. Probably copper hydroxide (770 g kg^{-1}; copper equivalent: 500 g kg^{-1}) applied (dosage 3.5 kg ha^{-1}) at bud break reduced incidence of fruit rot in storage 2010. American cranberry growers and researchers recommend copper hydroxide better for upright dieback control (Cranberry diseases, 1995). Although in cranberry plantations of Rucava (Number 1) and Ape (Number 3) municipalities fungicides were applied (n=6), the incidence of fruit rot was at the same level as in plantations where fungicides were not used (Fig. 3). It means that application of fungicides was not effective to reduce the incidence of fruit rot in storage. Researcher S.N. Jeffers (Jeffers, 1991) from North America has verified that fungicides application in bloom did not affect incidence of fruit rot in storage, for the severest infection by fungi occurred at harvest. Many times of applications with fungicides in bloom affect incidence level of fruit rot on field. That is the most important problem in North America (Cranberry diseases, 1995; Stiles and Oudemans, 1999; Charles, 2003; Johnson - Cicales et al., 2009; Polashock et al., 2009).

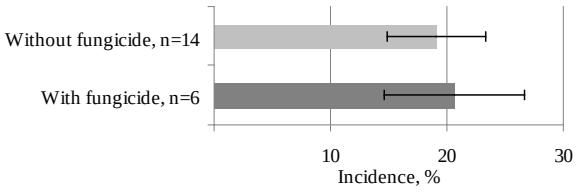

Figure 3. Incidence of fruit rot after a month's storage depending on fungicide application in Latvia.

In general, the average incidence level of fruit rot in storage in Latvia is lower than in North America, wich means that local berries are competitive on local and foreign markets. Customers have to freeze the fresh cranberries as far as possible after berries purchase.

Conclusions

1. In 2007 – 2011, the incidence of fruit rot after a month's storage reached 12 - 15% and, an upwards trend was observed with every successive year.
2. The high level of precipitation (compared to the norm) during the summer and autumn of 2010, significantly reduced the quality of berries in storage, reaching an average of 33% of decayed berries
3. The incidence of fruit rot among the inspected cranberry plantations was highly variable and trend was observed that older plantations had higher levels of fruit rot, for example, the oldest plantation in Alsunga municipality, had 12 - 50% of decayed berries**.**
4. Fungicide applications did not decrease the cranberry post-harvest diseases in storage during our investigations.

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