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EFFECTS OF VOEN COVER ON THE GROWTH AND YIELD OF TWO SWEET CHERRY CULTIVARS

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In 1998, a trial was established with cultivars 'Iputj' and 'Krupnoplodnaya' at the Latvia State Institute of Fruit-Growing. A VOEN covering system was installed on part of the orchard in summer 2008. Considerable lowering of the canopy and renewed pruning were carried out throughout the trial. During 2009–2012, sweet cherry growth, yield and fruit quality were monitored. The cover was installed before flowering in each spring and uncovered after harvest. The cultivar 'Krupnoplodnaya' had a tendency for faster canopy growth under VOEN. Influence of VOEN cover on total yield was not significant, but had a positive tendency on marketable yield. In 2012, the marketable yield was 85% under VOEN, but only 53% without cover due to high precipitation. The cover decreased fruit decay significantly. Fruits damaged by birds (bird pecks) varied year by year. In the first part of the observation period, many damaged fruits were observed also under VOEN, but later the damage was decreased due to installed bird control devices. The fruits of sweet cherries were larger under cover. A positive effect of cover on amount of soluble solids and phenols in fruits was observed for cultivar 'Krupnoplodnaya' in 2011.

Key words: Prunus avium*, canopy volume, marketable yield, fruit weight.*

INTRODUCTION

Cracking of large, firm sweet cherry fruits and the subsequent fungal decay are two great problems in many areas with wet climate such as in Latvia. These factors cause serious losses of yield. It is known that fruit cracking is caused by water absorption through the skin (Christensen, 1973; 1996; Sekse, 1998; 2008). To protect the fruit surface from rain and subsequent cracking, as well as rotting, and to maintain fruit quality, plastic covers are often used (Meland and Skjervheim, 1998; Balkhoven-Baart and Groot, 2005; Meland, 2005; Simon, 2006). However, some of the systems have not only a positive influence on fruit quality, but also some negative aspects (Lang *et al*., 2011).

Under cover, pest damage caused by cherry aphids (*Myzus cerasi*) can increase above damage thresholds (Lang *et al*., 2011) causing reduced growth and yield. However, the slightly shaded conditions under the constructions can promote tree development, growth and yield, and the air temperature can be more stable and suitable. In young orchards, trees under cover can faster fill in the available space with fruit-bearing laterals (Lang *et al*., 2011).

The production of fruit crops under cover (also tunnels) requires a high potential market value to justify the added expense of constructions and orchard management costs. The market returns for fresh sweet cherry fruit could be effective, especially in a market insufficiently supplied with local production, as in Latvia (Skrivele *et al*., 2008). In this study, we determined the effect of a cover system set up in an orchard at the stage of production. It was thought that the investments of the cover system could be returned in comparably shorter time. The objective of this investigation was to assess the reaction of the cultivars grown under the VOEN cover system.

MATERIAL AND METHODS

The study on the effects of the VOEN cover (www.voen.eu) was conducted in 2009–2012 on two cultivars (early ripening 'Iputj' (syn. 'Iput') and medium ripening 'Krupnoplodnaya') in an orchard, where one part of the trees was covered. The trial was performed with three replications. Cultivars were placed alternately with three trees per plot.

The study was set in a trial orchard planted in 1998 (Ruisa and Rubauskis, 2004), in which the effect of rootstock and soil ammendment was studied previously. In the present study, the effect of rootstock and soil ammendment not considered and the average data for trees on rootstocks Gisela 4, Gisela 5 and Weiroot 154 were used.

The VOEN cover system was installed in 2008. Tree canopy was fitted to the cover system by reducing tree height, narrowing and renewing tree canopy in the second part of the growth season. The same procedure was performed in

the remaining area without cover. Irrigation was provided for all plots in 2012.

The soil was sod-podzolic sandy loam with pH 6.4, organic matter 3.2% and plant available K_2O and P_2O_5 293 mg·kg^{-1} and 234 mg·kg^{-1}, respectively (data of 2010). Ammonium nitrate and potassium nitrate fertilisation was applied at 6 g·m^{-2} N and 12 g·m^{-2} K_2O, respectively, applied in 1 m wide strips. Potassium nitrate was not used after 2011. Fertilisers containing phosphorus were not used at all.

In 2009–2012, the average air temperature registered by the meteorological station Dobele and meteorological station of LUFFT (www.lufft.com) near the trial was 6.2–7.8 °C. In winter, a relatively low air temperature was observed in three of the four years of observation. The temperature dropped down to –24 to –28 °C in winter, except in 2009. Unfavourable weather occurred in February of 2011, when the minimum of temperature reached –24 °C in the III decade of February. However, in December of 2010, cold temperature was stable (average –5 to –8 °C). The sum of active temperatures varied between 2738 °C and 3155 °C in 2009–2012. The precipitation sum was 479–793 mm annually and 350–648 mm in the vegetation period. In 2010, when the largest amount of precipitation occurred during the period of sweet cherry ripening (III decade of June and July) the precipitation sum was 152 mm. Similarly, in 2012, the precipation sum in this period was 158 mm (Fig. 1).

Plant protection and orchard management were provided as required, following the principles of Integrated (sustainable) Fruit Production (IFP).

The following parameters were assessed: flowering intensity (0–10 points), yield per tree, kg, size, shape and colour of fruits when harvested, weight of 50 fruits, percentage of damaged fruits at harvest — rain-induced cracking, disease infection and bird pecks, soluble solids (Brix) and total phenol concentrations of fruits, tree height and width in two directions to calculate the canopy volume as suggested by I. Dimza (Rubauskis *et al*., 2011).

SPSS for Windows was used for statistical analysis of data by ANOVA and Pearson bivariate correlation.

RESULTS

Cultivar 'Iputj' had significantly larger canopy volume than other cultivars in 2009 (Table 1). There were no significant differences in volume between cultivars in 2011. The canopy of trees did not significantly different between orchards with and without cover in 2009 and 2011.

In both parts of the orchard, flowering intensity was similar (Table 2) in 2009–2012. In 2012, cultivar 'Iputj' had significantly higher flowering intensity than 'Krupnoplodnaya'. In 2012, the interaction of factors (cultivars and VOEN cover) was also statistically significant. Lower flowering intensity was observed for 'Krupnoplodnaya' under cover. In the area without cover, the difference between cultivars 'Iputj' and 'Krupnoplodnaya' was not significant at 95% probability.

The yield under cover was similar to that without cover in the first season and no cultivar effect was found (Table 2). There was a small positive influence of cover on yield in 2010, when the tree canopy started to form new branches. However, this effect of cover was not observed every year.

Table 1

AVERAGE CANOPY VOLUME (m^3) OF TREES UNDER VOEN COVER AND WITHOUT COVER

Factors		Cover (VOEN)		*P* value		
Year	Cultivar	without cover	under cover	cover	cultivar	interaction
2009	Iputj	8.0	7.4	0.83	0.06	0.36
	Krupnoplodnaya	5.5	6.5			
2011	Iputj	7.2	7.3	0.11	0.52	0.14
	Krupnoplodnaya	5.6	8.0			

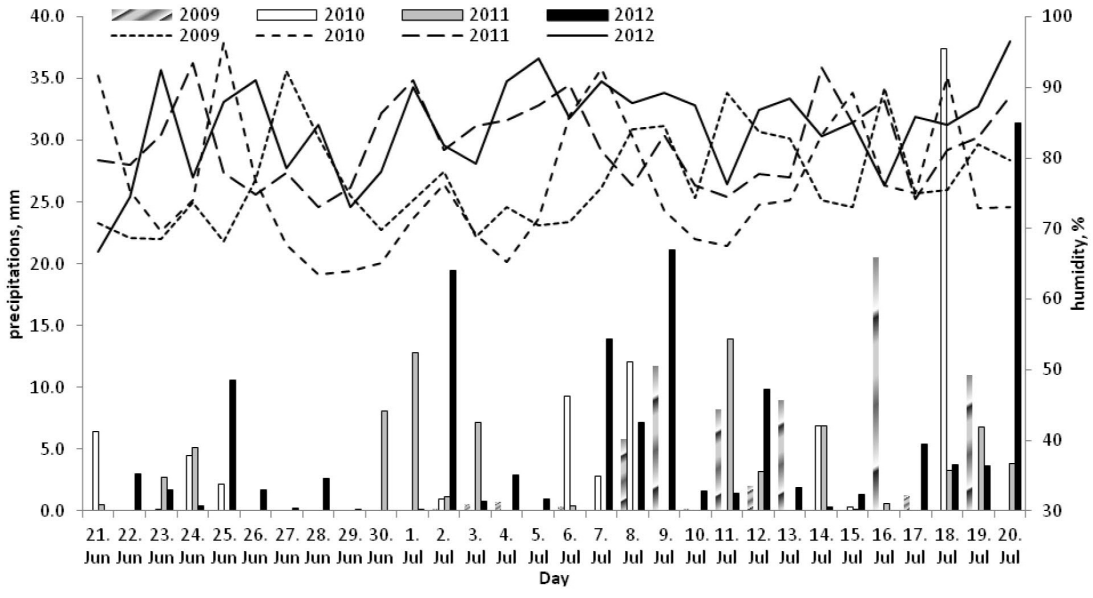

Fig. 1. Precipitation (mm) and relative air humidity (%) in the period of fruit ripening (III decade of June, I and II decades of July).

Table 2

FLOWERING AND YIELD OF SWEET CHERRY TREES UNDER VOEN COVER AND WITHOUT COVER

Year	Cultivar	Average flowering intensity (0–10 points)		Average yield per trees (kg)	
		without cover	VOEN	without cover	VOEN
2009	Iputj	10	9	4.0	4.2
	Krupnoplodnaya	10	9	4.1	5.5
2010	Iputj	8	8	1.7^{b}	2.5^{a}
	Krupnoplodnaya	8	8	1.7^{b}	3.4^{a}
2011	Iputj	8	8	6.7	5.0
	Krupnoplodnaya	9	8	6.8	4.7
2012	Iputj	9	9^{I}	9.6	10.8
	Krupnoplodnaya	8	7^{II}	8.5	9.0

* small letters (a and b) mark significant differences between data of orchard areas at probability level 95%, symbols I and II show significant differences between cultivars.

Table 3

AVERAGE MARKETABLE YIELD (kg) OF TREES UNDER VOEN COVER AND WITHOUT COVER

Year	Cultivar	Average marketable yield per tree (kg)		Amount of marketable fruits (%)	
		without cover	VOEN	without cover	VOEN
2009	Iputj	$2.5^{a, I}$	$0.9^{b, II}$	44.6^{a}	15.9^{b}
	Krupnoplodnaya	$0.0^{b, II}$	$3.6^{a, I}$	1.0^{b}	61.8^{a}
2011	Iputj	2.3	3.1	$37.6^{b, II}$	$66.2^{a, II}$
	Krupnoplodnaya	4.4	3.7	$61.3^{b, I}$	$73.7^{a, I}$
2012	Iputj	4.9^{b}	9.2^{a}	51.4^{b}	85.3^{a}
	Krupnoplodnaya	4.7^{b}	7.4^{a}	54.0^{b}	84.6^{a}

* small letters (a and b) mark significant differences between data of orchard areas at probability level 95%, symbols I and II show significant differences between cultivars.

In 2011 and 2012, the proportion of marketable fruit was significantly higher under VOEN cover (Table 3). In 2011, the proportion of marketable fruit was 70% for both cultivars under cover, but without cover only 50%. In 2012, the proportion of marketable fruits was 85% for both cultivars under cover, but without cover only 53% (Table 3). A significantly larger marketable yield under VOEN cover was obtained in 2012 (Table 3). On average, for the cultivars the marketable yield was 8.3 kg per tree under cover; 9.2 kg and 7.4 kg, respectively, for 'Iputj' and 'Krupnoplodnaya'.

The amount of damaged (int. al. cracked) fruit differed yearly in relation to precipitation and air humidity during the fruit ripening period. In 2009, cracked fruits were observed on cultivar 'Krupnoplodnaya' without cover, when more precipitation was observed in the second decade of July (Table 4, Fig. 1). In 2011 and 2012, more cracked fruits occurred on cultivar 'Iputj' without cover, due to high relative air moisture and precipitation in the end of June and beginning of July (Fig. 1).

A significantly larger amount of fruits of cv. 'Krupnoplodnaya' was found damaged by fruit rot comparing with 'Iputj' in 2011 and 2012 (Table 4), especially in the area without cover. More fruits of cultivar 'Krupnoplodnaya' were observed to be cracked and rotted than 'Iputj'. In 2012, when precipitation was heavier and more frequent (Fig. 1), twice more rotten fruits occurred under VOEN than in 2011. The difference proportion of rotted fruits between areas was 22% in 2011, but only 11.5% in 2012.

In 2009, many bird pecks were observed in both parts of the orchard (Table 4). The cultivars differed in cultivar ripening time, which caused differences in bird-caused damage due to bird (starling) migration. In general, the yield loss due to bird damage was significantly lower under cover comparing with the orchard part without cover, especially in 2011 and 2012 for cultivar 'Iputj'.

The cultivars differed in fruit weight. The cultivar 'Krupnoplodnaya' had larger fruits. The influence of the cover was found in the third and fourth years of observation (Table 5). In 2011, under VOEN the fruits were 9–10 % larger, but in 2012 even 16–19% larger than without cover.

In 2011, fruits under VOEN had higher concentration of soluble solids and total phenols, compared to those in the uncovered area. In 2012, no significant difference of fruit biochemical content between orchard parts was not found. A significant difference between cultivars was found:

Table 4

AMOUNT OF FRUITS CRACKED, DAMAGED BY ROT AND BIRDS (%) ON TREES UNDER VOEN COVER AND WITHOUT COVER

Year	Cultivar	Cracked fruits		Damaged by rot		Pecks of birds	
		without cover	VOEN	without cover	VOEN	without cover	VOEN
2009	Iputj	0.0	0.0	8.4^{I}	8.3^{I}	60.3^{I}	75.8^{I}
	Krupnoplodnaya	63.5^{a}	0.0^{b}	0.1^{II}	5.0^{II}	26.7^{II}	33.3^{II}
2011	Iputj	43.0^{I}	25.8^{I}	8.0	4.0	11.4^{a}	4.1^{b}
	Krupnoplodnaya	12.1^{II}	21.7^{II}	26.0^{a}	4.0^{b}	0.6	0.7
2012	Iputj	$33.3^{a, I}$	$6.1^{b, I}$	$7.2^{a, II}$	$4.9^{b, II}$	8.2^{a}	3.7^{b}
	Krupnoplodnaya	$20.9^{a, II}$	$2.0^{b, II}$	$22.4^{a, I}$	$10.9^{b, I}$	2.7	2.5

* small letters (a and b) mark significant differences between data of orchard areas at probability level 95%, symbols I and II show significant differences between cultivars.

Table 5

AVERAGE FRUIT WEIGHT (g) ON TREES UNDER VOEN COVER AND WITHOUT COVER

Year	Cultivar	Cover (VOEN)		*P* value		
		without cover	under cover	cover	cultivar	inter-action
2009	Iputj	5.2	5.9	0.14	0.00	0.22
	Krupnoplodnaya	9.2	9.3			
2010	Iputj	5.9	5.9	0.63	0.00	0.60
	Krupnoplodnaya	8.1	7.9			
2011	Iputj	6.1	6.8	0.01	0.00	0.41
	Krupnoplodnaya	8.8	10.0			
2012	Iputj	5.2	6.2	0.00	0.00	0.21
	Krupnoplodnaya	7.9	9.7			

Table 6

SOLUBLE SOLIDS AND TOTAL PHENOL CONCENTRATIONS IN FRUITS FROM TREES UNDER VOEN COVER AND WITHOUT COVER

Year	Cultivar	Soluble solids, °Brix		Phenols, mg 100 g^{-1}	
		without cover	VOEN	without cover	VOEN
2011	Iputj	14.4^{II}	14.8^{II}	$143.5^{b, I}$	$155.3^{a, I}$
	Krupnoplodnaya	$15.1^{b, I}$	$17.0^{a, I}$	$96.7^{b, II}$	$115.3^{a, II}$
2012	Iputj	14.3	14.9	195.9^{I}	186.1^{I}
	Krupnoplodnaya	14.6	14.6	98.4^{II}	113.5^{II}

* small letters (a and b) mark significant differences between data of orchard areas at probability level 95%, symbols I and II show significant differences between cultivars.

cultivar 'Krupnoplodnaya' had higher soluble solid content in 2011 (Table 6), and cultivar 'Iputj' had higher phenol concentration in 2011 and 2012.

DISCUSSION

After modification of the sweet tree canopy fit the frame of the cover system in 2008, a tendency of increase of canopy volume was found under cover, especially for cultivar 'Krupnoplodnaya'. There was also a positive correlation between trunk cross-section area and canopy volume (r = 0.75). The canopy volume increased due to the growth of new shoots, but not due to increase of tree height (Table 1). More vigorous tree growth under cover, compared to that without cover, was also observed in other investigations (Blanke and Balmer, 2008).

The reduction of flower amount in the first season in the orchard with cover cannot be explained by the effect of VOEN cover, as it was installed only in 2009. Smaller flowering intensity of 'Krupnoplodnaya' under cover was observed in 2012 (Table 2), which can be explained by larger tree canopy volume.

However, cover had effect on marketable yield, in relation to yield and amount of different damage caused by rain, pests, birds etc. The marketable yield under cover was 12.4 and 28.6% more than in the uncovered area for cultivars 'Krupnoplodnaya' and 'Iputj', respectively (Table 3). In 2012, the difference reached 30.6 and 33.9%, respectively. Similar results have been obtained in Norway, where three covering methods increased the proportion of marketable fruits from 54% on uncovered to 89% on covered trees (Børve *et al*., 2003).

Even under fully covered tunnels, fruit cracking can be observed (Christensen, 1996). In our trial cracked fruits were found also under cover, and in 2011 the amount of cracked fruits reached even 22–26% (Table 4). A significant difference between orchard parts was not always observed, and depended on cultivar ripening time and weather at that time. The consequence of fruit cracking is fruit damage by pathogens, which causes fruit rot. Fruit decay organisms need high water content or high relative humidity for infection (Ogava *et al*., 1995). *Monilinia laxa* (causing brown rot) and *Botrytis cinerea* (causing gray mold) are the most frequently observed pathogens in Norway (Børve and Stensvand, 2003). Similar to the results of our observation, in Norway covering of sweet cherries from three weeks prior to harvest and throughout the harvest period reduced fruit cracking significantly and fruit decay (Børve and Stensvand, 2003, Børve *et al*., 2008). However, the cover did not fully prevent yield loss under cover, as observed in other regions (Balmer, 1998). In our trial even under cover, 4–11 % (Table 4) of fruits were damaged by rot caused by *Monilinia laxa* and *Botrytis cinerea.*

Fruit pecks by birds were reduced when bird control devices were used in the third and fourth seasons of investigation. In our trials, a comparably small area was covered with VOEN. Probably, in larger covered fields, birds will damage fruits in a smaller amount. In our conditions, VOEN cover alone did not protect the yield (Table 4). In our case, the orchard sides need be shielded by net. In a study conducted at Michigan State University, a high tunnel cover system had some negative effects on cherry on yield in some years, due to decreased pollination by insects (Lang, 2009). With the VOEN used in our trial, pollination was not blocked as the lateral sides of trees were not closed.

In our trials, fruits were lager in the last two seasons (Table 5) which may be explained by a positive effect of temperature. However, it has been observed that under full cover the fruits can be slightly smaller, softer, but attractively coloured and taste better (Blanke and Balmer, 2008), when temperature increases.

Variation of qualitative parameters of fruits, such as concentration of soluble solids and phenols, was found (Table 6), perhaps due to the degree of maturity at harvesting. The effect of rain cover on fruit quality has been various also in other investigations. The concentration of soluble solids was significantly lower in fruits of cultivar 'Van' grown under umbrella type cover, which was explained by stress due to a changed microclimate in the canopy (Børve and Meland, 1998). In that study, there were no differences

in soluble solid concentration among other variants — permanent cover with polyethylene sheets from top, covering only when raining and uncovered trees

In conclusion, a significant effect of VOEN cover on total yield was not shown, but some positive tendencies were observed. There was an increase of marketable yield and decrease of amount of fruits damaged by rot when grown under VOEN. Fruits destroyed by birds (bird pecks) varied year by year. In first part of observation, many damaged fruits were observed also under VOEN, but in the following period under cover fruits were less damaged, when bird control devicess were used. The fruits of sweet cherries were larger under cover. A positive effect concentration of soluble solids and total phenols was shown for cultivar 'Krupnoplodnaya' in 2011.

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VOEN SEGUMA IETEKME UZ DIVU SALDO ĶIRŠU ŠĶIRŅU AUGŠANU UN RAŽĪBU

Izmēģinājums iekārtots Latvijas Valsts Augļkopības institūtā 1998. gada stādījumā ar šķirnēm 'Iputj' un 'Krupnoplodnaja'. 2008. gadā uzstādot VOEN seguma sistēmu, veikta ievērojama vainaga pazemināšana un atjaunošana gan variantā ar segumu, gan arī kontrolē. Dati par saldo ķiršu augšanu, ražošanu un augļu kvalitāti variantos ar segumu un bez tā iegūti no 2009. gada līdz 2012. gadam. Segums katru pavasari, sākot ar 2009. gadu, uzklāts pirms ziedēšanas un noņemts pēc ražas novākšanas. Šķirnei 'Krupnoplodnaja' pēc apgriešanas zem seguma bija vērojama izteikta tendence ātrāk atjaunot vainaga tilpumu, lai gan matemātiski to pierādīt neizdevās. Seguma ietekme uz ražas lielumu nebija pierādāma, lai gan tendence bija pozitīva. Variantā zem VOEN seguma iegūti vairāk realizācijai derīgu augļu. 2012. gadā, kad ķiršu ienākšanās laikā bija sevišķi daudz nokrišņu, zem seguma 85% augļu bija derīgi realizācijai, bet bez seguma tikai 53%. Segums ievērojami samazināja puves bojāto augļu daudzumu, bet putnu bojāto augļu daudzums bija atšķirīgs pa gadiem. Pirmos divus gadus to bija vairāk zem seguma, bet 2011.–2012. gada variantā bez seguma. Šajos gados ar augstu ticamību pierādījās seguma pozitīva ietekme uz augļu vidējo svaru, zem seguma tie bija lielāki. Seguma pozitīva ietekme uz šķīstošās sausnas un fenola saturu augļos bija pierādāma tikai 2011. gadā šķirnei 'Krupnoplodnaja'.