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INFLUENCE OF THE PLASTIC COVER ON THE PROTECTION OF SWEET CHERRY FRUIT AGAINST CRACKING, ON THE MICROCLIMATE UNDER COVER AND FRUIT QUALITY

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ABSTRACT

To study possibility of protection of sweet cherry fruit against cracking several rows of 'Lapins' sweet cherry (*Prunus avium* L.) trees grafted on 'Colt' rootstock, spaced 5 × 2.5 m and trained to a central leader were covered with a plastic foil to a height of 5 m. Several rows were left uncovered as a control. In the years 2016 and 2018, sun irradiation, air temperature and fruit quality were evaluated. The plastic cover reduced solar irradiation under the tunnel roof by around 40%. Light distribution within tree canopies was depleted by roughly 50%, but in the lower parts of the tree canopies, it was reduced to 6%, which is below the critical level (20%) estimated for apple trees. These results indicate the necessity to remove the covers as soon as possible after harvesting. Mean daily temperature near the ground was lower under the covers than outside, but at the height of 4.0 m, daily mean temperature was 0.4 °C higher and mean temperature during midday hours was 1.5 °C higher. The plastic covering reduced the fruit cracking from about 20% to 2% in both seasons but did not affect the fruit yield. The plastic covering did not affect the firmness and antioxidant activity and total anthocyanin content, but in the year 2018, it reduced the mean fruit weight, soluble solid, titratable acidity, dry matter and total polyphenols content.

Keywords: fruit cracking protection, sun irradiation, sweet cherry

INTRODUCTION

Sweet cherries (*Prunus avium* L.) are rich in anthocyanins, potassium, fiber, vitamin C, carotenoids, melatonin and other valuable elements (McCune et al. 2011). For this reason and excellent taste, they are highly marketable. Main obstacle in cherry production is rain-induced fruit cracking. Fruit cracking in sweet cherries causes serious losses in many production areas (Balbontin et al. 2013; Aksu et al. 2014). Cracking is usually the result of the wetted fruit surface prior to harvest. Water uptake through the fruit skin and pedicel results in increased turgor of the fruit and induces cracking (Measham et al. 2010; Measham et al. 2014). To eliminate this problem, Díaz-Mula et al. (2012) proposed fruit coating with sodium alginate after fruit harvesting. Another suggestion was the packing of cherry fruit to modified atmosphere – MAP (Wang & Long 2014). The fruit cracking appears to be essential in cherry producing regions with a climate like that of Norway, where precipitation during fruit ripening is around 100 mm (Meland et al. 2014). Rain and hail can reduce marketable yield of sweet cherry fruit of any plantation due to cracking and the rotting process that follows (Measham et al. 2012; Kafkaletou et al. 2015). Sweet cherries are an excellent crop for the production in high tunnels because they are highest valuated among temperate fruits, and their production in the open is highly risky (Lang 2013). Growing sweet cherries under plastic covers is proposed as the best method to avoid rain-induced cracking (Schmitz-Eiberger & Blanke 2012; Rubauskis et al. 2013). Sweet cherries grown

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in high polyethylene tunnels exhibit longer terminal growth, larger leaf area, premium fruit quality, higher crop value. Decreased incidence of diseases caused by *Blumeriella jaapi* and *Pseudomonas syringae*, was observed under cover whereas *Podosphaera clandestina* caused higher incidence (Rubauskis et al. 2013). Covers above cherry orchard enable to delay fruit harvesting 4 days beyond the current commercial harvest and achieve higher fruit quality (Díaz-Mula et al. 2010). High tunnels of plastic covers with different light spectral transmittance and dispersion properties modify the environmental microclimate (air and soil temperature, relative humidity, photosynthesis active radiation, leaf wetness, etc.) and have a significant impact on tree growth, reproductive performance, fruit quality, incidence of diseases and insect pests (Lang et al. 2011). The reduction in transmitted light under covers can affect not only photosynthesis, but, depending on specific spectral variations, can also influence the activity of pollinators and other insects (Lang 2014).

In a trial by Wallberg and Sagredo (2014) in Chile, the protective covering filtered approximately 40% of incident PAR, which stimulates shoot growth and reduced fruit coloration. The protective covering installed at flower bud-burst increased fruit size, weight and soluble solids content, but reduced fruit firmness. According to Wallberg and Sagredo (2014) covering advanced flower bud differentiation.

Insufficient information on the influence of covers on the interior microclimate was the reason for undertaking this work. The objective of the survey was to evaluate the effect of covers on the microclimate under them and on sweet cherry fruit quality.

MATERIALS AND METHODS

Experimental objects

The records were done in 2016 and 2018, in a commercial cherry orchard in Lewiczyn, situated in the main fruit-growing region of Mazovia, in central Poland. The experimental orchard occupied an area of around 1.0 ha and consisted of several rows of five-year-old cherry trees of the self-fertile cultivar 'Lapins' grafted on Colt rootstock, and spaced 5 × 2.5 m. The trees were trained to a central leader canopy to a 5.0 m height with a 0.8 m long trunk and a 3.0 m canopy spread. From the 4th year after planting, the trees were pruned by the renewal method. Old branches were cut out near the leader, whereas one-, two- and three-year-old wood was left for fruiting, and were thinned to avoid too much branches in the tree canopy. Due to intensive growth, the trees were pruned twice: in the springtime and after fruit harvesting in August. For weeds control, the herbicide sprays were applied in the tree rows with grass and frequently mowed in alleyways. Mineral fertilizers were applied to the soil in the spring, according to the results of soil analyzed. The following doses were applied: 80 kg K_2O, 60 kg P_2O_5, 40 kg MgO, 60 kg N. Trees were protected against diseases with two copper sprayings in early spring and late autumn. Three sprayings with triazoles and strobulines were applied in May and early June. In the first week of June 2016 and 2018, covers were mounted over the trees on 5 m, on a supporting system consisting of 6 m long wooden construction and high tensile wires were stretched along the rows on the top of the poles. The covers were reinforced using plastic foil (agricultural cover plastic OROPLUS® (Plastik SpA, Italy). The foil was fixed to the wires with ropes threaded through hooks in the foil. The covers were removed at the end of August. The control constituted uncovered trees.

On July 17, 2016 and June 13, 2018, fruits were sampled from 4 trees, taken at random in 3 replications to estimate yield and quality. On July 17 and July 30, 2016, solar irradiation coming from the sky hemisphere above the experimental grove was measured in order to calculate the percentage of light transmitted to the covers, trees and the ground. In 2017, there was no crop because of spring damage to flower buds. The measurements were repeated on June 13, 2018. Very sunny and warm spring in 2018 accelerated vegetation and cherry fruit ripening. Fruit harvesting began in the second week of June. The obtained values allowed the calculations of light distribution within the trees and light interception by the tree canopy.

All the measurements were taken on sunny days, between 11 and 12 o'clock. The light intensity was measured under the plastic foil and along the alleyway, at a level of 1.8 m. The distribution of light within the trees was measured under the tree canopy (0.6 m), at the lowest mantle of tree canopy (1.2 m), and in the middle mantle of tree canopy (1.8 m). As the tree rows were oriented N–S, the measurements within tree canopies were taken across the rows, towards the central leader, in the E–W direction. The same measuring pattern was followed within the trees growing outside covers. The measurements were taken from 15 trees at each level in one construction and then repeated in the second one. In the statistical evaluation, the 15 measurements were treated as replications. The results of light measurements in and outside the covers ($W \cdot m^{-2}$) were converted to the percentage of the irradiation above tree canopies. All the measurements were taken with a Delta-T Tube solarimeter type TSL (Delta-T Devices LTD, England). In the year 2016, the temperature in plastic covers was measured over two months (July and August) with Metos Pessel Instruments (Austria) mounted on metal poles in and outside the covers at the levels of 0.2, 2.0 and 4.0 m. In the year 2018, the temperature was measured only at the level 2.0 m.

Quality assessment of the cherry fruit

Just before the commercial harvest date, on July 31 in 2016, and June 13 in 2018, the representative samples of fruits were collected from trees growing both outside and inside the coverings to determine the effect of the shadow applied during fruit ripening on its quality characteristic. Four representative samples of 25 fruits each were picked for each treatment, which were taken as repetitions. After the harvest, the fruits were immediately transported to the premises of the laboratory and subjected to quality assessment. The percentage of cracked fruits were estimated in the 2 kg samples taken from the covered and uncovered trees. For this purpose, fruits were harvested from the height of 1.8 m and sorted.

The fruit weight (± 0.01 g) was determined for individual trees (4 × 25 measurements for both treatments). Fruit firmness (N) was measured with an Instron 4303 machine (Instron Ltd, England), and expressed as the force needed to puncture the fruit with a 3.5 mm diameter pin moving at a speed of 50 $mm \cdot min^{-1}$. After firmness measurement, the fruit of particular samples were pitted, disintegrated and preserved for further analyses. Soluble solids were measured with RE50 Refractometer (Mettler Toledo, Japan); dry matter was determined with the gravimetric method (drying to constant weight, 3×10^3 Pa vacuum, 70 °C). Titratable acidity was measured by titrating diluted fruit pulp to pH 8.1 with 0.1 $mol \cdot dm^{-3}$ NaOH by DL 58 Titrator (Mettler Toledo, Switzerland). Total anthocyanin content was determined after extraction from the solution of acidified ethanol using homogenizator (Ultra Turrax T25 Basic IKA-WERKE) and quantified spectrometrically according to Konopacka et al. (2014). Results were expressed as cyanidin-3-glucose ($mg \cdot 100\ g^{-1}$ of fresh fruits). Total phenolic contents were measured by the modified spectrophotometric method with Folin–Ciocalteu reagent (Konopacka et al. 2014) at 765 nm using the same extract as for anthocyanins. The contents of phenolic compounds were expressed as mg gallic acid equivalents. The antioxidant activity was determined from the samples after grinding in liquid nitrogen using mill (IKA A11 Basic IKA-WERKE) and expressed as 50% reduction of $ABTS^+$ solution absorbance and recalculated to mg of Trolox equivalents. All the measurements were carried out in two analytical replicates per each batch of fruit.

The one-way ANOVA was done and means comparisons were conducted by means of the Duncan's test at p = 0.05.

RESULTS AND DISCUSSION

In 2016, the solar irradiation from the blue sky hemisphere during the measurements between 11 a.m. and 12 p.m. ranged from 1050 to 1200 $W \cdot m^{-2}$. Light intensity under the covers, as measured in the alleyway between tree rows, below the roof of the plastic foil (1.8 m above the ground), was reduced by 42.5 and 36.2%, dependent on the term of measure in comparison with the control uncovered (Table 1). In 2018, the sky was not ideally clear and the irradiation was 856 $W \cdot m^{-2}$. Light intensity in alleyways under plastic covers was reduced by 61.9% (Table 1, Fig. 1).

Table 1. Influence of trees covering with foil on solar irradiation (W·m^{-2}) during noon hours

Details of measurement	Solar irradiation (W·m^{-2})		
	July 17, 2016	July 30, 2016	June 13, 2018
Above trees at cloudless sky	1200	1050	856
In the alleyways not covered with plastic foil	920	850	508
Percentage of light depletion compared with solar irradiation above the trees	23.3	19.0	40.7
In the alleyways covered with plastic foil	690	670	326
Percentage of light depletion compared with solar irradiation above the trees	42.5	36.2	61.9
Percentage of light in alleyways filtered into plastic covers	57.5	63.8	38.1

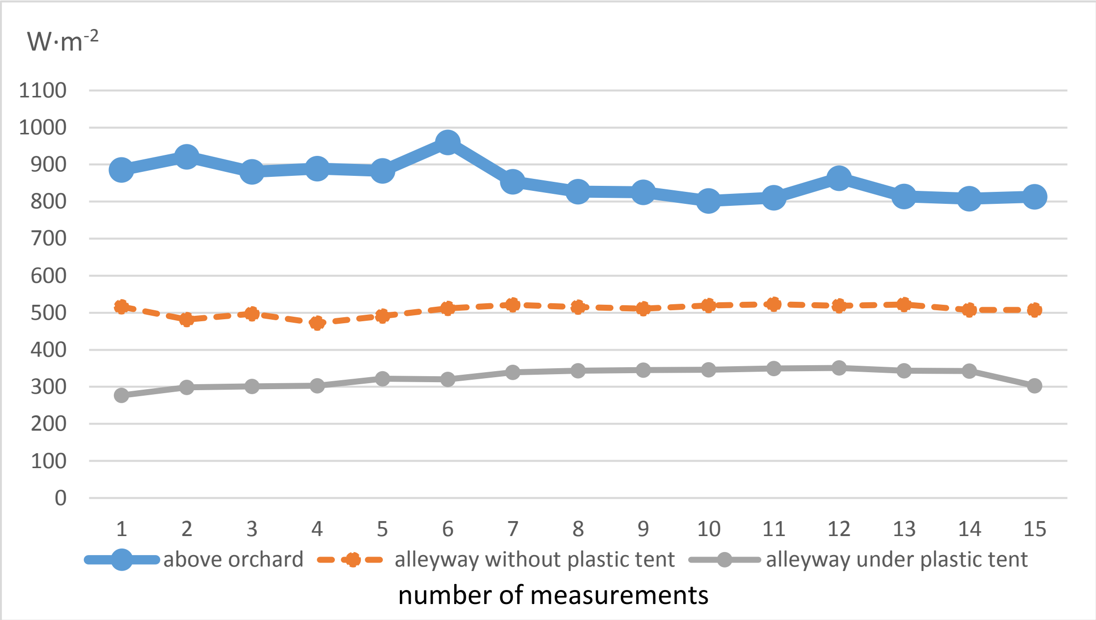

Fig. 1. Solar irradiation measured during one hour above the orchard as compared with irradiation in the alleyway under plastic covering and without it

Lowering the light intensity due to plastic cover in 2018 was similar as in the trial by Schmitz-Eiberger and Blanke (2012), Wallberg and Sagredo (2014), where a 60% light reduction by the foil cover was recorded. The light intensity under covers (38–63%) could be sufficient for satisfactory growth and fruiting of trees assuming that such light energy would penetrate uniformly the whole canopy (Mika & Buler 2016). Unfortunately, this is not so. It has been shown that light penetration within the tree canopy declines markedly from the top of the tree bottom and from the outer to the inner mantle of the tree canopy (Mika & Buler 2016). In this trial, light distribution within the tree canopy was significantly lower under covering when compared to the trees grown outside. In the measurements taken on July 17 and July 30, 2016, decrease was close to 50% and on June 13, 2018 the reduction was about trifold in comparison to the light under the covers (Table 2).

Light intensity under the covers were still lower than experimentally proved as sufficient in modern high-density apple orchards, which was estimated for plum trees on a minimum 20% in the lowest canopy mantle, 30–40% in the middle canopy mantle, and 60–70% in the canopy top (Mika & Buler 2016). Such poor illumination in sweet cherries under covers may have an adverse influence on fruit productivity and fruit quality if the covers would be left over trees for the full growing season. Pruning of trees for good light exposure throughout the canopy is important for sweet cherry fruit quality (Lang et al. 2011). There are also evidences from some Polish orchards that cherries growing in high tunnels with insufficient ventilation may become overheated, and in such a case, they did not set fruit buds (unpublished results). To avoid overheating, the plastic foil should be removed soon after harvesting.

The covering with plastics did not affect fruit yield but significantly reduced fruit cracking from about 20% to about 2% (Table 3). The cultivar ‘Lapins’ is known for its high productivity, but it is also very susceptible to rain-induced cracking because it produces fruit in large, tight clusters that absorb water and remain damp for a long time. In the both seasons, weather was not critical for cracking.

The mean temperature measured from July 17 to September 3, 2016 depended on the distance from the ground and on the covering. Mean daily temperature at the level of 0.2 m was 0.3 °C lower in the covered part but at 2 and 4 m above the ground was higher by 0.1 and 0.4 °C than in the uncovered part (Fig. 2).

The differences were greater when comparisons were made at the midday hours. At 0.2 m, the mean temperature was lower by 0.7 °C, but at 2 and 4 m was higher by 0.1 and 1.5 °C, respectively (Fig. 3). In 2018, the mean daily temperature measured 2.0 m above the ground was mainly the same but during the 6 days, the outside temperature was higher by 1-2 °C (Fig. 4). A similar trend was evident in the temperatures recorded during the middays (Fig. 5). Lang et al. (2011) reported that the high temperature under the roof of plastic covers could influence fruit quality, if it occurred earlier, in June/July, at the beginning of fruit ripening.

In our survey, a tendency was observed that the fruits that ripened under the covering had a paler skin color, but the contents of anthocyanins were not significantly different (Table 4). Wallberg and Sagredo (2014) also reported that the fruit of cherry trees covered during the color development phase showed lighter color.

The covering of trees did not affect firmness, anthocyanin content and antioxidant activity (Table 4). In 2018, significantly lowest fruit weight was detected in sweet cherries ripened outside. Also, in the fruit from trees that grew open, more soluble solids and total polyphenols as well as more dry matter was found (Table 4). Sotiropoulos et al. (2014) reported that covering of the cherry trees with the plastic polyethylene films increased marketable yield and did not have much adverse effect on fruit quality.

Table 2. Influence of foil covering on light distribution within the tree canopies in a cherry orchard expressed in a percentage of irradiation above the trees

The level above ground	July 17, 2016		July 30, 2016		June 13, 2018	
	under covering	control	under covering	control	under covering	control
0.6 m	5.8 a ± 0.75*	9.7 a ± 2.34	6.4 a ± 1.01	12.5 b ± 2.37	2.6 a ± 0.48	10.8 b ± 1.97
1.2 m	15.6 a ± 1.83	36.1 b ± 8.18	9.4 ab ± 1.24	30.9 d ± 2.92	7.8 a ± 0.82	28.4 d ± 2.11
1.8 m	31.1 b ± 1.82	54.0 c ± 6.77	23.2 c ± 3.24	46.0 e ± 2.78	16.4 c ± 1.80	41.8 e ± 4.50

*Means in rows with the same date followed with the same letter are not significantly different at p = 0.05 according to Duncan’s test; means ± SE.

Table 3. Influence of foil covering on yield and percentage of cracked fruits of sweet cherry

Yield	2016		2018	
	under covering	control	under covering	control
Yield (kg·tree^{-1})	19.7 a ± 0.28*	18.5 a ± 0.11	21.0 a ± 0.57	20.5 a ± 0.40
Cracked fruits (%)	1.5 a ± 0.23	23.0 b ± 1.15	2.0 a ± 0.11	19.7 b ± 1.44

*Means in rows compared within years followed with the same letter are not significantly different at p = 0.05 according to Duncan’s test; means ± SE.

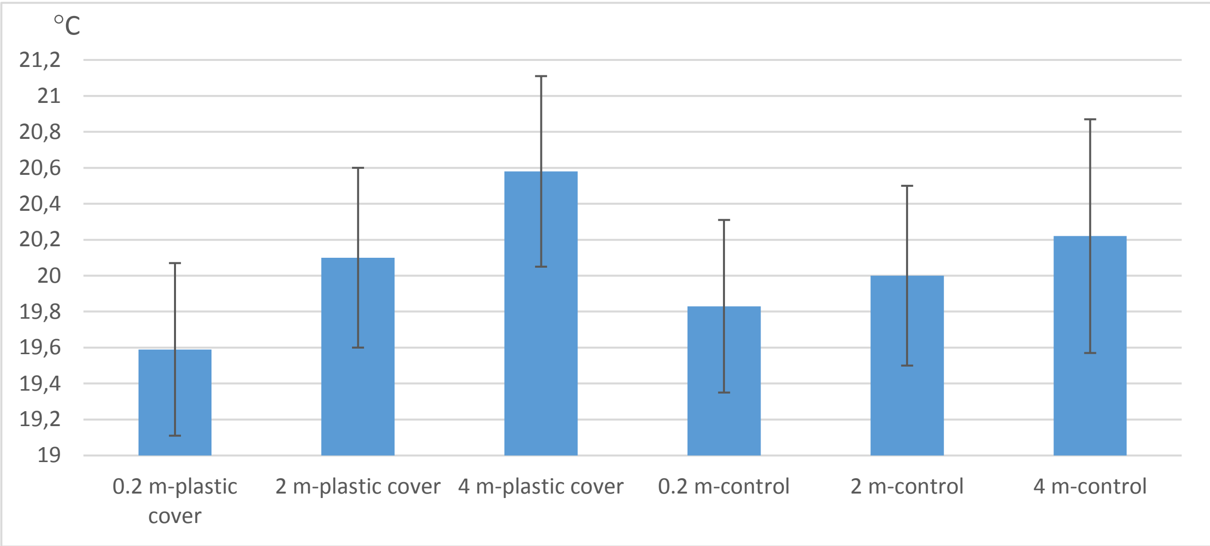

Fig. 2. Mean day temperature ± SE measured on three levels above the ground (0.2, 2.0 and 4.0 m) during six weeks (July 17 – September 3, 2016) in the alleyway under plastic cover and without plastic cover (control)

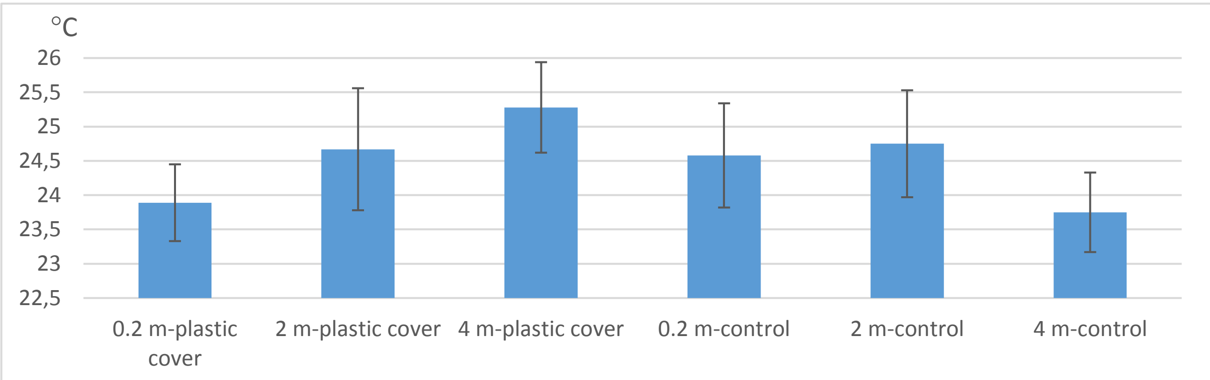

Fig. 3. Mean noon temperature ±SE (hours 10–14) measured on three levels above the ground (0.2, 2.0 and 4.0 m) during six weeks (July 17 – September 3, 2016) in the alleyway under plastic cover and without plastic cover (control)

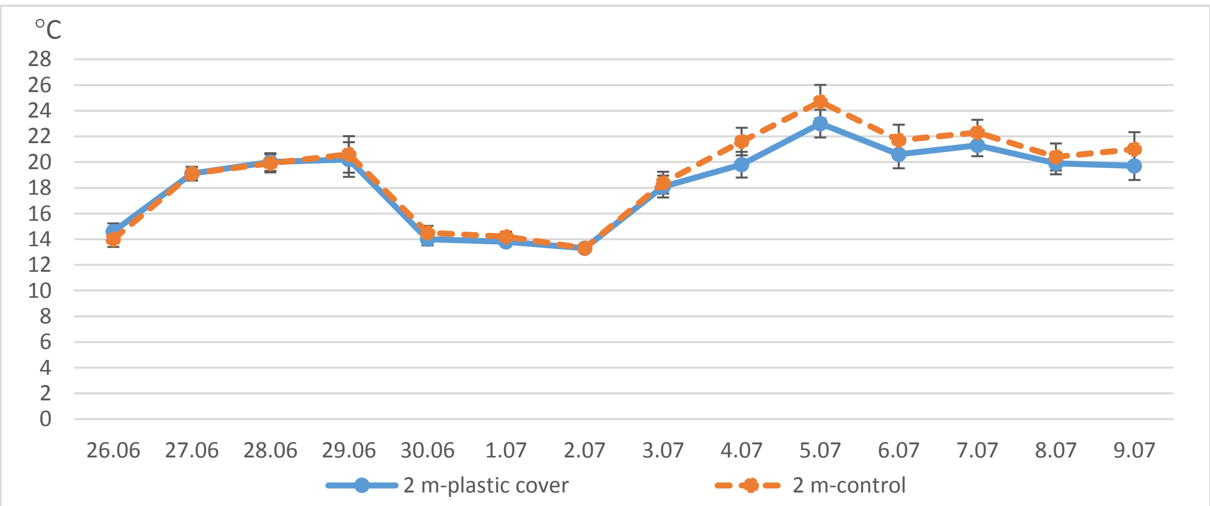

Fig. 4. Mean day temperature measured 2.0 m above the ground during two weeks (June 26 – July 09, 2018) in alleyway under plastic cover and without plastic cover (control)

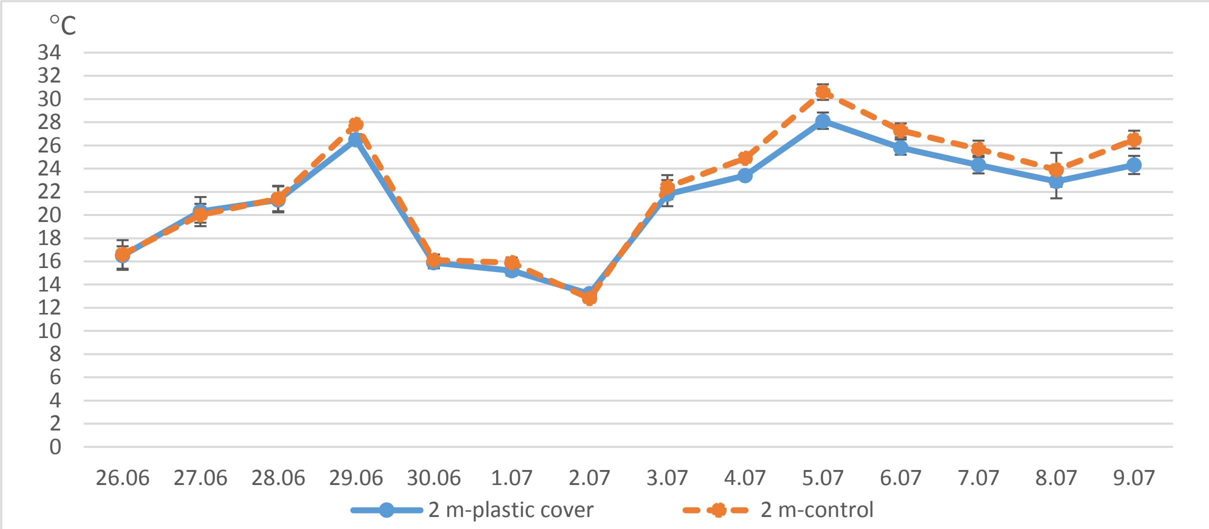

Fig. 5. Mean noon temperature (hours 10–14) measured 2.0 m above the ground during two weeks (June 26 – July 09, 2018) in the alleyway under plastic cover and without plastic cover (control)

Table 4. Influence of foil covering on the quality characteristics of sweet cherry fruit

Physicochemical properties of fruit	2016		2018	
	under covering	control	under covering	control
Mean fruit weight (g)	10.7 a ± 0.20*	11.0 a ± 0.09	9.2 a ± 0.02	9.8 b ± 0.06
Firmness (%)	5.3 a ± 0.33	4.7 a ± 0.10	3.8 a ± 0.04	3.9 a ± 0.07
Soluble solids (°Brix)	16.9 a ± 0.20	16.3 a ± 0.52	14.2 a ± 0.24	16.8 b ± 0.19
Titratable acidity (%)	0.558 a ± 0.50	0.472 a ± 0.35	0.565 a ± 0.08	0.643 b ± 0.15
Dry matter (%)	18.0 a ± 0.13	17.4 a ± 0.48	15.5 a ± 0.34	17.5 b ± 0.17
Total anthocyanins (mg·100 g^{-1})	20.7 a ± 3.07	21.3 a ± 0.63	36.5 a ± 1.01	35.8 a ± 1.27
Total polyphenols (mg·100 g^{-1})	67.0 a ± 2.50	67.3 a ± 3.15	95.1 a ± 0.64	103.2 b ± 2.13
Antioxidant activity as $ABTS^+$ Trolox (mg·100 g^{-1})	0.795 a ± 0.07	0.760 a ± 0.02	1.33 a ± 0.03	1.27 a ± 0.03

*Means in rows are compared within years followed with the same letter are not significantly different at p = 0.05 according to Duncan's test; means ± SE.

Considerable reduction of sunlight intensity under covers suggests that the cover should not be installed too early because it may promote intensive growth and suppress fruiting and flower setting intensity. In our trial, cherry trees were covered for a short period during the warm and dry weather under very intense solar radiation (started beginning of June).

During the two years of the trial, we were not able to observe spectacular effects of covers in protection of sweet cherry fruit against cracking, because of an usual dry weather. Dry season during fruit ripening was exceptional in this area, because rain precipitation in Poland is the highest in June and July.

CONCLUSIONS

1. High covers constructed with plastic foil significantly reduced the light levels within the canopies and decreased the temperature in the upper part of the tunnels.
2. Plastic covers protected the cherry fruit against cracking.

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