

# The Effect of Photoselective Nets on Fruit Quality of Apple cv. 'Cripps Pink'

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## Summary

The use of anti-hail photoselective nets is new approach in protecting the fruits against hail damage, sunburn and against pests in combination with activating desired physiological responses in fruit trees. The trial was established on the apple *Malus domestica* Borkh. cv. 'Cripps Pink' grafted on M9 rootstock in Mediterranean climate of Croatia. Four nets were used: white (W), yellow (Y) and red (R) net from Tenax Company (Italy) and Stop Drosophila Normal (D) from Artes Politecnica Company (Italy). Only white net showed higher yield than control (C). The trees grown under the W and R nets had higher portion of fruits diameter 70-80 mm than C trees and trees grown under the Y net, while D net was similar to other treatments. Nets reduced fruit skin colour, especially Y net which had highest portion of less coloured fruit. Maturation of fruit grown on the trees under the W and R nets, was 9 days earlier than fruit grown on the trees under the D and Y nets. The study showed that net colour has variable influence on physiological response of the tree and it is necessary to test the nets type in specific geographical location.

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## Key words

anti-hail net, photoselective, soluble solids, sustainability, titratable acidity

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## Introduction

Extreme climate conditions demand development of better approaches in integrated pest management of sustainable fruit production. The use of anti-hail photoselective nets is one of newer approaches where protecting the fruits against hail damage, sunburn and pests is combined with activating desired physiological responses in fruit trees. The photoselective nets are currently under intensive trials in various ecological conditions (Corollaro et al., 2015; Meinhold et al., 2011; Shahak et al., 2008).

Codling moth, *Cydia pomonella* (Linnaeus, 1758), is the main threat in apple orchards because of its spreading in all areas where apple and pear are produced and its resistance to some insecticides (Pajac et al., 2011). The anti-hail nets have positive effects in protection against codling moth. The nets reduce fruit damage and female mating frequency (Tasin et al., 2008).

The photoselective nets of various colours are designed to, besides protecting crops from environmental damage, absorb reactive part of solar spectra and increase relative amount of diffraction light which penetrates to inner part of the three canopy (Wachsmann et al., 2014). Environmental conditions under the net are changed. The white net reduce the photosynthetically active radiation (PAR) ( $\lambda = 400-700$  nm) accumulated over the tree canopy along a day by 18.4% (do Amarante et al., 2011). The white and red-black nets reduce light and humidity by 6-10% (Hunsche et al., 2010). Temperature in the canopy is reduced by 0.2-0.8 °C (Kuhrt et al., 2006). The nets slightly increase minimal temperature and lower maximal temperature, with simultaneous increase in relative humidity and reduced wind (Wachsmann et al., 2014).

The white and red-black nets have no effect on leaf thickness, amount of cuticle wax, cuticle thickness and calcium permeability (Hunsche et al., 2010).

The photoselective nets induce various responses to the trees. The increase in yield of *Citrus* crops is observed under the white and transparent nets, while the external fruit quality is increased under red, yellow, white and transparent nets (Wachsmann et al., 2014). The nets have some negative effect on organoleptic characteristics of apple in Northern Italy (Biamonte et al., 2016). The white protective net reduce soluble solids content (SSC), flesh firmness and increase starch index at harvest, and reduce SSC and flesh firmness after the cold storage (do Amarante et al., 2011).

The factors which affect amount of incident solar radiation energy per area and day, such as solar radiation geometry (which include local and geographical factors and season and time of the year), local climate and inclination of the collecting surface in the direction of the sun, can affect the physiological response of the tree under the photoselective net. Until now the exclusion nets were not tested in Mediterranean climate of Croatia. Therefore, the aim was to study the effect of photoselective nets on the yield and quality of apple fruits in Baštica agroecological conditions.

## Materials and methods

The trial was established at Zadar University's orchard Baštica located N44.159 E15.435 at 100 m a.s.l. in June 2015 on the apple *Malus domestica* Borkh. cv. 'Cripps Pink' grafted on M9 rootstock.

The apples were raised as slender spindles with a spacing of 3.4 m x 1.3 m. Four nets were used: white (W), yellow (Y) and red (R) net from Tenax Company (Italy) and Stop Drosophila Normal (D) from Artes Politechnica Company (Italy). Uncovered trees were used as control treatment. Four trees were under each treatment. The nets were spread over the trees on June 19<sup>th</sup> 2015. The apples were harvested on two dates on November 2<sup>nd</sup> (W and R nets) and on November 11<sup>th</sup> 2015 at (Y and D nets).

Fruit quality parameters measured were: fruit number, average fruit mass and fruit mass per tree. The fruits were divided in three classes based on the fruit diameter (<70 mm, 70-80 mm and >80 mm). The fruits were also divided in four classes based on the portion of skin covered with red colour (<25%, 26-50%, 51-75% and 76-100%). Fruit chemical parameters measured were: titratable acidity (TA) determined by titration with 0.1 M NaOH and expressed as malic acid, soluble solids content (SSC) determined by hand refractometer and ratio of SSC/TA was calculated.

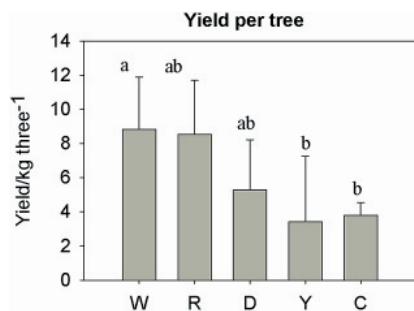
The one-way ANOVA statistical analysis was performed using R statistical package (R Core Team, 2012). The nets type was the independent variable, the fruit quality parameters were dependent variable with data from individual trees being repetitions of the dependent variable.

## Results and discussion

### Fruit yield and fruit diameter

The effect of nets was tested on parameters of average fruit weight, number of fruits per tree and total weight of fruits per tree (Fig. 1). Yield was significantly higher on trees under the W net ( $8.83 \pm 3.04$  kg tree<sup>-1</sup>) than on the trees under Y net and on the C trees ( $3.41 \pm 3.84$  and  $3.79 \pm 0.73$  kg tree<sup>-1</sup>, respectively). The R and D nets were similar to control. Wachsmann et al. (2014) found positive effect of photoselective nets on the yield of *Citrus* crops only with white and transparent nets but not with the yellow net. The difference in yield on trees under the R, D ( $8.54 \pm 3.15$  and  $5.28 \pm 2.94$  kg tree<sup>-1</sup>, respectively) and Y nets as well as on C trees was not statistically significant. Total fruit number per three and average fruit weight were similar among all treatments (data not shown). The yield of apple cv. 'Golden Delicious' in agroecological conditions of Israel is higher under the pearl (P), W and R nets compared to un-netted control (Shahak et al., 2008). The white net colour has different effect on fruit size of apple cv. 'Fuji' in agroecological conditions of Ferrara, Italy than in Israel and in this study. The fruit weight is higher under the black and red nets than under the white net, while blue and yellow nets were similar to all treatments (Corollaro et al., 2015). Therefore, both ecological conditions and genotype affect the physiological response to photoselective nets.

The effect of net type on fruits size is shown in Fig. 2. Fruits of 70-80 mm diameter (marketable yield) have the best value on the market. The trees grown under W and R net had significantly higher portion of fruits belonging to marketable yield than trees grown under Y net and C trees. The portion of marketable yield fruits on trees grown under D net was similar to other treatments. Shahak et al. (2008) observe the positive effect of photoselective net on fruit size. The P net shifts the size distribution of apple cv 'Golden Delicious' towards larger sizes compared with the un-netted control as well as with black net.



**Figure 1.** Average fruit yield per three of apple fruits cv. 'Cripps Pink' grown on trees under white (W), red (R), Stop Drosophila (D), yellow (Y) nets and control trees (C) at Baštica in 2015. Different lower case letters indicate significant difference at 0.05 level of significance

Apple cultivar 'Cripps Pink' is appreciated by consumers for its red fruit skin. The anthocianins, chemicals responsible for red skin colour, synthesize in fruits when enough sun irradiance is present. Nets can interfere in red skin colour development.

Statistically higher portion of fruits having less than 25% red skin colour was found on trees grown under Y net as compared to other treatments (Fig. 3). Statistically higher number of fruits having less than 26-50% of red skin colour was found on the trees grown under W and R nets as compared to trees grown under D net and C trees. Portion of fruits with good coloration 51-75% of red skin colour was statistically highest on trees grown under W and R nets as compared to other treatments. Highest portion fully coloured fruits (76-100% of red skin colour) was found on fruits from C trees and difference was significant as compared to fruit grown on trees under W and R nets. The trees grown under D net had similar portion of fully coloured as trees grown under R net. These results correspond with the results published by Shahak et al (2004).

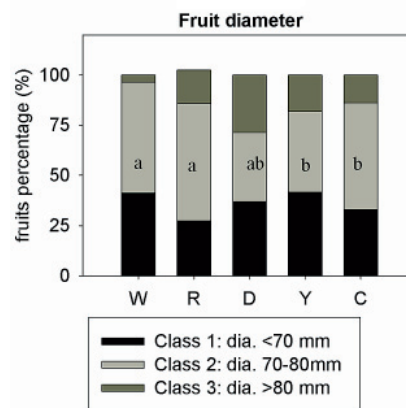
The results in our study show that, although nets reduced fruit red coloration, the effect of the net colour on fruit coloration is quite a different. D and, especially, Y net have greater effect on red skin reduction than R and W nets.

### Fruit chemistry

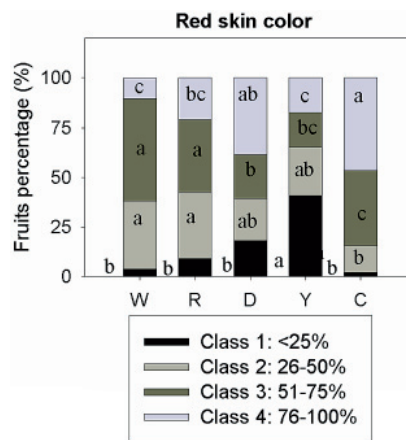
Titrate acidity (TA) and soluble solids content (SSC) are important components of fruit flavour. TA decreases during maturation and storage as a result of cell respiration while soluble solids content rises during maturation. SSC/TA is good indicator of state of fruit ripeness, higher ratio indicates higher ripeness.

Nets significantly affected the stage of fruit maturity (Table 1). Fruits from trees grown under W and R nets matured earlier than fruit from trees grown under D and Y net. Fruit grown under the W and R nets accumulated similar amounts SSC and TA. Fruit firmness was significantly lower and SSC/TA ratio was slightly, but significantly higher in the fruit grown under the W and R nets than in the fruit from control trees, showing that the ripeness was better than control.

In the second harvest, fruit grown on trees under the D and C nets had significantly higher TA, than fruit grown on trees under Y net. SSC was significantly higher in fruit grown on C



**Figure 2.** Fruit diameter classes of apple fruits cv. 'Cripps Pink' grown on trees under white (W), red (R), Stop Drosophila (D), yellow (Y) nets and control trees (C) at Baštica in 2015. Different lower case letters within a class indicate significant difference at 0.05 level of significance



**Figure 3.** Red skin coloration classes of apple fruits cv. 'Cripps Pink' grown on trees under white (W), red (R), yellow (Y), Drosophila Stop (D) nets and on control trees (C) at Baštica in 2015. Different lower case letters within a class indicate significant difference at 0.05 level of significance

trees, SSC/TA ratio was higher in fruits grown on trees under Y net and firmness was similar in D, Y and C fruits. That means that Y net significantly promoted maturation. The nets colour has no effect on SSC and TA of apple cv. 'Fuji' grown in Italy near Ferrara but had affected the fruit firmness (Corollaro et al., 2015). Klein et al. (2001) found that shaded apple fruit produce less ethylene than sun exposed fruits, and at harvest sun exposed fruit have higher soluble solids than shaded fruits. In this study the nets colour affected soluble solids and titrate acidity which was probably caused by the changes in diffusion light that reached the canopy. The difference in fruit maturity between W and R nets on one side and D and Y net on other side found in this study should be also connected to ethylene, which probably was produced more slowly under the W and R net. Shading level of W and R net is only about 9%, so the change in light spectra caused by net must be reason for such result. Beside

**Table 1.** Parameters of apple fruits cv. 'Cripps Pink' grown on trees under four net types and on uncovered trees

Treatment	Titratable acidity (% malic acid)	Soluble solids content (°Brix)	Total acidity/soluble solids	Firmness (kg cm <sup>-2</sup> )
First harvest (November 2 <sup>nd</sup> 2015)				
White	0.63 ± 0.12	14.81 ± 1.25	24.01 ± 3.47 a*	7.63 ± 0.92 b
Red	0.65 ± 0.13	15.11 ± 0.74	24.18 ± 4.69 a	7.84 ± 1.06 b
Uncovered	0.71 ± 0.10	15.84 ± 1.00	22.63 ± 2.28 b	8.26 ± 0.56 a
Second harvest (November 11 <sup>th</sup> 2015)				
Yellow	0.67 ± 0.12 a	15.31 ± 0.91 b	23.55 ± 4.64 b	7.86 ± 1.54 a
Drosophila Stop	0.54 ± 0.20 b	15.89 ± 1.51 b	32.26 ± 8.46 a	7.91 ± 1.46 a
Uncovered	0.61 ± 0.11 a	16.34 ± 0.62 a	27.54 ± 4.43 b	7.85 ± 0.75 a

\*Different lower case letters indicate significant difference at 0.05 level of significance.

this, fruit from trees grown under W and R net were better coloured than fruit under D and Y net which additionally supports our hypothesis. Red colour formation is connected with ethylene production (Morgan and Drew, 1997; Solomakhin and Blanke, 2010), and red, white and pearl net promote apple maturation (Shahak et al., 2004). Therefore, it can be concluded that these factors together contributed significantly to the advanced maturation of fruit under the W and R nets.

### Conclusions

The nets affected the fruit quality parameters. Portion of fruits in class 2 (diameter 70-80 mm) was higher at white and red net than at yellow net and control. Coloration was highest at control except at Drosophila net. Fruit titratable acidity and soluble solids content at harvest showed delayed ripening effect for Drosophila and yellow net while white and red net were similar to control. Based on all parameters examined it is shown that net type affects yield and quality of the fruit. The white net had good yield and chemical parameters but the coloration is lower than control. The red net is second best having slightly lower yield. Drosophila net is lower in yield and in chemical parameters but the coloration of the skin is good. The worse net was yellow which had low yield, low coloration and low content of soluble solids and titratable acidity. We showed that colour of nets has variable influence on physiological response of the tree and that it is necessary to test the nets in specific geographical location.

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