Generative and Vegetative Traits of the 'Granny Smith' Apple Grown under an Anti-Insect Photoselective Red Net

Utjecaj crvene protuinsektne fotoselektivne mreže na generativne i vegetativne karakteristike jabuke 'Granny smith'

Jemrić, T., Brkljača, M., Vinceković, M., Antolković, A. M., Mikec, D., Vuković, M.

Poljoprivreda/Agriculture

ISSN: 1848-8080 (Online)
ISSN: 1330-7142 (Print)

https://doi.org/10.18047/poljo.27.2.4

Fakultet agrobiotehničkih znanosti Osijek, Poljoprivredni institut Osijek

Faculty of Agrobiotechnical Sciences Osijek, Agricultural Institute Osijek

ISSN 1330-7142
UDK=634.42:632.934.4
https://doi.org/10.18047/poljo.27.2.4

GENERATIVE AND VEGETATIVE TRAITS OF THE 'GRANNY SMITH' APPLE GROWN UNDER AN ANTI-INSECT PHOTOSELECTIVE RED NET

Jemrić, T.[1], Brkljača, M.[2], Vinceković, M.[3], Antolković, A. M.[1], Mikec, D.[1], Vuković, M.[1]

Original scientific paper
Izvorni znanstveni članak

SUMMARY

Anti-insect photoselective nets present a new technology that combines light manipulation and pest protection in orchards. In this study, the effect of the anti-insect photoselective red net on the generative and vegetative traits was studied in an apple orchard near the city of Zadar, Croatia. 'Granny Smith' apples were grown on M9 rootstock and raised as slender spindles. The experiment consisted of two treatments: the trees covered with the red photoselective anti-insect nets (AGRITECH S. r. l., Eboli, Italy; mesh size of 2.4 × 4.8 mm) and uncovered trees as control. Yield, percentage of fruit with diameter >70 mm and fruit mass were not significantly different between treatments. L* color value was higher on skin of fruit grown under the red net, and there was no significant difference in other color values (a*, b*, C* and h°). Soluble solids concentration (SSC) and total flavonoid content were significantly lower in fruit grown under red net than in control, and there was no significant difference in titratable acidity (TA), SSC/TA ratio, starch degradation and Streif maturity index. Red net proved to be effective against fruit red blush development (undesirable trait for 'Granny Smith' apple) and sunburn damage occurrence.

Keywords: photoselective nets, anti-insect nets, red net, apple 'Granny Smith', fruit quality, light modification

INTRODUCTION

The application of nets in fruit production has a long history and is of a prime importance for the protection against various hazards, such as the hail and wind, excessive sun radiation, birds, etc. (Bosco et al., 2015). Not so long ago, a possibility of net application as a mean of pest protection started to be researched (Pajač Živković et al., 2016, 2018; Sauphanor et al., 2012). Anti-insect nets are similar to the anti-hail nets, but they differ from the anti-hail nets in the mesh size and application way (Pajač Živković et al., 2018). Anti-insect nets overlay a fruit tree canopy and the edge parts of the orchard and therefore create a barrier that disrupts the pest propagation due to a prevention of their flight (Tasin et al., 2008). However, almost all netting creates a certain amount of shade, thus reducing a solar radiation, which can have a potentially negative effect on fruit quality (except in the areas that exhibit an extreme sun radiation or in a case of the shade-tolerant cultures). Traditionally used black nets are fully opaque and therefore only reduce a light quantity, while the translucent nets have an additional light scattering ability (Ilić & Fallik, 2017; Shahak, 2008), but neither can influence the light quality properties. Then, a new agro-technical concept emerged, where in addition to its basic protective function nets also modify the quality of the transmitted light (Basile et al., 2012). Technology is based on the incorporation of various chromophores and light dispersive elements in the plastic nets during their production (Shahak et al., 2008). However, the literature

(1) Prof. Dr. Tomislav Jemrić, Ana Marija Antolković, Mag. Eng. Agr., David Mikec, Mag. Eng. Agr., Marko Vuković, Mag. Eng. Agr. (mvukovic@agr.hr) – University of Zagreb, Faculty of Agriculture, Svetošimunska cesta 25, 10000 Zagreb, Croatia, (2) Mia Brkljača, Mag. Eng. Agr. – University of Zagreb, Faculty of Food Technology and Biotechnology, Pierottijeva 6, 10000 Zagreb, Croatia, (3) Assoc. Prof. Marko Vinceković – University of Zagreb, Faculty of Agriculture, Svetošimunska cesta 25, 10000 Zagreb, Croatia

available heretofore is still insufficient regarding the effect of photoselective nets on the cultivated fruit species underneath. Therefore, it is hard to appoint which type of photoselective net should be applied for the pest protection so that the multiple benefits can be achieved. An additional problem is that the effect of photoselective nets differs between the species and varieties that are cultivated underneath them (Amarante et al., 2011; Aoun & Manja, 2020; Zoratti et al., 2015). Also, it should be further noted that there is a lack of studies that deal with an effect of photoselective nets on the apples' bioactive compounds. In our previous studies, the red photoselective anti-insect net exerted a satisfactory pre-harvest effect on the ´Cripps Pink´ apple, ´Sugar Time´ peach, and the ´Big Bang´ nectarine (Brkljača et al., 2016; Vuković et al., 2016), an optimum effect on post-harvest performance of the ´Granny Smith´ apple (Vuković et al., 2020), and the satisfactory pest control properties (Pajač Živković et al., 2016, 2018). Consequently, the present work is an extension to our previous studies. The aim of this study is to test the effect of the red photoselective anti-insect net on the ´Granny Smith´ apples, with an emphasis laid to its effect on the bioactive compounds in fruit.

MATERIALS AND METHODS

Plant material and treatments

The experiment was conducted in an apple orchard near the city of Zadar, Croatia, in April 2016 on the apple (*Malus domestica* Borkh.) ´Granny Smith´, grafted on the M9 rootstocks. The apples were raised as the slender spindles, with a spacing amounting to 3.4 m $\times$ 1.3 m. The experiment consisted of two treatments: 1) the trees covered with red photoselective nets (AGRITECH S. r. l., Eboli, Italy) subsequent to the petal fall, and 2) the uncovered trees that served as a control. The red photoselective nets had a mesh size of 2.4 $\times$ 4.8 mm. For each treatment, there were three replications, each consisting of five trees. The fruits were harvested having reached an optimal commercial maturity, determined by the measurement of firmness, soluble solids concentration (SSC), and titratable acidity levels (TA).

Physicochemical properties

The analyses of physicochemical properties were conducted at the Department of Pomology and at the Department of Chemistry, Faculty of Agriculture, University of Zagreb, Croatia.

The share of fruits with the red blush, the share of fruits with the sunburn symptoms

The share of fruits with the red blush was determined visually and expressed as a percentage of fruits with the red blush. The share of fruits with the sunburn symptoms was determined according to the seizure of symptoms on the apple surface as 1 (without symptoms), 2 ($>$0 and $\leq$30 % fruit surface [medium severity]), and 3 ($>$30 % fruit surface [severe symptoms]). In this study, the symptoms included a discoloration or browning, since other sunburn symptoms did not occur. A sunburn index was calculated from the corresponding aforementioned values according to the following formula: $\sum$ (value of hedonic scale $\times$ number of fruits with the corresponding scale number) / total number of fruits in the sample. These parameters where measured on the randomly selected 100 fruits per replication, since it was a minimal number of apples used per a replicate in other studies (Mupambi et al., 2017, 2018).

CIE color variables

The fruit skin color variables were measured according to the CIE L*a*b* and CIE L*C*h° systems, using a colorimeter (ColorTec PCM; ColorTec Associates Inc., USA). The color measurement was taken at two opposite equatorial positions on each fruit at 90°, and the mean value for each fruit was calculated. These parameters where measured on 10 randomly selected fruits per replication, since it was the number of samples used in other study figuring the similar measurements (Solomakhin & Blanke, 2010).

Yield, yield efficiency, crop density, the share of fruit with diameter >70 mm

These parameters were measured on four fruit trees for each replication. A yield per tree (kg) was determined in the orchard immediately subsequent to the harvest by weighing the total fruit yield for each tree. A yield efficiency (kg cm^{-2}) was calculated according to the following formula: yield per tree (kg) / trunk cross-sectional area (TCSA) (cm^{-2}). Crop density (fruits cm^{-2}) was calculated according to the following formula: number of fruits per tree / TCSA (cm^{-2}). A share of fruit having a diameter above 70 mm was determined by counting the total number of fruits with a diameter above 70 mm and expressing it as a percentage of the total number of fruits for each tree.

Fruit mass, firmness, starch degradation level, total soluble solids (SSC), titratable acidity (TA), SSC/TA ratio and Streif maturity index

All measurements were taken from 10 randomly selected fruits from each replication, since it was the usual number used in other studies for the obtainment of similar measurements (Gao et al., 2019; Ordóñez et al., 2016). The average value of fruit mass was calculated using a digital analytical balance (OHAUS Adventurer AX2202, Ohaus Corporation Parsippani, NJ, USA), with an accuracy of 0.01 g. The firmness was measured using the PCE PTR-200 (PCE Instruments, Jupiter/Palm Beach, USA), fitted with an 11 mm diameter plunger and expressed in kg cm^{-2}. The measurements were taken at four opposite equatorial positions on each fruit at 90°. The starch degradation level was scored using a 10-point CTIFL scale (Centre Technique Interprofessionnel des fruits et Légumes, Paris, France). The SSC was measured by a hand digital refractometer (Atago, PAL-1, Tokyo, Japan) and expressed as ° Brix, according to the AOAC 932.14c (AOAC, 1999). The TA was determined by the titration method with 0.1 N NaOH and expressed as percentage of malic acid, according to the AOAC 954.07 (AOAC, 1999). The SSC/TA ratio was calculated from the corresponding SCC and TA values for each fruit. The maturity index (Streif) was calculated as the quotient of [firmness / (SSC · starch index)] (Streif, 1996).

Total polyphenolic content (TPC), antioxidant potential (AOP) and total flavonoid content (TFC)

Preparation of extracts. One extract consisting of 10 randomly selected fruits per each replication was used. The fresh apple fruits were grinded and homogenized by a hand mixer until a homogenized fraction was obtained. Subsequently, 30 g of sample was weighed and put in tubes. The sample tubes were centrifuged at 9000 rpm for 20 minutes, and the supernatants were subsequently filtered using the Whatman No. 4 filter paper.

TPC. The modified Folin Ciocalteu's method of Singleton et al. (1999) was used for the determination of TPC. A mixture of 0.1 ml of apple extracted juice with 7.9 mL of distilled water and 0.5 ml Folin Ciocalteu's reagent (diluted with distilled water in a 1:2 ratio) and 1.5 mL 20% sodium carbonate was vortexed and left for two hrs. to complete the reaction. The optical absorbance was measured at 765 nm (Ough & Amerine, 1988), and the data were expressed as the gallic acid equivalents, mg GAE·100 g^{-1} of fresh fruit weight (Fw).

AOP. The antioxidant potential was determined as the 2.2-diphenyl-1-picrylhydrazyl (AOP-DPPH) and 2.2'-azino-bis (3-ethylbenzothiazoline-6-sulfonic acid) (AOP-ABTS) antioxidant activities, according to the procedures of Brand-Williams et al. (1995) and Re et al. (1999), respectively. The data obtained were expressed as μmol Trolox equivalents (μmol TE·100 g^{-1} Fw).

TFC. The total flavonoids were measured using a modified spectrophotometric method (Ivanova et al., 2010). The extract (1 mL) was added to 4 mL of distilled water and 300 μL of $NaNO_2$ (0.5 g/L), vortexed and left for five minutes. Subsequently, 300 μL of $AlCl_3$ (1 g/L) was added and vortexed, and 2 mL of 1 mol/L NaOH were added to the mixture after six minutes. A final volume was set to 10 mL with the aid of distilled water. The absorbance was measured at 360 nm, and the quercetin standard was used for the preparation of calibration curve. The results were expressed as a mg of quercetin equivalents per a L of extract.

Chlorophyll a, chlorophyll b, and total chlorophyll content

Chlorophyll a, b, and total chlorophylls were determined by extracting 1.000 g of apple puree with 25 mL of 80% (v/v) acetone while shaking the suspension vigorously. After two minutes of extraction, the suspension was filtered through the filter paper. The final volume was set to 25 mL with a solvent. The absorbances were measured at 663 nm and 645 nm, and the results were calculated pursuant to the determining equations of Huang et al. (2007). The results were expressed as a mg of chlorophylls per a L of apple puree extract.

Vegetative parameters

Vegetative parameters were measured subsequent to the completion of the vegetative period. A trunk cross-sectional area (TCSA) was measured on four trees per replication at a height of 15 cm above the graft place and expressed in cm^2. The length of a one-year shoot (cm), an internode length (cm), and the thickness of a one-year shoot (mm) was measured on 10 randomly selected shoots from the middle—the outer part of tree canopy per replication. The thickness was measured two cm from the shoot base. The node density (nodes cm^{-1}) was calculated according to the following formula: number of nodes per shoot / length of the shoot.

Statistical analysis

The data were analyzed using the T-test in the SAS statistical software ver. 9.4 (SAS Institute, NC). The T-test was used, since there were only two experimental treatments (a control and a red net, respectively), and it was sufficient for the determination of statistical difference.

RESULTS AND DISCUSSION

The apples grown under the red net had a significantly lower L^* value ($P \leq 0.01$) in comparison with the apples grown without the nets, while regarding other color parameters (a^*, b^*, C^* and $h°$) no significant differences were recorded (Table 1). Since the L* value is defined as a vertical coordinate that defines the lightness in a three-dimensional uniform space (AN 1005.00, 2012), it is evident that the apples grown under a red net were brighter than those without a net. The intensity of light that reaches fruit skin (Hamadziripi, 2012) and the light spectra (Reay & Lancaster, 2001) are of a major importance concerning the color development. Therefore, the nets may influence the fruit color development primarily by light modification. Since the ´Granny Smith´ apple has the monochromatic fruits, the available literature regarding this topic can be used for comparison only to some extent (more like a trend). The results in this study are contrary to the ones published by Amarante et al. (2011) and Solomakhin & Blanke (2010) when it comes to the L* value and are not identical (but are not the opposite either) with regard to some other color variables. However, similar to this study, Fruk et al. (2016) reported a lack of significant influence of red photoselective net on L*, a*, and b* color parameters measured on the green and red part of the ´Braeburn´ apple skin. Moreover, in the same study, it was reported that the apples grown under a red net had a higher average L* value measured on the green part of the fruit than the apples from the control batch. A lack of studies regarding the effect of photoselective nets on the color of monochromatic apple varieties is evident, and this area needs more research to elucidate the effect of netting on a fruit color under the different agroecological conditions.

Table 1. The effect of red net application on the skin color variables of the ´Granny Smith´ apple

Tablica 1. Utjecaj primjene crvene mreže na parametre boje kožice jabuke 'Granny Smith'

	CIE Color Variables / *Varijable boje CIE*				
	*L**	*a**	*b**	*C**	*h°*
Red net / *Crvena mreža*	58.69 ± 0.54	-8.46 ± 0.27	40.14 ± 1.22	41.03 ± 1.25	101.93 ± 0.20
Control / *Kontrola*	60.66 ± 0.41	-8.28 ± 0.13	39.08 ± 0.68	39.96 ± 0.68	102.01 ± 0.18
T test	0.01**	0.54$^{n.s.}$	0.46$^{n.s.}$	0.45$^{n.s.}$	0.75$^{n.s.}$

[1] All numbers present an average value ± standard error except in the T-test row, where they present the P values – *Svi brojevi predstavljaju prosječnu vrijednost ± standardna greška s izuzetkom T-testa, gdje predstavljaju P vrijednosti*

[2] $^{n.s.}$, ** nonsignificant or significant at P ≤ 0.01, respectively - $^{n.s.}$, ** *nesignifikantno ili signifikantno pri P ≤ 0.01, respektivno*

A yield, yield efficiency, crop density, the share of fruit with a diameter >70 mm and the fruit mass demonstrated no significant differences between the treatments (Table 2). A frost-caused damage in the second year of study terminated our research and forced us to analyze the results from the first year only. Therefore, a possible major effect on the yield in the following year as a consequence of the red net effect on the flowering bud formation could not be seen. Although the fruit mass and size did not significantly differ between the treatments in this study, it can be seen that the fruits grown under a red net tend to have a higher weight and a larger size than those grown without a net (Table 2). Similarly and significantly, a tendency was reported concerning the 'Jonagold' and 'Fuji' apples by Aoun & Manja (2020) and concerning the 'Golden Delicious' apple by Shahak et al. (2008). However, regarding the 'Topred' apple, no significant influence of a red net on the fruit size was reported (Shahak et al., 2008).

Regarding an internal fruit quality, the SSC content was significantly higher (P ≤ 0.01) in the fruits grown without a net while the firmness, TA, SSC/TA, starch degradation level and maturity index (Streif) demonstrated no significant differences between the treatments (Table 2). Regarding the SSC content, our results are in agreement with Aoun & Manja (2020), who reported a lower SSC of the 'Jonagold' apples grown under the red net, Amarante et al. (2011), who reported a lower SSC of the 'Gala' apple cultivated under the white net, and Brkljača et al. (2016), who reported a lower SSC content of the 'Cripps Pink' apple cultivated under a yellow and stop drosophila normal net. Also, in some of these studies, a SSC difference was not significant in the case of a different apple variety (Amarante et al., 2011; Aoun & Manja, 2020) or net color and harvest date (Brkljača et al., 2016). A possible explanation for a lower SSC in the fruits grown under the nets can be explained by a carbohydrate limitations imposed by the shading and a different source – consumer relationship (Amarante et al., 2011; Basile et al., 2012; Giaccone et al., 2012; Lobos et al., 2013). A lack of significant difference regarding firmness, TA, starch degradation level and Streif maturity index also occurred in other studies (Amarante et al., 2011; Aoun & Manja, 2020; Brkljača et al., 2016; Corollaro et al., 2015; Solomakhin & Blanke, 2010). An inconsistency of such parameters is probably due to the interference of agroecological and genetic parameters, so additional research efforts are necessary to be invested.

Table 2. A red net effect on the physicochemical properties of the ´Granny Smith´ apple

Tablica 2. Utjecaj crvene mreže na fizičko-kemijska svojstva jabuke 'Granny Smith'

Parameter / *Parametar*	Red net / *Crvena mreža*	Control / *Kontrola*	T test
Yield (kg tree^{-1}) / *Prinos (kg stablo^{-1})*	17.96 ± 0.68	18.85 ± 1.29	0.55$^{n.s.}$
Yield efficiency (kg cm^{-2}) / *Učinkovitost prinosa (kg cm^{-2})*	0.21 ± 0.02	0.20 ± 0.02	0.74$^{n.s.}$
Crop density (fruit cm^{-2}) / *Gustoća priroda (plod cm^{-2})*	1.41 ± 0.12	1.28 ± 0.13	0.47$^{n.s.}$
% of fruit >70 mm / *% plodova >70 mm*	71.74 ± 6.89	46.63 ± 14.75	0.20$^{n.s.}$
Mass (g) / *Masa (g)*	182.59 ± 4.74	170.75 ± 5.31	0.10$^{n.s.}$
Firmness (kg cm^{-2}) / *Čvrstoća (kg cm^{-2})*	8.60 ± 0.20	8.68 ± 0.16	0.74$^{n.s.}$
SSC (° Brix)	11.78 ± 0.15	12.49 ± 0.14	0.002**
TA (as % of malic) / *TA (kao % jabučne kiseline)*	0.82 ± 0.03	0.83 ± 0.02	0.64$^{n.s.}$
SSC/TA	14.68 ± 0.55	15.11 ± 0.34	0.50$^{n.s.}$
Starch (110 CTIFL Scale) / *Škrob (1 – 10 prema ljestvici CTIFL)*	5.30 ± 0.51	5.80 ± 0.35	0.43$^{n.s.}$
Maturity index (Streif) / *Indeks zrelosti (Streif)*	0.16 ± 0.02	0.13 ± 0.01	0.12$^{n.s.}$

[1]All numbers present average value ± standard error except in the T-test row, where they present the P values – *Svi brojevi predstavljaju prosječnu vrijednost ± standardna greška s izuzetkom T-testa, gdje predstavljaju P vrijednosti*

[2] $^{n.s.}$, ** nonsignificant or significant at P ≤ 0.01, respectively - $^{n.s.}$, ** *nesignifikantno ili signifikantno pri P ≤ 0.01, respektivno*

The TFC content was significantly smaller ($P \leq 0.01$) in the fruits grown under a red net than in those from a control batch, while no significant differences were recorded between the treatments regarding the TPC, AOP – DPPH and AOP – ABTS (Table 3). According to Basile et al. (2012), an antioxidant activity and polyphenol concentration in the flesh of the 'Hayward' kiwifruit at harvest was higher in the fruits grown without a net than under a red net. Awad et al. (2001) reported that the 'Jonagold' apple fruits from the outer part of canopy had a significantly higher total flavonoid content than those from its inner part. The reasons for such findings in the literature referenced above are mainly due to a possibility of light intensity and quality to affect the antioxidant and phenol biosynthesis (Bakhshi & Arakawa, 2006). Regarding chlorophyll a, chlorophyll b, and a total chlorophyll content, no significant differences were recorded between the treatments (Table 3). However, a fruit grown under a red net tends to have a higher chlorophyll a and a total chlorophyll content. A similar tendency was also recorded in the studies conducted on the 'Fuji Kiku 8' and the 'Pinova' apples (Solomakhin & Blanke, 2010) and the 'Hayward' kiwifruit (Basile et al., 2012). The reason for a higher average chlorophyll a and a total chlorophyll content of the apples grown under a red net is probably due to the shading effect of the net, which complies with Solomakhin and Blanke (2010) and regarding the 'Antonovka' apple with Merzlyak et al. (2002), since it has a similar coloration as the 'Granny Smith' apples.

Table 3. A red net effect on the bioactive compounds of the Granny Smith apple
Tablica 3. Utjecaj crvene mreže na bioaktivne komponente jabuke 'Granny Smith'

Parameter / *Parametar*	Red net / *Crvena mreža*	Control / *Kontrola*	T test
TPC (mg L^{-1})	456.60 ± 44.81	448.92 ± 37.52	$0.90^{n.s.}$
AOP – DPPH (μmol TE L^{-1})	1163.60 ± 87.09	1132.59 ± 60.50	$0.78^{n.s.}$
AOP – ABTS (μmol TE L^{-1})	1684.35 ± 156.76	1811.24 ± 65.58	$0.50^{n.s.}$
TFC (mg L^{-1})	189.23 ± 2.91	214.43 ± 4.19	0.01^{**}
Chlorophyll a (mg L^{-1}) / *Klorofil a (mg L^{-1})*	0.49 ± 0.02	0.46 ± 0.01	$0.16^{n.s.}$
Chlorophyll b (mg L^{-1}) / *Klorofil b (mg L^{-1})*	0.36 ± 0.05	0.35 ± 0.03	$0.80^{n.s.}$
Total chlorophyll content (mg L^{-1}) / *Ukupan sadržaj klorofila (mg L^{-1})*	0.85 ± 0.07	0.74 ± 0.07	$0.31^{n.s.}$

[1]All numbers present average value ± standard error except in T-test row where they present P values – *Svi brojevi predstavljaju prosječnu vrijednost ± standardna greška s izuzetkom T-testa, gdje predstavljaju P vrijednosti*

[2] $^{n.s.}$, ** nonsignificant or significant at $P \leq 0.01$, respectively - $^{n.s.}$, ** *nesignifikantno ili signifikantno pri $P \leq 0.01$, respektivno*

The fruits grown under a red net had a significantly smaller share of fruits with a red blush ($P \leq 0.05$) and sunburn index ($P \leq 0.01$) (Table 4). The share of fruits without sunburn symptoms was significantly higher ($P \leq 0.01$) with the fruits grown under a red net, while the share of fruits with a medium sunburn severity was significantly ($P \leq 0.01$) higher with regard to the fruits grown without a net (control batch, Table 4). The fruits grown under a red net had a smaller average share of fruits with a severe sunburn severity, but no significant difference was recorded (Table 4). A positive effect of photoselective nets on the apple sunburn symptoms reduction was also recorded in other studies (Amarante et al., 2011; Kalcsits et al., 2017). Since the sunburns are caused by an exposure to excessive heat and/or sunlight (Racsko & Schrader, 2012) a reduction of sunburn damages under the nets is due to their lower direct incident radiation and due to a lower temperature (Iglesias & Alegre, 2006), which can be primarily contributed to their shade properties. With the 'Granny Smith' apple variety, both red or orange blush skin developments are considered undesirable, which means that the fruits need to have a blemish-free, uniformly green skin color (Hirst et al., 1990). So, in the case of the 'Granny Smith' apple, a reduction of red blush area is a positive occurrence.

Table 4. A red net effect on the red blush and sunburn fruit occurrence in the ´Granny Smith´ apples
Tablica 4. Utjecaj crvene mreže na pojavnost dopunskoga crvenila i ožegotina od sunca na jabukama 'Granny Smith'

Parameter / *Parametar*	Red net / *Crvena mreža*	Control / *Kontrola*	T test
Share of fruits with a red blush (%) / *Udio plodova s crvenilom*	2.80 ± 0.97	11.51 ± 3.01	0.01^{**}
Sunburn index / Indeks sunčanih ožegotina	1.23 ± 0.03	1.40 ± 0.04	0.004^{**}
Share of fruits without sunburn symptoms (%) / *Udio plodova bez simptoma sunčanih ožegotina (%)*	78.54 ± 3.07	63.44 ± 3.32	0.004^{**}
Share of fruits with the medium-severity sunburn symptoms (%) / *Udio plodova sa simptomima sunčanih ožegotina srednje težine (%)*	19.91 ± 3.00	32.69 ± 2.66	0.005^{**}
Share of fruits with the strong-severity sunburn symptoms (%) / *Udio plodova sa simptomima sunčanih ožegotina jake težine (%)*	1.55 ± 0.36	3.87 ± 1.10	$0.062^{n.s.}$

[1]All numbers present average value ± standard error except in T-test row where they present P values – *Svi brojevi predstavljaju prosječnu vrijednost ± standardna greška s izuzetkom T-testa, gdje predstavljaju P vrijednosti*

[2] $^{n.s.}$, ** nonsignificant or significant at $P \leq 0.01$, respectively - $^{n.s.}$, ** *nesignifikantno ili signifikantno pri $P \leq 0.01$, respektivno*

The apple trees grown under a red net had the significantly smaller length of the one-year-old shoots ($P \leq 0.01$), internode length ($P \leq 0.01$), and the one-year-old shoot thickness ($P \leq 0.001$) than those grown without the nets (control), while the TCSA and node density did not significantly differ between the treatments (Table 5). In the majority of studies (Aoun & Manja, 2020; Basile et al., 2014; Bastias, 2011; Brar et al., 2020), a red net increased a vegetative growth, which is opposite to the findings in this study. A shade avoidance mechanism was mentioned as a probable explanation for nets impact on a plant's vegetative growth (Basile et al., 2014; Bastias, 2011), but it was not the case under all colored nets, according to Oren-Shamir et al. (2001). It may be so in this study. Similar situation was also reported in other studies. In the second research year, Aoun & Manja (2020) reported a non-significant trend, where the 'Fuji' apples grown under a red net had a lower shoot length than those grown in the open field conditions. Also, Mazhawu (2016) emphasized a non-significant trend, whereby the avocado grown under a crystal net had a smaller average shoot length. It is also necessary to mention the importance of agroecological conditions in which the nets are applied, since they can modify a net performance to certain extent and hence exert a different effect on the plants. Also, each net is not equally desirable in all agroecological conditions. For example, in some extremely warm regions, shading is advisable in order to alleviate a plant damage from an excessive sun radiation, while it may exert an undesirable influence in the colder regions. This finding highlights the importance of this study, since other mechanism has probably overpowered the usual ones and had a detrimental effect on the reduction of vegetative growth.

Table 5. A red net effect on the vegetative parameters of the ´Granny Smith´ apple

Tablica 5. Utjecaj crvene mreže na vegetativne parametre jabuke 'Granny Smith'

Parameter / *Parametar*	Red net / *Crvena mreža*	Control / *Kontrola*	T test
TCSA (cm^2)	89.90 ± 8.21	97.19 ± 7.97	$0.53^{n.s.}$
Length of the one-year-old shoot (cm) / *Duljina jednogodišnjega izboja (cm)*	40.08 ± 1.67	46.54 ± 2.04	0.017^{**}
Internode length (cm) / *Duljina međukoljenca (cm)*	1.67 ± 0.07	1.94 ± 0.09	0.017^{**}
Node density (nodes cm^{-1}) / *Gustoća koljenaca (koljence cm^{-1})*	0.52 ± 0.02	0.52 ± 0.02	$0.91^{n.s.}$
Thickness of of the one-year-old shoot (mm) / *Debljina jednogodišnjega izboja (mm)*	4.90 ± 0.11	5.63 ± 0.16	0.0005^{***}

[1]All numbers present an average value ± standard error except in the T-test row, where they present the P values – *Svi brojevi predstavljaju prosječnu vrijednost ± standardna greška s izuzetkom T-testa, gdje predstavljaju P vrijednosti*

[2] $^{n.s.}$, **, *** nonsignificant or significant at $P \leq 0.01$ or $P \leq 0.001$, respectively - $^{n.s.}$, **, *** *nesignifikantno ili signifikantno pri $P \leq 0.01$ ili* $P \leq 0.001$, *respektivno*

CONCLUSION

It is evident that the application of anti-insect photoselective red net on the 'Granny Smith' apple did not negatively influence the basic fruit quality parameters (except the SSC reduction), while it has simultaneously provided the useful protection purposes against hail and wind, as well as the reduced sunburn damages and red blush. In some cases, despite a lack of significant differences, a trend is evident that the red net tends to increase the chlorophyll content, and therefore a basic green color in apples (linked with a statistically significantly smaller L* color value under the red net), as well as delay ripening (a smaller starch degradation level and a higher Streif maturity index of apples under the red net, on an average value level). New studies should be based on the determination of the effect of anti-insect photoselective nets on other varieties and in other agroecological conditions.

ACKNOWLEDGMENTS

This study was carried out with a contribution of the LIFE financial instrument of the European Union for the project *Low Pesticide IPM in Sustainable and Safe Fruit Production* (Contract No. LIFE13 ENV/HR/000580).

REFERENCES

1. Amarante, C. V. T., Steffens, C. A., & Argenta, L. C. (2011). Yield and fruit quality of 'Gala' and 'Fuji' apple trees protected by white anti-hail net. *Scientia Horticulturae*, *129*(1), 79–85. https://doi.org/10.1016/j.scienta.2011.03.010
2. AN 1005.00. (2012). Measuring Color using Hunter L, a, b versus CIE 1976 L*a*b*. In *Application Note AN 1005.00*. https://doi.org/10.1128/AEM.02997-13
3. AOAC. (1999). *Official methods of analysis of AOAC International, 16th Ed., 5th Rev., Association of Official Analytical Chemists, Gaithersburg, Maryland, USA*.
4. Aoun, M., & Manja, K. (2020). Effects of a photoselective netting system on Fuji and Jonagold apples in a Mediterranean orchard. *Scientia Horticulturae*, *263*, 1–8. https://doi.org/10.1016/j.scienta.2019.109104
5. Awad, M. A., Wagenmakers, P. S., & Jager, A. D. (2001). Effects of light on flavonoid and chlorogenic acid levels in the skin of 'jonagold' apples. *Scientia Horticulturae*, *88*, 289–298.
6. Bakhshi, D., & Arakawa, O. (2006). Induction of phenolic compounds biosynthesis with light irradiation in the flesh of red and yellow apples. *Journal of Applied Horticulture*, *8*(2), 101–104.

7. Basile, B., Giaccone, M., Cirillo, C., Ritieni, A., Graziani, G., Shahak, Y., & Forlani, M. (2012). Photo-selective hail nets affect fruit size and quality in Hayward kiwifruit. *Scientia Horticulturae*, *141*, 91–97. https://doi.org/10.1016/j.scienta.2012.04.022

8. Basile, B., Giaccone, M., Shahak, Y., Forlani, M., & Cirillo, C. (2014). Regulation of the vegetative growth of kiwifruit vines by photo-selective anti-hail netting. *Scientia Horticulturae*, *172*, 300–307. https://doi.org/10.1016/j.scienta.2014.04.011

9. Bastias, R. M. (2011). *Morphological and physiological responses of apple trees under photoselective colored nets*. Alma Mater Studiorum – Università di Bologna.

10. Bosco, L. C., Bergamaschi, H., Cardoso, L. S., de Paula, V. A., Marodin, G. A. B., & Nachtigall, G. R. (2015). Apple production and quality when cultivated under anti-hail cover in Southern Brazil. *International Journal of Biometeorology*, *59*(7), 773–782. https://doi.org/10.1007/s00484-014-0893-6

11. Brand-Williams, W., Cuvelier, M. E., & Brest, C. (1995). Use of free radical method to evaluate antioxidant activity. *LWT - Food Science and Technology*, *28*(1), 25–30.

12. Brar, H. S., Thakur, A., Singh, H., & Kaur, N. (2020). Photoselective coverings influence plant growth, root development, and buddability of citrus plants in protected nursery. *Acta Physiologiae Plantarum*, *42*(18), 1–15. https://doi.org/10.1007/s11738-019-2998-3

13. Brkljača, M., Rumora, J., Vuković, M., & Jemrić, T. (2016). The effect of photoselective nets on fruit quality of apple cv. "Cripps Pink." *Agriculturae Conspectus Scientificus*, *81*(2), 87–90.

14. Corollaro, M. L., Manfrini, L., Endrizzi, I., Aprea, E., Demattè, M. L., Charles, M., Bergamaschi, M., Biasioli, F., Zibordi, M., Corelli Grappadelli, L., & Gasperi, F. (2015). The effect of two orchard light management practices on the sensory quality of apple: Fruit thinning by shading or photo-selective nets. *Journal of Horticultural Science and Biotechnology*, *90*(1), 99–107. https://doi.org/10.1080/14620316.2015.11513159

15. Fruk, G., Fruk, M., Vuković, M., Buhin, J., Jatoi, M. A., & Jemrić, T. (2016). Colouration of apple cv. 'Braeburn' grown under anti-hail nets in Croatia. *Acta Horticulturae et Regiotecturae*, *19*(s1), 1–4. https://doi.org/10.1515/ahr-2016-0013

16. Gao, Y., Liu, Y., Kan, C., Chen, M., & Chen, J. (2019). Changes of peel color and fruit quality in navel orange fruits under different storage methods. *Scientia Horticulturae*, *256*, 1–8. https://doi.org/10.1016/j.scienta.2019.05.049

17. Giaccone, M., Forlani, M., & Basilea, B. (2012). Tree vigor, fruit yield and quality of nectarine trees grown under red photoselective anti- hail nets in Southern Italy. *Acta Horticulturae*, *962*, 387–394. https://doi.org/10.17660/ActaHortic.2012.962.53

18. Hamadziripi, E. T. (2012). *The effect of canopy position on the fruit quality and consumer preference of apples* [Stellenbosch University]. http://library.sun.ac.za/English/Pages/default.aspx

19. Hirst, P. M., Tustin, D. S., & Warrington, I. J. (1990). Fruit colour responses of 'Granny Smith' apple to variable light environments. *New Zealand Journal of Crop and Horticultural Science*, *18*(4), 205–214. https://doi.org/10.1080/01140671.1990.10428096

20. Huang, Y., Sheng, J., Yang, F., & Hu, Q. (2007). Effect of enzyme inactivation by microwave and oven heating on preservation quality of green tea. *Journal of Food Engineering*, *78*, 687–692.

21. Iglesias, I., & Alegre, S. (2006). The effect of anti-hail nets on fruit protection, radiation, temperature, quality and profi tability of 'Mondial Gala' apples. *Journal of Applied Horticulture*, *8*(2), 91–100.

22. Ilić, Z. S., & Fallik, E. (2017). Light quality manipulation improves vegetable quality at harvest and postharvest: a review. *Environmental and Experimental Botany*, *139*, 79–90.

23. Ivanova, V., Stefova, M., & Chinnici, F. (2010). Determination of the polyphenol contents in Macedonian grapes and wines by standardized spectrophotometric methods. *Journal of the Serbian Chemical Society*, *75*, 45–59.

24. Kalcsits, L., Musacchi, S., Layne, D. R., Schmidt, T., Mupambi, G., Serra, S., Mendoza, M., Asteggiano, L., Jarolmasjed, S., Sankaran, S., Khot, L. R., & Espinoza, C. Z. (2017). Above and below-ground environmental changes associated with the use of photoselective protective netting to reduce sunburn in apple. *Agricultural and Forest Meteorology*, *237–238*, 9–17. https://doi.org/10.1016/j.agrformet.2017.01.016

25. Lobos, G. A., Retamales, J. B., Hancock, J. F., Flore, J. A., Romero-bravo, S., & Pozo, A. (2013). Productivity and fruit quality of Vaccinium corymbosum cv. Elliott under photo-selective shading nets. *Scientia Horticulturae*, *153*, 143–149. https://doi.org/10.1016/j.scienta.2013.02.012

26. Mazhawu, E. (2016). *The effect of shadenetting on '3-29-5'avocado production under subtropical conditions*. University of KwaZulu-Natal.

27. Merzlyak, M. N., Solovchenko, A. E., & Chivkunova, O. B. (2002). Patterns of pigment changes in apple fruits during adaptation to high sunlight and sunscald development. *Plant Physiology and Biochemistry*, *40*(6–8), 679–684. https://doi.org/10.1016/S0981-9428(02)01408-0

28. Mupambi, G., Schmeisser, M., Dzikiti, S., Reynolds, S., & Steyn, W. J. (2018). Ineffectiveness of foliar S-ABA application as an apple sunburn suppressant explained through effects on peel biochemistry and leaf ecophysiology. *Scientia Horticulturae*, *232*, 256–263. https://doi.org/10.1016/j.scienta.2018.01.021

29. Mupambi, G., Schmeisser, M., Lötze, E., Malan, C., Dzikiti, S., & Steyn, W. J. (2017). Effect of supplementary irrigation at high ambient temperatures on sunburn, plant physiology, soil and canopy environment of "Granny Smith" apple. *Acta Horticulturae*, *1150*, 239–244. https://doi.org/10.17660/ActaHortic.2017.1150.33

30. Ordóñez, V., Molina-Corral, F. J., Olivas-Dorantes, C. L., Jacobo-Cuéllar, J. L., González-Aguilar, G., Espino, M., Sepulveda, D., & Olivas, G. I. (2016). Comparative study of the effects of black or white hail nets on the fruit qua-

lity of "Golden Delicious" apples. *Fruits*, *71*(4), 229–238. https://doi.org/10.1051/fruits/2016015

31. Oren-Shamir, M., Gussakovsky, E. E., Shpiegel, E., Nissim-Levi, A., Ratner, K., Ovadia, R., Giller, Y. E., & Shahak, Y. (2001). Coloured shade nets can improve the yield and quality of green decorative branches of Pittosporum variegatum. *Journal of Horticultural Science and Biotechnology*, *76*(3), 353–361. https://doi.org/10.1080/14620316.2001.11511377
32. Ough, C. S., & Amerine, M. A. (1988). Acidity and individual acids. In *Methods for analysis of musts and wine* (2nd edn, pp. 50–70). John Wiley & Sons.
33. Pajač Živković, I., Jemrić, T., Fruk, M., & Barić, B. (2018). Upotreba fotoselektivnih mreža u zaštiti od važnih štetnika breskve. *Glasilo Biljne Zaštite*, *18*(4), 399–406.
34. Pajač Živković, I., Jemrić, T., Fruk, M., Buhin, J., & Barić, B. (2016). Influence of different netting structures on codling moth and apple fruit damages in Northwest Croatia. *Agriculturae Conspectus Scientificus*, *81*(2), 99–102.
35. Racsko, J., & Schrader, L. E. (2012). Sunburn of apple fruit: historical background, recent advances and future perspectives. *Critical Reviews in Plant Sciences*, *31*(6), 455–504. https://doi.org/10.1080/07352689.2012.696453
36. Re, R., Pellegrini, N., Proteggente, A., Pannala, A., Yang, M., & Rice-Evans, C. (1999). Antioxidant activity applying an improved ABTS radical cation decolorization assay. *Free Radical Biology and Medicine*, *26*(9–10), 1231–1237.
37. Reay, P. F., & Lancaster, J. E. (2001). Accumulation of anthocyanins and quercetin glycosides in 'Gala' and 'Royal Gala' apple fruit skinwith UVB- Visible irradiation: modifying effects of fruit maturity, fruit side, and temperature. *Sci Hortic*, *90*, 57–68. https://doi.org/10.1016/S0304-4238(00) 00247-8
38. Sauphanor, B., Severac, G., Maugin, S., Toubon, J. F., & Capowiez, Y. (2012). Exclusion netting may alter reproduction of the codling moth (*Cydia pomonella*) and prevent associated fruit damage to apple orchards. *Entomologia Experimentalis et Applicata*, *145*(2), 134–142. https://doi.org/10.1111/j.1570-7458.2012.01320.x
39. Shahak, Y. (2008). Photo-selective netting for improved performance of horticultural crops. A review of ornamental and vegetable studies carried out in Israel. *Acta Horticulturae*, *770*, 161–168. https://doi.org/10.17660/ActaHortic.2008.770.18
40. Shahak, Y., Ratner, K., Giller, Y. E., Zur, N., Or, E., Gussakovsky, E. E., Stern, R., Sarig, P., Raban, E., Harcavi, E., Doron, I., & Greenblat-Avron, Y. (2008). Improving solar energy utilization, productivity and fruit quality in orchards and vineyards by photoselective netting. *Acta Horticulturae*, *772*, 65–72. https://doi.org/10.17660/ActaHortic.2008.772.7
41. Singleton, V. L., Orthofer, R., & Lamuela-Raventos, R. M. (1999). Analysis of total phenols and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. *Methods in Enzymology*, *299*, 152–178.
42. Solomakhin, A., & Blanke, M. M. (2010). Can coloured hailnets improve taste (sugar, sugar: acid ratio), consumer appeal (colouration) and nutritional value (anthocyanin, vitamin C) of apple fruit? *LWT - Food Science and Technology*, *43*, 1277–1284.
43. Streif, J. (1996). Optimum harvest date for different apple cultivars in the 'Bodensee' area. In A. Jager, D. Johnson, & E. Hohn (Eds.), *Determination and prediction of optimum harvest date of apples and pears* (pp. 15–20). Office for the Offic. Publ. of the European Communities, Luxembourg.
44. Tasin, M., Demaria, D., Ryne, C., Cesano, A., Galliano, A., Anfora, G., Ioriatti, C., & Alma, A. (2008). Effect of anti-hail nets on Cydia pomonella behavior in apple orchards. *Entomologia Experimentalis et Applicata*, *129*(1), 32–36.
45. Vuković, M., Brkljača, M., Rumora, J., Fruk, M., Jatoi, M. A., & Jemrić, T. (2016). Vegetative and reproductive traits of young peaches and nectarines grown under red photoselective net. *Agriculturae Conspectus Scientificus*, *81*(3), 181–185.
46. Vuković, M., Buhin, J., Brkljača, M., Jatoi, M. A., & Jemrić, T. (2020). Postharvest quality of "Granny Smith" apple grown under photo-selective red net. *Journal of Central European Agriculture*, *21*(1), 124–128. https://doi.org/10.5513/JCEA01/21.1.2777
47. Zoratti, L., Jaakola, L., Häggman, H., & Giongo, L. (2015). Modification of sunlight radiation through colored photo-selective nets affects anthocyanin profile in Vaccinium spp. berries. *PLoS ONE*, *10*(8), 1–17. https://doi.org/10.1371/journal.pone.0135935

UTJECAJ CRVENE PROTUINSEKTNE FOTOSELEKTIVNE MREŽE NA GENERATIVNE I VEGETATIVNE KARAKTERISTIKE JABUKE 'GRANNY SMITH'

SAŽETAK

Protuinsektne fotoselektivne mreže predstavljaju novu tehnologiju koja istovremeno kombinira manipulaciju svjetlom i zaštitu od štetnika. U voćnjaku jabuka pokraj Zadra (Hrvatska) istraživan je utjecaj crvene protuinsektne fotoselektivne mreže na generativne i vegetativne parametre jabuke 'Granny Smith'. Jabuke su uzgajane na M9 podlozi te su imale uzgojni oblik vretenastoga grma. Istraživanje se sastojalo od dvaju tretmana: stabla prekrivena crvenom protuinsektnom fotoselektivnom mrežom (AGRITECH S. r. l., Eboli, Italija; veličina okca od 2.4 × 4.8 mm) i nepokrivena stabla kao kontrola. Prirod, udio plodova s promjerom >70 mm i masa plodova nisu se signifikantno razlikovali između tretmana. Jabuke uzgajane ispod crvene mreže imale su signifikantno veću L* vrijednost parametra boje kožice, dok za ostale parametre boje nije zabilježena signifikantna razlika (a*, b*, C* i h°). Sadržaj topljive suhe tvari (TST) i ukupni sadržaj flavonoida bio je signifikantno niži u jabukama uzgajanima ispod crvene mreže, dok nije zabilježen signifikantan utjecaj crvene mreže na titracijsku kiselost (TA), TST / TA, stupanj razgradnje škroba i indeks zrelosti (Streif). Primjena crvene mreže pokazala se vrlo djelotvornom u smanjenju pojavnosti dopunskoga crvenila (koje je kod jabuke 'Granny Smith' nepoželjno svojstvo) i ožegotina od sunca na plodovima.

Ključne riječi: fotoselektivne mreže, protuinsektne mreže, crvena mreža, jabuka 'Granny Smith', kakvoća voća, modifikacija svjetla

(Received on March 26, 2021; accepted on October 21, 2021 – *Primljeno 26. ožujka 2021.; prihvaćeno 21. listopada 2021.)*