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# YIELD AND PEPPER QUALITY AS AFFECTED BY LIGHT INTENSITY USING COLOUR SHADE NETS


## SUMMARY

The yield and quality of pepper were affected by environmental factors and the agronomic techniques used. The photoselective netting concept was tested in greenhouse pepper (*Capsicum annuum* 'Chameleon') production under high solar radiation 942 W•m$^{-2}$ (value of photosynthetic photon flux density - PPFD is about 1600 µmol•m-2•s$^{-1}$) in the south part of Serbia (Aleksinac). Four different coloured shade-nets (pearl, red, blue and black) with different relative shading (40% and 50% PAR) were mounted over the plastic-house and applied at the start of warm weather in the middle of June.

Shading of pepper plants affected both fruit yield and quality. Total and marketable yield increased with 40% shading level and then decreased (with 50% shade). Shading of pepper (40%) may be an option to reduce heat stress conditions and extend the spring-summer season toward September. Although light is not essential for the synthesis of vitamin C in plants, the amount and intensity of light during the growing season influence the amount of vitamin C formed. Significantly higher vitamin C content was observed in greenhouse pepper integrated with red shade netting technologies (188.4 mg•100g$^{-1}$) than in greenhouse pepper without colour nets (151.4 mg•100g$^{-1}$). The results of the present study should provide useful preliminary data for detecting differences among environment variation in quality and light-dispersive colour shade nets, as a new multi-benefit tool for crop protection.


**Key words:** shade, colour-net, pepper, yield, vitamin C

## INTRODUCTION

Pepper (*Capsicum annuum* L.) cultivars have been identified as potential vegetables with a wide spectrum of antioxidant compounds (Navarro et al. 2006) and high antioxidant activity (Kevers et al. 2007).

Vitamin C, as an antioxidant, reportedly reduces the risk of arteriosclerosis, cardiovascular diseases and some forms of cancer (Harris 1996).

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A high intake of 100-200 mg/day has been recommended, since stress in modern life is known to increase the requirement for vitamin C (Lee and Kader 2000). Fresh pepper is one of the vegetables that have a high content of vitamin C (0.15 to 2.0 $mg.g^{-1}$fresh weight) compared to other fruit and vegetables (Vanderslice et al. 1990). In traditional vegetable-producing regions, pepper cultivation in a protected environment has expanded to prevent seasonality in the availability of fruit. The total area of protected vegetable cultivation in different types of greenhouses in Serbia reached 2500-3000 ha and the main vegetables are peppers, tomatoes and cucumbers (Ilić et al. 2011).

The use of shading nets has become very popular in Serbia due to the very high temperatures in the summer season (35~40°C). Efforts to manipulate plant morphology and physiology using photoselective filters have been ongoing for decades, especially in greenhouse environments (Wilson and Rajapakse 2001). ColorNets represent a new agro-technological concept, which aims at combining physical protection with differential filtrations of solar radiation. They are based on the incorporation of various chromatic additives, light dispersive and reflective elements into the netting materials during manufacturing (Shahak et al. 2004a). They can provide physical protection (birds, hail, insects, excessive radiation), affect environmental modification (humidity, shade, temperature) (Perez et al. 2006) and increase the relative proportion of diffuse (scattered) light as well as absorb various spectral bands, thereby affecting light quality (Stamps 2009).

The netting is either applied by itself over net-house constructions, or combined with greenhouse technologies (Shahak et al. 2004a). Movable shade, applied only during sunny periods, should be less deleterious than constant shade. In pepper, reduced fruit set is common when day temperatures are ≥32°C. Rylski and Spigelman (1982, 1986) showed that under field conditions in the summer, a reduction in radiation of approximately 26% had a significant impact and increased production in *C. annuum* compared with exposure to full sunlight. With roughly 50% shade, commercial production was greater than in full sunlight, although less than with 26%. Depending on the year, the total fruit yields (t/ha) under the coloured shade nets were higher by 113 to 131%, relative to the equivalent black shade net (Ilić et al. 2011). It is also possible that the increase in pepper yield is due to larger numbers of branches and flowers per plant (Nissim-Levi et al. 2008).

Positive effects of the red net on pepper productivity were also obtained by the group of Fernández-Rodriguez for plastic tunnel cultivation in Almeria, Spain (Shahak et al. 2004b). Peppers grown in an arid region under red and yellow shade nets (30% relative shading in PAR) had a significant higher yield compared with black nets of the same shading factors, without no reduction in fruit size (Fallik et al. 2009).

The number of fruit produced per plant throughout the growing season was 30-40% higher, and the yield (t/ha) 20-30% higher under these photoselective nets, in all tested cultivars, while fruit size was comparable with the black shade net control (Shahak 2008). The lowest total yield was obtained from black net treatment (Medany et al. 2008). In experiments with shade levels (60%, 40% and full sunlight) Jaimez and Rada (2006) found significantly higher yield differences for plants with 40% shade and full sunlight compared to plants with 60% shade. Shahak (2008) reported that production of three cultivars of bell pepper was increased by 16% to 32% under pearl and red compared with black netting.

Climatic conditions including light and average temperature have a strong influence on the chemical composition of horticultural crops (Klein and Perry 1982). Shade netting not only decreases light quantity but also alters light quality to a varying extent and might also change other environmental conditions (Stamps 2009). However, little is known about how various types of netting affect the biochemical quality of pepper.

Dry matter was decreased linearly with increasing shade (Smith et al. 1984). Light exposure has been reported to favour the accumulation of vitamin C (Dumas et al. 2003).

Only limited or no data can be found in the literature dealing with the contents of vitamin C in pepper fruits as a response to growing conditions, particularly variations in solar radiation and temperature. Vitamin C development in pepper and other fruit is related to glucose metabolism and light exposure, and concentrations of both vitamin C and reducing sugars typically increased as the fruit matures (Fox et al. 2005).

The vitamin C content of pepper was affected by cultural practices on one hand – genotype and agronomic technique (Lee et al. 1995, Lee and Kader 2000,Navarro et al. 2006, Topuz and Ozdemir 2007) and abiotic factors on the other hand – light and temperature (Klein and Perry 1982, Lopez-Marin et al. 2011).

The higher the intensity of light during the growing season, the greater is vitamin C content in plant tissues (Harris 1975). The content of vitamin C and carotenoids could be heterogeneous within the fruit and related to fruit exposure to light (Venter 1977), but few studies had investigated the role of different wavelengths in their regulation.

## MATERIAL AND METHODS

The pepper (*Capsicum annum* L.) variety ‘Chameleon’ was grown during 2008-2009 in a plastic tunnel (2.5m high), covered with a polyethylene film (0.15 mm thick; Ginegar Plastic Products-Ltd.). The experiments were performed in an experimental garden located in the village of Moravac near Aleksinac, (Longitude: 21$^{o}$42' E, Latitude: 43$^{o}$87 30' N, altitude 159 m) in the central area of south Serbia. The shade nets were applied at the start of warm weather in early June. The houses were shaded for the rest of the summer and vegetables were harvested until late August. A completely randomized block design was used, with four blocks assigned to each of four treatments (black, pearl, blue and red net) plus control. Each treatment and block consisted of four rows of 20 plants.

***Plant material***

The plants were grown following the technique usually implemented by the local producers. Peppers were grown in soil, with a 3.94 % humus content, pH 6.65 (in KCl) containing nutrients as follows: N 10 mg·100 $g^{-1}$, P >40 mg·100$g^{-1}$, K >40mg·100$g^{-1}$. Stable manure (20t $ha^{-1}$) was used as an organic fertilizer and nitrophos blue special (N12:P12:K17, + 2MgO 98 +8S + Trace elements, K+S Nitrogen) was used as a mineral fertiliser. Seedlings were transplanted on May 5 (plant density was 2.6 plants $m^{-2}$), the shading nets were subsequently installed above the crop on June 10 (35 days after transplanting) and the measurements were carried out until September 5. All plants were irrigated using drip irrigation. The peppers used in the study were harvested at the mature-green stage.

***Net characteristics***

In order to test the effect of shading nets (colour and shading intensity), four different shading nets were used: the photo-selective nets including ‘coloured ColorNets‘ (red, blue and black) as well as ‘neutral-ColorNets’ (pearl) with shading intensity of 40% and 50% relative shading. The photosynthetically active radiation (PAR) was compared to the open field microclimate and production. The coloured shade nets were obtained from Polysack Plastics

Industries (Nir-Yitzhak, Israel) operate under the trademark ChromatiNet. These nets are unique in that they both spectrally modify as well as scatter the transmitted light. The photo-selective net products are based on the incorporation of various chromatic additives, light dispersive and reflective elements into the netting materials during manufacturing. The shading nets were mounted on a structure about 2.0 m in height over the plants in a screen house or combined with greenhouse technologies.

***Light interception by nets***

The effect of nets on the interception of light was measured annually as a percentage of total PAR above canopy, using a Ceptometer model Sun Scan SS1-UM-1.05 (Delta-T Devices Ltd Cambridge, UK) with a 64-sensor photodiode linearly sorted in a 100 cm length sword. Readings are in units of PAR quantum flux (µmol $m^{-2}s^{-1}$). All measurements were conducted on clear days at noontime. Measurements of global radiation were made every second day, three times during the day. The Solarimeter- SL 100 is an easy-to-use portable autonomous Solarimeter that measures solar irrigation range from 1 W·$m^{-2}$ to 1300 W·$m^{-2}$. All spectral data were expressed as radiation intensity flux distribution in W·$m^{-2}nm^{-1}$.

Monthly meteorological data from May 2008 to September 2009 from the meteorological stations in Aleksinac were used (Table 1). The microclimates were similar under the nets, with slightly lower values of temperature and air humidity than in open air. The air temperature on an average day in July under different coloured shade nets was between 0.9 °C (pearl) and 3.0 °C (black) lower when compared to open field air temperature (Figure 1). Coloured shade nets benefit in temperature control; they improve productivity by alleviating temperature extremes. Since air movement is restricted, wind damage to the crop is reduced by more than 50% (data not shown) as is evaporation. The air beneath the shade cloth remains humid, which is of further benefit to the plant.

***Vitamin C***

Ascorbic acid was quantitatively determined according to 2, 6 dichlorophenolindophenol-dye method as described by Jones and Hughes (1983) with slight modifications. The ascorbic acid in 10 g of fresh sample was extracted by grinding with a small amount of acid-washed quartz sand and 3% meta-phosphoric acid (v/v). The extract volume was made up to 100 ml, mixed and centrifuged at 3000 g for 15 min at room temperature. Ten millilitres were titrated against standard 2, 6-dichlorophenolindophenol dye, which was already standardized against standard ascorbic acid. Results were expressed on mg /100g fw.

Negligible differences were observed in temperature between inside and outside of the screen houses. The plastic house maximum and minimum daily temperatures were 3 and 1 ºC warmer than outside, respectively.

Table 1. Temperature ($^{o}$C) and solar radiation (MJ/m$^{2}$) during the growing season (Aleksinac)

| Month | TS | | TOD | | TX | | TM | | MSR |
|---|---|---|---|---|---|---|---|---|---|
| | 2008 | 2009 | 2008 | 2009 | 2008 | 2009 | 2008 | 2009 | |
| Maj | 18.4 | 18.7 | 1.8 | 2.1 | 25.1 | 25.5 | 11.4 | 11.8 | 219.0 |
| Jun | 22.6 | 20.9 | 3.1 | 1.4 | 29.2 | 27.3 | 15.6 | 14.8 | 237.2 |
| July | 22.9 | 23.3 | 1.6 | 2.0 | 29.9 | 30.3 | 15.7 | 16.1 | 289.0 |
| August | 23.5 | 23.5 | 2.4 | 2.4 | 31.3 | 30.9 | 15.6 | 16.2 | 276.0 |
| Septem | 16.6 | 19.0 | 0.6 | 1.8 | 22.7 | 26.8 | 11.1 | 12.4 | 210.0 |

***TS***-mean monthly air temperature ($^{o}$C); ***TOD***-temperature deviation from 1961-1990 average ($^{o}$C); ***TX***-mean daily temperature maximum for month ($^{o}$C); ***TM***-mean daily temperature minimum for month ($^{o}$C); ***MSR,*** mean daily solar radiation (MJ/m$^{2}$);

Monthly meteorological data from May 2008 to September 2009 from the meteorological stations in Aleksinac were used (Table 1). The microclimates were similar under nets, with slightly lower values of temperature and air humidity than in open air. The air temperature on an average day in July under different coloured shade nets was between 0.9 °C (pearl) and 3.0 °C (black) lower when compared to open field air temperature (control). Coloured shade nets benefit in temperature control; they improve productivity by alleviating temperature extremes. Since air movement is restricted, wind damage to the crop is reduced by more than 50% (data not shown) as is evaporation. The air beneath the shade cloth remains humid, which is of further benefit to the plant. There were negligible differences between relative humidity observed in the screen-house and outside. Maximum and minimum daily relative humidity was up to 12 and 25% higher than outside, respectively.

## RESULT AND DISCUSSIONS

Net radiation was dependent on net colour and extent of shadowing. Solar radiation was lower in the plastic house, at about 857 $W \cdot m^{-2}$, in comparison to radiation in the open field, at about 942 $W \cdot m^{-2}$, as shown in Table 2. Compared to the control, solar radiation was significantly reduced by a shade of 50% compared to 40% shade. The greatest decrease in radiation intensity was recorded with black nets with 50% shade about 515 $W \cdot m^{-2}$.

However, while the greenhouse without shading reached very high levels of solar radiation during the midday, solar radiation in the shaded greenhouse with 50% shading did not exceed 650 $W \cdot m^{-2}$ (Table 2). The difference in incoming solar radiation between the control greenhouse and the greenhouse with the highest shading intensity (50%) was 410 $W \cdot m^{-2}$ and 270 $W \cdot m^{-2}$ for black and red colour-nets, respectively. During a sunny day in July, solar radiation was about 950 $W \cdot m^{-2}$. Under high solar radiation conditions (south Serbia in July and August), the value of the photosynthetic photon flux density (PPFD) was about 1600 $\mu mol\ m^{-2} s^{-1}$, which means that unshaded plants are exposed to high light stress throughout the growing season, as shown in Table 2.

Table 2. Reduction (%) of solar radiation ($W \cdot m^{-2}$) and photo-synthetically active radiation (PAR) $\mu mol\ m^{-2} s^{-1}$ of the control at noon of sunny day in July by different colour shade nets

| | PH + colour-nets | | Only colour nets | | PH+ colour-nets | | Only colour nets | |
|---|---|---|---|---|---|---|---|---|
| | 40% | 50% | 40% | 50% | 40% | 50% | 40% | 50% |
| | percent of the radiation ($W \cdot m^{-2}$) of the control | | | | percent of PPFD* ($\mu mol\ m^{-2} s^{-1}$) of the control | | | |
| Red | 44.0 | 46.2 | 51.2 | 57.0 | 66.9 | 90.0 | 66.2 | 125.1 |
| White | 54.4 | 74.1 | 66.7 | 82.0 | 64.7 | 94.4 | 85.7 | 107.2 |
| Blue | 72.0 | 91.7 | 80.8 | 98.7 | 72.7 | 101.3 | 89.5 | 130.0 |
| Black | 108.0 | 107.0 | 101.7 | 125.0 | 90.9 | 143.8 | 128.7 | 147.5 |
| Control | $PH^{+}$ 857 | | $OF^{++}$ 942 | | 1112 | | 1594 | |

Control: $PH^{+}$-plastic house; $OF^{++}$- open field (exposure to full sunlight).
*PPFD - photon flux density

The values for PPFD varied between 1593 $\mu mol\ m^{-2} s^{-1}$ on sunny days and 700 to 920 $\mu mol\ m^{-2} s^{-1}$ on cloudy days. The solar radiation registered on sunny days resulted in high PAR values (maximum 1600-2000 $\mu mol\ m^{-2} s^{-1}$), which are common to the arid conditions in southern Europe. On cloudy days (complete clouds cover), the maximum values ranged from 800-900 $\mu mol\ m^{-2} s^{-1}$. Some shade conditions may be optimal to produce high quality peppers in a greenhouse during the summer months in south Serbia. To determine the effects of shade more precisely, simultaneous comparisons were made among greenhouses that were either not shaded, or covered with photo-selective shade nets that attenuated 40% or 50% of the direct sunlight. In the similarly experiment, PPFD reached 2000 μmol $m^{-2}$ $s^{-1}$ at noon in pepper plants growing in full sunlight (Jaminez and Rada 2011). Under 40% shade, it ranged from 1100 to 1250 μmol $m^{-2}$ $s^{-1}$ and for 60 % shade, it remained below 800 μmol $m^{-2}s^{-1.}$ These differences affected VPD; with highest values obtained in plants growing in full sunlight during most of the day.

A study by Möller and Assouline (2007) on sweet peppers growth under a screenhouse showed that shading of the screen reduced mean global radiation by more than 40, wind speed inside the screenhouse was reduced by more than 50%. However, the screen did not significantly modify maximum temperature and daily vapour pressure deficit. Natural ventilation, especially in early transplanting in August, might lead to increases in vegetative growth and early yield. In a plastic-house and white net house, high temperatures cause heat stress, while in the winter time plants need warmer conditions and higher light intensity, which were obtained under plastic-house.

Plants grown under black colour-nets with 40% shadow had higher yield of 10.5% than control plants grown without nets. Red and pearl shade nets significantly increased the total yield by 43.5% and 49.5% respectively, which was associated with both higher productivity for number of fruits produced per plant and larger fruits (data not show). Pepper plants under 50% shadow achieved similar fruit yield in comparison with the yield obtained from 40% colour shade nets, except under black shade net where the achieved yield was lower than the control, as shown in figure 2.

Fig.2. Influence of colour shade nets integrated with plastic-house on pepper yield

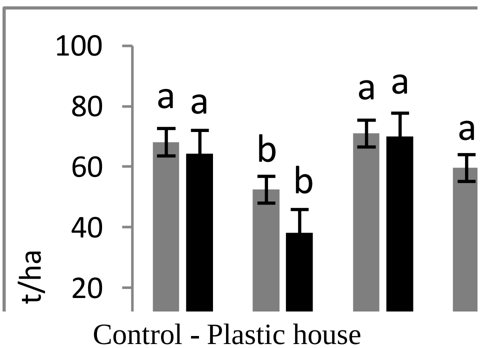
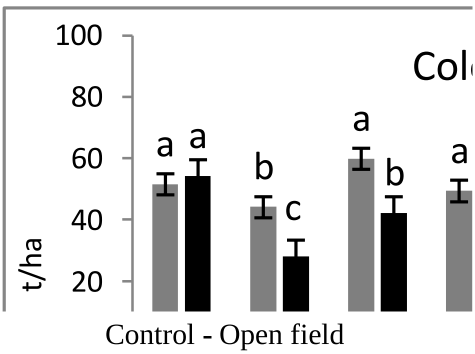



Fig.3. Influence of colour shade nets on pepper yield (t/ha)




The relative difference between the coloured and the black shade nets with regards to export-quality fruit yield was even more prominent. Rylski and Spigelman (1986) showed that under field conditions during the summer, a reduction in radiation of approximately 26% had a significant impact and increased production in *C. annuum* compared with exposure to full sunlight.

With roughly 50% shade, commercial production was greater than in full sunlight, although less than with 26%. Under greenhouse conditions in Israel, increased shading rate between 40 and 90% resulted with a higher flower abscission rate and reduced assimilation rates, which differed among the cultivars (Aloni et al. 1996). Depending on the year, the total fruit yields (t/ha) under the coloured shade nets were higher by 113 to 131%, relative to the equivalent black shade net. The highest fruit yield resulted mostly from enhanced fruit production rates, namely the number of fruits produced per plant, while average fruit size was not significantly affected in most cases. Research results showed that shading of bell pepper plants affected both fruit yield and quality. Total and marketable yield increased at a 40% shading level and then decreased with when shading was increased to 50%. Reduction in total and marketable yield of un-shaded plants was probably caused by high heat stress. Moderate shading of about 40% for bell peppers may be an option to reduce heat stress conditions and extend the spring-summer season toward September. We speculate that the modification of light quality by the tested photo-selective shade nets promotes fruit-set and fruit survival rate or decreases temperature compared with black shading. This might be due to the highest content of scattered/diffuse light. These studies suggest that shade is more beneficial under high compared with low sunlight intensity on both a daily and a seasonal basis (Gent 2008). The number of pepper fruits produced per plant throughout the growing season was also 30-40% higher, and the yield ($t{\cdot}ha^{-1}$) 20-30% higher under these photo-selective nets, in all tested cultivars (Shahak et al. 2008).

Opposite results were reported by Sandri et al. (2003) and Gent (2007) for tomato production under shade nets. In the present study, shading of pepper plants affected both fruit yield and quality. Total and market yields increased with shading levels up to 40% and then decreased with increasing 50% shading levels. The greater fruit yield produced by shaded plants may be explained by the assumption that, during the summer, high temperature increases the shedding of pepper flowers and reduces fruit set. Since the nets are composed of holes, in addition to the translucent photo-selective plastic threads, shade nets actually create mixtures of natural, unmodified light, which is passing through the holes, together with the diffused, spectrally modified light, which is emitted by the photo-selective threads (Shahak et al. 2008). The reduced total and marketable yields of unshaded plants were probably due to high heat stress. A 40% shading of peppers may be an option to reduce heat stress conditions and extend the summer season toward September (Ilić et al. 2012).

The major response to the photoselective filtration was the production of more fruits per plant, with essentially no reduction of fruit size or quality. Additional benefits relate to photoselective improvement of pest control (Shahak et al. 2009).

Shade netting that increases light scattering but does not affect the light spectrum has been shown to increase branching, plant compactness, and the number of flowers per plant (Nissim-Levi et al. 2008). Light and temperature have a strong influence on the chemical composition of fruit. Coloured shade nets are being intensively tested primarily because of their ability to manipulate the spectra of radiation. They can be used to change red to far-red light ratios that are detected by phytochrome, the amounts of radiation available to activate the blue/ultraviolet-A photoreceptors, blue light involved in phototropic responses mediated by phototropins, and radiation at other wavelengths that can influence plant growth and development (Stamps 2009). In general, few studies have investigated about how various types of netting affect the biochemical quality of peppers.

Table 3 shows that peppers grown in plastic houses had significant differences in dry matter contents, at about 6.58%, compared to control, open field conditions, at about 8.03%. The highest concentration of dry matter was detected in peppers grown in fields covered with black and blue nets, at about 7.19% and 7.12%, respectively, while peppers grown in plastic houses integrated with red colour nets had the lowest dry matter, at about 6.39%. Dry matter decreased linearly with increasing shade (Smith et al. 1984). Results confirmed the positive correlation between TSS and vitamin C; this relationship could be due to the association between sugar and vitamin C metabolism (Wheeler et al. 1998).

Table 3. Influence of colour shade nets integrated in a greenhouse on pepper dry matter and vitamin C content

| Shade (40%) | Dry matter % | | Vitamin C $mg \cdot 100g^{-1}$ | |
|---|---|---|---|---|
| | Plastic-house + colour nets | Only colour nets | Plastic-house + colour nets | Only colour nets |
| Red | 6.39b | 6.95b | 175.77b | 148.50b |
| Black | 6.44b | 7.19b | 145.26a | 166.39a |
| Pearl | 6.54a | 6.64c | 151.28a | 162.02a |
| Blue | 6.47b | 7.12b | 136.50a | 168.80a |
| Control | Plastic-house 6.58a | Open field 8.03a | Plastic-house 151.37a | Open field 171.27a |

Vitamin C is a functional and nutritional constituent of pepper fruit, and is well known as an antioxidant and a biologically active compound (Rietjens et al. 2002).

The composition of *Capsicum* fruit can vary greatly by genotype and maturity. The content of vitamin C in pepper fruit increases upon maturation (Howard et al. 1994). Peppers are also influenced by growing and processing conditions (Hornero-Mendez et al. 2000). Seasonal variations in vitamin C content observed in greenhouse-grown peppers at the mature-green stage may be a result of temperature variations under greenhouse conditions. In general, limited information is available on the effects of temperature on vitamin C content of pepper fruits. Table 3 shows that significant differences in vitamin C contents were observed in peppers grown in plastic houses, at about 151.37 $mg \cdot 100g^{-1}$ compared to control of open field conditions at about 171.27 $mg \cdot 100g^{-1}$. The highest concentration of vitamin C was detected in peppers grown in plastic houses integrated with red colour nets, at about 175.77 $mg \cdot 100g^{-1}$ while peppers grown in fields covered with red nets had the lowest levels of vitamin C, at about 148.50 $mg \cdot 100g^{-1}$. Light exposure has been reported to favour the accumulation of vitamin C in tomato fruit (Dumas et al. 2003).

Earlier, Hamner et al. (1945) reported that the tomato fruit produced under shade had low vitamin C content, at about 15.5 $mg \cdot 100g^{-1}$ fresh weight, when compared to the fruit produced under sunshine conditions, at about 25.8 $mg \cdot 100g^{-1}$ fresh weight.

Although light is not essential for the synthesis of vitamin C in plants, the amount and intensity of light during the growing season have a definite influence on the amount of vitamin C formed. Vitamin C is synthesized from sugars supplied through photosynthesis in plants. Fruit on the outside of the canopy that are exposed to maximum sunlight contain higher amounts of vitamin C than fruits that are inside and shaded on the same plant. In the present study, the use of filters with different transmission properties was useful in distinguishing the light wavelengths active in stimulating the synthesis of vitamin C. This study was not aimed at determining which filter could be used to improve fruit quality, but to understand if changes in fruit microclimate during maturation impact fruit traits.

Pepper fruits grown in an open field as a control and under blue nets had significantly more vitamin C than fruits grown under black or red nets. Pepper fruits grown in a plastic house as a control and under integrated plastic house with red net had more significantly vitamin C level than fruits grown under black and pearl nets, as shown in table 3. Photo-selective nets were designed to selectively filter different spectral bands of solar radiation, and/or transform direct light into scattered light. The spectral manipulation intends to specifically promote desired physiological responses, while the scattering improves the penetration of the spectrally modified light into the inner plant canopy. The effects of the blue and red nets might be attributed to their relative enriching/reducing of the blue vs. red and far-red spectral bands in the filtered light, and might further be related to similar effects reported for photo selective films

## CONCLUSIONS

The photoselective, light-dispersive shade nets provide a new, multi-benefit tool for crop protection. Changing the light intensity and radiation spectrum has a large impact on the total production system. Microclimate and energy consumption are influenced; costs and benefits are affected. Research on light in horticultural systems is necessary for a sustainable and market-oriented greenhouse production in the future. The results of the present study provide useful data for detecting differences among environment variation in vitamin C content and colour shade nets. However, the data are preliminary and more research is required to understand the physiological mechanisms behind the plant responses and for testing results with other crops and other environmental conditions.

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## UTICAJ INTENZITETA SVIJETLA KORIŠĆENJEM OBOJENIH MREŽA NA KVALITET I PRINOS PAPRIKA


### SAŽETAK

Na prinos i kvalitet paprika su uticali faktori okoline i korištene agronomske tehnike. Koncept foto selektivne mreže je bio testiran u pčasteničkoj proizvodnji paprika (*Capsicum annuum* 'Cameleon') pod visokom solarnom radijacijom 942 $W \cdot m^{-2}$(vrijednost indukcije fotosintetičkih fotona -PPFD je oko 1600 $\mu mol \cdot m^{-2} \cdot s^{-1}$) u južnom dijelu Srbije (Aleksinac), korišćenjem četiri raznobojne mreže (biserna, crvena, plava i crna) sa različitim relativnim zasjenčivanjem (40% i 50% PAR). Mreže za zamračivanje su bile montirane preko plastenika i primjenjivane su od početka toplog vremena sredinom juna.

Rezultati su pokazali da zasjenčivanje biljaka paprika utiče i na prinos i na kvalitet. Ukupan prinos koji se može prodati na tržištu je porastao sa stepenom zasjenčivanja od 40%, a onda opao (sa 50% sjenke). Zasjenčivanje paprika (40%) može biti opcija radi smanjenja toplotnih stresnih uslova i proširiti sezonu proljeće-ljeto do septembra. Iako svijetlo nije osnovno za sintezu vitamina C kod biljaka, količina i intentzitet svijetla za vrijeme sezone rasta ima uticaj na količinu formiranog vitamina C. Značajno više sadržaja vitamina C je primiječeno kod paprika koje su u plasteniku integrisane sa tehnologijom zasjenčivanja crvenom mrežom (188.4 $mg \cdot 100g^{-1}$) nego u plastenicima paprika bez obojenih mreža (151.4 $mg \cdot 100g^{-1}$). Rezultati sadašnje studije bi trebali da obezbijede korisne preliminarne podatke za otkrivanje razlika između variranja u okolini u kvalitetu obojenim svjetlo-disperzivnim mrežama za sjenčenje, za nas višestruko korisno sredstvo za zaštitu usjeva.


**Ključne riječi**: sjenka, obojene mreže, paprika, prinos, vitamin C