The effect of color shade nets on the greenhouse climate and pepper yield

Zoran ILIĆ, Lidija MILENKOVIC, Mihal ĐUROVKA, Nikolaos KAPOULAS

1Faculty of Agriculture Priština-Lešak, Kopaonička bb, 38219 Lešak, Serbia, (e-mail: zoran_ilić63@yahoo.com)
2Faculty of Agriculture Novi Sad, Trg D. Obradovića 8, 21000 Novi Sad, Serbia
3Regional Development Agency of Rodopi, N. 69100 Komotini, Greece

Abstract

The goal of the three-year trial was to evaluate the influence of different colored shade nets (photoselective) on the plant development, yield and quality of bell pepper (Capsicum annuum L.). Pepper was grown under four different colored shade-nets (pearl, red, blue and black) with different relative shading (40% and 50%). Exposure to full sunlight was used as a control. Used color-shade nets improved productivity by moderating climatic extremes. Depending on the year, the total fruit yields (t/ha) under the colored shade nets were higher by 113 to 131%, relative to the open field. In this investigation the potential use of pearl and red colored shade nets (40% by FAR) was demonstrated.

Key words: photoselective net, solar radiation, Capsicum annuum L., yield

Introduction

During the last decades, due to increased air temperature and intensity of solar radiation caused by climate changes, an increasing area of crops is being grown under shading materials of various types. ColorNets represent a new agro-technological concept, which aims at combining the physical protection, together with differential filtration of the solar radiation. They are based on the incorporation of various chromatic additives, light dispersive and reflective elements into the netting materials during manufacturing. It is either applied by itself over net-house constructions, or combined with greenhouse technologies. The ColorNet approach was evaluated in numerous ornamentals (Nissim-Levi et al., 2008), vegetables (Fallik et al., 2009, 2010), fruit trees (Shahak et al., 2004a) and vineyards. Netting is frequently used to protect agricultural crops from excessive solar radiation (shade-nets), improving the thermal climate (Kittas et al., 2009), sheltering from wind and hail and exclusion of bird and insect-transmitted virus diseases (Teitel et al., 2008). The shading of crops results in number of changes on both local microclimate and crop activity. These changes on local microclimate modify CO₂ assimilation and consequently crop growth and development (Kittas et al., 2009). Smith et al. (1984) observed that under shading nets the air temperature was lower than that of the ambient air, depending on the shading intensity. Shade netting not only decreases light quantity but also alters light quality to a varying extent and might also change other environmental conditions. The target responses are those determining the commercial value of each crop, including yield, product quality, and rate of maturation (Shahak et al., 2004b). The total area of protected vegetable cultivation in different types of greenhouse in Serbia reached 2-3.000 ha and the main vegetables are, peppers, tomatoes, cucumbers... The use of shading nets has become very popular in Serbia due to the very high temperatures in the summer season (35-42 °C). Pepper grown in an arid region under red and yellow shade nets, had a significant higher yield compared with black nets of the same shading factors, without reducing fruit size. In addition, the export-quality fruit yield was also significantly increased under the red and yellow shade nets (Fallik et al., 2009).

The goal of the present three-year trial was to evaluate, the influence of different colored shade nets on the plant development, yield and quality of fresh harvested pepper.
Material and methods

The experiments were performed in an experimental garden located at village Moravac near Aleksinac, (Longitude: 21° 42' E, Latitude: 43° 30' N, altitude 159 m) on the central area of South Serbia, during spring and summer of 2008 to 2010. Trials were set up to the randomized complete block design with three replications. The shading nets were mounted on a structure about 2.0 m height over the plants same as a screen house or combined with greenhouse technologies.

Net characteristics

In order to test the effect of shading nets (colour and shading intensity), four different shading nets were used: the photoselective nets include “coloured-ColorNets” (red, blue and black) as well as “neutral-ColorNets” (pearl) with shading intensity of 40% and 50% relative shading (photosynthesis active radiation-PAR) and were compared with the open field microclimate and production. Color shade nets were obtained from Polysack Plastics Industries (Nir-Yitzhak, Israel) under the trade mark ChromatiNet.

Plant material

The pepper (*Capsicum annum* L.) ‘Cameleon’ was planted with an intra-row distance of 0.30 m and an inter-row distance of 0.60 m, and the final plant density was 5,6 plants per m². The plants were grown following the technique that is usually implemented by the local producers. Seedlings (60 day-old plants) were transplanted on May 5, while the shading nets were installed above the crop on June 10 (35 days after transplanting). The measurements were carried out until September 5.

Light interception by nets

A Sun Scan light interception measurement system was used for solar radiation properties measurements. The effect of nets on the interception of light was measured daily as a percentage of total above canopy photosynthetically active radiation (PAR), using a 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 were in units of PAR quantum flux ($\mu$mol m$^{-2}$ s$^{-1}$). Solarimeter - SL 100 is easy to use portable autonomous solarimeter that measures solar irrigation range from 1 to 1300 W.m$^{-2}$. All spectral data were expressed as radiation intensity flux distribution in W m$^{-2}$ nm$^{-1}$.

Results and discussion

The word Colorshade Net is termed for a net which prevents excess sunlight and retain soil moisture levels for proper plants growth. This leads to an increase in productivity (yield) of the plants. The response of pepper plants to shading will probably vary in different geographical areas, seasons and cultivars, and from different agricultural practices such as planting density, irrigation, fertilization, and other factors. The microclimates were similar under nets, with slightly lower values of temperature and air humidity than in the open air.

The average air temperature (at July 15) below different color-shade nets was between 0.9 °C (pearl) and 3.0 °C (black) lower in comparison with air temperature at open field (control) (figure 1). Advantages of color-shade net are reflected in temperature control: improves productivity by moderating extremes of
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Temperatures. Air movement is restricted, thus reducing wind damage to the crop and evaporation of soil moisture. Air beneath the shade cloth stays humid which is of further benefit to the plant. Wind speed inside the screenhouse was reduced by more than 50% (data not show).

### Table 1. Solar radiation and Photosynthetically Active Radiation of sunny day at noon - July

<table>
<thead>
<tr>
<th>Color Nets</th>
<th>Solar radiation (W·m⁻²)</th>
<th>Photosynthetically Active Radiation (PAR) μmol·m⁻²·s⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Plastichouse + color nets</td>
<td>Only color nets</td>
</tr>
<tr>
<td></td>
<td>Relative shading</td>
<td>Relative shading</td>
</tr>
<tr>
<td>Red</td>
<td>40% 50%</td>
<td>40% 50%</td>
</tr>
<tr>
<td></td>
<td>595</td>
<td>586</td>
</tr>
<tr>
<td>Black</td>
<td>412</td>
<td>414</td>
</tr>
<tr>
<td>White</td>
<td>555</td>
<td>492</td>
</tr>
<tr>
<td>Blue</td>
<td>498</td>
<td>447</td>
</tr>
<tr>
<td>Control Plastichouse</td>
<td>857</td>
<td>Open field 942</td>
</tr>
</tbody>
</table>

Results (table 1) show that net radiation depending of color nets and intensity of shadow. Solar radiation was lower in the plastic house (857 W·m⁻²) in relation to radiation in the open field (942 W·m⁻²). Compared with the control, solar radiation was significantly reduced by the 50% shadow intensity in relation to that of 40%. The greatest decrease in radiation intensity was recorded below black net with 50% shade (515 W·m⁻²). It seems that while the solar radiation in the greenhouse without shading reached very high level during the midday, solar radiation in shaded greenhouse (with 50% shading) did not exceed 650 W·m⁻². From table 1 we can see that incoming solar radiation between the control greenhouse and the greenhouse with the highest shading intensity (50%) was 410 W·m⁻² and 270 W·m⁻² for black and red color-nets, respectively. Our data shows that during a sunny day in July (with solar radiation at 950 W·m⁻²) the reduction did not exceed 1 °C in greenhouse with moderate shade so, air temperature increased for 1 °C with every solar radiation increasing by 100 W·m⁻². The net radiation is strongly correlated to the incoming solar radiation, in analogy to what is known to occur over open ground. Under high solar radiation conditions (in South Serbia at July and August) value of photosynthetic photon flux density (PPFD) is about 1600 μmol·m⁻²·s⁻¹, so unshaded plants were exposed to high heat stress throughout the growing season. Value for PPFD varied between 1593 μmol m⁻²·s⁻¹ on sunny days and 700 to 920 μmol·m⁻²·s⁻¹ when it was cloudy. Shade was not uniform in that there were patches of light which changes during the course of the day and fell on different part of the plants. It was possible to find horizontal differences in PPFD greater than 500 μmol·m⁻²·s⁻¹ at a given time (table 1). The solar radiation registered on sunny days resulted in high PAR values (maximum 1600 to 2000 μmol-m⁻²-s⁻¹), which are common in southern Europe arid conditions. On cloudy days (complete clouds cover), the maximum values ranged from 800 to 900 μmol·m⁻²·s⁻¹. In both cases, the registered values were twice as great as those for northern Europe (Belgium, Germany, etc.) and for this reason radiation disability is not a limitation even when black net is used (maximum PAR values around 1200 μmol m⁻² s⁻¹), Iglesias and Alegre (2006).

Plants grown under black color-nets with 40% shadow had higher yield for 10.5% than control plants grown without nets. It was founded that red and pearl shade nets significantly increased the total yield (43.5% and 49.5%) which was associated with both higher productivity (number of fruits produced per plant) and larger fruits (data not show). Pepper under 50% shadow achieved similar fruit yield in comparison with yield

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**Figure 2. Influence of color shade nets integrated with greenhouse on pepper yield**

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obtained from 40% color shade nets, except under black shade net where achieved yield was lower than control. The relative difference between the colored 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 colored shade nets were higher by 113 to 131%, relative to the equivalent black shade net. The higher 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 with 40% shading level and then decreased with increased shading level (50%). Reduced total and marketable yield of un-shaded plants was probably caused with high heat stress. Moderate shading (about 40%) of bell pepper may be an option to reduce heat stress conditions and extend the spring-summer season toward September.

**Conclusion**

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.

**References**


