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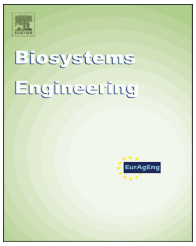

Research Paper

Effects of cover optical properties on screenhouse radiative environment and sweet pepper productivity

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The effects of cover optical properties on screenhouse radiative environment and sweet pepper productivity were investigated in a Mediterranean climate (Eastern Greece) under three covering materials (i) a pearl insect-proof screen (IP-78), (ii) a white insect proof screen (IP-59) and (iii) a green shade-screen (GS-62) with values of the transmittance to photosynthetically active radiation (τ_{PAR}) of 78%, 59% and 62%, respectively. All screens induced impoverishment in the blue wavelength band (B, 400–500 nm) and enrichment in near-infrared broadband (NIR, 700–1100 nm) with respect to photosynthetically active radiation (PAR) (400–700 nm), and modified photomorphogenetic parameters such as the ratio R:FR (Red:Far-Red). From a 2-year agronomic survey, it was found that the lowest performance in terms of crop productivity was observed in the open field, and the highest under the IP-78 screenhouse. At final harvest, aboveground dry biomass and total yield of screenhouse crops were linearly and positively correlated with τ_{PAR}, while plant height was negatively correlated with the ratio R:FR. The results suggested that (i) the more diffuse radiation regime prevailing under screenhouse is likely to be at the root of the higher crop performances observed under the screenhouses and (ii) τ_{PAR} and R:FR are likely to act synergistically in light capture. We conclude that both changes in transmittance and light quality must be accounted for when analysing productivity and yield regulation of screenhouse-grown crops. From a practical point of view, a shading factor no higher than 20% is recommended for sweet pepper cropping under Mediterranean conditions similar to those of this study.

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1. Introduction

Screenhouses, also called net-houses, are becoming popular among growers in arid and semiarid regions like the Mediterranean area, due to the environmental, economic and agronomic benefits they offer (Castellano et al., 2008). Insect proof screenhouses are environmental friendly as they reduce the amount of chemical inputs in pesticides and their associated costs, health risks for workers and potential environmental pollution (Möller, Tanny, Li, & Cohen, 2004). Economically, screenhouses have lower costs than conventional greenhouses (Möller & Assouline, 2007). The reduction of solar radiation due to net-covering may alleviate stress conditions that induced limitations to physiological fluxes (Stanhill & Cohen, 2001) that are a major constraint in the productivity and quality of greenhouse-grown crops. The positive impact of a net-covering on plant behaviour can be mostly explained by the more favourable microclimate under a screenhouse than outdoors. Screens modify in a positive way several microclimatic variables that drive plant physiological and morphological processes, i.e. incident light, air and soil temperature, air humidity and air speed, among the most relevant. Net-covering increased the relative fraction of diffuse radiation that positively affected the amount of radiation absorbed by crops (Goudriaan, 1977), the photosynthetic rate (Monteith & Unsworth, 1990; Spitters, 1986), crop radiation use efficiency (Cockshull, Graves, & Cave, 1992), crop yield (Healey, Rickert, Hammer, & Bange, 1998) and the spatial distribution inside the greenhouse of both solar radiation (Dayan, Enoch, Fuchs, & Zipori, 1986) and yield (Adams, Valdes, Hamer, & Bailey, 2000). Several studies in semiarid areas have demonstrated that crops grown under nets experience a notable increase in production (Abdel-Mawgoud, El-Abd, Singer, Abou-Hadid, & Hsiao, 1996; El-Gizawy, Abdallah, Gomaa, & Mohamed, 1993; Kitta, Katsoulas, & Savvas, 2012; Kittas, Katsoulas, Rigakis, Bartzanas, & Kitta, 2012; Leonardi, Baille, & Guichard, 2000) and/or in quality (Rylski, 1986; Whaley-Emmons & Scott, 1997) with respect to open-field crops.

Net-covering has a positive effect on plant physiology by preventing a down-regulation of photosynthesis during periods of high radiation (Kato, Hikosaka, Hirotsu, Makino, & Hirose, 2003; Medina, Souza, Machado, Ribeiro, & Silva, 2002). It has been observed that the midday depression of photosynthesis under harsh environmental conditions along with the reduction of transpiration rate can be compensated by higher values of stomatal conductance induced by net-screens (Raveh, Cohen, Raz, Grava, & Goldschmidt, 2003). However, this behaviour has not been observed in some species (Barradas, Nicolás, Torrecillas, & Alarcón, 2005).

As counterpart, nets reduce the amount of light during periods of low radiation, therefore limiting the potential for plant light capture and biomass production. There is therefore a compromise to find between the requirements of protecting the plants from excessive radiation load and high temperature, and the objective of maximising light capture and standing biomass of the plant canopy. This compromise is not straightforward to find. Manipulation of light environment by artificial shading requires the knowledge of (i) the characteristics and parameters of the modified light regime, on both the quantitative and qualitative aspects and (ii) the response of the crop to the modified regime. Some previous studies have dealt with the quality of screenhouse light environment (Castellano et al., 2008; Schettini, De Salvador, Scarascia Mugnozza, & Vox, 2012; Schettini & Vox, 2012; Shahak, 2008), but most studies on the agronomic impact of nets consider only the quantitative aspects, that is, the amount of light reduction due to the nets. The parameter that is currently used by manufacturers to characterise the impact on light is the shading factor (SF, %), which corresponds to the relative amount of radiation that is absorbed and reflected in the visible range (380–760 nm) of solar radiation (Castellano et al., 2008), or in the photosynthetically active radiation (PAR: 400–700 nm). As such, SF represents a quantitative estimate of the light loss due to the net, but does not inform on the qualitative (spectral) changes.

This work aims to provide more insight into the modification of the light environment under screenhouses and its impact on crop (sweet pepper) productivity: The main objective is to characterise and disentangle the effects of changes in light quantity and light quality on the crop performances through (i) the *in situ* characterisation and comparative analysis of the light environment under three different screen materials, and (ii) the evaluation of their effects on crop aboveground biomass and fruit yield. A specific objective was to investigate whether a general relationship may stand that relates final agronomic attributes (biomass and yield) to some specific screenhouse-radiation parameters.

2. Materials and methods

2.1. Screenhouses

The experiments were performed in three experimental flat roof screenhouses, N–S oriented (36° declination clockwise from North), located at the University of Thessaly near Volos (Velestino: Latitude 39° 22′, longitude 22° 44′, altitude 85 m), on the continental area of Eastern Greece. The geometrical characteristics of the screenhouses were as follows: length 20 m, width 10 m and height 3.2 m. The distance between two adjacent screenhouses was 8 m.

Three different screens were tested. Two were insect-proof (IP) screens (Fig. 1a) manufactured by Meteor Ltd., Israel: (1) a pearl 50 mesh (20/10) AntiVirus™ screen with a mean PAR (400–700 nm) transmittance of 78%, that is, a PAR-shading factor of 22% (hereafter, IP-78); and (2) a white 50 mesh Bio-Net™ (BN) with a mean PAR transmission of 59% (hereafter IP-59). The third one (Fig. 1b) was a green shade screen (Thrace Plastics C S.A. Xanthi, Greece) with a mean PAR transmission of 62% (hereafter GS-62). The insect proof net has a regular mesh netting of 0.27 mm × 0.27 mm, while the green shading net, due to its different knitting (Fig. 1b), presents meshes that are irregular in size and arrangement, with dimensions varying in the range 0.5–3.0 mm.

2.2. Cropping techniques

2.2.1. Crops

Sweet pepper plants (*Capsicum annuum* L., cv. Dolmi) were transplanted on May 31 and May 7 in 2011 and 2012,