45. SIMPOZIJ AKTUALNI ZADACI MEHANIZACIJE POLJOPRIVREDE

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MICRO-CLIMATIC EFFECT OF SHADING PLASTIC NETS FOR CROP PROTECTION IN MEDITERRANEAN AREAS

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SUMMARY

Mediterranean areas are characterized by hot summers that can determine bad environmental conditions for the growth of vegetable crops cultivated inside greenhouse. In Southern Italy, the traditional technique often employed by farmers during summer to reduce sun radiation and excessive internal air temperature is the whitening of the external side of the greenhouse plastic film through painting it with liquid calcium carbonate. More recently, the use of plastic shading nets is progressively affirming, thanks to a cheaper price and improved photo-selective properties, as a way to more effectively control the micro-climatic conditions inside closed greenhouse and tunnel. Thanks to a specific formulation of their chemical and physical properties, plastic nets may indeed combine the shade effect with some specific features useful for creating more favourable microclimatic conditions for the crop growth.

With the aim to analyze the efficacy of different greenhouse shading techniques, an experimental trial was carried out by comparing two commercial plastic nets characterized by different shade effects, respectively equal to 60 % and 36%. These two plastic nets were tested in laboratory, where their radiometrical characteristics were determined. The same plastic nets were then installed on two different small-scale tunnels located in Southern Italy, in which inside air and relative humidity were measured during some late spring days. The results obtained through these experimental trails enabled to start a comparative analysis of the performances of the two tested shading nets, highlighting the role that a correct selection of the most suitable net may play on the final results in terms of crop protection from high temperatures and sunburns.

Key words: plastic nets, crop shading, radiometric characteristics, micro-climatic effect.

INTRODUCTION

Excessive levels of solar radiation may determine negative effects on the crop growth. Sunlight can affect indeed more than the opening and closing of plant stomata. While some plants have specialized proteins that protect them from sunburn, others do not, and intense solar radiation can damage their leaves. Plants that are not adapted to full or intense sunlight can develop heat stress. Many plants are susceptible to leaf scorch, where parts of the plant die due to excessive water loss through transpiration. In addition to slowing or halting photosynthesis, heat stress and leaf scorch can make plants more susceptible to disease or insect infestations. Most of these negative effects may be avoided, mostly in the case of crop protection under greenhouse, when some suitable shading devices are properly employed (Castronuovo et al., 2015; López-Marín et al., 2012; Statuto et al., 2013).

In order to control hot indoor air temperate, one of the most common traditional solution utilized by growers in Southern Europe is the shading of the greenhouse against excessive solar radiation through the application of calcium hydroxide (*i.e.*, slaked lime) or other chemicals on the cover of the greenhouse (so-called, *whitening*) to create some shade and then limit the raising of the air temperature (Gázqueza et al., 2012).

More recently, the use of plastic shading nets is progressively affirming, thanks to a cheaper price and improved photo-selective properties, as a way to more effectively control the late spring and summer micro-climatic conditions inside close greenhouse and tunnel (Picuno et al., 2008; Kitta et al., 2012). Plastic nets are usually characterized by a shading factor, ranging from 10% to 90%, which represents the capacity of the net to reduce the incoming solar radiation, related to the average value of the transmissivity of the net in the solar wavelength band from 380 nm to 760 nm (Schettini et al., 2012).

A plastic net performs indirect effects as well, when it is employed to cover close greenhouse and tunnel. Due to its influence on the values of the main microclimatic parameters (temperature, relative humidity, carbon dioxide concentration, solar radiation, *etc.*), it could play, if used as standalone cover or even in synergy with a cladding plastic film, a fundamental role on creating more favourable microclimatic conditions during the crop growth (Picuno & Abdel-Ghany, 2016). Thanks to a specific formulation of their chemical and physical properties, plastic nets may indeed combine the shade effect with some specific features useful for creating suitable conditions for the crop growth and to guarantee healthy conditions for workers. Each plastic net modifies the solar radiation that arrives on the crop, by reducing the light flow and varying the available radiant spectrum. Apart from the net structure, the spectrum of the transmittance is also influenced by the diameter of the thread, color and thickness of the net, and the radiometric properties of absorbance, transmittance and reflectance of the plastic material (Sica & Picuno, 2008).

Different shading strategies using plastic nets were recently developed by some Authors. Abdel-Ghany et al. (2015) evaluated the effect of different shading configurations on the solar and thermal radiation in a greenhouse. The results showed that external roof-shading is desirable, as it reduced the generated thermal radiation in the greenhouse by 21% and 15% during the day and night time, respectively and reduced the greenhouse air temperature during the day. The internal shading (roof and side walls) is undesirable, since it drastically increased the generated thermal radiation in the greenhouse by 147% and strongly increased the greenhouse air temperature during the day. Shading the side-walls is not recommended because it significantly reduces the transmitted solar radiation in the morning and afternoon (when the outside irradiance is low) and is useless at around noon when the outside irradiance is extremely high.

The use of coloured plastic nets was examined by some researchers, with the aim to partially limit the incoming solar radiation so as to define optimal condition for the crop growth. With this aim, Schettini et al. (2012) investigated the influence of different coloured nets on peach trees. The nets positively influenced the fruit characteristics, such as size, colour and sugar content, in comparison to open-field. The higher growth observed under some red-coloured film can be attributed to its capacity to increase the level of radiation emitted in the red-wavelength range, where photosystem absorption by trees is optimal. Such results are consistent with the results obtained using coloured nets as covering material for ornamental plants (Schettini et al., 2011).

The geometry of a net-house may play also a considerable role in the diffusion of radiation under a shading net, since the transmitted radiation may not fulfill the crop growth requirements. To approach this problem, Abdel-Ghany et al. (2016) have designed and realized two innovative types of net-house models (polygon and curved-arch net-houses), each one of them having seven surfaces made up of different net types. The spectral radiative properties of 32 nets were examined and three nets were selected to cover the surfaces of each model. The results showed that the PAR and microclimate in the net-houses and in a cooled greenhouse used for comparison were similar, but the net-house reduced water consumption and electric energy consumption both in summer and in winter.

Plastic covers plays a critical role not only towards the internal environment, influencing the crop growth, but also towards the external surrounding landscape, strongly influencing the visual aspect of the rural land (Statuto et al., 2016; Tortora et al., 2015). From this point of view, a suitable landscape planning approach appears absolutely necessary, in order to consider in a holistic way all aspects connected to the use of plastic nets in agricultural application (Statuto et al., 2015).

Despite their widespread use, however, neither growers nor net producers have clear ideas about the relationship between the net typology optimization for a specific application and the technical characteristics of the net. The choice often depends on empirical or economic criteria, not on scientific considerations (Castellano et al., 2008; Shahak, 2008).

In this paper, an experimental trial was carried out by comparing two commercial plastic nets characterized by different shading effects, so as to compare their effect on the internal micro-climate of a greenhouse, depending on their different radiometrical properties.

MATERIALS AND METHODS

Two plastic nets with different shading effect - respectively equal to 60% and 36% (fig. 1) - were analyzed in in the Laboratory of Material Tests of the SAFE School of the University of Basilicata (Italy), where their spectro-radiometrical characteristics in the UV-VIS-NIR wavelength were determined through a Jasco V-570 spectro-radiometer.

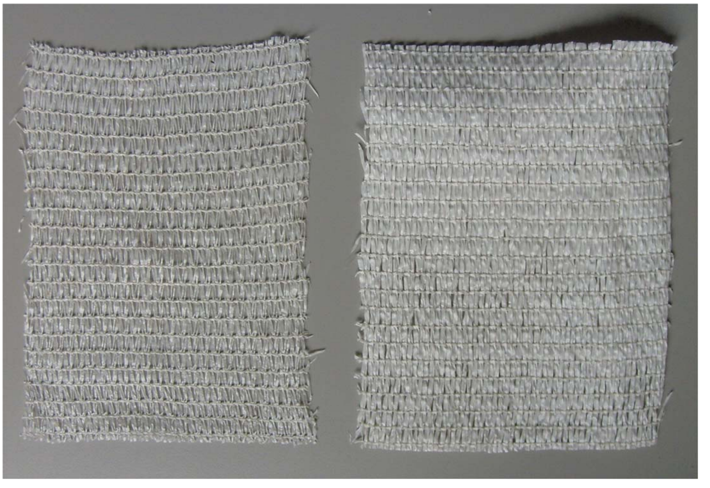

Figure 1. The two tested nets having different shading effect (36% - left; 60% - right).

In order to evaluate the shading effect of these two different plastic nets on the internal environment of the greenhouse, as well as their performance on the general thermodynamic inside conditions, two small tunnels (fig. 2) reproduced in scale were realized in an experimental area located in Pontecagnano (Southern Italy).

Figure 2. Trial small-scale tunnel covered with a 36% (left) and 60% (right) shading net.

These experimental small-scale tunnels, both covered with an EVA plastic film, were left without any cultivation. Inside air temperature and relative humidity were recorded during spring 2016 by CS500-L probes (modified version of Vaisala's 50Y Humitter, Campbell Scientific Inc, Utah, USA). The relevant data were recorded by a CR10X data-logger (Campbell Scientific Inc, Utah, USA).

RESULTS AND DISCUSSION

The results of the spectro-radiometrical analysis over the tested materials are reported in Tables 1 and 2, in terms of the main characteristics measured in different significant ranges within the solar spectrum.

In the case of the white plastic net with 36% shading effect, its level of transmittance (over 60% - Table 2) joined to its significant reflectance - that generates mutual progressive reflections with the greenhouse cladding sheet inside the greenhouse - confirms once more that shading nets should be employed only outside the greenhouse (Abdel-Ghany et al., 2016), in order to fully express their potential of shading the incoming solar radiation.

Table 1. Results of the spectro-radiometrical analysis on the 60% shading net.

Range	Wavelength nm	Transmittance %	Reflectance %	Absorptivity %	Shading effect %
Solar	200 - 2500	45.19	27.82	26.99	54.81
PAR	400 - 700	28.90	47.46	23.64	71.10
Solar IR	700 - 2500	52.15	26.75	21.10	47.85
UV	280 - 380	6.75	6.66	86.59	93.25
UVA	320 - 380	6.78	6.91	86.31	93.22
UVB	280 - 320	6.71	6.25	87.04	93.29

Table 2. Results of the spectro-radiometrical analysis on the 36% shading net.

Range	Wavelength nm	Transmittance %	Reflectance %	Absorptivity %	Shading effect %
Solar	200 - 2500	62.63	18.06	19.31	37.37
PAR	400 - 700	47.82	28.08	24.72	52.18
Solar IR	700 - 2500	68.91	17.66	13.43	37.82
UV	280 - 380	28.43	5.80	65.77	71.57
UVA	320 - 380	28.73	5.99	65.28	71.27
UVB	280 - 320	27.94	5.50	66.56	72.06

In figures 3 and 4 the diagrams of solar transmittance and reflectance of the two tested nets along the whole UV-VIS-NIR wavelength [200 – 2.500 nm] are reported.

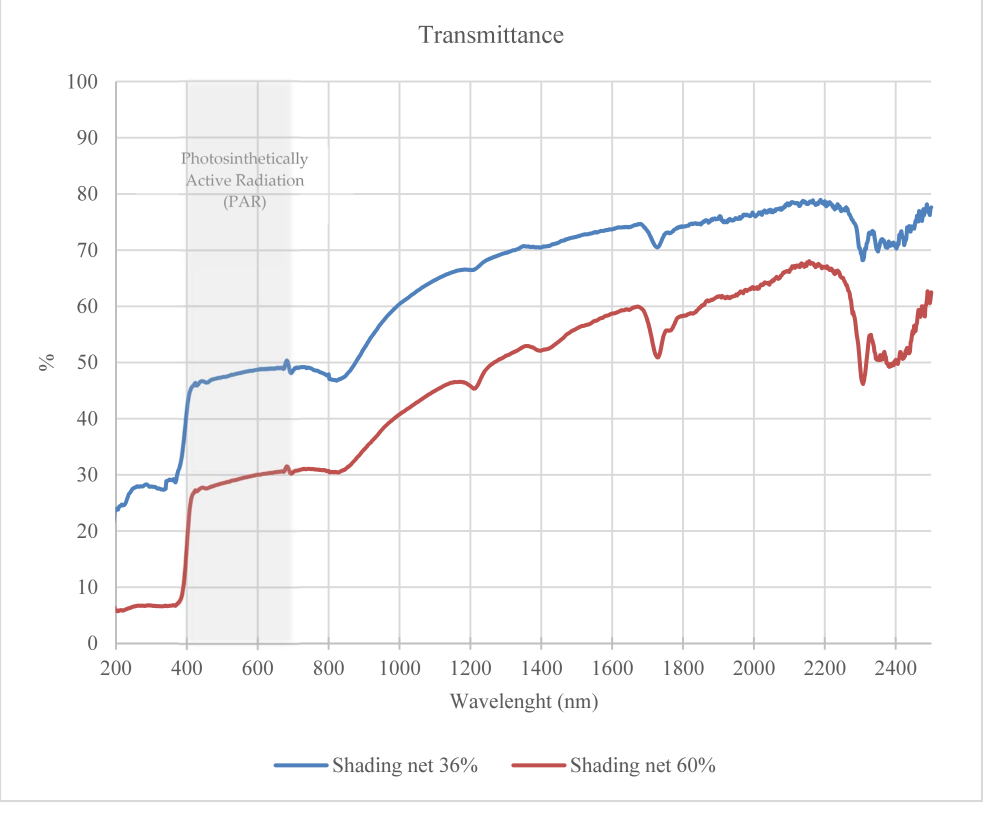

Figure 3. Transmittance of the two nets in the UV-VIS-NIR wavelength.

From the results of the spectro-radiometric analysis performed in the solar range, it would be deduced that the shading effect declared by the plastic net producer seems quite close to the value that was detected (i.e., the complement to 1 of the transmissivity coefficient). This value, that could be evaluated into the different wavelength ranges (i.e., UVB, UVA, PAR, etc.) may give further information about the effective capability of the net to protect the crop from excessive solar radiation. It seems particularly interesting the value that the two tested shading nets present in the UVA and UVB ranges, in which the shading effect is very high - around 50-90% higher than the nominal shading effect of each net - so effectively protecting crops from possible sunburn and scorch.

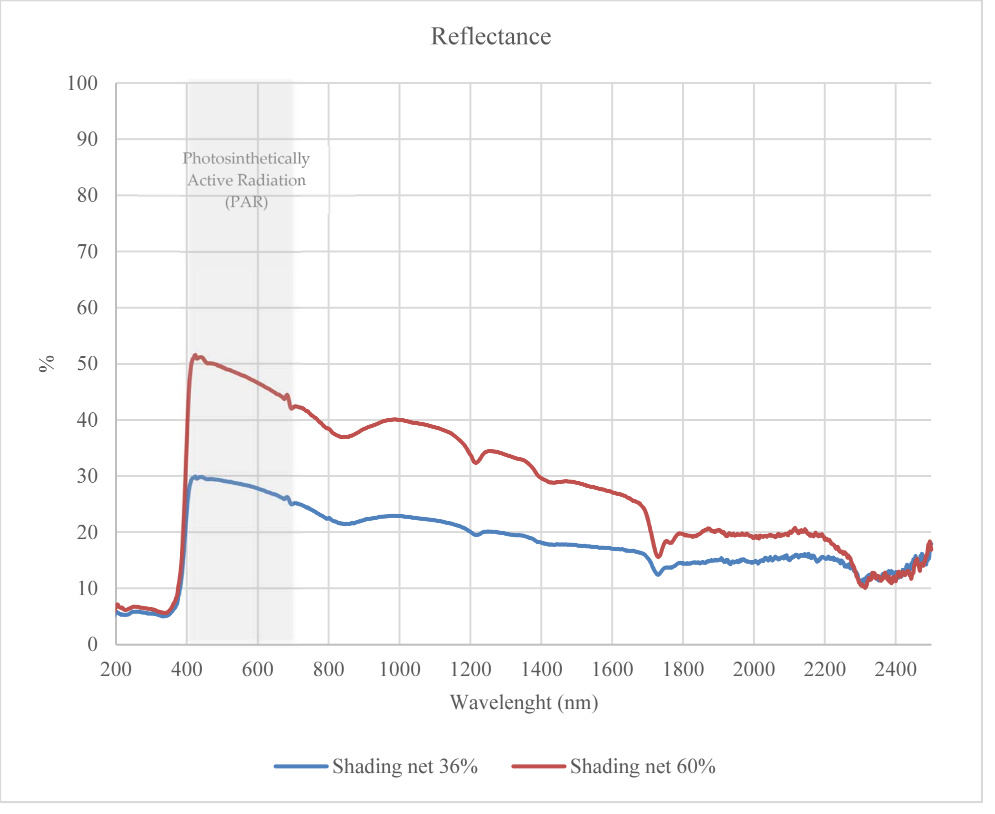

Figure 4. Reflectance of the two nets in the UV-VIS-NIR wavelength.

The difference between the shading factor of the two plastic nets did not seem to have significant influence on the thermodynamic behaviour within the two different small-scale tunnels during the testing period. As it is reported in figure 5, temperatures within these close small structures were almost the same along three trial days of late spring (16-18 June 2016).

A different behaviour was detected, however, in the case of relative humidity, that in the case of the small-scale tunnel covered with the 60% shading net, was higher during daytime. The values of the relative humidity under the two scale-tunnels covered with the two different shading nets were very similar, conversely, during the night (fig. 6). The difference in the level of relative humidity, at the same temperature, could be connected to different levels of enthalpy that the air inside the scale-tunnel covered with different shading nets is probably able to capture during daytime.

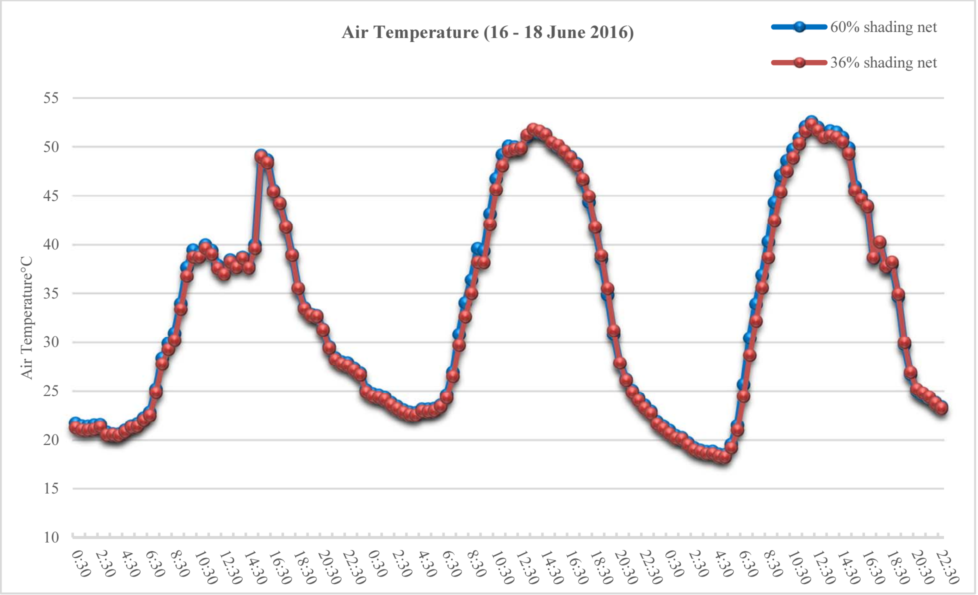

Figure 5. Air temperature detected in the trial greenhouses.

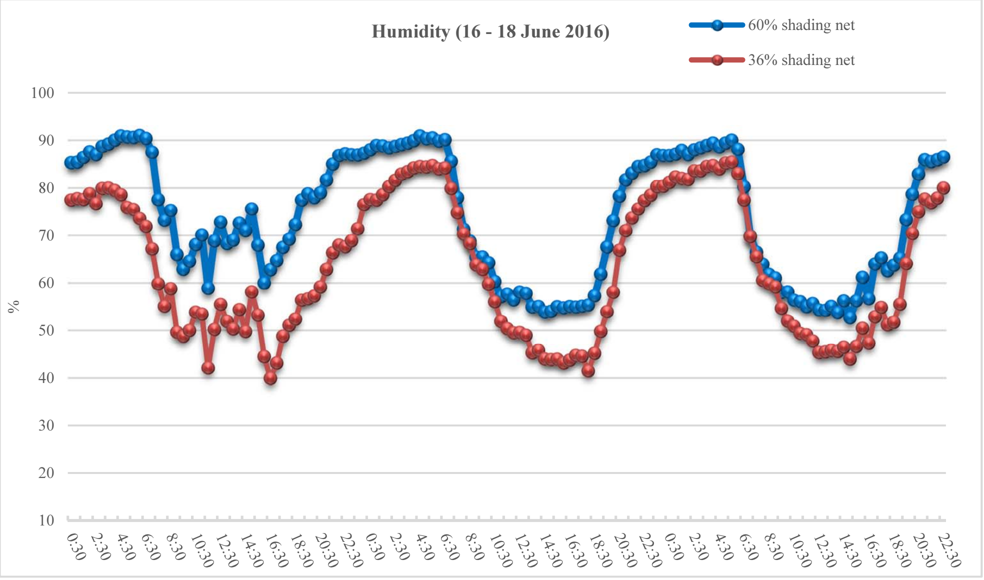

Figure 6. Relative humidity detected in the trial greenhouses.

From the results of the present research, it would be concluded that an accurate evaluation of shading effects of a plastic net for different wavelength ranges (e.g., UVA, UVB, PAR, etc.) may give useful hints for the evaluation of the its technical performance, in terms of real efficacy in protecting the crops from excessive sun radiation and possible consequent damages to the crop, *e.g.*, sunburn, scorch, *etc.*

Since, at present, only the global shading factor is usually reported by the industries as a technical information on the leaflet that accompanies the material, from the analysis of the two different shading nets it appears very important that nets would be accompanied by technical information about the shading effect along the whole solar range. A specific information about the shading factor in the principal wavelength ranges - mostly in the Photosynthetically Active Radiation and UVA/UVB bands - seems very meaningful, taking into account the different effects on the crop as well as on the protected environment.

CONCLUSIONS

The progressive extensive use of agricultural plastic nets in protected agriculture that was recorded during the last years, thanks to their beneficial effects on the crop compared to a decreasing price, sets fundamental issues concerning the need of a suitable design phase of their technical characteristics (polymer, dimensions, thread properties, *etc.*) that play a considerable role on the greenhouse internal microclimate. Nets are currently often employed as covering elements without any proper design, only basing on the knowledge of some technical characteristics. The lack of a specific Standard for determining the spectro-radiometrical characteristics of agricultural nets - with the consequence that laboratory test may be conducted on the basis of Standards applicable to different materials (*e.g.* glass, or transparent film) - still asks further investigations aimed to support an improvement of the technical properties of the plastic nets, in order to make them more finalized to the biological necessities of the crop.

From the present research, it was clear that transmittance coefficients, detailed at the different wavelength ranges playing a role in the crop growth, appear as an indispensable tool, able to classify the covering material in relation to the micro-climatic parameters of the protected environment, the quality of the radiation, the temperature and the air flow. More research is anyway needed to characterize different types of nets for specific purposes, as well as to quantify the effects of the shading effect on the greenhouse internal climate and crop response. Also the duration of a plastic net, depending on the site and condition of application still needs further investigations.

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