INFLUENCE OF MICROCLIMATIC CONDITIONS ON VEGETATIVE GROWTH AND FRUIT QUALITY OF A PEACH ORCHARD (*PRUNUS PERSICA* (L.) BATSCH) GROWN UNDER COLORED SHADING NET (CHROMATINET® RED 40%)

INFLUENZA DELLE CONDIZIONI MICROCLIMATICHE SULLA CRESCITA VEGETATIVA E SULLA QUALITÀ DEI FRUTTI DI UN PESCHETO (PRUNUS PERSICA (L.) BATSCH) ALLEVATO SOTTO RETE OMBREGGIANTE COLORATA (CHROMATINET® RED 40%)

Liliana Gaeta[1*], Maria Roberta Bruno[1], Pasquale Campi[1], Onofrio Cappelluti[1], Gabriele De Carolis[1], Anna Francesca Modugno[1], Gianfranco Rana[1], Rossana Monica Ferrara[1]

[1]Research Centre for Agriculture and Environment, CREA-Council for Agricultural Research and Economics, Bari, 70125, Italy
* liliana.gaeta@crea.gov.it

Abstract
The strategies to mitigate climate change such as the use of shading covers in agriculture are increasingly important. During 2021, in an experimental peach orchard of CREA-AA located in South Italy, the effects of a red shading net (ChromatiNet® Red 40%) on modulation of microclima and plant performance were evaluated. Climatic variables, shoot growth, fruit weight, fruit size, overcolor, flesh firmness and soluble solids content (SSC) were measured. The microclimatic conditions under covered (C) showed little variation than uncovered (NC). The red shading net seems to stimulate vegetative growth rate on pech tree. In general, fruit quality seems to be better under C than NC, except for SSC soluble solids content (14,8°Brix for NC vs 13,7°Brix for C). Further investigations are needed for confirming these preliminary data to better understand the role of red photoselective nets on physiology of peach trees under semi-arid climate conditions.

Parole chiave italiano
Cambiamento climatico, temperatura, velocità del vento, crescita germogli, contenuto in solidi solubili.
Keywords english
Climate change, temperature, wind speed, shoots growth, soluble solids content.

Introduction
Due to the climatic changes of the last decades, which have led to more extreme weather conditions, it has become necessary to use techniques that protect the crops from abiotic stress without compromising quality and productivity. Different colored nets have been used with different effects on trees crops depending on the net color and specie.The photo-selective nets improved yields in apple (Shahak *et al.*, 2008; Ombódi *et al.*, 2015), fruit quality in kiwi and apple (Basile *et al.*, 2008; Lobos *et al.*, 2013; Corollaro *et al.*, 2015), and tree vigor in nectarine (Giaccone *et al.*, 2012; Bastias *et al.*, 2015). The aim of this study was to evaluate the effect of microclimatic changes due to red shading nets on shoot growth and fruit quality of peach trees.

Materials and Methods
The study was carried out during 2021, in the experimental field of CREA-AA located in Rutigliano-Bari South Italy (lat.: 40◦59′N, long.: 17◦01′E, alt.: 147 m asl) on peach orchard, cv "Calred" grafted on Missour. Trees were trained as slender spindle and spaced 4.0 x 2.5 m. The growing area is characterized by a typical Mediterranean climate (Losciale et al., 2020). On an area of 210 m^2 with 21 trees, ChromatiNet® Red 40% shading net (C, PolyEur Srl., Benevento, Italy) was applied and compared with the same area without a cover net (NC, fig. 1-2).

Fig.1 - Pescheto coperto con rete ombreggiante rossa (ChromatiNet® Red 40%)
Fig.1 - Peach tree under red shading net (ChromatiNet® Red 40%)

Two agrometeorological stations (Tecno.el Srl, Rome, Italy) (fig. 3) were located in the experimental site, below and outside the shading net. Precipitation (mm) with a rain

gauge, solar radiation (W/m^2) with a radiometer, temperature (°C) and relative humidity of air (%) with a thermo-hygrometer were recorded every 60 min. These last two parameters were utilized to calculate the vapor pressure deficit (VPD). Growing Degree Days (GDD) were computed from 6th May at harvest (16 September) considering the minimum and maximum temperature and 7 and 35 °C as threshold values for peach (McMaster and Wilhelm 1997; Souza *et al.*, 2019).

Fig.2 - Piante di pesco non coperte
Fig.2 - Peach trees uncovered

Fig.3 - Stazione meteorologica sotto rete ombreggiante
Fig.3 - Meteorological station under shading net

Four shoots (fig. 4) per tree (5 tree for treatment) were measured (cm) during the season in the following days of the year (DOY): 139, 152, 168, 187, 203, 217, 249 and the absolute growth rate (AGR, cm day^{-1}) was calculated.
At harvest (DOY 259), the fruit weight (g), fruit size (mm), flesh firmness (kg/0,5cm^2), total soluble solids content (°Brix) and fruit skin red overcolor (%) were measured on 18 fruits per treatment.

Fig.4 - Misurazione lunghezza germogli
Fig.4 - Shoot length measurement

The ANOVA was used to analyze the significant difference in the treatments. The statistical analyses were computed using the R statistical software environment (http://www.r-project.org).

Results and Discussion

The air temperature and VPD (fig. 5, 6, standard deviations not shown for clarity, values are the average of all available data), showed differences between the treatments during daytime hours with higher values in C than NC. Although the covered treatment was not completely enclosed, these results are in agreement with Pérez et al. (2006) and Stamps (1994) that observed during daytime higher temperatures under enclosed net (shade) houses than outside.

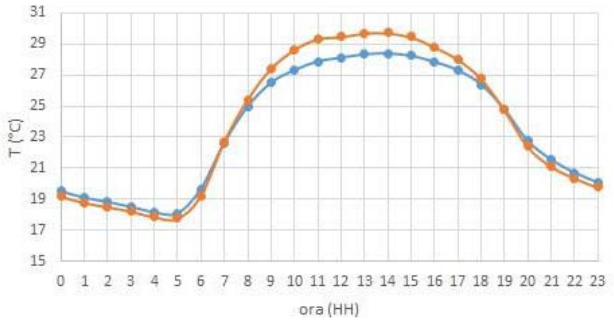

Fig.5 - Temperatura giornaliera calcolata come media oraria dell'intera stagione di crescita 2021 nel non coperto (NC-linea blu) e coperto (C_in-linea arancione)
Fig.5 - Daily temperature calculated as houly mean of the entire season 2021 in non covered (NC- blue line) and indoor (C-orange line)

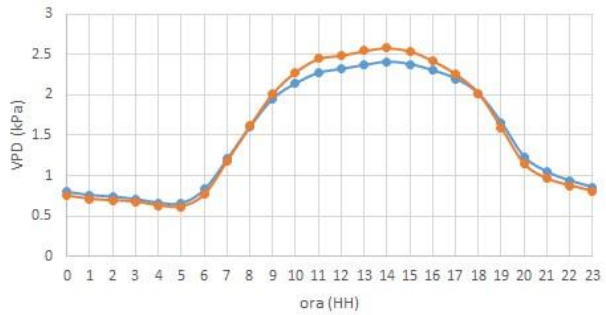

Fig.6 - Deficit di pressone di vapore (VPD) calcolato come media oraria dell'intera stagione di crescita 2021 nel non coperto (NC-linea blu) e coperto (C -linea arancio)
Fig.6 - Daily vapour pressure deficit (VPD) calculated as haurly mean of the entire season 2021 in non covered (NC-blue line) and indoor (C-orange line)

Significant differences were recorded for wind speed (fig. 7) in the two treatments. Under the net, wind speed was lower than outside, in accordance with Illic *et al.* (2017). According to Novello *et al.* (2013), covering nets can reduce wind speed by 80-85%.

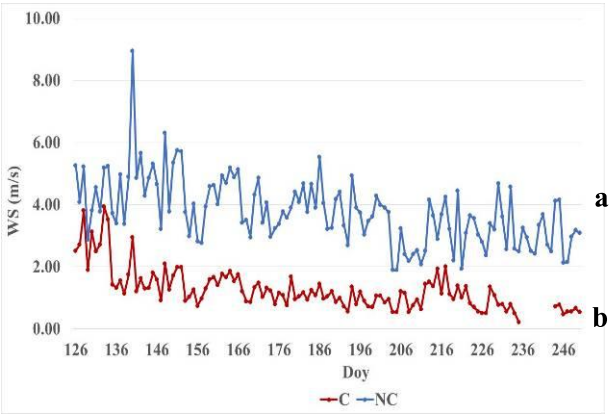

Fig.7 - Velocita del vento (WS) misurati nella stagione produttiva 2021, nel coperto (C) e nel non coperto (NC). Lettere diverse (a-b) indicano una differenza significativa (p-value <0.001)
Fig.7 - Wind speeds (WS) measured in the 2021 production season, in the covered (C) and uncovered (NC). Different letters (a-b) indicate a significant difference (p-value <0.001)

Global radiation under the net has an average value 25% lower than outside, while the GDD values under the cover were only 1% greater than outside (data not shown).
These differences in microclimatic conditions have impacts on the development of shoots (fig. 8 a, b) with higher length (+12%) and absolute relative growth in covered than non-covered treatment. In general, different studies showed a significant improvement on vegetative growth rate for trees growing under covering (Shahak *et al.*, 2016), witha higher vigour of foliage (leaf surface) in peach (Vuković *et al.*, 2016).

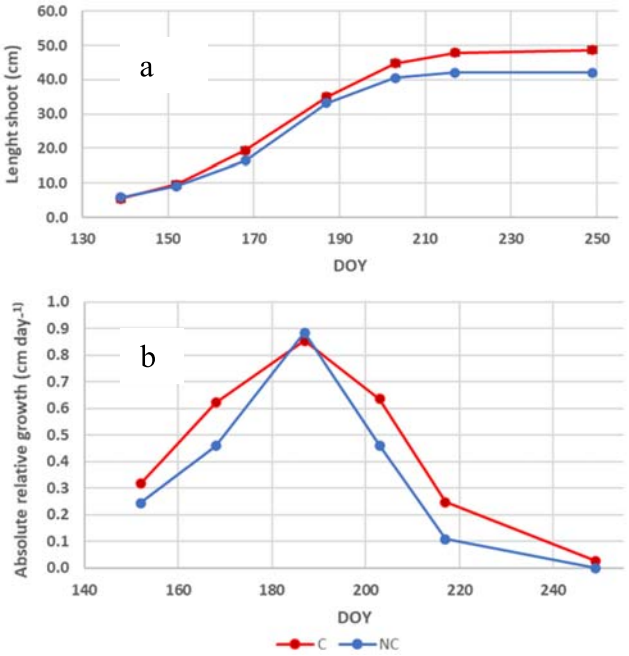

Fig.8 - a) Lunghezza dei germogli e b) tasso di crescita misurati nella stagione produttiva 2021, nel coperto (C) e nel non coperto (NC)
Fig.8 - b) Shoot length and absolute relative growth (AGR) measured in the 2021 production season, in the covered (C) and uncovered (NC)

Most of the ripening indexes used to identify the quality of the fruit were higher in covered than control, except to flesh firmness and sugar content.
The major average fruit weight (fig. 9) and fruit size (fig. 10) in C than NC is probably due to higher VPD values observed in covered than non-covered treatment (fig. 6); indeed, as reported by Morandi *et al.* (2010), VPD is considered the driven force for fruit growth.

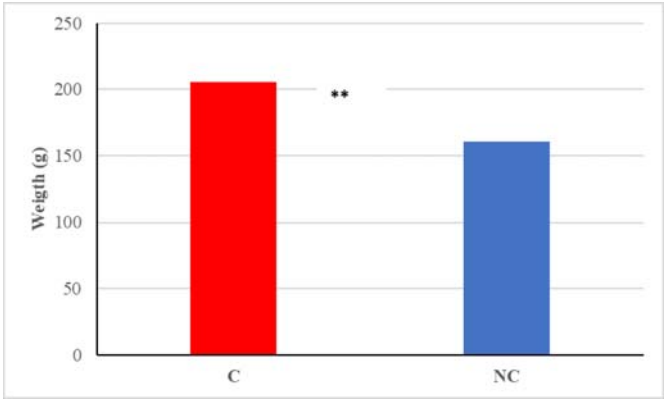

*Fig.9 - Peso medio dei frutti alla raccolta, nel coperto (C) e nel non coperto (NC). ** indicano una differenza significativa per p-value <0.01*
*Fig.9 - Mean fruit weight measured at harvest, in the covered (C) and uncovered (NC). ** indicate a significant difference for p-value <0.01*

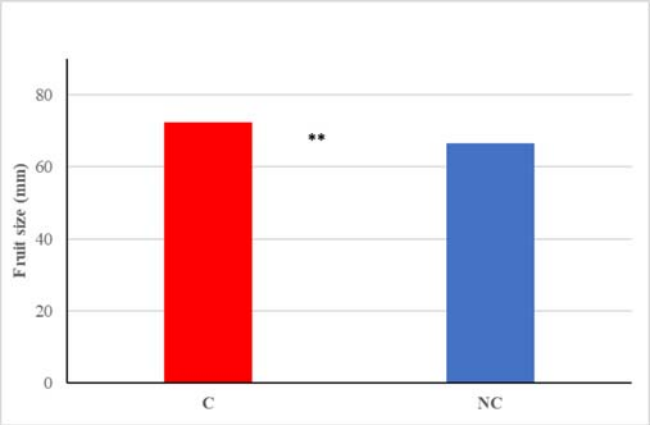

*Fig.10 - Calibro del frutto alla raccolta, nel coperto (C) e nel non coperto (NC). ** indicano una differenza significativa per p-value <0.01*
*Fig.10 - Fruit size at harvest, in covered (C) and uncovered (NC) ** indicate a significant difference for p-value <0.01*

The flesh firmness was lower in covered than control (fig. 11), in agreement with Vuković *et al.* (2016) that observed a fruit ripening acceleration in peach fruits grown under red net than no covered. However, our results are in contrast with other authors that observed a delay of harvest in peach fruit growing under red net with flesh firmness higher than uncoverd (Schettini *et al.*, 2009; Giaccone *et al.*, 2012).

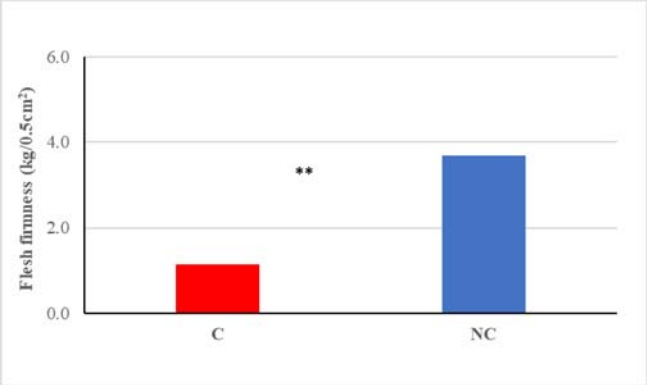

*Fig.11 - Consistenza della polpa alla raccolta, nel coperto (C) e nel non coperto (NC).). ** indicano una differenza significativa per p-value <0.01*
*Fig.11 - Flesh firmness at harvest, in covered (C) and uncovered (NC. ** indicate a significant difference for p-value <0.01*

The percentage of skin overcolor not showed differences between the treatments (fig. 12); Giaccone *et al.* (2012) observed similar results on nectarine grown under red photoselective anti-hail nets.

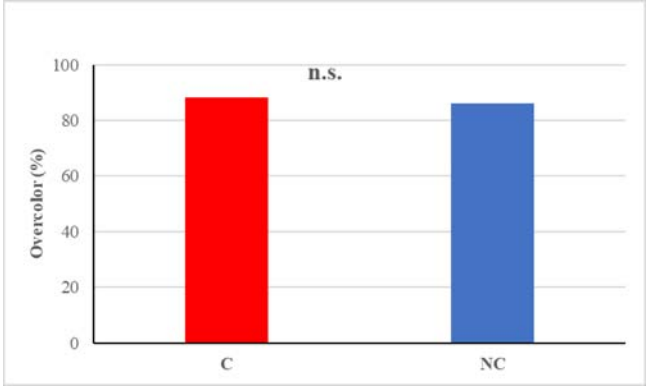

Fig.12 - Sovracolore frutti misurato alla raccolta, nel coperto (C) e nel non coperto (NC). n.s. indica nessuna differenza significativa
Fig.12 - Fruit overcolor measured at harvest, in the covered (C) and uncovered (NC). n.s. indicates no difference significant

The soluble solids content was significant different in the two treatments (fig. 13), with highest values in uncovered than covered, in agreement with Schettini *et al.* (2009). According to Grasso *et al.* (2022), cover nets can reduce the accumulation of carbohydrates, moreover, the quality parameters of fruits placed under nets show results related to the varietal characteristics of the fruits. However, the sugar content obtained in C abundantly exceeds the minimum value of 9°Brix below which negative judgment have been found by the consumer (Neri *et al.*, 2003).

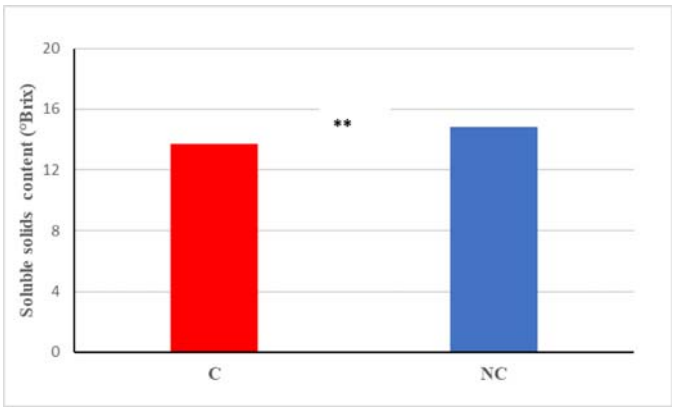

*Fig.13 - Contenuto zuccherino dei frutti alla raccolta nel coperto (C) e nel non coperto (NC). ** indicano una differenza significativa per p-value <0.01*
*Fig.13 - Soluble solids content of fruits at harvest in the covered (C) and uncovered (NC). ** indicate a significant difference for p-value <0.01*

Conclusions

The preliminary results obtained suggest that changing in microclimate variables under red photoselective nets affects shoot development and fruit quality. Probably, the better vigor of plant (length of shoot) grown under the shading net could improve the assimilation of the photosynthetates, favoring the formation of larger fruits compared to the control treatment, but with a slight disadvantage of the sugar content. However, the sugar content of the fruit was always higher than the minimum value considered by different authors as acceptable by consumers and exceeds the minimum value (8°Brix) permitted for marketing according to European provisions (Commission Delegated Regulation EU 2021/1890). Therefore, the redshading could be used to modulate the microclima and to improve the peach orchard performance, especially in semi-arid climate conditions like Apulia region.

However, future details are necessary to support the results and to better understand the role of red photoselective nets on physiology of peach trees in our climate conditions.

Acknowledgments

This study was carried out with a contribution of the following founfing project: "Water4AgriFood, Miglioramento delle produzioni agroalimentari mediterranee in condizioni di carenza di risorse idriche", PNR 2015–2020", Area Agrifood, funded by MIUR, PON ARS01_00825 "Ricerca e Innovazione" 2014–2020.

References

Basile, B., Romano, R., Giaccone, M. and Forlani, M., 2008. Intra-canopy variability of fruit quality in kiwifruit vines protected by anti-hail nets. *Acta Hort*. 801, 1445-1452.

Bastías, R. M., and Corelli-Grappadelli, L., 2012. Light quality management in fruit orchards: physiological and technological aspects. *Chilean Journal of Agricultural Research*, *72*(4), 574.

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. *The Journal of Horticultural Science and Biotechnology*, *90*(1), 99-108.

Giaccone, M., Forlani, M., Basile, B., 2012. Tree vigor, fruit yield and quality of nectarine trees grown under red photoselective antihail nets in Southern Italy. *Acta Hortic*., 962: 287-29.

Grasso, C., Forniti, R., Botondi, R., 2022. Post-Harvest Quality Evaluation of "Soreli" Kiwifruit at Two Ripening° Brix Values from Vineyards of Different Age Under Hail Nets. *Foods*, *11*(3), 431.

Lobos, G. A., Retamales, J. B., Hancock, J. F., Flore, J. A., Romero-Bravo, S., Del Pozo, A., 2013. Productivity and fruit quality of Vaccinium corymbosum cv. Elliott under photo-selective shading nets. *Scientia Horticulturae*, 153, 143-149.

Losciale, P., Gaeta, L., Manfrini, L., Tarricone, L., Campi, P., 2020. Orchard Floor Management Affects Tree Functionality, Productivity and Water Consumption of a Late Ripening Peach Orchard under Semi-Arid Conditions. *Applied Sciences*, 10(22), 8135.

McMaster, G. S., Wilhelm, W.W., 1997. Growing degree-days:one equation, two interpretations. *Agric. Meteorol.*, 87, 291–300.

Neri, F., Pratella, G.C., Brigati, S., 2003. Gli indici di maturazione per ottimizzare la qualità organolettica della frutta. *Frutticoltura*, 5, 20-29.

Novello, V., De Palma, L., 2013. Shade nets on table grapes. In *1er. Simposium Internacional de Vid*. AALPUM, 133-142.

Ombódi, A., Pék, Z., Szuvandzsiev, P., Tóthné Taskovics, Z., Kohazi-Kis, A., Kovacs, A., Ledóné Darázsi, H., Helyes, L., 2015. Effects of external coloured shade nets on sweet peppers cultivated in walk-in plastic tunnels. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *43* (2), 398-403.

Pérez, M., Plaza, B. M. Jime´nez, S., Lao, M. T., Barbero, J., Bosch., J. L., 2006. The radiation spectrum through ornamental net houses and its impact on the climate generated. *Acta Hort*. 719, 631–636.

Schettini, E., De Salvador, F. R., Scarascia Mugnozza, G., Vox, G., 2009. Evaluation of coloured nets in peach protected cultivation. In *International Symposium on High Technology for Greenhouse Systems: GreenSys, 893,* 235-242.

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 Hortic*. 772, 65–72.

Shahak, Y., Kong, Y., Ratner, K., 2016. The wonders of yellow netting. *Acta Hortic*., 1134, 327- 334.

Souza, F., Alves, E., Pio, R., Castro, E., Reighard, G.; Freire, A.I., Mayer, N.A., Pimentel, R., 2019. Influence of Temperature on the Development of Peach Fruit in a Subtropical Climate Region. *Agronomy*, 9 (20), 1-10.

Stamps, R.H. (1994). Evapotranspiration and nitrogen leaching during leatherleaf fern production in shadehouses. *St. Johns River Water ManagementDistrict*, Palatka, FL, 1-102.

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. *Agric. conspec. sci.* 81 (3), 181-185.