EFFETTO DELLA PACCIAMATURA SULL'EFFICIENZA DI USO DELL'ACQUA DI UN PESCHETO IN AMBIENTE MEDITERRANEO

EFFECTS OF MULCHING ON WATER USE EFFICIENCY OF PEACH ORCHARD UNDER MEDITERRANEAN CLIMATE

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Abstract

The study was carried out on 5-year-old peach trees cultivated at in southern Italy, under two mulching treatments: Black/White cover, Black Silver cover. Actual transpiration (T) along two growth seasons was measured by the sap flow thermal dissipation method (TDM) in selected plants for three treatments. Water use efficiency (WUE) and water productivity (WP) were calculated as ratio T/water supply (precipitation plus irrigation) and yield/T, respectively. Considerations on the effects of the mulching type on WUE and WP at different time scales, from hour to season, are deeply discussed. Here, moreover, we show how the microclimate of the soil environment, in terms of water content, changes in the different treatments. The WUE of mulching color treatments results higher than the control in both experimental seasons.

Parole chiave

Flusso di linfa, metodo della dissipazione del calore, produttività dell'acqua, traspirazione, teli pacciamanti

Keywords

Sap flow, Thermal dissipation method, water productivity, transpiration, mulching covers

Introduction

The coloured plastic mulches on soil surface are used for different aims, mainly for modifying the radiation budget and decreasing the soil water loss (Amare and Desta, 2021). Due to the effect of different colours on quality and quantity of light reflected by the mulches, impacts of coloured films on plant growth and yield of plants can be detected (Matsoukis and Gasparatos, 2015). Other effect of mulching regards the impact on soil temperature (e.g., white cools the soils) and weed and insect infestation.

The observed reduction of water availability imposes water saving in every production sector (UNEP/MAP-Plan Bleu, 2009), then, considering the improvement of water storage by mulching, the use of plastic mulches has become increasingly popular in orchards in recent years (Suo et al., 2019). Campi et al. (2020) demonstrated that mulching reduces evapotranspiration (ET) and improves fruit yield in peach orchards. However, to correctly evaluate the water use efficiency (WUE) of a crop, it is necessary to determine with high accuracy the crop water losses (Katerji et al., 2008), by measuring transpiration (T) at plant level. The most spread methods to determine T at single plant scale are the techniques based on the measurement of the sap flow density (Rana and Katerji, 2000). Moreover, further research it is necessary to determine how the mulching covers affect the partitioning of ET in T and evaporation (E), in the different ecosystems and for the different crops (Wang et al., 2015).

The main objective of this study is to preliminarily evaluate the effect of mulching on actual transpiration, focusing attention on the seasonal water use efficiency (WUE) and water productivity (WP) of a peach orchard where two types of commercial-coloured mulches were applied for two consecutive growing seasons.

Material and Methods

The trial was carried out for two years (2021, 2022) at the experimental farm of CREA-AA, located in Southern Italy (Rutigliano, Bari, 41° 01' N, 17° 01' E, altitude 147 m a.s.l). Monitoring was performed on a five-years old peach orchard (45 m x 60 m) of late ripening (cv. Redcall), grown in a traditional pot and grafted onto rootstock GF677, spaced 5.0 m × 5.0 m. The site is submitted to Mediterranean semi-arid climate (Campi et al., 2009). The soil features are described in Losciale et al. (2020).

The peach orchard was irrigated by a drip irrigation system with two drippers per tree and a flow rate of 16 L h^{-1} per dripper: 116.5 mm and 135.8 mm of water were by irrigation (I) during 2021 and 2022, respectively, sufficient to restore 100% of the crop evapotranspiration.

Two different plastic mulching (treatments) were applied (PolyEur srl, Benevento, Italy) at the beginning of the first vegetative season (14th April 2021) along the rows: C/902 Black White Orchard (hereafter "white", PAR diffusivity 75%, measured reflectance 38%; P1); C/820 Black Silver Orchard (hereafter "silver", PAR diffusivity 28%, measured reflectance 26%; P2). A bare soil strip about two-meter large was maintained between two longitudinal strips of mulching material. Treatments together with the no mulching - control were arranged under a randomized complete block design with three replicates.

The peach actual transpiration (T) was measured by the TDM method (Granier, 1987), in three plants per treatment, representative of the whole stand, selected by the trunk diameters frequency distribution. The FLGS-TDP Model XM1000 sap velocity system (DYNAMAX Inc, Houston TX 77099 USA) with CR1000X data logger (Campbell Scientific, Utah, USA) was used: The TDP30 sensor was installed approximately 0.60 m above the soil surface, 0.20 m above the plant graft union, at the north face and protected by reflecting material; data were acquired continuously and stored as average at 15 minutes intervals, then hourly data were calculated and stored. In this first preliminary study, following Wang et al. (2015) among others, we do not consider: (i) the TDM specific calibration; (ii) the corrections for both azimuthal and transversal gradients, and for the damages caused by the trunk wounds by the probes set up. The T was monitored only during the vegetative season, when the plants are photosynthetically: in this study the periods May - September are analysed.

Soil water content (θ) and soil temperature (Tsoil) were measured at -0.15, -0.3, and -0.45 m from the soil surface using capacitive probes (Sentek, Drill & Drop, Sentek Sensor Technologies, Australia) starting from 06th May 2021, installed on the same plants of T monitoring. Soil water availability was described through the relative extractable water (REW, unitless) calculated using the average soil water content across positions around the tree and soil layers as:

$$REW = \frac{\theta - \theta_{min}}{\theta_{max} - \theta_{min}} \quad (1)$$

where θ is the actual soil water content in the root zone, θ_{min} and θ_{max} are the minimum and maximum soil water content observed during the experiment, respectively.

At harvest (09 September 2021; 06 September 2022) tree productivity (kg tree^{-1}) was measured on the same plants used in measure of T. This data was used to determine the potential production per hectare (yield, t ha^{-1}).

Air temperature, relative humidity, precipitation and incident global radiation were continuously measured at 10 s interval by standard meteorological sensors on a reference meadow 350 m far from the experimental field and recorded at hourly frequency by an automatic weather station (Campbell Sci., USA). Crop WUE and WP (Fernández et al., 2020) were determined in the two growth seasons as:

$$WUE = \frac{T}{P+I} \quad (2)$$

$$WP = \frac{yield}{T} \quad (3)$$

Results and Discussion

Firstly, the dynamics of measured θ at daily scale (data not shown) revealed that the water supplied by precipitations has direct effect on all treatments. In fact, for mulching treatments the precipitated water filters through privileged channels, both by infiltrating laterally and through the inevitable accidental cracks in the sheets. Therefore, in the calculation of WUE, both precipitations and irrigations must be considered for all treatments (Wang et al., 2015).

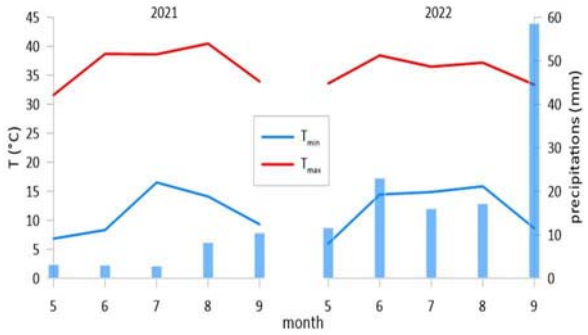

Fig.1 – Minimum, maximum air temperature and precipitations at monthly in the experimental site.
Fig.1 – Temperatura minima e massima dell'aria e precipitazioni a scala mensile nel sito sperimentale.

In Fig. 1. it is clear that the two years were characterized by quite contrasting weathers: year 2021 being much drier than the year 2022. Moreover, the year 2022 presented extreme high values of the air temperature and vapour pressure deficit (data VPD not shown). By considering the potential evaporation of the atmosphere (data not shown), calculated by the Penman model (Katerji and Rana, 2011), during the second experimental season the water demand of atmosphere is greater than in the first season. A violent hailstorm occurred several days before the harvest in 2022.

Different authors (Fernández et al., 1997; Grossiord et al., 2015), indicated a REW value of 0.4 as critical threshold to reveal the water stress in woody species under arid and semiarid Mediterranean conditions. The figure 2 shows that the crop, under any treatment, was generally under good water conditions in 2021 and 2022, except for the final period of the growth season, correspondent to the September month. Furthermore, the control crop showed an increasing stress since the August month of 2022 year, until the end of the season, when it was under severe water stress. Actually, daily REW values (data not shown) indicated that, occasionally, the crop under both mulching covering treatments was under water stress for two – four days consecutively, usually just before the scheduled irrigation. In these moderate stress periods, irrigation and/or rain restored the good tree water conditions in a couple of days.

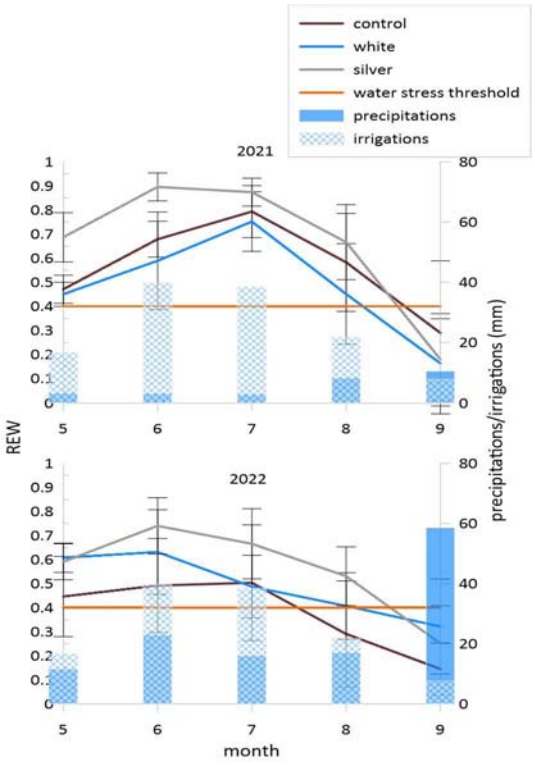

Fig.2 – Relative extractable water at monthly scale for all treatments; precipitation and irrigations.
Fig.2 – Relative extractable water a scala mensile in tutti i trattamenti; precipitazioni e irrigazioni.

The peach trees showed a specific transpiration diurnal course during day (see sample days in Fig. 3), with a sudden increase in early morning and a gentle decreasing until late afternoon, when it decreases steeper until evening. According to Wang et al. (2015), maximum levels of water-use occurred at 08:00 h, and near maximal values remained through-out the midday and afternoon. In our conditions, T in the control plot is generally lower than in the mulching treatments. More specifically, when the day is quite clear and the crop is in good water condition (Fig. 3a) the transpiration of white mulching cover was slightly higher (+6.5%) than that treated with the silver cover, probably because of the higher available energy due to the higher reflectivity of the white surface with respect to the silver one (Ham et al., 1993); this point requires further detailed developments. When the crop under white treatment is under water stress (Fig. 3b, REW=0.22) it transpires slightly lower (-13.2%) than the silver treatments.

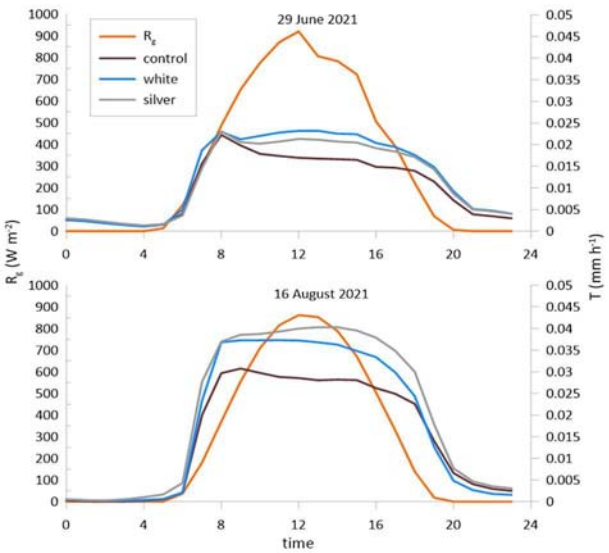

Fig.3 – Hourly path of transpiration (T) of three treatments and global radiation (R_g) in two sample days, characterized by different soil water conditions.
Fig.3 – Andamento orario di traspirazione (T) nei tre trattamenti considerati e radiazione globale (Rg) in due giorni presi come esempio di due diverse condizioni idriche del suolo.

The water losses by transpiration during the growing season were used to calculate the monthly transpiration rates (mm month^{-1}) as presented in fig. 4. During the growth period, when gradual increases in the intensity and frequency of precipitation, air temperature and available energy were observed, peach orchard T gradually increased and became more variable. In absolute terms, in the first experimental season the peach trees transpire less than the second season, because of the greater availability of energy which increased the evaporation demand of the atmosphere. The fig. 4 also shows that the transpiration of the control trees was always lower than that of the other mulching treatments. Moreover, the peach trees treated with the silver covering generally transpired as well as or more than the trees treated with the white covering, except in the first three months of 2021. Further research is necessary to study the impacts of covering color on the partitioning of ET in E and T.

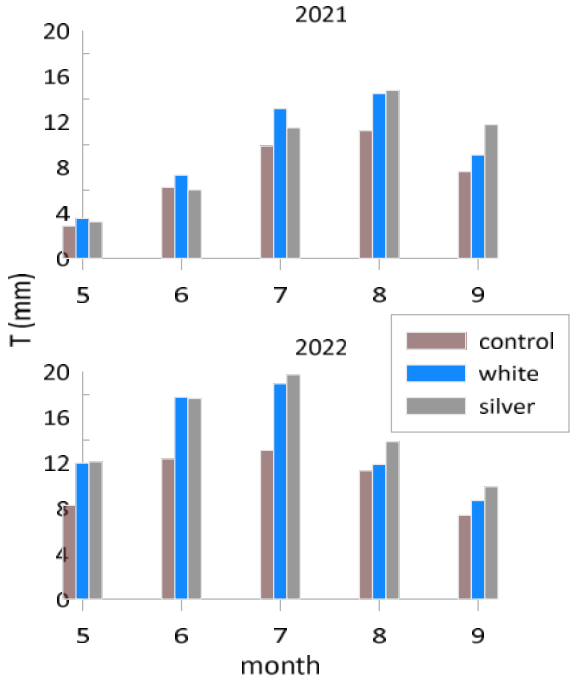

Fig.4 – Cumulated transpiration (T) at monthly scale for all treatments during the two experimental seasons.
Fig.4 – Traspirazione cumulata (T) a scala mensile in tutti i trattamenti nelle due stagioni colturali.

The summary of cumulated values of transpiration, water supplied by irrigation and precipitation, yield, water use efficiency and productivity are given in table 1 for the two experimental seasons and the three treatments. The total T of both treatments is higher than the control in both seasons as well as the yields. The yield in the second year has been strongly compromised by the hailstorm in 2022, affecting of course the WP. In fact, it was lower in 2022 than in 2021 year, being not significantly different among treatments in 2021 and slightly lower in the silver colour treatment than the control and white treatments in 2022. The WUE was generally higher in the mulching treatments than in the control in both seasons. Moreover, the WUE of the silver treatment was slightly higher in the silver colour than in the white one. Our results are in accordance with Wang et al. (2015), who found greater WUE in mulched crop than in the control one, mainly attributing this difference to the increasing of ET due to increasing fraction of evaporated water.

Tab.1 - Summary of transpiration, yield, water use efficiency (WUE) and water productivity (WP) in the two experimental seasons for all treatments.
Tab.1 - Sintesi di traspirazione, resa, water use efficiency (WUE) e water productivity (WP) nelle due stagioni e per tutti I trattamenti.

	Transpiration (mm)			water	Yield (gm^{-2})			WUE			WP ($g\,kg^{-1}$)		
Year	control	white	silver	(mm)	control	white	silver	control	white	silver	control	white	silver
2021	37.8	47.6	47.2	187.5	290	360	360	0.20	0.25	0.25	7.6	7.5	7.5
2022	52.4	69.2	73.3	262.1	360	490	370	0.20	0.26	0.28	6.9	7.1	5.1

Conclusions

Mulch covers increased soil water content in the whole peach orchard growth season. While the actual transpiration in mulched plots was greater than in control. Thus, in this semi-arid ecosystem, compared with control, the peach WUE increased when the soil is mulched by colored covers. While, the WP is essential invariated, except for the silver treatment, which showed the lowest WP value in the second year of experiment. The hailstorm could have altherated the final results; therefore, further studies are needed to obtain a better understanding of theleaf water-use efficiency, drought resistance capacity, and photo-synthetic characteristics of mulching treatments aimed at reducing transpiration in Mediterranean region.

Acknowledgements

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References

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. 1998. Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. Fao, Rome, 300(9), D05109.

Amare, G, Desta, B, 2021. Coloured plastic mulches: impact on soil properties and crop productivity. Chem. Biol. Technol. Agric. 8, 4.

Bleu, U. UNEP/MAP-Plan Bleu: State of the Environment and Development in the Mediterranean. Athens 2009. https://mcc.jrc.ec.europa.eu/documents/201607121602.pdf (accessed on 24 April 2023).

Campi, P.; Palumbo, A.; Mastrorilli, M. 2009, Effects of tree windbreak on microclimate and wheat productivity in a Mediterranean environment. Eur. J. Agron. 30, 220–227.

Campi, P., Gaeta, L., Mastrorilli, M., & Losciale, P. 2020. Innovative soil management and micro-climate modulation for saving water in peach orchards. Frontiers in Plant Science, 11, 1052.

Fernández, J-E, Moreno, F, Girón, IF, Blázquez, OM, 1997. Stomatal control of water use in olive tree leaves. Plant and Soil 190: 179–192.

Fernández, J.E-. Alcon, F., Diaz-Espejo, A., Hernandez-Santana, V., Cuevas, M.V., 2020. Water use indicators and economic analysis for on-farm irrigation decision: A case study of a super high density olive tree orchard. Agricultural Water Management, 237, 106074.Granier, A, 1987. Evaluation of transpiration in a Douglas-fir stand by means of sapflow measurements. Tree Physiol. 3, 309–320.

Grossiord, C, Forner, A, Gessler, A, Granier, A, Pollastrini, M, Valladares, F, Bonal, D, 2015. Influence of species interactions on transpiration of Mediterranean tree species during a summer drought. Eur. J. Forest Res. 134: 365–376.

Ham, JM, Kluitenberg, JG, Lamont, WJ, 1993. Optical Properties of Plastic Mulches Affect the Field Temperature Regime J Amer Soc Hort Sci 18(2):188-193.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. Appl. Sci (10) 8135, 1-20.

Matsoukis, A., Gasparatos, D., & Chronopoulou-Sereli, A. (2015). Mepiquat chloride and shading effects on specific leaf area and K, P, Ca, Fe and Mn content of Lantana camara L. Emirates Journal of Food and Agriculture, 121-125.

Katerji, N, Mastrorilli, M, Rana, G, 2008. Water use efficiency of crops cultivated in Mediterranean region: Review and analysis. European Journal of Agronomy, 28(4), 493-507.

Katerji, N, Rana, G, 2011. Crop reference evapotranspiration: a discussion of the concept, analysis of the process and validation. Water Resources Management, 25, 1581-1600.

Rana, G, Katerji, N, 2000. Measurement and estimation of actual evapotranspiration in the field under Mediterranean climate: a review. European Journal of Agronomy, 13(2-3), 125-153.

Suo, G. D., Xie, Y. S., Zhang, Y., & Luo, H. (2019). Long-term effects of different surface mulching techniques on soil water and fruit yield in an apple orchard on the Loess Plateau of China. Scientia Horticulturae, 246, 643-651.

Wang, H., Wang, C., Zhao, X., & Wang, F. 2015. Mulching increases water-use efficiency of peach production on the rainfed semiarid Loess Plateau of China. Agricultural Water Management, 154, 20-28.