VALUTAZIONE DELLE VARIABILI AGRO-CLIMATICHE MISURATE IN TEMPO REALE SULLA CRESCITA DEL PESCO PACCIAMATO (PRUNUS PERSICA (L.) BATSCH) IN DUE ANNI PRODUTTIVI

EVALUATION OF AGRO-CLIMATIC VARIABLES MEASURED IN REAL-TIME ON THE GROWTH OF MULCHED PEACH (PRUNUS PERSICA (L.) BATSCH) TREES IN TWO PRODUCTION YEARS

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Abstract
In an experimental farm of Research Centre for Agriculture and Environment (CREA-AA) located in southern Italy, data from continuous monitoring of peach fruit growth (cv. Calred), weather and soil (temperature and water content) during the final fruit development phase of two seasons 2021 and 2022 (6 - 18 August) were analysed. The trial examined the differences between control (P0) and two mulch cloths: black/white (P1) and black/silver (P2) plastic film. Fruit monitoring was conducted using a system of custom-built fruit diameter gauges. The data, which was manipulated as less as possible using z-score standardization, showed that the relative growth rate (RGR) was mainly affected by vapor pressure deficit and, to a lesser extent, by soil temperature in both years. During the stable weather conditions occurs in 2021, the RGR measured in P1 was greater than in P2 and P0.

Parole chiave
pacciamatura riflettente, tasso di crescita relativo, z-scores, contenuto idrico del suolo, deficit di pressione di vapore
Keywords
reflective mulching, relative growth rate, z-scores, soil water content, vapour pressure deficit

Introduction

Over the past three decades, Mediterranean regions have experienced global warming that has caused a shift in temperature patterns between seasons, resulting in shorter winters and earlier springs (Lionello, 2014; Lionello and Scarascia, 2018). This change has led to an increase in vapor pressure deficit (VPD), which is mainly related to water use in fruit trees (López et al., 2021). Additionally, this shift in temperature patterns has caused a significant reduction in rainfall (Hunt et al., 2019) and an overall increase in temperatures that are projected to rise by up to 2°C by the year 2100 (Malhi et al., 2021). Unfortunately, rainfall events have become increasingly extreme and violent (Armal et al., 2018), leading to devastating floods and landslides. (Frame et al., 2020). Plants are among the living organisms that are best suited for studying the effects of climate on phenology because they can adapt to changes in climatic conditions in their habitats through various adaptation mechanisms (Gordo and Sanz, 2010). As such, it is important to continuously monitor climatic and soil factors related to the vegetative-productive cycle of plants in agriculture to plan interventions wisely and avoid wasting resources, particularly water. Fruit crops require a significant amount of water to produce a good yield, with peach trees requiring approximately 150 liters of water per plant (Frecon, 2002). Therefore, studies are required to improve and assess the water use efficiency of fruit crops (Jiménez et al., 2020). Colored mulching films have become increasingly popular in orchards in recent years because they improve the water and heat cycle in the soil ecosystem (Suo et al., 2019). Mulching has been shown to reduce evapotranspiration and improve fruit yield in peach orchards (Campi et al., 2020). However, it is important to constantly monitor soil temperature and moisture when using mulching films, as they can significantly impact the soil environment (Fares and Alva, 2000; Wang et al., 2015). To monitor fruit development, some devices have been developed in recent decades that allow for the constant measurement of fruit gauge diameter and provide real-time information on fruit growth (Boini et al., 2019; Morandi et al., 2007). Fruit health should be monitored during different growth phases, especially during the final phase when plants require large amounts of water (Morandi et al., 2009).

This preliminary study aims to analyze recorded data (RD) from continuous monitoring of weather, soil, and fruit from the day of the year (DOY) 219 to 230 in 2021 and 2022, to understand how vapor pressure deficit (VPD) and pedo-climatic factors can impact the development of peach fruit during the final growth phase.

Material and Methods

In 2021 and 2022, a trial was conducted at the CREA-AA experimental farm in Rutigliano, Italy (lat.: 40.590 N, long.: 17.010 E, alt.: 147 m asl) on 6-year-old peach trees (Prunus

Persica L.), cv Calred, grafted on GF 677 with a 5m x 5m planting. Fruit growth was monitored using a custom-built fruit gauge developed by Winet, Srl. (Cesena, Italy) which was able to acquire changes in fruit growth every 15 minutes. The trial involved two different mulching films with colorations C/902 Black White and C/820 Black Silver (PolyEur Srl., Benevento, Italy). Standard meteorological sensors were used to collect weather data, including air temperature, relative humidity, precipitation, and incident global radiation. These sensors were continuously measured at 10-second intervals over a fescue grass (Festuca arundinacea Schreb.) near the experimental field and hourly recorded by an automatic weather station (Campbell Sci., USA). The fruit was monitored during the final production phase (5 August to 7 September) in 2021 and during all development phases in 2022. To compare the data from both years, the period from 6 to 18 August (DOY 219 to DOY 230) was chosen because a hailstorm occurred on 19 August 2022, which dislodged several fruits on which the fruit gauges were placed. The fruits that had recorded data (RD) with an R_2 between 0.84 and 0.98 during the period under study were chosen for analysis. Daily data of 7 fruits per trial were standardized using z-scores to compare recorded data (RD) of fruit diameter with other variables that have different units. The hysteresis curves were analyzed and compared with vapor pressure deficit (VPD), which was used to assess the trend in fruit growth over 24 hours and its response to VPD. The relative growth rates (RGR) were calculated during the monitoring period using the equation:
RGR = $[ln(RD_1)-ln(RD_0)]/(t_1-t_0)$.
Soil water content (SWC) and temperature (Tsoil) were monitored using FDR probes (Sentek Sensor Technologies, Stepney, South Australia, Australia) installed in the three treatments (P0, P1, P2) in three replicates. The Spearman correlation coefficient was determined to verify the correlations between RGR, environmental, and soil variables. The raw data, z-scores, and soil data were analyzed using analysis of variance and Tukey's multiple comparisons. All statistical analyzes were performed using the R statistical software environment (http://www.r-project.org). The magnitude of hysteresis curves was divided into four groups according to Khosravi et al. (2021): no hysteresis, incomplete hysteresis, partial hysteresis, and full hysteresis, which indicate the daily growth of the fruit changes based on the variation of VPD. The hysteresis curves vary following a clockwise or anticlockwise loop.

Results and Discussion

Meteorological conditions during the 2021 monitoring period (data not shown) exhibited mean values of temperature and VPD of 27 °C and 1.82 kPa, respectively, with 15 mm of water applied, out of which only 2.5 mm was from rain. In 2022 (data not shown), the average temperature was 25 °C and the average VPD was 0.95 kPa, with more notable temperature fluctuations compared to 2021. A total of 22 mm of water was applied, out of which 10 mm was from rain. The study revealed that the relationship between VPD and standardized fruit data differed for different fruits and days in both years. Analysis of the 91 daily hysteresis trends (Table 1) for selected fruits per treatment indicated that, in 2021, most fruits in all three treatments showed no hysteresis curves. The percentage values of different hysteresis widths did not significantly differ between the treatments, except for the small number of full hysteresis curves in the P1 treatment. In 2022 (Table 1), the number of hysteresis of no type increased and accounted for almost all measured hysteresis. The percentage of different hysteresis types did not vary significantly across treatments, although full curves were not recorded in treatment P2, unlike in 2021.

Tab.1 – Percentages of hysteresis curves observed in P0, P1, P2 treatments in 2021 and 2022 classified according to Khosravi et al., (2021)
Tab.1 – Percentuali di curve di isteresi osservate nei trattamenti P0, P1, P2 nel 2021 e nel 2022 classificate secondo Khosravi et al.

2021			
Hysteresis	**P0**	**P1**	**P2**
No	63%	66%	63%
Partial	30%	26%	27%
Incomplete	7%	8%	8%
Full	1%	0%	2%

2022			
Hysteresis	**P0**	**P1**	**P2**
No	82%	86%	87%
Partial	9%	11%	11%
Incomplete	5%	2%	2%
Full	3%	1%	0%

The instruments used to measure fruit size in this study may have potential stability issues over time, which has been noted in previous research (Scalisi et al., 2020). However, during the study period, the instruments were found to maintain sufficient stability. The hysteresis measurements indicate that the partial and incomplete hysteresis observed in 2021 was likely due to the VPD trend (Zucchini et al., 2021). In contrast, the lack of hysteresis observed in 2022 may be attributed to earlier fruit ripening compared to 2021, as reported by Khosravi et al., (2021), who found that the percentage of complete clockwise hysteresis declines with increasing fruit ripeness.
In Figure 1, the relative growth rates for the three treatments during the considered period (DOY 219 to DOY 230) in 2021 are presented. The growth rates for all three treatments followed a pattern of alternating decreasing and increasing phases, with the increasing phases occurring on the DOY when rain and irrigation occurred (DOY 221, 229). However, the P1 treatment exhibited a significantly different trend compared to P0 and P2.

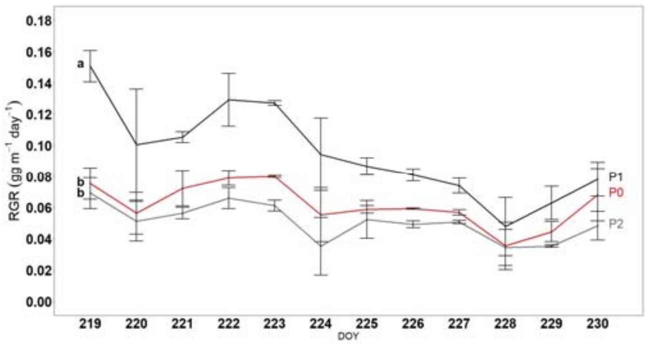

Fig.1 – Variation of Relative Growth Rate (RGR) from DOY219 to 230 in 2021. P0 (control), P1 (Black/White mulching), P2 (Black/Silver mulching). Different letters indicate a significant difference (p-value <0.05).

Fig.1 - Variazione del tasso di crescita relativo (RGR) dal DOY 219 a 230 nel 2021. P0 (controllo), P1 (pacciamatura Nera/Bianca), P2 (pacciamatura Nera/Argento). Le lettere diverse indicano una differenza significativa (valore p <0,05).

In 2022 (Figure 2), the relative growth rates in the three treatments alternated between increasing and decreasing phases, although less pronounced than in 2021. Overall, from DOY 221, the growth rates in all treatments showed a decreasing trend. A growth peak was observed in the control (P0) on DOY 220, when irrigation occurred. However, in the following days, the growth curve of the control decreased visibly, recording lower values compared to the two mulching treatments (P1, P2). Figure 2 shows a general decrease in RGR patterns in all three treatments in 2022 compared to 2021 (Figure 1), likely due to earlier fruit ripening.

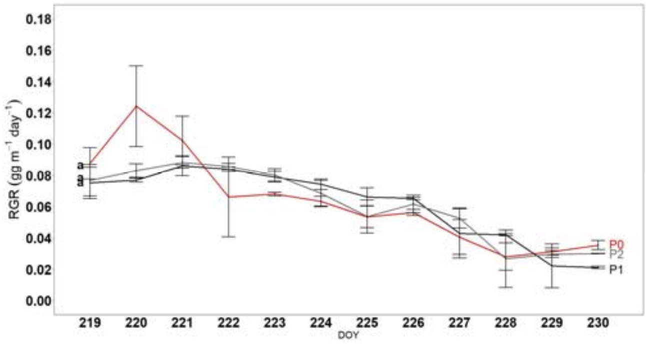

Fig.2 - Variation of Relative Growth Rate (RGR) from DOY 219 to 230 in 2022. P0 (control), P1 (Black/White mulching), P2 (Black/Silver mulching). Different letters indicate a significant difference (p-value <0.05).

Fig.2 - Variazione del tasso di crescita relativo (RGR) dal DOY 219 a 230 nel 2022. P0 (controllo), P1 (pacciamatura Nera/Bianca), P2 (pacciamatura Nera/Argento). Le lettere diverse indicano una differenza significativa (valore p <0,05).

Additionally, analyses of fruit relative growth rates showed that irrigation and rainfall led to peaks in RGR in both years, highlighting the effect of soil water content on growth rates (Priya and Bhat, 1999; Van Zyl, 1984). In 2021, the RGR of the different treatments appears to vary in response to soil water content (Figure 3), although with relatively low values of R_2. It is interesting to note that higher relative growth rates were observed in the P1 treatment compared to P2 at the same soil water content values, which could be attributed to the difference in soil temperatures (data not shown) between the two treatments. In 2021, the weather conditions were more stable and SWC had a positive effect on both mulch treatments, in agreement with Losciale et al., (2020), who found that reflective mulching helped maintain favorable pedo-climatic conditions.

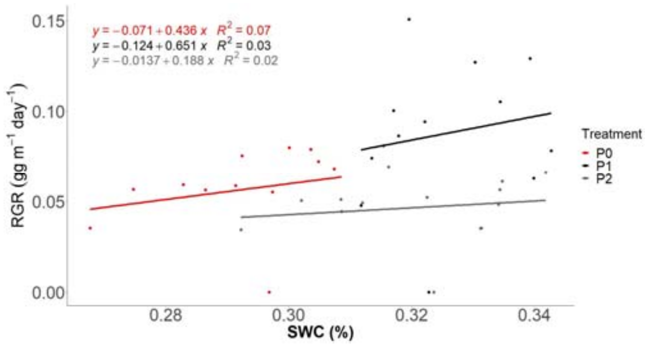

Fig.3 – Relative Growth Rate (RGR) in 2021 in function of soil water content (SWC) in the three treatments, P0 (control), P1 (Black/White mulching), P2 (Black/Silver mulching); (p-value <0.05).

Fig.3 – Tasso di crescita relativo (RGR) nel 2021 in funzione del contenuto idrico del suolo (SWC) nei tre trattamenti, P0 (controllo), P1 (pacciamatura Nera/Bianca), P2 (pacciamatura Nera/Argento); (p-value <0.05).

In 2022, the linear correlation between RGR and SWC (Figure 4) did not show a clear trend among the treatments. Also in 2022, the R_2 values for the correlation between RGR and SWC was lower than in 2021. The effects of colored mulches, according to Díaz-Pérez and Dumičić (2022), can vary depending on differences in climatic conditions, not only between different seasons but also within the same season of different years.

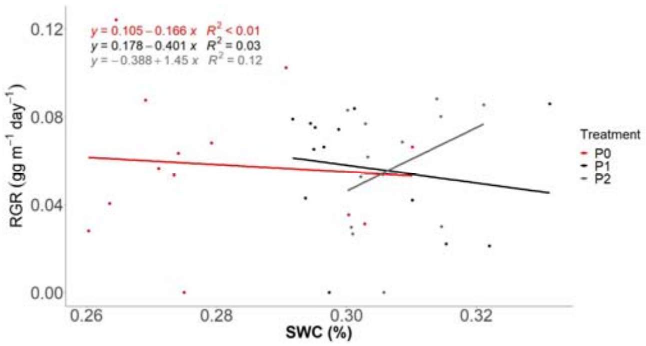

Fig.4 – Relative Growth Rate (RGR) in 2022 in function of soil water content (SWC) in the three treatments, P0 (control), P1 (Black/White mulching), P2 (Black/Silver mulching); (p-value <0.05).
Fig.4 – Tasso di crescita relativo (RGR) nel 2022 in funzione del contenuto idrico del suolo (SWC) nei tre trattamenti, P0 (controllo), P1 (pacciamatura Nera/Bianca), P2 (pacciamatura Nera/Argento); (p-value <0.05).

Relationships between relative growth rates (RGR) and meteorological parameters (VPD), soil conditions (SWC, T_Soil), irrigation, and precipitation, using the Spearman correlation coefficient (r) were evaluated (Figure 5). In both years, the RGR was negatively correlated with soil temperature and VPD, indicating that as the values of these two variables increase, the growth rate tends to decrease. These observations were reasonable because according to George and Nissen (1988), the increase in soil temperature and VPD leads to a decrease in fruit growth.

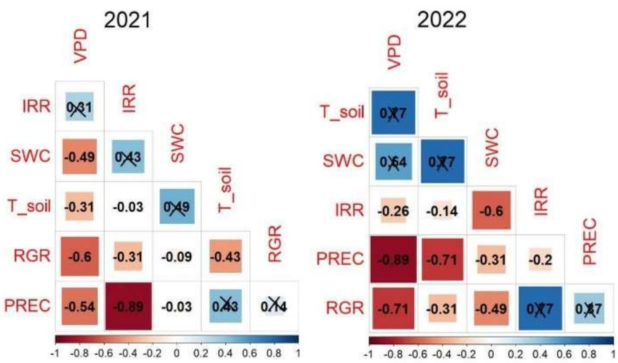

Fig.5 – The relationships (r) between Relative Growth Rate (RGR) and Vapour Pressure Deficit (VPD), Irrigation (IRR), soil water continent (SWC), Temperature soil (T_soil), Precipitation (PREC) in the 2021 and 2022. The coefficients with a black-cross on them indicate statistically not significant correlations; p-value 0.05.
Fig.5 – Le relazioni (r) tra deficit di pressione di vapore (VPD), irrigazione (IRR), continente idrico del suolo (SWC), temperatura del suolo (T_soil), tasso di crescita relativo (RGR) e precipitazioni (PREC) negli anni 2021 e 2022. I coefficienti contrassegnati da una croce nera indicano correlazioni statisticamente non significative; p-value 0,05.

Conclusion

Continuous monitoring tools for the soil-plant-atmosphere system can provide valuable and timely information on peach tree growth during various production phases, potentially reducing the need for time-consuming data manipulation. With stable environmental conditions and no violent weather events, the use of mulching film C/902 Black White (P1) during the monitored period resulted in a greater relative growth rate in peach fruit, which was well-correlated to observed climatic and pedoclimatic conditions within the treatment. However, further investigation is needed to improve tools for continuously measuring fruit development, as some experimental tools exhibited criticalities requiring continuous monitoring of their functionality, particularly those placed on fruits that are subjected to various biotic and abiotic stresses. The use of precision agriculture tools, such as those employed in this study, opens up new production scenarios in which environmental resources such as water can be optimised for better management.

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