Atti del XXIV Convegno Nazionale di Agrometeorologia

L'Agrometeorologia a supporto dei sistemi colturali e zootecnici

CAGLIARI, 15-17 Giugno 2022

A cura di
Francesca Ventura, Gabriele Cola, Giovanni Maria Poggi

Dipartimento di Scienze e Tecnologie Agro-Alimentari
Università di Bologna

ISBN 9788854970892
DOI 10.6092/unibo/amsacta/6936

Comitato Scientifico
Francesca Ventura
Federica Rossi
Filiberto Altobelli
Maria Carmen Beltrano
Anna Dalla Marta
Emanuele Scalcione
Federico Spanna
Domenico Ventrella

Comitato organizzatore
Marcello Giovanni Onorato
Marco Secondo Gerardi
Salvatore Aresu

Segreteria Organizzativa
Simone Falzoi
Tiziana La Iacona
Irene Vercellino
Alessandro Corona
Angela Scano
Antonella Barbara Corda
Alessandra Cornaglia

Bologna, 2022

Atti del XXIV Convegno Nazionale di Agrometeorologia

L'Agrometeorologia a supporto dei sistemi colturali e zootecnici

CAGLIARI, 15-17 Giugno 2022

A cura di Francesca Ventura, Gabriele Cola, Giovanni Maria Poggi

Dipartimento di Scienze e Tecnologie Agro-Alimentari
Università di Bologna

L’Agrometeorologia a supporto dei sistemi colturali e zootecnici

Sessione 1 - **Modellistica agrometeorologica per le produzioni vegetali**

POSTERS

Sessione 2 - **Modellistica agrometeorologica per la zootecnia**

POSTERS

Sessione 3 - **Strategie e sistemi per la fornitura di servizi agrometeorologici**

POSTERS

ANALISI DEI FLUSSI DI RESPIRAZIONE DEL SUOLO IN UN AGRUMENTO SOTTOPOSTO A DIFFERENTI PRATICHE IRRIGUE E DI GESTIONE DEL SUOLO

COMPARATIVE ANALYSIS OF SOIL RESPIRATION IN A CITRUS ORCHARD UNDER DIFFERENT SOIL AND WATER MANAGEMENT PRACTICES

Serena Guarrera[1*], Gaetano Giudice[2], Daniela Vanella[3], Simona Consoli[3], Mirco Milani[3], Domenico Longo[3]

[1]Ph.D. Scholar, International Doctorate in Agricultural, Food and Environmental Science—Di3A—University of Catania, Catania 95124, Italy
[2]Istituto Nazionale di Geofisica e Vulcanologia, Sezione di Catania, Osservatorio Etneo (INGV-OE), Piazza Roma 2, 95125, Catania.
[3]Department of Agriculture, Food and Environment of University of Catania (Di3A-UniCT), Via S. Sofia, 100, Catania 95123, Italy
*serena.guarrera@phd.unict.it

Abstract

The role of soil carbon dioxide (CO_2) is difficult to be quantified, being mainly dominated by soil microbial biomass and plant roots activity. The purpose of this study was to compare the CO_2 flux rates obtained by carrying-out soil respiration measurements with an *ad hoc* designed accumulation chambers in an orange orchard subjected to different irrigation regimes (full irrigation, FI, and regulated deficit irrigation, RDI) and soil management practices (bare soil *versus* organic mulching cover). Preliminary results showed that the CO_2 activity was greater in the treatments subjected to FI than RDI strategies under both bare soil and organic mulching, showing average values of 0.10 ± 0.01 mg m^{-2} s^{-1} and 0.08 ± 0.01 mg m^{-2} s^{-1} and 0.10 ± 0.03 mg m^{-2} s^{-1} and 0.08 ± 0.03 mg m^{-2} s^{-1} respectively.

Parole chiave
Flussi di anidride carbonica – respirazione del suolo – pacciamatura organica – strategie di irrigazione
Key word
Carbon dioxide fluxes – soil respiration – organic mulching – irrigation strategies

Introduction

In most agro-ecosystems, soil respiration (SR) is a complex process that is descriptive of soil activity in terms of soil carbon dioxide (CO_2) release (Sagi et al., 2021). The gas flux from soil/atmosphere interface is attributed to several phenomena that occurs at the soil level, and it can be time-varying. In addition, a fraction of the CO_2 flux cannot directly correlated to agricultural activities deriving from deep geological activity.

SR is defined as the combination of two biological sources: (i) the autotrophic respiration by plant roots and associated microorganisms (i.e., rhizosphere respiration), and (ii) the heterotrophic respiration, via microbial decomposition of soil organic matter (Hanson et al. 2000; Högberg and Read 2006; Ryan and Law 2005). In this sense, a fraction of CO_2 flux is related to root microbiome and mycorrhizae activity in rhizosphere. In the latter, fungi and bacteria establish a mutual symbiotic association with crop roots. Specifically, using root exudates, they can survive and reproduce in rhizosphere while providing nutrients (mainly nitrogen-based molecules) to the plants and releasing CO_2 (Vives-Peris et al., 2020; Girkin et al. 2018). The other CO_2 flux fraction is related to processes that occurs in the first few centimetres of the soil depth, due to leaves litter decomposition or soil management operations, as soil tilling.

SR depends on many different parameters seasonally time-varying, such as soil texture, soil compaction, roots density, available soil organic matter, soil temperature, pH, soil water content (SWC) (Wang et al. 2016).

Moyano et al. (2012) showed that the relationship between soil heterotrophic respiration and soil moisture is consistently affected by soil texture and other properties (e.g., soil bulk density and soil organic carbon). The relationship between SWC and SR is also strongly related to soil texture. Many studies have shown that no single factor can fully explain SWC variation (Holsten et al., 2009).

The proportion of SR from autotrophic and heterotrophic contributions may vary annually and seasonally among the terrestrial ecosystems (Hanson et al. 2000). Across a range of studies, the heterotrophic contribution varied from 10 to 95%, and averaged 54% annually and 40% during the growing season (Hanson et al. 2000). The SR is the main pathway for carbon moving from the agro-ecosystem to the atmosphere (Ryan et al., 2005; Hou et al., 2021) and represents a major flux in the global CO_2 cycle (Vargas et al.2010). Small changes in SR can also have a significant impact on atmospheric CO_2 concentrations at the global level.

The accurate quantification of CO_2 emissions through SR is of great significance for understanding climate change and the CO_2 cycle (Hou et al., 2021). Because, as above-mentioned, soil autotrophic and heterotrophic activity is controlled by substrate availability, the SR is strongly linked to plant metabolism, photosynthesis and leaves litter fall. This link dominates both base rates and short-term fluctuations in SR and suggests many roles for SR as an indicator of ecosystem metabolism (Ryan et al., 2005). SR and soil processes are linked, but their understanding can be complicated (Ryan et al., 2005). In general, photosynthesis supplies carbon substrate for root metabolism and growth, and a decrease in substrate supply may decrease SR within days (Högberg et al. 2001). In addition to this direct effect, the fraction of photosynthesis may vary as function of nutrition (Giardina et al. 2003), water availability (Stape 2002), and phenology. These effects are furthermore influenced under heterogeneous agro-systems in Mediterranean climate conditions. In this sense, Consoli et al. (2014) highlighted the role of the orchard system in sequestering atmospheric CO_2. Additionally effects on CO_2 in these contexts are dependent on the agronomic practices applied in situ.

Sustainable soil and water management practices have been applied in this study by combining the regulated deficit irrigation strategy (RDI) with the use of organic mulching. In particular, a water shortage can affect the performance of soil microbial communities in natural ecosystems at the level of microbial growth and biomass (Meisner et al., 2013), microbial composition (Hawkes et al., 2011; Placella et al., 2012), and biogeochemical cycles (Goransson et al., 2013; Placella et al., 2012). However, the concrete effect of RDI on soil microbial communities in agro-systems has been poorly studied. Bastida et al. (2017) reported that RDI had a negative impact on the soil microbial biomass and enzyme activities in a grapefruit orchard, with a slow-down of organic matter decomposition under deficit irrigation condition. In addition, the use of organic mulching often contains soluble organic matter and nutrients that may benefit the development and activity of the soil microbial community (Adrover et al., 2012; Chevremont et al., 2013), with potential changes in its composition (Bastida et al., 2017; Zolti et al., 2019).

This study focuses on understanding the separate and combined effects of the application of deficit irrigation regime (RDI) and organic mulching, in semiarid Mediterranean conditions, on SR. Further measurements of CO2 fluxes in the soil are planned to be compared with the in-situ CO2 fluxes measured by an Eddy Covariance tower to distinguish the role of plant contribution to the overall CO2 flux.

2. Material and methods

2.1 Study site description

The study was conducted in an experimental orange orchard (*Citrus sinensis* (L.) Osbeck, Tarocco Sciara grafted on *Carrizo citrange Poncirus trifoliata* (L.) Raf. × _*C. sinensis* (L.) Osbeck), managed by the Italian Council for Agricultural Research and Agricultural Economics Analyses (CREA-OFA, Acireale). The study site is located in the insular part of Italy (eastern Sicily, Lentini, SR, 37° 20' 12.65" N, 14° 53' 33.04" E, WGS84, Figure 1) and characterized by semi-arid Mediterranean climate, with warm and dry summers. During the years 2010–21, the mean air temperature, annual precipitation and reference evapotranspiration values were about 18.2◦C, 587 mm and 1264 mm, respectively (data provided by a weather station located about 2 km far from the study site and managed by Servizio Informativo Agrometeorologico Siciliano, SIAS).

The experimental design at the study site provided the integration of soil sustainable and water management practices by RDI (i.e. water deficits supplied during specific phenological phases, when crops are less sensitive to water stress, without affecting yield and quality features, Romero-Trigueros et al., 2017; Saitta et al., 2021) and organic mulching (crop residues from pruning and weeds) practices, as in the follows:

- FI Bare, fully irrigated treatment (FI), where irrigation rate is 100% of ET_c in bare soil condition.
- FI Mulch, fully irrigated treatment (FI), where irrigation is 100% of ET_c in organic mulching condition.
- RDI Bare, irrigated at 100% of ET_c, except for the II phenological stage (i.e., fruit growth) when irrigation corresponds to 50% of ET_c in bare soil condition.
- RDI Mulch, irrigated at 100% of ET_c, except for the II phenological stage (i.e., fruit growth) when irrigation corresponds to 50% of ET_c with organic mulching condition.

The study site was equipped with an Eddy Covariance (EC) tower located at 7 m above the ground (two times the canopy height). The EC system was equipped by a three-dimensional sonic anemometer (CSAT3-3D, Campbell Scientific Inc.) and an infrared open-path gas analyzer (Li-7500, Li-cor Biosciences Inc.) to obtain high frequency (10 Hz) measurements of the three wind components and the H_2O and CO_2 concentrations, respectively. Low frequency data (30-min) were obtained for: net radiation (R_n, W m^{-2}, net radiometer CNR-1 Kipp & Zonen located 7 m above the ground) and soil heat flux (G, W m^{-2}) identified by self-calibrated soil heat flux plates (HFP01SC, Hukseflux) placed in the exposed, half-exposed and shadowed soil, at about 0.05 m of depth. High and low frequency data were recorded by a CR1000 logger (Campbell Scientific Inc.). The standard EUROFLUX rules (Aubinet et al., 2000) were adopted for EC measurements and data processing. Common errors in the measured high frequency data, such as running means for detrending, three angles coordinate rotations and despiking, were removed during the post processing by quality checks (Vanella & Consoli, 2018).

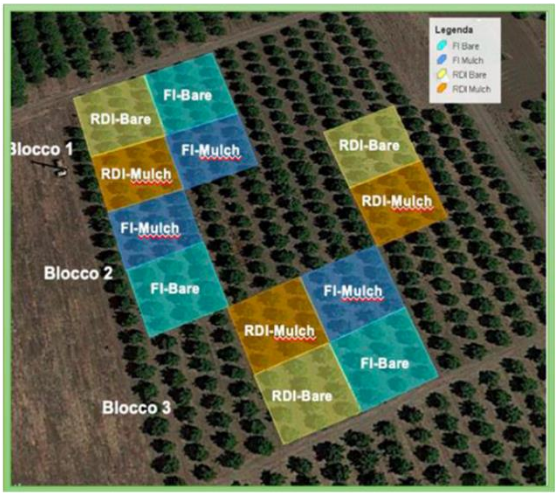


Fig. 1. Experimental treatments at the study area
Fig. 1. Schema dei trattamenti sperimentali

2.2 Soil respiration measurements

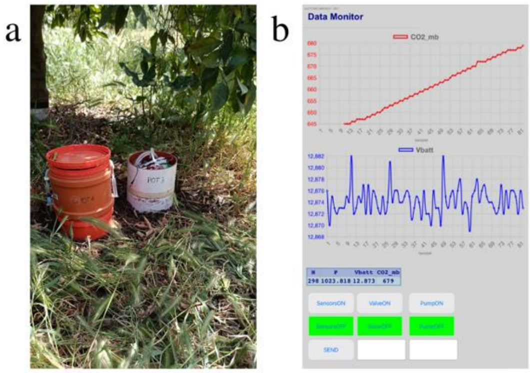
The most common approach to measure the SR is based on the use of static accumulation chamber (Ceccon, et al., 2010). There are different commercial instruments available, like LI-COR LI-8100 or Li-COR LI-6800 or the Portable soil Fluxmeter from WEST Systems. While they can be suitable for research use, their cost cannot be often affordable for those farms that wish to implement Precision Agriculture techniques, using multiple chambers. In this study, during the month of December 2021, SR measurements were conducted on the treatments under study using an accumulation chamber.

2.2.1 Accumulation chamber set-up

An *ad hoc* low-cost accumulation chamber is under development and design by the researchers of INGV and UniCT. The camera prototype is already in use for the SR measurements. The chamber (based also on the research of Chiodini, et al. 1998) it is suitable to be left on site for serval days and will also allow to take measurements on saturated soil, or when it will be equipped with a float even on the water surface.

To guarantee soil seal and limit wind adverse effect, a collar semi-buried in soil can be used. Long-term data collection campaign may not be recommended because the prolonged presence of the chamber can modify soil behaviour.

The accumulation chamber in use in our experiment was made by non-transparent PVC (i.e., photosynthetic activity inside the chamber was not considered) with a cylindrical shape, with 10 cm and 20 cm of height and diameter, respectively (Figure 2a).



H	P	Vbatt	CO2_mb
298	1023.818	12.873	679

Fig. 2. Accumulation chamber (a) and the data monitor on board the logger (b).
Fig. 2. Camera di accumulo (a) e visualizzazione dei dati attraverso il logger (b).

The chamber was atmospheric pressure-compensated by a small vent, designed to limit the Venturi effect due to wind. On the top of the chamber, another similar PVC cylinder hosted the electro-pneumatic sub-systems, the IR gas analyser (IRGA) and a data logger. Each measurement cycle started with a chamber cleaning phase in which an high rate of fresh air from atmosphere is pumped inside for few minutes in order to remove CO_2 accumulation. Exhaust air is discarded into the atmosphere. At the end of the cleaning phase, a valve sealed the chamber and the accumulating gas inside is pumped into the IRGA at a low rate and then put back into the chamber. This allowed for gas mixing, to prevent stratification, inside the chamber, without the need of mechanical fan. In order to avoid non-linear accumulation rate inside the chamber, the measurement cycle was limited to 300 s. The concentration data, in ppm, was stored on the on board data logger, while they can be accessed in real time by means of a WiFi connection. In this sense, a smartphone with an available web browser can be used. The system provided a suitable-developed Javascript web application in which concentration data (with air temperature, pressure and others parameters) are shown in real time graphs (Figure 2b).

2.2.2 Data processing and comparison with CO_2 turbulent fluxes

A Matlab tool was designed to process the accumulation chamber CO_2 concentration time series in CSV format. Due the short sampling time (300 s), a modified linear regression model was used. The RANSAC algorithm, that is able to automatically discard data in the initial dead-band (mainly due to internal pneumatic dead volumes) and different other kind of noises in time series, was used.

For the comparison between the CO_2 flux measurements of the soil and the turbulent CO_2 fluxes measured by the EC system, the WINDTRAX software has been identified and will be applied in the near future. This software takes into account the micrometeorological variables allowing to translate the measured CO_2 fluxes on the soil at the height of the EC (h = 7 m) in order to have up scaled and comparable data. To discriminate the soil component from the CO_2 fluxes of EC, we will use the integrated measurement approach in which a Lagrangian stochastic model (LS) is applied to simulate the transport of CO_2 from single or composite sources. Based on meteorological parameters, the LS model will allow to determine unknown CO_2 emission rates from sources but also, vice versa, to find the distribution of CO_2 concentration from known or measured CO_2 emissions from sources (Federico, C. et al., 2019).

3. Results and discussion

The preliminary results achieved in this study using the *ad hoc* accumulation chamber showed that the CO_2 activity was greater in the treatments subjected to FI than to RDI strategies under bare soil, showing average values of 0.10 (± 0.01) mg m^{-2} s^{-1} and 0.08 (± 0.01) mg m^{-2} s^{-1}, respectively. Greater CO_2 fluxes were also observed at FI under organic mulching condition, showing average values of 0.10 (± 0.03) mg m^{-2} s^{-1} and 0.08 (± 0.03) mg m^{-2} s^{-1}, respectively (Figure 3).

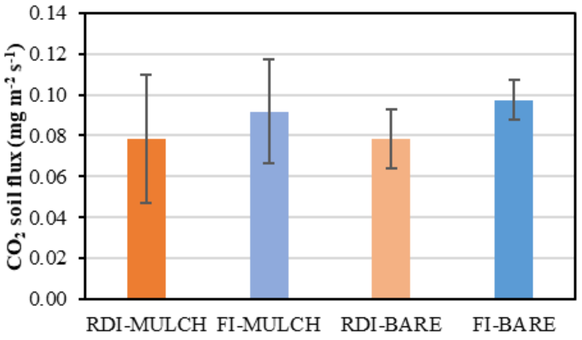


Fig. 3. Measured CO_2 fluxes
Fig. 3. Flussi misurati di CO_2

The effects on CO_2 fluctuations due to different SWC conditions were also observed by other authors (Flechard et al. 2007, Jassal et al. 2005, Maier et al. 2010). These evidences were interpreted as the result of the stimulation and intensification of biological activity in the soil and the decrease in diffusivity of the topsoil due to SWC changes (Borken et al., 2003, Lee et al., 2004). Hou et al. (2021) recognized the SWC as the main controlling factor on CO_2 in tree orchards supplied by drip irrigation. Moreover, these authors highlighted the importance of evaluating the role of the adoption of different agricultural practices on the temporal and spatial variations of SR fluxes. However, the discussion of the results of this study is still limited due to the few dataset collected, since it refers to a single month of observation.

4. Conclusion

In this study, the effects of different irrigation strategies and soil management practices have been investigated by measuring soil CO_2 fluxes using an accumulation chamber. Even if the preliminary results of this study are in agreement with literature, in which a greater CO_2 activity in well irrigated soils is detected in comparison to lower irrigated soil conditions; further analyses are needed to corroborate these findings and to upscale the CO_2 fluxes at the EC soil-plant-atmosphere level.

5. References

Adrover M., Farrús E., Moyà G., Vadell J., 2012. Chemical properties and biological activity in soils of Mallorca following twenty years of treated wastewater irrigation. Journal of environmental management, 95, S188-S192.

Aubinet M., Rannik U., Snijders W., Valentini R., Vesala T., 2000. Exchange of forests: The Euroflux methodology.

Bastida F., Torres I. F., Romero-Trigueros C., Baldrian P., Větrovský T., Bayona J. M., ... & Nicolás, E., 2017. Combined effects of reduced irrigation and water quality on the soil microbial community of a citrus orchard under semi-arid conditions. Soil Biology and Biochemistry, 104, 226-237.

Borken W., Davidson E.A., Savage K., Gaudinski J., Trumbore S.E., 2003. Drying and wetting effects on carbon dioxide release from organic horizons. Soil Sci. Soc. Am. J. 67, 1888–1896.

Ceccon C., Panzacchi P., Scandellari F., Prandi L., Ventura M., Russo B., ... & Tagliavini M., 2011. Spatial and temporal effects of soil temperature and moisture and the relation to fine root density on root and soil respiration in a mature apple orchard. Plant and Soil, 342(1), 195-206.

Chevremont A. C., Boudenne J. L., Coulomb B., Farnet A. M., 2013. Impact of watering with UV-LED-treated wastewater on microbial and physico-chemical parameters of soil. Water research, 47(6), 1971-1982.

Chiodini G., Cioni R., Guidi M., Raco B., Marini L., 1998. Soil CO2 flux measurements in volcanic and geothermal areas. Applied Geochemistry, 13(5), 543-552.

Consoli S., Facini O., Nardino M., Rossi F., 2014. Carbon balance and energy fluxes of a Mediterranean crop. Italian Journal of Agrometeorology, 19 (3), 15 – 24.

Federico C., Liuzzo M., Giudice G., Capasso G., Pisciotta A., Pedone M., 2019. Variations in CO2 emissions at a mud volcano at the southern base of Mt Etna: are they due to volcanic activity interference or a geyser-like mechanism? Bulletin of Volcanology, 81(1), 1-18.

Flechard C., Neftel A., Jocher M., Ammann C., Leifeld J., Fuhrer J., 2007. Temporal changes in soil pore space CO2 concentration and storage under permanent grassland. Agric. For. Meteorol. 142, 66–84.

Giardina C. P., Ryan M. G., Binkley D., Fownes J. H., 2003. Primary production and carbon allocation in relation to nutrient supply in a tropical experimental forest. Global Change Biology, 9(10), 1438-1450.

Girkin N. T., Turner B. L., Ostle N., Craigon J., Sjögersten S., 2018. Root exudate analogues accelerate CO2 and CH4 production in tropical peat. Soil Biology and Biochemistry, 117, 48-55.

Göransson H., Godbold D. L., Jones D. L., Rousk J., 2013. Bacterial growth and respiration responses upon rewetting dry forest soils: impact of drought-legacy. Soil Biology and Biochemistry, 57, 477-486.

Hanson P. J., Edwards N. T., Garten C. T., Andrews J. A., 2000. Separating root and soil microbial contributions to soil respiration: a review of methods and observations. Biogeochemistry, 48(1), 115-146.

Hawkes C. V., Kivlin S. N., Rocca J. D., Huguet V., Thomsen M. A., Suttle K. B., 2011. Fungal community responses to precipitation. Global Change Biology, 17(4), 1637-1645.

Högberg P., Nordgren A., Buchmann N., Taylor A. F., Ekblad A., HoÈgberg M. N., ... & Read D. J., 2001. Large-scale forest girdling shows that current photosynthesis drives soil respiration. Nature, 411(6839), 789-792.

Högberg P., Read D. J., 2006. Towards a more plant physiological perspective on soil ecology. Trends in ecology & evolution, 21(10), 548-554.

Holsten A., Vetter T., Vohland K., Krysanova V., 2009. Impact of climate change on soil moisture dynamics in Brandenburg with a focus on nature conservation areas. Ecological Modelling, 220(17), 2076-2087.

Hou T., Wang Y., Guo F., Jia Q., Wu X., Wang E., Hong J., 2021. Soil Respiration Characteristics and Influencing Factors for Apple Orchards in Different Regions on the Loess Plateau of Shaanxi Province. Sustainability, 13(9), 4780.

Jassal R., Black A., Novak M., Morgenstern K., Nesic Z., Gaumont-Guay D., 2005. Relationship between soil CO2 concentrations and forest-floor CO2 effluxes. Agricultural and Forest Meteorology, 130(3-4), 176-192.

Lee X., Wu H., Sigler J., Oishi C., Siccama T., 2004. Rapid and transient response of soil respiration to rain. Global Change Biol. 10, 1017–1026.

Maier M., Schack-Kirchner H., Hildebrand E. E., Holst J., 2010. Pore-space CO2 dynamics in a deep, well-aerated soil. European Journal of Soil Science, 61(6), 877-887.

Meisner A., Bååth E., Rousk J., 2013. Microbial growth responses upon rewetting soil dried for four days or one year. Soil Biology and Biochemistry, 66, 188-192.

Moyano F. E., Vasilyeva N., Bouckaert L., Cook F., Craine J., Curiel Yuste J., ... & Chenu C., 2012. The moisture response of soil heterotrophic respiration: interaction with soil properties. Biogeosciences, 9(3), 1173-1182.

Placella S. A., Brodie E. L., Firestone M. K., 2012. Rainfall-induced carbon dioxide pulses result from sequential resuscitation of phylogenetically clustered microbial groups. Proceedings of the National Academy of Sciences, 109(27), 10931-10936.

Ryan M. G., Law B. E., 2005. Interpreting, measuring, and modeling soil respiration. Biogeochemistry, 73(1), 3-27.

Romero-Trigueros C., Parra M., Bayona, J. M. Nortes, P. A., Alarcón J. J., Nicolás E., 2017. Effect of deficit irrigation and reclaimed water on yield and quality of grapefruits at harvest and postharvest. LWT-Food Science and Technology, 85, 405-411.

Sagi N., Zaguri M., Hawlena D., 2021. Soil CO2 influx in drylands: A conceptual framework and empirical examination. Soil Biology and Biochemistry, 156, 108209.

Saitta D., Consoli S., Ferlito F., Torrisi B., Allegra M., Longo-Minnolo G., ... & Vanella D., 2021. Adaptation of citrus orchards to deficit irrigation strategies. Agricultural Water Management, 247, 106734.

Stape J. L., 2002. Production ecology of clonal Eucalyptus plantations in northeastern Brazil. Colorado State University.

Vanella D., Consoli S., 2018. Eddy covariance fluxes versus satellite-based modelisation in a deficit irrigated orchard. Ital. J. Agrometeorol, 2, 41-52.

Vargas R., Baldocchi D. D., Allen M. F., Bahn M., Black T. A., Collins S. L., ... & Tang J., 2010. Looking deeper into the soil: biophysical controls and seasonal lags of soil CO2 production and efflux. Ecological Applications, 20(6), 1569-1582.

Vives-Peris V., de Ollas C., Gómez-Cadenas A., Pérez-Clemente R. M., 2020. Root exudates: from plant to rhizosphere and beyond. Plant cell reports, 39(1), 3-17.

Wang R., Wang Z., Sun Q., Zhao M., Du L., Wu D., ... & Guo S., 2016. Effects of crop types and nitrogen fertilization on temperature sensitivity of soil respiration in the semi-arid Loess Plateau. Soil and Tillage Research, 163, 1-9.

Zolti A., Green S. J., Mordechay E. B., Hadar Y., Minz D., 2019. Root microbiome response to treated wastewater irrigation. Science of the Total Environment, 655, 899-907.