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Evaluation of agronomic and physiological effects of fertigation with treated wastewater on crop production

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Introduction

In Italy, the agricultural sector is increasingly facing water scarcity, which has marked effects on crop cultivation and food safety (García-Herrero et al., 2022). Many regions are experiencing diminished rainfall and more frequent heatwaves, all attributable to climate change. The utilization of reclaimed water emerges as a sustainable solution to address water scarcity by ensuring a reliable source of water and nutrients (Cirelli et al., 2012), all while preserving freshwater reservoirs and diminishing the reliance on synthetic fertilizers. The nutrient composition of reclaimed water varies based on the level of wastewater treatment and can fluctuate throughout the irrigation season. To prevent imbalances in nutrient provision to crops, continuous monitoring of nutrient levels in reclaimed water is imperative. Indeed, fluctuating nutrient concentrations can result in excessive vegetative growth, uneven ripening of fruits, and diminished yields (Pedrero et al., 2010). In this study, conducted over a three-year period (from 2021 to 2023), a field trial was undertaken to implement a novel smart fertigation system for peach trees and processing tomatoes. Secondary and tertiary treated water were utilized for irrigation, with an innovative system designed to supplement fertilizers, taking into account those already present in the wastewater.

Materials and Methods

To assess the system's efficacy, three irrigation methods were compared: treated wastewater without additional mineral fertilising solution (TWW); fresh water with additional fertilising solution (FW+F); treated wastewater with additional mineral fertilising solution (TWW+F). Macronutrients (N, P, K) were balanced between the two treatments that foresaw additional supply (FW+F, SW+F) through a smart fertigation system, designed especially for this experimental platform (Figure 1), based on the constant monitoring of water quality and volume, implementing a specific algorithm (Figure 2) as described in Odone et al. (2024).

Figure 1. Experimental set-up of the smart fertigation system on processing tomato plants cultivated on bins (left) and potted peach trees (right), inside the municipal wastewater treatment plant of Cesena (Italy).

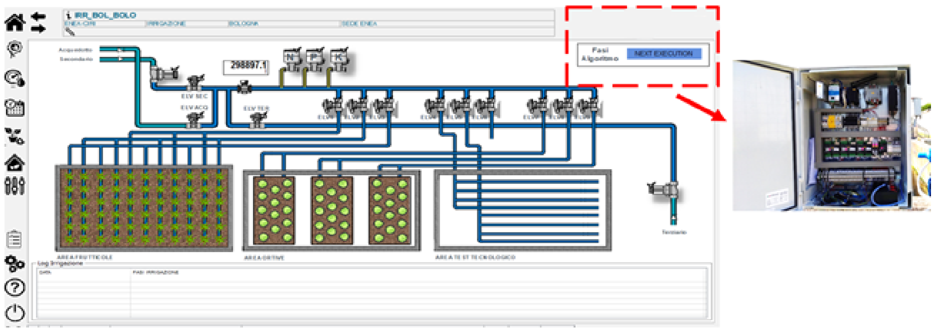

Figure 2. Control unit and synoptic panel of the fertigation system

In particular, the SW+F treatment plants received fertilizer doses adjusted for the difference between the plants' nutritional requirements and the macronutrients provided by the treated water (secondary or tertiary). Conversely, the FW+F plants were supplied with the full dose of macronutrients corresponding to their nutritional needs. This setup allowed for a comparison of the N, P, and K doses delivered across the three different treatments.

Results

Only the treatment using treated wastewater alone, without additional fertilizers, fell short of meeting the crops' nutritional requirements, albeit significant savings in macronutrients were still achieved. Throughout the irrigation seasons (e.g., 2021, 2022, 2023), for peach crops, reclaimed water enabled satisfying of up to 40.6%, 27.7%, and 100.0% of nitrogen, phosphorus, and potassium requirements, respectively, instead of relying on artificial fertilizers (Figure 3).

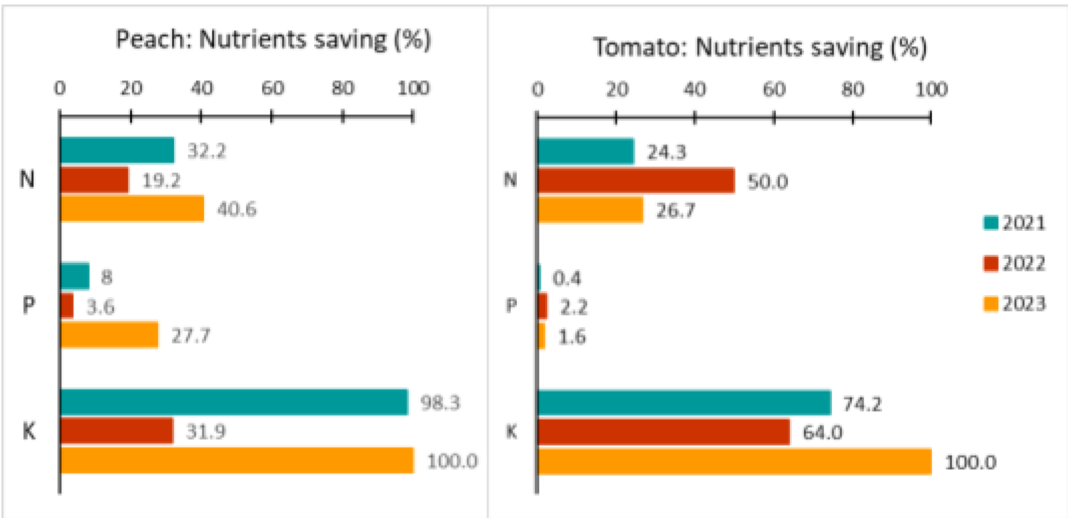

Figure 3. Peach and tomato nutrients saving (%) in 2021, 2022 and 2023.

Similarly, for tomatoes, nutrient savings percentages reached up to 50.0%, 2.2%, and 100.0% for nitrogen, phosphorus, and potassium, respectively (Figure 3). No adverse effects on soil or plant physiology were observed across the three seasons. Plants irrigated with wastewater exhibited comparable growth and productivity to the control treatment and no significant differences in fruit quality were found. The use of tertiary treated wastewater for fertigation didn't show any negative effects on soil properties and plant physiology for both crops. For peach tree, while treated wastewater slightly increased soil electrical conductivity and trace element concentrations, it did not adversely affect the plants' seasonal water status or lead to phytotoxic effects. When complemented with mineral fertigation, treated wastewater generally produced fruit similar to that of fruit from trees irrigated with fresh water from the qualitative point of view. Analyses of leaf and fruit mineral concentrations showed no accumulation of critical elements beyond the safety thresholds, proving that the resulting product is perfectly marketable and consumable. In the case of peach tree, the limited impact of water salinity observed over two consecutive seasons of daily treated wastewater irrigation suggests that this practice could be sustainable in commercial orchards, provided that autumn-spring rainfall or other water sources ensure adequate soil salt leaching.

Conclusion

This research presents a two years field study of reuse of secondary and tertiary treated wastewater for processing tomato and peach fertigation, showing suitability and benefits of this practice. The proposed smart fertigation system successfully contributed to satisfying a significant need of both macro and micronutrients during the irrigation seasons. Therefore, this innovative system can be exploited to save nutrients and to cope with the natural fluctuations in nutrients concentration in treated wastewater, especially since this practice has not shown negative effects. It was shown that under the same conditions, the growth and productivity of plants irrigated with wastewater are similar compared to the control ones irrigated with mains water.

Further studies will be needed to verify the sustainability of direct reuse of tertiary treated wastewater for crop fertigation, with respect to potentially problematic factors that this study did not address: these include the presence of emerging contaminants (CECs), long-term salinization of soils, and the conveying of bacteria and/or genes for antibiotic resistance.

Bibliography

Cirelli, G. L., Consoli, S., Licciardello, F., Aiello, R., Giuffrida, F., & Leonardi, C. (2012). Treated municipal wastewater reuse in vegetable production. *Agricultural Water Management*, *104*, 163–170. https://doi.org/10.1016/j.agwat.2011.12.011

García-Herrero, L., Lavrnić, S., Guerrieri, V., Toscano, A., Milani, M., Cirelli, G. L., & Vittuari, M. (2022). Cost-benefit of green infrastructures for water management: A sustainability assessment of full-scale constructed wetlands in Northern and Southern Italy. *Ecological Engineering*, *185*(February). https://doi.org/10.1016/j.ecoleng.2022.106797

Odone, G., Perulli, G. D., Mancuso, G., Lavrnić, S., & Toscano, A. (2024). A novel smart fertigation system for irrigation with treated wastewater: Effects on nutrient recovery, crop and soil. *Agricultural Water Management*, *297*, 108832. https://doi.org/10.1016/j.agwat.2024.108832

Pedrero, F., Kalavrouziotis, I., Alarcón, J. J., Koukoulakis, P., & Asano, T. (2010). Use of treated municipal wastewater in irrigated agriculture—Review of some practices in Spain and Greece. *Agricultural Water Management*, *97*(9), 1233–1241. https://doi.org/10.1016/j.agwat.2010.03.003