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Irrigation Water Management and Quality in Two Rocha Pear Orchards †

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Abstract: Tackling human malnutrition resulting from mineral deficits in foods is currently an agro-industrial problem. To address this problematic, an agronomic workflow to enrich Rocha pears in calcium (Ca) was considered in two orchards of Portugal. This study aims to assess quality differences in irrigation water of two orchards (of Rocha pear) where an agronomic Ca enrichment workflow would be performed, and identify possible conditioning to Ca increases in fruits. Thus, electrical conductivity (EC), pH, pHs, cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (HCO_3^-, Cl^-, SO_4^{2-}) were attained to calculate Sodium Adsorption Ratio (SAR) index and Langelier Saturation Index (LSI) and assess the agricultural use. Values of EC, pH, pHs, SAR index and LSI of both orchards varied between 1198 – 1211 μS/cm, 7.4 – 7.5, 7.7 – 8.1, 3.5 – 7.4 and -0.69 – -0.21. Regarding Piper classification, irrigation waters were classified as sodium bicarbonate (orchard 1) and sodium chloride bicarbonate (orchard 2). Both orchards presented different classifications regarding the agricultural use, namely C3S1 (orchard 2) and C3S2 (orchard 1). The water of both orchards presented the same salinity hazard (C3), but the use of these irrigation waters is enabled since these trees can be considered salt-tolerant. However, regarding the alkalinization hazard to soils, irrigation water from orchard 2 offers less danger (S1) in comparison to orchard 1 (S2). But a slight inferior LSI (orchard 1) can favor a higher tendency to dissolve calcium carbonate. In conclusion, although slightly –different, analysis indicate that waters of both orchards did not induce toxicity to Rocha pear trees.

Keywords: Irrigation water quality; LSI; Piper diagram; *Pyrus communis* L.; SAR index; Water hydrochemistry facies

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1. Introduction

Agroindustries are currently struggling to improve food quality and minimize mineral deficit in human diets, especially in meads of land and hydric shortage [1]. Agronomic biofortification is a practice focused on the use of soil fertilizers or foliar sprays that

increases levels of mineral elements in edible parts of plants [2]. In this regard, calcium (Ca) is a mineral element that if in deficit can promote bone deformations or condition mobility [3]. Furthermore, an increase in fruit consumption is expected [1] and Rocha pear (*Pyrus communis* L.) is a Portuguese variety of importance to the country`s market [4]. However, in comparison to smaller size crops where agronomic enrichment trials can be firstly performed in controlled environment chambers, for tree crops a field trial is often needed, which infatuates the importance of monitoring field conditions. Pear trees are not considered a drought resistance crop, with its production in dry climates being highly dependent on irrigation practices [5]. In Rocha pear orchards, drip irrigation systems can be used and can be one of the most efficient for this crop [6].

Agriculture is the sector with higher global freshwater use (about 70%), and with food demand bound to increase, the same is expected to happen to water resources [7]. It is also known that water supply to plants can affect the soils (moister, nutrient availability) and ultimately fruits quality, since water is crucial for nutrient absorption as well as maintenance of evapotranspiration processes among others [8]. Furthermore, the dissolution and precipitation of mineral elements can be related with chemical balances, water saturation and drainage conditions.

The Langelier Saturation Index (LSI) is used to verify the encrusting tendency that waters present in relation to calcium carbonate (positive values indicate encrustation tendencies, while negative values suggest a dissolution tendency of calcium carbonate) [9].

The Wilcox diagram relates salinity (C) and alkalinization (S) hazards, based on conductivity and Sodium Adsorption Ratio (SAR) index respectively [10]. The SAR index considers the ratio between the concentration of sodium (Na), Ca and magnesium (Mg) in the water, and the ionic balance between the soil and water. Thus, waters that are richer in Na relatively to Ca and Mg, tend to balance with the soil, dissolving Ca and Mg besides precipitating Na. Ultimately, these waters tend to leach Ca and Mg from the soil. In this context, variations of Ca in waters (for instance by fertirrigation practices) could affect the SAR index, and eventually impact agronomic enrichment workflows, namely the ones done with soil fertilizers in comparison to foliar sprays.

In this context, the following study aimed not only to evaluate quality differences between the irrigation water of two different orchards where Rocha pear variety is produced, but also identify possible conditionings to Ca increases in fruits.

2. Materials and Methods

2.1. Orchards Location

Both orchards are located in the West region of Portugal, in the same district (Leiria). Orchard 1 (GPS coordinates: 39°23′28.997′′N; 9°4′52.483′′O), is located in Caldas da Rainha region, and further north, orchard 2 is located in Alcobaça region (GPS coordinates: 39°29′52.641′′N; 9°1′19.604′′O). Both orchards had a drip irrigation system installed.

2.2. Irrigation Water Quality

Water samples were collected from both orchards in 10th September 2019. Electrical conductivity (EC), pH, pHs, cations (Na^+, K^+, Ca^{2+}, Mg^{2+}) and anions (HCO_3^-, Cl^-, SO_4^{2-}) were analysed as described in Daccak et al. (2023) [11]. The SAR index and LSI were then calculated.

3. Results

In Table 1 EC, pH, SAR index and pHs values of the irrigation water used in both orchards are shown.

Table 1. Values of electrical conductivity (EC), pH, Sodium Adsorption Ratio (SAR) index, pHs and Langelier Saturation Index (LSI) of irrigation waters from two Rocha pear orchards.

Parameter	Orchard 1	Orchard 2
EC (at 20 °C)	1211 µS/cm	1198 µS/cm
pH	7.4	7.5
SAR index	7.4	3.5
pHs	8.1	7.7
LSI	-0.69	-0.21

The projection of the hydrochemical facies in a Piper's triangular diagram (Figure 1), reveals that orchard 1 presents higher values of Na^+, K^+, SO_4^{2-} and HCO_3^- and inferior values of Ca^{2+}, Mg^{2+} and Cl^- than orchard 2. Water classification for agricultural use (Figure 2), presents similar values of EC while SAR index is superior in orchard 1.

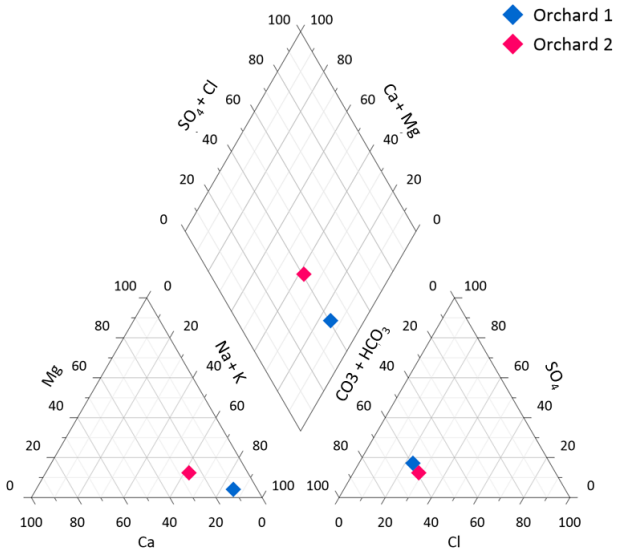

Figure 1. Classification of the hydrochemical facies of irrigation water (from two Rocha pear orchards) in a Piper's triangular diagram.

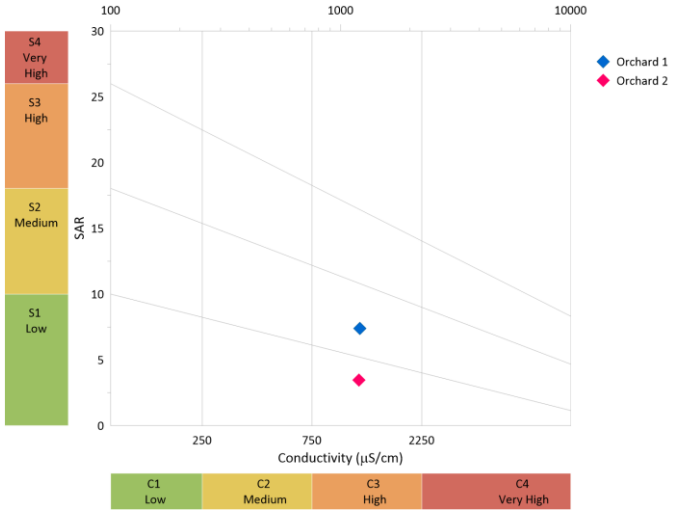

Figure 2. Water classification for agricultural use in Wilcox diagram, of irrigation waters from two Rocha pear orchards.

The irrigation water from both orchards differs slightly, with water from orchard 1 being sodium bicarbonate according to Piper classification, while orchard 2 was sodium chloride bicarbonate (Figure 1). Higher values of EC, SAR index and pHs were attained

for orchard 1 (Table 1), while orchard 2 presented higher values of pH and LSI (Table 1). Based on the EC and SAR index of these waters, both projected in the Wilcox diagram (Table 1, Figure 2), when regarding their agricultural use orchard 2 was classified as C3S1, while orchard 1 was classified as C3S2.

4. Discussion

Proper irrigation practices play a key role in fruit trees and poor management can compromise fruit size and quality [8]. Furthermore, the physical and chemical composition of irrigation waters provide information about its effects on crops (toxicity) and soils (impermeability and/or alkalinization), as well as maintenance of irrigation equipment's (risk of scaling and corrosion).

Orchards for Rocha pear production can be installed near water lines with a pH of 6 to 7.5 [12]. Also, irrigation water used in pome fruit crops should have an EC value lower than 3000 $\mu S\ cm^{-1}$ and a concentration of chloride ions (Cl^-) inferior to 355 $mg.L^{-1}$ [6]. The pH, EC and [Cl^-] values of both orchards (Table 1) (pH 7.4–7.5; EC–1198–1211 $\mu S\ cm^{-1}$; [Cl^-]–125 to 143 $mg.L^{-1}$, for orchard 1 and 2 respectively) are in accordance with these reference values. Additionally, EC values are related to the total content of dissolved salts in water (salinity hazard), and it is known that the uptake of water in the roots zone of crops can be hindered by higher salinity values of the soil solution. Thus, the accumulation of salts in the root zone can be harmful, since inhibition or reversal of the osmosis process can occur, compromising the acquisition of nutrients by pear trees from the soil [13]. Based on the information of Figure 2, higher concentration of salts (C3) observed in both orchards, makes its use in soils with poor drainage unadvisable, and even in soils with adequate drainage, it may be necessary to apply additional measures to control salinization [10]. Thus, regarding salinity hazard, both orchards present very similar values. However, crops such as Rocha pear trees can be considered salt-tolerant (since EC values should be less than 3000 $\mu S\ cm^{-1}$) [6] enabling the use of these irrigation waters for this crop.

Regarding the alkalinization hazard to soils, irrigation water from orchard 2 offers less danger of alkalinization (S1) in comparison to orchard 1 (S2), because the irrigation water used in orchard 2 has a lower concentration of Na^+ in comparison to Ca^{2+} and Mg^{2+} ions, which favors its use in almost all soil types [10]. Thus, in orchard 1 an increase in danger of soil alkalinization is observed, especially if the soils are poorly drained (with a predominance of fine textures such as clay) [10]. The SAR index is calculated based on Ca^{2+}, Mg^{2+} and Na^+ ions. Both Mg and Ca counteract the effects of Na, since waters with high values of SAR, can alter soil physical parameters since the adsorption of Na to soil particles promotes its hardening and compaction [14]. According to the same author [14], soils with finer textures are particularly affected, but the presence of high Ca and Mg contents in agricultural soils can counteract the mentioned effects. Thus, it should be noted that despite the increase in the SAR index, the danger of alkalinization in orchard 1 may have been minimized by higher Ca levels in the soil (data not shown) compared to orchard 2.

The irrigation of both orchards (as previously mentioned), is done through the localized method, namely drip irrigation, which is an irrigation method authorized for pear crops [6]. Based on the LSI (-0.69 and -0.21), the negative values indicate that these are waters with a non-fouling tendency, with slight propensity for dissolution because they are subsaturated in calcium carbonate and have a slightly corrosive tendency when circulating in pipes with this composition [9]. Orchard 1 showed a slightly higher tendency to dissolve calcium carbonate, which may favor Ca absorption, through the roots, and accumulation in the plant.

Overall, the values suggest that the water from both orchards cannot induce toxicity to the crop nor damage the soil in which they are located, and thus perhaps not compromise the biofortification route (by not damaging the soil in which the pear trees are located, nor compromising nutrient acquisition).

5. Conclusion

The irrigation waters used in both orchards presented a slight difference, namely when considering the alkalinization hazard to the soils in which the orchards are located.

When considering performing enrichment trials with fertilizer`s applications, fluctuation in the ratio between the concentration of Na, Ca and Mg in the water, as well as the ionic balance between the soil and the water should be considered since it could impact the outcome of these trials.

Since water is crucial for fruit development, the study indicates that the waters of both orchards do not induce toxicity to Rocha pear trees and damages the soil can be avoided with monitoring of both texture and mineral composition of soils. Overall, nutrient absorption appears to not have been conditioned, suggesting that fruits development was not impaired.

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