Use of reclaimed water for hop irrigation in Galicia and Castilla-León (Spain)

Cancela J.J., Rodríguez-Febereiro M., Teijeiro M.T. & Fandiño M.

GI-1716. Dpto. Ingeniería Agroforestal. Campus Terra. Universidad de Santiago de Compostela. Escuela Politécnica Superior de Enxeñaría, Campus Universitario s/n, 27002, Lugo, Spain; javierjose.cancela@usc.es

Abstract

The use and production of reclaimed water is regulated in Spain by Royal Decree 1085/2024, establishing agriculture (irrigation) as one of the possible uses. Within the I-ReWater project (Interreg SUDOE), two pilot actions were carried out in Abegondo (Galicia) and Cubillos del Sil (Castilla-León), irrigating with reclaimed water from an urban treatment plant during the 2024 season. The water status of the crop was monitored as well as hop quality and production. To guarantee the safety of water quality, analyses of the irrigation water (reclaimed and conventional) were carried out. The presence of nutrients in the reclaimed water did not affect hop cone yield in both action pilots, similar to other measured parameters, without significant differences between treatments, including qualitative aspects. The quantity of alpha and beta acids was similar in the hop cones irrigated with conventional resources (well or irrigation canal). Moreover, no variations were observed in the composition of essential oils. In global terms, reclaimed water to irrigate hops could be a safe water resource during drought periods, when no conventional water resources are available. First results show that no effects to production and quality were detected. Other micro-contaminants with possible presence in reclaimed water will be analyzed during the coming seasons.

Key words. Action pilots, hop cone yield, quality, essential oils.

Introduction

Climate change has generated the need to search water resources to cover hop water requirements during the growing season. In this way, policies to achieve a reliable water management are establishing innovative procedures based on “circular water management”, increasing water efficiency and water-saving, including the treated wastewater in the urban wastewater treatment plants (HUERTA et al. 2015). Regulation on minimum requirements for water reuse for agricultural irrigation entered into force in 2020 (REGULATION (EU) 2020/741), which was transposed into Spanish regulations in 2024 (ROYAL DECREE 1085/2024).

The objective of this study is to demonstrate the feasibility of using reclaimed water in hop cultivation in two regions of Spain (Galicia and León) by 2024. Two experimental irrigation treatments were implemented: well or canal water, versus a mix of conventional water with reclaimed water. The following aspects were evaluated: i) the plant water status and its response to irrigation; ii) yield assessment; and iii) the effects on hop cone quality (acids and essential oils).

Material and methods

The two pilot plots are located in Presedo-Abegondo (Galicia) (PRE) and Cubillos del Sil (Castilla-León) (CDS) (Fig. 1). PRE is characterized by Atlantic climate, with dry hot summers, and CDS by a subhumid continental Mediterranean climate, with dry, short and hot summers. In both cases, the hop variety is Nugget, established in 2008 in PRE and in 2022 in CDS. The drip irrigation dose is 0.89 mm h^{-1} (PRE) and 1.47 mm h^{-1} (CDS), applying in 2024 a total irrigation of 91 mm and 283 mm in PRE and CDS, respectively, from June to early September. The amount of reclaimed water applied through irrigation was 40 mm (PRE) and 167 mm (CDS), representing about 50% of total water applied next season.

Two irrigation water treatments were implemented: conventional water (PRE-well and CDS-irrigation canal) and a water mix (reclaimed water and conventional water). A total of three replicates were implemented per treatment and plot, with a total of 14 plants per experimental unit. All measurements were taken in each experimental unit (e.u.). BBCH scale was determined weekly from end of May to harvest, considering the average value of three plants per e.u. (ROSSBAUER et al. 1995). Well/Canal and reclaimed water were sampling, to determine analytical parameters (pH, SS, BOD_5, EC, Phosphorum, Nitrates and ammoniacal nitrogen) in laboratory during the irrigation period, to obtain the final amount nutrients applied with the irrigation water. Moreover, microbiological parameters were measure (nematode eggs, *Legionella* spp, *E. coli* and Taenia species) to determine compliance with water quality (Class C) as established by legislation (ROYAL DECREE 1085/2024).

To monitor plant water status, leaf water potential (Ψ_l) measurements were taken at solar noon every 7-10 days using a Scholander chamber (PMS-600, PMS Instrument, USA) in three healthy leaves per e.u., at 1.5-2.0 m above the ground. Moreover, stomatal conductance (g_s) was measured weekly with a porometer (SC1, Decagon Devices,USA) in market leaves from July to August. In order to control the irrigation volume applied to both treatments and plots, measures of soil water content were determined weekly from May to August, using a TDR-100 (Campbell Scientific, USA) with long stainless steel rods (60 cm) (FANDIÑO et al 2019).

At harvest time – PRE: 28 August, CDS: 2 September – a representative complete plant per e.u. was analysed by separating all cones manually from stems and leaves. Total green yield per plant was measured and two samples of 500 g (dry weight) were transported to Campus Terra facilities in Lugo. All hop cone samples were dried to a humidity of 10 % or higher. To determine alpha and beta acids and for quantification of essential oils (EBC 7.7 and EBC 7.10, respectively), one sample of dried hop cones (100 gr $sample^{-1}$) was sent to an external laboratory, and store in correct conditions until the final analysis.

Figure 1. Hydrographic limits (red lines) and location of Actions Pilots plots (blue points). Left: Abegondo (Galicia); Right: Cubillos del Sil (Castilla-León)

Results

The phenology of the two pilot actions was similar for both irrigation treatments (Fig. 2), with an advance of 15-20 days in CDS to reach BBCH stage 61 (flowering), compared to PRE. In the Galician plot an earlier harvest was required due to a severe fungal affection during August. Plant water status measure with Ψ_l and g_s (Fig. 3), showed similar trends to Ψ_l in both

treatments and plot, with a slightly higher values (-6.5 bar) in Galicia at the end of July. In relation to stomatal closure (g_s) lower values were measured during the whole growing season in CDS, without significant difference between Mix and Canal irrigation treatments. However, in Galicia, higher values were measured in well treatment plants in August. This aspect is related with the higher relative humidity and disease effects at the end of season.

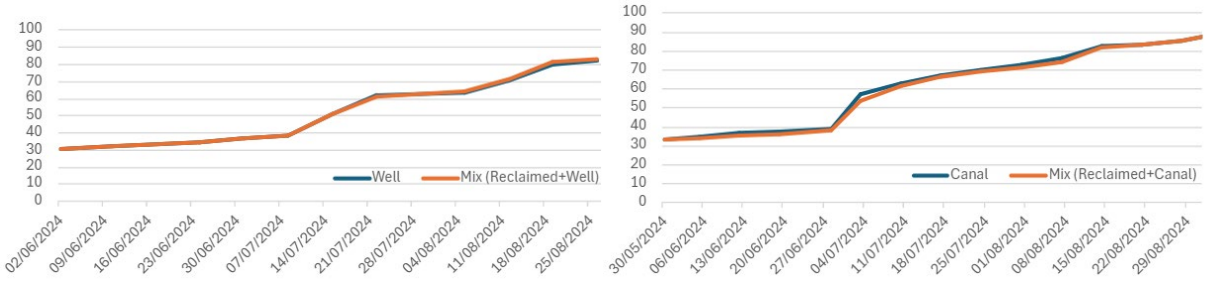

Figure 2. BBCH evolution in both action pilot - 2024 season. Left: Abegondo (Galicia); Right: Cubillos del Sil (Castilla-León)

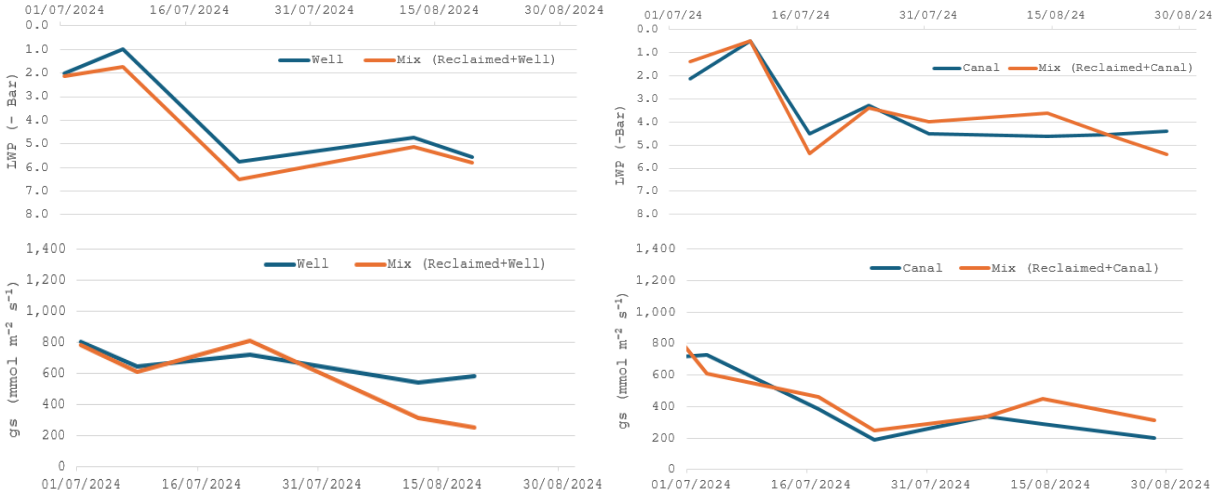

Figure 3. Leaf water potential (above) and conductance stomatal (below) dynamics - 2024 season. Left: Abegondo (Galicia); Right: Cubillos del Sil (Castilla-León)

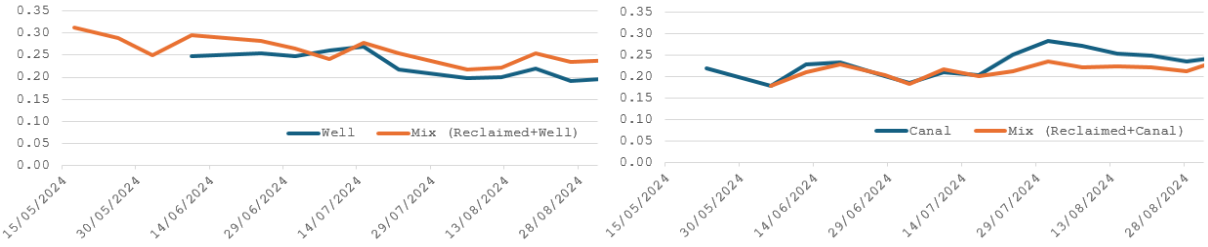

Figure 4. Soil water content ($m^3\ m^{-3}$) dynamics - 2024 season. Left: Abegondo (Galicia); Right: Cubillos del Sil (Castilla-León)

Dynamic of soil water content was similar to both treatments, with higher average values of SWC in PRE (0.25 $m^3\ m^{-3}$) than CDS (0.22 $m^3\ m^{-3}$), related mainly with soil conditions (Fig. 4).

In global terms, yield has similar to both treatments in PRE and CDS, but a higher production was obtained in CDS (Table 1). Drying process were irregular, with difference between

treatments, especially in Galicia. No significate difference were obtained to quality parameters, but a trend to higher α-acids, β-acids and myrcene was determined in Mix irrigated treatments.

Table 1. Yield and quality parameters in Galicia (PRE) and Castilla-León (CDS).

Plot & Treatment	Dry cones (kg ha^{-1})	Humidity (%)	α-acids	β-acids	Essential oils (ml /100g)	Myrcene (% Total oils)
PRE-Well	860.7	14.7	9.83	3.75	1.03	46.4
PRE-Mix	748.1	18.5	10.35	3.90	0.89	47.5
CDS-Canal	2579.9	13.0	10.27	2.67	1.42	61.5
CDS-Mix	2677.5	13.4	10.70	2.80	1.62	63.8

Discussion

The use of reclaimed water, mixed with conventional irrigation water, proved to have neither short-term impact on the plant's water status nor on the yield and quality parameters of the final product. Especial relevant were the nutrients added. The contribution of nutrients, ammonium nitrogen and nitrates, was different in both plots compared to the control (Well or Canal). In the case of PRE, there was an input of 1 kg/ha in the irrigation water for both NH4-N and NO3-N, while in the case of CDS, 2 kg/ha of ammonium nitrogen and 5 kg/ha of nitrates were added. The higher nutrient inputs in the Mix treatment could be responsible for an increase in the amount of alpha and beta acids, as well as the higher production per hectare in CDS. The PRE plantation was severely affected by a fungal attack, so the production and quality results should be viewed with caution. In summary, the use of reclaimed water offers good expectations in terms of production and quality, although the safety of this resource's quality and handling is high. Other micro-contaminants in the reclaimed water should be analyzed to determine a possible risk of soil degradation, or accumulation effects in a long-term way, avoiding negative effects on the crop.

Acknowledgement

This study was supported by the project ‘Sustainable management of water resources in irrigated agriculture in the SUDOE area (I-ReWater-S1/2.5/E0136)’ co-funded by the programme INTERREG SUDOE. Especial thanks to GESTAGUA to facilitate reclaimed water resource in both study areas. Thanks to all entities involved in the experiment: LU.TE.GA., Concello de Carballo, SAT Lúpulos de León, Lúpulos del Bierzo and Concello de Lugo.

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