Water saving in rice irrigation: assessment of alternate wetting and drying flooding in the Center of Portugal

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Abstract

Continuous flooding irrigation of rice is highly demanding on water compared to the irrigation methods for most other crops. Despite the great advances due to precision land leveling, there are still some recognized problems related with water scarcity and pollution. Saving water in rice production becomes a priority, to safeguard its economic and environmental sustainability. To contribute to this solution, an experimental study of alternate wetting and drying flooding (AWD) was carried out in the Center of Portugal in farmer's paddies, using the methodology of field irrigation evaluation, under the MEDWATERICE project. It was concluded that the AWD technique should be applied after the reproductive phase, through 2 to 4 drying cycles, with a dry period of 4-5 days in each cycle, allowing water savings in relation to the traditional continuous flooding of about 10%-13%, an additional 10-20 days with dry soil, without significantly compromising rice production. It was also concluded that the process of application and extension of AWD must be guided by a progressive adaptation of irrigation techniques, to obtain consolidated knowledge adaptable to local conditions, to limit the risks of loss of income and to build confidence in farmers for technological change.

Keywords: Oryza sativa L., AWD, MEDWATERICE, www.medwaterice.org, Lis Valley, Lower Mondego Valley.

1. Introduction

Rice (*Oryza sativa* L.) is the worldwide major staple crop, cultivated over 164 Mha (AQUASTAT/FAO, 2022), essential for ensuring global food security, given that over 90% of production is used directly for human consumption. In Portugal, rice is cultivated in about 30 thousand ha, in lowland areas and coastal wetlands, with a particular role in the preservation of the biodiversity and soil conservation. Rice is cultivated in paddies and traditionally is irrigated by wet seeding and continuous flooding (CF). Facing the increasing threat of water scarcity, it urges developing agronomic and irrigation practices to reduce water use, while maintaining or increasing land and water productivity. In short, the efforts for sustainability of rice crop are of strategic importance in the context of food security (Reba and Massey, 2020).

Alternate wetting and drying irrigation (AWD) consists of intermittent flooding, through a sequence of flooding cycles with very thin water depths (about 5 cm), followed by drying periods. The recession is only due to infiltration and evaporation, leaving, the soil surface layer in a non-saturation condition for a few days (a condition called "dry soil", in contrast to "flooded soil"), until the next reflooding cycle (Richards & Sander, 2014). The benefits of AWD, when compared with CF, include the irrigation water savings, by up to 30%, due to the decrease of deep percolation, facing a lower soil water pressure, and a decrease of the soil evaporation, the reduction of greenhouse gas emissions (methane plus nitrous oxide) by 45–90%, the reduction of the arsenic accumulation in the grain by 50%, and reduction of methylmercury concentrations in rice grain by 38–60% and in the soil (Linquist et al., 2014; Tanner et al., 2018).

The objective of this field experimental study was to test the AWD rice irrigation strategy as a water saving alternative to the conventional continuous flooding. This research was carried out on Center of Portugal, sponsored by the project MEDWATERICE.

2. Materials and Methods

The experimental study was carried out in 2020 and 2021 seasons in the Lower-Mondego and in the Lis Valley Irrigation Districts, located in Coastal Center of Portugal, with a total irrigated area of about 14,000 ha, and a rice area of about 6,000 ha. This region has a Mediterranean climate, Csb and Csa of Köppen classification, with an annual average precipitation of about 800 mm to 900 mm. It has temperate and mild summers, with virtually no rainfall, and rainy winters with mild temperatures (Figure 1). The soils are mainly alluvial with high agricultural quality, some of which are poorly drained, with waterlogging and salinization risks, particularly on the downstream areas where rice is cultivated in paddies. The river water used for irrigation is diverted and conveyed mainly by gravity, from weirs, through a collective system managed by Water User's Associations (Gonçalves et al., 2022).

The experimental AWD design, at each one of the three experimental sites (QC, BB, NG sites), consisted of two rice plots located in identical edaphoclimatic conditions, one irrigated by CF and the other by AWD. A single Italian rice cultivar, Ariete (japonica type), classified as semi-early, with a cycle of about 139-150 days, was used in all the sites. It was sown in mid-May, and harvested throughout October, and was fertilized with doses of about 70-90 kg N/ha. The methodology adopted in the AWD plots was based on those of Bouman et al. (2007), in the framework of the Mild version, being the experimental procedure described by Gonçalves et al. (2022).

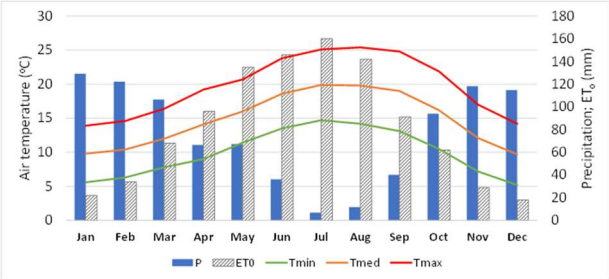

Figure 1. Average monthly air temperature, precipitation and reference evapotranspiration of the Lower Mondego study area (P—precipitation; ET0—reference evapotranspiration; Tmin—minimum air temperature; Tmed—medium air temperature; Tmax—maximum air temperature) (source: www.ipma.pt).

3. Results and Discussion

The characterization of the traditional CF practice, illustrated in Figure 2 with data from the NG site in the 2021 season, evidenced the contrast with the dry periods in the AWD treatment. The AWD technique was applied, making up to three wet-dry cycles, until the final period of 30 days before the harvest. These cycles corresponded to a period three weeks, with irrigation depths between 72 and 210 mm, and 4 to 6 days with dry soil, per cycle.

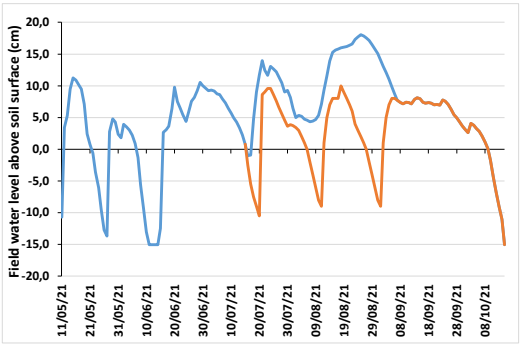

Figure 2. Water level above and below the soil surface (cm) of CF (blue line) and AWD (orange line) irrigation during 2021 rice crop season in NG site, Lis Valley.

The increase in time with dry soil due to AWD, in contrast with CF, was within the interval 10 to 29 days.

The irrigation water use (IWU), yield (Y, unhusked grain with 14% of humidity), and the irrigation water productivity (kg/m^3) for the three sites and both crop seasons, are presented in Table 1. These results correspond to AWD relative water savings (ΔIWU) of 9.5% to 29%, which corresponds mainly to the decrease of deep percolation. These results also highlight that a high severity of water stress could significantly affect the yield, like the example of BB site in 2021, in which ΔIWU of -29% implied a relative decrease of yield (ΔY) of 20%, a value too high, and economically unacceptable. These results prove that the management of the mild AWD requires an accurate irrigation control to avoid excessive plant stress.

The water productivity increased in all trials, showing this positive perspective of AWD. However, yield varied significantly between the sites, possibly due to the local edaphoclimatic conditions (Table 1).

Table 1. AWD water use and farm productivity results, and comparison with CF (relative differences).

Plot, year	IWU (mm)	Y (t/ha)	IWP (kg/m^3)	ΔIWU (%)	ΔY (%)	ΔIWP (%)
QC-20	1388	9.25	0.666	-12.6	-3.4	10.5
QC-21	1235	6.95	0.562	-9.85	-7.4	2.76
BB-20	1522	8.12	0,534	-11.8	0.28	13.7
BB-21	1350	4.13	0.306	-29.0	-20.0	13.3
NG-20	1169	5.66	0.484	-9.52	-5.6	4.36
NG-21	1220	6.30	0.516	-10.4	0.0	11.6

4. Conclusions

This study confirmed the interest of the AWD irrigation of rice paddies in the Center of Portugal, a technique to be applied after the reproductive phase of the crop. AWD technique should be applied after the reproductive phase, through 2 to 4 drying cycles, with a dry period of 4-5 days in each cycle, allowing water savings in relation to the traditional continuous flooding of about 10%-13%, an additional 10-20 days with dry soil, without significantly compromising rice production. It was also concluded that the process of application and extension of AWD must be guided by a progressive adaptation of irrigation techniques, to obtain consolidated knowledge and adapted to local conditions, to limit the risks of loss of income and to build up the confidence in farmers for technological change.

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