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Water use efficiency in two-flood management systems in Southern Spain

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Abstract. In Southern Spain, Andalucia, the surface of rice growing is about 35.000 has except in years of water shortage.

Preliminary studies about the effect of two flooding management systems, irrigating seven days a week (traditional continuously flooding system) or five days a week (maintaining the traditional continuously irrigation until 55 days after seeding and then closing the inlet gates two days a week), were carried out.

Similar responses have been found in both systems about rice growth and yield. A significant water saving, 5.184 m^3/ha, without grain yield decreasing, was obtained with the new system.

Key Words. Rice – Flooding management – Water requirement – Water efficiency – Growth and yield.

Andalucia rice area is located in the final stretch of the Gualdalquivir river, between Sevilla and the river mouth, covering both banks, in the "Marismas" marshlands. Rice is grown under a Mediterranean (temperate) climate characterized by a warm and dry summer, long growing season and getting high rice yields. The soil is clayey and saline, poorly drained with impervious claypans and sedimentary origin. Rice production in Andalucia is highly mechanized, including laser technology, self-propelled combines and aircraft utilization for seeding and pest control.

Nitrogen fertilization is applied before initial flooding. It is rare topdressing application. Thaibonnet (L-202), early long grain cultivar, occupies most of the rice acreage (Aguilar et al., 1997).

The irrigation water is pumped up from the river, less than 5 percent is pumped from wells. The water is supplied by irrigation districts and conveyed through channels to the rice farms. The salty tidal sea water tends to flow upstream while the fresh water flows in the opposite direction (intrusion). At least a 25 m^3/s river flow of fresh water is necessary to avoid a saline content in the central rice zone above 0.8 g ClNa/l which carries out a reduction in rice yield. Rice paddies are irrigated under a continuously flooded, flow-through system (lowland irrigated rice).

Irrigation system consist of a series of basins (1-3) surrounded by levees at successively lower elevations. Water is supplied serially from the topmost to the bottommost "check". Supplies of water into the uppermost basin is controlled by one or, more frecuently, several inlet gates. Water depth in the paddy is controlled by drop structures called "boxes" placed in the lower levee of each basin to permit flow into lower basins or from the lowest basin into a drain canal by one or several outlet gates. Water depth may be increased or decreased by adding or removing flash boards which are set in grooves in the sides of the rice boxes.

Water is supplied to each basin from a delivery ditch. Drain water use is frequent

Initial flooding must be done in a way the checks fill quickly. Seeding must be immediately carried out after flooding in order to rice can compete efficiently with weeds. It is necessary to control water height in

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the check to get an accurate control of weeds and pesticide movement, a vigorous rice stand, young panicle developing protection and drainage the paddy about two weeks before harvest to increase combine efficiency. Timing of drainage is very important. Seasonal water delivery for Andalucìa rice crop ranges from 20 000 to 40 000 m^3/ha. It depends on type of soil, district policy, etc. This water requirement is high because the paddies are continuously flooded, salt content in the soil must be reduced, and farmers consider oxygenated water enhances grain yield. Losses due to spillage of water at the lower ends of rice fields are very high, between 11 000 and 31 000 m^3/ha. Evapotranspiration is about 9 000 m^3/ha and percolation is negligible. Average seasonal rainfall is about 90 mm.

Flooded rice culture requires large water quantities. Permanent flooded conditions provide a continuos supply of water and oxygen, reduce ammonium fertilizer losses, enhance nutrients availability such as phosphorus, manganese, iron, etc. (Patrick et al., 1985). Typical seasonal water delivery for California rice is estimated to be 4.5 to 7.5 acre-feet. Three to 3.5 acre-feet are required for evapotranspiration, and in most rice soils 0.5 to 2 acre-feet go to deep percolation. Although rice is flooded throughout most of the growing season, net water use is similar to that of pasture, alfalfa or cotton (Hill et al., 1992). Water represents a major and necessary production cost for rice farmers. De Datta (1975) indicates that rice does not require continuously conditions for getting high yields and more than 7 t/ha have been recorded under upland condition. Continuously flooding system is applied as a management tool not like a specific requirement of the crop. Farmers have to face increasing competitive use of irrigation water. Different methods of irrigation should be studied to save water in the rice production.

Water saving is a major concern in Southern Spain rice area. This paper shows the preliminary studies about the response of rice crop to two flood management systems, traditional continuously flooding and only five days a week flooding system (maintaining the traditional system until 55 days after seeding).

I – Material and Methods

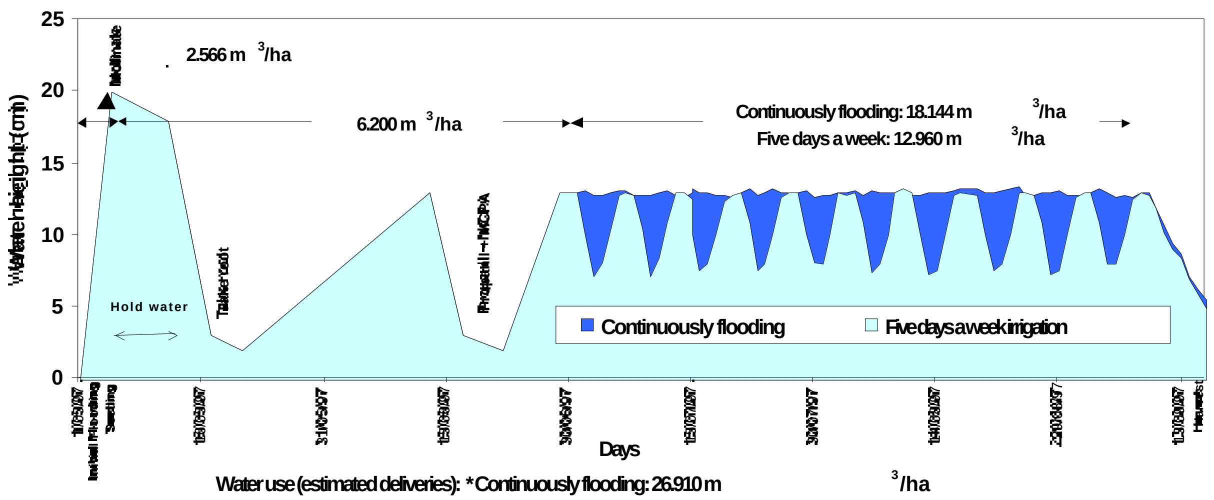
The experiment was conducted in 1997 on a typical clayey soil (Table 1) in Villafranco del Guadalquivir (Seville) to find out the response of the major commercial rice cultivar in the rice area, Thaibonnet, to two different irrigation systems: The traditional continuously flooding system (irrigating seven days a week) and irrigating only five days a week (maintaining the traditional system until 55 days after seeding) system.

Table 1. Some physical and chemical characteristics of experimental soil

Components	Depth: 0-20 cm
Clay (%)	47
Loam (%)	35
Sand (%)	18
PH	7,9
Organic matter ($^{o}/_{o}$)	2.01
Total Nitrogen ($^{o}/_{oo}$)	1.24
Total Phosphorous ($^{o}/_{oo}$)	1.18
Exchangeable Potassium (ppm)	369
E. C. (Extr. 1:5)	1.69 dS/m

After sedge and broadleaf herbicides application, about 50 days after seeding, the usual water delivery per hectare is about 3 l/s, maintaining this flow until two weeks before harvest (Figure 1). During that period, with the new irrigation system (five days a week) we have closed the inlet gates two days a week and compared rice growth and yield responses. In this way, the flow rate in the four elemental plots was calibrate in order to get 3 $l \cdot s^{-1} \cdot ha^{-1}$ when irrigated. In a seven days a week plot was recorded the seasonal water delivery. Studies by water scientists in the Guadalquivir Hydrographic Institute have provided estimated of seasonal evapotranspiration from rice fields about 890 mm. Percolation is negligible.

Fig. 1. Water height evolution in a rice paddy. Continuously versus five days a week flooding system. Sevile (Spain) 1997.



Water use (estimated deliveries): *Continuously flooding: 26.910 m3/ha
* Five days a week: 21.726 m3/ha

The experiment was a complete randomized block design with two replications. Elemental plots were 6.25 ha sized. The seeding was performed by hand on May 4th and the harvest on September 18th by combine. Standard cultural procedures were adopted. Phosphorus (50 kg/ha P_2O_5) and nitrogen (150 kg/ha), like urea 46%, were applied before seeding as recommended.

Recorded observations included: heading cycle (days from sowing to 50% heading), ripening cycle (20% grain humidity), plant height (between the ground and the tip of the panicle in flowering), lodging in harvest time (de visu), panicles/m^2 (mean of four samples, 0.25 m^2/sample), grains/panicle (mean of 40 panicles, considering the sum of blank and filled grains), blank grains (%), weight of 1000 grains, grain yield (the whole plot was harvested) and water height evolution (a stick meter was placed in each elemental plot).

Water use efficiency in both flooding management systems was determined.

II – Results and discussion

In Southern Spain rice area, the average water balance in a paddy may be resumed as follows:

- ❑ Deliveries: from 20 000 to 40 000 m^3/ha.
- ❑ Rainfall (May-September) = 90 mm.
- ❑ ET (Evapotraspiration) = 890 mm.
- ❑ Percolation is negligible because soil is impervious.
- ❑ Spillage (run off): from 11 000 to 31 000 m^3/ha.
- ❑ Recycling (reuse of drain water) is frequent.
  When no recycling: use > consumption.

Under our experimental conditions, estimated deliveries and water height evolution in both flooding management systems are shown in Figure 1. With respect the traditional irrigation system we can save 5 184 m^3/ha (26 910-21 726 m^3/ha) if watering only five days a week during the last 3 months of the rice growth. During a ten weeks period, two days a week, inlet gates were closed when irrigating with the new system (20 days x 3 l seg-1 ha-1= 5 184 m^3/ha).

The main result observed in Table 2 is that similar responses have been got about rice growth and yield in both water management systems.

If the new irrigation system is applied, farmers can reach the same grain yield with a significant water saving.

A higher water use efficiency was obtained with the new five days a week irrigation system (Table 3). We considered spillage is high enough so new experiments must be carried out to decrease, if convenient, water deliveries in the Andalucia rice paddies.

Table 2. Effect of two water management systems on rice growth and yield. Seville (Spain) 1997

	Days to heading	**Days to maturity 20%**	**Plant height** (cm)	**Lodging** (%)	**Panicles** (m^2)	**Grains/ panicle**	**Blanks** (%)	**Grains weight x1000** (g)	**Yield 14% moisture** (kg/ha)
Continuously Flooding	89	136	73.3	0	791	54	12,0	28.7	8 267
Five days a week	89	135	72.6	0	782	53	12,1	29.1	8 319

Table 3. Water use efficiency in two flood management systems. Seville (Spain) 1997

	Water (mm) **Continuously Flooding**	**Five days a week**
Irrigation	2.691	2.173
Rainfall	90	90
Total	2.781	2.263
Evapotranspiration	890	890
Percolation	0	0
Total	**890**	**890**
Evapotranspiraton (mm)	890	890
Water use efficiency	890/2.781=0,32	890/2.263=0,39
Grain yield (kg ha^{-1})	8.267	8.319
Efficiency (kg ha^{-1} mm^{-1})	8.267/890=9,28	8.319/890=9,34

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