RICE YIELD COMPONENTS UNDER WATER STRESS IMPOSED AT DIFFERENT GROWTH STAGES

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Keywords: *Oryza sativa*; productivity; water demand.

INTRODUCTION

Rice is a staple food for nearly half the world's population, being cultivated in 112 countries, with 90% of the global production concentrated in Asia. In Brazil, about 3 million hectares of rice are cultivated every year and the cereal is important part of Brazilians diet, regardless of social class (GOMES & MAGALHÃES Jr., 2004).

The demand for water in flooded rice cultivation is considerably higher than the water requirement of crops traditionally sprinkler irrigated, such as soybeans and corn. This raises a series of questions regarding to water use efficiency and environmental impact caused by rice cultivation.

Sprinkler irrigation by pivots and linears has been, and continues to be, tested for rice cultivation. There are claims for 50% water savings when rice is grown under pivot irrigation when compared to continuous flooding (PARFITT et al., 2011). This is mainly observed when the system is installed in uneven areas or in fields with significant slope, as well as where water is scarce.

In order to support rice growing systems which demand less water and help environmental conservation, there is need to understand how rice grain yield is affected by water stress imposed at different phenological stages of the crop.

Rice yield components are factors greatly responsible for its productivity (GOMES & MAGALHÃES Jr., 2004). For instance, water content in plants is important for keeping hydration, maintaining cell turgidity for structure and growth; it is also responsible for the transport of nutrients and organic compounds into the plant, which are the greatest determiners of crop productivity (GUREVITCH et al., 2009).

We aimed with this study to assess rice yield components as function of water stress levels imposed at different stages of crop development.

MATERIAL AND METHODS

The experiment was installed in a greenhouse with controlled environment at Embrapa Clima Temperado, Pelotas-RS, Brazil, during the traditional rice growing season. We used a randomized complete-block design with plots arranged in a factorial scheme, 3 x 4 + 1, with four replications. The rice variety was BRS-Querencia, with early cycle duration. Factor "A" comprised the growth stage when water stress was imposed on the treatments, being (1) vegetative (tillering start through panicle differentiation), (2) reproductive 1 (panicle

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differentiation through anthesis), and (3) reproductive 2 (anthesis through ripening start). Factor "B" comprised the four levels of water stress imposed on the plants. The additional treatment consisted of a constantly flooded treatment (control).

From emergence to the beginning of tillering, all plots were maintained with soil water tension less than 10 kPa – including plots which would be flooded from tillering onward. Every time the treatment reached the threshold level of water deficit, it was irrigated back to saturation. Treatments which were not at the developmental stage when the stress was to be applied, were maintained under 10 kPa. Treatments are listed in Table 1.

Table 1. Water stress levels (treatments) studied under controlled environment aiming to assess the impact on crop productivity.

FACTOR "B" - Water Tension (kPa)	FACTOR "A" - Crop Stage with Water Stress *		
	Vegetative (v)	Reproductive 1 (R1)	Reproductive 2 (R2)
0 (Flooded)	0 (7cm layer)	0 (7cm layer)	0 (7cm layer)
10	0 – 10 kPa	0 – 10 kPa	0 – 10 kPa
30	0 – 30 kPa	0 – 30 kPa	0 – 30 kPa
60	- - -	0 – 60 kPa	0 – 60 kPa
100	0 – 100 kPa	- - -	- - -
130	- - -	0 – 130 kPa	0 – 130 kPa
200	0 – 200 kPa	- - -	- - -

* When not under the moment where the stress was to be applied, all treatments (except the flooded check) were kept below 10 kPa.

Experimental units consisted of black plastic pots, each with capacity of 12 L, filled with 10 kg of previously corrected and fertilized soil. The soil used at the experiment was collected in agriculture-free natural areas near rice fields at Terras Baixas Experimental Station, Capão do Leão, RS, Brazil. Soil was fertilized with N-P-K and corrected for pH 6.0 with ground limestone. In rice fields, pH is usually not corrected because the water layer is enough to correct the pH after flooding is established, but as most plots of the trial were not going to be submitted to flooding, we decided to correct soil pH in order to guarantee equal soil pH conditions for all plots. Seven rice seeds were planted into each experimental unit, and after emergence the five most homogeneous plants were maintained.

Water stress was monitored by using sets of Watermark electro-tensiometers (Irrometer Co.), with a single sensor installed in each experimental unit (pot), at 10 cm soil depth. Temperature sensors were also installed at 10 cm soil depth.

At the end of the cycle, all panicles were counted and collected, per plant, for further analysis. In the lab, grains per panicle were counted, being classified either as whole kernel or aborted grains, whose results were used for obtaining sterility percentage. Whole kernel grains were weighted for obtaining the 1000 grains weight for each treatment, and the consequent plant grain yields. Data were analyzed into the "R" statistical environment (R CORE TEAM, 2016).

RESULTS AND DISCUSSION

As expected, the number of panicles per plant (Figure 1) was not affected when the water stress was imposed after panicle initiation, since this variable is defined at the vegetative cycle, between germination and ten days after panicle primordium is visible

(MAUAD et al., 2003). Directly or indirectly, nitrogen fertilization, water stress, environmental conditions and tiller number will define the number of panicles per plant (GOMES & MAGALHÃES Jr., 2004). Thus, water stress at tillering reduced the number of panicles per plant, as previously discussed, being this one of the definers of panicle number.

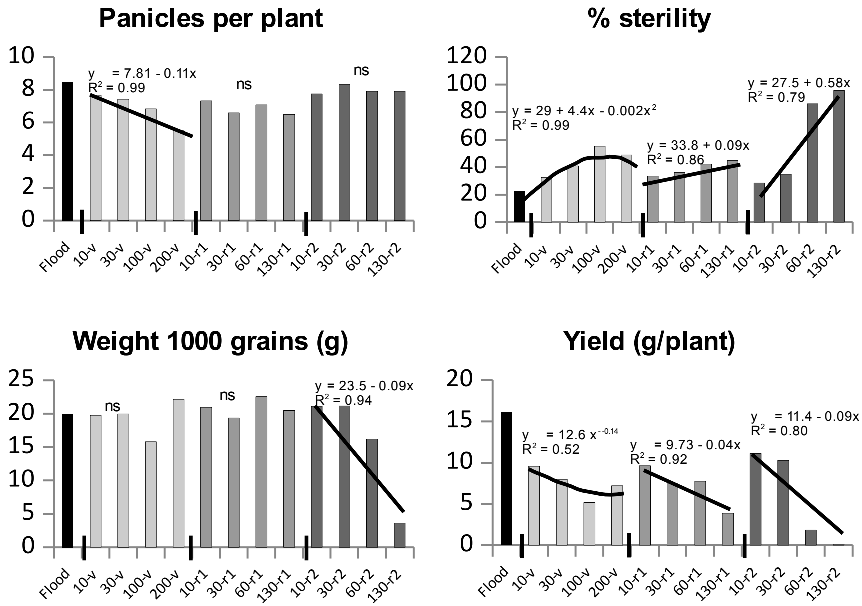

Figure 1. Panicles per plant, grain sterility (%), weight of 100 grains (g) and rice grain yield (g plant^{-1}) as function of water stress levels imposed at distinct phenological stages under controlled environment.

Rice grains sterility (Figure 1) was affected by the water stress applied to any developmental stage. At grain filling ("r2"), however, the water stress promoted grains sterility higher than 90% at stress levels above 60 kPa. In fact, grain filling (and consequently grain sterility) is mostly determined between rice crop stages R4 (anthesis) and R9 (harvest), the period when most of the photosynthates are directed to grain filling (GUREVITCH et al., 2009). As plants may directed reserves to form roots when under stress (Pascual & Wang, 2017), for the treatment imposed at "R2" it is likely that there was not enough carbohydrates to fill all rice grains formed during panicle development (rice stages R0 to R4).

Regarding only the filled grains, rice grain weight (Figure 1) was only reduced where carbohydrates were most probably directed to the primary metabolism aiming survival, and possibly also to root formation in detriment of grain filling (60 kPa - 130 kPa, applied to the R2 stage). The weight of 1000 grains for Brazilian rice varieties (long and thin grain type) is about 23 - 30 g (SOARES et al., 2010; LEITE et al., 2011), which was also observed in the present study when the stress was imposed previously to anthesis. When stress was imposed at R2, rice grains (1000) weighted less than 5 g, practically halting rice grain yield. In addition, supposing these low weight grains were screened for viability, most of them would be sterile (AKIL & ARAUJO, 1977).

Rice grain yield is a result of the number of panicles per area, number of grains per panicle and grain weight, which are termed “yield components” (GOMES & MAGALHÃES Jr., 2004). Lower rice grain yield was observed even when treatments were maintained under 10 kPa all along the crop cycle, compared to the flooded treatment. One have to consider, however, that in studies conducted under controlled environments, treatment effects are usually intensified compared to studies installed in field conditions (STEFFEN et al., 2010). Thus, these results should be further evaluated in field trials.

CONCLUSIONS

The number of panicles per plant was not affected when stress was imposed after panicle initiation, but when imposed at tillering it reduced the number of panicles per plant;

At grain filling (“R2”), water stress promoted grains sterility higher than 90%;

Grain weight was only reduced when carbohydrates were directed to root formation in detriment of grain filling (60-R2 and 130-R2);

Lower rice grain yield per plant was observed even when treatments were maintained under 10kPa all along the cycle in relation to the flooded treatment.

ACKNOWLEDGEMENTS

To Valmont Industries – Irrigation Division, Omaha-NE, USA, for the financial and technical support with data logger hardware that made possible to install the present study.

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