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ORIGINAL ARTICLE

Effect of Water Stress on Rice Regrowth Crop. Second Part

Efecto del estrés hídrico en el cultivo de rebrote (*Oryza sativa* L.). Segunda parte

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ABSTRACT: The research was conducted at "Los Palacios" Scientific and Technological Base Unit, from 2014 to 2017, on a Gleysol Nodular Ferruginous Petroferric soil, to evaluate the effect of water stress on the yield in the regrowth crop in a variety of short -cycle rice INCA LP-5. The results showed that in the new variant of water managing (water stress with ratoon), the highest agricultural and industrial yields of the grain were obtained. They ranged between 4,0 and 5,8 t.ha^{-1} and 62,3 and 63 , 9% of whole grains, respectively, for the plant cutting height of 5 cm. The lowest agricultural and industrial yields ranged between 3,0 and 3,4 t.ha^{-1} and 58,6 and 61 , 1% of whole grains, respectively, for the plant cutting height of 20 cm (control), during the four years that the research was carried out. Similar behavior presented the number of panicles per square meter; while the water consumption and the industrial quality of the grain was lower in the variant with water stress, which represents a saving for the concept of irrigation water economy, and a fundamental parameter that decides whether a rice variety is commercially accepted.

Keywords: rice, water, whole grains, quality.

RESUMEN: La investigación se condujo en la Unidad Científico Tecnológica de Base "Los Palacios", desde el año 2014 hasta el 2017, sobre un suelo Gleysol Nodular Ferruginoso Petroférrico, para evaluar el efecto del estrés hídrico sobre el rendimiento en el cultivo de rebrote en la variedad de ciclo corto INCA LP-5. Los resultados arrojaron que en la nueva variante de manejar el agua (estrés hídrico con rebrote) se obtuvo el mayor rendimiento agrícola e industrial del grano, que oscilaron entre 4,0 y 5,8 t.ha^{-1} y 62,3 y 63,9 % de granos enteros respectivamente, para la altura de corte de la planta de 5 cm, mientras que, los rendimientos agrícolas e industrial más bajos oscilaron entre 3,0 y 3,4 t.ha^{-1} y 58,6 y 61,1 % de granos enteros respectivamente, para la altura de corte de la planta de 20 cm (testigo), durante los cuatro años que se desarrolló la investigación. Similar comportamiento presentó el número de panículas por metro cuadrado; mientras que el consumo de agua y la calidad industrial del grano fue menor en la variante con estrés hídrico, lo que representa un ahorro por concepto de economía del agua de riego, y un parámetro fundamental que decide si una variedad de arroz sea aceptada comercialmente.

Palabras clave: arroz, agua, granos enteros, calidad.

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop for human consumption, it constitutes the basic food for more than half of the world population (Ruiz *et al.*, 2014). According to FAO, the world production of this crop has been increasing in recent years concentrated mostly in the main producing countries: China, India and Indonesia, which account for almost two thirds of world production (FAOSTAT, 2015).

In Cuba, this cereal is a basic food of the Cuban population, so that the national rice production does not satisfy domestic demand, hence more than 40% of this product, that is destined for the consumption of the population, is imported (Minag, 2014).

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Water is one of the most important inputs for any crop and especially rice Jahan y Jesperson (2015); PUND (2016); the reduction in the use of this input, in addition to a sustainable increase in rice production in the country, is achieved by using the regrowth rice crop also known as soca or sapling.

One of the advantages of the shoot is that the production cycle is shorter than the main harvest. In addition, the production costs are substantially reduced, because the soil must not be prepared, leveled, sown, seed does not have to be acquired, and fertilizers are used in less quantity than in the main crop. Likewise, it requires less irrigation, because it ripens more quickly and the use of the land is more efficient, because erosion is avoided.

In the cooperative production sector, agricultural yields are reported, with the use of the regrowth crop, fluctuating between 2,5 and 4,27 t. ha $^{-1}$ with excellent industrial grain quality, crystal clear grains, no white belly in the grain. In addition, the total production of several cultivars, such as INCA LP-5, INCA LP-7 and J-104, is higher than 10 t ha $^{-1}$, being able to recommend them for use in production for this purpose (Castro *et al.*, 2014).

In Cuba, in research carried out under both research and production conditions, a considerable reduction of irrigation water in this farming system is reported, up to 40% with a variety of medium cycle (Polón *et al.*, 2012).

The realization of water stress to rice cultivation sometimes improves the yield, depending on the stage and the intensity of the stress, reaching the best results in the vegetative phase, not achieving the same results when applied in the reproductive phase of the crop, affecting also grain quality (Verma *et al.*, 2014).

The objective of the present work was to evaluate the effect of water stress on the yield in the regrowth crop in INCA LP-5, a rice variety of short cycle.

METHODS

The research was conducted during four years, from 2014 to 2017 at the UCTB Los Palacios, on a Gleysol Nodular Ferruginous Petroferric soil (Hernández *et al.*, 2015).

Treatments:

T $_1$. Regrowth with water stress to the crop in seedling phase, 10 days after the start of the regrowth with a stress duration of 15 days.

T $_2$. Regrowth without water stress to the crop in the seedling phase (production control)

The seeding density used was 120 kg. ha $^{-1}$ (Minag, 2014).

For the development of the experiment, the INCA LP-5 short cycle commercial variety was used.

The cut made to the regrowth crop was from the soil surface to the desired height (AC).

Evaluations and measurements made:

- Agricultural yield (t ha $^{-1}$ to 14% humidity).
- Industrial performance (% of whole grains).
- Panicles per square meter
- Water consumption (m ^{3}. ha $^{-1}$)
- Water productivity (kg. m $^{-3}$)

$$WP = \frac{Yiel(\ kg.\ \ ha^{-1})}{water\ \ expenditure(m^3.ha^{-1})}$$

Where:

WP - water productivity

Water consumption was estimated from the delivery of each plot (20 L. s $^{-1}$) according to the construction project of the irrigation system of Scientific Technology "Los Palacios", Pinar del Río Unit. For the industrial yield of the grain a sample of 1 kg of seed was taken, determining the percentage of whole grains. An experimental design of blocks was used at random, with two treatments, one with water stress and one without stress, which was maintained with a water sheet (10 cm) throughout its cycle, according to Minag (2014). Water stress was applied in the vegetative phase with wilting of the leaves, and the soil totally cracked.

The data obtained were subjected to an analysis of t-Student when significant differences were found between the means for the level of significance ($p \leq 0.05$).

RESULTS AND DISCUSSION

Among the factors affecting the yield of rice, they were found the moment of harvesting and the irrigation management, as both affect decreasing percentages of whole grains, the amount of panicles per square meter and other components that significantly affect agricultural culture performance and its industrial quality (Ruiz *et al.*, 2014; de Avila *et al.*, 2015). However, in this work, when the regrowth or soca culture was used and the irrigation was managed in a different way to the traditional (permanent water), that is, causing a water stress condition by default, the grain agricultural and industrial yield (% whole grains), panicles per square meter and a significant decrease in water consumption for the years of study.

The behavior of the panicles per square meter (Table 1) for the investigation period always showed higher values when the regrowth was cut at 5 cm from the soil surface, with respect to the cutting at height higher than 20 cm, regardless of whether the regrowth is without or with water stress. The latter, yield the greatest amount of panicles. m^{-2} , behavior that coincides with that reported by several authors (Polón *et al.*, 1995; Polón y Castro, 1999).

As it can be seen in Table 2, a significantly better performance of the agricultural yield was obtained, exceeding regrowth with water stress to regrowth without water stress (control). The former reached values that oscillate between 5,8 t. ha $^{-1}$ and 5,0 t. ha $^{-1}$, compared to 4,7 and 4,0 t. ha $^{-1}$ (regrowth without water stress), and with the variant of cutting at 5 cm from the soil surface. This result coincides with that reported by Polón *et al.* (2012), when practicing equal cutting heights to the regrowth crop, which seems to indicate that, as the cut of the soca is lower, there is a favorable response in the crop in terms of its agricultural yield.

With a management of the irrigation and using the crop of regrowth with hydric stress, a high efficiency in the use of the water and a high productivity of the irrigation water is demonstrated (Table 3).

The values reached in water consumption were always lower in the regrowth treatment with water stress, with values of 4100 $m^3.ha^{-1}$ to 5700 $m^3.ha^{-1}$, respectively, with respect to regrowth treatment without water stress (control). This latter showed the highest water consumption reported of 6 800 $m^3.ha^{-1}$; however, it can be observed that the values of water resource savings oscillate in the order of 1700 and 1100 $m^3. ha^{-1}$. These results coincide with those reported by the researchers Polón and Castro (1999) and Polón *et al.* (2012). They refer the benefits of

TABLE 1. Behavior of panicles. m^{-2} in the dry season, during the years 2014-2017

Treatment	Panicles .m $^{-2}$			
	2014	**2015**	**2016**	**2017**
Regrowth with water stress	AC- 5 cm- 370 a	AC- 5 cm - 240 a	AC- 5 cm -245 a	AC- 5 cm - 286 a
	AC- 20 cm-296 c	AC- 20 cm- 228 c	AC-20 cm-230 c	AC-20 cm -251 c
ESx	1,35	1,3	1,29	1,37
Regrowth without water stress (control)	AC- 5 cm- 285 b	AC- 5 cm -220 b	AC- 5 cm - 240 b	AC- 5 cm - 266 b
	AC- 20 cm-222 d	AC-20 cm -189 d	AC-20 cm -225 d	AC-20 cm -200 d
ESx	1,32	1,27	1,26	1,34

Means with letters in common do not differ significantly according to Duncan's 5% test.

TABLE 2. Behavior of agricultural yield in the dry season, during the years 2014-2017

Treatment	Agricultural yield (t.ha $^{-1}$ at 14% humidity)			
	2014	**2015**	**2016**	**2017**
Regrowth with water stress	AC- 5 cm - 5,5 a	AC- 5 cm - 5,8 a	AC- 5 cm - 5,00 a	AC- 5 cm - 5,5 a
	AC- 20 cm- 3,1 c	AC-20 cm - 3,2 c	AC-20 cm - 4,00 c	AC-20 cm - 4,4 c
ESx	0,012	0,013	0,09	0,09
Regrowth without water stress (control)	AC- 5 cm- 4,2 b	AC- 5 cm - 4,7 b	AC- 5 cm - 4,0 b	AC- 5 cm - 4,5 b
	AC-20 cm- 3,0 d	AC-20 cm -3,4 d	AC-20 cm -3,00 d	AC-20 cm - 3,3 d
ESx	0,011	0,011	0,08	0,089

Means with letters in common do not differ significantly according to Duncan's 5% test.

TABLE 3. Water consumption and productivity of irrigation water in the dry season, during the years 2014-2017

Treatment	2014		2015		2016		2017	
	Cons. of water ($m^3.ha^{-1}$)	**Prod. of irrigation water ($kg.m^{-3}$)**	**Cons. of water ($m^3.ha^{-1}$)**	**Prod. of irrigation water ($kg.m^{-3}$)**	**Cons. of water ($m^3.ha^{-1}$)**	**Prod. of irrigation water ($kg.m^{-3}$)**	**Cons. of water ($m^3.ha^{-1}$)**	**Prod. of irrigation water ($kg.m^{-3}$)**
Regrowth with water stress	4 100	1,34	5700	1, 01	4 1 90	1, 19	4 3 00	1, 27
Regrowth without water stress (control)	5 800	0,72	6 800	0, 69	5 5 00	0, 72	6 2 00	0, 73
ESx	-	-	-	-	-	-	-	-

water stress in the vegetative phase of the crop, with the use of regrowth and with a cutting height of 5 cm from the soil surface, since a greater economy of water is always reached, for being the greatest period without irrigation.

The values of water productivity ranging generally between 0,69 and 0,73 $kg.m^{-3}$ for the control treatment (stress regrowth) and 1,34 $kg.m^{-3}$ and 1,01 $kg.m^{-3}$ for the regrowth with stress. These values are so high since the regrowth crop has a shorter cycle (70 days) and they differ much more than what was reported by Colom (2012) in Cuba of 0,31 $kg.m^{-3}$ for long cycles (135 days). These values of water productivity, in turn, are located in the ranges of values reported by different authors (DIEA, 2014; de Avila *et al.*, 2015; Ruiz *et al.*, 2016; Riccetto *et al.*, 2017).

Similar behavior presented the industrial yield of the grain (% of whole grains) as it can be seen in Table 4, where values of 63,9 % to 62,3 % of whole grains were reached in the treatment with water stress and without. However, in the control it was 64,9 % to 61,8 % whole grains, both for a cutting height of 5 cm. These values demonstrate once again the benefit of applying water stress in the increase of agricultural yield without affecting the industrial quality of the grain, as reported by several researchers (Polón and Castro, 1999; Polón *et al.*, 2012; Castro *et al.*, 2014; Ruiz *et al.*, 2014; Bergson *et al.*, 2015).

CONCLUSIONS

It can be concluded that, when irrigation is managed in rice cultivation for the short-cycle variety INCA LP-5, in a different way to the traditional (permanent water), that is, causing a water stress condition by default, cultivation in the vegetative phase, with regrowth and under 5cm regrowth cutting height, the agricultural yield is increased by approximately 0,5 $t.\ ha^{-1}$. In addition, the industrial yield of the grain improves with values higher than 63 % whole grains, and the number of panicles per square

TABLE 4. Industrial yields in the dry season during the years 2014 -2017.

Treatment	Industrial yield (% of whole grains)			
	2014	**2015**	**2016**	**2017**
Regrowth with water stress	AC- 5 cm- 63,3 a AC-20 cm- 60,0 c	AC- 5 cm - 63,9 a AC-20 cm - 60,8 c	AC- 5 cm - 62,3 a AC-20 cm - 60,2 c	AC- 5 cm - 63,8 a AC-20 cm - 60,9 c
ESx	1,85	1,86	1,82	1,29
Regrowth without water stress (control)	AC- 5 cm- 64,9 b AC-20 cm- 61,1 d	AC- 5 cm - 62,8 b AC-20 cm - 60,4 d	AC- 5 cm - 61,8 b AC-20 cm - 59,2 d	AC- 5 cm - 61,5 b AC-20 cm - 58,6 d
ESx	1,89	1,84	1,79	1,27

Means with letters in common do not differ significantly according to Duncan's 5% test.

meter, with respect to the regrowth without water deficit (control).

Moreover, lower water consumption is achieved in favor of the regrowth treatment with water stress, compared to the control, with a water resource saving of approximately 1700 m^3. ha^{-1}, which leads to a high productivity of irrigation water in the new treatment.

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