ORIGINAL ARTICLE

Water Stress Effects on Grain Quality in the Cultivation of Rice (*Oryza sativa* L.)

Estrés hídrico sobre la calidad del grano en el cultivo de arroz (*Oryza sativa* L.)

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ABSTRACT. The experiment performed in UCTB Los Palacios from 2014 to 2017, on Hydromorphic Gley Nodular Ferruginous Petroferric soil, in order to know the effect of water stress on grain quality with a middle cycle rice variety. Results showed that in the new variants of water management, a bigger percent of white entire grains was obtained. It oscillated between 55,9 and 65,3 %, while in the traditional management (control) the lowest percent of white entire grains was obtained (between 48,3 and 50,5 %), with a bigger quantity of chalky grains (with white belly) and fissures in the grains. However, with the new variants of water management the percentage of grains with white belly and fissures was lower than with the traditional water management being these last unfavorable elements, one of the reasons why some varieties could not continue in the national rice production.

Keywords: grain, quality, middle cycle rice variety, water.

RESUMEN. La investigación se condujo en la Unidad Científico Tecnológica de Base Los Palacios (UCTB Los Palacios), desde el año 2014 hasta el 2017, sobre un suelo Hidromórfico Gley Nodular Ferruginoso Petroférrico, para conocer el efecto del estrés hídrico en la calidad industrial del grano en una variedad de ciclo medio. Los resultados arrojaron que en las nuevas variantes de manejar el agua se obtuvo un por ciento mayor de granos blancos enteros que osciló entre 55,9 y 65,3, mientras que en el manejo tradicional (testigo) se obtuvo el más bajo por ciento de granos blancos enteros entre 48,3 y 50,5 con una mayor cantidad de granos yesosos (con panza blanca) y fisuras en los granos, mientras que en las nuevas variantes de manejos del agua el comportamiento de los granos con panza blanca y figurados de los granos fue mucho menor respecto al manejo del agua tradicional siendo estos últimos elementos desfavorables una de las causas por la que algunas variedades no hayan podido continuar en la producción arrocera nacional.

***Palabras clave*:** calidad industrial del grano, variedad de ciclo medio, agua.

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INTRODUCTION

Rice (*Oryza sativa* L.) is the most important crop for human consumption. It is the main food for more than half of the world's population (Ruiz *et al.*, 2012). In Cuba, this cereal is a basic food for the Cuban population, followed by beans (MINAG, 2014, 2015).

By tradition and food habits, Cuba is among the nations with high rice consumption, with 60 kg per capita per year. National rice production does not meet domestic demand, so more than 40% of this product, that is destined to the population's consumption, is imported (MINAG, 2014, 2015).

Cuban economy has to import annually about 4 x 10^5 t of white grain, which amounts to 60% of total consumption. Nevertheless, the aim is to fully satisfy the demand for this food, including tourism consumption, through the structure of the production chain and the network of scientific research, which cover an area of 16 x 10^4 ha belonging to the state, more than 32 x 10^3 ha belonging to private producers, in small plots (Polón *et al.*, 2014).

In the cooperative production sector, with the use of regrowth, agricultural yields are reported fluctuating between 2.5 and 4.7 t. ha^{-1} with excellent industrial grain quality, both crystalline grains and white belly in grains (Castro *et al.*, 2014).

Studies on bean (*Phaseolus vulgaris* L.) cultivation by other researchers (Polón *et al.*, 2012), also report an increase in grain yield and better grain quality, when water stress is applied to the crop.

One of the most important agricultural inputs for any crop and especially rice is undoubtedly water (PNUD, 2016). The reduction in the use of this input is one of the benefits of the regrowth system. In Cuba, research carried out under both, research and production conditions, shows a considerable reduction of irrigation water in this cropping system up to 40% with a middle cycle variety (Polón *et al.*, 2014).

According to FAO, world production in 2011 reached 722 million tons compared to 700 million tons in 2010. Crops have improved in almost all rice regions of the world, thanks to an extension of cultivated areas, which would reach 164 million hectares (Barrios *et al.*, 2016). This increase is concentrated in the main producing countries, especially China, India and Indonesia, which account for almost two-thirds of world production (FAOSTAT, 2015).

An economical way to increase the industrial yield of white rice is by increasing whole grains per ton of white rice obtained from paddy rice harvested.

The industrial quality, denominated in the national and international norm as a component of the industrial yield, is the percentage of whole grains obtained after the elaboration process in the industry (Camargo *et al.*, 2014). In the particular case of Cuba, the specifications of the Cuban standard of quality establishes that rice consume takes a percentage of broken rice, and the lower it is, the greater the quality of the product is.

On the other hand, studying the mechanism through which moisture is retained in the mature rice grain, which strongly influences its quality, is another important aspect to evaluate. Along with this, it is not only necessary to know the evolution of water within the grain, but also the storage kinetics of the dry matter in the grain, particularly, by measuring the growth of endosperm mass during ripening (Tosquy *et al.*, 2014).

The greater nitrogen presence in the fertilization increases the crystal appearance of the grain (little white belly), reduces the fissuring and the parting of the grain in the bleaching mill. It also influences the mechanical resistance of rice starch paste when heated and then cooled (Camargo *et al.*, 2014). The cracking of the rice grain has been studied rigorously in many institutions of the world.

The objective of the present work was to know the effect of water stress on the industrial quality of the grain in the vegetative phenological phase of the crop in a variety of short cycle.

METHODS

The experiment was conducted for four years, from 2014 to 2017 at UCTB Los Palacios, on a Hydromorphic Gley Nodular Ferruginous Petroferric soil (Hernández *et al.*, 1999).

Treatments:

- T_1- Water stress in the soil for 20 days from the application of the first herbicide and then normal irrigation
- T_2- Water stress in the soil for 25 days from the application of the first herbicide and then normal irrigation
- T_3- Water stress in the soil for 30 days from the application of the first herbicide and then normal irrigation
- T_4- Water stress in the soil for 35 days from the first application of herbicide and then normal irrigation
- T_5- Water stress in the soil for 40 days from the first application of herbicide and then normal irrigation
- T_6- Normal irrigation throughout the crop cycle without water stress (control)

Seed density was 120 $kg \cdot ha^{-1}$ (MINAG, 2014).

For the development of the experiment, the commercial variety of short cycle Perla de Cuba was used.

Evaluations:

- Industrial yield (% of whole grains)
- White balance (%)
- Cracked grains (%)
- Total nitrogen (%)

For the industrial yield of the grain, a sample of 1 kg of seed was taken, and then, the percentage of whole grains, white belly and cracked grains were determined. For these last components of the industrial yield, subsamples of 100 grains were taken and observing them with a glass magnifying the amount of grains with white belly and cracks in the grain were counted.

A randomized block design was used with six treatments, five with water stress and one control with normal irrigation according to Technical Instruction (MINAG, 2014).The water stress was applied in the vegetative phase from leaf wilting to yellowing, and the soil totally cracked.

The data obtained were submitted to a simple variance analysis, applying Duncan's multiple range scores when significant differences were found among the means for the significance level ($p \leq 0.05$).

Determination of total nitrogen. Rationale: The traditional (and most accurate) method for determining N is based on converting all forms of it to ammoniac nitrogen which in acid medium has the NH_4 + form and is stable. Then an alkaline medium is propitiated to pass it to NH_3, distill it and collect it in acid medium and value it, but it is a very long method and requires a lot of dedication. Therefore, for the determination in a simpler way, the colorimetric method is utilized with the reagent of Nessler (Paneque, 2010).

RESULTS AND DISCUSSION

There are many factors that affect rice yield and its industrial quality, among them, the time of harvesting and the irrigation management prior to harvest, resulting in decreasing of the percentage of whole and cracked grains and grains with white belly (Thompson y Mutters, 2006). However, in this research, when the water in the crop was managed in a different way from the traditional one (permanent flooding), that is to say, provoking a condition of water stress by default, the industrial quality of the grain was favored for the years of study.

When water stress (by default) was applied to the crop in the vegetative phase, for the low rainy period during the four years of research, the stress variants significantly outperformed the control (permanent flooding) in percent of whole grains and total nitrogen in the leaf. Nevertheless, the percentage of cracked and white belly behaved in a lower percentage with water stress compared to the control, as it can be seen in Tables 1, 2, 3 and 4.

TABLE 1. Industrial yield of grain during 2014 dry season.

Treatments	Whole grains (%)	Cracked grains (%)	White-bellied grains (%)	Total leaf nitrogen (%)
T_1	62,7 e	2,6 b	6,8 b	2,2 b
T_2	63,5 d	2,0 b	6,6 b	2,1 b
T_3	64,4 c	2,0 b	5,0 c	2,3 b
T_4	66,6 b	0,0 c	4,0 d	3,5 a
T_5	68,8 a	0,0 c	2,0 e	3,4 a
T_6	58,6 f	7,0 a	28,1 a	1,0 c
ESx	0,06	0,28	0,46	0,26

Means with letters in common did not differ significantly according to Duncan's test for p≤0,05.

TABLE 2. Industrial yield of grain during the dry season 2015.

Treatments	Whole grains (%)	Cracked grains (%)	White-bellied grains (%)	Total leaf nitrogen (%)
T_1	61,4 e	3,8 b	6,1 b	2,3 b
T_2	63,4 d	4,0 b	6,1 b	2,3 b
T_3	65,6 c	2,3 c	5,0 bc	2,4 b
T_4	66,4 b	0,0 d	4,1 dc	3,7 a
T_5	68,3 a	0,0 d	2,4 e	3,6 a
T_6	58,3 f	7,5 a	27,8 a	1,1 c
ESx	0,064	0,27	0,45	0,28

Means with letters in common did not differ significantly according to Duncan's test for p≤0,05.

TABLE 3. Industrial yield of grain during the dry season 2016.

Treatments	Whole grains (%)	Cracked grains (%)	White-bellied grains (%)	Total leaf nitrogen (%)
T_1	62,2 e	3,3 b	5,8 b	2,4 b
T_2	63,0 d	2,0 c	6,0 b	2,4 b
T_3	64,1 c	2,1 d	5,1 c	2,3 b
T_4	66,5 b	0,0 e	4,3 dc	3,8 a
T_5	68,1 a	0,0 e	2,3 e	3,6 a
T_6	59,5 f	6,8 a	27,3 a	1,0 c
ESx	0,083	0,26	0,41	0,29

Means with letters in common did not differ significantly according to Duncan's test for p≤0,05.

TABLA 4. Industrial yield of grain during the low rainy season 2017.

Treatments	Whole grains (%)	Cracked grains (%)	White-bellied grains (%)	Total leaf nitrogen (%)
T_1	63,6 e	4,1 b	6,0 b	2,5 b
T_2	64,5 d	1,8 d	6,1 b	2,6 b
T_3	65,6 c	2,1 c	5,0 c	2,7 b
T_4	67,6 b	0,0 e	3,8 d	3,7 a
T_5	69,6 a	0,0 e	2,8 e	3,8 a
T_6	59,6 f	8,2 a	27,0 a	1,1 c
ESx	0,056	0,29	0,39	0,29

Means with letters in common did not differ significantly according to Duncan's test for $p \leq 0,05$.

Table 1 (2013) shows that the best treatment in percent of whole grains was T_5 with 68.8%, followed by T_4 with 66.6%, the worst of the treatments being T_6 with 58, 6%. These higher percentages of whole grains in the stress variants, could be attributed to, among other causes, that these treatments also had the lower percentages of cracked grains, T_4 and T_5 with 0% cracked grains. Similarly, the lowest percentages of white-bellied grains also corresponded to treatments T_4 and T_5 with 4, 0 and 2.0%, respectively. It motivates greater percentages of whole grains, whereas the control reached 7.0 and 28.1% of cracked and white-bellied grains, respectively. Consequently, that motivates lower percentages of whole grains in the control, in relation to variants with water stress. These results differ from those reported by several researchers, when studying the industrial quality of the grain in the crop with water deficit during its development. (Alvarado and Hernaiz, 1995; Acosta *et al.*, 2004; García *et al.*, 2011; Osuna *et al.*, 2013; Sarwar *et al.*, 2013; Ndindeng *et al.*, 2014; Polón *et al.*, 2014).

The industrial yield, as percent of whole and cracked grains for the other dry periods (2015, 2016 and 2017) studied, remained with the same behavior as in dry season 2014. The best treatments in percent of grains (T_4 and T_5), significantly exceeded the control, which was the lowest value. That behavior is attributed to a higher percentage of whole grains in the treatments with water stress and to a null (0%) production in the percentage of cracked grains. That could also be due to the low percentages of grains with white belly, not coinciding with those reported by other authors that refer impacts in whole grains when going through periods with water stress (Cuevas y Fitzgerald, 2012; Sarwar *et al.*, 2013; Ndindeng *et al.*, 2014; Londero *et al.*, 2015; Cuevas *et al.*, 2016).

The formation of white belly in the grain for the four years studied was always lower in treatments T_4 and T_5 with water stress (Tables 1, 2, 3 and 4). That allowed obtaining a greater quantity of whole grains in these two treatments per year of study. This result does not coincide with that reported in the scientific literature, which proposes a lower production of whole grains with water deficit (Thompson y Mutters, 2006; Sarwar *et al.*, 2013). On the other hand, T_6, reached the highest values of white-bellied grains in the studied years, which contributed to the lower percentage of whole grains, as it can be seen in Tables 1, 2, 3 and 4. It seems that the condition of water stress imposed on the crop allowed for a better distribution and organization of the starch grains (more compact), reducing the parting of the grain in the mill, resulting in the obtaining of a greater amount of whole grains. Apparently, this phenomenon does not happen in the control treatment (without water stress). In this respect Acosta *et al.* (2004), argues that, when the starch grains are not well distributed in the grain, it creates empty spaces with air in it, which contributes to a greater parting of the grain in the mill, decreasing the percent of whole grains in a significant and important way.

As it can be seen in Tables 1, 2, 3 and 4, T_1, T_2, T_3 and T_4 treatments with water stress were obtained for the low rainy season, obtaining the highest percentages of industrial yield of whole grains and of better quality, compared to (T_6). It seems that when water stress condition is applied to the crop in the vegetative phase, there is an increase in the industrial yield of the grain. This coincides with that reported in bean cultivation by other researchers (Polón *et al.*, 2003; Polón *et al.*, 2014; Tosquy *et al.*, 2014).

Tables 1, 2, 3 and 4 for the low rainy periods reflect the behavior of the percent of total nitrogen in the rice grain. The best treatments were T_4 and T_5 with significant differences with respect to the rest of the treatments studied, being the worst of all T_6 (control). It also corresponds to the best and worst treatment of whole grains, respectively. This behavior allowed a higher production of whole grains with better quality. It could be attributed among other causes, to the higher production of total nitrogen, when the condition of water stress is practiced to the crop, also obtaining less cracked grains and white belly in the grain, allowing smaller parting of the grain.

These results coincide with what was reported by Acosta *et al.* (2004), who states that the greater nitrogen presence in fertilization increases the crystal appearance of the grain, reduces cracking and splitting of the grain in the bleaching mill, increasing the quantity of whole grains in a variety of short cycle.

CONCLUSIONS

As a conclusion, it could be said that by subjecting the rice cultivation to a period of time under water stress, the percentage of whole grains is increased, the cracked grains and the presence of white belly in the grain are reduced, as well as the amount of nitrogen in the leaf is increased in J-104 middle cycle variety.

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NOTES
*The authors of this work declare no conflicts of interest.

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