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IRRIGATION WATER MANAGEMENT IN RICE CROP (*Oryza sativa* L.) BY TRANSPLANT, IT'S EFFECT ON THE AGRICULTURAL AND INDUSTRIAL PERFORMANCE

Manejo del agua de riego en el cultivo de arroz (Oryza sativa L.) por trasplante, su efecto en el rendimiento agrícola e industrial

Michel Ruiz Sánchez[1]✉, Yaumara Muñoz Hernández[2], José M. Dell´Amico[1] and Ricardo Polón Pérez[1]

ABSTRACT. Rice cultivation transplant traditionally spends most of its life cycle with flooding and exhibits high adaptability to these conditions, consequently its production consumes a lot of water, although less than in the cultivation by direct seeding. This research was conducted to evaluate the effect of irrigation water management in the agricultural and industrial yield of rice transplanting technology. Plants remained in flooded conditions throughout the cycle and plants undergoing suspension of the water surface for a period of 15 at three different times tillering stage were evaluated. The suspension of the water level increased agricultural yields between 16 and 32 % over the flooded control and industrial yield was 67 % on average. The highest percentage of whole grains were obtained in the treatments under suspension of the sheet, achieving the best results with the suspension at 30 DDT. This operation allows water savings of approximately 1 931,4 m^3 ha^{-1}, for the flooded treatment. The water saved would increase the area under irrigation by 11,19 % for rice cultivation.

Key words: water, saving water, rice, agronomic yield, irrigation

RESUMEN. El cultivo del arroz por trasplante, tradicionalmente, permanece la mayor parte de su ciclo biológico con inundación y manifiesta una elevada adaptabilidad a dichas condiciones, consecuentemente su producción consume una gran cantidad de agua, aunque menor que en el cultivo por siembra directa. Esta investigación se realizó con el objetivo de evaluar el efecto del manejo del agua de riego en el rendimiento agrícola e industrial del arroz por la tecnología de trasplante. Se evaluaron plantas que permanecieron en condiciones inundadas durante todo su ciclo y plantas que se sometieron a suspensión de la lámina de agua por un periodo de 15 días en tres momentos diferentes de la etapa de ahijamiento. La suspensión de la lámina de agua incrementó el rendimiento agrícola entre un 16 y 32 %, con respecto al control inundado y el rendimiento industrial fue de un 67 %, como promedio. Los porcentajes mayores de granos enteros se lograron en los tratamientos sometidos a suspensión de la lámina, alcanzándose los mejores resultados con la suspensión a los 30 DDT. Este manejo permitió un ahorro de agua aproximadamente de 1 931,4 m^3 ha^{-1}, respecto al tratamiento inundado. El agua ahorrada pudiera incrementar el área bajo riego en un 11,19 % para el cultivo del arroz.

Palabras clave: agua, ahorro de agua, arroz, rendimiento agronómico, riego

INTRODUCTION

Rice (*Oryza sativa* L.) has the distinction of being a semi-aquatic plant and traditionally it is planted in continuous flooding during most of their growth cycle (1), states that has relatively few adaptations to water conditions limited and it is extremely sensitive to drought (2).

[1] Unidad Científico Tecnológica de Base «Los Palacios», Instituto Nacional de Ciencias Agrícolas, gaveta postal 1, San José de las Lajas, Mayabeque, CP 32 700.
[2] Universidad de Pinar del Río «Hermanos Saiz Montes de Oca», calle Martí final, # 270 esq. a 27 de noviembre, Pinar del Río, Cuba.
✉ mich@inca.edu.cu

About half of the arable land of rice in the world does not have enough water to keep the flooding conditions and intermittent drought stress at critical stages can cause considerable yield reduction (3). The low water availability is a challenge for rice production, because every year it needs to produce more grain with less water for irrigation (4). Additionally, it is important to note that not only the lack of water reduces yield potential, but also the time and duration of drought, in relation to phonological processes and periods of flooding, which cause physiological changes, physicochemical and microbiological in the soil-plant-water interaction (5).

Current commercial cultivars have shown a potential yield that exceeds 7 t ha^{-1}; however, in the productive conditions of Cuba in the last 20 years, does not exceed 3,5 t ha^{-1} on average. Among the most common causes of this problem technological indiscipline and breach of good agricultural practices, soil, nutritional problems and the availability of water resources to meet production plans were identified. That is why, we are working on finding alternative water management that will maintain or increase production of this cereal.

Given raised as soon as the objective of this research was to evaluate the effect on irrigation management in rice cultivation transplant, and agricultural and industrial yield.

MATERIALS AND METHODS

The experiment was conducted in the field areas of Scientific and Technological Base Unit “Los Palacios” in the months from January to July, which corresponded with the planting of seedlings to harvest grain, coinciding with the planting season just rainy 2011, in a soil classified as Hydromorphic Gley Nodular petroferric (6). To fulfill the target, four plots were planted, with a measure of 40 x 80 m (terrace) and where independent irrigation was applied. Three of them were exposed to suspension of the water layer (non-flooded) at 30, 40 and 50 days after transplantation (DAT) for a period of 15 days, moments that were part of the tillering stage (7) and each with the fourth terrace were compared where plants remained in flooded conditions throughout the cycle (flooded). Completion of each suspension period of the water surface it recovered up to 10 cm (8).

Treatments

Time of suspension of the water sheet:

A1 - suspension of the water level at 30 DAT

A2 - suspension of the water level at 40 DAT

A3 - suspension of the water level at 50 DAT

A4 – control (flooded)

Before starting research the analysis of soil chemical properties, from five samples taken in the form of English flag, to form a single sample terrace at a depth of 0-20 cm, which were processed in the held Provincial laboratory of the Institute of Soil, Pinar del Río (Table I).

The experimental area was previously prepared by puddling technology (8). Soil preparation was carried out at a depth between 0 and 25 cm, with a water depth not exceeding 10 cm. Transplanting was done 30 days after emergence (DAE) manually to a distance between plants 20 x 20 cm and a plant niche. The behavior of the meteorological variables during the field test was evaluated *in situ* (Table II), to measure precipitation a graduated pluviometer of wedge was used (mm) attached to a wooden stand at 1 m height from soil surface located in the center of the experimental area. Temperature (°C) and relative humidity (%) were measured with a Testoterm (JAPAN, testo® 610) equipment.

Table I. Some properties that characterize the fertility of the arable horizon (0-0,20 m) of the experimental area

Property	Unit	Mean	Median	Standard error	Variance
pH		6,46	6,50	0,15	0,09
MO	%	2,86	2,80	0,13	0,07
Ca^{2+}		6,97	7,01	0,13	0,08
Mg^{2+}	cmol kg^{-1}	3,11	3,09	0,06	0,01
Na^{+}		0,21	0,19	0,02	0,01
K^{+}		0,18	0,18	0,02	0,01
P assimilable	mg kg^{-1}	46,80	46,00	3,80	5,70

Table II. Behavior of meteorological variables (year 2011), monthly averages

Months	Temperatures (ºC)			Precipitations (mm)	Relative humidity (%)
	minimum	maximum	mean		
January	17,67	25,71	21,69	8,72	63
February	18,44	27,64	23,04	0,00	61
Marcho	18,79	28,95	23,87	11,70	67
April	22,05	31,58	26,82	2,81	72
May	22,95	31,70	27,33	20,60	76
June	24,34	31,97	28,15	9,38	79
July	24,60	31,96	28,28	12,74	83

Fertilization was performed as recommended by the Technical Instructions Crop Rice (8), using Urea (46 %), triple superphosphate (46 %) and potassium chloride (60%) as carriers of nitrogen, phosphorus and potassium, respectively. Fertilizers were applied at 20, 35 and 70 DAT. At all times 30, 40 and 30 % of the total dose of each fertilizer respectively was applied (total dose: 185 kg ha^{-1} of nitrogen, 75 kg ha^{-1} of phosphorus and 90 kg ha^{-1} potassium).

Two samplings, one after each period of suspension of the water sheet, at 45, 55 and 65 DAT and the other at the time of the harvest grain rice (130 DAT) were performed. In each sample 20 plants were randomly taken per terrace.

Plant height (cm), as measured from the soil surface to the upper end of the longest leaf projected in the same direction from the stem was evaluated; the number of tillers was determined by counting each sampled plant stems and a certain amount was deducted the value 1 (mother plant).

After making height measurements and counting tillers, plants were taken and evaluated through a cut in the stem base. The aerial part of the root system is removed to determine the dry mass of both. The roots were washed with water to remove adhering soil and dried with paper towels. Both sections of the plant were kept in an oven with forced air at 70 °C until constant mass, as measured in a technical balance (Denver Instrument PK-601), the result is expressed in g plant^{-1}.

At the harvest time the same variables were evaluated, in addition to agricultural yield 14 % grain moisture (t ha^{-1}) and its components (panicles per m^2, filled grains per panicle and mass of 1000 grains) and , productivity (kg m^{-3}) and the water efficiency (m^3 kg^{-1}).

Productivity and efficiency in water use were determined according to the following expressions[A].

Water productivity (WP): (1)

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

Eficiency in water use (EUA): (2)

$$EUA=\frac{\text{water expenditure(m}^3\text{ ha}^{-1})}{\text{Yield (kg ha}^{-1})}$$

where:

Agricultural yield of 14 % grain moisture.

Water consumption was estimated from each parcel delivery (20 L s^{-1}), according to the construction project of the irrigation system of the Scientific Technology unit "Los Palacios", Pinar del Rio.

The data obtained for each sample after the suspension of the water surface were analyzed from confidence intervals (α≤0,05). At the time of harvest, samples were taken four plots and simple analysis of variance was performed. The differences among treatment means were determined from the Tukey test for (p ≤ 0,05).

RESULTS AND DISCUSSION

The properties that characterize the arable horizon fertility (0 to 0,20 m) in the experiment showed no standard error values and variances that indicate variability within these characters, a result that allowed rule out the effect of fertility behavior plants during the experiment.

Climate variables that influenced during the experiment in terms of precipitation was not representative, because below 20,60 mm values

[A] Walser, S.; Schütze, N. y Schmidhalter, U. ''Yield response and water use efficiency of deficit irrigated aerobic rice under highly controlled conditions''. En: *XXIII European Regional Conference of ICID*, Lviv, Ukraine, 2009, pp. 17-22. [A] Walser, S.; Schütze, N. y Schmidhalter, U. ''Yield response and water use efficiency of deficit irrigated aerobic rice under highly controlled conditions''. En: *XXIII European Regional Conference of ICID*, Lviv, Ukraine, 2009, pp. 17-22.

were recorded, that below rainfall of 25 mm of precipitation do not cause sudden physiological changes in the rice plant (5). Minimum temperatures influenced from the stage seedlings to 40 DAT, since rice growth depends mainly on the temperature as a factor of the medium, those below 25 °C decrease the absorption of nutrients and metabolic processes in the plant occur slowly (7).

At the moment the water level recovered in each of the terraces were subjected to suspension of the water surface for a period of 15 days, the soil was cracked and more than 50 % of the plant leaves rolled, behavior that indicated a water deficit in plants conditioned by the period without sheet of water tax.

After the period of suspension of the water surface.

The meteorological variables that prevailed in the area of research enabled the successful development of plants, except the minimum temperature, which could be the cause of lengthening the cycle; however, the results are the effect of treatments.

In assessing the height of the plants after each suspension period of the water level (A1, A2 and A3), it was observed that the applied management reduces the growth of rice plants with respect to the flooded control (Figure 1). These differences represent a lower height of plants 10,20; 9,61 and 7,99 % (A1, A2 and A3, respectively) relative to cultivated in flooded conditions (A4).

Apparently the suspension of the water level response mechanisms triggered in plants to water deficit condition, specifically evasion (9), behavior that is closely related to the physiology of plants (7, 10). Similar findings by other researchers (9, 10) were reported by subjecting rice plants to flooding and drought conditions.

Growth is associated process, both the increase in cell number (cell division) and in size (cell elongation) (7). Reduced growth expressed by the plant height, could be interpreted as an inhibition in cell elongation, as this is more sensitive to reducing turgor cell division (11). Moreover, flooded treatments are influenced by the height of the water surface (15 cm), which induces elongation in internodes of plant[B] (9) with respect to non-flooded during the suspension period of water sheet.

In evaluating tillering per plant (Figure 1 D, E and F) in the treatments were subjected to suspension of the water surface 30, 40 and 50 DAT, it was observed that the handling applied not stimulate tillering, although suspending the sheet of water at 40 DAT (A2) found no differences. Tillering has a marked influence on the results of production (12); it is related to the number of plant stems with the possibility of paniculate and mature to be a varietal character with relevance in participatory selection (13).

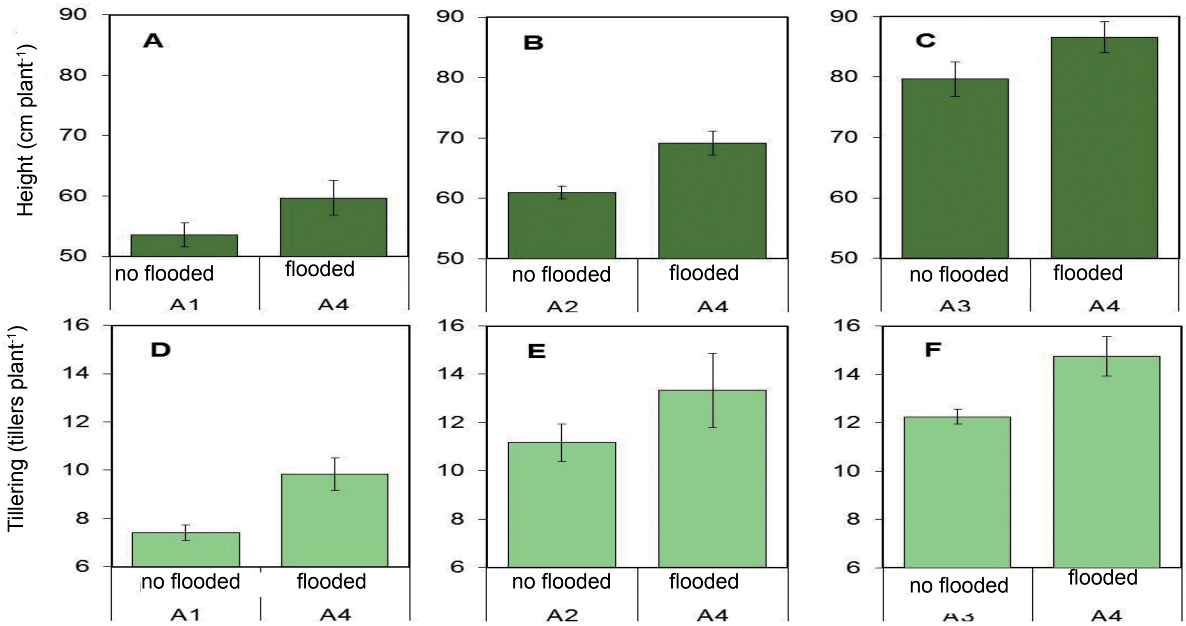
It is important to note that the condition imposed (suspension of the water surface) reduced plant height through the mechanisms of evasion experiencing the same. It presumably could be associated with a change in mobilizing growth hormones from the area apical of leaves towards the root base of the plant, as a way to adapt to a possible stress condition that could result in the plant, if the suspension period is extended.

Increasing the number of tillers in the non-flooded throughout the cycle plants may be due to the effect of soil oxygenation (14). The incidence of the temperatures in heating the surface to the other flooded land, which could stimulate tillering (15), in addition to increased fertility condition of the secondary and tertiary tillers who manage to complete their life cycle in conjunction with the parent plant.

In Figure 2, the behavior of the dry mass accumulation area (DMA) and root (RDM) is shown. Plants were exposed to suspension of the water level in the vegetative phase, accumulated less DMA than control (flooded) in the three times when the irrigation management was applied, although the suspension of the water surface the 40-DAT (A2) found no differences.

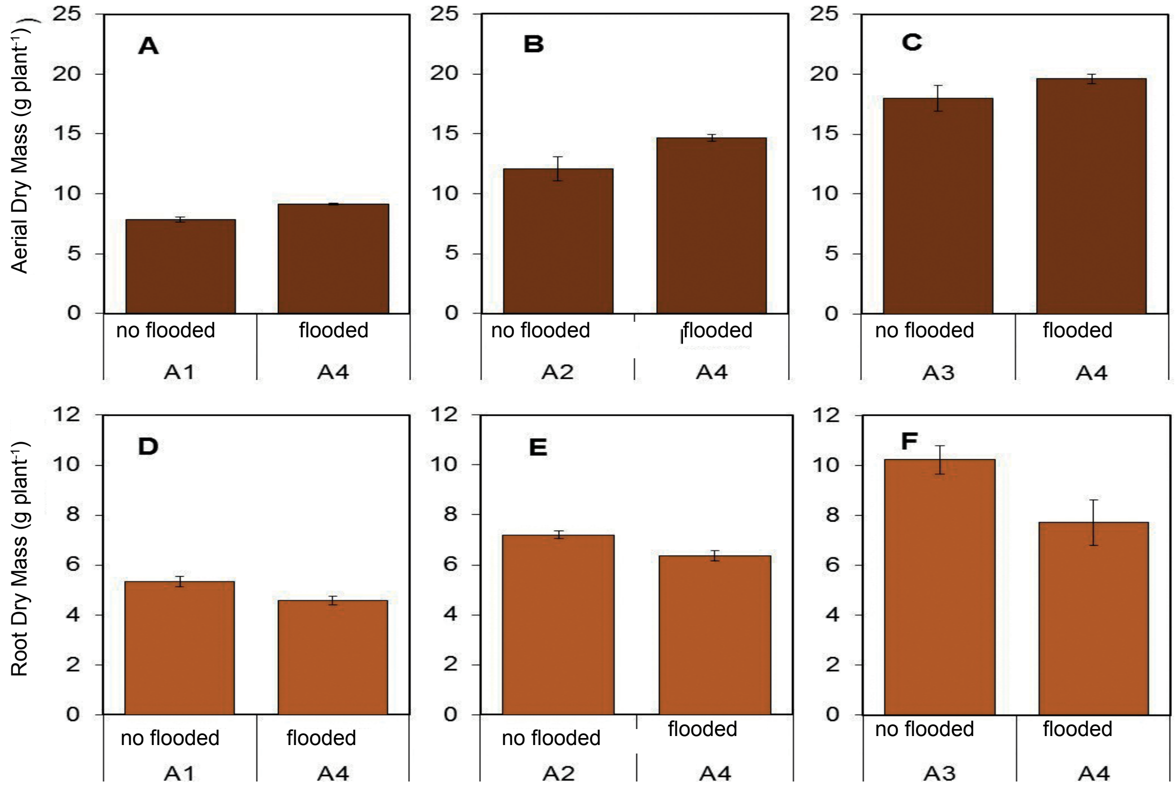
However, for the behavior of inverse response RDM (Figure 2 D, E and F) it was observed. Results management responding to applied water from a water deficiency in the soil; condition which in turn caused a reduction in air growth and an increase in the root system. Several authors found similar response by subjecting the cultivation of rice to water stress during the vegetative stage (16-18), demonstrating that adaptive response of rice plants to water deficit in the soil.

[B] Bharat, B. V. *Evaluación de la simbiosis micorrízica de Glomus intraradices en plantas de arroz* (*Oryza sativa* L.) *cv. INCA LP-5, en condiciones inundadas y no inundadas*. Tesis de Grado, Universidad de Pinar del Río, Pinar del Río, Cuba, 2012, 63 p.



Means with same letters are not significantly different (α≤0,05) according to Tukey test

Figure 1. Height in plants (A, B and C) and number of children per rice plant (D, E and F) exposed to suspension of the water sheet (noflooded) at 30, 40 and 50 DAT (A1, A2 and A3) respectively for a period of 15 days in each water management and its flooded control (A4) during the entire cycle (Flooded)



Bars ± confidence interval (α≤0,05), n = 4

Figure 2. Accumulation of aerial dry mass (A, B and C) and of the root in rice plants (D, E and F) exposed to suspension of the water sheet (noflooded) at 30,40 and 50 DAT (A1, A2 and A3) respectively for a period of 15 days in each water management and its flooded witness (A4) during the entire cycle (Flooded)

At the time of harvest

In assessing the plant height at the time of harvest (Table III) was observed that A1 and A2 treatments, despite it having been suspension of the water level during the vegetative phase (at 30 and 40 DAT respectively) achieved the highest values of the reference variable with respect to treatment A3 and A4 witness. Results demonstrating that the suspension of the sheet of water during the vegetative stage at baseline (30 DAT) and 15 days after starting it, did not affect plant growth at the end of its cycle.

Both the accumulation of DMA RDM as the highest values were found in plants exposed to suspension of the water layer 30 DAT relative to the control flooded A4; although in the last variable there was no difference with the suspension of the water level at 40 DAT. These results indicate that plants recovered from the condition to which they were exposed (suspension of the water surface, for a period of 15 days), which allowed stimulate plant development, because it can be considered as a water stress (17, 19). Increases in these variables play an important role in agricultural yields, the matter was reported that the dry mass, has a close relationship with the final crop yield (20), which is in line with a good root system; then yield components and translocation of assimilates in grain filling (20) are favored.

As for grain yield components and filled by panicles and panicles per m^2 was found that no significant differences among treatments A1 and A2 and A3 with respect to the flooded witness A4. However, in terms of agricultural yields the highest values were observed when the water level was suspended at 30 DAT (A1), in conjunction with other treatments, results are closely related to its components.

The suspension of the water sheet at 30, 40 and 50 DAT in this production technology showed differences in relation to the flooded treatment, with increases in agricultural yields 1,84; 1,52 and 0,79 t ha^{-1}, respectively, values which accounted for 31,03; 27,09 and 16,11 % of difference.

It is important to note that the suspension of the water sheet at 50 DAT, when physiologically rice plant begins to prepare to begin their reproductive phase, causes a decrease in agricultural yield. In addition, the period without water surface could not be considered a severe water stress, because performance is not decreased relative to the control. The difference in the agricultural performance over this time is justified by the increase in the number of panicles per m^2, as in the rest of the variables that make up the same. No difference was found with the control; as well as growth variables, height, air dry mass and root, indicating a strong water stress effect on these variables, which did not recover the same.

In industrial quality was no difference in performance milling (industrial) (Figure 3) was found; however, the highest values white whole grains and broken grains under treatment were found in suspension exposed to the water level at 30 and 40 DAT, although both treatments differ from other water handling.

The increase in whole grain treatment regarding A1 A2 and A3 was 4,93 and 35,65 % respectively. These results indicate that water management has a strong component in industrial quality of the rice grain as well as the planting season (21). Apparently the water at 50 DAT transplantation deficits near the reproductive phase it affects the filling and grains[C]

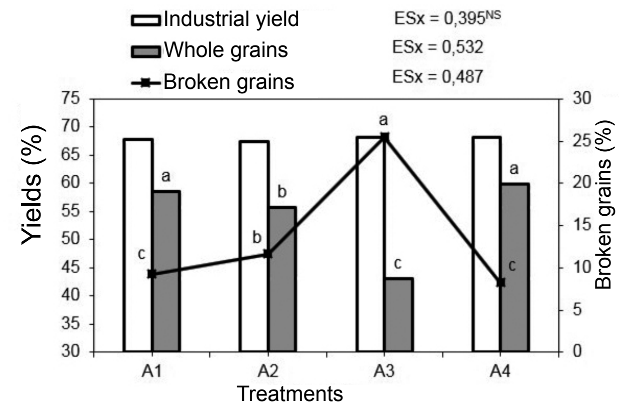
[C] Polón, R. "Impacto nacional en el incremento del rendimiento agrícola, economizar agua de riego y energía en el cultivo del arroz (*Oryza sativa* L.) como consecuencia del estrés hídrico" [en línea]. En: *XVI Forum de Ciencia y Técnica Nacional*, 2007, [Consultado: 1 de diciembre de 2015], Disponible en: <http://www.forumcyt.cu/UserFiles/forum/Textos/0109604.pdf>.

Table III. Behavior of height, aerial dry mass (DMA) and radical RDM), grains filled by panicles (Gll panicles-1), panicles per m2 (P m^{-2}) and agricultural yield at the time of harvest of exposed rice plants a suspension of the sheet of water (nolnund) at 30, 40 and 50 DAT (A1, A2 and A3) respectively and its witness flooded (Flooded)

Treatments		Height (cm)	MSA	MSR	Full grains panicule^{-1}	P m^{-2}	Yield (t ha^{-1})
Moment	Handling		(g plant^{-1})				
A1		92,62 a	48,01 a	27,80 a	83,63 ab	411,11 a	5,94 a
A2	noflooded	92,37 a	43,62 b	26,80 ab	90,05 a	381,94 a	5,61 b
A3		88,56 b	39,57 c	26,55 b	77,57 bc	306,25 b	4,88 c
A4	flooded	89,50 b	39,52 c	26,22 b	72,67 c	270,83 c	4,09 d
ESx		0,488	0,45	0,289	1,945	7,595	0,079

Means with the same letters do not differ significantly (p≤0,05) according to Tukey's test, n = 4

Therefore, it caused the milling process becomes broken. Added to this, the percentage of relative humidity were the highest (79 and 83 %, June and July, respectively) during the filling and ripening grain, values that could raise the moisture content in the grain and contribute to the crack it. In this regard, the author in an earlier study on planting season, with the rice cultivar INCA LP-4 found that planting February that were harvested in June and July decreased their industrial quality, due to flooding and high culture percentage relative humidity in the ripening phase bead (21).



Means with the same letters do not differ significantly (p≤0.05), according to Tukey´s test, n=4

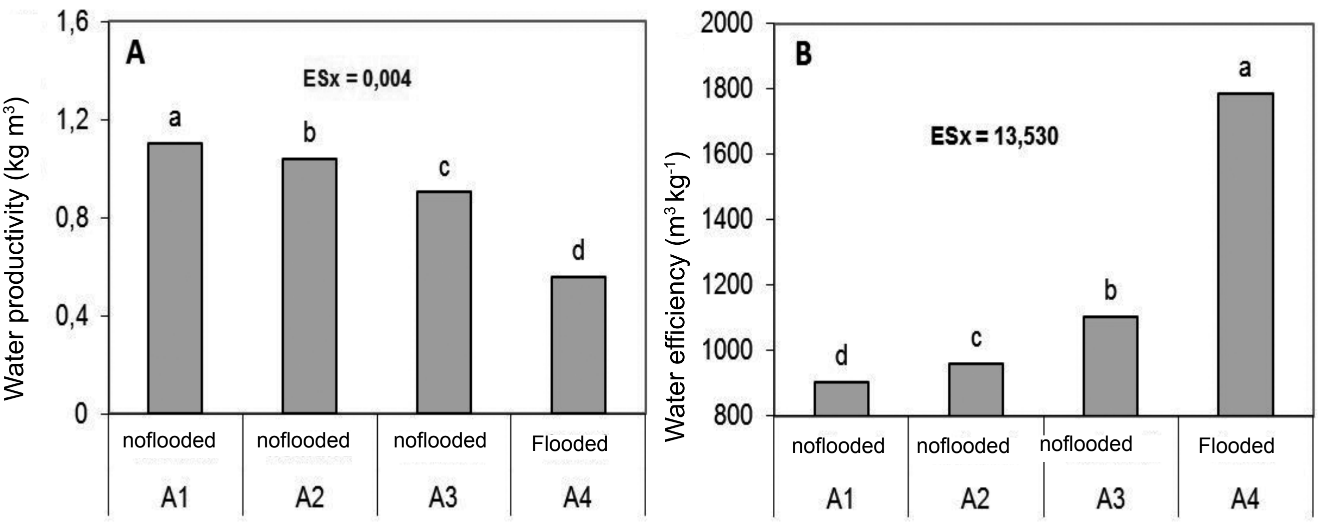
Figure 3. Industrial quality (milling performance, whole grains and broken grains) in rice plants exposed to suspension of the water sheet (nolnund) at 30,40 and 50 DAT (A1, A2 and A3) respectively for a period of 15 days in each water management and its witness flooded during the whole cycle (Flooded)

In assessing water productivity (WP), from yields, it was found that the WP was higher in the plot in which the water sheet at 30, 40 and 50 DAT (A1, A2 and A3) was suspended, respectively. whereas in the control treatment (flooded) resulted in a lower yield (Figure 4); it is important to note that there were differences among the treatments and the highest values of the reference variable is found when water at 30 DAT was discontinued.

In this study, productivity in the use of irrigation water (Wp) ranged from 1,11 kg m^{-3} in the treatment (A1) suspension of the water layer (non-flooded) to 0,56 kg m^{-3} the control treatment (A4); while the WP increased due to the suspension of the water level (A1, A2 and A3) in 49,74; 46,32 and 38,24 %, respectively, compared with the control (A4). These results demonstrate that there were differences in the behavior of the WP, motivated by the time the water suspension was applied.

This behavior helped ensure that the suspension of the water level in the vegetative phase contributes to the conservation of water resources and increase rice yields depending on the irrigation. In this regard, it was reported that, as long as productivity increases irrigation water increases the efficiency of use (4, 22).

Greater efficiency in water use (Ew) was obtained in plants that were exposed to suspension of the water level at 30 DAT, with values of 889,91 m^3 kg^{-1}. The results of productivity and efficiency are acceptable if we consider reported by other authors who have cultivated rice with intermittent irrigation, without sheet of water (aerobic) and rainfed[B] conditions (19).



Means with the same letters do not differ significantly (p≤0,05) according to Tukey's test, n = 4

Figure 4. Productivity (A) and efficiency in the use of water (B) in rice plants exposed to suspension of the water sheet (noFlooded) at 30,40 and 50 DAT (A1, A2 and A3) respectively by a period of 15 days in each water management and its witness flooded during the entire cycle (Flooded)

Moreover, it can be said that the suspension of the sheet of water or irrigation in a controlled way, always contributes to the WP, from an increase of agronomic performance of plants (23).

CONCLUSIONS

♦The suspension of the water level increased agricultural yields between 16 and 32 % over the flooded control and industrial was 67 %, with 58 % of whole grains when the water level was suspended at 30 DAT.

♦Water savings was achieved by suspending the sheet of water about 1 931,4 m^3 ha^{-1} in the cultivation of rice planting technology used by transplant flooded regarding treatment throughout its cycle (7 321,20 m^3 ha^{-1}).

♦ The saved water could increase the area under irrigation by 11,19 %.

♦ The suspension of the water level at 30 and 40 DAT allowed productivity in water use top irrigation 1 kg of rice per m^3 of water and the suspension permanent 30 DAT waterlogging is proposed for a period 15 days, at which time the water level is reset to 15 days before the grain harvest.

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