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EVALUATION OF NEW RICE (*Oryza sativa* L.) CULTIVARS UNDER LOW WATER AND FERTILIZER SUPPLY CONDITIONS IN PINAR DEL RÍO PROVINCE

Evaluación de nuevos cultivares de arroz (*Oryza sativa* L.) en condiciones de bajos suministros de agua y fertilizante en la provincia Pinar del Río

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ABSTRACT. This work was conducted at "Los Palacios" Scientific-Technological Base Unit (STBU), belonging to the National Institute of Agricultural Sciences (INCA), located in "Los Palacios" municipality, Pinar del Río province, in order to study the behavior of eleven rice cultivars, derived from different breeding methods, compared with the commercial cultivar J-104, during the dry season of 2011 and rainy season of 2012, both under low water and fertilizer supply conditions. Water management consisted of establishing a layer 15 days after rice germination, suspending its entry 35 days after germination and putting it back at primordial change until after 50 % flowering. At harvest time, evaluations were performed to leaf number, final plant height, crop cycle, agricultural yield and its components, industrial yield as well as its resistance to lodging, shattering and the main pests. Jose LP-20 and Guillemar LP-19 cultivars achieved the best agricultural and industrial yields, resistance against Piriculariosis and black kernel.

Key words: crossing, drought, somaclonal

RESUMEN. El trabajo se desarrolló en la Unidad Científico Tecnológica de Base "Los Palacios" (UCTB), perteneciente al Instituto Nacional de Ciencias Agrícolas, ubicado en el Municipio Los Palacios, provincia Pinar del Río, con el objetivo de estudiar el comportamiento de once cultivares de arroz, obtenidos a través de diferentes vías de mejoramiento, comparados con el cultivar comercial J-104, en el período poco lluvioso del 2011 y el lluvioso del 2012, ambos en condiciones de bajos suministros de agua y fertilizante. El manejo del agua consistió en el establecimiento de la lámina a los 15 días de germinado el arroz, suspensión de la entrada a los 35 días después de germinado y reposición en el cambio de primordio, hasta después del 50 % de floración. En el momento de la cosecha fueron evaluados el número de hojas, la altura final, ciclo del cultivo, rendimiento agrícola y sus componentes, rendimiento industrial, así como la resistencia al acame, el desgrane y el comportamiento ante las principales plagas. Los cultivares José LP–20 y Guillemar LP–19 obtuvieron los mejores rendimientos agrícolas e industriales, así como resistencia a la Piriculariosis y el manchado del grano.

Palabras clave: cruzamiento, sequía, somaclonal

INTRODUCTION

Rice is the staple food for more than 50 % world population; it is seeded and destined for marketing in every continent except Antarctica (1, 2). It ranks the second place after wheat, with regard to the harvested area, but considering its significance as a food product, it provides more calories per hectare than any other cereal; in addition, it has some other nutritional values, since it is rich in vitamins and minerals, low in fat and salt, and it is free of cholesterol (3). In Cuba, it is our people's main food, with an annual consumption close to 72 kg per capita, ranking the top places of Latin America; however, the national production just meets a little over 50 % of the needs until today, so the country is forced to fulfil them with imports (2).

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Although Cuban varietal policy has more than 10 rice cultivars, they have had some difficulties to show their full productive potential and the average crop yield is lower than the world average and close to 3,2 t ha^{-1}, caused by various reasons, such as climatic damage, technological indiscipline, pests and low water availability, the latter being one of the most important reasons, because more than 100 000 ha are grown without securing irrigation (4, 5).

At present, about 60 % available water is applied to agriculture in Cuba (6) and 40 % world-wide food production is achieved in irrigated areas. Flooded rice consumes, according to its cycle, 16 000 m^3 ha^{-1} (7). Global environmental changes predict a future drought increase (8); thus, it is necessary to look for some alternatives that enable a more efficient water use and reduce its consumption, taking into account that it is a limited resource (6), then, it is very important to reckon with genetic breeding focused on attaining tolerant rice cultivars to low water supplies (4, 9).

Regarding the existing problem and knowing how significant is for the country to obtain and assess tolerant cultivars to low water supplies, this study was aimed at evaluating the behavior of new rice cultivars under low water and fertilizer supply conditions in Pinar del Río province.

MATERIALS AND METHODS

The work was conducted at "Los Palacios" Scientific-Technological Base Unit (STBU), belonging to the National Institute of Agricultural Sciences (INCA), located in Los Palacios municipality, Pinar del Río province, on a Petroferric Nodular Gley Hydromorphic soil (10), during the dry season of January, 2011 and rainy season of April, 2012, for evaluating eleven rice cultivars coming from different breeding methods (Table I), which were directly drilled in 5-m-longx3-m-wide plots spaced at 15 cm between rows using a randomized block design with three repetitions.

Water management consisted of establishing a layer 15 days after rice germination, suspending its entry 35 days after germination and putting it back at primordial change until after 50 % flowering.

Table I. Cultivars evaluated under low water and fertilizer supply conditions in "Los Palacios" town

No	Cultivars	Progenitors	Origin
1	José LP-20	Amistad-82/J-112	Cuba
2	Guillemar LP-19	Amistad-82/INCA LP-7	Cuba
3	INCA LP-7	Somaclón Amistad-82	Cuba
4	INCA LP-10	Somaclón Amistad-82	Cuba
5	8825	Somaclón INCA LP-7	Cuba
6	8491	Somaclón Amistad-82	Cuba
7	9381	Somaclón Amistad-82	Cuba
8	INCA LP-17	Selección INCA LP-7	Cuba
9	INCA LP-13	Selección INCA LP-7	Cuba
10	J-104 (T)*	IR 480-5-9-2/IR930-16-1	Perú
11	Gines LP-18	Mutante J-104 (rapid neutrons 20 Gy)	Cuba

(T)* Commercial check control

With regard to fertilization, phosphorus and potassium were applied according to what is established by the technical crop instruction, besides taking into account the initial area fertility (7), whereas nitrogen was applied at a rate of 90 kg ha^{-1} during the dry season, splitted into three equal parts in three different times: from 10 to 15 days after germination, when the fifth leaf was issued; between 30 and 35 days after germination, after suspending irrigation; between 60 and 65 days after germination, before putting water back. During the rainy season, 70 kg ha^{-1} was applied at similar splits and times.

The other cultural practices followed the technical rice crop instruction (7).

At harvesting time, these indicators were evaluated:

- Leaf number in 10 plants selected at random by treatment
- Final plant height (cm) in 10 plants selected at random by treatment
- Crop cycle (days) at 50 % flowering
- Full grain number per panicle (1000 grains were weighed per treatment in 20 panicles taken at random)
- Panicle number per square meter (two samples of 0,25 m^2 per plot)
- 1000-grain mass (20 panicles)
- Agricultural yield (t ha^{-1}) in an area of 8 m^2 per treatment, although the area is of 15 m^2, just 8 m^2 are used for yield to avoid border effect
- Industrial yield (a sample of 1 kg dry paddy rice per treatment)

- ♦ Lodging and shattering resistance according to rice standard evaluation system (11).
- ♦ Pest occurrence of *Pyricularia grisea* Sacc, *Sarocladium oryza*, *Steneotarxonemus spinki* smiley, borer (*Diatrea sacharalis*) and black kernel.

Data were processed by a two-way classification variance analysis, whereas means were analyzed by Tukey's test at 5 % probability of error also using STATGRAPHICS statistical program (12).

Climatological data of average temperature, rainfall and relative humidity during the experimental time were recorded at "Paso Real de San Diego" Weather Station in "Los Palacios" town and processed by the Provincial Meteorological Center from the Ministry of Science, Technology and Environment (CITMA) in Pinar del Rio province.

RESULTS AND DISCUSSION

Table II shows the behavior of plant height, leaf number and cultivar cycle evaluated in "Los Palacios" town. Significant plant height differences were observed in all cultivars compared with the control J-104, which had the lowest values, whereas the greatest plant heights were recorded by INCA LP-10 during both seeding periods.

Some authors point out that water is physiologically important for rice plant growth and all its phenological phases depend on it (2, 6, 13). The first measurable effect of water stress is growth reduction and, in turn, cell length inhibition; however, this effect is less pronounced when using resistant cultivars (4, 6, 9), which has also been confirmed by trials with compounds, such as polyethylene glycol (PEG-6000)[A].

In relation to leaf number, there were significant differences among cultivars, since they formed from 12 to 14 leaves and it did not vary with season, except for Guillemar LP-19 and INCA LP cultivars that showed one leaf missing during the dry season of 2011, which could be related to crop management and nutrition, as this trait does not change. Some works conducted in China and Japan have shown that the number of days required for a single leaf to develop varies depending on its stem node position; the number of days increases from the first to the seventh leaf blade, followed by a decline until the tenth leaf; in addition, this a genetic trait that does not vary, as it depends just on each cultivar (14).

In relation to crop cycle, there were significant differences among cultivars (Table II), showing a longer cycle during the dry season of 2011 and J-104 always recorded the greatest value. However, differences in days were not the same for every season, with values ranging between 4 and 18 days.

These results differ from literature with regard to the behavior of short-cycle cultivars employed in Cuba, which show a range of differences from 11 to 18 days between both seasons, whereas for the average cycle, differences may be of up to 26 days (7), which could be associated to environmental influence on the agronomic behavior of cultivars.

In relation to agricultural yield, there were significant differences among cultivars during the two seeding seasons (Table III), compared to the production control J-104, highlighting Guillemar LP-19 and Jose LP-20 cultivars with the highest values in both seeding periods, without significant differences between them and with 0,3 to 0,4 t ha^{-1} in both seasons.

In this sense, yield is settled in terms of its components: 1000-grain mass, full grains per panicle and panicle number per m^2; however, according to many authors, the most directly influencing components on yield are panicles per square meter and full grains per panicle, which are considered selective markers in early generations of high-yielding cultivars (1, 4, 14, 15).

In relation to 1000-grain mass, there were significant differences among cultivars evaluated during both seasons, compared to the production control J-104, highlighting INCA LP-17 and Jose LP-20 with the highest values in the two sowing periods.

Regarding full grains per panicle, significant differences were recorded among cultivars evaluated during both seeding periods, highlighting Guillemar LP-19 and INCA LP-7 with the best behavior in both periods, as well as Jose LP-20 during the dry period. Apparently, these cultivars are better adapted to these low water supply conditions. Therefore, results from various investigations state that by subjecting rice crop to stressful conditions during the vegetative phase, there is a greater photosynthate accumulation that is subsequently translocated to form carbohydrates for grain filling, reaching a greater panicle mass and length (13, 14).

[A] García, A. Efectos fisiológicos del déficit hídrico inducido en fases tempranas del crecimiento de plantas de arroz (*Oryza sativa* L.) y su aplicación en la selección de variedades tolerantes. Tesis de Doctorado, Instituto Nacional de Ciencias Agrícolas, Mayabeque, 2009, 132 p.

Table II. Behavior of plant height, leaf number and cultivar cycle evaluated under low water and fertilizer supply conditions in "Los Palacios" town

Cultivars	Plant height (cm)		Leaf number		Cultivar cycle (days)	
	2011	2012	2011	2012	2011	2012
José LP-20	80,3 cd	73,7 c	13 a	13 ab	138 b	120 b
Guillemar LP-19	74,7 e	71,7 e	13 a	14 a	134 d	120 b
INCA LP-7	80,7 bc	73,7 c	13 a	13 ab	136 c	120 b
INCA LP-10	84,7 a	75,7 a	12 b	13 ab	121 f	115 c
8825	80,3 cd	72,7 d	13 a	13 ab	115 h	109 e
8491	81,3 b	74,7 b	12 b	12 b	114 h	109 e
9381	73,3 f	60,3 f	12 b	12 b	119 g	110 d
INCA LP-17	79,7 d	74,3 bc	12 b	12 b	121 f	115 c
INCA LP-13	79,7 d	74,3 bc	12 b	12 b	119 g	115 c
J-104 (T)	69,3 g	59,3 g	12 b	12 b	139 a	126 a
Gines LP-18	81,3 b	72,7 d	12 b	12 b	130 e	115 c
Average	78,8	71,18	12	13	126	116
SEx	0,28	0,33	0,24	0,28	0,27	0,24

Means with the same letters per column, do not differ significantly according to Tukey's test at 5 % probability of error

Table III. Behavior of agricultural yield (t ha^{-1}) and its components: 1000-grain mass, full grains per panicle and panicles per square meter of cultivars evaluated under low water and fertilizer supply conditions in "Los Palacios" town

Cultivars	Yield t ha^{-1}		1000-grain mass (g)		Full grains per panicle		Panicles per m^2	
	2011	2012	2011	2012	2011	2012	2011	2012
José LP-20	5,6 ab	5,3 a	31,1 ab	30,5 ab	102 b	99 a	299 ab	296 a
Guillemar LP-19	5,7 a	5,3 a	29,6 e	29,7 de	107 a	102 a	303 a	298 a
INCA LP-7	5,3 d	4,4 bc	30,0 d	30,1 bc	106 a	99 a	292 bcd	257 d
INCA LP-10	5,1 e	4,5 b	30,8 bc	29,2 f	98 c	90 b	288 cd	273 b
8825	4,6 f	4,4 bc	29,3 e	29,8 cde	92 e	90 b	286 d	251 d
8491	4,0 h	3,8 e	30,6 c	29,6 ef	90 e	81 c	303 a	266 c
9381	4,4 g	3,9 de	28,3 f	28,3 g	102 b	90 b	288 cd	265 c
INCA LP-17	5,4 c	4,5 b	31,3 a	30,9 a	102 b	90 b	295 abc	275 b
INCA LP-13	5,5 bc	4,2 cd	30,7 c	30,0 bcd	101 b	80 c	295 abc	275b
J-104 (T)	4,0 h	3,0 f	28,1 f	28,2 g	85 f	62 e	260 e	244 e
Ginés LP- 18	5,2 de	4,4 bc	30,7 c	30,2 b	94 d	75 d	295 abc	275 b
X	5,0	4,5	30,0	29,7	98	87	291	270
SE	0,03	0,05	0,13	0,14	0,44	0,73	1,67	1,30

Means with the same letters per column, do not differ significantly according to Tukey's test at 5 % probability of error

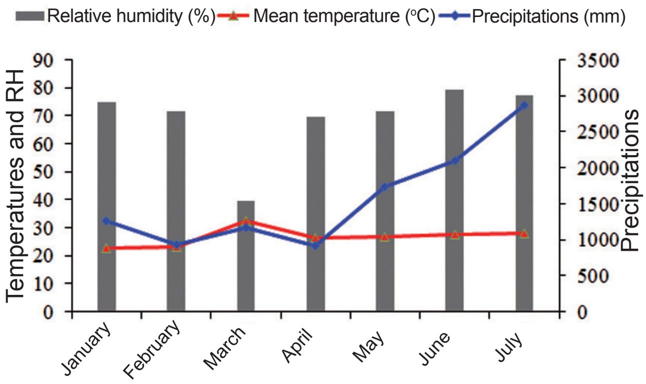
Regarding panicle number per square meter, a significant difference was observed in all cultivars evaluated during both seeding periods: in the dry season, 8491 and Guillemar LP-19 cultivars showed the highest amounts of panicles, followed by Jose LP-20 and, during the rainy season, the best results were obtained by Jose LP-20 and Guillemar LP-19, meanwhile in both seasons the cultivar J-104 differed from the rest with the lowest panicle number per square meter, which could mean that J-104 is more susceptible to these stressful conditions than the other cultivars evaluated.

Some researchers pointed out that stress resistance is not a single phenomenon that is presented in two forms: through internal mechanisms that the plant develops to remove cells from stress conditions and plant ability to survive and function properly under extreme drought conditions (9, 13). Similarly, others suggest that stress affects carbon and nitrogen metabolism, so that productivity and yield decrease (5, 13). Furthermore, higher soil temperature increases ammoniac N enzyme concentration under stress conditions, promotes a greater amount of panicles per square meter and of full grain number per panicle (2, 14).

Figures 1 and 2 show that temperature was profitable for tillering development, it ranging from 28 to 30 °C in this phenophase; this result is consistent with that reported by other authors in studies about the climatic influence on rice crop phenophases (14). Optimum temperatures for tillering and elongation range from 30 to 34 °C respectively and they may vary according to rice cultivar and each plant growth stage (14).

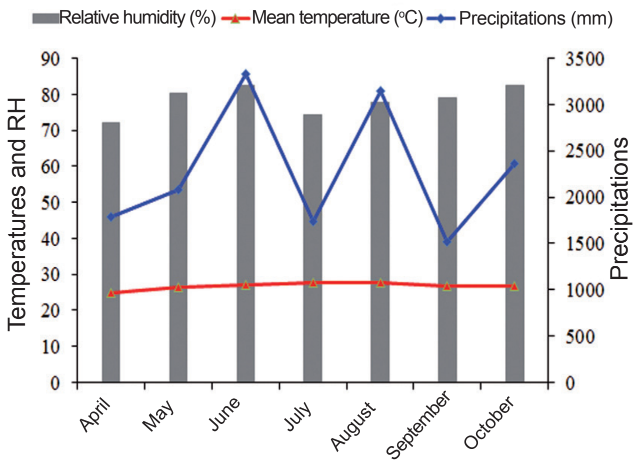
Industrial yield (Table IV) is an important trait for recording cultivars and its appropriate value for Cuba must be greater than 52 %. In this study, significant differences were observed in all the material evaluated, highlighting Guillemar LP-19 with the highest whole grain percentage in both seeding seasons and Jose LP-20 in the dry season, meanwhile J-104 obtained the lowest values for both sowing periods. Similar results have been obtained by other researchers when studying J-104 cultivar under permanent waterlogging and favored upland conditions (5, 9).

As for lodging resistance (Table V), only 9381showed susceptibility that could be mainly due to its quick drying and leaf sheath weakening.



Weather conditions: rainfall (Rain), temperature (Temp) and relative humidity (RH): monthly averages for the experimental months during the dry season of 2011

Figure 1. Behavior of meteorological variables (2011), monthly averages



Weather conditions: rainfall (Rain), temperature (Temp) and relative humidity (RH): monthly averages for the experimental months during the dry season of 2012

Figure 2. Behavior of meteorological variables (2012), monthly averages

According to several authors, lodging or overturning is influenced by an excessive amount of nitrogen fertilizer, the effect of some pathogens on the stem and climatic factors, such as wind and rain.

As for shattering resistance, line 8491 behaved as a susceptible cultivar, with higher percentages than 50 % detached grains and four of them showed an intermediate resistance of 25 to 50 %; the rest classified as resistant cultivars. It is known that this trait is influenced by the environment and it is very important for breeding programs, since it makes agricultural yield losses.

When evaluating Piriculariosis (Table V), not all cultivars had good behavior, only eight of them classified as resistant in both seeding periods, whereas J-104, 9381 and 8491 showed susceptibility. J-104 cultivar has been seeded for many years, reaching 80 % of all the national area, but its seedings declined on account of its susceptibility to this disease and to poor industrial quality (whole grain percentage). The cultivars with better behavior could be resistant to haplotypes present under these conditions, so that they are important materials to consider for this crop genetic breeding (15, 16).

As for black kernel, Jose LP-20, Guillemar LP-19, INCA LP-7 and Gines LP-18 cultivars showed the best results for both sowing periods, meanwhile the others behaved as intermediate and susceptible cultivars.

For *Sarocladium oryzae*, the causal agent of sheath rot, Guillemar LP-19, INCA LP-7, INCA LP-10 and Gines LP-18 cultivars showed the best behavior in both sowing periods; in addition, it was found that all the material evaluated during this period had a good behavior against borer (*Diatrea sacharalis*).

In the rainy season, except for INCA LP-7 that behaved as resistant cultivar, every material showed mite susceptibility. As it is known, there are ideal weather conditions for this pest occurrence during this season.

In general, results showed an excellent behavior of Jose LP-20 and Guillemar LP-19 cultivars, as for agricultural and industrial yields, and to major pests affecting the crop, except for *Steneotarxonemus spinki* smiley (mite) under low water and fertilizer supply conditions.

Table IV. Behavior of industrial yield (whole grain percentage) of cultivars evaluated under low water and fertilizer supply conditions of "Los Palacios" town

Cultivars	Industrial yield	
	2011	2012
José LP-20	58,33 a	58,66 b
Guillemar LP-19	59,00 a	60,66 a
INCA LP-7	55,33 bc	57,33 c
INCA LP-10	56,33 b	58,00 bc
8825	56,33 b	58,33 b
8491	56,33 b	57,33 c
9381	54,00 de	56,33 d
INCA LP-17	53,33 e	55,66 d
INCA LP-13	53,33 e	55,66 d
J-104 (T)	45,33 f	47,66 e
Ginés LP-18	54,66 cd	58,75 b
X	54,75	56,82
SE	0,38	0,27

Means with the same letters per column, do not differ significantly according to Tukey's test at 5 % probability of error

Table V. Behavior of pest occurrence in cultivars evaluated under low water and fertilizer supply conditions of "Los Palacios" town

Cultivars	Periods													
	2011							2012						
	L	Sh	Pg	Bk	S	Ac	B	L	Sh	Pg	Bk	S	Ac	B
José LP-20	R	R	R	R	I	R	R	R	R	R	R	I	S	R
Guillemar LP-19	R	R	R	R	R	R	R	R	R	R	R	R	S	R
INCA LP-7	R	R	R	R	R	R	R	R	R	R	R	R	R	R
INCA LP-10	R	I	R	S	R	I	R	R	I	R	S	R	S	R
8825	R	I	R	I	S	I	R	R	I	R	I	S	S	R
8491	R	S	S	S	S	I	R	R	S	S	S	S	S	R
9381	S	I	S	S	S	I	R	S	I	S	S	S	S	R
INCA LP-17	R	R	R	I	I	R	R	R	R	R	I	I	S	R
INCA LP-13	R	R	R	S	I	R	R	R	R	R	S	I	S	R
J-104 (T)	R	I	S	S	S	S	R	R	I	S	S	S	S	R
Ginés LP-18	R	R	R	R	R	R	R	R	R	R	R	R	S	R

L: Lodging
Sh: Shattering
S: *Sarocladium oryzae*
Bk: Black kernel
B: *Diatrea sacharalis* (borer)
Pg: *Pyricularia grisea*
Ac: *Steneotarxonemus spinki* (mite)
R: resistant
I: intermediate
MR: moderately resistant
S: susceptible

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