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INFLUENCE OF ENVIRONMENTAL TEMPERATURE AND SOWING DATE ON THE PHENOLOGICAL PHASE LENGTHENING OF FOUR RICE (*Oryza sativa* L.) CULTIVARS

Influencia de la temperatura ambiental y la fecha de siembra sobre la duración de las fases fenológicas en cuatro cultivares de arroz (*Oryza sativa* L.)

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ABSTRACT. This research was conducted in areas from "Los Palacios" Scientific-Technological Base Unit (UCTB) in Pinar del Rio province, pertaining to the National Institute of Agricultural Sciences.Two short-season cultivars (INCA LP-5 and Reform) and two half-season cultivars (INCA LP-2 and J-104) were used and seeded in four sowing dates (January-2004, December-2004, February-2005 and January-2006) over the winter season, on a Petroferric Ferruginous Nodular Gley Hydromorphic soil. The objective was to determine the influence of environmental temperature and seeding date on the phenological phase variation of four rice cultivars. A randomized block design with four replications was used. Based on the results, it can be concluded that the longest vegetative and reproductive phase was recorded at the dates of December-2004 and January-2006, corresponding to the lowest temperature values reported in this work. The accumulated temperature necessary to complete the biological cycle of INCA LP-5, Reform and INCA LP-2 cultivars is within a range from 1900 to 2150 °C, whereas for J-104 is between 2200 and 2260 °C. Highest yields correspond to the longest reproductive phase forevery cultivar studied.

Key words: rice, phenology, yield, accumulated temperatures

RESUMEN. La investigación se desarrolló en áreas de la Unidad Científico-Tecnológica de Base "Los Palacios" (UCTB) en la provincia de Pinar del Río, perteneciente al Instituto Nacional de Ciencias Agrícolas. Se utilizaron dos cultivares de ciclo corto (INCA LP-5 y Reforma) y dos cultivares de ciclo medio (INCA LP-2 y J-104), los cuales se sembraron en cuatro fechas de siembra (enero-2004, diciembre-2004, febrero-2005 y enero-2006) en la campaña de frío, sobre un suelo Hidromórfico Gley Nodular Ferruginoso Petroférrico. El objetivo fue determinar la influencia de la temperatura ambiental y la fecha de siembra en la variación de las fases fenológicas de cuatro cultivares de arroz. Se utilizó un diseño experimental de bloques al azar con cuatro réplicas. Atendiendo a los resultados, se puede concluir que la mayor duración de la fase vegetativa y reproductiva se encontró en las fechas de diciembre-2004 y enero-2006, lo que se corresponde con los valores más bajos de temperatura informados en el trabajo. La temperatura acumulada necesaria para poder completar el ciclo biológico de los cultivares INCA LP-5, Reforma e INCA LP-2 está comprendida en un rango de 1900 a 2150 ºC, mientras que para J-104 es de 2200 a 2260 ºC. Los mayores rendimientos se corresponden con la mayor duración de la fase reproductiva para todos los cultivares estudiados.

Palabras clave: arroz, fenología, rendimiento, temperaturas acumuladas

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most consumed cereals and is the main source of food for more than half of the world population after wheat[A]. There are many investigations carried out in the growing and, according to different authors, the study of phenological behavior is among the most important because it is

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[A] Méndez, del V. P. *ARROZ: ¿estabilidad o nueva alza de los precios mundiales?* [en línea]. Informativo mensual del mercado mundial del arroz, febrero de 2011, [Consultado: 21 de marzo de 2016], Disponible en: <http://www.infoarroz.org/portal/uploadfiles/20110305051805_15_ia0211es.pdf>.

useful for the development of phytotechnical activities[B]. That is the reason why there has been much work aimed to study the physiological process (1) the growth of the rice plant, which comprises, from germination to maturity of the grain. This is divided into three main phases: the vegetative, reproductive and maturation.

The duration of these phases may differ under different climatic conditions and, in general, the temperatures are which accelerate or retard the phenological behavior (2) controlling the rate of crop development, since the accumulation of a certain amount of required heat to move from one phase to another in their life cycle (2). For this reason, the accumulated temperatures needed are determined to complete phases and phenological stages in crops, in order to accurately predict the occurrence date of the different development stages of a plant and establish the planting schedule and gathering, and choose accordingly, more cultivars adapted for each area in question.

Thermal units or degrees days of growth are determined from a base (3) temperature, which varies among species and possibly between cultivars; likewise, can vary between stages of development or according to physiological process that is considered (4). Such thermal units can be calculated for some of the development stages or for the entire cycle, from planting or emergency to maturity (3).

Thus, considering that to evaluate the growth of the rice plant in Cuba conditions patterns empirical behavior, which in most cases is overestimated or underestimated the phases duration of the cultivars are applied and it is impossible to plan management activities at the most opportune moment, therefore, developed this work, in order to determine the influence of environmental temperature and planting date on the variation of phenological phases of four rice cultivars.

MATERIALS AND METHODS

This research was conducted in areas from Scientific-Technological Base Unit (UCTB) "Los Palacios" in Pinar del Rio province belonging to the National Institute of Agricultural Sciences. Two short-season cultivars (INCA LP-5 and Reform) and two half-season cultivars (INCA LP-2 and J-104) were used and seeded in four sowing dates (January-2004, December-2004, February-2005 and January-2006) over the winter season, on a Petroferric Ferruginous Nodular Gley Hydromorphic soil

Direct seeding technology was used, with a standard of 120 kg ha^{-1}. The plant breeding activities were developed, as recommended by the Technical Instructions of Rice (6). The experimental design was randomized blocks with four treatments and four replications or blocks, experimental plots of 25 m^2. Daily maximum and minimum temperature data during the cycle of the cultivars studied for each planting date were taken from the weather station "Paso Real", San Diego, near the site of experimentation. The duration in days was calculated for each of the growth phases, taking into account reported by the International Center for Tropical Agriculture (CIAT), shown in Table I (7).

Each phase was declared when more than 50 % of plants in the experimental plots had the characteristics described. Data duration of the different phases and cycle to cultivate in each planting date were processed by analysis of dual classification variance using the Windows program STATGRAPHICS Plus version 5.0 (8).

Significant differences between the means of the different treatments were verified by Tukey test at 95 %. Temperature data were plotted for analysis, in conjunction with the duration of phenological phases of each cultivar.

The accumulated temperature was determined from the sum of the growth days degree (GDC) (3) by the equation; the data average were determined the confidence interval and graphed for their analysis.

Table I. Description of each of growth different stages in rice cultivation (9)

Phases	Phases´ description
Vegetative	It begins after seed germination when the first leaf emerges and ends when more than 50 % of the mother plants (main stem) present the third elongated internode and has begun the panicle formation
Reproductive	It begins with the onset of panicle and ends when the output of the whitish appearance anthers in the middle third and the bottom third of the panicle is noted, the tip of the panicle begins to bend
Maduration	It begins when the output of the whitish appearance anthers in the middle third and the bottom third of the panicle note and ends with the complete ripening grain

[B] Giambastiani, G. *ClimAgri 2.0: Programa de Simulación de Fenología de Cultivos con Fines Educacionales* [en línea]. Facultad de Ciencias Agropecuarias, Universidad Nacional de Córdoba, 2005, [Consultado: 21 de marzo de 2016], Disponible en: <http://sedici.unlp.edu.ar/bitstream/handle/10915/19115/Documento_completo__.pdf?sequence=1>.

$$GDC = \frac{T_{maximum} + T_{minimum}}{2} - T_{base}$$

where:

$T_{maximum}$: maximum daily air temperature.

$T_{minimum}$: minimum daily air temperature.

T_{base}: Base temperature, which is the temperature at which the process does not, progresses and in this case 10 ºC was taken (1).

Performance was determined by the system used in rice cultivation in Cuba (9) in an area of 8 m^2; these data were subjected to analysis of bifactorial arrangement variance.

The treatments are made up of the four times of planting where the factors are the INCA LP-5, Reforma, INCA LP-2 and J-104 cultivars and planting dates were: January 2004, December 2004, February-2005 January-2006. Significant differences between the means of the different treatments were verified by Tukey test at 95 %.

RESULTS AND DISCUSSION

Table II shows the phenological phase's duration of the crop, according to the different planting dates. For most cultivars vegetative phase exceeded 80 days, except INCA LP-5 and Reform, when they were sown in January 2006.

The reproductive phase, in general, was more than 30 days, only INCA LP-2 and J-104 cultivars, in January 2004 showed the lowest values, with 28 and 27 days respectively. When cultivars were planted in December 2004 showed a longer duration of the reproductive phase, with significant statistical differences from other crops, except for INCA LP-2 and Reform cultivars, which showed no differences with plantings January 2006.

The maturation phase for all cultivars and planting dates lasted between 21 and 28 days; the highest values were found in sowing January 2006 for INCA LP-2, INCA LP-5 and Reforma cultivars, which also were statistically different from the rest of the dates. J-104 cultivar had a longer duration of the maturation phase when planted in December 2004, no statistically significant differences with sowing January 2006. As for the cycle, it is noteworthy that cultivars planted in December 2004 lasted longer than when sown in the rest of the months studied, with statistically significant differences among them.

These results do not match what is set so far for rice cultivation, as in literature stands that the reproductive and ripening phases do not suffer variations depending on planting date and have a duration of 30 days, only the vegetative phase is characterized by its variation (6, 10). In addition, for the conditions of Cuba also it states that the cycles of cultivation are defined as short cycle cultivars with less than 130 days and half cycle for those whose duration is between 130 and 150 days in the dry season (6). However, the results of this work, the duration of the reproductive phase and maturation, showed lower and higher than those established for these phases values and the duration of the cycle, INCA cultivars LP-5 and Reforma (considered short-cycle cultivars) exceeded 130 days. The cultivars INCA LP-2 and J-104, to be planted in December 2004, exceeded 150 days, even J-104 cultivar maintained this behavior in January 2006 planting.

From these results, it should be noted that a regular pattern as to the duration of the phases and cycle cultivars should not be established, as this depends largely on planting dates at the times set for the culture.

Table II. Anova results for the duration of the phenological phases and the cycle (days) of four cultivars of rice (*Oryza sativa* L.) in different planting dates

Planting date	Vegetative phase	Reproductive phase	Maturation phase	Cycle	Vegetative Phase	Reproductive phase	Maturation phase	Cycle
		INCA LP-5				Reforma		
January 2004	87 a	35 b	21 c	143 b	87 a	30 b	21 c	138 b
December 2004	89 a	41 a	21 c	151 a	87 a	36 a	23 bc	146 a
February 2005	83 b	31 c	25 b	139 c	80 b	30 b	25 b	135 c
January 2006	74 c	36 b	28 a	138 c	74 c	36 a	28 a	138 b
ESx	± 1,51	± 0,94	± 0,82	± 1,35	?1,44	± 0,79	± 0,73	± 1,09
CV (%)	7,24	10,54	13,79	3,78	7,01	9,65	11,99	3,14
		INCA LP-2				J-104		
January 2004	92 a	28 c	25 b	145 b	100 a	27 d	22 b	149 c
December 2004	94 a	36 a	24 b	155 a	101 a	41 a	25 a	167 a
February 2005	88 b	32 b	24 b	144 b	95 c	30 c	22 b	147 c
January 2006	83 c	36 a	28 a	147 b	97 b	36 b	24 ab	157 b
ESx	± 1,12	± 0,89	± 0,49	± 1,22	± 0,64	± 1,42	± 0,41	± 2,04
CV (%)	5,00	10,79	7,72	3,31	2,59	16,92	7,11	5,28

Mean with common letters are not significantly different among them p<0,05 according Tukey test (n=4)

Due to this, other results (1, 11), highlights that short cycle cultivars behave like half cycle in the dry season and there are even cultivars have been introduced in the country, whose cycle is lengthened from six to ten days for the established to Cuban cultivars. This aspect is influenced by the behavior of the climate, which varies from planting date (12).

Concerning this, Figure 1 shows the behavior of daily maximum and minimum temperatures throughout the crop cycle and differences in these weather variables for different planting dates are observed. In general, plants grown in December 2004 were exposed to lower values of temperature throughout their cycle, when compared with the other planting dates; however, February 2005 were subjected to the highest values of this variable and reached an earlier cycle.

In this regard, studies with the Fe rice cultivar in Colombia showed that when this was planted under temperature between 20 and 36 °C, the development period ranged from 127 to 135 days, whereas when temperatures ranged between 16 and 32 °C, this period lasted from 140 to 150 days (13).

Also noteworthy is that there are reports where it is highlighted that the temperature has a strong influence on the growth of crops (14, 15). In the rice case highlights the vegetative phase, especially in the beginning stage of tillering (10); moreover, it has demonstrated the effect of these in the production of stems (10). These authors found that, in a range of 24,1 to 27,4 °C of average temperature, increased the number of stems per m^2 in the order of 453 to 689. With temperature values above the above, there were no increases in the number of plant stems. The agrometeorologic temperature is a variable that affects the crop from seed germination until harvesting and related even with the quality of the grain being harvested (16).

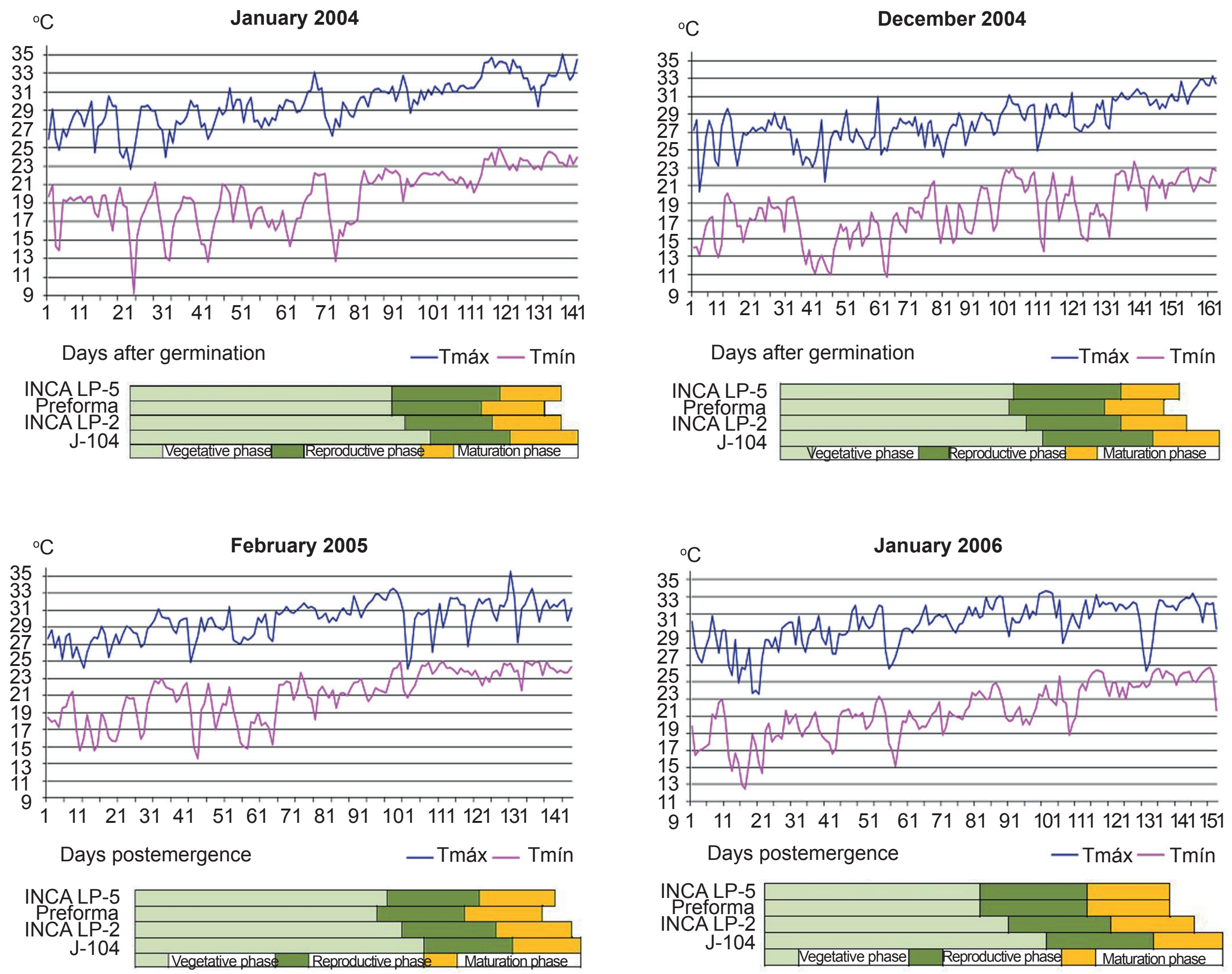

Figure 1. Behavior of the maximum and minimum air temperatures during the established crop period, planting dates

From the above results, it can be noted that there is a wide variation in the phases duration of rice cultivation in the established plantings dates, due to the influence of temperature, so it is clear that each development phase a crop requires minimal accumulation temperature to reach its term and move to the next phase (Figure 2).

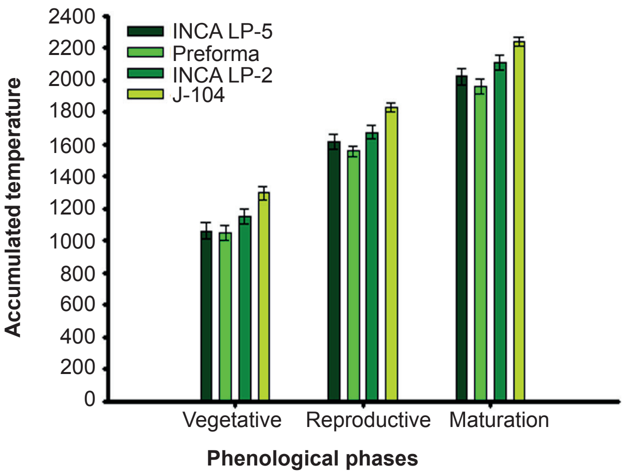

Figure 2. Behavior of the different phenological stages in evaluated cultivars and their relationship to the accumulated temperature ($p<0,05$)

In determining the cumulative temperature from degree days of growth (GDC, °C-day), no marked differences between planting dates were found, an aspect that has been highlighted by other authors (17) However, differences among cultivars are noted, as J-104 differs from the rest in all phases of the culture and INCA LP-5 shows no difference with Reforma and INCA LP-2, although the latter two differ significantly in each phase.

It is noted that INCA LP-5, Reforma and INCA LP-2 require a cumulative temperature range to complete their life cycle, ranging between 1900 and 2150 °C, while J-104 requires 2200 to 2260 °C.

In terms of performance, Anova results showed that there was interaction among the different levels of the studied factors (Table III).

The best performance occurred in December 2004 and January 2006, achieving the highest values with cultivars INCA LP-5 and Reforma, in December 2004, with 6,2 and 6,1 t ha^{-1} respectively and 6, 6 and 6,3 t ha^{-1} in these same cultivars in January 2006, with no statistically significant differences between them. However, lower yields were achieved by INCA LP-2 and J-104 in January 2004 and January 2005. This is related to the results in Table II on lengthening the reproductive stage reached by cultivars being planted in those two dates (December 2004 and January 2006).

Regarding this, studies in other cereals, in conditions of Cuba, reported a direct relationship between performance and paniculation stage duration (17). This demonstrates the importance of reproductive phase to obtain good yields, especially when there is a longer period of solar radiation interception by the crop at this stage, which facilitates higher productivity (3). Lengthen the period in which the productivity per unit area of the plant is high, can achieve greater dry mass production and higher yield per plant (17).

CONCLUSIONS

- Based on the results of this research, it can be concluded that longer duration of vegetative and reproductive phases of cultivars was reached in December 2004 and January 2006 planting dates, which corresponds to the lowest values temperature reported.
- The accumulated temperature needed to complete the life cycle of the INCA LP-5, Reforma and INCA LP-2 cultivars falls within a range of 1900-2150 °C, while for the J-104 is 2200 -2260 °C.
- The higher agricultural yields correspond to the longer duration of the reproductive phase, for all cultivars studied.

Table III. Anova results with bifactorial arrangement for agricultural yield (t ha^{-1}) to 14 % grain moisture cultivars in each planting date

	January 2004	December 2004	February 2005	January 2006
INCA LP-5	5,9 bcd	6,2 abc	5,3 efg	6,6 a
Reforma	5,5 def	6,1 abc	5,2 efgh	6,3 ab
INCA LP-2	5,0 gh	5,8 bcde	4,8 gh	5,6 cdef
J-104	5,1 fgh	5,0 gh	4,7 h	5,7 bcd
ESx	±0,07			

Means with common letters are not significantly different among them p <0.05 according to Tukey test (n=4)

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