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DURATION OF THE PHENOLOGICAL PHASES, ITS INFLUENCE IN YIELDS OF RICE (*Oryza sativa* L.)

Duración de las fases fenológicas, su influencia en el rendimiento del arroz (*Oryza sativa* L.)

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ABSTRACT. The research was conducted in areas of the Technological Scientific Base Unit "Los Palacios" (UCTB Los Palacios), Pinar del Rio, part of the National Institute of Agricultural Sciences of Cuba. Two short cycle cultivars (INCA LP -5 and Reform), and two half cycle cultivars (INCA LP-2 and J-104). Were used which were planted in four planting dates of the cold season, on a Gley Nodular Hydromorphic Ferruginous Petroferric soil. The objective was to determine the influence of the phenological phases duration in yield of rice cultivars (*Oryza sativa* L.) under the conditions of spring season. A randomized block experimental design was used with four replications. Based on the results of this study, it can be concluded that the duration of the reproductive phase in rice cultivars closely positive and direct relationship with of yield in the conditions of the spring season.

Key words: rice, phenology, *Oryza sativa*, yield

RESUMEN. La investigación se desarrolló en áreas de la Unidad Científico Tecnológica de Base "Los Palacios" (UCTB Los Palacios), Pinar del Río, que pertenece al Instituto Nacional de Ciencias Agrícolas en Cuba. 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 cinco fechas de siembra en la campaña de "primavera", sobre un suelo Hidromórfico Gley Nodular Ferruginoso Petroférrico. El objetivo fue determinar la influencia de la duración de las fases fenológicas en el rendimiento de cultivares de arroz (*Oryza sativa* L.) en época de primavera. El diseño experimental usado fue de bloques al azar con cuatro réplicas. Basado en los resultados del presente estudio se puedo concluir que la duración de la fase reproductiva en cultivares de arroz, guarda una relación positiva y directa con el comportamiento del rendimiento agrícola en las condiciones de la época de "primavera".

Palabras clave: arroz, fenología, *Oryza sativa*, rendimiento

INTRODUCTION

Rice (*Oryza sativa* L.) is a crop of great importance throughout the world since it is one of the most consumed cereals and the main food source for more than half of the world's population (1,2). Studies on phenology in this crop are an essential aspect to identify the adaptation and response of cultivars to diverse environmental conditions (3).

The purpose of phenology is to study and comprehensively describe the different events during the development that occur in plant species within natural or agricultural ecosystems, in their interaction with the environment. In this sense, the realization of phenological observations are the basis for the implementation of any agricultural system, which allows producers to obtain with the application of knowledge on the subject, greater efficiency in planning and programming of different activities agriculture, leading to increased productivity and production in crops (4,5).

There are several researches worldwide that evaluate the climate incidence, the phenological behavior and its relation with the yield in rice cultivars; since in today's agriculture the importance

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of the genotype is increasingly valued developing in a given environment, in order to achieve an adequate management that allows a greater agricultural production (2, 5, 6). In Cuba, also in order to increase the productivity of crops, various works have been developed related to the study of phenology and its relationship with the behavior of environmental temperature and performance, in these studies has been taken into account the use of different sowing dates (7). These aspects are among the most important actions for the planning of crop plantings in the country and the development of adaptation measures to the impacts of climate change (8).

However, the great climatic variability and especially the tendency that exists to temperature increases (9), cause that in the planning process in the agricultural production the duration of the phases of the cultivars is overestimated or underestimated, especially when sowing is done in "spring". All this makes it difficult for crop management activities to develop at the most opportune moment and consequently a decrease in yield. From the above, this work was developed, with the aim of determining the duration influence of the phenological phases on the agricultural yield of rice (*Oryza sativa* L.) cultivars in the "spring" season.

MATERIALS AND METHODS

The work was carried out in areas of the UCTB "Los Palacios", Pinar del Río, belonging to the National Institute of Agricultural Sciences, in Cuba. Two short-cycle cultivars (INCA LP-5 and Reforma) and two medium-cycle cultivars (INCA LP-2 and J-104) were used, which were planted in five moments (March 2006, August 2006, April 2007, April 2008). and April 2009), from the time called "rainy" (Spring), on a Gley Nodular Ferruginous Petroferric Hydromorphic soil (10).

Direct sowing technology was used, with a seed sowing standard of 120 kg ha^{-1}. The phytotechnical activities were developed as recommended by the Technical Instruction for rice cultivation (11). The experimental design, at each time of sowing, was of random blocks with four treatments and four replications, with experimental plots of 25 m^2. The duration of each of the growth phases in days was calculated, taking into account what was indicated by the International Center for Tropical Agriculture (CIAT) (12). Each phase was decreed more than 50 % of the plants in the experimental plots presented the characteristics according to what was described. The maximum and minimum temperature data taken from the Paso Real de San Diego agrometeorological station were recorded. These data were plotted for analysis, together with the duration of the phenological phases of each cultivar.

In each experimental plot, the agricultural yield was also determined at 14 % moisture of the grain (13). The duration data of the different phases and the cycle, in addition to the agricultural yield to be cultivated at each planting date, were subjected to analysis of variance, taking into account the experimental design used. From the resulting experimental error, the confidence interval of the means was calculated. A data matrix was also built; cultivars, duration of phenological phases and yield and this was processed by the multivariate technique of Principal Components, by means of the representation of a Biplot to establish the degree of association between the determined variables with the yield for the conditions of the sowing time.

RESULTS AND DISCUSSION

The Table shows the duration of the phenological phases of the crop, according to the different sowing dates. For most cultivars the vegetative phase exceeded 60 days. The reproductive phase, as the average of the cultivars at each planting date, was never less than 24 days and did not exceed 44 days. However, in these ranges, the behavior of the cultivars suffered variations due to the effect of the cultivation conditions on the specific sowing dates. The maturation phase for all the cultivars and planting dates lasted between 23 and 38 days. In this sense, the existing environmental conditions, in particular the variation of temperatures in a certain period can minimize or maximize the differences in to the duration of the phases and therefore also to the duration of the cycle (6).

All this is motivated by the fact that the development of a cultivar is conditioned by modifications in the biochemical-physiological order that the genotype presents as a function of its interaction with the environment. Therefore, this irregular behavior in terms of the duration of the phases and the cycle of the cultivation in these cultivars (Table 1) can be related to the prevailing temperature in the different sowing dates.

This relation between the duration of the phases and the behavior of the prevailing temperatures in the period of the crop development is evidenced in Figure 1 which shows the values of the maximum and minimum temperatures of the air, diurnal, in each phenological phase of the development of rice cultivars.

Table 1. Range of cycle length (days) of rice cultivars (*Oryza sativa* L.) on different sowing dates

Cultivars	Vegetative phase (days)	Reproductive phase (days)	Maturation phase (days)	Cycle (days)
March 2006				
INCA LP-5	63-73	38-44	31-35	138-146
Reforma	63-73	33-39	24-28	126-134
INCA LP-2	83-93	24-30	30-34	143-151
J-104	85-95	26-32	26-30	143-151
ESx	2,74*	1,41*	0,70*	1,81*
August 2006				
INCA LP-5	57-63	31-33	26-30	116-124
Reforma	53-59	28-30	32-36	115-123
INCA LP-2	66-72	28-30	27-31	123-131
J-104	68-74	29-31	34-38	133-141
ESx	1,63*	0,37*	0,89*	1,90*
April 2007				
INCA LP-5	61-65	27-29	27-29	114-120
Reforma	57-61	25-27	31-33	114-120
INCA LP-2	63-67	30-32	26-28	120-126
J-104	70-74	31-33	26-28	128-134
ESx	1,16*	0,65*	0,62*	1,49*
April 2008				
INCA LP-5	63-69	33-35	26-28	124-130
Reforma	59-65	32-34	27-29	120-126
INCA LP-2	73-79	28-30	23-25	126-132
J-104	74-80	31-33	29-31	136-142
ESx	1,69*	0,48*	0,60*	1,53*
April 2008				
INCA LP-5	59-69	32-36	28-30	123-131
Reforma	52-62	25-29	31-33	112-120
INCA LP-2	70-80	27-31	25-27	126-134
J-104	80-90	27-31	24-26	135-143
ESx	2,76*	0,88*	0,70*	2,17*

Range calculated from the mean and its confidence interval at 95% probability taking into account the experimental error of the analysis of variance

In Figure 1, in general, differences are observed regarding the behavior of the maximum and minimum temperatures between planting dates. The plants planted in March 2006 were exposed during most of their life cycle to lower temperature values than the rest of the sowing dates and presented a longer duration of the growth phases.

In the literature there are reports where it is emphasized that the crop cycle is affected significantly by this environmental factor, which can cause a lengthening or shortening in the phases that result in the plant's life period (5). From the results of the present work, it can be highlighted that there is a wide variation in the duration of the rice cultivation phases in these sowing dates, due to the influence, fundamentally of the temperature.

Regarding the performance of the agricultural yield to 14 % moisture of the grain, the values oscillated between 3 and 5 t ha^{-1}. In general, the variation of this indicator for the different cultivars in the same sowing date and between dates stands out. In this variable it was evident how difficult it is to establish a definite pattern of performance behavior especially for the spring season in a given cultivar.

In Cuba, the agricultural yields in the rice cultivation vary significantly between the sowing months and it is reported that the sowings made in the "cold" or "slightly rainy" season turn out to be those with the highest yields and even with a more stable behavior. (14) In this sense, the results of this work are in correspondence with what was previously stated in the literature, since in general the values of yields reached on the sowing dates studied are lower than those achieved in similar studies on the dates of the "little rainy" season, which exceeds 5 t ha^{-1} (15).

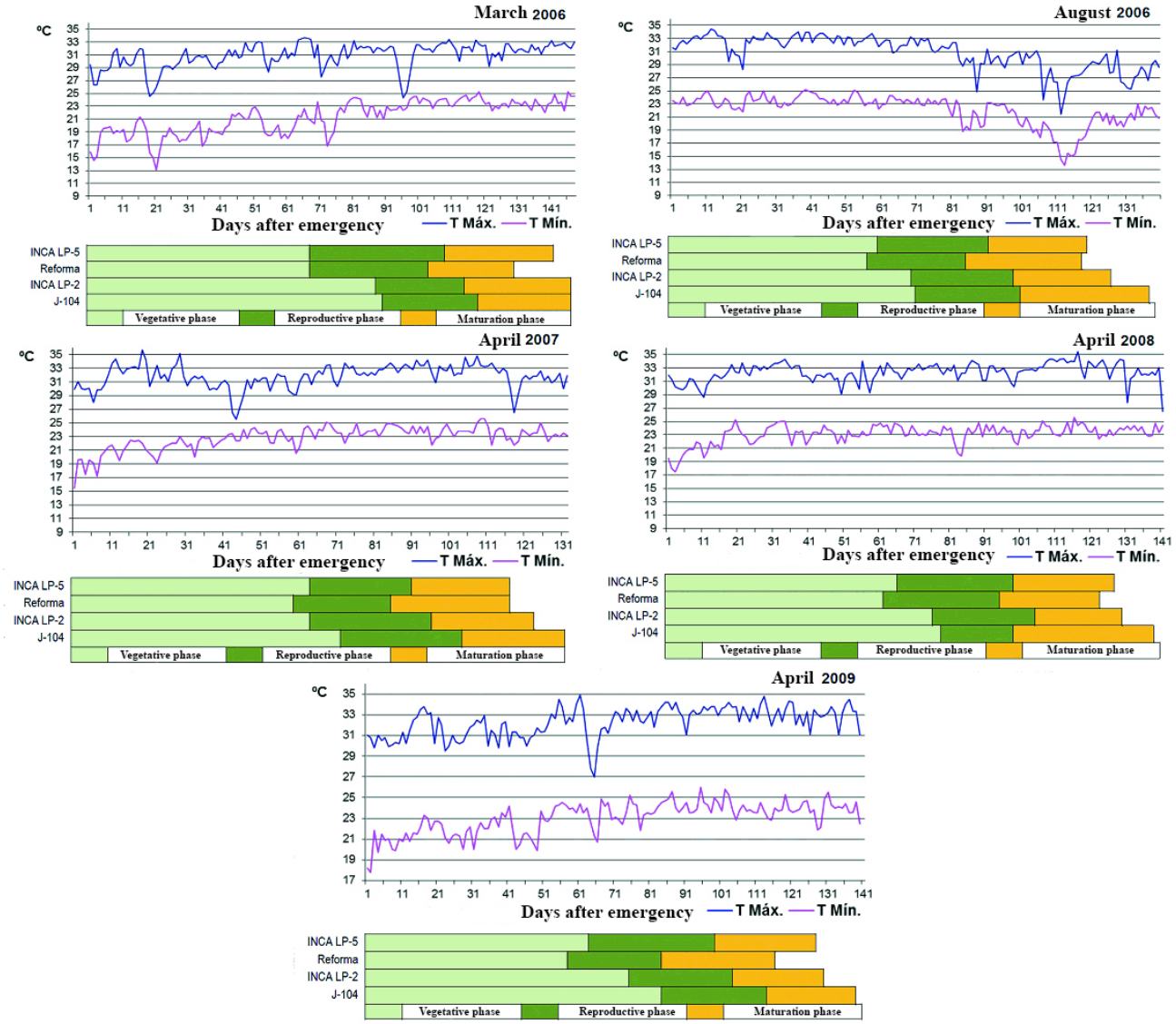
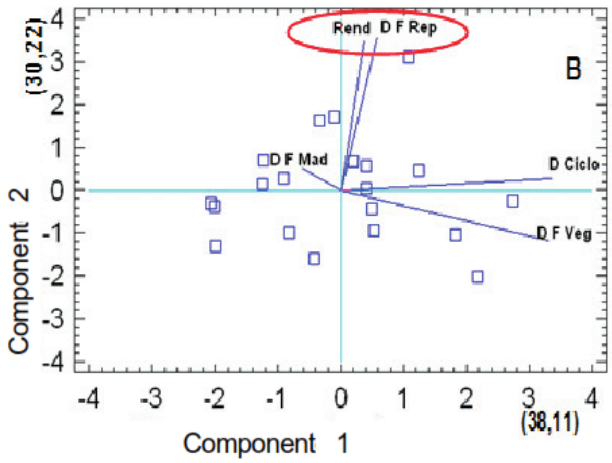


Figure 1. Maximum and minimum air temperatures, diurnal, in each phenological phase of the development of rice cultivars (*Oryza sativa* L.), on sowing dates of the "rainy" season

When determining the degree of association between the duration of the phases and the cycle of the crop, with the yield (Figure 2), it is verified that the best association with the yield was found with the duration of the reproductive phase, which indicates that under the conditions of this time a determining role could have the size of the sinks, since it is in this phase where the amount of panicles and the total of grains per panicle in each cultivar is decided (16). This strong association exists between the yield and the phase that precedes the final stage of development, the maturation, demonstrates the importance of the size and activity of the sink and the capacity of the sources to meet their requirements, in order to obtain high yields.

In this sense, achieving an adequate number of fertile stems that support spikes with a high number of grains and increasing the capacity and photosynthetic efficiency of the crop, as well as optimizing the partitioning of assimilates, constitute fundamental proposals for increasing crop yields of rice, especially in the reproductive and maturation phases (17), without taking into account the effect that the behavior of meteorological variables has on all these processes, as part of the abiotic factors that affect yield.

In the literature it is indicated that the variations in the development and yield of rice cultivars worldwide in the last 10 years, are closely related to the effect of biotic and abiotic factors, where the behavior of temperatures and radiation during the phenological phases of the crop, and especially in the reproductive phase, play a fundamental role due to its relationship with the sterility of the spikelets during this (reproductive) phase (18).



DF Rep.: duration of the reproductive phase (days). D F Mad.: duration of the maturation phase (days). D Ciclo: duration of cycle (days). Rend.: yield (t ha^{-1}). Percent contribution of each component, n=20

Figure 2. Association of agricultural yield and duration of phenological phases of rice plants (*Oryza sativa* L.) in the "rainy" season

Although in the present work the duration of the reproductive phase is the most influential in obtaining higher yields. The literature does not always highlight the positive and significant influence of the performance with the duration of the final phases of development, and the vegetative phase is highlighted to a greater extent (16). These authors are in favor of the stimulus of early vigor that can reach the plants during the vegetative phase because they guarantee a greater accumulation of dry mass from early ages and this contributes positively to the yield. Other authors (19), despite this, consider that the excessive vegetative growth in the first stages causes a decrease in the uptake of solar radiation, since there may be an exaggerated leaf area. In addition, they add that the mortality of stems is increased, the maturation process is weakened and the risk of lodging increases; aspects that, in general, do not suppose any advantage to the crop or even reduce its yield (19).

However, it is important to point out that studies carried out on other grains, such as wheat, under Cuban conditions and in the “slightly rainy” season, report a direct relationship between yield and duration of the paniculation stage (20); this also demonstrates the importance of the reproductive phase to obtain good yields. In addition, in works carried out with rice cultivars in the “slightly rainy” season, results similar to those reached in the wheat studies are shown (15). This shows that the relationships between the duration of one stage and another with the yield depend fundamentally on the sowing season.

Based on the results of this research, it can be concluded that the duration of the reproductive phase in rice cultivation is closely related to the performance of agricultural yield under the conditions of the “rainy” or “spring” season.

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