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BEHAVIOR OF GROWTH AND AGRICULTURAL YIELD OF TWO SORGHUM VARIETIES (*Sorghum bicolor* L. Moench) IN THE DRY SEASON IN LOS PALACIOS TOWN

Comportamiento del crecimiento y rendimiento agrícola de dos cultivares de sorgo (*Sorghum bicolor* L. Moench) en la época poco lluviosa en la localidad de Los Palacios

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ABSTRACT. This work was developed at Basic Scientific and Technological Unit of "Los Palacios" with the objective of evaluating the behavior of growth and yield of two sorghum varieties (*Sorghum bicolor* L. Moench) in Los Palacios town. The varieties Gilded ISIAP and CIAP 132 R were used, which were sowed in the sowing dates of December, 2009 and February, 2010. The technology of direct sowing was used and the cultural activities were developed according to that recommended by the Crop Technical Instructive. A Randomized complete experimental design with four replicas was used. The dry mass distribution of the air part and the leaf area index, in 10 plants for each parcel, every 15 days until the physiologic maturity, were evaluated. With these variables the dynamics of growth were established and the agricultural yield was determined, data that were processed by T Student, to 5 % of error probability. Considering the results it can be concluded that yields were influenced by sowing date and its biggest values were in correspondence with a bigger development of the leaf surface. Both varieties can be used in the town since their productive results exceed the values set in Cuba for sorghum crop.

Key words: dry matter content, growth, yield, sorghum

RESUMEN. El trabajo se desarrolló en la Unidad Científica Tecnológica de Base "Los Palacios", con el objetivo de evaluar el comportamiento del crecimiento y el rendimiento de dos cultivares de sorgo (*Sorghum bicolor* L. Moench) en la localidad de Los Palacios. Se emplearon los cultivares ISIAP Dorado y CIAP 132 R, los cuales se sembraron en las fechas de siembra diciembre, 2009, y febrero, 2010. Se empleó la tecnología de siembra directa y las actividades fitotécnicas se desarrollaron según lo recomendado por el Instructivo Técnico del Cultivo. El diseño experimental fue de bloques completamente aleatorizado con cuatro réplicas. Se evaluó la distribución de la masa seca de la parte aérea y el índice del área foliar en diez plantas por parcela, cada 15 días hasta la madurez fisiológica. Se estableció las dinámicas de crecimiento con dichas variables, se determinó el rendimiento agrícola, datos que fueron procesados mediante la prueba T Student al 5 % de probabilidad de error. Teniendo en cuenta los resultados se puede concluir que los rendimientos estuvieron influenciados por la fecha de siembra y los mayores valores del mismo estuvieron en correspondencia con un mayor desarrollo de la superficie foliar. Ambos cultivares pueden ser utilizados en la localidad ya que sus resultados productivos superan los valores que se establecen en Cuba para el cultivo del sorgo.

Palabras clave: contenido de masa seca, crecimiento, rendimiento, sorgo

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INTRODUCTION

Sorghum (*Sorghum bicolor* L. Moench) seems to be a native of Central and East Africa, probably from Ethiopia and Sudan. This plant has been widely used in warm and dry areas with a great diversity of applications (grain, fodder and raw material for alcoholic drinks, fiber or other special uses). Together with barley, it is the fourth most important cereal in the world, after wheat, rice and corn; also, it is a basic food for human beings in many Asian and African regions, but it is destined to animal feeding in developed countries. In America, this crop was introduced by African slaves, probably through West Indies, in the XVIII and XIX centuries (1, 2). At present, the highest sorghum producing countries worldwide are Nigeria, Mexico, United States and Argentina (3).

In Cuba, sorghum has been well adapted to soil and climatic conditions, especially for its tolerance to drought conditions. Therefore, it is essential to evaluate the behavior of its cultivars in the dry season before introducing them. This crop is very important, because its grain and fodder are used for animal feeding, although it is also employed as a living barrier in urban agricultural areas or associated to common bean, cowpea, pumpkin, and soybean, among other crops. In addition, it has been recommended for crop rotation, especially with tobacco and rice, due to its qualities to improve soil structure and productivity (4, 5). In our country, as part of a comprehensive grain development program, more than 35 000 ha were intended to seed in 2015[A].

Taking into account the aforementioned reasons and based on its significance for crop rotation in rice-growing areas, this work was conducted with the aim of evaluating the behavior of crop growth and yield of two sorghum (*Sorghum bicolor* L. Moench) cultivars in Los Palacios municipality during dry season.

MATERIALS AND METHODS

The work was carried out in areas from "Los Palacios" Scientific and Technological Base Unit (STBU), belonging to the National Institute of Agricultural Sciences (INCA), which is located in the southern plain of Pinar del Rio province, at 22°44' North latitude and 83°45' West latitude, 60 m above sea level, with a slope of about 1 %, using two cultivars: ISIAP Dorado and CIAP 132 R, that were seeded in December 2009 and February 2010 (dry season) on a Petroferric Ferruginous Nodular Gley Hydromorphic soil (6).

The technology employed was direct seeding at a rate of 13 kg ha^{-1}. Farming activities were performed according to sorghum recommendations[B]. A randomized complete block design with four replications was used and experimental plots had an area of about 40 m^2. Agricultural yield was determined and processed through Student's T test at 5 % probability of error.

Every 15 days, destructive samplings were made in ten plants, from emergence up to physiological maturity, in order to calculate dry mass of the aerial part (g) by adding each individual organ (leaves, stem, leaf pods and panicle), which were kept in an oven until its constant weight. Besides, leaf area (m^2) was estimated from the product of length by width by 0,7 (7).

Growth dynamics of the above mentioned variables (dry mass of the aerial part and leaf area) was established and fitted to a second-degree polynomial exponential mathematical function:

$$Y= e^{(bo+b1+b2x2)}.$$

Subsequently, Absolute Growth Rate (AGR) and Leaf Area Index (LAI) were calculated (7).

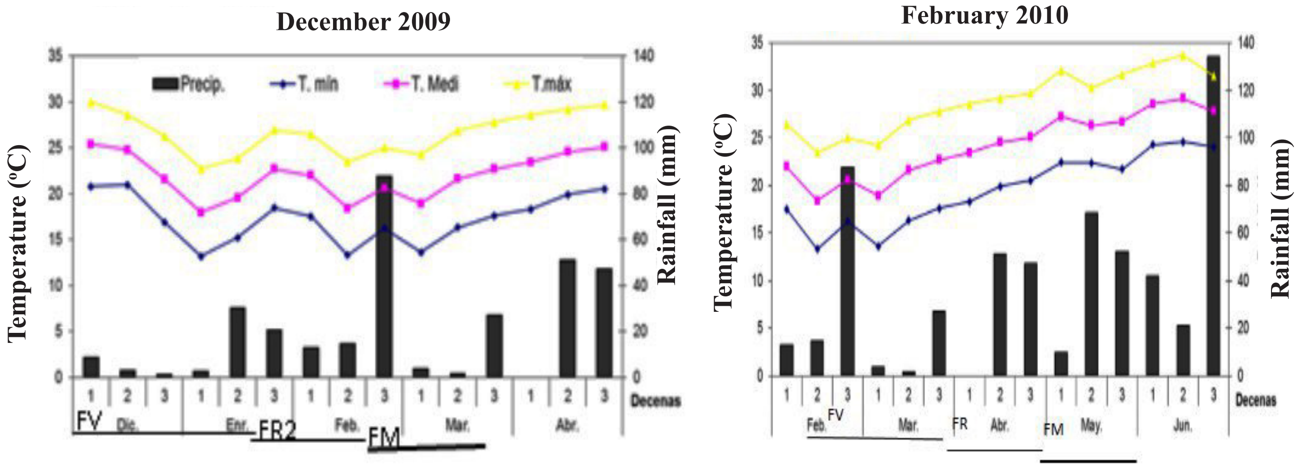
Mean temperature (maximum, medium and minimum per decade) and rainfall (accumulated per decade) values corresponded to the periods studied (Figure 1), which were recorded at the agrometeorological station located in Los Palacios municipality, Paso Real de San Diego, about 6 km far from the experimental area.

RESULTS AND DISCUSSION

Figure 1 presents mean temperature (maximum, medium and minimum) and rainfall (accumulated per decade) values. As for rainfall, taking into account the amount and distribution, it is clearly evident that there were fewer amounts in December 2010 than in February 2009. It is notable that maximum temperatures did not reach 30 °C in December 2009, but they exceeded this value in February 2010 since the end of the reproductive phase and throughout the maturity phase. As for minimum temperatures, in December 2009, at certain times, they were below 15 °C, especially at the end of the reproductive phase and the beginning of the maturity phase.

[A] Pérez, J. *Programa Integral de Granos. Proyección estratégica hasta el 2015*, edit. IIG, 2010, 80 p.

[B] García, E.; Permuy, V.; Chaveco, O. y Segura, T. *Recomendaciones para el cultivo del Sorgo para granos (Sorghum bicolor, L. Moench)*, 2005, [Holguín].



FV: Vegetative phase FR: Reproductive phase FM: Maturity phase

Figure 1. Behavior of temperatures (maximum, medium and minimum) per decade and accumulated rainfall per decade during field experimental time

Quite different conditions are observed in February 2010 for this meteorological variable, as values were below 15 °C only during the early stages of the vegetative phase.

In general, critical values affecting agricultural yield, tillering, grain formation and filling are below 20 °C and above 30 °C (1). Therefore, although climatological conditions generally behaved favorable for cultivar development, it should be noted that locality variability may cause growth and yield variations.

Table shows the mathematic expressions of adjusting actual data of each variable studied, in order to estimate their behavior and to interpret results. As it can be seen in most cases, regression coefficients ranged between 0,95 and 0,97, so a good fit was achieved both from the mathematical and biological points of view. In the case of LAI, CIAP 132 R in December 2009 and ISIAP Dorado in February 2010 showed lower coefficients than 0,95, which can be explained by a higher crop growth, considering this variable 40 days after germination (DAG) that was not homogeneous at the beginning in all plants, close to the reproductive phase. Thus, there was no phenological stage uniformity during that period for all cultivars, but plants were further recovered and reached their homogeneity in the field.

Figure 2 shows growth dynamics of dry mass in plants. In both sowing dates, a very similar cultivar behavior was obtained up to approximately 90 DAG, although in December 2009, CIAP 132 R exceeded the values achieved by ISIAP Dorado, with an earlier growth and lower values at the maximum growth point. However, in February 2010, there was a different behavior, since ISIAP Dorado surpassed CIAP 132 R up to about 90 DAG and then very similar values were recorded at the final growth stages. In this sense, it can be highlighted that there is a marked influence of seeding date on cultivar growth.

Moreover, it should be noted that maximum values of total dry mass in both cultivars did not exceed 1000 g m^{-2} at different sowing dates; however, according to some results (1, 6), in most cases, the dry mass of plants exceeded 1100 g m^{-2}; this may be due to sowing density in these experiments for the existing soil and climatic conditions, as there could be a greater population compared to that used by other authors, which might reduce plant photosynthetic efficiency caused by leaf self-shading.

There is another aspect that should be regarded: climatic conditions. Sorghum is considered a warm climate plant that responds to high temperatures and the optimal for its development is between 29 and 30 °C; this is due to its morphological characteristics, because it has an appropriate root system growth, with a low transpiration level in relation to the high capacity of root absorption and a waxy coating on stems and leaves that make this crop very efficient under such conditions (8, 9).

Table. Functions used and regression coefficients obtained

Cultivar	Leaf area index	R^2	Dry mass of the aerial part	R^2
December 2009				
ISIAP Dorado	$Y = e^{(-8,58+0,25x-0,001x^2)}$	0,97	$Y = e^{(-3,30+0,20x-0,001x^2)}$	0,99
CIAP 132 R	$Y = e^{(-6,87+0,21x-0,001x^2)}$	0,83	$Y = e^{(-3,84+0,24x-0,0001x^2)}$	0,98
February 2010				
ISIAP Dorado	$Y = e^{(-3,53+0,12x-0,0007x^2)}$	0,86	$Y = e^{(-0,89+0,15x-0,0007x^2)}$	0,99
CIAP 132 R	$Y = e^{(-6,05+0,18x-0,0001x^2)}$	0,95	$Y = e^{(-2,51+0,17x-0,0008x^2)}$	0,98

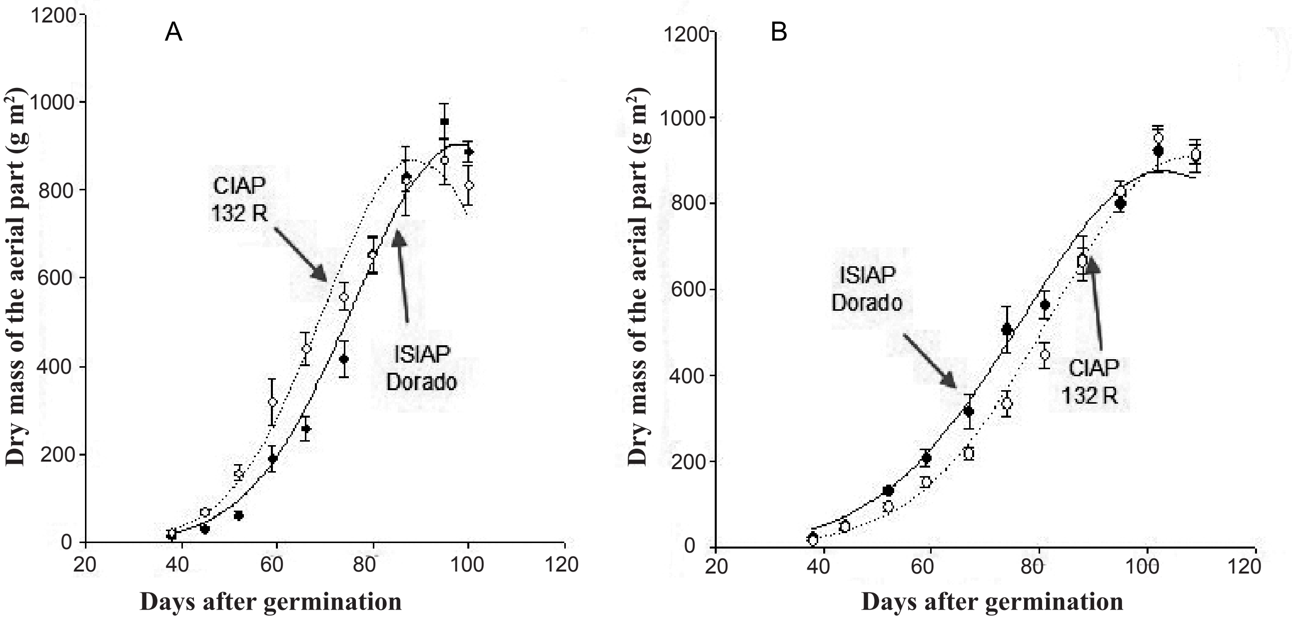


Figure 2. Growth dynamics of dry mass in the aerial part of sorghum cultivars at two sowing dates, December 2009 (A) and February 2010 (B)

In other studies made in Cuba (10), differences were recorded in the maximum dry mass value of the aerial part, as influenced by sowing date. In this study, ISIAP Dorado plants reached higher values when seeded in July 2009, with approximately 1400 g m^{-2} compared to 1100 g m^{-2} reached in November 2008. Such aspect was related to weather conditions.

Figure 3 shows LAI dynamics for each cultivar in both seeding dates; in December 2009, maximum values were 3,0 and 2,8 for CIAP 132 R and ISIAP Dorado cultivars, respectively, whereas in February 2010, they were 3,5 and 3,1 respectively for both cultivars. It is valid to point out that, in every case, the maximum value was recorded at the reproductive phase and CIAP 132 R presented the highest values.

It is important to state that leaf area is essential, because its development depends on the interception of photosynthetically active radiation required for biomass production and the corresponding contribution to yield. In this sense, the values obtained in this study are lower than those highlighted in other studies of literature, where 4,5 and 5,5 are remarkable (10). In this aspect, climatic conditions could be the reasons; minimum temperatures during the reproductive phase in December 2009 were very close to 15 °C and even lower, which could have caused less leaf growth and thereby lower LAI values on that date.

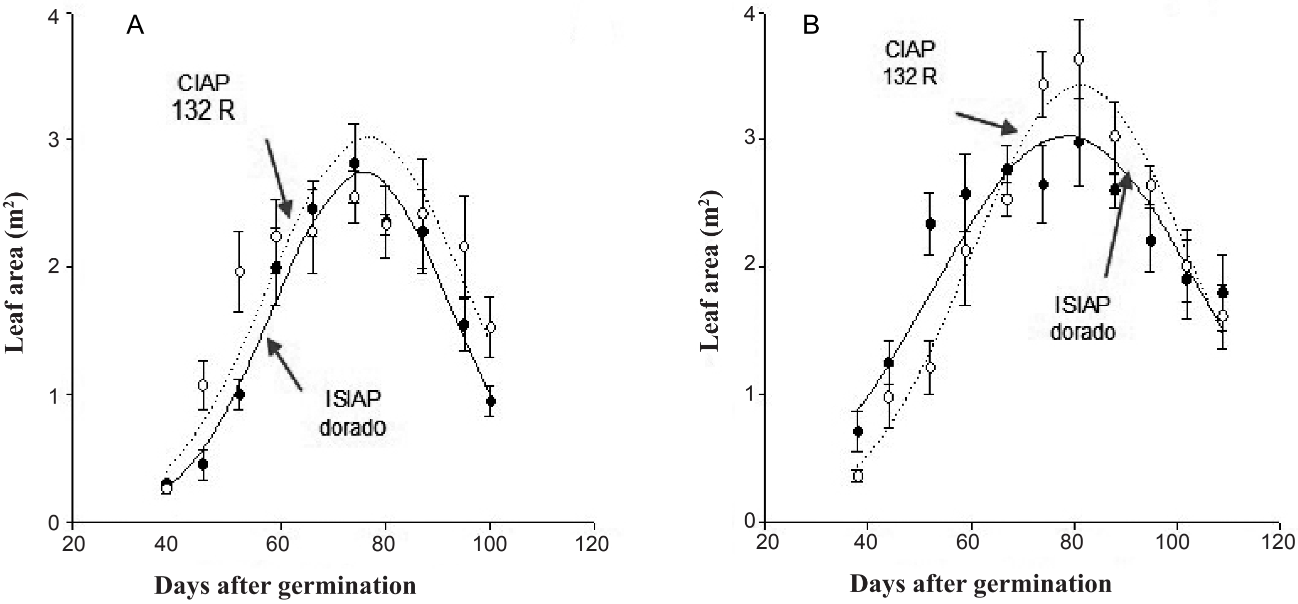
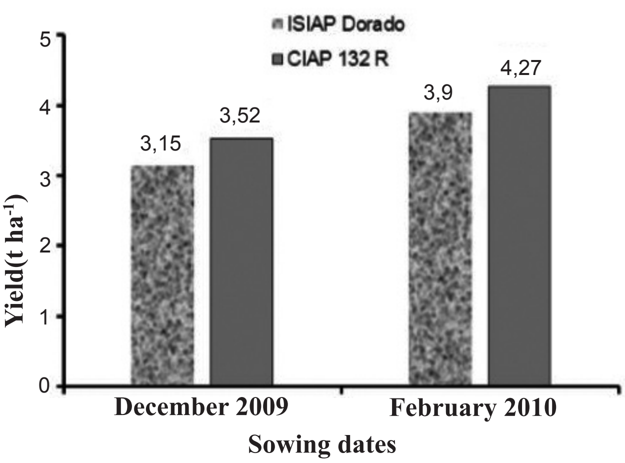


Figure 3. Behavior of leaf area index (LAI) of sorghum cultivars at two sowing dates, December 2009 (A) and February 2010 (B)

Some reports stress that temperatures regulate cereal leaf growth (1, 11) and either leaf number or its size constitute an important LAI factor.

As for agricultural yield behavior (Figure 4), there were differences between sowing dates. The highest yields of both cultivars were achieved in February 2010, without significant differences between them.



Treatment means differ at 0,05, n=4

Figure 4. Behavior of agricultural yields (t ha^{-1}) at 14 % grain humidity of two sorghum cultivars (CIAP 132 R and ISIAP Dorado) in two sowing dates

From the climatic point of view, this may be related to the best conditions existing for crop development that allowed greater productivity efficiency, especially the behavior of temperatures throughout crop cycle, which were more favorable in February 2010 (Figure 1). In addition, it should be noted that yield corresponded to the highest LAI values on that date during the reproductive phase (Figure 3). Similar results have been achieved in other studies with corn and rice crops (12-15).

In this regard, sorghum is considered a very efficient crop in terms of environmental conditions, noting that the critical period starts when the panicle appears wrapped by leaf sheath, mainly of flag leaf (booting stage) until the end of the milky stage at the maturity phase; thus, the final yield will essentially depend on the conditions that sorghum has to face in this period and its development. Another aspect to remark is that adequate yields of about 3,0 t ha^{-1} are established in Cuba (16) and this value is exceeded by the results of this work, although they are lower than those achieved by other authors under the conditions of Cuba.

CONCLUSIONS

It was concluded that yields were influenced by sowing date and the highest values were in correspondence with a greater leaf area development. Both cultivars can be used in Los Palacios municipality, as their productive results exceed the values established in Cuba for sorghum crop.

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