ISSN impreso: 0258-5936
ISSN digital: 1819-4087
Ministerio de Educación Superior. Cuba
Instituto Nacional de Ciencias Agrícolas
http://ediciones.inca.edu.cu

EFFECT OF CALIBER SEED (MASS) IN THE GERMINATION OF SORGHUM

Efecto del calibre semilla (masa) en la germinación del sorgo

Michel Ruiz Sánchez[1]✉, Yaumara Muñoz Hernández[2], Daniel Guzmán[1], Raiza Velázquez Rodríguez[1], Guillermo S. Díaz López[1], Alexeis Y. Martinez[2] and Fernando M. Almeida[3]

ABSTRACT. The research was carried out at the Base Scientific Technological Unit "Los Palacios", Cuba, with the objective of determining the effect of the size of the seed (mass) of sorghum in its germination during the dry periods of 2017 and 2018. He worked with two cultivars of sorghum CIAP 132R and ISIAP Dorado. The first experiment was developed in Petri dishes and the second in metal trays (0.70 x 0.50 x 0.08 m), which contained a Gleysol Nodular ferruginoso petroférrico. Six calibers of seeds (mass) were evaluated in the two experiments: M1 (0.015 - 0.020 g); M2 (0.021-0.025 g); M3 (0.026 - 0.030 g); M4 (0.031 - 0.035 g); M5 (0.036 - 0.040 g) and the control treatment (mixture of seed size). The germination percentage (PG) was evaluated in time, with a 24 h interval until 96 h after sowing, the germination speed index (IVG), the average number of days to germination (NMDG) and the accumulation of aerial dry mass (MSA) at 10 days after the emergency (DDE). It was found that always the highest seed size (mass) corresponded to the highest PG, IVG and lowest NMDG in both cultivars. The quality indicators PG, IVG and NMDG deteriorate less in the greater seed caliber, in addition to that, to the 10 DDE accumulated greater MSA. A strong and positive relationship was found between the PG and the MSA, which indicated a dependence on the germinative power of the seed.

Key words: cereal, *Sorghum bicolor*, reserve, vigor

RESUMEN. La investigación se realizó en la Unidad Científico Tecnológica de Base "Los Palacios", Cuba, con el objetivo de determinar el efecto del calibre de la semilla (masa) de sorgo en su germinación, en los periodos poco lluviosos de 2017 y 2018. Se trabajó con dos cultivares de sorgo CIAP 132R y ISIAP Dorado. El primer experimento se desarrolló en placas Petri y el segundo en bandejas metálicas (0,70 x 0,50 x 0,08 m), las cuales contenían un suelo Gleysol Nodular ferruginoso petroférrico. Se evaluaron seis calibres de semillas (masa): M1 (0,015-0,020 g); M2 (0,021-0,025 g); M3 (0,026-0,030 g); M4 (0,031-0,035 g); M5 (0,036-0,040 g) y un tratamiento testigo (mezcla de calibre de semillas). Se evaluó el porcentaje de germinación (PG) en el tiempo, con un intervalo de 24 horas hasta las 96 horas después de la siembra, el índice de velocidad de germinación (IVG), el número medio de días a la germinación (NMDG) y la acumulación de masa seca aérea (MSA) a los 10 días después de la emergencia (DDE). Se encontró que siempre el mayor calibre semilla (masa) se correspondió con el mayor PG, IVG y menor NMDG en ambos cultivares. Los indicadores de calidad PG, IVG y NMDG se deterioran menos en el mayor calibre semilla, además de que, a los 10 DDE acumularon mayor MSA. Se encontró una relación fuerte y positiva entre el PG y la MSA, que indicó una dependencia del poder germinativo de la semilla.

Palabras clave: cereal, *Sorghum bicolor*, reserva, vigor

[1] Instituto Nacional de Ciencias Agrícolas (INCA), gaveta postal 1, San José de las Lajas, Mayabeque, Cuba, CP 32 700

[2] Universidad "Hermanos Saiz Montes de Oca", calle Martí final, Pinar del Río, Cuba

[3] Profesor Asistente, Facultad de Ciencias Agrarias de la Universidad "José Eduardo dos Santos", Huambo, Angola

✉ mich@inca.edu.cu

INTRODUCTION

Sorghum (*Sorghum* sp.) is the fourth cereal in world importance. Approximately in the world, 40 million hectares are sown in the belt between 50 º North latitude and 50 º South latitude. This crop is a typical species of warm zones (1). The main producing countries are: India, Nigeria, United States of North America, Sudan, Mexico and Argentina, being this culture of great importance in developing countries (2). Africa is the country with the largest arable land of this cereal (1).

Sorghum is one of the cereals that, due to its agronomic and nutritional characteristics, could bring great benefits to food, both human and animal, nationally and worldwide. Its importance lies fundamentally in the use of grain and fodder for animal feed and as an essential part of a system of rotations to maintain the productivity and structure of the soil. Although destiny, at the local level, has been animal feeding, in the world, around 40 % of the production of grain sorghum is destined for human consumption, as a participant in the production of food and beverages for human beings (2).

In Cuba, specifically in the province of Pinar del Río, in the last decade the arable land of this cereal increased up to 700 ha and it is estimated that it reaches 4000 ha if the necessary infrastructural conditions existed, due to its high value in food swine (3). For this purpose, actions are carried out based on the drying and storage of the grain.

The germination is the restart of the growth of the embryo, paralyzed during the final stages of maturation. The physiological processes of growth require accelerated metabolic activities and the initial phase of germination consists primarily in the activation of the processes, by increase in humidity and respiratory activity of the seed (4). The absorption of water by the seed triggers a sequence of metabolic changes that includes respiration, protein synthesis and mobilization of reserves. In turn, cell division and elongation in the embryo cause rupture of the seminal covers, which are generally produced by the emergence of the radicle (5). However, the seeds of many species are unable to germinate, even when they have favorable conditions for it, which is due to the fact that the seeds are in a dormant state. While the appropriate conditions for germination are not present, the seed remains in a latent state for a variable time, depending on the species, until at a given moment it loses its ability to germinate (5).

The low percentage of germination of the seed and the loss of it is today one of the main problems affecting Cuban agriculture (6), a situation that depends on several external factors that affect germination and the speed with which it occurs. . Among these, to the humidity of the substrate, temperature, light, oxygen and carbon dioxide (7-9), post-harvest handling is added, which includes the conditions of storage and conservation of the seeds, elements that are fundamental to maintain the quality parameters of the same in time. The size of the seed and the habit of growth are related to the efficiency in the allocation of biomass to the grain in the growing environment, but it also depends on other characteristics of the seed, such as vigor (10).

The emergence of a seedling then depends on the physiological and biochemical characteristics of the seeds, their reaction to the conditions external to it and the efficiency of using their reserves during germination (11).

As an indispensable requirement in the cultivation of sorghum, to achieve a good emergence, it is important an initial rapid growth, which is achieved among other factors, with a seed of quality and the soil, humidity and temperature conditions that are created to it. Because this grain, due to its botanical characteristics, rapidly loses germination, germination speed and short-term latency period, this research was carried out with the objective of determining the effect of seed size (mass) of sorghum in its germination.

MATERIALS AND METHODS

The research was carried out at the "Los Palacios" Base Scientific and Technological Unit (UCTB Los Palacios) Cuba, at 22 ° 34 '32.73' 'N and 83 ° 14' 11.95'' O, belonging to the National Institute of Agricultural Sciences (INCA)), in the vegetative phase of sorghum (*Sorghum bicolor* L. Moench), with cultivars CIAP 132R and ISIAP Dorado. The experiment was carried out in the dry periods of 2017 and 2018 (January-March), in two stages, a first experiment under semicontrolled conditions in Petri dishes and a second experiment in conditions of metal trays.

The seeds of cultivars CIAP 132R and ISIAP Dorado, came from the marketing company of Consolación del Sur, Pinar del Río province which, according to the invoice, its percentage of germination was 85 %. In the case of the ISIAP Dorado cultivar, fresh seed was used, which was reproduced in the UCTB "Los Palacios", with germination percentage of 93 %.

For the assembly of the germination tests from different seed calibers (mass), first, the seeds were classified optically (to the naked eye), which were separated according to their size, to form six groups and by means of an Analytical Scale (Model ML 204/01), six ranges were established for their mass, which formed the treatments in the two sorghum cultivars. With the help of a grain counter (Model LG-A), 20 seeds were counted at random and the treatments were shaped with their replicas and replications.

Treatments:
M1= 0,015 - 0,020 g
M2= 0,021 - 0,025 g
M3= 0,026 - 0,030 g
M4= 0,031 - 0,035 g
M5= 0,036 - 0,040 g
Control (seed gauge mix)

First Experiment

Seeds were placed in Petri dishes (diameter 0.1 m), on filter paper at the bottom of the plates, for a total of 20 seeds per plate, with ten replicates for each treatment and two repetitions in time, with interval between these 30 days. The experiment was conducted following a Fully Randomized Experimental Design.

The imbibition of the seed was done with the initial addition of 10 mL of distilled water per plate, 72 h later, 5 mL per plate was added. In addition, three germination tests of 100 seeds per plate were prepared to corroborate the percentage of commercial germination.

The percentage of germination (PG), average number of days to germination (NMDG) and germination rate index (IVG) were determined. The PG was determined by quantifying the germinated seeds at 24, 48, 72, 96 hours after sowing, the one with the visible radicle was considered as germinated seed. The mean number of days to germination (NMDG) and germination rate index (IVG) were determined using the mathematical formulas proposed by Maguire (12):

$$NDM = \sum_{i=1}^{n} \frac{(N_i * T_i)}{n} \quad (1)$$

$$IVG = \sum_{i=1}^{n} \frac{N_i}{Ti} \quad (2)$$

where:
N_i is the number of seeds germinated within consecutive time intervals
T_i is the time in hours between the start of the test and the end of the interval
n is the total number of germinated seeds

Second experiment

In the second experiment, seeds of sorghum were planted in metal tray (0.70 x 0.50 x 0.08 m), in the dry season of 2018 (January-March), which contained soil from the areas of the UCTB "Los Palacios". The same treatments that were carried out in Petri dishes were established; but the 100 seeds that represent a treatment were deposited in each furrow. The trays were placed in a glass greenhouse.

The soil (Table 1) was classified as Gleysol Nodular ferruginous petroferric (13) and it was characterized by a slightly acidic pH; low organic matter (MO) content; interchangeable bases with typical contents for this type of soil and considered low and assimilable phosphorus (P) low (14).

Table 1. Some properties that characterize the fertility of the arable horizon

Property	Unit	Media	Standard error
pH		6,46	0,15
MO	%	2,86	0,13
Ca^{2+}	cmol kg^{-1}	6,97	0,13
Mg^{2+}		3,11	0,06
Na^{+}		0,21	0,02
K^{+}		0,18	0,02
Assimilable P	mg kg^{-1}	46,80	3,80

(0-0,20 m) of Gleysol Nodular ferruginous petroferric soil, n= 4 (15)

The analytical techniques used for the soil determinations of the UCTB "Los Palacios" were: pH: potentiometry, soil: water ratio 1: 2.5 (NC ISO 10390); organic matter (MO) by the Walkley and Black method (NC 51); interchangeable cations, from an extraction with NH4OAc 1 mol L^{-1} at pH 7 and determination by complexometry (Ca^{2+} and Mg^{2+}) and flame photometry (Na^{+} and K^{+}), according to NC 65 (2000); assimilable phosphorus (P), according to the Oniani method (extractive solution H_2SO_4 0.1 N), according to NC 52.

Before starting the sowing in the trays, 500 mL of distilled water was applied, then the seeds were deposited in the furrows (depth of sowing 0.01 m), which were covered with the same soil and another irrigation was carried out with 200 mL of distilled water. At 48 hours after sowing, irrigation was alternated with 400 mL of distilled water, to maintain soil moisture until the end of the experiment (10 DAE).

Four repetitions were carried out under these conditions for the germination count (emergence), which started 48 hours after sowing in the trays and every 24 hours the same procedure was repeated until 96 hours after the first stage was made the first counting. In the last repetition after the germination count, the plants were allowed to grow until 10 days after the emergence, to determine the aerial dry mass. Twenty plants were taken by treatments of the central part of each furrow in the tray.

The samples were placed in a stove with forced draft of air at 70 ºC, until reaching constant mass, which was measured in an Analytical Balance (Model ML 204/01), the result obtained was expressed in g plant^{-1}.

Data processing and statistical analysis

In all the experiments, the assumptions of normality and variance homogeneity (Bartlett's Test and Kolmogórov-Smirnov, respectively) were checked in each evaluated variable. The results of the soil analyzes were determined the Average, Medium, Standard Error and Variance.

The means of the treatments in the case of the germination percentage in time were compared from the Confidence Intervals for α = 0.05. The data obtained from the percentage of germination (PG), the index of germination speed (IVG), the average number of days to germinate (NMDG) and the accumulation of aerial dry mass (MSA) at -10 days after the emergence, they were processed by Analysis of Simple Classification Variance and when there were significant differences, the means were compared according to Duncan's Multiple Range Test (p≤0,05). Simple regression analysis was also carried out between the percentage of final germination (PG) and the aerial dry mass (MSA) obtained at 10 DAE.

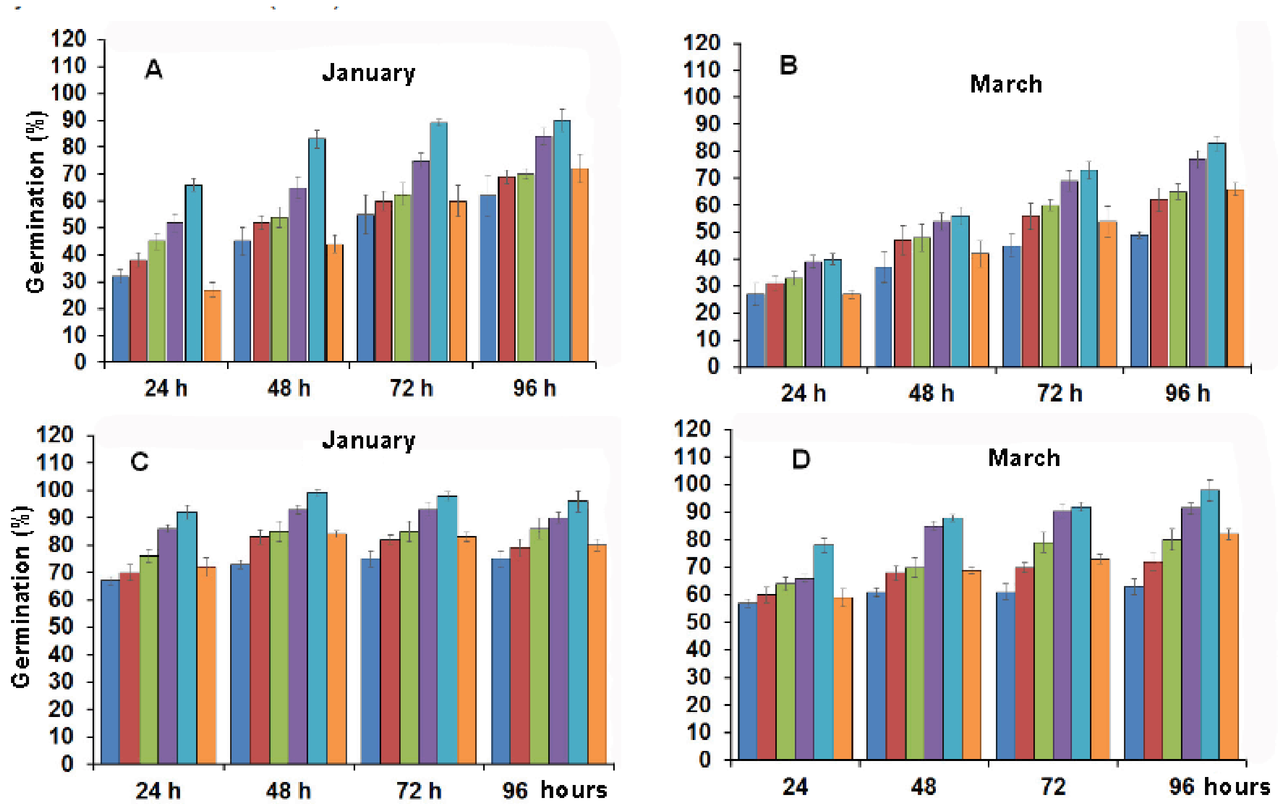
For all statistical analyzes the STATGRAPHICS Centurion on Windows Program, version XV was used.

RESULTS AND DISCUSSION

Taking as hypothesis that the mass of the seed (caliber) could be a fundamental element in the loss of the germination of the same, the mass of the grains (seed) was determined, being heterogeneous, with values from 0.013 g each seed up to 0.055 g. The variability in seed mass did not allow the selection of single values of seed sizes, so six groups of seeds were established for the investigation, which formed the treatments.

In the case of the percentage of germination (PG) of the cultivars evaluated in the time interval from 24 hours to 96 hours, they showed in general a tendency to increase in time, from the M1 treatment to the control. The germination percentage in the seed (mass) gauge was higher for both cultivars CIAP 132R (Figure 1 A and B) and ISIAP Dorado (Figure 1 C and D).

The seed size (mass) that showed the highest values were those that were in the range of 0.036-0.040 g, followed by 0.031-0.035 g.



Marks on the columns indicate Confidence intervals (α = 0.05), n = 10

Figure 1. Percentage of germination of sorghum (PG), cultivate CIAP 132R (A, repeat I and B, repeat II and ISIAP Dorado (C, repeat I and D, repeat II) in a 24 hour interval, until 96 hours

The percentage of germination at 96 hours under the conditions of Petri dish, for the cultivar CIAP 132R ranged between 62 and 90 % with fresh seed (Table 2); However, 30 days after the experiment was repeated, the germination percentage ranged between 49 and 83 %, with the lowest germination values corresponding to the seeds with the lowest mass.

In the case of the ISIAP Dorado cultivar, a behavior similar to the cultivar CIAP 132R was found, in terms of the percentage of germination at 96 hours. The highest values of germination corresponded to the seeds with the highest mass; that is, those that were in the range 0.036-0.040 g, followed by the seed calibers of 0.031-0.035 g. The percentage of germination for this cultivar ranged between 75 and 96 % with fresh seed, on the contrary, 30 days later in the repetition of the experiment, the percentage of minor germination (63 %), corresponded to the sizes of smaller seeds. mass and the treatment M4 and M5 maintained their percentage of germination, with respect to repetition I.

The IVG (Table 2) in both cultivars (CIAP 132R and ISIAP Dorado), showed a behavior similar to the germination dynamics in time and the percentage of final germination, depending on the seed size (mass). The IVG was always higher in the seeds of higher caliber. In the case of CIAP 132R, the IVG when the fresh seed was sown, the values oscillated between 0.73 and 1.33.

At 30 days later in the repetition of the experiment, the values ranged between 0.60 and 0.94. On the contrary, IVG values were higher in the ISIAP Dorado cultivar, which oscillated between 1.22 and 1.65 with fresh seed and in the repetition of the experiment after 30 days, the values decreased to 1.03 and 1,15 always the lowest values of IVG corresponded in both cultivars to the seeds with the highest mass.

The average number of days to germinate in sorghum (Table 2), in the cultivar CIAP 132R was lower in the M5 treatment in the first repetition and in the second repetition after 30 days, followed by the M4 treatment. In the case of the ISIAP Dorado cultivar, a behavior similar to the cultivar CIAP 132R was found, the lower values of NMDG corresponded to the M5 treatment in the first repetition and in the second to the M5 and M4 treatments. The highest NMDG corresponded to the control treatment in both cultivars.

The percentage of germination with an interval of 24 hours until 96 hours after planting under tray conditions (Figure 2A and B), showed the positive effect of the size of the seed (mass) in this indicator. The M5 treatment turned out to be the one with the highest percentage of germination for both cultivars (CIAP 132R and ISIAP Dorado). These results showed a behavior similar to the experiment under Petri dish conditions.

The percentage of final germination in the tray and soil conditions showed a behavior similar to the Petri dish conditions, both in the cultivar CIAP 132R and ISIAP Dorado, the seeds of greater caliber (mass) showed greater germinative power, with a 15 % of germination higher than the seeds of lower mass (Table 3).

Table 2. Germination percentage, germination rate index and average number of days to germination of sorghum seed, cultivars CIAP 132R and Golden ISIAP under Petri dish conditions at 96 hours

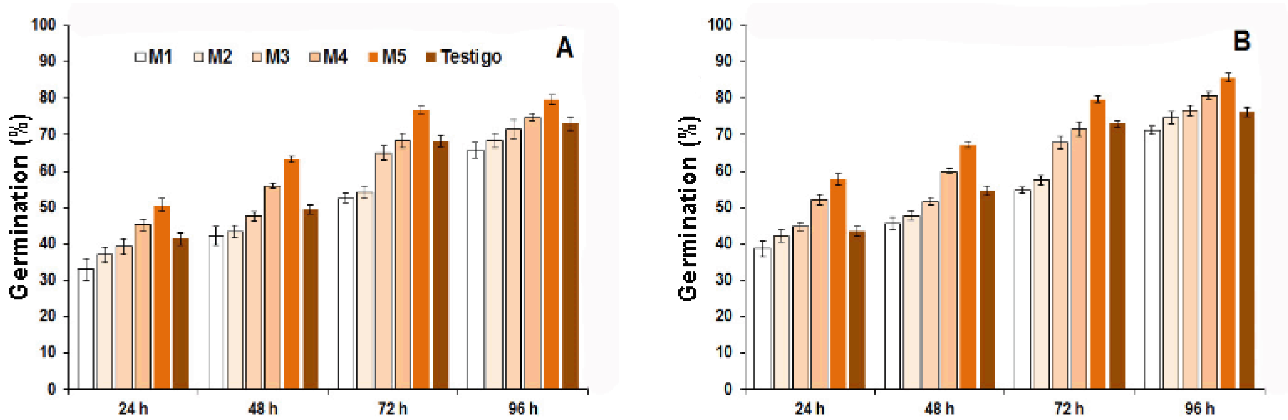
Treatments	CIAP 132R		ISIAP Dorado		CIAP 132R		ISIAP Dorado		CIAP 132R		ISIAP Dorado	
	PG (%)				IVG				NMDG			
	R I	R II	R I	R II	R I	R II	R I	R II	R I	R II	R I	R II
M1	62 c	49 d	75 d	63 e	0,73 e	0,60 d	1,22 e	1,03 e	1,77 b	1,96 b	1,12 a	1,37 b
M2	69 b	62 c	79 cd	72 d	0,84 d	0,73 bc	1,32 d	1,12 d	1,75 b	1,89 bc	1,05 b	1,32 b
M3	70 b	65 c	86 b	80 c	0,92 c	0,77 b	1,40 c	1,21 c	1,72 b	1,82 c	1,03 bc	1,29 bc
M4	84 a	77 b	90 b	92 b	1,08 b	0,90 a	1,55 b	1,35 b	1,64 c	1,78 c	0,99 c	1,19 cd
M5	90 a	83 a	96 a	98 a	1,33 a	0,94 a	1,65 a	1,45 a	1,43 d	1,66 d	0,85 d	1,16 d
Testigo	72 b	66 c	80 c	82 c	0,78 e	0,68 c	1,34 d	1,15 cd	2,08 a	2,13 a	1,11 a	1,54 a
ESx	1,536	2,038	2,317	1,527	0,015	0,024	0,022	0,020	0,038	0,058	0,023	0,054

Uneven letters in the column differ significantly (p <0.05), according to Duncan's Multiple Range Test, n = 10

Calibers seeds M1 (0.015-0.020 g); M2 (0.021-0.025 g); M3 (0.026-0.030 g); M4 (0.031-0.035 g); M5 (0.036-0.040 g) and control (mixture of seed size)

(PG) percentage of germination (IVG) germination rate index (NMDG) average number of days to germination

(RI) first repetition with fresh seed (RII) Second repetition at 30 days after (ESx) Standard error of the mean



Marks on the columns indicate confidence intervals (α = 0.05), n = 4

Figure 2. Percentage of germination of sorghum, cultivate CIAP 132R (A) and ISIAP Dorado (B), in an interval of 24 h, until 96 h

It is important to note that the germination values in the cultivar CIAP 132R ranged between 66 and 80 %; however, for ISIAP Dorado they were superior, ranging between 71 and 86 %.

Table 3. Percentage of sorghum germination, cultivate CIAP 132R (A) and Golden ISIAP (B) under tray conditions at 120 hours

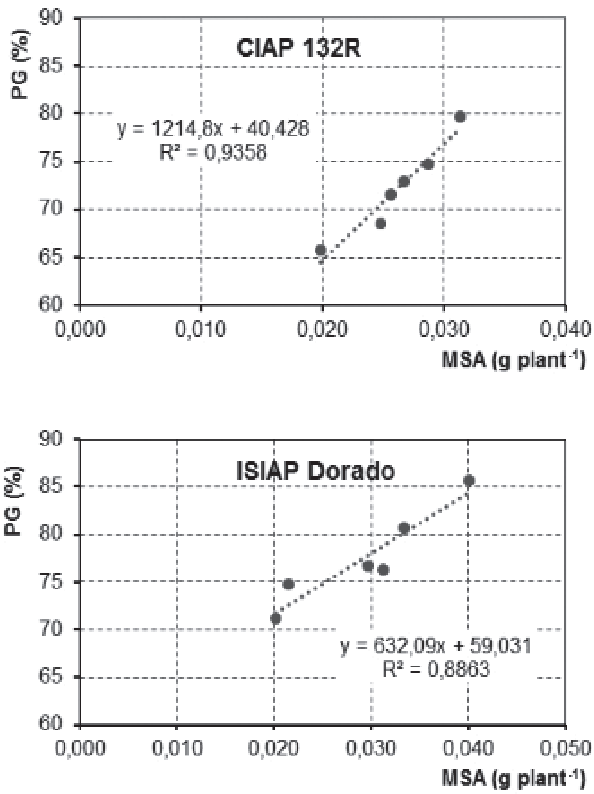
Treatments	CIAP 132R	ISIAP Dorado
M1	65,75 d	71,25 d
M2	68,50 d	74,75 c
M3	71,50 c	76,75 c
M4	74,75 b	80,75 b
M5	79,75 a	85,75 a
Testigo	73,00 bc	76,25 c
ESx	3,68	1,80

Uneven letters in the column differ significantly (p <0.05), according to Duncan's Multiple Range Test, n = 20

Calibers seeds M1 (0.015-0.020 g); M2 (0.021-0.025 g); M3 (0.026-0.030 g); M4 (0.031-0.035 g); M5 (0.036-0.040 g) and control (mixture of seed size)

The dry aerial mass at the end of the experiment; that is, at 10 days after the emergency, it showed the positive effect that the seed size (mass) has on the variables previously evaluated and specifically on the total dry mass, after the treatments of greater caliber (M4 and M5) were the ones that accumulated greater dry aerial mass in the two cultivars.

From a regression analysis, a strong relationship was found between the percentage of germination (PG) and the aerial dry mass (MSA) in both cultivars, with coefficients of determination of R2=0.9358 for cultivating CIAP 132R and R2=0.9358 for the cultivated ISIAP Dorado (Figure 3).



Regression coefficient (R2) Aerial dry mass (MSA)

Figure 3. Regression between the percentage of germination (PG) at 96 hours and the aerial dry mass (MSA) at 10 days after the emergence of sorghum plants, cultivars CIAP 132R and ISIAP Dorado, grown in a tray on a Gleysol Nodular ferruginous petroferric soil

The variability found in the grain mass, with values ranging from 0.015 g to 0.040 g for these two cultivars, may be due to the specific characteristics of the sorghum plant. As for its own growth and development, which must be associated with genetic and environmental patterns. The size of the grain and its mass varies in sorghum, usually from 2.0 to 4.5 mm in diameter and on average its mass is around 25 g per 1000 grains, but it can vary from 13 to 40 g per 1 000 grains (16). This variation in the mass of the grain will depend on the genetic factor (potential mass) and the ability of the plant to accumulate dry matter during the growth stage of grain filling (16). Climate, soil fertility and available water influence the size and final mass (weight) of grains. In general terms, 85% of the dry matter produced by the plant during the GS III growth stage (grain filling stage) goes directly to the grain (16).

In this regard it was reported that the mass of the seed is related to the amount of reserve it has, to subsequently complete the germination process with greater vigor (17). The size of the seed is considered as an indicator of physiological quality, due to the fact that seeds of greater size or greater mass show better germination and vigor (18,19). However, for other graniferous species, what is expressed above in relation to grain size is not fulfilled, as is the case of rice grain (*Oryza sativa* L), where its mass varies by type and cultivar (20,21).

For the CIAP 132R sorghum cultivar it was indicated that the mass of the grains as average of a panicle is 26.8 g (8.22), and for the case of the ISIAP Dorado cultivar the average is 29.5 g (23,24), therefore, the presence of larger grains is possible in the ISIAP Dorado cultivar; Not so for the CIAP 132R, which has a lower average mass. However, the seed is marketed with a variety of seed size.

The percentage of germination in time, in the two cultivars (CIAP 132R and ISIAP Dorado) up to 96 hours after sowing, the rate of germination speed and the average number of days to germinate, was in correspondence with the size of the seed. These results may be due to the fact that the seeds of higher caliber contain a greater amount of reserve substance and associated with this the possibility that they can store a greater quantity of water, necessary to complete the germination. It was reported that in the seed several processes occur that depend solely on seed reserves.

The embryo's gibberellic acid acts on the aleurone layer where the amylase enzyme is activated, which initiates the degradation of reserve substances contained in the endosperm and cotyledon. From the digestion of reserve tissues, various compounds are released to be reused in multiple synthesis processes. Complex molecules such as: celluloses, hemicelluloses, starches, amylopectins, lipids, lignins, proteins, nucleic acids, vitamins and hormones, are degraded to simple molecules by specific enzymes (17,20).

The decreases in the values of germination between one moment and the other, that is, the experiment that was mounted with fresh seed and 30 days later, can be due fundamentally to three factors, to the physiological maturation of the seed, to the conditions of storage of them and internal changes in the seed caused by the two previous factors. This result indicated that the sorghum seed quickly loses its germinative power, from the transformations that occur in the seed.

In this regard, it was indicated that the causes that cause the degradation of these substances and that lead to the loss of vigor and the germinability of the seeds are diverse and not yet known (25). However, as the subcellular structures are composed of lipids and proteins, over time, the cell membrane gradually degrades, losing its selective capacity. This deterioration is carried out as a result of the autoxidation of the lipids, in seeds with reserves of oils, forming peroxides that activate some enzymes and that affect the viability and vigor of the seeds (9).

To use in the productive practice seeds of sorghum of greater caliber (mass), is an important element to guarantee the production, as well as increases in the same one. That is why, the tests of emergency speed or of germination, to establish the IVG, allows to obtain better estimators of vigor of these, to be used in programs of genetic improvement, since it has been demonstrated that plants with greater vigor, possess superior characteristics of leaf area, dry mass and root length (12).

The results in soil tray conditions corroborate what was found in the previous experiment, in terms of the percentage of germination in time and 96 hours after sowing, as well as the aerial dry mass 10 days after emergence. Always the largest seed size showed the best results in these indicators (PG over time, PG and MSA). These results suggest the use of seeds of greater caliber, which correspond to a greater filling and biological maturation in the panicle (16,17).

Several studies on seed germination analyze the factors that can influence germination, such as light, temperature, and humidity (18,26). However, there are few studies that take into account the mass of the seed as an essential element to achieve high production. It is important to point out that the conditions in which the experiment was carried out, the emergence of coleoptile was visible at 48 hours, and that is, 24 hours after what happened in the Petri dishes.

In order to increase the indicators of germination in sorghum it is necessary to classify the seed, with the purpose of marketing those of greater caliber and achieve high percentages of germination and uniformity in the plantation. Sorghum seeds are small in size, with few reserves, are demanding in soil conditions for their implantation and weeds compete with advantage in the early stages. Its initial growth is slow compared to corn (*Zea mays* L.) and soybean (*Glycine max* L.), in fact, the growth is not fast until 15 cm high, which is when the plant begins to accelerate its growth (24).

The NMDG is an important indicator in the agronomic management of sorghum, due to its positive effect on competition with weeds and is directly related to the IVG. That is why, finding a higher NVDG in the control treatment in both cultivars can be considered unfavorable for the crop, mainly due to the mixture of seed size.

The high relation that was found between the percentage of germination (PG) and the aerial dry mass (MSA) in both cultivars (CIAP 132R and ISIAP Dorado), corroborated with the coefficients of determination, explained 93 % of the adjusted model of the variability in PG for the cv. CIAP 132R and in the case of cv. ISIAP Dorado the adjusted model explained 88 % of the variability in PG. These results again indicated the positive effect of seed size (mass), to achieve greater growth in its first stage of development. Element that is fundamental for the adaptability and competence of these plants in field conditions and, therefore, achieve a greater population and survival, from which the slow growth of sorghum is recognized in its first stage of development (1,16, 23.27,28).

Based on the results achieved under Petri dish conditions and in trays with soil, the seed size 0.036-0.040 g could be considered the adequate mass to ensure a rapid and successful germination product of a balance between physiological maturity and the reserves of the seed. These results, in terms of the effect of the seed size (mass) for this crop, suggest that small seeds are not capable of surviving a greater number of microsites and currently the influences of climate change processes (29). On the contrary, the seeds of greater caliber (mass) have a greater metabolic reserve, which increases the probability of establishment of the seedlings and of adapting to the adverse conditions created by climate change.

CONCLUSIONS AND RECOMMENDATIONS

- ♦ The seeds of sorghum of greater caliber (0.036-0.040 g) reach higher percentage of germination, index of speed of germination, smaller number of days to germinate and conserve for a longer time their germinative power.
- ♦ It is crucial in the first stage of growth of the sorghum crop the seed size (mass), because it has greater germinative power and accumulation of aerial dry mass.
- ♦ It is recommended to use seed size (dough) greater than 0.030 g and perform other investigations at the biochemical level that explain the germinative power of the seeds of higher caliber (mass) in the sorghum culture.

BIBLIOGRAPHY

1. Canet R, Rivero L, Armenteros M. Manual para la producción del cultivo del sorgo (*Sorghum bicolor* (L.) Moench. 2da ed. La Habana, Cuba: Instituto de Investigaciones de Granos; 2011. 19 p.
2. FAO. La economía del sorgo y del mijo en el mundo: hechos, tendencias y perspectivas [Internet]. Food & Agriculture Org.; 1997. 72 p. Available from: https://books.google.com.cu/books/about/La_econom%C3%A-Da_del_sorgo_y_del_mijo_en_el.html?id=pKtRbOpFY-VEC&redir_esc=y
3. García M. Potencian cultivo del sorgo en Pinar del Río [Internet]. Periódico Juventud Rebelde. 2014 [cited 2018 Oct 5]. Available from: http://www.juventudrebelde.cu/cuba/2014-07-10/potencian-cultivo-del-sorgo-en-pinar-del-rio
4. Obregon P. La Germinación [Internet]. Monografias.com. [cited 2018 Oct 12]. Available from: https://www.monografias.com/trabajos70/germinacion/germinacion.shtml
5. Chessa A. Sorgo Granífero–La importancia de su cultivo y correcto manejo en Siembra Directa – Campaña 2014/15 [Internet]. Argentina; 2015 p. 1–10. Available from: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=2ahUKEwiQquCZl4HeAhUl01kKHW3A8wQFjAAegQICRAC&url=https%3A%2F%2Fwww.agroconsultasonline.com.ar%2Fdocumento.html%2FSorgo%2520Gran%25C3%2583%25C2%25ADero.%2520La%2520importancia%2520de%2520su%2520cultivo%2520y%2520correcto%2520manejo%2520en%2520Siembra%2520Directa.%2520Campa%25C3%2583%25C2%25B1a%25202014-15%2520(2014).pdf%3Fop%3Dd%26documento_id%3D511&usg=AOvVaw33C-vKGgRr4YlukJENwB2k

6. Cueto N, Morejón L, Herrera R, Porras Á. BIOFIE: una experiencia positiva en ayuda a las semillas. Agricultura Orgánica. 2013;19(1):12–4.
7. Machado MI, Herrera RV, Morales MC. Efecto del ozono (O_3) sobre el vigor de las semillas de sorgo (*Sorghum bicolor* (L.) Moench) variedad UDG-11. Centro Agrícola. 2015;42(1):11–6.
8. Martínez S de J, Gómez R, Rodríguez G, Veitia N, Saucedo O, Gil V. Caracterización morfoagronómica de plantas de sorgo granífero variedad CIAP 132R-05 regeneradas vía embriogénesis somática en condiciones de campo. Centro Agrícola. 2016;43(3):73–9.
9. Caroca R, Zapata N, Vargas M. Efecto de la temperatura sobre la germinación de cuatro genotipos de maní (*Arachis hypogaea* L.). Chilean journal of agricultural & animal sciences. 2016;32(2):94–101. doi:10.4067/S0719-38902016000200002
10. OECD. Safety Assessment of Transgenic Organisms in the Environment [Internet]. OECD Publishing, Paris; 2016 [cited 2018 Oct 12]. (OECD Consensus Documents, Harmonisation of Regulatory Oversight in Biotechnology). Report No.: volumen 6. Available from: https://doi.org/10.1787/9789264253421-en.
11. Peña-Valdivia CB, Trejo C, Celis-Velazquez R, López Ordáz A. Reacción del frijol silvestre (*Phaseolus vulgaris* L.) a la profundidad de siembra. Revista Mexicana de Ciencias Agrícolas. 2013;4(1):89–102.
12. Maguire JD. Speed of Germination—Aid In Selection And Evaluation for Seedling Emergence And Vigor1. Crop Science. 1962;2(2):176–7. doi:10.2135/cropsci1962.0011183X000200020033x
13. Hernández A, Pérez J, Bosch D, Castro N. Clasificación de los suelos de Cuba. Mayabeque, Cuba: Ediciones INCA; 2015. 93 p.
14. Pozo C, Cabrera JR, Márquez E, Hernández O, Ruiz M, Domínguez D. Características y clasificación de suelos Gley Nodular Ferruginoso bajo cultivo intensivo de arroz en Los Palacios. Cultivos Tropicales. 2017;38(4):58–64.
15. Ruiz M. Comportamiento del arroz (*Oryza sativa* L.) inoculado con hongos micorrízico arbusculares y expuesto a diferentes condiciones hídricas en el suelo. [Tesis de Doctorado]. [Mayabeque, Cuba]: Universidad Agraria de La Habana; Instituto Nacional de Ciencias Agrícolas; 2016. 98 p.
16. PIONEER. Sorgo: crecimiento y desarrollo del cultivo [Internet]. Argentina: Pioneer Argentina S.R.L.; 2018 [cited 2018 Apr 20] p. 4. (BOLETÍN TÉCNICO PIONEER). Available from: https://www.pioneer.com/CMRoot/International/Argentina_Intl/AGRONOMIA/boletines/SorgoCrecimiento_y_desarrollo_del_cultivo.pdf
17. Ríos GFL. Ecofisiología de árboles [Internet]. Universidad Autónoma de Chapingo, México: Chapingo; 2009. 490 p. Available from: https://books.google.com.cu/books?id=Az5OnQAACAAJ
18. Aguiar I de. Conservação de sementes. Manual Técnico De Sementes Florestais. 1995;(14):33–44.
19. Ayala G, Terraza T, López L, Trejo C. Variación en el tamaño y peso de la semilla y su relación con la germinación en una población de Stenocereus beneckei. Interciencia. 2004;29(12):692–7.
20. Pérez I, Montoya MA. Calidad del grano y variabilidad genética de variedades y líneas de arroz del Instituto Nacional de Investigaciones Agrícolas (INIA). Agronomía Tropical. 2009;59(4):445–56.
21. Díaz SH, Cristo E, Morejón R, Castro R, Shiraishi M, Dhanapala MP, *et al*. Análisis de la estructura productiva y comportamiento del rendimiento de cuatro variedades de arroz (*Oryza sativa* L.) de diferentes orígenes en la prefectura de Ibaraki, Japón. Cultivos Tropicales. 2013;34(1):42–50.
22. Saucedo OM, Fernández LE, Quiñones R, Rodríguez G, Moya A. Las aves granívoras y el cultivo del sorgo en la provincia de Villa Clara, Cuba. Centro Agrícola. 2017;44(2):36–43.
23. Oramas G. Informe de nuevas variedades: ISIAP Dorado, primera variedad de sorgo de grano blanco para consumo humano en Cuba. Cultivos Tropicales. 2013;23(4):75. doi:10.1234/ct.v23i4.630
24. Carrasco N, Zamora M, Melin A. Manual de sorgo [Internet]. 1ra ed. Carrasco N, Zamora M, Melin A, editors. Instituto Nacional de Tecnología Agropecuaria: Buenos Aires: INTA. Chacra Experimental Integrada Barrow; 2011 [cited 2018 Oct 12]. 105 p. (Publicaciones Regionales). Available from: https://inta.gob.ar/documentos/manual-de-sorgo
25. Palafox SS. Priming para incrementar la calidad fisiológica de la semilla de chile ancho [Internet] [Tesis de Diploma]. [México]: Universidad Autónoma de San Luís de Potosí; 2012. 60 p. Available from: http://ninive.uaslp.mx/jspui/bitstream/i/3471/1/IAF1PRI01201.pdf
26. Ruedas M, Valverde T, Argüero SC. Respuesta germinativa y crecimiento de plántulas de Mammillaria magnimamma (Cactaceae) bajo diferentes condiciones ambientales. Boletín de la Sociedad Botánica de México. 2000;(66):25–35.
27. García G. El sorgo para grano [Internet]. Madrid, España: Ministerio de Agricultura, Pesca y Alimentación; 2017. 20 p. Available from: www.mapama.gob.es/ministerio/pags/biblioteca/hojas/hd_1982_07.pdf
28. García E, Permuy V, Chaveco O, Segura T. Recomendaciones para el cultivo de sorgo para granos (*Sorghum bicolor* L. Moench). Holguín, Cuba: Estación Territorial de Investigaciones Agropecuarias de Holguín. Ministerio de la Agricultura; 2005.
29. FAO. El cambio climático, la agricultura y la seguridad alimentaria [Internet]. Roma, Italia: FAO. Organización de las Naciones Unidas para la Alimentación y la Agricultura; 2016 p. 4. Report No.: 5349S/1/01.16. Available from: http://www.fao.org/3/a-i5349s.pdf

Received: July 11th, 2018
Accepted: October 5th, 2018