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Article

Determination of physical and physiological quality in seeds from sorghums evaluated in the Bajío

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Abstract

For a seed to be considered of high quality, its attributes of physical, physiological, and genetic purity must be in balance; therefore, it is vitally important to evaluate it through scientific criteria for its production and marketing. In the Seed Analysis Laboratory of the Seed Production Program of the College of Postgraduates, Montecillo *Campus* , in 2022, the moisture content, volumetric weight, and weight of 1000 seeds were determined and a standard germination test was established with the aim of determining the physical and physiological quality in seeds of sorghums grown during the autumn-winter agricultural cycle of 2021 in the Bajío Experimental Field of INIFAP. Physical and physiological quality parameters were evaluated using a completely randomized design. The statistical analysis was performed using an analysis of variance and Tukey's test #0.5, with the RStudio 4.3.3 statistical package. The cultivars ET-V5 (78.74 g) and Súper Sorgo 35 (38.5 g) presented the highest values in terms of the variables volumetric weight and weight of 1 000 seeds, respectively. The Silo Máster cultivar showed the highest values for germination percentage and viability percentage (82.75 and 86.25%), respectively. The cultivars ET-V5, Súper Sorgo 09, and Súper Sorgo 35 presented the best physical quality in seeds among the materials evaluated. Silo Máster surpassed the other cultivars evaluated, obtaining the highest values in terms of physiological quality in seeds. The seeds of the commercial hybrids with forage purpose had better physical and physiological quality than the experimental varieties of dual purpose, forage-ethanol, with the cultivars Silo Máster, Súper Sorgo 09, Súper Sorgo 35, and ET-V5, standing out.

Keywords:

(*Sorghum bicolor* (L.) Moench), physical quality, physiological quality, standard germination test, vigor test by accelerated aging.

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Introduction

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal in the world after wheat, rice, corn, and barley and one of the staple foods of the world's most dispossessed population, particularly in developing countries in Africa and South Asia (FAO, 2022). Globally, sorghum plays a critical role in the supply of food, feed, forage, and fuel, and provides half of the world's dietary calories (Reynolds *et al* ., 2016).

The phenology of sorghum crops is determined by the rate of development, which represents the age of a plant, and is mainly affected by photoperiod and temperature (Caddel and Weibel, 1971 ; Quinby *et al* ., 1973 ; Gerik and Miller, 1984 ; Hammer *et al* ., 1989 ; Craufurd *et al* ., 1999). In contrast, the growth of the crop, which represents the biomass produced, is mainly affected by incident radiation (Hammer *et al* ., 2010).

The forage-ethanol sorghums evaluated in this research are of intermediate cycle (135 to 140 days to grain maturity), adapt to warm, semi-warm, and temperate climates, have autumn-winter and spring-summer sowing dates, sowing density of 15 kg ha-1, 75 to 85 days to flowering, present a potential biomass yield of 55 to 80 t ha-1, concentrate 16° Brix, and allow 2 to 3 cuts to be made, depending on irrigation, sowing date, and locality (INIFAP, 2010). Súper Sorgos are hybrids that have an approximate growth rate of 6.4 cm day-1, a height at the base of the panicle of 5.2 m at 81 das and a green matter production of 173 t ha-1 and concentrate 14° Brix. They can be used as biofuel based on their high biomass yield; as fodder to feed animals, the demand of which grows every day worldwide (INIFAP, 2010).

Developing countries account for 92% of the total area planted with sorghum worldwide; Africa has 65% of this area and 43% of world production, followed by Asia with 17 and 13.5% and Latin America with 10 and 20%, in terms of area and production of this crop worldwide, respectively (FAO, 2022). In Africa, sorghum is grown on marginal land under low-input conditions, and consequently, yield levels are relatively low (Orr *et al* ., 2016). In Latin America, yield levels are high due to more intensive cultivation practices as in developed countries.

To achieve high yields, seeds used in sowing must be of high quality (Almekinders and Louwaars, 1999). Seed quality includes the sum of physical, physiological, genetic, and health attributes responsible for the performance of seeds in the field, contributing to the proper establishment of seedlings, which is crucial for the success of a crop (Bishaw *et al* ., 2007). Physical quality can be assessed by determining the moisture content, volumetric weight, and weight of 1 000 seeds (Delouche, 1980). Physiological quality comprises those intrinsic attributes that determine its ability to germinate and can be measured through standard germination tests and vigor tests by accelerated aging.

In Mexico, the production of certified sorghum seed at the national level in the 2018-2019 autumn-winter agricultural cycle was 33.23 t, which represents less than 1% of the requirement for the planting of this crop at the national level, the other 99% is supplied through imports (Córdova *et al* ., 2019). During the 2023 AW+SS agricultural year, 1 336 145.92 ha of sorghum for grain were planted, of which 1 233 595.92 ha were harvested, with a production of 4 539 101.71 t of sorghum; of the total planted area, 31.38% (419 245.28 ha) corresponded to the irrigated modality, with an

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average yield of 3.68 t ha-1 and 68.62% (916 900.64 ha) to rainfed land, with an average yield of 2.96 t ha-1 of sorghum (SIAP, 2023).

Pecina-Becerril *et al* . (2021) evaluated the quality of seeds from fourteen lines of sorghum generated by INIFAP, through the days to flowering, the weight of a 1 000 seeds and germination at the time of harvest and after six months of storage; regarding seed quality, they pointed out that despite the fact that there was heavy rainfall during grain filling and physiological maturity, the lines SBA-25, LBA-98, LBA-101 and the cross SBA25 x SBR-31 stood out for their high percentage of germination and maintained their quality after six months of storage. On the other hand, in Brazil, Rodrigues *et al* . (2020) evaluated the effect of different drying temperatures and storage times on the physiological quality in seeds of sorghum for grain; the results showed that parameters such as emergence, accelerated aging, and seedling length decreased during storage, whereas electrical conductivity increased over time.

The purpose of this research was to determine the physical and physiological quality of seeds of cultivars of forage-ethanol sorghums and Súper Sorgos that were grown in the Bajío of Mexico.

Materials and methods

Location of the experimental site

This research was conducted in the Seed Analysis Laboratory of the Postgraduate Program in Genetic Resources and Productivity, Seed Production Program, of the College of Postgraduates, Montecillo *Campus* . It should be noted that the agronomic evaluation of sorghum genotypes was carried out at the Bajío Experimental Field of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP), for its acronym in Spanish, located in the municipality of Celaya, state of Guanajuato, Mexico, during the autumn-winter agricultural cycle of 2021.

Agronomic management in the field

Fertilization at the time of sowing was done using the formula 90-40-00 (kg ha-1 of N-P2O5-K2O); then, 35 days after sowing, at the time of the first weeding, 90 kg ha-1 of nitrogen was applied. The crop’s water requirement was met through emergence irrigation, although four irrigations were scheduled with the calendar 0-35-75-110 days after sowing, the last three were not provided since the rainfall during the crop cycle (750 mm) was higher than average (520 mm). Weed control was performed in pre-emergence by applying 2 L h-1 a of Gesaprim Combi (Atrazine + Terbutryn). The yellow sorghum aphid (*Melanaphis sacchari*), a pest that appeared 45 days after planting, was controlled with the insecticide Toretto (Sulfoxaflor) with doses of 50 ml ha-1.

Genetic material

The genetic material consisted of harvested seeds from sorghum cultivars evaluated in the Bajío Experimental Field, Silo Máster, Silo Miel, Silage King, RB-Cañero, Súper Sorgo 02, Súper Sorgo 09, and Súper Sorgo 35 (commercial hybrids with forage purpose), ETV1, ETV-2, ET-V3, ET-V4, and ET-V5 (experimental varieties of dual-purpose, forage-ethanol) of the National Institute of Forestry, Agricultural and Livestock Research (INIFAP, for its acronym in Spanish), during the autumn-winter agricultural cycle of 2021.

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Experimental design

The physical and physiological quality in sorghum seeds was evaluated through an experiment established under a randomized complete design with the number of replications established by the ISTA, 2015 , for each test. In the field, the experimental design used was randomized complete blocks with four replications, the experimental unit consisted of four 5 m long furrows with a distance between rows of 0.76 m, the useful plot was a central row, sowing was carried out manually with continuous seed deposit (*chorrillo*).

Variables evaluated

Physical quality variables

Physical quality was determined through moisture content (MC), volumetric weight (VW), and weight of 1 000 seeds (WTS). The MC was determined by the method of drying in an oven at a temperature of 130 °C for 2 h. In this method, it is assumed that, through the heat applied to the sample, only the water is removed from the grain, then the dry matter is measured, and by weight difference, the moisture content, expressed as a percentage, is calculated (ISTA, 2015). For the procedure, empty boxes were used, which were weighed with their respective lids, 5 g of whole sorghum seed were placed in each box, four replications per genotype, they were covered and immediately weighed, then they were placed inside the oven, after the drying period, the boxes were removed from the oven and weighed. The MC was calculated using the following equation: $\%moisture = \frac{M2 - M3 \times 100}{M2 - M1}$, where M1= weight in grams of the box and its lid; M2= weight in grams of the box, lid and seed before drying; M3= weight in grams of the box, lid and seed after drying.

The VW was evaluated from a sample of 100 g of seed, which was placed in a 100 ml test tube to determine the volume occupied. The data was taken in four replications per genotype. The VW was calculated with the following equation: $Volumetricweight = \frac{seedweight\,(100g)}{volumeocuppiedbythe100g} \times 100$. To obtain the WTS, eight replications of 100 seeds per genotype were weighed, and the data obtained were used to calculate the average, variance, standard deviation, and coefficient of variation. When the coefficient of variation obtained is less than 4, the WTS is obtained by multiplying the arithmetic mean of the eight replications by 10 (ISTA, 2015).

Physiological quality variables

Physiological quality was assessed with a standard germination test using the variables of germination percentage (GP), percentage of abnormal seedlings (PAS), percentage of non-germinated seeds (PNGS) and viability percentage (VP).

Standard germination test

a sample of 100 seeds was taken from each genotype to establish four replications of 25 seeds. The experiment was conducted using the “between paper” method recommended by the ISTA (2015) , with some modification regarding the disinfection of the seeds, which consisted of soaking the seeds in a solution of 5% sodium hypochlorite for 10 min. The ‘between paper’ method consists of spreading two paper towels previously moistened with distilled water on a flat surface previously disinfected with ethanol and sodium hypochlorite, and on the towels, 25 seeds were

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placed, distributing them in five columns and five rows; the seeds were then covered with two other wet towels, rolled up, and placed in vertically oriented plastic bags. The "rolls" were then taken to a germination room with a temperature of 25 °C. In the germination room, the distribution of the treatments was under a completely randomized design with four replications. During the test, moisture levels and temperature of 25 °C were kept constant. The test lasted 10 days.

The GP was estimated based on seedlings with normal germination, that is, those that present root, mesocotyl, coleoptile, and well-developed, healthy leaves without malformations. A single count was carried out 10 days after the test was established. The GP was calculated using the following equation: $Germination percentage = \frac{number of normal plants}{100} \times 100$. PAS, seedlings that presented malformations in some of their essential structures were counted. The PAS was determined with the following equation: $Percentage of abnormal seedlings = \frac{number of abnormal plants}{100} \times 100$. PNGS, the seeds that did not present essential structures were counted. The PNGS was determined using the following equation: $Percentage of non-germinated seeds = \frac{number of non-germinated seeds}{100} \times 100$. The VP refers to the percentage of seeds that showed visible germination (normal seedlings plus abnormal seedlings) at the end of the test. The determination of the VP was made using the following equation: $Viability percentage = \frac{normal seedlings + abnormal seedlings}{100} \times 100$.

Statistical analysis

The data obtained were analyzed through an analysis of variance and Tukey's test at 5%, using the statistical package of RStudio 4.3.3., 2020 .

Results and discussion

Assessment of seed physical quality

The analysis of variance showed highly significant differences ($p \leq 0.01$) among the treatments evaluated (Table 1).

Table 1. Statistical significance of the mean squares of the physical quality variables.

Variables evaluated	Sources of variation	CV (%)	R2
	Sorghum cultivars		
Moisture content	0.74**	3.78	0.59
Volumetric weight	24.69**	1.27	0.89
Weight of 1000 seeds	1.27**	2.42	0.97

Significance at $p \leq 0.05$; **= $p \leq 0.01$; CV= coefficient of variation; R2= coefficient of determination.

Comparison of means

Regarding the MC, the cultivars Súper Sorgo 02 (11%), Silo Miel (10.91%), ET-V4 (10.75%), and ET-V3 (10.4%) presented the highest values, and Súper Sorgo 09 (9.35%), the lowest (Table 2). Seeds contain about 30% moisture at physiological maturity, and the level drops to 10-15% 20-25 days after reaching physiological maturity (House, 1985).

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Table 2. Comparison of means of physical quality variables.

Cultivars	Moisture content (%)	Volumetric weight (kg hl-1)	Weight of 1 000 seeds (g)
ET-V1*	10.15 b	71.05 c	24.3 e
ET-V2*	10.25 b	72.5 b	35.8 b
ET-V3*	10.4 a	75.62 b	35.9 b
ET-V4*	10.75 a	74.1 b	26 e
ET-V5*	10.3 b	78.74 a	31.9 c
Súper Sorgo 02**	11 a	72.33 b	21.8 f
Súper Sorgo 09**	9.35 c	77.82 b	36.9 b
Súper Sorgo 35**	10.15 b	77.22 b	38.5 a
Silo Máster**	10.15 b	75.62 b	25.2 e
Silo Miel**	10.91 a	77.07 b	25.8 e
Silage King**	10.3 b	77.82 b	29.4 d
RB Cañero**	10.3 b	74.78 b	29.1 d

Means with equal letters within columns are not statistically different (Tukey $\leq$ 0.05). *= experimental varieties; **= commercial hybrids.

The percentage of seed moisture is generally higher at harvest time when seeds with low levels of vigor are used in the establishment of the crop. This finding indicates that the ripening process may be delayed due to the low vigor of the seeds used in planting (Camargo and Vaughan, 1973).

Regarding the variables of VW and WTS, the cultivars ET-V5 (78.74%) and Súper Sorgo 35 (38.5 g) presented the highest values, respectively, and ET-V1 (71.05%) and Súper Sorgo 02 (21.8 g), the lowest values, differing from the results obtained by Bravo *et al* . (2021) , who evaluated the grain yield of four different grain sorghum hybrids, MALÓN, ADVANTA 1302, ADVANTA 1350, ADVANTA 1250, and their adaptability in three agroecosystems of the province of Los Ríos, Ecuador, and reported that the average weight of 1 000 seeds ranged from 22.9 to 32.6 g.

It is important to highlight that although the evaluated materials presented a statistically significant difference with respect to the measured variables, these are above the average of the values reported in the literature for this crop, which shows the good physical quality that these sorghum cultivars possess (ISTA, 2015), with respect to the measured variables.

Assessment of seed physiological quality

Standard germination test

The analysis of variance showed highly significant differences ($p \leq 0.01$) in all the variables studied, except for the percentage of abnormal seedlings (Table 3).

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Table 3. Statistical significance of the mean squares of the variables evaluated in the standard germination test.

Variables	Sources of variation	CV (%)	R2
	Sorghum cultivars		
Germination (%)	245.37**	7.72	0.75
Abnormal seedlings (%)	23.14	46.3	0.39
Non-germinated seeds (%)	186.02**	17.08	0.72
Viability (%)	186.02**	6.49	0.72

Significance at $p \leq 0.05$; **= $p \leq 0.01$; CV= coefficient of variation; R2= coefficient of determination.

Comparison of means

The Silo Máster cultivar presented the highest values for GP and VP (82.75 and 86.25%), respectively, and the lowest value was shown by the ET-V1 cultivar (53.75%). On the other hand, regarding NGS, the highest value corresponded to the ET-V1 cultivar (41%) and the lowest to the Silo Máster cultivar (13.75%) (Table 4). Ruiz *et al* . (2018) , when studying the effect of seed caliber on the germination of the sorghum cultivars ISIAP Dorado and CIAP 132R, reported germination values between 65.75 to 79.75% for CIAP 132R and between 71.25 to 85.75% for ISIAP Dorado. The results reported by the authors are somewhat related to those found in this study.

Table 4. Comparison of means of the variables evaluated in the standard germination test.

Cultivars	Germination (%)	Abnormal seedlings (%)	Non-germinated seeds (%)	Viability (%)
ET-V1*	53.75 c	5.25 a	41 a	59 c
ET-V2*	66 b	9 a	25 b	75 b
ET-V3*	72.5 b	5.5 a	22 b	78 b
ET-V4*	68.25 b	8 a	23.75 b	76.25 b
ET-V5*	60.75 b	8.5 a	30.75 b	69.25 b
Súper Sorgo 02**	61.75 b	11 a	27.25 b	72.75 b
Súper Sorgo 09**	58.5 b	8 a	33.5 b	66.5 b
Súper Sorgo 35**	61.25 b	7.75 a	31 b	69 b
Silo Máster**	82.75 a	3.75 a	13.75 c	86.25 a
Silo Miel**	67.5 b	3.75 a	28.75 b	71.25 b
Silage King**	71.5 b	5.5 a	23 b	77 b
RB Cañero**	59.25 b	10.25 a	30.5 b	69.5 b

Means with equal letters within columns are not statistically different (Tukey ≤ 0.05). *= experimental varieties; **= commercial hybrids.

In the standard germination test, the Silo Máster cultivar stood out compared to the other cultivars evaluated, presenting the highest GP and VP and the lowest PNGS, in contrast to the ET-V1 cultivar, which showed the lowest values in terms of GP and VP and the highest PNGS. Batista *et al* . (2022) , when evaluating the physiological quality and initial performance of sorghum plants whose seeds were coated with zinc, reported germination values ranging from 80 to 85.5%. Muui *et al* . (2020) evaluated physiological quality attributes of seeds from sorghum germplasm accessions from the eastern, coastal, and Nyanza regions of Kenya, and the authors reported germination percentages ranging from 18 to 100%. The results obtained in both studies are somewhat related to those obtained in this research.

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Conclusions

The seeds of the commercial hybrids with forage purpose presented better physical and physiological quality than the experimental varieties of dual purpose, forage-ethanol, with the cultivars Silo Máster, Súper Sorgo 09, Súper Sorgo 35, and ET-V5 standing out.

Bibliography

1 Almekinders, C. J. M. and Louwaars, N. P. 1999. Farmers' seed production: new approaches and practices. Intermediate Technology Publications, London. 250-285 pp.

2 Batista, V. A. P.; Vieira, H. D.; Pires, J. I. C. and Acha, A. J. 2022. Sorghum seed coating with zinc: Physiological quality and initial performance of plants. Acta Scientiarum. Agronomy. 44(1):e53803. https://doi.org/10.4025/actasciagron.v44i1.53803.

3 Bishaw, Z.; Niane, A. A. and Gan, Y. 2007. Quality seed production. Lentil: an ancient crop for modern times. 349-383 pp.

4 Bravo, B. D. A.; Pacheco, F. A.; Pérez, J. J. R.; Mesa, R. R.; Yánez, J. C. O. and Salvatierra, J. B. 2021. Comportamiento agronómico y productivo de híbridos de sorgo (Sorghum bicolor L. Moench) en zonas agroecológicas de la Región Costa del Ecuador. Revista Científica Agroecosistemas. 9(3):168-178.

5 Caddel, J. L. and Weibel, D. E. 1971. Effect of photoperiod and temperature on the development of sorghum. Agronomic Journal. 6(3):799-803.

6 Camargo, C. P. and Vaughan, C. E. 1973. Effect of seed vigor on field performance and yield of grain sorghum (Sorghum bicolor (L.) Moench). Proceedings of the Association of Official Seed Analysts. 63:135-147.

7 Córdova-Téllez, L.; Caballero-García, M. A.; Hernández-Nicolás, N. Y. and Ríos-Santos, E. 2019. Boletín informativo de producción de semilla calificada por el SNICS. 25-43 pp.

8 Craufurd, P. Q.; Mahalakshmi, V.; Bidinger, F. R.; Mukuru, S. Z.; Chantereau, J.; Omanga, P. A.; Qi, A.; Roberts, E. H.; Ellis, R. H.; Summerfield, R. J. and Hammer, G. L. 1999. Adaptation of sorghum: characterization of genotypic flowering responses to temperature and photoperiod. Theory Applied Genetic. 99(5):900-911.

9 Delouche, J. C. 1980. Environmental effects on seed development and seed quality. Hort Science. 15(6):13-18.

10 FAO. 2022. Organización de las Naciones Unidas para la Alimentación y la Agricultura. Cultivos y productos de ganadería. https://www.fao.org/faostat/es/#data/QCL.

11 Gerik, T. J.; Miller, F. R. 1984. Photoperiod and temperature effects on tropically and temperatelyadapted sorghum. Field Crops Res. 9:29-40.

12 Hammer, G. L.; Van Oosterom, E. V.; McLean, G.; Chapman, S. C.; Broad, I.; Harland, P. and Muchow, R. C. 2010. Adapting APSIM to model the physiology and genetics of complex adaptive traits in field crops. J. Exp. Bot. 61(8):2185-2202.

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13 Hammer, G. L.; Vanderlip, R. L.; Gibson, G.; Wade, L. J.; Henzell, R. G.; Younger, D. R.; Warren, J. and Dale, A. B. 1989. Genotype-by-environment interaction in grain sorghum II. Effects of temperature and photoperiod on ontogeny. Crop Science. 29:376-384.

14 House, L. R. 1985. A guide to sorghum breeding, 2nd Ed. ICRISAT, Patancheru. 206 p.

15 INIFAP. 2010. Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias. Centro de Investigación Regional del Noreste-Campo Experimental Río Bravo. Folleto técnico núm. 43. 13-25 pp. ISBN: 978-607-425-355-9.

16 ISTA. 2015. International Seed Testing Association. International rules for seed testing. Published by The International Seed Testing Association. PO. BOX 308, 8303 Bassersdorf, CH-Switzerland. 243 p.

17 Muui, C. W.; Muasya, R. M.; Nguluu, S. y Kambura, A. 2020. Evaluation of seed quality attributes of sorghum germplasm accessions from eastern, coastal and Nyanza regions, Kenya. Sustainable Agriculture Research. 9(3):1-9. https://doi.org/10.5539/sar.v9n3p9.

18 Orr, A.; Mwema, C.; Gierend, A. and Nedumaran, S. 2016. Sorghum and millets in Eastern and Southern Africa. Facts, trends and outlook. Working Paper Series No. 62. ICRISAT Research Program, Markets, Institutions and Policies. International Crops Research Institute for the Semi-Arid Tropics, Patancheru. 76 p.

19 Pecina-Becerril, A.; Yáñez-López, R.; Quijano-Carranza, J. A.; Bujanos-Muñiz, R.; Andrio-Enriquez, E. y Pecina-Quintero, V. 2021. Producción y calidad de la semilla de sorgo en el Centro de México bajo polinización controlada: comportamiento de progenitores de sorgo. Ciencia y Tecnología Agropecuaria. 23(1):20-79. https://doi.org/10.21930/rcta.vol23-num1-art:2079.

20 Quinby, J. R.; Hesketh, J. D. and Voigt, R. L. 1973. Influence of temperature and photoperiod on floral initiation and leaf number in sorghum. Crop Science. 13(2):243-246.

21 Reynolds, M. P.; Quilligan, E.; Aggarwal, P. K.; Bansal, K. C.; Cavalieri, A. J.; Chapman, S.; Chapotin, S. M.; Datta, S. K.; Duveiller, E.; Gill, K. S.; Krishna, S. V. J.; Joshi, A. K.; Koehler, A. K.; Kosina, P.; Krishnan, S.; Lafitte, R.; Mahala, R. S.; Muthurajan, R.; Paterson, A. H.; Prasanna, B. M.; Rakshit, S.; Rosegrant, M. W.; Sharma, I.; Singh, R. P.; Sivasankar, S.; Vadez, V.; Ravi, V.; Vara-Prasad, P. V. and Yadav, O. P. 2016. An integrated approach to maintaining cereal productivity under climate change. Glob Food Sec. 8:9-18.

22 Rodrígues, G. B.; Resende, O.; Silva, L. C. D. M. and Ferreira-Junior, W. N. 2020. Physiological quality of graniferous sorghum seeds during storage. Research, Society and Development. 9(6):e27963152. https://doi.org/10.33448/rsd-v9i6.3152.

23 RStudio Team. 2020. RStudio: integrated development environment for R. Boston, MA: RStudio, PBC. http://www.rstudio.com/.

24 Ruiz-Sánchez, M.; Muñoz-Hernández, Y.; Guzmán, D.; Velázquez-Rodríguez, R.; Díaz-López, G. S.; Martínez, A. Y. y Almeida, F. M. 2018. Efecto del calibre semilla (masa) en la germinación del sorgo. Cultivos Tropicales. 39(4):51-59.

25 SIAP. 2023. Servicio de Información Agroalimentaria y Pesquera. Anuario estadístico de la producción agrícola. Secretaría de Agricultura y Desarrollo Rural. Ciudad de México. https://nube.siap.gob.mx/cierreagricola/.

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