



Advances in biology through agronomy, aquaculture, coastal and environmental sciences

— Volume II —

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Editors

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**Advances in biology through
agronomy, aquaculture, coastal and
environmental sciences**
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Advances in Biology through Agronomy, Aquaculture, Coastal and Environmental Sciences, Volume II, is an e-book that continues the work of the first version (<https://editorapantanal.com.br/ebooks/2023/advances-in-biology-through-agronomy-aquaculture-coastal-and-environmental-sciences/ebook.pdf>), published in 2023 by Leandris Argente!-Martínez and Ofelda Peñuelas-Rubio.

Our e-book compiles 25 manuscripts that present scientific results and reviews based on biological aspects. All of them contribute to explaining the responses of living organisms to agricultural, aquaculture, and coastal ecosystems, as well as those facing fragility or threat of climate change. This e-book was edited by Leandris Argente!-Martínez, Ofelda Peñuelas-Rubio, and Joe Luis Arias-Mosc!so, members of the Consolidated Academic Group ITVAYA-CA-3.

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Effects of sowing date and size on the physical and physiological quality of bread wheat seeds in southern Sonora, Mexico

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ABSTRACT

This study aimed to determine the influence of sowing date and seed size on the physical and physiological quality of bread wheat seeds. Eighteen lines provided by the International Maize and Wheat Improvement Center (CIMMYT) and two commercial checks were used. A randomized complete block design with three replications and a factorial arrangement was applied, where factor (A) was the genotype, factor (B) was the sowing date, and factor (C) was the small and large seed size. The grain yield, hectoliter weight, thousand-seed weight, emergence rate, emergence percentage, seedling length, and root length were determined. The results revealed statistically significant differences in all the study factors and their interactions for the recorded traits. Lines L-1, L-18, L-6, and L-7 presented superior agronomic characteristics and seed physical and physiological quality, achieving optimal expression of these traits and surpassing those of the commercial controls. The best sowing date was November 19th, and the use of large seeds favored agronomic expression, yield, seed physical and physiological quality, and initial seedling vigor in most of the evaluated genotypes.

Keywords: *Triticum aestivum* L., seed quality, sowing dates, seed size.

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INTRODUCTION

In Mexico, 567,000 hectares of wheat are planted in 2023. Sonora was the state with the largest planted area, at approximately 230,000 hectares, representing 41% of the national total. Its production reached 1.53 million tons, contributing 52.76% of the national total. In Sonora, durum wheat predominates, covering approximately 135,000 hectares, in contrast to bread wheat, with only 96,000 hectares (SIAP, 2023).

Genotype establishment in the field is crucial for successful plant development and the achievement of desirable yields, along with the use of high-quality seeds. This process is determined by germination. However, this test must be performed under favorable environmental conditions. Therefore, while it can be efficient for counting seeds with good germination that will produce viable plants in the field, it is important to consider the type of substrate, humidity, and temperature, as these factors can have adverse effects on seed quality (Baldini et al., 2018). For this reason, seed quality germination systems are conducted under controlled environments. These systems develop rapid, simple, and precise techniques for farmers to ensure good seed quality during sowing, growth, harvesting, and storage (Baldini et al., 2018).

Physical quality depends on size, bulk density, analytical purity, and the absence of weed seeds and seeds from other crops (Rathore et al., 2021). Furthermore, physical quality is evaluated using the variables of thousand-seed weight, seed size, bulk density, and physical purity (Fernández et al., 2015). It can also be characterized by the flotation index, hardness, and grain density (Kang et al., 2020; Beyaz, 2019).

Physiological quality, particularly seed vigor, is associated with germination uniformity, seedling development, and field adaptation. In this sense, seed vigor is defined as the property that determines behavior during germination and seedling emergence (ISTA, 2005). The main parameter of physiological quality deterioration is seed vigor, followed by reduced germination or a relatively high percentage of abnormal seedlings (Rathore et al., 2021; Finch-Savage, 2020).

In wheat, greater viability and germination occur before physiological maturity, whereas maximum vigor is expressed at physiological maturity (Wu et al., 2017). Physiological quality can be evaluated by conducting germination tests in the laboratory (Cardoso et al., 2021). Additionally, seedlings must have the capacity to emerge in the field (Derebe et al., 2022). Vigor tests have been used to determine the potential for rapid seedling emergence and development under diverse environmental conditions (Bayisa et al., 2023; Chaichi et al., 2022). Various evaluations have demonstrated that early planting dates result in optimal yields (Gadisa, 2019; Beyzi et al., 2019) and strong initial seedling vigor with good crop development in the field. Similarly, Baloch et al. (2010) demonstrated that early plantings, aligned with the agricultural cycle, tend to produce better expression of agronomic characteristics and grain physical quality.

The effects of seed size on germination and vigor have been studied in various plant species (Cardoza-Viera et al., 2024; Do Nascimento et al., 2022). Several studies have reported positive associations between seed vigor and productivity when larger seeds are used than when smaller seeds are used. Larger seeds tend to increase germination and emergence (Escobar-Álvarez et al., 2021; Domic et al., 2020). In wheat, larger seed size not only influences germination and establishment (Carranza-González et al., 2022) but also affects yield and its components (Llivicura et al., 2021); these results are attributed to the greater number of reserves in the seed. Seed size depends on the genotype and the environmental conditions in which the plants develop. According to Gadisa et al. (2019), Ceseski and Al-Khatib (2021) reported that seed size is important because it affects the percentage of total emergence, survival, growth, and seedling development; therefore, seed size is strongly related to physiological quality. However, Gadisa et al. (2019) reported that there is no significant effect of seed size on the germination percentage of bread wheat varieties. In this context, the objective of this study was to determine the influence of sowing date and seed size on the agronomic traits, physical quality, and initial seedling vigor of elite bread wheat lines in southern Sonora, Mexico.

MATERIALS AND METHODS

Study site

The research was conducted at the Technological Institute of the Yaqui Valley, located in BÁCUM, Sonora, between the Sierra Madre Occidental Mountain range and the Sea of Cortez, at 27°24'49" north latitude and 11°07'47" west longitude, with an average annual rainfall of 45 mm and an altitude of 13 meters above sea level. The predominant climate is BW(h), which is extremely hot, with an average annual temperature of 24°C and an average maximum of 31°C; from July to August, the maximum reaches 48°C, and in January, the minimum is 16°C, with an average annual rainfall of 450 mm. The arable soils are Vertisols, fertile, and rich in clay and are generally located in arid subhumid zones with hydration and humid exposure and cracks when dry (García, 1973).

In the fall–winter of 2020–2021, 18 previously selected lines were established from a total of 276 lines from an experiment conducted during the fall–winter cycle of 2019. Two commercial controls were used (Table 1) on two sowing dates, November 19, 2020, and January 12, 2021, with two seed sizes: large and small. A 19 × 3 mm oblong sieve was used to separate the seeds; those that remained on the sieve were considered large, and those that passed through were considered small.

The factorial design consisted of three study factors, factor A (genotypes = 20), factor B (sowing dates = 2), and factor C (seed size = 2), under a randomized complete block design with three replications, resulting in a total of 240 experimental units. The experimental unit was composed of four rows three meters long, separated by 80 cm and sown in double rows; the usable area was 9.6 m². The harvest was carried out on May 16 and June 20, 2021, corresponding to the first and second sowing dates, respectively.

Table 1. Commercial lines and varieties of bread wheat used in the field and sand bed evaluation in Yaqui Valley, Sonora, Mexico. 2020-2021.

Line	Genealogy	Line	Genealogy
L-1	CMSS07Y01083T-099TOPM	L-11	CMSS12Y00235S-099Y-099 N
L-2	CMSS10Y00374S-099 M-1WGY-0B	L-12	CMSS12Y00276S-099Y-0WGY
L-3	CMSS10Y00023S-099Y-4WGY	L-13	CMSS12Y00276S-099Y-0WGY
L-4	CMSS12Y00031S-38Y-0WGY	L-14	CMSS12Y00276S-099Y-16Y
L-5	CMSS12Y00064S-130 M--0WGY	L-15	CMSS12Y00307S-129Y-0WGY
L-6	CMSS12Y00069S-119Y-20Y	L-16	CMSS12Y00311S-130Y-7Y
L-7	CMSS12Y00070S-112 M-21Y	L-17	CMSS12Y00395S-099Y-3Y-0WGY
L-8	CMSS12Y00072S-9Y-0WGY1B	L-18	CMSS12Y00072S-115Y-9Y-10B
L-9	CMSS12Y00083S-099Y-5Y-6Y	Control	Borlaug F100
L-10	CMSS12Y00163S-152 M-099NJ-3	Control	Kronstad F2004

In the field, the grain yield (GR) was determined. The four rows were harvested, the seeds were cleaned, and a digital scale was used to record the data in kilograms. This was later converted to tons per hectare, adjusted for 15% moisture. Once the seed was cleaned, the weight of one thousand grains (PMG) was recorded using a digital scale, and the data were recorded in grams and hectoliter weight (PH). For the latter, a 1 L container was filled with seed until it overflowed and leveled off in a zigzag motion to remove the excess. The contents were weighed on an Ohaus volumetric weight balance (Parsippany, NJ, USA), and the readings were recorded in kg hL⁻¹. The standard germination percentage was determined at two points in time: on the fourth day (GE4) and on the seventh day (GE7), according to the ISTA (2015) guidelines.

Once the experiment was completed, the seeds obtained from each line were identified and stored in a warehouse at 22°C and 55% relative humidity until September, at which point the seed quality evaluation began.

The initial seedling vigor was subsequently determined in sand beds under nursery conditions during the period of September–November 2021. A completely randomized design with three replicates was used in this experiment. The experimental unit consisted of 100 seeds per genotype, and the following traits were measured: emergence rate (ER), percentage of emergence (PE), seedling length (SL), and root length (RL). The emergence rate was determined using the following formula (Maguire, 1962).

$$VE = \frac{\text{number of normal plants} + \dots + \text{number of normal plants}}{\text{day of the first account} \quad \text{day of the final account}}$$

Emergence counts were performed at 4, 5, 6, and 7 days after sowing (DAS). The percentage of emergence (PE) was determined by the number of seedlings that emerged on the seventh day using the following equation:

$$PE = \frac{\text{Number of emerged plants at the seven day}}{\text{Number of total seed sowed}} (100)$$

Seedling length (SL) and root length (RL) were recorded 15 days after the plants were planted in a random sample of 10 plants in full competition. Coleoptile length was measured from the substrate level to the leaf apex, and root length was measured from the base of the coleoptile to the extreme tip of root growth.

Statistical analysis

The characteristics were subjected to a combined analysis using the PROC GLM procedure of the SAS statistical package Ver. 9.3 (2012). The comparison of means was performed using Tukey's multiple range test ($P \leq 0.05$).

RESULTS AND DISCUSSION

Analysis of variance revealed significant differences ($P \leq 0.01$) in the main effects of genotype (G), date (D), and seed size (SS) across all the study variables, indicating that all the genotypes differed because of their genetic makeup (Table 2). These results may be attributable to the expression of traits that are strongly influenced by the environment (Gharoobi, 2011).

Table 2. Mean squares of the analysis of variance for the agronomic and physical quality characteristics of the bread wheat seeds. Yaqui Valley, Sonora. 2020-2021.

SV	DF	TSW (g)	HW (kg hL ⁻¹)	GY (t há ⁻¹)	SL (cm)	RL (cm)	ER (%)	PE (%)	G4 (days)	G7 (days)
Repetition (R)	2	10.09	2.08	0.29	0.16	0.39	0.061	0.46	3.42	0.67
Genotype (G)	19	383.31**	175.81**	3.99 *	6.25**	5.09**	0.33**	20.21**	384.51**	18.53**
date (D)	1	16.85**	0.14*	0.41 *	0.33**	0.004*	0.40**	3.26**	11.70**	0.26*
Size (S)	1	0.006 *	0.16**	1.71**	4.03**	0.024*	0.007*	4.81**	1.50**	2.40**
G × F	19	6.18**	0.31 *	0.10 *	2.53**	1.82**	0.205**	15.06**	2.02**	4.52**
G × T	19	5.52**	0.48 *	0.26 *	0.74*	0.30*	0.14*	10.06**	0.61*	4.23**
F × T	1	2.15**	0.10 *	0.02*	0.39**	0.17*	0.10*	0.41*	0.33*	2.40**
G × D × S	19	6.18**	0.45 *	0.18 *	0.66**	0.81**	0.25*	4.86**	0.78**	1.23**
Error	158	5.59	0.4	0.06	0.45	0.08	0.11	2.30	0.98	1.69
CV (%)		5.86	0.86	3.9	11.71	5.37	1.91	1.96	5.26	5.23

SV: source of variation; DF: degree of freedom; *, **, and **, indicate significance at the 0.05 and 0.01 probability levels, respectively. TSW: thousand-seed weight, HW: hectoliter weight, GY: grain yield, SL = seedling length, RL = root length, ER = emergence rate, PE = percentage of emergence, G4 = germination on the 4th day after sowing, G7 = germination on the 7th day after sowing, and CV: coefficient of variation.

The simple interactions GxF, GxT, and FxT significantly differed across all the variables studied, whereas the triple interaction GxFxT significantly differed across four of the five study variables. These results demonstrate that the response of the genotypes varied according to environmental conditions, or this could also be attributed to the maturity cycle.

On the other hand, the analysis of variance generated by the three study factors and their interactions revealed that genotypes contributed most to the total variation detected, as the variability encompassed by this factor in the expression of the variables PMS, PH, and RG exceeded that recorded for planting date (F) and seed size. The interaction (GxF) was the most statistically significant because of its impact on the expression of variability for the PMS variable; however, for (PH) and (RG), the interaction (GxT) made the greatest contribution to the total variation. The coefficients of variation for the characteristics studied in the experiment are low and therefore considered acceptable (Khan et al., 2010).

The mean comparison test (Table 3) revealed that L-18 had the highest hectoliter weight at 79.5 kg hL⁻¹, followed by Borlaug F-100 and L-1 at 78.5 and 77.2 kg hL⁻¹, respectively. These results are indicators of the quality obtained in the field in relation to the agronomic management and environmental conditions present during the experiment, which are ultimately expressed in the seed. However, the results obtained in this study are lower than the 83.1 kg hL⁻¹ reported by Moreno (1993) but higher than the values reported by Baloch et al. (2010). The averages of at least eight lines were consistent with the Mexican Official Standard NMX-FF-036-1996, which ranges from 74 to 76.3 kg hL⁻¹ for high-quality materials.

Table 3. Comparison of means for physical seed quality traits in bread wheat genotypes. Yaqui Valley, Sonora. 2021.

Line	HW (kg hL ⁻¹)	WTG (g)	GY (t ha ⁻¹)
L-1	77.2 c	47.9 ab	7.0 bc
L-2	75.1 f	38.9 g	5.9 fgh
L-3	69.9 k	36.2 i	5.8 gh
L-4	76.1 e	39.1 fg	6.1 f
L-5	70.9 ij	34.7 ij	5.8 hi
L-6	76.0 e	47.1 bc	6.9 c
L-7	76.6 d	45.8 cd	7.0 bc
L-8	70.5 j	43.9 de	6.6 d
L-9	68.4 l	32.2 kl	5.7 hi
L-10	76.8 cd	45.1 de	6.8 c
L-11	71.9 h	35.1 ij	5.8 h
L-12	67.9 lm	33.2 jk	5.7 hi
L-13	73.9 g	43.1 e	6.4 e
L-14	71.4 i	38.1 gh	5.8 fgh

Line	HW (kg hL ⁻¹)	WTG (g)	GY (t ha ⁻¹)
L-15	67.6 m	31.1 l	5.6 i
L-16	76.5 de	40.9 f	6.4 de
L-17	68.1 lm	36.5 h	5.8 gh
L-18	79.5 a	47.9 ab	7.4 a
Borlaug F100	78.5 b	49.1 a	7.1 b
Kronstad F2004	75.1 f	40.0 fg	6.0 fg
DSH (0.05)	0.93	3.47	0.36
Seed size			
large	73.4 a	40.3 a	6.39 a
Small	72.8 b	39.7 b	5.25 b
DSH (0.05)	0.16	0.5	0.8
Sowing date			
19 November 2020	75.31a	41.57 a	6.36 a
12 January 2021	74.14 b	40.04 b	5.82 b
DSH (0.05)	0.8	1.2	0.7

With respect to PMS (processed dry matter), the control variety Bourlaug F-100 had the highest value of 49.1 g, followed by lines L-18, L-1, and L-6, whose values ranged from 47.1 to 47.9 g. Lines L-5, L-9, L-12, and L-15 presented the worst performance. These results indicate that thousand-seed weight is the most important direct trait in the indirect selection of yield for genotype selection. In this regard, the yields obtained in this research can be attributed to the accumulation of chilling hours during crop development, which were strongly related to the thousand-seed weight, which accumulated 796 chilling hours, exceeding the average of 600 hours required for good production (CONAGUA, 2021).

In terms of field yield, the experimental line L-18 showed outstanding performance (7.4 t ha⁻¹), surpassing the commercial controls Bourlaug F100 and Kronstad F2004 (300 and 1400 kg ha⁻¹, respectively). Furthermore, it is important to highlight that lines L-1 and L-7 obtained 7.0 t ha⁻¹, making them competitive, as they exhibited the same response as the commercial variety Bourlaug F-100. The results of this research are superior to those reported by Castañeda et al. (2009), who reported average yields of 5 t ha⁻¹ in bread wheat but are similar to those reported by Buenrostro-Rodríguez et al. (2022), who reported average yields of 7.2 t ha⁻¹ in the 2015/2016 cycle in varieties in the state of Guanajuato.

Large seed size yielded the best average results, and the best planting date was November 19, 2020, for all the recorded agronomic traits. In this context, Zareian et al. (2013), Akhter et al. (2017), and Huang et al. (2015) reported that large seed size in wheat favors yield expression in the field. These results were reflected in the production environments, highlighting positive effects on yield and grain physical quality, as reported by Villaseñor et al. (2012). They also mention that while production environments present critical conditions, these are not recommended for seed production, as they affect seed quality.

Table 4 presents the results of the Tukey test for comparing means for the physiological quality traits. Seedling length (SL), root length (RL), emergence rate (ER), emergence percentage (EP), standard germination on day four (EG4), and standard germination on day seven (EG7) were measured. With respect to SL, the lengths of the L-18, L-1, L-7, Borlaug F-100, and L-6 genotypes were consistently the greatest, with values exceeding 6 cm. In terms of root length, the L-7, L-1, L-18, and Borlaug F-100 genotypes again presented the greatest length, with L-10 having the longest roots. Furthermore, these genotypes consistently demonstrated the best performance for ER and EP, surpassing the commercial control Kronstad F-2004. These findings suggest that in this study, any of these genotypes offered guaranteed uniformity in terms of field establishment on the basis of their seedling vigor performance. Furthermore, 17 to 18 plants emerged per day, with 74 to 78% emergence in sand beds. These results differ from those reported by Noriega-Carmona et al. (2019), who reported higher values for both characteristics in wheat genotypes from the Bajío region of Guanajuato. It is important to note, however, that a significant number of lines—L-2, L-3, L-4, L-5, L-9, L-11, L-12, L-14, L-15, and L-17—exhibited poor performance in terms of all recorded physiological characteristics and were inferior to the commercial controls (Yousefi et al., 2020).

Table 4. Comparison of means for physiological seed quality traits among bread wheat genotypes. Yaqui Valley, Sonora. 2021.

Genotypes	G4	G7	LC	RL	VE	PE
	(%)	(%)	(cm)	(cm)	(p dia ⁻¹)	(%)
L-1	22.75 de	94.16 bcde	7.1 ab	6.2 a	17.9 a	78.7 ab
L-2	24.41 ab	95.52 a	5.5 cde	5.4 b-f	17.7 ab	77.1 abc
L-3	24.25 bc	94.91 abc	5.3 de	5.2 f	17.7 ab	76.5 bcd
L-4	21.58 efg	94.31 bcde	5.7 cde	5.4 b-f	17.7 ab	77.5 abc
L-5	23.16 cd	95.08 ab	5.2 de	4.3 gh	17.6 ab	75.5 cd
L-6	21.41 fg	93.75 cde	6.2 cd	5.5 bc	17.8 a	78.4 ab
L-7	22.41 def	94.58 abcd	6.4 bc	6.4 a	17.9 a	78.6 ab
L-8	22.41 def	94.08 bcde	5.8 cd	5.6 b	17.7 ab	78.4 ab
L-9	21.25 fg	91.41 f	5.1 de	4.6 g	18.4 a	75.5 cd
L-10	21.52 fg	93.53 de	5.9 cd	5.7 b	17.8 a	78.5 ab
L-11	21.41 fg	93.08 e	5.2 de	5.1 ef	17.6 ab	76.9 abc
L-12	24.41 ab	95.09 ab	5.1 de	4.2 h	17.5 ab	74.4 d
L-13	21.75 efg	93.83 cde	5.6 cde	5.5 bcd	17.8 ab	77.5 abc
L-14	23.08 cd	94.91 abc	4.7 e	5.1 def	17.7 ab	75.7 cd

Genotypes	G4	G7	LC	RL	VE	PE
	(%)	(%)	(cm)	(cm)	(p dia⁻¹)	(%)
L-15	21.19 g	93.52 de	5.1 de	4.2 gh	17.5 ab	78.2 ab
L-16	23.34 d	94.41 abcd	5.9 cd	5.6 b	17.8 ab	78.2 ab
L-17	21.58 efg	93.58 de	5.3 de	5.1 c-f	17.6 ab	76.8 abc
L-18	23.41 bcd	94.91 abc	7.8 a	6.2 a	17.9 a	78.6 ab
Borlaug F-100	25.58 a	95.07 ab	6.2 cd	5.7 b	17.3 b	79.5 a
Kronstad F-2004	21.75 efg	94.31 bcde	5.6 cde	5.4 b-f	17.7 ab	77.2 abc
Tukey (0.05)	1.46	1.2	0.99	0.42	0.5	2.23
Tamaño semilla						
Large	18.92 a	95.28a	5.79 a	5.34 a	17.79 a	77.51 a
Small	17.67 b	94.04b	4.81 b	4.16 b	16.14 b	76.83 b
Tukey (0.05)	0.85	0.65	0.47	0.07	0.9	0.58
Sowing date						
19 November 2020	19.06 a	95.15 a	5.88 a	5.35 a	17.76 a	77.54 a
12 January 2021	18.62 b	94.19 b	5.62 b	4.71 b	16.08 b	76.25 b
Tukey (0.05)	0.25	0.75	0.18	0.36	1.25	1.05

A comparison of the means for the physiological traits revealed that the percentage of emergence on day 4 ranged from 21.08% to 25.58%, with the commercial variety Borlaug F-100 consistently showing the highest percentage, followed by lines L-2, L-3, and L-12. On the other hand, the Kronstad F-204 variety and the L-15, L-9, and L-11 lines exhibited low germination in this first count. For standard germination recorded in the second count (day 7), lines L-2, L-5, L-12, and L-3 and the variety Borlaug F-100 presented the highest germination values; however, lines L-9, L-11, and L-15 presented the worst performance.

The early sowing date of November 19, 2020 had a significant positive effect on the expression of initial seedling vigor. These findings indicate that early planting dates are favorable for wheat seed production, as confirmed by Villaseñor et al. (2012) and García-Rodríguez et al. (2018). Conversely, in late planting, all the genotypes performed poorly for all the variables studied. These results are consistent with those reported by Noriega-Carmona et al. (2019) and Martínez et al. (2010).

Large seed size favors the expression of physiological quality and initial seedling vigor, as has been reported in several studies on various crops, indicating that large seeds tend to germinate more successfully in the field and produce more vigorous seedlings (Gutiérrez-García et al., 2006; Zareian et

al., 2013), mainly because of the nutritional reserves of the seeds. In contrast, small seeds are characterized by low percentages of germination and seedling vigor (Bockstaller; Girardin, 1994); in addition, the large size of the grain in wheat favors the characteristics of milling in the agro-industrial sector (Dziki; Laskowski, 2004).

CONCLUSIONS

The evaluated genotypes responded differently to the planting date and seed size. Lines L-1, L-18, L-6, and L-7 presented high values for agronomic characteristics and physical and physiological seed quality, achieving optimal expression of these traits and outperforming the commercial controls. Finally, the early planting date of November 19th and the use of large seeds favored agronomic expression, yield, physical and physiological seed quality, and initial seedling vigor in most of the evaluated genotypes.

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