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Article

Variation in physical and physiological seed quality caused by the origin of the H-520 corn hybrid

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Abstract

The physical and physiological quality of seeds are parameters that directly influence during establishment in the field, impacting the viability and vigor of seeds and seedling. The objective was to assess the variation in physical and physiological quality caused by the origin in seed production of the H-520 white-grained tropical corn hybrid. Seed samples were obtained from different seed companies. Physical and physiological variables were recorded in seeds and seedlings. The data analyzed showed differences ($p \geq 0.05$) in most of the physical and physiological variables of seeds, except for the variables of percentage of anthocyanins in seedling and plumule length. The mean values obtained for the standard germination test were (95.2%), normal plants (90.5%), abnormal plants (4.6%), non-germinated seeds (4.9%), presence of anthocyanins (50.35%), plumule dry weight (36.4 g), plumule length (11.5 cm), radicle length (15.3 cm), radicle dry weight (24.7 g), seed width (8.7 mm), seed length (11.5 mm), seed thickness (4.1 mm), weight of 1 000 seeds (238.7 g), flotation index (27.3), and hectoliter weight (76.6 kg hl^{-1}). Although the tests carried out showed variations in the physical and physiological quality of seeds of the origins, the values are acceptable, suggesting that the management in seed production of the H-520 corn hybrid has been effective over time.

Keywords:

Zea mays L., commercial hybrid, seed-producing companies, seed test, varietal maintenance.

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Introduction

Corn (Zea mays L.) is one of the three crops of global importance, followed by wheat (Triticum spp.) and rice (Oryza sativa L.). The main destination of the grain is for direct human food, and it is also intended for a large number of derivatives that are used to manufacture industrial products (Adebisi et al., 2013), such as corn flour and tortillas, as well as snacks and industrial cereals from them (Gouttefanjat, 2021).

Globally, each year there is a production volume of 1 163 million tons produced in almost 206 million hectares with an average yield of 5 878.6 kg ha^{-1} (FAOSTAT, 2023). Of the world total, Mexico contributes about 2.3% (26.6 million tons) of the grain produced, which places it among the first six countries with the highest production volume (SIAP, 2023).

Specifically in the state of Veracruz, corn is one of the most important crops since, during the year 2020-2021, the harvested area was 436 222 ha, with a production volume of 1.2 million tons (INFOSIAP, 2024). Of these values, the south of Veracruz, which includes the area of influence of the Rural Development Districts of San Andrés Tuxtla, Jáltipan and Las Choapas, represented 37 and 48% of the state total (SADER, 2022).

In Mexico, efforts have been made to increase productivity in the different production systems through the use of corn varieties and hybrids; nevertheless, only 30% of the total area is sown with improved seeds (Turrent et al., 2012; SNICS, 2024) and the rest is sown with open-pollinated varieties or native varieties (Sierra et al., 2008). On the other hand, low productivity is due to the use of seed with poor physiological quality, which causes large economic losses to farmers (González-Zertuche and Orozco-Segovia, 1996; Liu et al., 2023).

The physiological quality of a seed in terms of viability, germination, and vigor is the most important aspect that directly influences field establishment and its productivity (Olisa et al., 2024). Thus, seed quality is very important to increase production, which is necessary to maintain the varietal purity of the seed and the control of its quality (Kormawa et al., 2019). Therefore, the study of physical and physiological activity in corn seed is important to ensure high grain yield per unit area.

Some traditional methods for assessing seed quality have proven to be a powerful tool as a complement to various genetic improvement and seed production programs (ISTA, 2024). Accurate study of the physiological quality of any commercial seed batch (original, basic, certified, and qualified) is essential to safeguard the interest of producers in obtaining good quality seeds for an optimal yield of their crops. Therefore, the present study assessed the variation in physical and physiological quality caused by the origin in seed production of the H-520 white-grained tropical corn hybrid.

Materials and methods

Collection of plant material and establishment of the trial

This research work was conducted in two stages: in the first stage, samples of seeds in certified category of the H-520 tropical white-grained corn hybrid that were produced during the spring-summer agricultural cycle of 2020 were collected. The origins were the National Institute of Forestry, Agricultural, and Livestock Research (control) (hereinafter INIFAP-control), Terra Semillas SA, Semillas Iyadilpro SA de CV, Maíces del Trópico, and Semillas La Ejidal. During this first stage, the physiological quality of the seeds was evaluated. The information was analyzed under a completely randomized design with four replications.

In the second stage, the remaining certified seed was used to set up two trials in the localities of Piedras Negras and Cotaxtla, Veracruz; the grain harvested in both environments was used to measure the physical characteristics of the grain. All tests were performed following the procedures outlined by the International Seed Testing Association (ISTA) (ISTA, 2024). The experimental design used for the physical test of the grain was a completely randomized with four replications of 25 seeds.

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Standard germination test

A total of 400 seeds from each origin (hereinafter treatment) were used; each treatment was arranged in four replications of 100 seeds. Each replication was sown on wide wet paper and rolled into a taco shape; subsequently, they were placed for six days in a controlled germination chamber at a temperature of 25 °C and in the absence of light. Visually, at seven days after sowing (das), the number of seeds that produced normal and abnormal seedlings, the number of non-germinated seeds, and the number of seedlings with the presence of anthocyanins in the stem were counted.

Seed vigor test

From the original batch of seedlings germinated using the standard germination test method. At 7 das, ten normal seedlings were harvested per replication, where plumule length (PLUML) and radicle length (RADL) were measured, both were recorded in mm using a ruler. Likewise, the plumule dry weight (PLUMDW) and radicle dry weight (RADDW) were determined, both were recorded in g with a Seedburo-Model 8800® analytical balance with an accuracy margin of 0.001g.

Physical characteristics

During the second stage of the experiment, physical variables such as the following were recorded in seeds: seed width (SEEW), seed length (SEEL), seed thickness (SEETH); all variables were recorded in mm with a Digital vernier caliper®. Weight of 1 000 seeds (W1000SEE), it was done with a Seedburo-Model 8800® analytical balance.

The flotation index (FLOTI) was determined following the procedure in accordance with the NMX-FF-034/1-SCFI-2002 standard (Secretaría de Economía, 2002). The hectoliter weight (HECW) was determined using a DICKEY-John mini Gac® Plus grain hectoliter balance. All trials were carried out in the Seed Quality Laboratory of the College of Postgraduates-Campus Montecillo, Texcoco, state of Mexico.

Statistical analysis

The data collected were used to test the assumptions of the analysis of variance (normality, homoscedasticity, and independence of errors). Those variables recorded as a percentage were transformed by square root (%) to comply with the assumptions of the analysis of variance. Subsequently, all variables were subjected to an analysis of variance (ANOVA) and Tukey's mean comparison tests (α= 0.05). The statistical package used was Sas/Stat® version 9.1 (Castillo, 2007).

Results and discussion

Physiological quality

The individual analysis of variance (ANOVA) yielded statistically significant differences ($p \leq 0.05$) for the origin variation factor in all the variables assessed, except for the ABS and PLUL variables (Table 1). This indicates that the origins evaluated differ in the physiological quality of the seed. These results can be attributed to the formation process that each company integrates into its seed multiplication schemes, which can range from the elimination of out-of-type plants during the development of the crop to the emasculation of the plant during the anthesis period.

On the other hand, the coefficients of variation obtained ranged from 1.87 to 23.31%, which suggests that the conduct and management of the experiment are reliable, of quality and precise (Meneses-Márquez et al., 2006). It was found that the ABS and NGES variables had the highest coefficients of variation; however, it was not enough to indicate a strong variation between the origins for these two variables (Rojas and Flores, 2017).

The test of means associated with physiological variables (Table 1) showed that the origins of Semillas La Ejidal, INIFAP-control, and Terra Semillas presented the highest percentage for NOS;

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likewise, acceptable values for ABS (≤ 10%) were observed. Abnormal seedlings are those that germinated but presented abnormalities in the development of their essential structures mainly due to deleterious genes (Musito et al., 2008).

Table 1. Mean squares, statistical significance, and comparison of means in nine physiological variables evaluated in five origins of the H-520 white-grained tropical corn hybrid.

Origin	NOS (%)	ABS (%)	NGES (%)	PANT (%)	PGE (%)	PLUW (g)	RADW (g)	PLUL (cm)	RADL (cm)
INIFAP-control	92.3ab	3.3b	4.5ab	44.3a	95.5ab	59.3a	37.3a	12.7a	18.3a
Terra Semillas	91ab	4b	5ab	64.8a	95ab	25.3c	20.7b	11.2a	13.2b
Iyadilpro	88.8bc	4.3b	7a	50a	93b	27.3c	15b	11.1a	14.5b
Maíces del Trópico	83.5c	10a	6.5a	47.5a	93.5b	26.3c	16.7b	10.7a	13.7b
Semillas La Ejidal	97.3a	1.5b	1.3b	45.3a	98.8a	43.7b	34a	11.9a	17.1ab
Overall mean	90.5	4.6	4.85	50.4	95.2	36.4	24.7	11.5	15.3
CMO	403.7**	164.3**	81.8**	1115.3ns	81.8**	663.6**	315.7**	1.8ns	15.1**
CV (%)	3.47	23.31	14.26	12.09	1.87	13.29	11.39	7.92	4.51

Means with equal letters are not statistically different (Tukey, 0.05); *= significant; **= highly significant; ns= not significant; CV (%)= coefficient of variation; NOS= normal seedlings; ABS= abnormal seedlings; NGES= non-germinated seeds; PANT= presence of anthocyanins; PGE= percentage of germination; PLUW= plumule weight; RADW= radicle weight; PLUL= plumule length; RADL= radicle length.

On the other hand, the Terra Semillas origin differed from the other origins by presenting a high percentage of ABS (≥64%). For the NGES variable, values ranging from 1.2 to 7% were observed. These values are low when compared to other studies where values from 12 to 78% have been reported (Durán-Hernández et al., 2011); in contrast, Ruiz-Torres et al. (2012) report values of less than 5% in two populations of improved native corn in Celaya, Guanajuato, Mexico. NGESs are those soaked seeds that did not germinate due to physical or physiological damage, which lead to a low population density on the field (Ramírez et al., 2020).

None of the origins presented germination equal to or less than 90% (Table 1). This suggests that the origins comply with the standard norm established by the SNICS, which is 85% (SNICS, 2024). Again, the origins of Semillas La Ejidal, INIFAP-control and Terra Semillas presented the highest PGE, with 98.75, 95.5, and 95%, respectively (Table 1). This is consistent as there was a low percentage of non-germinated seeds. George et al. (2003) report that the percentage of germination decreases when the harvest is carried out before physiological maturity.

Nonetheless, to improve quality, many companies have adopted pregermination treatments, which results in a significant increase in the physiological quality of the seeds. In this regard, García-Rodríguez et al. (2020) showed that sowing patterns and seed size can affect germination percentage. On the other hand, Olisa et al. (2022) report that the percentage of germination allowed ranges from 80 to 90% for open-pollinated varieties, indicating that the values recorded among the origins were satisfactory (Table 1).

As for PLUW, the values ranged from 25.33 to 59.33 g, with the INIFAP-control origin standing out, which showed the highest weights for this variable. In the same order of ideas, RADW had values from 15 to 37.33 g, again observing high values for the INIFAP-control origin. Regarding PLUL, values from 13.17 to 18.27 cm were obtained; however, the test of means detected no variation between origins.

This characteristic is decisive for the vigor of the seed since it will later be reflected in the consistency and firmness of the stem (Salinas et al., 2013). A long, well-developed plumule indicates that the plant has sufficient energy stored in the seed and that the metabolic and physiological processes function properly (Pérez et al., 2006).

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In relation to RADL, the origins of INIFAP-control and Semillas La Ejidal obtained longer roots. Long roots indicate that the plants will have a good anchorage to the soil, which represents an advantage in places where rainfall events are scarce, allowing the plant to better use the available water (Sierra et al., 2008; Magdaleno-Hernández et al., 2020). A strong and extensive root system allows the plant to obtain the necessary resources to sustain its growth, especially in the early stages of development when nutrient demand is high (Navarro et al., 2012).

Physical quality

It was observed that the origins presented statistically significant differences (p# 0.05) in all the variables assessed, SEEW, SEEL, SEETH, W1000SEE, FLOTI, and HECW. Likewise, for the environmental variation factor, ANOVA showed significant statistical differences (p# 0.05) for all variables, except for W1000SEE and SEEW, which indicates that the latter were not affected in the same way by the environment. The coefficients of variation obtained are low and acceptable, suggesting reliability in the experiments (Table 2).

Table 2. Combined ANOVA in six physical variables evaluated in five origins of the H-520 tropical corn hybrid.

Source of variation	Origin	Environment	Error	Total	CV (%)
DF	4	1	114	119	
Hectoliter weight	26.53*	838.87**	7.39		3.55
Seed thickness	0.37*	0.48*	0.08		7.02
Weight of one thousand seeds	6 521.67**	163.33 ns	360.85		7.96
Seed width	2.59**	0.01 ns	0.15		4.49
Seed length	7.65**	1.47*	0.37		5.32
Flotation index	323.88**	2 050.13**	74.64		31.67

(Tukey, 0.05) *= significance at 5%; **= significance at 1%; ns= not significant.

Results such as Pérez de la Cerda et al. (2007) mentions that genotype plays an important role in seed composition. The quality of corn seed is important to farmers and the seed industry. For the latter, the quality of the seed is important due to the great variation in the type of grain exhibited by the varieties and hybrids of corn.

To identify the behavior of the average of the variables in each of the origins, a Tukey mean comparison test was performed (Table 3). Among the origins, the grain with the highest HW corresponded to Terra Semillas and Maíces del Trópico with values of 77.75 and 77.49 kg hl^{-1}. In the FI, INIFAP-control, Maíces del Trópico, and Iyadilpro were the origins with the highest values, with 29.54, 29.21 and 29.13%.

Table 3. Physical characteristics of corn seed from five origins of the H-520 white-grained tropical hybrid.

Origin	HW (kg hl^{-1})	ST (cm)	W1000S (g)	SW (cm)	SL (cm)	FI (%)
INIFAP (c)	75.14 b	3.91 b	255 a	8.95 a	11.9 a	29.54 a (H)
Terra Semillas	77.75 a	4.06 ab	220.83 c	8.49 bc	10.67 c	20.83 b (H)
Iyadilpro	76.19 ab	4.13 ab	239.17 b	8.61 b	11.27 b	29.13 a (H)
Maíces del Trópico	77.49 a	4.21 a	223.33 c	8.21 c	11.34 b	29.21 a (H)
Semillas La Ejidal	76.64 ab	3.95 b	255 a	9 a	12.1 a	27.71 ab (H)
Average Environment	76.642	4.052	238.666	8.652	11.456	27.284

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Origin	HW (kg hl^{-1})	ST (cm)	W1000S (g)	SW (cm)	SL (cm)	FI (%)
Piedras Negras	74 b	4.11 a	239.83 a	8.64 a	11.57 a	31.42 a
Cotaxtla	79.29 a	3.99 b	237.5 a	8.66 a	11.35 b	23.15 b
Average	76.645	4.05	238.665	8.65	11.46	27.285

Means with equal letters are not statistically different (Tukey, 0.05). Values between 13 and 37% correspond to hard texture (H) and from 38 to 62% to intermediate texture (I). HW= hectoliter weight; ST= seed thickness; W1000S= weight of 100 seeds; SW= seed width; SL= seed length; FI= flotation index.

A quality indicator for corn intended for the production of nixtamalized products is the hardness of the grain, which is estimated indirectly with the values of HW and FI (Salinas et al., 2013), variables that are inversely correlated (Salinas et al., 1992). It is important to highlight that the level of varietal maintenance has been effective for these characteristics since in the varietal description for H-520, FI values of 30% and a density of 77 kg hl^{-1} were reported, characterizing it as a type of hard grain (Sierra et al., 2008).

For the W1000S, the INIFAP-control and La Ejidal Seeds origins presented high values for this variable with 255 g (Table 3), which suggests that they have better quality because they have a higher weight in 1000 seeds (Magdaleno-Hernández et al., 2020). W1000S is a variable that is closely related to the type, composition and hardness of the grain (Figueroa et al., 2013).

Some authors have reported values for the W1000S ranging from 272 to 427.9 g (Salinas et al., 2013; Virgen-Vargas et al., 2016; Guillen-de la Cruz et al., 2018; Ramírez et al., 2020). Mauricio et al. (2004) report that the W1000S is an indicator of grain size and density, an important characteristic for flour producers because these grains contain a higher proportion of endosperm than the small ones, so they have a higher yield.

On the other hand, the Semillas La Ejidal origin presented the highest value of SW and SL, with 9 and 12.1 mm, respectively (Table 3). These data are within the values reported by Gutiérrez-Coronado et al. (2009) for corn hybrids of improved protein quality, ranging from 6.9 to 8.73 mm for SW and from 7.95 to 11.32 mm for SL. For the ST variable, three statistical groups were observed, with Maíces del Trópico being the origin that had the seeds with the greatest thickness.

Some authors consider that characteristics such as length, width, and thickness of seeds act as components in seed weight and size, which indirectly contribute to seed yield, and that it is associated with the nixtamalization process (Carranza-González et al., 2022). On the other hand, endosperm hardness is related to water absorption capacity (Mauricio et al., 2004), a maximum water absorption capacity is related to higher mass yield (Vázquez et al., 2010).

Finally, grain size is a variable of interest in nixtamalization processing due to its impact on cooking processing and water absorption (Sánchez et al., 2007; Salinas et al., 2013). Regarding the evaluation environments, it can be observed that the environment of Piedras Negras showed the best values in the variables evaluated, except for HW, where it was slightly lower than the environment of Cotaxtla (Table 3).

Likewise, it was found that the environment did not influence the W1000S and SW variables, that is, their expression was not differentially affected by the change of genotypes across environments. These results are partly attributed to the fact that origins were represented by different sample sizes and partly to the fact that the process of primary seed production is different. This is important as it ensures greater uniformity in the seeds produced and makes it easier to predict the behavior of plants in different environments.

It is important to mention that genetic purity is an essential requirement for quality at its different levels, and this is achieved by keeping the variety in its area of adaptation to minimize the influence of environmental stress (Zeven, 2002). Seed multiplication under unfavorable conditions results in genetic drift that causes deviations in plant type, such as variation in maturity, low seed yield, susceptibility to pests and diseases, poor adaptation to specific environmental conditions, among others (Sundareswaran et al., 2022).

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Finally, it is necessary for breeders to select varieties with high physical and physiological quality; likewise, it should be followed by a good seed multiplication program and pay full attention to seed production strategies and procedures.

Conclusions

The results obtained suggest that the genetic purity control scheme during the seed production process used by breeders and seed-producing companies of the H-520 white-grained corn hybrid has been effective. The differences in physiological quality between seed origins can be attributed to the intrinsic processes that take place during the germination process, which is reflected in seedling vigor. The morphological traits of the seed and seedling caused by the origin helped us to deduce that the companies comply with the certification standards established by the SNICS.

It is necessary to complement seed quality tests by applying biochemical and molecular techniques in accordance with current international standards. Finally, to ensure the quality and purity of the hybrid seed, it is necessary to carry out periodic assessments of yield and seed quality. This process will ensure that the desirable characteristics of the hybrid are preserved over generations.

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