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Agronomic and physical traits of grain in transgenic and conventional corn for industrial use[1]

Características agronômicas e físicas de grãos de milhos transgênicos e convencionais para o uso industrial

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HIGHLIGHTS:

Corn hybrids should be considered to define the best results for grits and germ in the food industry.
1000-grain weight, grain yield, and rotten grains are influenced by hybrids and crop seasons.
The flotation and the vitreousness behave oppositely in the three crop seasons.

ABSTRACT: The agronomic and physical traits of corn are fundamental for producers and industries that use this cereal as a raw material since they interfere in the industrialization processes, yield, and quality of the final products. This study aimed to evaluate the agronomic and physical traits of the grain in transgenic and conventional corn hybrids grown in the first crop season (summer) in Paraná State. Three experiments were set up in 2017/18, 2018/19, and 2019/20 crop seasons. A randomized block design with three replications was used. Eight hybrids (Supremo Vip, Supremo, P30F53VYH, P30F53, P3456H, P3456, DKB290PRO3, DKB290) were evaluated. The physical traits of grains for industrial purposes, such as grits, germ, vitreousness, flotation, and hectoliter weight, and the agronomic traits (percentage of rot grains, 1000-grain weight, and grain yield) were evaluated. The hybrids and crop seasons influence the industrial physical traits of grits and germ. The hybrids Supremo (conventional), Supremo Vip (transgenic), and P3456 (conventional) had the best results. The hybrids and crop season influenced the flotation, hectoliter weight, and vitreousness, highlighting the hybrids Supremo (conventional), Supremo Vip (transgenic), P30F53 (conventional), P30F53 VYH (transgenic), P3456 (conventional), P3456 VYH (transgenic), with the best results. The conventional hybrids showed industrial superiority compared to transgenic hybrids for grits, flotation, and vitreousness.

Key words: *Zea mays*, grits, germ, flotation, vitreousness

RESUMO: As características agronômicas e físicas do milho são fundamentais para produtores e indústrias que utilizam este cereal como matéria-prima, pois, interferem nos processos de industrialização, rendimento e qualidade dos produtos finais. Desse modo, o objetivo com este estudo foi avaliar as características agronômicas e físicas do grão de híbridos de milho transgênicos e convencionais cultivados na primeira safra (verão) no Estado do Paraná. Foram instalados três experimentos, nas safras agrícolas 2017/18, 2018/19 e 2019/20. O delineamento experimental utilizado foi de blocos casualizados com oito híbridos: (Supremo Vip, Supremo, P30F53VYH, P30F53, P3456H, P3456, DKB290PRO3, DKB290) e três repetições. Foram avaliadas as características físicas dos grãos para fins industriais como a canjica, gérmen, vitreosidade, flutuação e peso hectolitro, e as características agronômicas como a porcentagem de grãos ardidos, peso de mil grãos e produtividade de grãos. A canjica e gérmen são influenciados pela escolha do híbrido e pela safra agrícola avaliada, em que os híbridos Supremo (convencional), Supremo Vip (transgênico) e P3456 (convencional) apresentaram os melhores resultados. As características físicas de flutuação, peso hectolitro e vitreosidade foram influenciadas pela escolha do híbrido e safra agrícola avaliada, destacando-se os híbridos Supremo (convencional), Supremo Vip (transgênico), P30F53 (convencional), P30F53 VYH (transgênico), P3456 (convencional), P3456 VYH (transgênico), com os melhores resultados. Os híbridos convencionais mostraram superioridade industrial comparados aos híbridos transgênicos para canjica, flutuação e vitreosidade.

Palavras-chave: *Zea mays*, canjica, gérmen, flutuação, vitreosidade

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Introduction

The corn production chain is one of the most important economic segments of Brazilian agribusiness and has great versatility for use in human nutrition, constituting an excellent food supplement, fresh or in the form of derivatives (ABIMILHO, 2013; Cordeiro et al., 2021).

Corn is a cereal of great industrial use, including for processing industries, generating by-products for human consumption, where the transformation of corn into derivatives occurs, allowing the use of this cereal as an excellent source of raw material for the food industries (Macias et al., 2022). Corn is classified, based on the consistency and shape of the grain, into four groups: flint, dent, semi-flint, and mixed, with hybrids with flint grain, the most used in industry (Arcari et al., 2016).

The hardness of the endosperm directly interferes with industrial yield and is essential for producers and industries that use this cereal as a raw material; it is evaluated with good precision through the analysis of vitreousness, which allows classifying corn hybrids in terms of the percentage of vitreous grain endosperm, however, as it is commonly evaluated only by the visual aspect, there are few studies published with results of real vitreousness, through manual separation of the vitreous and farinaceous parts in maize hybrids, and when they exist, few maize hybrids are evaluated Rossi et al. (2016 a, b).

Currently, the industry has been working with conventional hybrids, a requirement of customers looking for corn by-products associated with grain hardness and related to the region of the study site according to the demand for the development and the local food industry. However, research is needed to assess the relationship between vitreousness and industrial yield in transgenic and conventional corn hybrids because the greater the vitreousness of the grains, the greater the yield of grits, consequently, the greater the yield in the industry, and that also present satisfactory agronomic traits, so that the farmer can grow these hybrids, generating enough raw material for the food industry. The study aimed to evaluate the agronomic and physical traits of the grain for industrial purposes in dry processing in transgenic and conventional corn hybrids cultivated in the first crop season (summer) in Paraná State.

Material and Methods

The experiments were carried out in Guarapuava, Paraná State, Midwestern Brazil, at 25°38'32" S, 51°55'21" W, and an altitude of 940 m during 2017/18, 2018/19, and 2019/20 crop seasons. The topography of the region is considered flat, and the soil from the experiment site is classified as Oxisol. The climate of the region is Cfb type according to the Köppen classification. There was a high rainfall in the 2017/18 crop season (crop season 1), totaling 1404 mm, during the crop cycle compared to the 2018/19 season (crop season 2), which was 1041 mm, and for the 2019/20 season (crop season 3), totaling 769 mm. The average minimum temperature in crop season 1 was 14.1 °C, and the maximum of 25.8 °C. In crop season 2, the minimum average was 14.8 °C and the maximum 25.8 °C. In season 3, the minimum average was 14.2 °C, and the maximum average was 26.9 °C. Although these climatic conditions are sufficient for the satisfactory development of the corn in the field, these variations between the studied crop seasons can affect the performance of the hybrids in the field and the studied traits.

The randomized block design with three replicates was used. Eight corn hybrids, Supremo (conventional), Supremo Vip (transgenic), P30F53 (conventional), P30F53 VYH (transgenic), P3456 (conventional), P3456 VYH (transgenic), DKB 290 (conventional), DKB 290 PRO3 (transgenic) were evaluated (Table 1). The area of each experimental unit was 9 m^2 (1.8 x 5 m). In the three crop seasons, the sowing was performed on the first week of October, after black oat cultivation, with row spacing of 0.45 m and 3.8 seeds m^{-1}. The fertilization in the sowing furrow was an average of 400 kg ha^{-1} of fertilizer, NPK formulation of 12:31:17+Zn. For nitrogen fertilization, 160 kg ha^{-1} of N was applied at the V4 stage. The management regarding the chemical control of weeds, pests, and disease control occurred according to recommendations for corn in this region (Embrapa, 2012).

The physical traits of the grains were evaluated for industrial purposes considering the dry processing factor, such as grits, germ, flotation, hectoliter weight, and vitreousness. The agronomic traits, such as percentage of rot grains, 1000-grain weight, and grain yield, were also assessed. For the determination of grits and germ, a sample with a volume of 600 g of clean and dry grains (selected grains) was used, which went through a milling process using Grainman brand equipment for milling and classification of rice; however, adapted in the corn industry as an "experimental mill".

The process occurs as follows; the 600 g sample is inserted into the equipment, the scale or torque weight (of the equipment itself) is activated, then the motor is activated, which in turn works at standard rotation for a period of 40

Table 1. Traits of transgenic and conventional corn hybrids used in the experiments in 2017/18, 2018/19, and 2019/20 crop seasons

Hybrids	Brand	Produced protein	Type	Cycle	Texture	Color	Use
Supremo	Conv.		SH	E	Flint	Yellowish	G
Supremo Vip	Viptera®	VIP3Aa20	SH	E	Flint	Yellowish	G
P30F53	Conv.		SH	E	Semi-flint	Yellowish	G/WPS
P30F53 VYH	YieldGard® + Herculex® + Viptera®	Cry1Ab, Cry1F e VIP3Aa20	SH	E	Semi-flint	Yellowish	G/WPS
P3456	Conv.		SH	E	Semi-dent	Yellowish	G/WPS
P3456 H	Herculex®	Cry1F	SH	E	Semi-dent	Yellowish	G/WPS
DKB 290	Conv.		SH	E	Semi-dent	Reddish	G
DKB 290 PRO3	VT PRO 3TM	Cry 1A105 (1Ab, 1Ac, 1F) + Cry2Ab2 + Cry3Bb1	SH	E	Semi-dent	Reddish	G

Information provided by seed companies. Conv - Conventional, without the use of transgenic technology; SH - Single-cross hybrid; E - Early; G - Grain; WPS - Whole plant silage

s, the germ and grits are therefore separated; subsequently, weighing is carried out with the aid of a Dalle Molle scale, performing the calculation as a percentage of the proportion of each by-product.

To determine the flotation (hardness), five repetitions of 100 whole grains were used, removing the rot and broken grains. After submerging the grains in the sodium nitrate solution at 25%, the shaking was performed for 30/30 s, until completing 5 min, using a spoon, glass stick, or similar. Then, the floating grains (supernatants) were removed, counted, and discounted from 100. This is the value of each repetition (R1, R2...R5). The extreme values (smallest and highest) were removed, and the remaining three values were averaged. This value is the % of hard grains in the sample. With the sodium nitrate solution, the water density increases, and the grains that float will be considered lighter and softer and are not interesting for the industry since they will have lower performance.

The hectoliter weight was determined according to Rules for Seed Testing Brasil (2009), using a Dalle Molle brand scale, and the results were expressed in kg hL^{-1}.

Vitreousness is obtained through grain dissection and calculated by the proportion of vitreous endosperm concerning the total endosperm. To analyze the vitreous endosperm, the grains were collected at physiological maturity and dried. To reduce the effect of grain position on the ear, 100 grains were randomly selected from each experimental plot and divided into ten groups homogeneous in size and shape so that each group had 10 grains (Rossi et al., 2016 a, b).

The incidence of rot grains was determined according to the procedure proposed in normative instruction Ministério da Agricultura, Pecuária e Abastecimento (MAPA, 2011). The 1000-grain weight was determined by counting eight repetitions of 100 grains from each plot and then weighing (Brasil, 2009). The average was multiplied by 10 and expressed in grams.

All ears of the two central rows were harvested to estimate the yield. Grain yield was obtained by weighing the grains of each plot. The data obtained were transformed into kg ha^{-1}, considering the moisture of 13%.

All data of the evaluated traits were submitted to the test of homogeneity of variances by the Harley test (Ramalho et al., 2000). Subsequently, individual and joint analyzes of variance involving crop seasons were performed, and the means were grouped by the Scott-Knott test at $p \leq 0.05$. Conventional versus transgenic contrast was also performed using SISVAR® statistical software (Ferreira, 2019).

Results and Discussion

For the agronomic traits of 1000-grain weight, grain yield, and rot grains, significant effects were observed for the hybrid x crop season interaction. In the physical traits, the interaction of hybrids x crop season was significant for grits and germ. For the other traits, flotation, vitreousness, and hectoliter weight (HW), there was a significant effect ($p \leq 0.01$) for hybrids and crop seasons.

Regarding the average results obtained for the 1000-grain weight (1000W), in crop season 1, there was a statistical difference between the transgenic and conventional hybrids evaluated, with the hybrids DKB290 and DKB290 PRO3 presenting the best results compared to the other hybrids studied (Table 2). In crop season 2, there was a statistical difference between the hybrids, with the conventional hybrid DKB290 differing from the other hybrids. In crop season 3, there was also a statistical difference between the hybrids, in which the transgenic hybrid P3456 H, with the lowest value obtained, differed from the other hybrids. However, the results of Zucareli et al. (2013) do not corroborate the data obtained in this work, as there were no differences for 1000W, even when evaluating different corn hybrids in the off-season in the Northern region of Paraná State. This variable is influenced by the hybrid and crop season assessed, being necessary for the evaluation for the recommendation of hybrids. Comparing the 1000W values obtained in the different crop seasons, crop season 1 was superior in all hybrids (Table 2). This difference may be related to environmental factors; as in crop season 1, there was a higher rainfall compared to crop seasons 2 and 3. Moraes et al. (2015), evaluating ten hybrids, transgenic and conventional, observed statistical differences for the 100-grain weight; the transgenic hybrid Maximus Vip had the highest average, however, differing only from the conventional hybrid P30F53. The average 1000W values obtained in this study, ranging from 236 to 368 g (Table 2), were similar to those obtained in other studies (Šeremešić et al., 2019).

For the trait grain yield (Yield), considering the crop seasons, in crop season 1, there was a statistical difference between the hybrids studied; the transgenic hybrids P30F53VYH, P3456 H, and DKB290 PRO3 showed the best results, differing statistically from the other hybrids (Table 2). In crop season 2, there was a statistical difference; the hybrids Supremo Vip, P30F53, P3456, and DKB290 had the highest yields. In crop season 3, they did not differ statistically from each other. Chagas et al. (2018), evaluating conventional and

Table 2. Means of 1000-grain weight (1000W), yield, and rot grains (RG) of corn hybrids in three crop seasons

Hybrids	1000W (g)			Yield (kg ha^{-1})			RG (%)		
	C.S. 1	C.S. 2	C.S. 3	C.S. 1	C.S. 2	C.S. 3	C.S. 1	C.S. 2	C.S. 3
Supremo	321 bA	277 bB	286 aB	10231 cA	10564 bA	8643 aA	1.98 bB	0.61 aA	0.62 aA
Supremo Vip	301 cA	268 bB	282 aB	11401 bA	11754 aA	7995 aB	6.14 dB	0.44 aA	0.35 aA
P30F53	303 cA	257 cB	265 aB	12860 bA	11539 aA	7915 aB	3.64 cB	1.79 bA	1.32 aA
P30F53 VYH	325 bA	240 cC	268 aB	15964 aA	10509 bB	9618 aB	7.31 eB	2.18 bA	1.33 aA
P3456	326 bA	272 bB	272 aB	10030 cB	13120 aA	10335 aB	2.67 cB	0.49 aA	0.62 aA
P3456 H	306 cA	277 bB	236 bC	16179 aA	10747 bB	9654 aB	7.53 eC	2.25 bB	0.79 aA
DKB 290	361 aA	318 aB	295 aB	12003 bA	12055 aA	8355 aB	0.65 aA	0.94 aA	0.33 aA
DKB 290 PRO3	368 aA	267 bB	272 aB	15373 aA	9543 bB	8822 aB	7.65 eB	0.95 aA	0.36 aA
CV (%)	4.96	4.73	4.55	10.67	11.22	9.6	23.29	28.28	21.29

Means followed by the same lowercase letter in the columns and uppercase letter in the line belong to the same group by the Scott-Knott test at $p \leq 0.05$. C.S. 1 - Crop season 1 (2017/18), C. S. 2 - Crop season 2 (2018/19), and C. S. 3 - Crop season 3 (2019/20)

transgenic hybrids, tested the effect of nitrogen fertilization on the severity of foliar diseases and grain yield and found that the 2B710 and 3H842 hybrids stood out and had the highest grain yields. Batista et al. (2018), evaluating morphological traits and yield components of 18 corn hybrids grown during the off-season (second harvest) in Dois Vizinhos, Paraná, verified that the hybrids AS1635PRO3, AS1777PRO3, DKB290PRO3, 2B533PW, P30F53VYHR, AG8780PRO2, 2B500PW, 2B633PW, 2B450PW, AG9030PRO3, and 2B210PW, stand out with the highest yields. Thus, whether conventional or transgenic, the choice of genotype interferes with the grain yield to be achieved.

When the season crops for each hybrid of conventional and transgenic corn were analyzed, there was a significant difference between the seasons, except for the Supremo hybrid, which stood out to be more stable in the evaluated crop seasons. Seasons 1 and 2 were superior to season 3 for the Supremo Vip, P30F53, and DBK290 hybrids (Table 2). Crop season 1 was superior to seasons 2 and 3 in hybrid P30F53VYH, P3456H, and DKB290PRO3, yet, crop season 2 was superior compared to seasons 1 and 3 in the hybrid P3456; that is, the conditions of the crop seasons interfere, so that the hybrid can better express their productive potential. In a study by Anjos et al. (2022), they found that the hybrid AG 7088 had a higher CO2 assimilation rate, stomatal conductance, transpiration, water use efficiency, and leaf temperature reduction. These factors may have influenced this research, responding to the variation between hybrids and crop seasons.

Araújo et al. (2016) emphasize that, in the evaluation of the components of production and grain yield, the hybrids show different results, assuming that the genotype x environment interaction explains the variation in results; that is, the crop season plays a vital role in the definition of the yield potential of the selected corn hybrid, even more on single-cross hybrids like the ones used in this work.

There was a statistical difference between the evaluated hybrids for the evaluation of rot grains in crop season 1. The hybrid DKB290 was superior to the other hybrids, showing the lowest percentage of rot grains (Table 2). Mendes et al. (2012), studying corn hybrids with and without inoculation of ear rot fungi in two crop seasons and two cropping systems (conventional and no-tillage), found that the type of hybrid influenced the percentage of rot grains. This difference is due to the greater tolerance of these hybrids to the incidence of fungi that cause kernel rot.

In crop season 2, there was a statistical difference between the hybrids, with the hybrids Supremo, Supremo Vip, P3456, DKB290, and DBK290 PRO3 presenting the lowest percentage of rot grains. These data corroborate with Kluge et al. (2017). They evaluated the effect of fungicide application on grain rot in commercial corn hybrids and observed that fungicide application reduced the incidence of rot grains, and the greatest reduction occurred in susceptible hybrids. This trait is essential for the qualitative improvement of the grains produced, with lower levels of mycotoxins and reduced products generated in the industry.

There was a significant difference when comparing conventional and transgenic hybrids within each crop season. The crop seasons 2 and 3, compared to season 1, had the lowest percentage of rot grains for hybrids Supremo, Supremo Vip, P30F53, P30F53VYH, P3456, and DBK290PRO3. For Mendes et al. (2011), there was an influence of the hybrid, the crop season, and the growing system on the infection of fungi that cause ear rot, and the no-tillage system favors the increase of the fungi responsible for the rot grains in corn. In this way, the choice of hybrid and crop season evaluated influences this parameter.

For the physical traits of grits and germ, evaluating the hybrids used, in the three evaluated seasons, there was a statistical difference in crop season 1 and crop season 3. The Supremo and Supremo Vip hybrids showed the best results (Table 3), 69.8% and 72.3% for grits and 30.1% and 27.7% for germ, respectively, being superior to the others. This result is of interest to the industry; for a good industrial yield, it should be below 30% of degermination since this by-product is not interesting for the grits and flakes industry since higher grits yields mean greater volume product for the consumer.

The hybrids, Supremo and Supremo Vip, obtained the lowest germ values in crop season 1 and season 3; however, it is worth noting that the germ yield is inversely proportional to grits. These data corroborate with Paterniani et al. (2019) since there are few corn hybrids with this desirable trait; therefore, studying a selection of white corn hybrids intended for human consumption concluded that certain hybrids (HI29 and HI35), for having high productivity and being classified as flint grains, which pre-dispose to high yield of grits can be indicated as promising commercial hybrids for grits consumption. In crop season 2, the conventional hybrid P3456 statistically differed from its transgenic reciprocal. It did not differ from conventional hybrid Supremo, which showed

Table 3. Means of grits and germ of conventional and transgenic corn hybrids in three crop seasons

Hybrids	Grits (%)			Germ (%)		
	C. S. 1	C. S. 2	C. S. 3	C. S. 1	C. S. 2	C. S. 3
Supremo	69.88 aA	69.95 aA	72.29 aA	30.12 aA	30.05 aA	27.70 aA
Supremo Vip	72.34 aA	65.16 bB	72.34 aA	27.75 aA	34.84 bB	27.65 aA
P30F53	63.76 bA	65.32 bA	67.43 bA	36.23 bA	34.68 bA	32.57 bA
P30F53 VYH	64.44 bB	62.83 bB	68.04 bA	35.26 bB	37.16 bB	31.97 bA
P3456	62.33 bB	68.45 aA	66.51 bA	37.67 bA	31.54 aB	33.48 bB
P3456 H	66.06 bA	65.47 bA	66.80 bA	33.93 bA	34.52 bA	34.20 bA
DKB 290	62.16 bA	65.85 bA	64.32 bA	37.83 bA	34.14 bA	35.67 bA
DKB 290 PRO3	64.15 bA	66.38 bA	65.67 bA	35.84 bA	33.62 bA	34.32 bA
CV (%)	7.05	3.00	4.03	3.73	5.96	3.98

Means followed by the same lowercase letter in the columns and uppercase letter in the line belong to the same cluster by the Scott-Knott clustering algorithm at $p \leq 0.05$. C.S. 1 - Crop season 1 (2017/18), C. S. 2 - Crop season 2 (2018/19), and C. S. 3 - Crop season 3 (2019/20)

the best results for grits and germ, demonstrating the effect of the evaluated season (Table 3). Rovaris et al. (2017), studying promising white corn populations and hybrids, managed to estimate parental genetic parameters for agronomic traits and grain processing targeting the industry. Also, it was possible to observe that the P3 x P6 hybrid stood out for the best grits production performance, corroborating the need to evaluate these characteristics in commercial corn hybrids. Castro et al. (2009), evaluating different corn genotypes, observed significant differences in the yield of the endosperm and germ with pericarp; among the hybrids being assessed, the Alpha 090, 30F80, and AG7000 showed the lowest yield of the germ fraction with pericarp, consequently, a higher yield of the endosperm (grits), compared to other varieties studied. In this sense, evaluating these traits in hybrids for the industry is necessary.

When analyzing the performance of hybrids evaluated in different crop seasons, for grits and germ, the hybrid P30F53VYH obtained better results in crop season 3, whereas the conventional hybrid P3456 was statistically superior in seasons 2 and 3. Therefore, the performance variation from some hybrids in industrial yield to these industrial traits is dependent on the crop season; that is, it depends on meteorological, rainfall, and temperature variations.

Regarding the results of flotation and HW, there was a statistical difference between the conventional and transgenic hybrids, as follows: Supremo, Supremo Vip, P30F53, P30F53 VYH, P3456, P3456 H, which showed the best results for flotation and HW, proving to be higher than the others for this industrial trait (Table 4). Musulini et al. (2014), evaluating different hybrids according to the floating grain test, obtained a difference between them, which were classified as semi-dent and flint. It was possible to get similar values for the floating grains, independent of classification. The hybrid Somma, which has a more vitreous appearance, obtained the highest volumetric mass or hectoliter weight.

Table 4. Means of flotation, vitreousness, and hectoliter weight (HW) of corn hybrids in three crop seasons

Hybrids	Flotation (%)	Hw (kg hL^{-1})	Vitreousness (%)
Supremo	96.96 a	72.26 a	86.60 a
Supremo Vip	96.29 a	73.51 a	89.43 a
P30F53	94.11 a	74.93 a	88.43 a
P30F53 VYH	91.48 a	74.57 a	84.77 b
P3456	92.81 a	73.88 a	86.73 a
P3456 H	95.51 a	72.86 a	87.43 a
DKB 290	76.00 b	70.24 b	83.81 b
DKB 290 PRO3	76.37 b	70.22 b	85.73 b
CV (%)	5.91	3.46	2.72
Crop season 1	88.62 b	67.08 c	88.89 a
Crop season 2	87.70 b	80.93 a	86.27 b
Crop season 3	93.49 a	70.42 b	84.68 c

Means followed by the same letter belong to the same group by the Scott-Knott test at $p \leq 0.05$. Crop season 1 - 2017/18, Crop season 2 - 2018/19, and Crop season 3 - 2019/20

For the vitreousness, the hybrids Supremo (86.60%), Supremo Vip (89.43%), P30F53 (88.43%), P3456 (86.73%), and P3456H (87.43%) presented the higher values (Table 4). Commercial corn germplasm from vitreous endosperm occurs in greater amounts in flint grain genotypes and less in dent grain genotypes (Piovesan et al., 2011). In another study, during the summer season in the state of Paraná and in the site under study, where 12 commercial hybrids adapted to the region were evaluated, the vitreous percentage obtained ranged from 58,5 to 75,2% (Rossi et al., 2016 a, b), results lower than those found in this study.

The physical parameters of flotation, HW, and vitreousness behaved differently for each crop season. It is worth noting that the flotation was the opposite of vitreousness and that season 2 was better for HW. Kljak et al. (2020) evaluated eighty commercial hybrids that also showed variability in physical traits. The HW ranged from 70.19 to 82.05 kg hL^{-1}. The flotation index varied from 8 to 100% across tested hybrids. Density was the trait with the lowest variability among the hybrids tested. The HW and flotation index were used as simple grain hardness estimators. These simple methods could be used to discriminate commercial high-yielding hybrids based on hardness, as this trait is related to dry-milling performance in the food industry. These values of HW were somewhat similar to values of 72 US maize hybrids (on average 76±2 kg hL^{-1}) from multiple locations (Harlesson et al., 2019).

Based on the conventional versus transgenic contrast, for physical traits, conventional hybrids were superior to transgenic ones for grits, flotation, vitreousness, and HW (Table 5); that is, conventional hybrids presented the best indexes for the evaluated industrial parameters. For the germ trait, transgenic hybrids showed the highest germ indexes.

For agronomic traits, the contrast between conventional versus transgenic hybrids was significant for 1000W (Table 5), where transgenic hybrids had the highest 1000W indexes, not differing from conventional ones for RG and Yield. Mendes et al. (2012), evaluating different hybrids, found that the significance of the contrast between hybrids considered resistant vs. hybrids considered susceptible for grain yield shows the existence of genotypes with greater resistance to the fungi *F. verticilioides*, *S. maydis*, and *S. macrospora*. Araújo et al. (2011), evaluating the population fluctuation of *S. frugiperda*, *D. saccharalis*, and the natural enemy *D. luteipes* in conventional and Bt corn hybrids and the grain yield in conventional corn hybrids, verified the result of contrast where the transgenic corn hybrid P 3041YG, showed higher grain mass per ear and grain yield compared to the conventional hybrid P 3041, that is, there is a possibility of a difference between hybrids in its conventional and transgenic versions for this trait.

Table 5. Probability (p) values of the conventional versus transgenic contrast between the means of grits, germ, flotation, vitreousness (Vitre), hectoliter weight (Hw), rot grains (RG), 1000-grain weight (1000W), and grain yield (Yield)

Contrasts	Physical traits										Agronomic traits					
	Grit		Germ		Flotation		Vitre		Hw		RG		1000W		Yield	
Conventional vs. transgenic	+	0.01	-	0.01	+	0.01	+	0.02	+	0.01	+	0.54	-	0.01	-	0.18

Conclusions

1. The best results of grits and germ were verified in the hybrids Supremo (conventional), Supremo Vip (transgenic), and P3456 (conventional) presenting.

2. There is interaction between the hybrids and the crop season studied for the agronomic traits of 1000-grain weight, grain yield, and rot grains.

3. The industrial superiority of conventional hybrids compared to transgenic hybrids for grits, flotation, and vitreousness was verified.

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