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Correlation and contrasts between agronomic and physical traits of grain in transgenic and conventional corn hybrids for the food industry

Correlação e contrastes entre características agronômicas e físicas dos grãos em híbridos de milho transgênicos e convencionais para a indústria alimentícia

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Highlights

Linking agronomic and physical corn traits is important for food industry needs.
Favorable water conditions during crop season enhance corn grain traits.
There was a positive correlation between grits and flotation in crop season 1.
Grits correlated positively with HW, and negatively with rot grains.
The choice of transgenic or conventional hybrids influenced vitreosity.

Abstract

The food industry is very interested in high-yield ingredients to enrich and develop new products that have an affordable value for the population. This work aimed to determine the correlations and contrasts between grain physical and agronomic traits of conventional and transgenic corn hybrids cultivated in the first crop season. The experiments were installed in the 2017/18, 2018/19, and 2019/20 crop seasons in Guarapuava - PR. The experimental design was a randomized block design with eight hybrids (SUPREMO VIP, SUPREMO, P30F53VYH, P30F53, P3456H, P3456, DKB290PRO3, and DKB290) and three replications. The agronomic traits, such as the percentage of rot grains, 1000-grain mass, and grain yield, also the physical traits of grains for industrial purposes, such as grits, germ, vitreousness, flotation, and

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hectoliter weight, were evaluated. There is a positive correlation between grits and flotation. The choice of hybrids for the food industry based on vitreousness positively favors flotation. The grits showed a positive correlation with hectoliter weight and a negative correlation with the incidence of rot grains. Vitreousness was influenced by the choice of conventional or transgenic hybrid and crop season. The environments of the crop seasons influence the grain yield, 1000-grain mass, and rot grain incidence of conventional and transgenic corn hybrids.
Key words: Flotation. Grits. Germ. Vitreousness. *Zea mays.*

Resumo

A indústria de alimentos tem grande interesse por ingredientes de elevado rendimento industrial para enriquecer e desenvolver novos produtos, e que tenha um valor acessível para a população. Os objetivos desse trabalho foram determinar as correlações e contrastes entre caracteres físicos de grãos e agronômicos de híbridos de milho convencionais e transgênicos cultivados na primeira safra. Os experimentos foram instalados nas safras agrícolas (2017/18, 2018/19 e 2019/20), no município de Guarapuava – PR. O delineamento experimental utilizado foi o de blocos casualizados com 8 híbridos: (SUPREMO VIP, SUPREMO, P30F53VYH, P30F53, P3456H, P3456, DKB290PRO3, DKB290) e três repetições. Foram avaliadas as características agronômicas como a porcentagem de grãos ardidos, peso de mil grãos e produtividade de grãos e também as características físicas dos grãos para fins industriais, como a canjica, gérmen, vitreosidade, flutuação e peso hectolítrico. Há correlação positiva entre a canjica e a flutuação. A escolha de híbridos para a indústria alimentícia com base na vitreosidade favorece positivamente a característica de flutuação. A canjica apresentou correlação positiva com peso hectolitro e negativa com incidência de grãos ardidos. A vitreosidade foi influenciada pela escolha do híbrido convencional ou transgênico e pela safra agrícola. Os ambientes das safras agrícolas influenciam as características produtividade de grãos, peso de mil grãos e incidência de grãos ardidos dos híbridos de milho convencional e transgênico.
Palavras-chave: Canjica. Flutuação. Gérmen. Vitreosidade. *Zea mays.*

Introduction

Corn is one of the most important crops for the Brazilian economy, being the second with the largest grain production in the national territory and a large share in exports and raw materials for the industry with various by-products, also aiming to serve human and animal feed. For corn to be used as a raw material in the extruded products industry, it is necessary to reduce grains by grinding (Mikalouski et al., 2014).

The most used process for the manufacture of by-products in the industry is the “dry milling” type, where the endosperm is separated from the germ and pericarp by mechanical friction in specific equipment. The grains produced in the field must undergo drying until the moisture content is close to 13%, which, due to customer requirements, must be done indirectly, avoiding the odor of smoke in the product. Still, in this sense, there is research concerning corn grains coming from conventional hybrids, which are a requirement of customers looking for corn by-products for the brewing industry. The transformation of corn grains into derivatives makes it possible to use this cereal as an excellent raw material source for the food industry. The grains have 83% by weight of endosperm (rich in starch), 11% of germ (rich in fat), and 6% of the pericarp (rich in fiber). Corn is classified, based on the consistency and shape of the grain, into four groups: hard, dent, semi-hard, and mixed. The hard type grains, characterized by the predominance of the crystalline (vitreous) part, are the most used in the industry (Arcari et al., 2016).

Also, for the food industry, conventional hybrids are prioritized for processing to comply with legislation and consumer preferences, who look for corn by-products associated with the hardness of the grains. However, due to the greater volume of transgenic hybrids in Brazil, it is necessary to carry out research that can evaluate the relationship between vitreousness and industrial yield in hybrids of transgenic and conventional corn that present agronomic and physical traits of the grains for the food industry, aiming to meet possible changes in prerequisites of the consumer market.

An alternative for further studies would be through the correlation between the traits of the components, aiming to understand the correlation between traits because it allows us to know the influence that the selection of one trait will have on another apparently independent trait or set and allows to understand better the correlation between the primary and secondary components of production (Souza et al., 2009). In this sense, a better understanding of the correlation between the physical industrial and agronomic components (percentage of rot grains, 1000-grain mass, and grain yield) of corn hybrids with industrial suitability can be used as selection strategies for new corn genotypes for the industry.

The edaphoclimatic conditions of crop seasons, i.e., the growing environment, can influence these physical parameters of grains (grits, germ, vitreousness, flotation, and hectoliter weight) and the agronomic traits of hybrids. Thus, the selection of corn hybrids can seek to meet the particularities of agricultural environments and farmers to obtain hybrids that are better adapted, productive, and with a profile for the industry. The correlations of their evaluated parameters may allow the food industry to select better-quality raw materials to be purchased. Research has already shown that in the development of corn hybrids, they should capitalize on the genotype x environment interaction, especially for the various edaphoclimatic and social conditions of production systems (Miranda et al., 2009; Souza et al., 2009).

However, we believe it is important to search for new alternatives to further increase the performance of this crop at an industrial level, whether aiming to improve the use of grain produced in the altitude region and in the first crop season or even through the use of transgenic hybrids, seen that currently, the market from the food industry has a preference for conventional hybrids towards customers; however, this may turn out to be a future change in consumer market prerequisites.

Thus, the study aimed to determine the correlations and contrasts between physical and agronomic traits of conventional and transgenic corn hybrids in the first crop season, aiming at the best use of these grains for the corn industry.

Materials and Methods

The experiments were installed in 2017/18, 2018/19, and 2019/20 crop seasons, in Guarapuava, Paraná State, Southern Brazil, at 25°8'32" S, 51°55'21" W, and an altitude of 940 m. 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 (Brazilian Society of Soil Science [BSSC], 2018).

The experimental design was a randomized block design with eight hybrids, four conventional (SUPREMO, P30F53, P3456, DKB290) and four transgenic (SUPREMO VIP, P30F53VYH, P3456H, DKB290PRO3), and three replications (Table 1).

Table 1
Information on the events available in transgenic and conventional corn hybrids used to implement the experiments in 2017/18, 2018/19, and 2019/20 crop seasons, Guarapuava, PR. 2021

Hybrids	Brand*	Protein produced	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.

The installation of the experiments took place in the no-tillage system (NTS), in an area where black oat (*Avena strigosa*) was grown in winter as a cover crop. Sowing was performed on the first week in October of each season, with 3.8 seeds per meter. A row spacing of 0.45 m, usually used in the region, was used. Each plot was composed of four rows 5 m long with an area of 9 m². The two central rows of each plot were used for the evaluations. In all experimental units, the fertilization in the sowing furrow was 400 kg ha^{-1} of fertilizer with the NPK formulation: 12-31-17+Zn. For the topdressing fertilization, 160 kg ha^{-1} of N was used in one application 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.

The physical traits of the grains were evaluated for industrial purposes in dry processing factors, such as grits, germ, flotation, hectoliter weight, and vitreousness. The agronomic traits of the percentage of rot grains, 1000-grain mass, and grain yield were also evaluated.

For the determination of grits and germ, a sample with a volume of 600 grams was used for this analysis of clean and dry grains (selected grains), which go through a milling process using a GRAINMAN brand equipment used for milling and classification of rice, however, adopted in the corn industry as an "experimental mill".

The process occurs as follows; the 600-gram work 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 40 seconds, 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 replicates of 100 whole grains were used, removing the rot and broken grains. After submerging the grains in the sodium nitrate solution, 25% g/cm³, the shaking was performed for 30/30 seconds, until completing 5 minutes, 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 replicate (R1, R2...R5). The extreme values (smallest and highest values) were removed, and the average of the remaining three values was estimated. This value is the % of hard grains in the sample (HARDNESS). With the sodium nitrate solution, the water density increases, and the grains that float will be considered lighter and softer and not interesting for the industry, as they will have lower performance.

The hectoliter weight was determined according to Rules for Seed Testing Ministério da Agricultura, Pecuária e Abastecimento [MAPA, 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. The grains were collected at physiological maturity and dried to analyze the vitreous endosperm. 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). The vitreousness analysis was performed manually, according to the methodology described by Dombrink-Kurtzman and Bietz (1993). For this analysis, dried grains harvested after physiological maturation were used. The grains were dissected with a scalpel to remove the pericarp (tubular, cross, and epidermal cells), germ, and pedicel (seed tip), leaving the total endosperm, which was weighed and then divided with the aid of a scalpel into a farinaceous and vitreous portion. Vitreousness was expressed as the ratio between the vitreous endosperm portion and the total endosperm, with the result expressed as a percentage.

The incidence of rot grains was determined according to the procedure proposed in normative instruction No. 60

of December 22, 2011 (MAPA, 2011). The 1000-grain mass was determined by counting eight replications of 100 grains from each plot and weighing them (MAPA, 2009). The average was multiplied by ten and expressed in grams.

The two central rows were used to estimate the yield by harvesting all the ears. The grain yield was determined by weighing the sample of grains from each plot and then adjusting for moisture to 13%, with the resulting data being expressed in units of kg ha^{-1}.

All data were submitted to the test of normality and homogeneity of variance using the Shapiro-Wilk and Bartlett tests, respectively. Subsequently, individual analyses of variance were performed for each crop season. Physical and agronomic traits were submitted to Pearson correlation analysis using the GENES program (Cruz, 2016). Subsequently, contrast tests were performed between the means, with seven orthogonal contrasts (H1 x H2; H3 x H4; H5 x H6; H7 x H8; S1 x S2; S1 x S3; S2 x S3) to compare the conventional hybrids and their transgenic versions, as well as the evaluated crop seasons, and for these, the SISVAR® statistical program was used (Ferreira, 2014).

Results and Discussion

The rainfall data during the crop seasons were obtained from the meteorological station of FAPA, and the values are shown in Figure 1A, 1B and 1C. The higher rainfall occurred in the 2017/18 crop season (crop season 1), totaling 1404 mm during the crop cycle, compared to the 2018/19 crop season (crop season 2), which showed 1041 mm, and the 2019/20 crop season (crop season 3), with 769 mm. The average minimum temperature in crop season 1 was 14.1 °C and the average maximum temperature was 25.8 °C; in crop season 2, the average minimum temperature was 14.8 °C and the average maximum temperature was 25.8 °C; in crop season 3, the average minimum temperature was 14.2 ºC, and the average maximum temperature was 26.9 ºC. These weather variations between seasons can affect crop performance.

Next, data from the correlation estimates obtained for the physical traits evaluated will be addressed: grits in grams (GRITS-g), germ in grams (GERM-g), flotation (FLOT), vitreousness (VITRE), and hectoliter weight (HW), and agronomic traits: rot grains (RG), 1000-grain mass (M1000), and grain yield (GY), with the obtained average values: 384; 193; 89; 86; 72; 2,2; 290 e 11050, respectively.

It is worth highlighting the correlation between the traits of the yield components, which makes it possible to know the potential of different hybrids in each crop season. The environment highly influences the correlation between grain yield and secondary yield traits in corn populations (Souza et al., 2009).

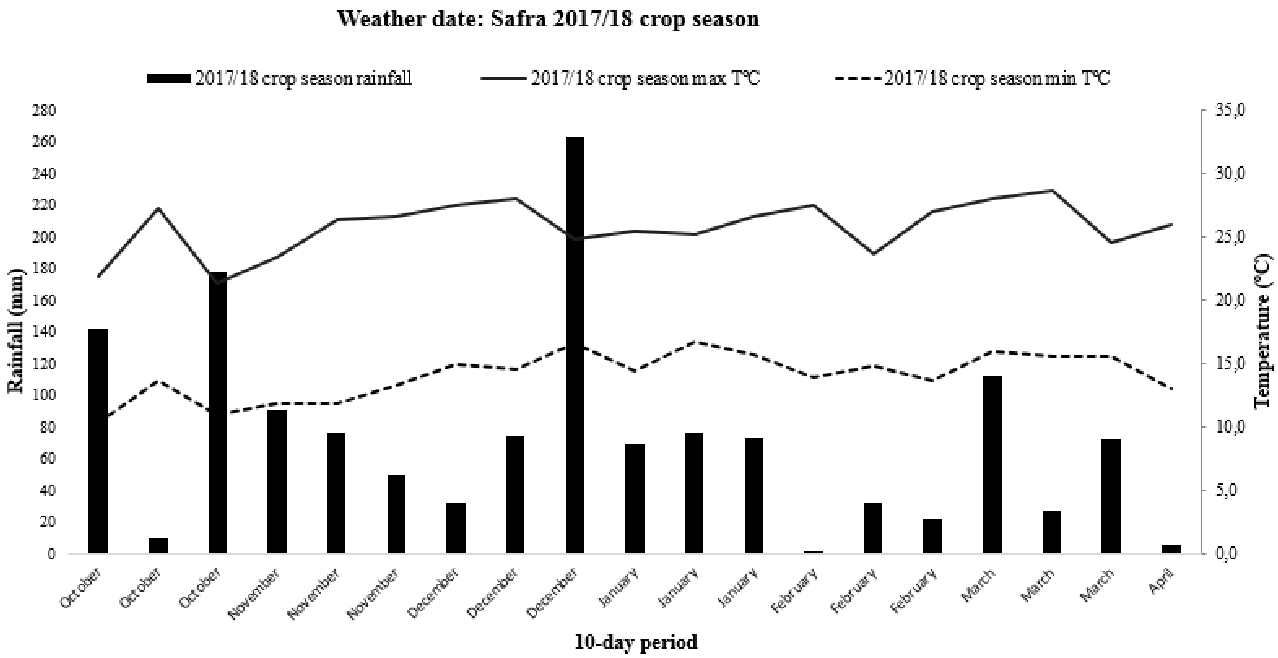

Figure 1A. Rainfall data (mm) and minimum and maximum temperatures per 10-day period, in the district of Entre Rios, Guarapuava - PR, from October to April in the 2017/2018 crop season (FAPA meteorological station – Agrária Foundation for Agricultural Research).

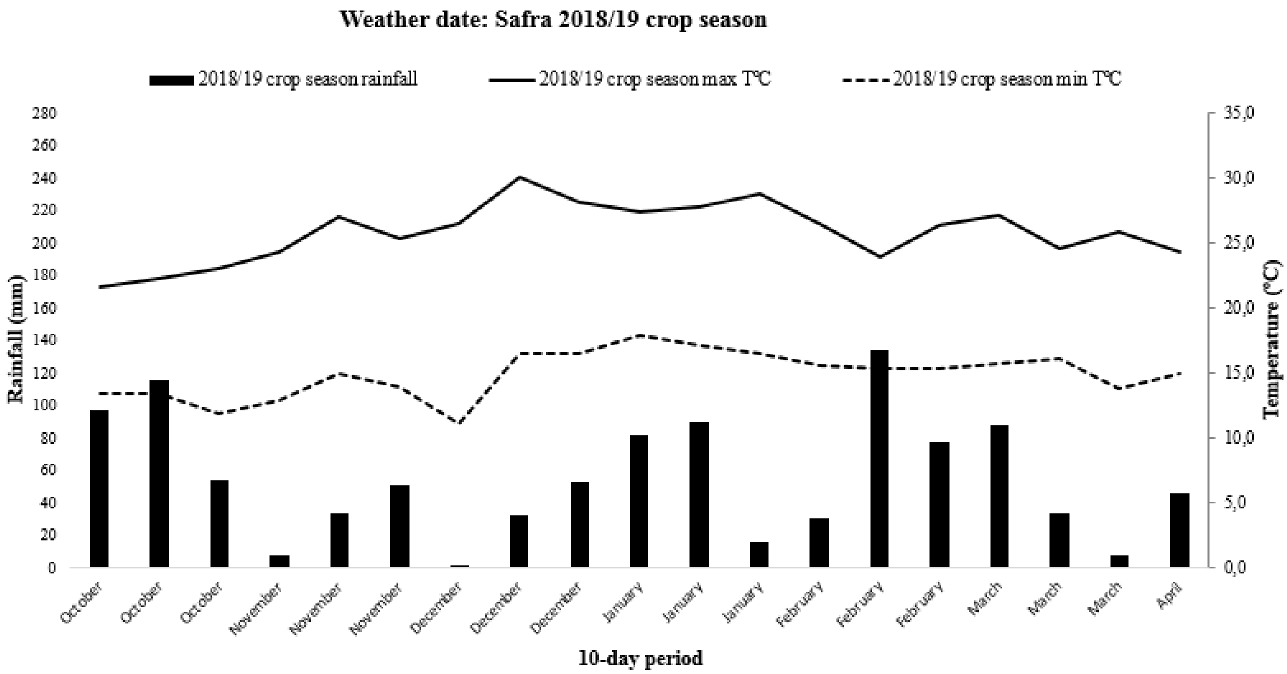

Figure 1B. Rainfall data (mm) and minimum and maximum temperatures per 10-day period, in the district of Entre Rios, Guarapuava - PR, from October to April in the 2018/19 crop season (FAPA meteorological station – Agrária Foundation for Agricultural Research).

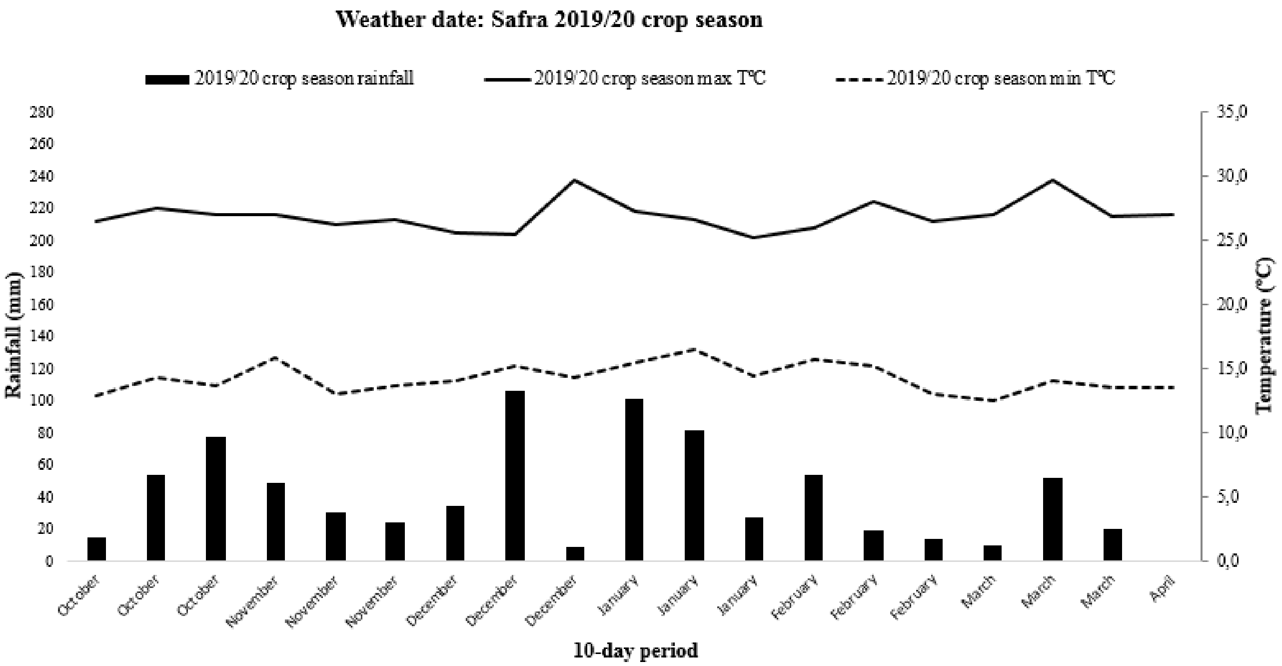

Figure 1C. Rainfall data (mm) and minimum and maximum temperatures per 10-day period, in the district of Entre Rios, Guarapuava - PR, from October to April in the 2019/20 crop season (FAPA meteorological station – Agrária Foundation for Agricultural Research).

Based on the correlations of physical traits, FLOT was positively correlated with GRITS 0.554 (P<0.01) in crop season 1, demonstrating that selection based on FLOT can play an important role in improving GRITS, dependent on crop season. FLOT had a negative correlation of 0.566 (P<0.01) and 0.686 (P<0.01) with GERM in seasons 1 and 3, respectively, which means that the higher the FLOT, the lower the GERM, which is desirable in the food industry, the germ being a secondary product (Table 2).

Hardness describes the resistance of grains to external deformations and mechanical breakage during harvesting and storage. The endosperm represents approximately 83% of the dry weight of the grain and consists mainly of starch granules, on average 88%, being classified into two types: farinaceous and vitreous, and concentration of reserve proteins, 8% zeins. In the vitreous endosperm of corn grain, there is a higher zein concentration than the farinaceous endosperm (Anderson & Lamsal, 2011).

Table 2

Estimate of the Pearson correlation between physical traits of grain and agronomic traits from eight corn hybrids, transgenic and conventional (reciprocal), evaluated in crop season 1 (2017/18 season), crop season 2 (2018/19 season), and crop season 3 (2019/20 season), in Guarapuava. UNICENTRO, 2021

CROP SEASON 1							
	Physical traits of grains				Agronomic traits		
Traits	GERM	FLOT	VITRE	HW	RG	M1000	GY
GRITS	-0,994**	0,554**	0,266	0,456*	0,215	-0,383	-0,166
GERM		-0,566**	-0,286	-0,454*	-0,204	0,410*	0,201
FLOT			0,433*	0,868**	0,067	-0,809**	-0,209
VITRE				0,460*	0,201	-0,447*	0,061
HW					0,326	-0,75**	-0,008
RG						-0,748**	0,759**
M1000							0,161
CROP SEASON 2							
GRITS	-0,999**	0,176	-0,054	-0,179	-0,454*	0,147	0,365
GERM		-0,170	0,060	0,182	0,453*	-0,162	-0,359
FLOT			-0,049	0,431*	0,019	-0,301	0,117
VITRE				-0,148	-0,283	-0,046	-0,152
HW					0,141	-0,287	0,073
RG						-0,139	-0,149
M1000							0,228
CROP SEASON 3							
GRITS	-0,455*	0,312	-0,203	0,541**	0,276	0,380	-0,369
GERM		-0,686**	-0,396	0,304	0,105	-0,139	0,082
FLOT			0,486*	0,092	0,167	-0,371	0,228
VITRE				-0,262	-0,037	-0,238	0,150
HW					0,428*	0,060	-0,090
RG						-0,280	-0,015
M1000							-0,320

GRITS - grits in grams (g), GERM - germ in grams (g), FLOT - flotation, VITRE – vitreousness, HW - hectoliter weight, RG - rot grains, M1000 – 1000-grain mass, and GY – grain yield. * and **: significant, at 5% and 1% probability by the t-test.

FLOT showed a positive correlation of 0.486 ($P<0.05$) and 0.433 ($P<0.05$) with VITRE in seasons 1 and 3, respectively (Table 2). These data are paramount in this work, as they demonstrate that FLOT has an important role in improving VITRE and vice versa. Although the correlation indexes are of medium magnitude, they demonstrate that hybrids with a higher flotation index present greater results from the vitreousness analysis and, consequently, higher yields of grits in the industry. (Martínez et al, 2006) showed positive correlations between grain hardness and density. Density can be used as an indirect measure to estimate vitreousness (Pereira et al, 2004), but grain dissection to determine the percentage of vitreous endosperm concerning the total endosperm is the best tool to determine vitreousness and characterize the grain texture. According to (Arcari et al, 2016), the forage of corn hybrids with medium vitreous endosperm tends to be more digestible than hybrids with high content of vitreous endosperm.

In this context, we can infer that the definition of vitreousness, which expresses the proportion of the vitreous region of the grain, is characterized by having a dense protein matrix surrounding the starch granules and therefore increasing the grain weight, positively influences the flotation analysis. The hardness of the endosperm directly interferes with industrial yield and is essential for industries that use this cereal as a raw material and is evaluated with good precision through the analysis of vitreousness, which allows classifying corn hybrids in terms of the percentage of endosperm vitreous grains (Piovesan et al., 2011). VITRE showed a positive correlation with HW (0.460) ($P<0.01$) in crop season 1.

However, there are few published studies with results of real vitreousness through manual separation of the vitreous and farinaceous parts in corn hybrids, and when they exist, few corn hybrids are evaluated (Rossi et al., 2016).

According to (Mikalouski et al., 2014), aiming to evaluate the effect of the particle size of different corn products on the expansion, texture, and sensory analysis of extruded snacks, in general, it was possible to observe that the raw materials used presented different particle sizes, but the starch content present in each sample was similar since all samples are derived from clean and ground corn.

FLOT showed a positive correlation of 0.868 ($P<0.01$) and 0.431 ($P<0.05$) with HW in crop seasons 1 and 2, respectively, demonstrating that HW plays an important role in improving FLOT (Table 2). (Duarte et al., 2008) evaluating different hybrids verified that the volumetric weight and floating grains correlated with index (-0.64) in the joint analysis; that is, the hybrids with a lower proportion of floating grains (floating) were among those with higher volumetric weight (HW) values.

GRITS showed a positive correlation of 0.456 ($P<0.05$) and 0.541 ($P<0.01$) with HW in seasons 1 and 3, respectively, showing that hybrids with higher HW will consequently have a higher industrial yield of grits (Table 2). As for GY, there was no correlation with GRITS (Table 2). In the study by (Rovaris et al,, 2017), whose objective was to identify promising white corn populations and hybrids for agronomic traits and grain processing and to estimate parental genetic parameters, as well as heteroses and their components, found hybrids of F2 generations of white corn targeting the grits market that showed no difference in performance between the crosses for grits yield; however, they verified a difference between the crosses for grain yield, in Mococa, SP in Brazil. Although any type of corn can be used in grit production, some genotypes show a greater conversion of grains into grits.

Based on the correlations of agronomic traits, RG showed a negative correlation of 0.454 (P<0.05) with GRITS in crop season 2, demonstrating that hybrids with a lower RG index have a higher yield of grits in the industry. It, in turn, had a positive correlation of 0.453 (P<0.05) with GERM (Table 2), demonstrating that hybrids with higher RG index have higher germ yield in the industry.

In crop season 3, the RG trait showed a positive correlation of 0.428 (P<0.05) with HW; although the correlation is weak, it demonstrates that hybrids with higher HW may present a higher index of rot grains (Table 2). In a study by (Mendes et al., 2012) concerning the percentage of rot grains, this trait was influenced by hybrids and crop seasons, being more verified in a no-tillage system.

The RG showed a negative correlation of 0.748 (P<0.01) with M1000 and a positive correlation of 0.759 (P<0.01) with GY in crop season 1; this performance demonstrates that hybrids with higher grain yields can also present a higher index of rot grains, especially in crops with higher rainfall. These data corroborate with (Rizzardi et al., 2017), evaluating the behavior of commercial corn hybrids, with and without artificial inoculation of the fungus *Stenocarpella maydis,* the causal agent of white ear rot, found a higher incidence of fungi that cause the rot grain complex in the season in which rainfall was high, and the greater availability of water in the field contributed to the greater development of the fungus. Regarding the percentage of rot grains, according to (Mendes et al., 2012), this trait is influenced by choice of hybrids and crop seasons, and the percentage of RG is associated with losses of a quantitative nature.

The M1000 showed a positive correlation of 0.410 (P<0.05) with the GERM in crop season 1, demonstrating that as there is an increase in M1000 (Table 2), there will be an increase in germ production, which was not expected in this research. The germ is removed for subsequent extraction of different by-products, leaving the endosperm. The endosperm consists of a translucent region called the vitreous and an opaque region characterized as the farinaceous. The proportion between regions depends on the hybrid and determines the grain texture (Ribas et al., 2007).

M1000 showed a high magnitude and negative correlation of 0.809 (P<0.01) in crop season 1 with FLOT, which means that the higher the M1000, the lower the FLOT. The M1000 showed a negative correlation (0.447) (P<0.05) with VITRE and also presented a negative correlation with HW 0.748 (P<0.01) in crop season 1, which means that the higher the M1000, the lower the HW (Table 2). These data do not corroborate with Duarte et al. (2008), who evaluated different hybrids in a joint analysis of two locations and found a positive correlation of 0.15 (P<0.05), between volumetric weight and 100-grain mass, despite being a low magnitude correlation.

To determine genetic correlations and define strategies for obtaining corn cultivars for the traditional production system, Souza et al. (2008) stated that the increase in grain yield could be achieved with direct or indirect selection for all environments. The estimate of the interaction variance, genotypes x environments, for grain yield corresponds to 72.2 and 70.9% of the estimated genetic variance in the western and southeast regions of Minas Gerais, respectively (Souza et al., 2009).

It was found that in the three crops evaluated, there was no correlation between yield and M1000. In a way, these data corroborate (Duarte et al., 2008), who evaluated different hybrids in a joint analysis of two locations and found a positive correlation of 0.34 (P <0.05) between yield and 100-grain mass, a correlation with relatively low indexes. These data do not corroborate (Faluba et al., 2010), who evaluated the genetic potential of the UFV7 corn population for breeding in Minas Gerais. The additive genetic, phenotypic, and significant environmental correlation coefficients were positive in all regions studied. In the western region of Minas Gerais, the additive correlation between grain yield, plant height, and ear height was of high magnitude. In the Southeast region, grain yield was correlated only with prolificacy. In the central region, grain yield was significantly correlated with all traits, and the highest magnitude additive genetic correlation (P<0.01) between grain yield and prolificacy was also observed.

Souza et al. (2008), to determine genetic correlations and define strategies for obtaining corn cultivars for the traditional production system, the grain yield trait presented low heritability and additive genetic variability values, having significant correlation only with ears without grains and plant height.

The highest levels of rainfall occurred in crop season 1, totaling 1404 mm during the crop cycle, compared to crop season 2, with 1041 mm, and crop season 3, with 769 mm (Figure 1A, 1B and 1C). In this sense, evaluating, it can be seen that there were more interactions between physical and agronomic traits in crop season 1 when better rainfall conditions happened; thus, we can infer that there is a relationship between environmental factors, with a greater water regime improving performance in grain filling, that is, the effect of the crop season is perceived.

The orthogonal contrasts between the means of the variables were performed using the t-test values for grits (GRITS), germ (GERM), flotation (FLOT), vitreousness (VITRE), rot grains (RG), hectoliter weight (HW), 1000-grain mass (M1000) and grain yield (GY), being significant with more than 95% probability for the orthogonal contrast concerning different conventional and transgenic corn hybrids in different crop seasons: 2017/2018, 2018 /19 and 2019/20 (Table 3).

For the physical traits of grits (GRITS-g), germ (GERM-g), and flotation (FLOT), considering the contrasts involving the conventional and transgenic hybrids, these were not significant for the contrasts: H1 x H2, H3 x H4, H5 x H6, and H7 x H8, with more than 95% probability (Table 3). Based on these results, it can be inferred that there was no difference between using the conventional or transgenic hybrid for these physical traits, aiming at industrial use.

Table 3
Values of the t-test of the orthogonal contrasts between the means of physical traits of grains [grits (GRITS-g), germ (GERM-g), flotation (FLOT), vitreousness (VITRE), and hectoliter weight (HW)], and agronomic traits [rot grains (RG), 1000-grain mass (M1000), and grain yield (GY)], from conventional and transgenic corn hybrids in different crop seasons: 2017/2018, 2018/19 and 2019/20. UNICENTRO. Guarapuava, PR. 2021

	Physical traits					Agronomic traits		
CONTRASTS[1]	GRITS(g)	GERM(g)	FLOT	VITRE	HW	RG	M1000	GY
H1 x H2	+ 0,58	- 0,52	+ 0,75	- 0,02	- 0,31	- 0,07	+ 0,24	- 0,52
H3 x H4	- 0,83	- 0,53	+ 0,29	+ 0,01	+ 0,77	- 0,05	- 0,73	- 0,16
H5 x H6	+ 0,92	+ 0,92	- 0,28	- 0,57	+ 0,4	- 0,01	+ 0,07	- 0,02
H7 x H8	- 0,58	+ 0,2	- 0,88	- 0,12	+ 0,98	- 0,01	+ 0,01	- 0,18
S1 x S2	- 0,54	+ 0,46	+ 0,55	+ 0,01	- 0,01	+ 0,01	+ 0,01	+ 0,01
S1 x S3	+ 0,01	+ 0,01	- 0,01	+ 0,01	- 0,01	+ 0,01	+ 0,01	+ 0,01
S2 x S3	+ 0,01	+ 0,01	- 0,01	+ 0,04	+ 0,01	+ 0,01	+ 0,01	+ 0,01

[1]H1 x H2 (HYBRID1: Supremo and HYBRID2: Supremo VIP, H3 x H4 (HYBRID3: P30F53 and HYBRID4: P30F53VYH, H5 x H6 (HYBRID5: P3456 and HYBRID6: P3456H, H7 x H8 (HYBRID7: DKB290 and HYBRID8: DKB290PRO3), S1 x S2 (CROP SEASON 1: 2017/18 Crop season and CROP SEASON 2: 2018/19 Crop season), S1 x S3 (CROP SEASON 1: 2017/18 Crop season and CROP SEASON 3: 2019/20 Crop season), S2 x S3 (CROP SEASON 2: 2018/19 Crop season and CROP SEASON 3: 2019/20 Crop season).

For the grits (GRITS-g), germ (GERM-g), and flotation (FLOT) traits, considering the crop seasons, the contrasts S1 x S3 and S2 x S3 with more than 95% probability were significant. However, for GRITS and GERM, seasons 1 and 2 were superior to season 3; for FLOT, season 3 was better (Table 3).

For VITRE, the hybrids were significant; the contrasts H1 x H2 and H3 x H4, that is, the hybrids SUPREMO VIP and P30F53, were superior to their other studied versions. The choice of the conventional or transgenic hybrid influenced VITRE. When analyzing the crop seasons for VITRE, the behavior was similar to data from GRITS and GERM but showed that the best values were obtained in season 1 > season 2 > season 3, respectively. Therefore, we can infer that interference was dependent on hybrids used, crops evaluated, and transgenics used. The contrasts for HW were not significant for the contrasts of the hybrids, not different between the conventional and transgenic versions. Still, all the contrasts were significant for the crops, in descending order: season 2 > season 3 > season 1.

For RG, considering the hybrids, the contrasts H1 x H2, H3 x H4, H5 x H6, and H7 x H8 were significant; that is, the hybrids Supremo VIP, P30F53VYH, P3456H, and DKB290PRO3 were superior to their studied versions (Table 3). RG was influenced by the choice of the transgenic hybrid, which had higher rates of rot grains. When analyzing the crop seasons for RG, the behavior was similar to the data for VITRE, showing that the best values were obtained in season 3 > season 2 > season 1, respectively (Table 3). (Kluge et al., 2017), evaluating the effect of fungicide application on grain rot in commercial corn hybrids, observed that fungicide application reduced the incidence of rot grains, and the greatest reduction occurred in susceptible hybrids.

Chaves et al. (2018), evaluating the application of different fungicides and hybrids, found an influence of the sowing system, the hybrid, and the application of fungicides on the infection of fungi that cause ear rot.

Mendes et al. (2012), evaluating different hybrids, found that the significance of the contrast between hybrids considered resistant vs. hybrids considered susceptible for the percentage of rot grains, evidencing the existence of genotypes with greater resistance to the fungi *F. verticilioides, S. maydis,* and *S. macrospora.*

For the M1000, considering the hybrids, the contrasts H5 x H6 and H7 x H8 were significant; that is, the hybrids, P3456 and DKB290, were superior to their studied transgenic reciprocal hybrids, showing that the choice of the conventional hybrid influenced M1000 (Table 3).

For the GY, considering the hybrids, the contrasts H3 x H4, H5 x H6, and H7 x H8 were significant; that is, the hybrids P30F53VYH, P3456H, and DKB290PRO3 were superior to their conventional reciprocal hybrids evaluated, demonstrating that the choice of the transgenic hybrid influenced GY (Table 3).

When analyzing the crop seasons for RG, M1000, and GY, the behavior was similar, showing that the best values were obtained in season 3 > season 2 > season 1, respectively (Table 3). (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 evidences 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, and the grain yield in conventional corn crops verified the result of contrast where the transgenic corn hybrid P 3041YG showed higher grain mass per ear and higher grain yield compared to the conventional hybrid P 3041.

Faluba et al. (2010), evaluating the genetic potential of the UFV7 corn population for breeding in Minas Gerais, found that genetic and environmental factors determine the phenotypic correlation; in their work, estimates of additive genetic correlations are available. Corn grain yield is the trait of greatest interest to farmers; therefore, increasing this is always a priority in any breeding program. The use of recurrent selection is an efficient breeding method when it is intended to increase the corn grain yield of a given population.

Conclusions

The positive correlation between grits and flotation demonstrates that the flotation analysis has an important role in the improvement of grits, which is dependent on the season condition and favorable water conditions.

The choice of hybrids for the food industry based on vitreousness positively favors flotation.

The grits showed a positive correlation with hectoliter weight and a negative correlation with the incidence of rot grains, demonstrating that hybrids with higher hectoliter weight and lower incidence of rot grains will consequently have a higher industrial yield of grits.

Vitreousness was influenced by choice of conventional or transgenic hybrid, with the SUPREMO VIP and P30F53 hybrids being superior to their other studied versions, and by the crop season, of interest to the dry-milling food industry, where the best values were obtained in season 1, season 2 and then season 3.

The environments of the seasons influence grain yield, 1000-grain mass, and rot grain incidence of conventional and transgenic corn hybrids, with favorable water conditions for better grain filling being a positive differential.

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