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Research Article

Initial growth and chlorophyll indices of maize plants originating from seeds of different shapes and sizes

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Abstract

The objective of this work was to evaluate the initial growth and chlorophyll content of maize plants originated from seeds with different sizes and shapes, as well as to establish the relationship between growth traits, chlorophyll index and seed formats. The experimental design was a randomized complete blocks, and the treatments were composed by seeds of four sizes and shapes for each of the two genotype used, and four collection periods (21, 24, 27 and 30 DAE) and four replications. The root and shoot length, stem diameter, leaf area, dry mass of leaf, stem, roots and total, leaf mass ratio, leaf area ratio, specific leaf area and chlorophyll a, b and total chlorophyll were determined. It was verified that seedlings of genotype "A" originated from large round seeds, presented the highest stem diameter, leaf dry mass, stem dry mass, root dry mass and total dry mass. There is a distinct response in the growth of maize plants as a function of the genotype. Regardless of the genotype, the size and shape of seeds do not influence the indexes of chlorophyll a, b and total. There is a positive and strong correlation between seeds of different sizes and shapes with leaf area, leaf dry mass and specific leaf area.

Keywords: *Zea mays* L; vigor; standardization; initial performance; growth rate; physiological qualities.

Introduction

Important grasses have been studied including maize (Ferreira et al., 2022; Facchinello et al., 2023; Karasawa et al 2023; Santos et al., 2023). Maize has showed significant production in winter crop in Brazil. So, it is fundamental to improve maize seed studies. Maize ears present seeds of different shapes and sizes, which may reflect in different physiological qualities (Zucareli, Brzezinski, Guiscem, Henning, Nakagawa, 2014). In maize, larger seeds tend to originate more vigorous plants, which are able to stablish faster in the field. Consequently, it may present positive influence on yield components (Enayatgholizadeh et al., 2012). However, other authors affirm that seed size reveals a more pronounced influence during the initial stages of development, and it does not affect yield components, evidencing that this subject is not yet fully clarified (Vazquez et al., 2012).

The standardization of the shape and size of the seeds favors the regulation of the seeder, improves the plantability allowing the correct adjustment of the seeding density. The seed distribution in the line should provide a similar distance between the plants, reducing intraspecific competition and favoring productivity (Schuch & Peske, 2008).

The evaluation of initial growth-related traits is an important tool to determine the influence of seeds size and shape for initial performance of the plants. Among the growth traits used, there is leaf area, length and dry mass, stem diameter, ratio between leaf area and leaf mass, and also the estimate of growth rates over the time of data collection (Aisenberg et al., 2016; Lopes & Lima, 2015).

Chlorophylls are the main photosynthetic pigments, whose function is to absorb solar radiation and perform energy transfer from the excitation of electrons to the photosynthesized reaction center (Kerbauy, 2012). The evaluation of chlorophyll indices is an important tool for cultivated plants (Silva-Lobo, Filippi, Silva, Venancio, & Prabhu, 2012). In this context, the objective of this work was to evaluate the initial growth of maize plants originated from seed of distinct ear fractions with different sizes and shapes, as well as the influence of seed size and shape on the indices of chlorophyll a, b and total.

Material and Methods

A seed company located in the State of Rio Grande do Sul, Brazil, provided the seeds used in the present research. Seeds of two simple hybrids were used, classified according to size and shape, being denominated as: large round, small round, large flat and small flat. The classification of the seeds was carried out in the company's own seed processing unit (UBS). The company did not allow the disclosure of the commercial names of the simple hybrids used in this research, so they were denominated in Genotype "A" and Genotype "B".

The study was carried out in the didactic and experimental area of the Federal University of Pelotas, campus Capão do Leão - RS, located at latitude 31º 48 '10.3' 'S and longitude 52º 25' 08.3 ''O. The data regarding temperature, precipitation and solar radiation during the experiment are shown in Figure 1.

The treatments consisted in the combination of seeds of different shapes and sizes, for each of the two genotypes, separately, being denominated as: large round, small round, large flat and small flat, and four collection stages (21, 24, 27 and 30 DAE). Six lines of 2.5m long, with 3m wide, composed the experimental unit. The spacing between lines was 0.45m. The useful area was 2m^2 and consisted of four central lines, discounting 0.5m from each extremity.

For genotype "A", the seeds were classified in circular hole sieve, being: large round (6.85mm width, 6.54mm thick and 9.47mm length) and small round (6.85mm width, 5.71mm thick and 10.23 mm length) and oblong hole sieve, being classified as large flat (8.72mm width, 4.28mm thick and 10.10mm length), and small flat (6.52mm width, 4.57mm thick and 10.21mm length). For genotype "B", the seeds were classified in the same sieves; however, the seed dimensions were: circular hole sieves: large round (9.01 mm width, 6.64 mm thick and 8.77 mm length) and small round (6.65 mm width, 5.50 mm thick and 10.08 mm length). In oblong hole sieve the seed dimensions were classified as large flat (5.54 mm width, 4.84 mm thick and 10.12mm length) and small flat (7.10mm width, 4.61mm thick and 10.07mm lenght).

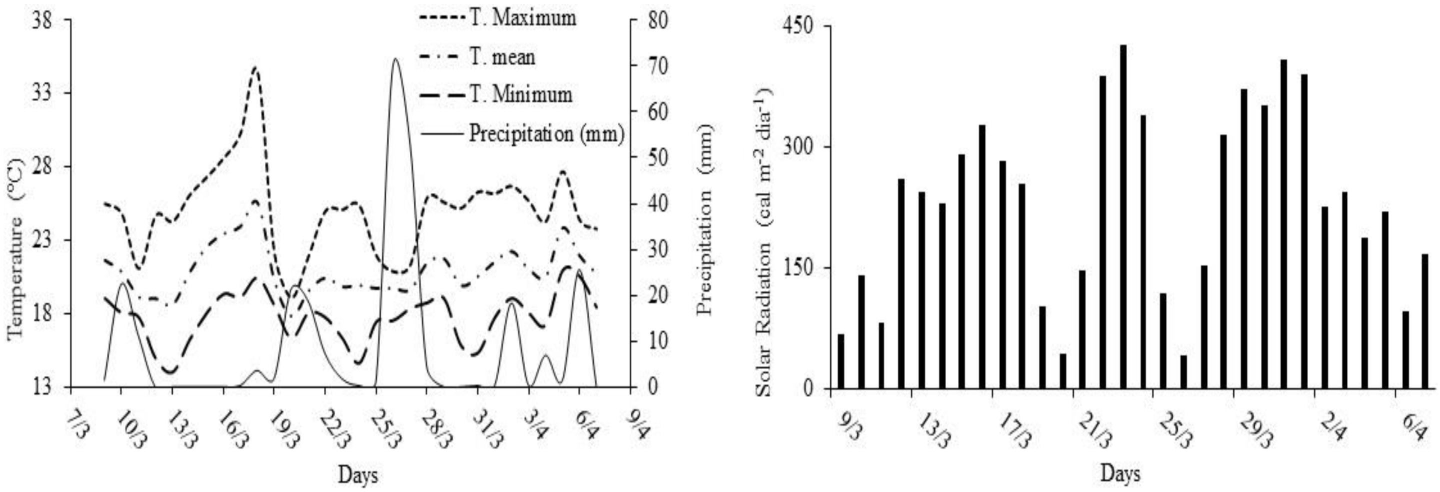

Figure 1. Graphs for precipitation (mm), maximum (T. max in ºC), mean (T. mean in ºC) and minimum temperature, (T. minimum in ºC), and solar radiation (cal m^{-2} day^{-1}), from March to April 2016. Pelotas, RS, 2016.
Source: Empresa Brasileira de Pesquisa Agropecuária (EMBRAPA, 2016).

The seeds were manually treated with Thiamethoxam-based insecticide at a concentration of 400 mL (100 kg of seeds) using a volume of 0.6 L 100 kg-1 of seeds (Nunes, 2005). The seeds were sown in a sandy-textured Hydromorphic Planosol (EMBRAPA, 2013), corrected for the expectation of 4 t ha^{-1} (CQFS, 2004). The summary of soil chemical analysis is shown in Table 1. Phosphorus and potassium fertilization was incorporated into the soil before sowing, consisting of 45 and 70 kg ha^{-1} of phosphorus and potassium, respectively, using triple super phosphate (41% P_2O_5) and potassium chloride (58 % K_2O). Nitrogen supply consisted of 30kg ha^{-1} of N incorporated into the soil at sowing and 60 kg ha^{-1} in topdressing at 14 days after emergence, using urea as N source (45% N).

Table 1. Chemical soil analysis used for sowing of two maize genotypes, Pelotas, RS, Brazil, 2016.

O.M.[1]	p.H.	Clay	P	K	Ca	Mg	Al	H+Al	CEC	V	SMP
%	(H_2O)	%	mg dm^{-3}		cmol$_c$ dm^{-3}					%	ind.
2.07	4.8	14	21.5	27	3.3	1.1	0.3	6.2	4.9	42	5.7

[1]O.M.=organic matter; p.H.=hydrogen potential; P=phosphor; K=potassium; Ca=calcium; Mg=Magnesium; Al=Aluminum; V= base saturation; and SMP= SMP index.

The following analyzes were performed: Four successive collections were carried out, from 21 days after sowing, with regular intervals of three days to 30 days after sowing. Four plants were evaluated for each treatment. The following evaluations were carried out:

a) Aerial (C_{pa}) and root (C_r) length: Aerial (C_{pa}) and root (C_r) length: evaluated measuring the distance between the basal portion of the root insertion and the aerial part apex. While the length of the root was verified by the distance from the neck to the root end. The results were expressed in cm per seedling.

b) Diameter of stem (D_c): was determined with the aid of a digital caliper, the measurement was performed one centimeter above the plant's neck. The data were expressed in mm seedling^{-1}.

c) Leaf area (A_f): determined using LI-3100 model leaf area meter. The results are expressed in square meters (m^2).

d) Dry mass of leaf (W_f), stem (W_c) and root (W_r): four plants per replicate were separated into different structures (leaves, stem and roots). The different structures were packed in brown paper bags and dried in a forced circulation oven at 70 ± 2ºC until constant mass.

e) Leaf area ratio (F_a): for the estimation of R_{la}, the equation $F_a = L_a / W_t$ was used, where L_a represents the leaf area and W_t represents the total dry mass. The results were expressed as m^2 g^{-1}.

f) Leaf mass ratio (F_w): for the estimation of M_{lr}, the equation $M_{lr} = W_l / W_t$ was used, where W_l represents the dry mass of leaves and W_t represents the total dry mass. The results were expressed as g g^{-1}.

g) Specific leaf area (S_a): for the estimation of S_a, the equation $S_a = A_l / W_t$ was used, where A_l represents the leaf area and W_t represents the total dry mass. The results were expressed as m^2 g^{-1}.

h) a, b and total chlorophyll index: Determined using the Falker CFL1030 electronic chlorophyll meter. The evaluations were performed at 21 days after sowing, with four replications, with six readings for each replication.

The experimental designed was randomized blocks, in a 4 x 4 factorial scheme (seed from different fractions of the ear x collection period), with four replications. The data were submitted to analysis of variance, and when significant at 5% of probability by the F test, the contrasts were adjusted through orthogonal polynomials. Pearson's linear correlation test at 5% of probability was applied between the initial growth variables and the a, b and total chlorophyll contents evaluated 21 days after sowing.

Results and Discussion

For both studied genotypes, there was a significant interaction between seed fractions (shapes and sizes) and the period of collection, for the traits aerial part length (C_{pa}) and root length (C_r), diameter of stem (D_s), leaf area (A_f), dry mass of stem (W_c), dry mass of root (W_r) and total dry mass (W_t) (Figure 2 and Figure 3). However, for leaf area ratio, leaf mass ratio and specific leaf area, there was no significant interaction. Similarly, indexes of chlorophyll a (C_{ha}), b (C_{hb}) and total (C_{ht}) of plants originating from seeds of different shapes and sizes, presented no significant difference.

Length of aerial part of plants for genotype "A", the length of aerial part of plants from large round, small round, large flat, and small flat seeds adjusted to the quadratic model with high coefficients of determination ($R^2 \geq 0.99$) (Figure 2A).

At 21 DAS, large round and large flat seeds produced plants with larger shoot length, not statistically different from each other. However, they were 9.4% and

7.8% higher than those from small round seeds, and 13.3% and 11.8% higher than those originated from small flat seeds. At 30 DAS, seedlings originated from large round seeds were 2%, 5% and 8% superior than seedlings from large flat, small round, and small flat seeds, respectively.

For genotype "B", aerial part length of seedlings originated from small round seeds, as well as small flat seeds, were adjusted to the quadratic model, with high coefficients of determination ($R^2 = 0.99$ and $R^2 = 0.94$, respectively). The large flat adjusted to the quadratic model with high coefficient of determination ($R^2 = 0.98$). In addition, for plants from large round seeds, the length of aerial part adjusted the linear model with high coefficient of determination ($R^2 = 0.99$) (Figure 2B).

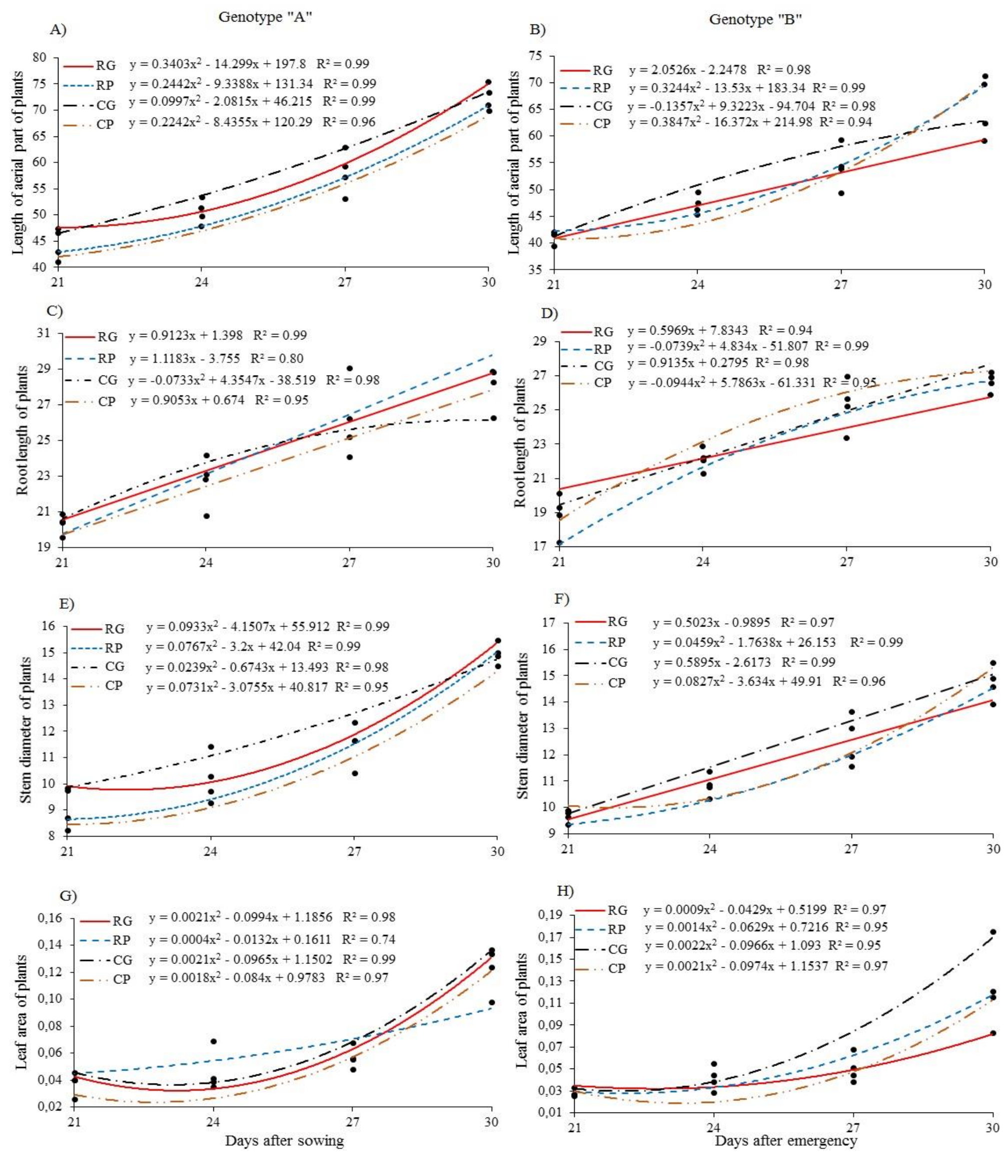

Figure 2. Graphs presenting aerial part length, root length, stem diameter and leaf area of maize plants originated from seeds of two genotypes fractionated in different formats and sizes. LR = Large Round Seed; SR = small round seed; LF = Large Flat Seed; and SF = small flat seed.

At 21 DAS, the highest values of aerial part length were observed in plants originated from small round, large flat and large round seeds, which were 6%, 5.2% and 5.1%, respectively, higher than seedlings from small flat seeds. The length of aerial part of plants originated from small flat and small round seeds did not differ from each other at 30 DAS. However, they were approximately 15% and 14% higher than plants originated from large round seeds, and superior 10% and 9% when compared to plants originated from large flat seeds.

At 21 DAS, the seedlings originated from seeds of all shapes and sizes did not differ from each other for root length. The plants originated from large round and small round seeds, at 30 DAS, reached root length values statistically significant, around 3% and 6% superior than small flat seeds, and around 9% and 12% higher when compared to those originated from large flat seeds. The root length of seedlings originated from small round, large round and small flat seeds did not show significant differences among them, however it significantly differed from those originated of large flat seeds.

Root length of plants for genotype "B", root length of plants originated from small round or small flat seeds adjusted to the quadratic model with high coefficients of determination (R^2 = 0.99 and R^2 = 0.95, respectively). Whereas those originated from large round and large flat seeds presented linear response, with coefficient of determination of R^2 = 0.94 and R^2 = 0.98, respectively (Figure 2D).

At 21 DAS, the highest root lengths were observed in plants originated from large round and large flat seeds, presenting superiority in the order of 6.3% and 2.4%, in relation to seedlings originated from small flat seeds, and 14.2% and 10.7% higher than those from small round seeds. However, at 30 DAS, the highest root lengths were observed in plants originated from small or large flat seeds, which did not differ statistically, but their magnitudes were 2% and 3% higher than those from small round seeds. In relation to large round seeds, the superiority was in the order of 6% and 7%.

Therefore, the evaluation of radicular system growth traits may estimate seed vigor, since shape and size of maize seeds appear to have great influence at the beginning of development stages (Vazquez et al., 2012). The higher root length of maize plants, when associated to their higher volume in soils with adequate compaction, permeability, aggregation and structure, allows a larger area to be occupied by roots, favoring the absorption of water, minerals, as well as to provide a competitive advantage in the growing environment, resulting in yield increments (Chioderoli et al., 2012; Szareski et al., 2018).

Stem diameter of plants the stem diameter of plants originated from different seed fractions, for genotype "A", was adjusted to the quadratic model, with coefficient of determination of $R^2 \geq 0.95$ (Figure 2E). Statistically, the highest stem diameter values at 21 DAS were observed for plants originated from large round and large flat seeds, which did not differ from each other, however, presented values 7.3% and 10.9% higher than those originated from small round seeds, and 16.2% and 15.5% higher than those originated from small flat seeds. However, at 30 DAS, large round seeds originated plants with statistically superior stem diameter, presenting 3%, 3.8% and 6.2% of superiority, respectively, in relation to plants originated from small rounds, large flat and small flat seeds.

For genotype "B", the stem diameter of plants originated from large flat, small flat and small round seeds adjusted to the quadratic model, whose determination coefficients were $R^2 \geq 0.96$ (Figure 2F). While the stem diameter of plants originated from large round seeds was adjusted to the linear model with high coefficient of determination (R^2 = 0.94).

At 21 DAS, the values of stem diameter did not differ among plants originated from different seed sizes and shapes. However, at 30 DAS, small flat seeds produced plants statistically superior for stem diameter, with values of 1.64%, 5.03% and 8.16% higher than plants from large flats, small round and large round seeds.

Maize seeds with high vigor result in plants with larger stem diameter than those from less vigorous seeds. However, this effect is only observed at the beginning of crop development (Dias et al., 2010).

The leaf area of plants originated from seeds of all shapes and sizes, for genotype "A", adjusted to the linear model with high coefficients of determination ($R^2 \geq 0.71$) (Figure 2G). The highest values of leaf area, at 21 DAS, were observed in plants from large flat, large round and small round seeds, which were not statistically different from each other. However, these values were higher than those of small flat seeds in the order of 42.4% 36.3% and 34.6%, respectively. At 30 DAS, the plants with statistically larger leaf area were those originated from large flat seeds, with values 2.2%, 9.1% and 28% higher than plants originated from large round, small flat and small round seeds.

Regarding genotype "B", the leaf area of plants formed from large round, small round, large flat or small flat seeds adjusted to the linear model, whose coefficients of determination were $R^2 \geq 0.70$ (Figure 2H). At 21 DAS, the leaf area of plants originated from all shapes and sizes did not differ from each other. However, at 30 DAS, the plants with larger leaf area were those from large flat seeds, which presented values 30.8%, 33.8% and 52.4% higher than plants from small round, small flat, and large round seeds, respectively.

The largest and most vigorous seedlings present a larger leaf area with a higher capacity for capturing solar energy, thus contributing to the greater production of assimilates destined to grain / seed production (Pedó et al., 2014; Lopes & Lima, 2015). Large seeds originate plants with higher dry mass of aerial part (Soares, Santos Junior, Simões, Pazzin, & Silva, 2015). This fact is explained by the greater accumulation of photoassimilates in larger seeds, which will be translocated to plant tissues that will be originated from these seeds, such as leaves, stems and roots, for example (Demari et al., 2016; Amaral et al., 2012).

The dry mass of leaves, for genotype "A", of plants originated from large round, small round or small flat adjusted to the quadratic model, with high determination coefficients ($R^2 \geq 0.99$). Those from large flat seeds adjusted to the linear model with high coefficient of determination ($R^2 = 0.99$) (Figure 3A). At 21 DAS, the plants originated from large flat and large round seeds presented the highest values of leaf dry mass, which were statistically superior to plants originated from large flat in the order of 20.3% and 17, 5%, respectively. The superiority compared to plants from small round seeds was 27.9% and 25.4%, respectively. At 30 DAS, the plants that presented statistical superiority for dry mass of leaves were those originated from large round seeds, which were higher in the order of 16.7%, 26.3% and 27.7%, compared to large flat, small round and small flat, respectively.

Regarding the genotype "B", the dry mass of leaves of plants originated from large round seeds was adjusted to the linear model with high coefficient of determination ($R^2 \geq 0.97$). Plants originated from small round, large flat and small flat seeds, adjusted to the quadratic model with high coefficients of determination ($R^2 \geq 0.94$) (Figure 3B).

The statistically highest leaf dry mass values, at 21 DAS, was evidenced for plants originated from large round seeds, whose superiority was in the order of 4.3%, 4.89% and 5%, compared to small flat, large flat and small round seeds. At 30 DAS, there was no significant difference among shapes and sizes for this trait.

The stem dry mass of plants from genotype "A", regardless of size and shape of the seeds, was adjusted to the linear model with high determination coefficient

($R^2 \geq 0.99$ in all treatments) (Figure 3C). For genotype "B", the stem dry mass of plants from large round ($R^2 = 0.97$) and large flat seeds ($R^2 = 0.99$) adjusted to the quadratic model with high coefficient of determination. However, the dry mass of plants originated from small, flat ($R^2 \geq 0.87$) or round seeds ($R^2 \geq 0.93$) presented linear tendency (Figure 3D).

For genotype "A", at 21 DAS, there was no significant difference among values of stem dry mass for all seed sizes and shapes. However, at 30 DAS, plants originated from large round seeds presented superiority of 28%, 32% and 33% in stem dry matter allocation, compared to plants from large flat, small flat and small round seeds.

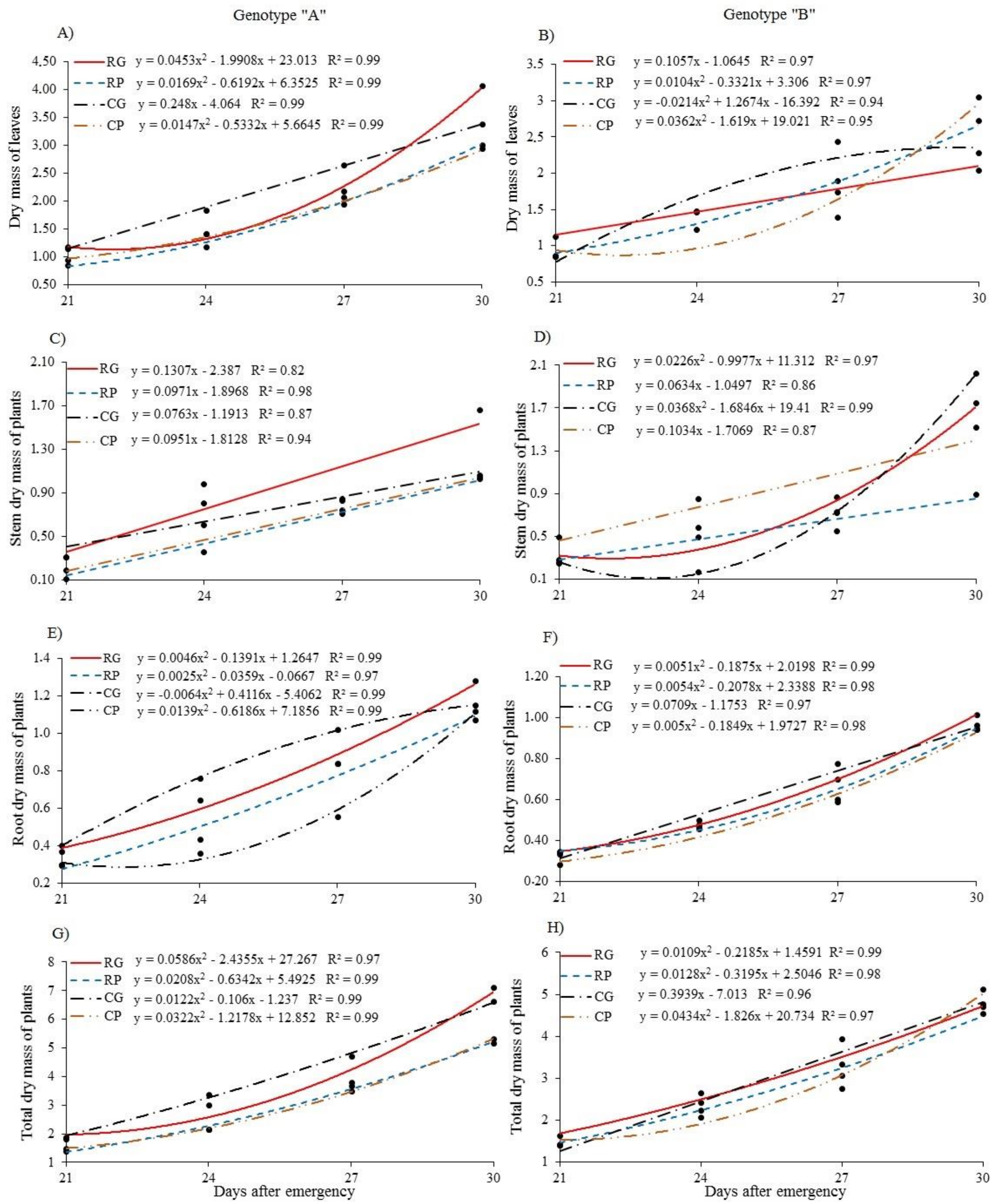

Figure 3. Graphs referent to dry mass of leaves, dry mass of stem, dry mass of roots and total dry mass of maize plants originated from seeds of two genotypes fractionated by different shapes and sizes. LR = Large Round Seed; SR = Small Round seed; LF = Large Flat Seed; and SF = Small Flat Seed.

For genotype "B", there was no significant difference between the values of stem dry mass for all shapes and sizes of seeds at 21 DAS. At 30 DAS, there was superiority of 50% in the dry mass allocated on stem of plants originated from large round seeds, compared to plants from small round seeds. The superiority was 30% for plants from large flat seeds in relation to those from small flat seeds.

Root dry mass of plants regarding root dry mass of plants from genotype "A", seedlings originated from large round (R^2 = 0.99), small round (R^2 = 0.97), large flat (R^2 = 0.99) and small flat seeds (R^2 = 0.99), adjusted to the quadratic model (Figure 3E). Regarding the genotype "B", the root dry mass of seedlings originated from large round (R^2 = 0.99), small round (R^2 = 0.98) and small flat seeds (R^2 = 0.98) presented quadratic adjustment, with high coefficients of determination (Figure 3F). In plants originated from large flat seeds, the root dry mass presented linear increment, with high coefficient of determination (R^2 = 0.97). For genotype "A" at 21 DAS, the plants originated from large flat and large round seeds did not differ from each other. However, they were superior in the order of 25.5% and 19.6% compared to the small flat, and superior in the order of 26% and 20% compared to the small round seeds, respectively. At 30 days after sowing, the plants originated from large round seeds were about 4%, 7% and 10% superior to those originated from large flat, small flat or small round seeds, respectively. For genotype "B", at 21 and 30 DAS, there was no significant difference between seed sizes and shapes.

During plant growth and development, the partition of dry mass to the organs may be altered due to changes in the plant, for example, beginning of flowering. In this situation, there will be a greater translocation of photoassimilates for flowers, fruits and seeds (Oliveira, Araújo, & Guerra, 2011; Kerbauy 2012). Seed vigor involves the biosynthesis of energy and metabolic compounds, associated with the integrity of cell membranes, transport and utilization of photoassimilates stored in the seed (Association of Official Seed Analysts [AOSA], 1983). In this context, seeds with less vigor present more variation in their composition, and the emergency will be slower and uneven (Henning et al., 2010; Szareski et al., 2016).

The total dry mass of plants from genotype "A" originated from large round (R^2 = 0.97), small round (R^2 = 0.99), large flat (R^2 = 0.99) and small flat seeds (R^2= 0.97), were adjusted to the quadratic model (Figure 3G). For genotype "B", the total dry mass of plants originated from large round, small round or small flat seeds showed a quadratic adjustment with high coefficients of determination (R^2 ≥ 0.97). For the total dry mass of plants originated from large flat seeds, a linear adjustment was verified, with high coefficient of determination (R^2 = 0.96).

For genotype "A", at 21 DAS, the plants originated from large flat and large round seeds presented statistically superior values for total dry mass compared to small flat seeds, in the order of 21.1% and 18.1%, and small round in the order of 25.9% and 23%. At 30 DAS, the highest values of total dry mass were observed in plants originated from large round seeds, which were higher in the order of 5.45%, 23.94% and 25.28%, compared to plants from large flat, small flat and small round seeds, respectively. For Genotype "B", at 21 DAS, there was no significant difference between seed sizes and shapes for this trait. However, at 30 DAS, the highest values of total dry mass were observed in plants originated from small flat seeds, which were higher in the order of 4.19%, 5, 98% and 11.54%, compared to those originated from large flat, large round and small round seeds, respectively.

Correlation among traits the leaf area of plants originated from small flat, large flat and large round seeds correlated significantly and positively with foliar mass ratio of plants originated from large round and small round seeds, and with the indexes of chlorophyll a and b of plants originated from small round seeds, whose coefficients were ≥ 0.74 (Table 2). There was also a positive correlation between the dry mass of leaves of plants originated from large flat seeds with large round. Correlation was also verified between large flat and small round seeds, with leaf mass ratio, presenting coefficients ≥ 0.72 (Table 2). The specific leaf area significantly and positively correlated with large flat or small flat seeds (0.91), as well as with small round seeds (0.78 and 0.82, respectively).

Regarding the Pearson's linear correlation analysis, it is important to note that, correlation coefficients above 0.70 are considered high (Carvalho et al., 2016; Dancey & Reidi, 2006). Thus, in the present study, all significant correlations observed showed a high correlation coefficient. The analysis of correlation evaluates the degree of association between two variables. When the values of a correlation coefficient approaches 1, this association is considered strong (Figueiredo Filho & Silva Júnior, 2009; Nardino et al., 2016; Szareski et al., 2017).

The large flat, small flat and small round seeds correlated with indexes of chlorophyll a, and b (0.75, 0.83 and 0.72, respectively), while the small round and large round seeds correlated with total chlorophyll index, with coefficients ≥ 0.71 (Table 2 and Table 3).

Table 2. Pearson correlation coefficients (r) for leaf area (A_f), dry leaf mass (W_f), leaf area ratio (F_a) and specific leaf area (S_a) of maize plants, originated from different seeds shapes and sizes. Pelotas, Brazil, RS.

		A_f	**A_f**	**W_f**	**W_f**	**W_f**	**F_a**	**F_a**	**F_a**	**S_a**	**S_a**	**S_a**	**S_a**
		RG	RP	CP	RG	RP	CG	RG	RP	CG	CP	RG	RP
A_f	CG	-0.09^{ns}[1]	0.98*	0.19^{ns}	0.49^{ns}	-0.12^{ns}	-0.37^{ns}	-0.24^{ns}	0.01^{ns}	-0.03^{ns}	-0.05^{ns}	-0.04^{ns}	0.15^{ns}
A_f	CP	0.62^{ns}	-0.13^{ns}	0.17^{ns}	0.38^{ns}	0.32^{ns}	0.15^{ns}	-0.05^{ns}	-0.03^{ns}	0.35^{ns}	0.33^{ns}	0.14^{ns}	0.20^{ns}
A_f	RG	0.00^{ns}	0.03^{ns}	0.31^{ns}	0.25^{ns}	0.25^{ns}	0.15^{ns}	0.69^{ns}	-0.11^{ns}	0.17^{ns}	0.02^{ns}	0.39^{ns}	-0.06^{ns}
A_f	RP		0.00^{ns}	0.26^{ns}	0.48^{ns}	-0.07^{ns}	-0.33^{ns}	-0.08^{ns}	-0.01^{ns}	0.01^{ns}	-0.06^{ns}	0.06^{ns}	0.14^{ns}
W_f	CG			0.00^{ns}	0.76*	-0.15^{ns}	-0.13^{ns}	-0.17^{ns}	0.63^{ns}	-0.19^{ns}	0.08^{ns}	-0.56^{ns}	0.47^{ns}
W_f	CP				0.70^{ns}	0.68^{ns}	0.70*	0.19^{ns}	0.21^{ns}	0.58^{ns}	0.42^{ns}	0.39^{ns}	0.35^{ns}
W_f	RP					0.00^{ns}	0.45^{ns}	-0.01^{ns}	-0.06^{ns}	0.31^{ns}	0.06^{ns}	0.13^{ns}	0.03^{ns}
F_a	CG						0.00^{ns}	0.18^{ns}	0.32^{ns}	0.75*	0.71*	0.51^{ns}	0.46^{ns}
F_a	CP							0.17^{ns}	0.66^{ns}	0.30^{ns}	0.53^{ns}	-0.08^{ns}	0.52^{ns}
F_a	RG								0.12^{ns}	-0.09^{ns}	-0.16^{ns}	0.26^{ns}	-0.12^{ns}
F_a	RP									0.15^{ns}	0.45^{ns}	-0.26^{ns}	0.81*
S_a	CG										0.91*	0.78*	0.68^{ns}
S_a	CP											0.55^{ns}	0.82*

[1]*significant linear correlation at 5% of probability; ^{ns} non-significant linear correlation. LR = Large Round Seed; SR = small round seed; LF = Large Flat Seed; and SF = Small Flat Seed.

Table 3. Pearson correlation coefficients (r) for leaf mass ratio (F_w), chlorophyll a (Chla), chlorophyll b (Chlb) and total chlorophyll (Chlto) of maize plants, originated from seeds of different sizes and shapes. Pelotas, RS, Brazil.

		F_w	**F_w**	**F_w**	***Chla***	***Chla***	***Chlb***	***Chlb***	***Chlb***	***Chlb***	***Chlto***	***Chlto***	***Chlto***
		CP	RG	RP	CG	RP	CG	CP	RG	RP	CG	CP	RP
F_w	CG	0.19^{ns}[1]	0.77*	0.72*	-0.44^{ns}	0.59^{ns}	-0.29^{ns}	-0.14^{ns}	-0.84*	0.04^{ns}	-0.16^{ns}	0.53^{ns}	-0.49^{ns}
F_w	CP		0.16^{ns}	0.29^{ns}	-0.38^{ns}	-0.01^{ns}	-0.62^{ns}	-0.72*	-0.31^{ns}	0.43^{ns}	-0.30^{ns}	-0.15^{ns}	-0.30^{ns}
F_w	RG			0.60^{ns}	-0.40^{ns}	0.46^{ns}	-0.29^{ns}	-0.09^{ns}	0.15^{ns}	0.36^{ns}	-0.31^{ns}	-0.27^{ns}	0.12^{ns}
F_w	RP				-0.40^{ns}	0.49^{ns}	-0.48^{ns}	-0.02^{ns}	-0.55^{ns}	-0.15^{ns}	0.08^{ns}	0.78*	-0.02^{ns}
Chla	CG					0.75*	-0.16^{ns}	0.02^{ns}	-0.38^{ns}	0.10^{ns}	0.00^{ns}	0.41^{ns}	0.08^{ns}
Chla	CP						0.83*	-0.23^{ns}	0.23^{ns}	0.42^{ns}	0.85*	-0.05^{ns}	0.25^{ns}
Chla	RG							0.28^{ns}	-0.33^{ns}	-0.42^{ns}	0.31^{ns}	0.71*	-0.20^{ns}
Chla	RP								0.72*	-0.05^{ns}	0.15^{ns}	-0.23^{ns}	0.87*
Chlb	CG									-0.38^{ns}	-0.31^{ns}	0.49^{ns}	0.01^{ns}
Chlb	CP										0.59^{ns}	-0.16^{ns}	0.12^{ns}
Chlb	RG											0.09^{ns}	0.42^{ns}
Chlb	RP												0.70^{ns}

[1]*significant linear correlation at 5% of probability; ^{ns} non-significant linear correlation. LR = Large Round Seed; SR = small round seed; LF = Large Flat Seed; SF = Small Flat Seed.

Chlorophyll content is related to the photosynthetic efficiency, growth and yield of cultivated plants (Angel & Poggiani, 1991). However, it is worth mentioning the high relation between seed vigor and growth traits, that is, maize seeds with high vigor produce larger plants with larger leaf area, higher photosynthetic rate and consequently higher photoassimilates allocation in plant tissues, compared to plants originated from seeds with less vigor (Ludwing et al., 2009; Troyjack et al., 2018).

Conclusions

There is a distinct response in the growth performance of maize plants depending on seeds size and shape, as well as genotype.

Regardless of the genotype, the size and shape of seeds do not influence the indexes of chlorophyll a, b and total.

For genotype "A", large round seeds result in greater length of aerial part, stem diameter, leaf dry mass, stem dry mass, root dry mass and total dry mass. For genotype "B", the small flat seeds reflect in higher length of aerial part, root length, stem diameter and total dry mass.

Positive and strong correlation occurs between large flat or small round seeds with leaf area. Similarly, large flat or large round seeds present strong correlation with leaf dry mass, while the specific leaf area with all seed sizes and shapes.

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References

Aisenberg, G. R., Zimmer, G., Koch, F., Dellagostin, S. M., Szareski, V. J., Carvalho, I. R., Nardino, M., Souza, V. Q., Pedó, T., Martinazzo, E. G., Villela, F. A., & Aumonde, T. Z. (2016). Biochemical performance, vigor and characteristics of initial growth of wheat plants under different sowing depths. *International Journal of Current Research*, *8*(8), 36704-36709.

Amaral, A. D., Medeiros, S. L. P., Menezes, N. L., Luz, G. L., Pivoto, D., & Bialozor, A. (2012). Canola seeds classified by density. *Revista Brasileira de Sementes*, *34*, 1-8. https://doi.org/10.1590/S0101-31222012000200016

Angel, V. l., & Poggiani, F. (1991). Study of the concentration of chlorophyll in leaves and their light absorption spectrum as a function of shading in seedlings of four native forest species. *Revista Brasileira de Fisiologia Vegetal, 3*, 39- 45.

AOSA - Association of Official Seed Analysts. (1983). *Seed vigor testing handbook*. East Lansing.

Carvalho, I. R., Nardino, M., Pelegrin, A. J., Ferrari, M., Demari, G. H., Szareski, V. J., Barbosa, M. H., & Souza, V. Q. (2016). Path analysis and Annicchiarico method applied in relation to protein in corn grains. *Australian Journal of Basic and Applied Sciences*, *10*(9), 300-306.

Chioderoli, C. A., Mello, L. M. M., Grigolli, P. J., Furlani, C. E. A., Silva, J. O. R., & Cesarin A. L. (2012). Soil physical attributes and soybean yield in corn and brachiaria consortium system. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *16*(1), 37-43.

Conceição, P. M., Sediyama, C. A. Z., Vieira, R. F., Galvão, J. C. C., Corrêa, M. L. P., & Conceição, O. S. (2012). Estimating the vigor of corn seeds through the evaluation of the root system of seedlings. *Ciência Rural*, *42*(4), 600-606.

Dancey, C., & Reidy, J. (2006). *Mathematical Statistics for Psychology: Using SPSS for Windows*. Porto Alegre, RS: Artmed.

Demari, G. H., Carvalho, I. R., Nardino, M., Szareski, V. J., Dellagostin, S. M., Rosa, T. C., Follmann, D. N., Monteiro, M. A., Basso, C. J., Pedo, T., Aumonde, T. Z., & Zimmer, P. D. 2016. Importance of nitrogen in maize production. *International Journal of Current Research*, *8*(8), 36629-36634.

EMBRAPA - Empresa Brasileira De Pesquisa Agropecuária. (2013). *Brazilian system of soil classification*. 3.ed. Brasília, DF: Embrapa Solos.

EMBRAPA - Empresa Brasileira De Pesquisa Agropecuária (2016). *Monthly climatological bulletin of the Agrometeorology Laboratory of Embrapa Clima Temperado*. Brasília, DF: Embrapa. Available in: http://agromet.cpact.embrapa.br.

Enayatgholizadeh, R. M., Bakhshandeh, M. A., Shoar, D. M., Ghaineh, H. M., Alami Saeid, H. K., & Sharafizadeh, M. (2012). Effect of source and seed size on yield component of corn S.C704 in Khuzestan. *African Journal of Biotechnology, 11*(12), 2938-2944. https://doi.org/10.5897/AJB11.2720

Facchinello, P. H. K., Carvalho, I. R., Streck, E. A., Aguiar, G. A., Goveia, J., Feijó, M., Pereira, R. R., Fagundes, P. R. R., Loro, M. V., Maia, L, C., & Magalhães Júnior, A. M. (2023). Genetic trends and multivariate interrelationships for grain quality of irrigated rice genotypes. Agronomy Science and Biotechnology, 9, 1-16. https://doi.org/10.33158/ASB.r192.v9.2023

Ferreira, L. L., Hunhoff, L. S., Amaral, U., Carvalho, I. R., Silva, R. V., Carrijo Santos, N. S., Fernandes, M. S., Lautenchleger, F., Azevedo Pereira, A. I., Silva Curvêlo, C. R., & Loro, M. V. (2022). Genetic variability and effect of plant arrangement on corn. *Agronomy Science and Biotechnology*, *8*, 1–16. https://doi.org/10.33158/asb.r162.v8.2022

Figueiredo Filho, D. B., & Silva Júnior, J. A. (2009). Unraveling the mysteries of Pearson's correlation coefficient (r). *Revista Política Hoje, 18*, 115-146.

Henning, F. A., Mertz, L. M., Jacob Junior, E. A., Machado, R. D., Fiss, G., & Zimmer, P. D. (2010). Chemical composition and mobilization of reserves in high and low vigor soybean seeds. *Bragantia, 69,* 727-734. https://doi.org/10.1590/S0006-87052010000300026

Karasawa, M. M. G., Tavares, V. B., Pinto, J. C., Lédo, F. J. S., Pereira, A. Vander, & Pinto, J. E. B. P. (2023). Effects of thermotherapy and meristem culture techniques on macro and micronutrients content in elephant grass cultivars. *Agronomy Science and Biotechnology*, *9*, 1–19. https://doi.org/10.33158/asb.r182.v9.2023

Kerbauy, G. B. (2012). *Fisiologia vegetal.* (2nd ed.). Rio de Janeiro, RJ: Guanabara Koogan.

Lopes, N. F., & Lima, M. G. S. (2015). *Physiology of production*. Viçosa, MG: Editora UFV.

Nardino, M., Baretta, D., Carvalho, I. R., Olivoto, T., Pelegrin, A. J., Ferrari, M., Szareski, VJ., Konflanz, VA., Caron, BO., Schmidt, D., Barros, WS., & Souza, V. Q. (2016). REML / BLUP in analysis of pre-commercial simple maize hybrid. *International Journal of Current Research*, *8*(8), 37008-37013.

Nunes, JC. (2005). *Seed treatment: quality and factors that may affect your laboratory performance*. Londrina, PR: Syngenta Proteção de Cultivos.

Oliveira, F. L., Araújo, A. P., & Guerra, J. G. M., (2011). Growth and accumulation of nutrients in taro plants under levels of artificial shading. *Horticultura Brasileira*, *29*, 291-298.

Pedó, T., Segalin, S. R., Silva, T. A., Martinazzo, E. G., Gazolla Neto, A., Aumonde, T. Z., & Villela, F. A. (2014). Seed vigor and initial performance of common bean seedlings at different seeding depths. *Revista Brasileira Ciências Agrárias*, *9*, 59-64.

Schuch L., & Peske, S. T. (2008). Failures and doubles in productivity. *Seeds News*, ano XII, n. 6. Available in: http://www.seednews.inf.br/portugues/seed126/print_artigo126.html

Santos, I. J., Carvalho, I. R., Cesar, L., Loro, M. V., Port, E. D., Stasiak, G., Maciel, D. G., Lopes, F., & Carioli, G. (2023). Agronomic performance of wheat genotypes and the use of nitrogen doses. *Agronomy Science and Biotechnology, 9*, 1–10. https://doi.org/10.33158/ASB.r193.v9.2023

Silva-Lobo, V., Filippi, M. C. C., Silva, G. B., Venancio, W. L., & Prabhu, A. S. (2012). Relação entre o teor de clorofila nas folhas e a severidade de brusone nas panículas em arroz de terras altas. *Tropical Plant Pathology*, *371*, 83-87. https://doi.org/10.1590/S1982-56762012000100011

Soares, M. M., Santos Junior, H. C., Simões, M. G., Pazzin, D., & Silva, L. J. (2015). Water and saline stress in soybean seeds classified in different sizes. *Pesquisa Agropecuária Tropical, 45*, 370-378. DOI:10.1590/1983-40632015v4535357

Szareski, V. J., Carvalho, I. R., Kehl, K., Pelegrin, A. J., Nardino, M., Demari, G. H., Barbosa, M. H., Lautenchleger, F., Smaniotto, D., Aumonde, T. Z., Pedo, T., & Souza, V. Q. (2018). Interrelations of Characters and Multivariate Analysis in Corn. *Journal of Agricultural Science*, *10*(2), 187-194. https://doi.org/10.5539/jas.v10n2p187

Szareski, V. J., Carvalho, I. R., Nardino, M., Demari, G. H., Bahry, C. A., Kehl, K., Pedo, T., Zimmer, P. D., Souza, V. Q., & Aumonde, T. Z. (2016). Phenotype stability of soybean genotypes for characters related to the physiological quality of seeds produced under different environmentall conditions. *Australian Journal of Basic and Applied Sciences*, *10*(15), 279-289.

Szareski, V. J., Ferrari, M., Nardino, M., Carvalho, IR., Pelegrin, A. J., Demari, G. H., Follmann, D. N., Meira, D., Meier, C., & Souza, V. Q. (2017). Performance de fertilizantes foliares e correlações lineares em componentes do rendimento da soja. *Revista Univap*, *22*(40), 443.

Troyjack, C., Pimentel, J. R., Dubal, I. T. P., Escalera, R. A. V., Jaques, L. A., Koch, F., Monteiro, M. A., Demari, G. H., Szareski, V. J., Carvalho, I. R., Shuch, L. O. B., Aumonde, T. Z., & Pedo, T. (2018). Nitrogen fertilization on maize sowing: plant growth and seed vigor. *American Journal of Plant Sciences*, *9*, 83-97. https://doi.org/10.4236/ajps.2018.91008

Vazquez, G. H., Orivaldo, A. R. F., Sargi, B. A., & Pessoa, A. C. O. (2012). Influence of corn seed size and shape on plant development and grain yield. *Bioscience Journal*, *28*, 16-24.

Zucareli, C., Brzezinski, C. R., Guiscem, J. M., Henning, F. A., Nakagawa, J.
2014. Physiological quality of sweet corn seed classified by thickness and width. *Pesquisa Agropecuária Tropical*, *44*, 71-78.