Australian Journal of Crop Science AJCS
AJCS 12(12):1882-1889 (2018) ISSN:1835-2707
doi: 10.21475/ajcs.18.12.12.p1165

Respiratory activity and physiological performance of maize seeds classified according to their shapes and sizes

Lucian Alex dos Santos*[1], Carolina Cipriano Pinto[1,] Vinícius Jardel Szareski[1], Ivan Ricardo Carvalho[1], Felipe Koch[1], João Roberto Pimentel[1], Cristian Troyjack[1], Ítala Thaísa Padilha Dubal[1],Fernanda Reolon[2], Tiago Corazza da Rosa[1], Ana Karina do Carmo Ferreira dos Santos[1], Tiago Pedó[3], Emanuela Garbin Martinazzo, Dario Munt de Moraes[3],Luis Osmar Braga Schuch[3], Francisco Amaral Villela[3], Tiago Zanatta Aumonde[3]

[1]Universidade Federal de Pelotas, CEP 96010-610, Capão do Leão, RS, Brazil
[2]Universidade Federal do Rio Grande, Instituto de Ciências Biológicas, Rio Grande, RS, Brazil

***Corresponding author: lucian.agronomo@gmail.com**

Abstract

The objective of this work was to evaluate the influence of seed size and shape on physiological performance and respiration, as well as to establish the relationship between physiological quality and respiratory activity of maize seeds. For studying the influence of size and shape of the different seed fractions, the following analyzes were performed: weight of one thousand seeds, germination, first germination counting, germination speed index, total seedlings dry mass, electric conductivity, cold test without soil, seeds respiratory activity, seedling emergence and emergency speed index.The data were submitted to analysis of variance, the variables were compared by the Tukey test. Pearson's correlation test was performed between seed shapes and sizes, and the attributes of physiological quality. The small flat seeds from genotype "A" present higher physiological quality than large flat, large round and small round seeds. Whereas, for genotype "B", seeds with the highest physiological quality are the flat shapes, regardless their size. Respiratory activity in both genotypes was not sensitive for detecting differences of vigor between different sizes and shapes. There is significant correlation between large flat seeds, as well as between small flats and large rounds and small seeds with germination speed index. Similarly, there is correlation between the different shapes and sizes with electrical conductivity.

Keywords: Physiological potential, seed production, vigor, *Zea mays* L.
Abbreviation: WTS_weight of one thousand seeds; G_germination; FC_first germination; GSI_germination speed index; CT_cold test; CO2_respiratory activity; EC_electric conductivity; LR_large round; SR_small round;LF_large flat; SF_small flat.

Introduction

Maize is one of the most important crops in Brazil, with area and yield of 15.92 million hectares and 4.17 t ha^{-1}, respectively, in the 15/16 growing season (Conab, 2016). Maize grains are used as raw material in the industry, as well as *in natura* or processed food for both human and animal consumption (Sousa et al., 2012; Carvalho et al., 2016). Therefore, maize seeds are classified according to their size and shapes (Andrade et al., 1997). This is necessary because maize seeds from a same earhave different shapes and sizes. Seeds from the ear´s base are round and large, those from ear´s apex are round and small, while those from the center-apex are flattened and small and those from the center-base are flat and large. According to Costa et al. (2010), ear wrapping is an important factor regarding the physiological and sanitary quality of seeds, as the spikes poorly wrapped tend to present greater exposure of the seeds located at the apex to environmental factors, such as high precipitation, which mayincrease seed deterioration.

The use of high physiological quality seeds is essential to obtain a suitable plant stand, and thus to establish high productive fields. Plant stand may be influenced by several factors, such as seed vigor, physical characteristics as size and shape, ensuring an adequate seed distribution in the sowing line (Sulewska et al., 2014; Carvalho et al., 2015; Szareski et al., 2016;Dellagostin et al., 2016;Nardino et al., 2016; Szareski et al., 2018).

According to Stumm et al. (2016), maize hybrid seeds with different shapes and sizes present distinct physiological quality. This information corroborates with that observed by Carneiro et al. (2003), where seeds of flat and larger size showed higher germination and vigorvalues. Similarly, Zucareli et al. (2014), observed that wider and thicker seeds presented greater vigor, compared to seeds with other sizes and formats studied.

Respiration is a process that involves several oxidation-reduction reactions, which is influenced by the seeds deterioration degree (Kerbauy, 2012). It may be evaluated by the Pettenkofer method, as performed for small bean (Aumonde et al., 2012) and rice (Marini et al., 2013).

The intensification of deterioration modifies the physiological potential of seeds from different fractions of the same ear; therefore, it is important to study the influence of size and shape of these species' perpetuation units on their initial performance, especially when using vigor tests, becausevigor reflects in results highly correlated to the conditions of seed production fields (Aisenberg et al., 2016; Szareski et al., 2016).

Therefore, the objective of this work was to evaluate the influence of seed size and shape on physiological performance and respiration, as well as to establish the relationship between physiological quality and respiratory activity of maize seeds.

Results and discussion

According to the results obtained in this study, it was observed that genotype "A" presented no significant differences between seed shapes and sizes and the first germination counting, total dry mass, respiratory activity and seedling emergence, while for genotype "B", the shapes and sizes of maize seeds did not differ in the cold test, respiratory activity, and seedling emergence (Tables 1 and 2).

When evaluating the weight of one thousand seeds in both "A" and "B" maize genotypes, it was observed that large round seeds presented superior weight of one thousand seeds, compared to large flats, small rounds and small flats, respectively (Table 1). These data corroborate with those obtained by Zucareli et al. (2014), who evaluated seed quality of two maize cultivars as function of thickness and width, observed that there is an increase in seed mass as seed width increases.

The process of seed formation involves fertilization, deposition of reserves and dehydration (Bewley and Black, 2013). In maize ears, seeds from the base are formed first than those closest to its apex, thus, there is a difference in the amount of assimilates received by each fraction of seeds within a same spike (Shieh and Mcdonald, 1982). The larger weight of one thousand seeds reports the greater amount of reserves in these seeds, what may be reflected in a superior physiological performance, especially in terms of vigor. According to Carvalho and Nakagawa (2012), heavier seeds of the same species have greater potential of being more vigorous than seeds of less density, as consequence, plants from higher density seeds are better developed.

For genotype "A", when comparing the different seeds sizes and shapes, a significant difference was observed for the germination data (Table 1). The large flat seeds, as well as the small flats, had superior germination results compared to large round seeds, however, small round seeds did not differentiate from the others. Similarly, for genotype "B", large flat seeds presented higher germination values than large round and small round seeds. These results corroborate with those observed by Carneiro et al. (2003) where popcorn seeds of flat shape and larger sizes showed higher germination percentage. However, seed size and shape, in general, should not affect germination, only seed vigor (Carvalho and Nakagawa, 2012). However, in the present study, even with significant difference of the means test, the germination values were high (≥97%) in both genotypes and for all sizes and shapes, indicating high quality.

Regarding the first germination counting, seeds of genotype "A" did not show germination differences between sizes and shapes evaluated, while for genotype "B", large flat and small flat seeds, as well as small round seeds were higher than the large and round ones (Table 1). These results agree with those observed by Zucareli et al. (2014), where the germination of sweet corn seeds in the first counting varied according to the genotype, however, these authors pointed out that seeds from the genotype BR-401 presented higher vigor without classification, while for genotype BR-402, seeds of flat shape showed higher vigor, whereas in this work only the large round seeds had lower vigor than the others.

The large round seeds are the first to be formed, therefore, these seeds have longer time to develop than the others, and depending on the conditions in which they are exposed, the process of deterioration might be accelerated, decreasing their vigor (Shieh and Mcdonald, 1982; Marcandalli et al., 2011).

When evaluating the germination speed index, seeds of genotype "A", when small round and small flat, presented higher results for this variable, compared to large flat and large round seeds, respectively (Table 1). While for seeds of genotype "B", the highest germination speed index occurred in small flat, large flat, small round and large round seeds, respectively.

The germination speed index keeps high relation with seed vigor (Peske et al., 2012). The highest germination speed index indicates a higher number of germinated seeds per unit of time; therefore, seeds with greater vigor tend to present higher values of this index (Nakagawa, 1999).

For genotype "A" when comparing the different seed sizes and formats, significant difference was observed in the cold test (Table 1). Large flat seeds, as well as small flats showed greater vigor compared to large round seeds, however, small round seeds did not differentiate in relation to large round seeds. Regarding genotype "B", there were no differences in vigor by the cold test between sizes and shapes evaluated, demonstrating that seed vigor varies according to the genotype. Sulewska et al. (2014) observed that small seeds showed higher germination in the cold test than larger seeds.

In the cold test, seeds are submitted to adverse conditions of low temperature, humidity and consequently pathogenic action, therefore, those seeds with higher vigor tend to present a higher percentage of germination than lower vigor seeds (Cícero and Vieira, 1994).

In general, and for genotype "A", in the electrical conductivity test, large seeds presented higher electrolyte extravasation than small seeds. For genotype "B", the small flat seeds presented higher electrical conductivity values (Table 2). Seeds electric conductivity is related to their vigor, since this test is based on the

Table 1. Weight of one thousand seeds (WTS), germination (G), first germination counting (FC), germination speed index (GSI), cold test (CT) and respiratory activity (CO2) of seeds with different shapes and sizes from two maize genotypes.

		WTS	G	FC	GSI	CT	CO_2
Gen	Shape	(g)	--(%)--	--(%)--	-----	--(%)--	$\mu g co_2 g^{-1}$
A	LR	366.17 a	97 b	96 a	20.33 c	97 b	2.47 a
A	SR	253.33 c	98 ab	98 a	22.55 a	98 ab	2.69 a
A	LF	314.74 b	99 a	98 a	21.20 b	99 a	2.56 a
A	SF	229.32 d	99 a	97 a	22.79 a	99 a	2.58 a
CV (%)		1.18	0.91	1.28	1.78	0.73	11.63
B	LR	350.84 a	97 b	91 b	17.10 c	97 a	2.32 a
B	SR	266.90 c	97 b	97 a	19.54 b	98 a	2.45 a
B	LF	317.35 b	99 a	96 a	20.54 b	99 a	2.46 a
B	SF	235.26 d	99 a	98 a	21.62 a	98 a	2.64 a
CV (%)		1.07	0.70	1.18	2.40	1.13	16.02

* Means followed by the same lowercase letter in the column do not differ from each other by the Tukey test at 5% probability. G = genotype; S = shape; LR = Large round; SR = small round; LF = Large flat; SF = Small flat; CV (%) = coefficient of variation.

Table 2. Electrical conductivity after 3 (EC 3h); 6 (EC 6h) and 24 hours (EC 24h) of imbibition, shoot and root length, determined from seeds with different shapes and sizes from two maize genotypes.

		EC 3h	EC 6h	EC 24h	W_t	E	IVE
Genotype	S	$\mu S \cdot m^{-1} \cdot g^{-1}$	$\mu S \cdot m^{-1} \cdot g^{-1}$	$\mu S \cdot m^{-1} \cdot g^{-1}$	-(mg)-	-(%)-	-----
A	LR	12.00 a	13.9 a	22.88 a	0.0883 a	96 a	9,41 ab
A	SR	8.21 c	9.95 b	20.47 ab	0.0848 a	97 a	9,45 ab
A	LF	11.58 a	13.26 a	20.63 ab	0.0893 a	97 a	9,31 b
A	SF	9.27 b	10.85 b	18.87 b	0.0817 a	97 a	9,66 a
CV (%)		4,59	4.87	6.54	5.03	1.89	1.19
B	LR	5.12 b	6.44 b	12.22 b	0.0952 ab	94 a	8,44 b
B	SR	4.22 c	5.78 c	12.73 b	0.0897 b	96 a	9,12 a
B	LF	5.62 b	6.76 b	11.39 b	0.1081 a	98 a	9,54 a
B	SF	6.20 a	7.76 a	15.07 a	0.0865 b	95 a	9,07 a
CV (%)		4,96	4.20	7.06	7.24	3.23	2.53

* Means followed by the same lowercase letter in the column do not differ from each other by the Tukey test at 5% probability. G = genotype; S = shape; LR = Large round; SR = small round; LF = Large flat; SF = Small flat; CV (%) = coefficient of variation.

Table 3. Pearson correlation coefficients (r) between the first germination counting (FC), emergency (E%), cold test (CT) and germination speed index (GSI) and different fractions of maize seeds (shapes and sizes).

		E	E	E	E	CT	CT	CT	CT	GSI	GSI	GSI	GSI
		LF	SF	LR	SR	LF	SF	LR	SR	LF	SF	LR	SR
FC	SF	0.61^{ns}	0.08^{ns}	0.24^{ns}	-0.08^{ns}	0.60^{ns}	-0.81*	0.75*	0.22^{ns}	-0.39^{ns}	-0.43^{ns}	-0.63^{ns}	-0.57^{ns}
FC	LR		0.50^{ns}	0.36^{ns}	0.38^{ns}	-0.53^{ns}	0.84*	-0.49^{ns}	-0.40^{ns}	0.64^{ns}	0.81*	0.92*	0.94*
FC	SR			0.58^{ns}	0.73*	-0.09^{ns}	0.59^{ns}	-0.25^{ns}	-0.24^{ns}	0.59^{ns}	0.85*	0.79*	0.73*
E	LF				0.00^{ns}	-0.42^{ns}	-0.39^{ns}	0.75*	0.35^{ns}	0.08^{ns}	-0.31^{ns}	-0.41^{ns}	-0.23^{ns}
E	LR					0.15^{ns}	0.01^{ns}	-0.16^{ns}	0.03^{ns}	-0.01^{ns}	0.31^{ns}	0.44^{ns}	0.38^{ns}
E	SR						0.44^{ns}	0.00^{ns}	-0.09^{ns}	0.30^{ns}	0.35^{ns}	0.35^{ns}	0.38^{ns}
CT	LF							0.75*	0.76*	-0.02^{ns}	-0.39^{ns}	-0.37^{ns}	-0.35^{ns}
CT	SF								-0.36^{ns}	0.54^{ns}	0.59^{ns}	0.81*	0.85*
CT	SR									0.22^{ns}	-0.35^{ns}	-0.14^{ns}	-0.12^{ns}
GSI	LF										0.73*	0.70^{ns}	0.71*
GSI	SF											0.80*	0.71*
GSI	LR												0.96*

* significant linear correlation at 5% probability; ^{ns} non-significant linear correlation. LR = Large Round Seed; SR = small round seed; LF = Large flat Seed; SF = small flat seed.

Table 4. Pearson correlation coefficients (r) between the first germination counting (FC), emergency (E%), cold test (CT), germination speed index (GSI), electrical conductivity with soaking period of 3, 6 and 24h, (C3h, C6h and C24h), and the respiratory activity (CO2) of maize seeds with different sizes and shapes.

		C3h	C3h	C3h	C3h	C6h	C6h	C6h	C6h	C24h	C24h	C24h	C24h	CO_2	CO_2
		LF	SF	LR	SR	LF	SF	LR	SR	LF	SF	LR	SR	LR	SR
FC	LR	0.92*	0.92*	0.93*	0.93*	0.93*	0.92*	0.93*	0.93*	0.93*	0.90*	0.94*	0.92*	0.22^{ns}	0.33^{ns}
FC	SR	0.74*	0.76*	0.77*	0.76*	0.77*	0.78*	0.77*	0.78*	0.78*	0.75*	0.77*	0.75*	0.28^{ns}	0.42^{ns}
E	LF	-0.39^{ns}	-0.41^{ns}	-0.37^{ns}	-0.35^{ns}	-0.38^{ns}	-0.43^{ns}	-0.37^{ns}	-0.37^{ns}	-0.37^{ns}	-0.46^{ns}	-0.36^{ns}	-0.37^{ns}	-0.66^{ns}	-0.87*
E	LR	0.40^{ns}	0.39^{ns}	0.42^{ns}	0.41^{ns}	0.41^{ns}	0.43^{ns}	0.43^{ns}	0.44^{ns}	0.41^{ns}	0.40^{ns}	0.42^{ns}	0.37^{ns}	-0.18^{ns}	-0.01^{ns}
E	LR	0.32^{ns}	0.33^{ns}	0.36^{ns}	0.33^{ns}	0.35^{ns}	0.34^{ns}	0.36^{ns}	0.36^{ns}	0.35^{ns}	0.28^{ns}	0.37^{ns}	0.33^{ns}	0.40^{ns}	0.33^{ns}
CT	SF	0.84*	0.84*	0.83*	0.82*	0.84*	0.82*	0.84*	0.82*	0.83*	0.81*	0.84*	0.83*	0.60^{ns}	0.61^{ns}
CT	LR	-0.53^{ns}	-0.51^{ns}	-0.50^{ns}	-0.49^{ns}	-0.50^{ns}	-0.53^{ns}	-0.50^{ns}	-0.49^{ns}	-0.50^{ns}	-0.61^{ns}	-0.50^{ns}	-0.48^{ns}	-0.40^{ns}	-0.65^{ns}
GSI	LF	0.69^{ns}	0.71*	0.71*	0.71*	0.71*	0.69^{ns}	0.69^{ns}	0.70^{ns}	0.71*	0.64^{ns}	0.69^{ns}	0.73*	0.15^{ns}	0.11^{ns}
GSI	SF	0.75*	0.78*	0.78*	0.78*	0.78*	0.79*	0.77*	0.78*	0.79*	0.79*	0.76*	0.78*	0.21^{ns}	0.40^{ns}
GSI	LR	0.99*	0.99*	0.99*	0.99*	0.99*	0.99*	0.99*	0.99*	0.99*	0.98*	0.99*	0.99*	0.31^{ns}	0.44^{ns}
GSI	SR	0.97*	0.97*	0.98*	0.98*	0.98*	0.96*	0.98*	0.98*	0.97*	0.93*	0.98*	0.97*	0.26^{ns}	0.31^{ns}

* significant linear correlation at 5% probability; ^{ns} non-significant linear correlation. LR = Large Round Seed; SR = small round seed; LF = Large flat Seed; SF = small flat seed.

Table 5. Pearson correlation coefficients (r) relating the electrical conductivity with soaking period of 3, 6 and 24 h (C3h, C6h and C24h), and the respiratory activity (CO2) of maize seeds with different sizes and shapes.

		C3h	C3h	C6h	C6h	C6h	C6h	C24h	C24h	C24h	C24h	CO_2	CO_2	CO_2
		LR	SR	LF	SF	LR	SR	LF	SF	LR	SR	SF	LR	SR
C3h	LF	0.99*	0.99*	0.99*	0.99*	0.99*	0.99*	0.99*	0.98*	0.99*	0.99*	-0.11^{ns}	0.31^{ns}	0.43^{ns}
C3h	SF		0.99*	0.99*	0.99*	0.99*	0.99*	0.99*	0.97*	0.99*	0.99*	-0.12^{ns}	0.35^{ns}	0.46^{ns}
C3h	LR			0.99*	0.99*	0.99*	0.99*	0.99*	0.97*	0.99*	0.99*	-0.14^{ns}	0.31^{ns}	0.42^{ns}
C3h	SR				0.99*	0.99*	0.99*	0.99*	0.98*	0.99*	0.99*	-0.14^{ns}	0.28^{ns}	0.39^{ns}
C6h	LF					0.99*	0.99*	0.99*	0.97*	0.99*	0.99*	-0.14^{ns}	0.32^{ns}	0.42^{ns}
C6h	SF						0.99*	0.99*	0.98*	0.99*	0.99*	-0.09^{ns}	0.33^{ns}	0.46^{ns}
C6h	LR							0.99*	0.97*	0.99*	0.99*	-0.14^{ns}	0.31^{ns}	0.42^{ns}
C6h	SR								0.97*	0.99*	0.99*	-0.14^{ns}	0.29^{ns}	0.41^{ns}
C24h	LF									0.99*	0.99*	-0.12^{ns}	0.30^{ns}	0.42^{ns}
C24h	SF										0.97*	0.04^{ns}	0.28^{ns}	0.46^{ns}
C24h	LR											-0.15^{ns}	0.31^{ns}	0.41^{ns}
CO2	LF												0.28^{ns}	0.49^{ns}
CO2	LR													0.91*

* 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.

evaluation of cell membranes integrity, that is, it measures the deterioration of the seeds. Therefore, the better the membranes integrity, lower will be the electrolyte release to the incubation medium and consequently, lower will be the electrical conductivity value and higher the seed vigor (Vieira and Krzyzanowski, 1999; Ribeiro et al., 2009; Zimmer et al., 2016).

Regarding the total dry mass of seedlings originated from genotype "A", it was observed no significant differences for seeds sizes and shapes (Table 2). However, for genotype "B", considering absolute values, large flat seeds originated seedlings with higher total dry mass, however, they were statistically similar to those from large round seeds, while the total dry mass of seedlings originated from small flat seeds and small round were inferior, not differing between themselves, indicating less vigor. Dode et al. (2016), evaluating the efficiency of Pettenkofer´s method to determine respiratory activity of wheat seed lots with different vigor levels, observed that seedlings with the highest total mass were those originated from seeds with higher vigor. In this sense, it should be emphasized that larger seeds tend to originate larger seedlings compared to those from smaller seeds (Stumm et al., 2016).

In the emergency test, no significant differences were observed, in terms of vigor, for seedlings originated from two genotypes regardless size and shape (Table 2). These data corroborate with those observed by Zucareli et al. (2014), that studying seed physiological quality of two maize cultivars, did not identify significant differences regarding seedlings emergence at field. Similar results were observed by Sangoi et al. (2004), who studied the influence of seed size, sowing depth and sowing time on the emergence and initial growth of maize, observed that seed size did not affect the emergence percentage 10 days after sowing.

The emergence speed index of genotype "A" from small flat seeds presented higher emergence speed, indicating that they had higher vigor than the others, while those from other sizes and shapes did not differ among themselves (Table 2). However, for genotype "B", the seedlings from large round seeds presented lower emergence speed than the others, and consequently, less vigor.

The emergence speed index is a measure of seed vigor, with the advantage of being carried out in conditions closer to the growing field. The higher emergence speed indexes indicate the greater vigor of the seeds, which is related to efficiency in reorganizing cell membrane system, hydrolysis and metabolization of reserves, as well as its use by the embryo during growth resumption (Bewley et al., 2013; Marcos Filho, 2015; Kehl et al., 2016).

According to the results obtained in the present study, no significant correlation was verified between large flat, small flat, large round seeds with emergence, and between respiratory activity with large flat, small flat and large round seeds (Table 3, 4 and 5). According to Dancey and Reidi (2006), correlation coefficient values above 0.70 are considered high. Based on this, all significant correlations observed in the present study presented high correlation coefficient.

The large round seeds at the first germination counting correlated significantly and positively with large rounds, with coefficient of 0.77. For the cold test, there was a significant and positive correlation between large flat seeds with the round and large or round and small seeds (0.75 and 0.76, respectively). For the electrical conductivity and seeds of all sizes and formats, there was a similar behavior, whose correlation coefficients were ≥ 0.73 (Table 3 and 4).

Pearson's linear correlation analysis showed that there is association between sizes and shapes of maize seeds with physiological quality related variables. This may be verified from the first germination counting, germination speed index and electrical conductivity, which presented correlation coefficients between 0.71 and 0.99. As correlation coefficients get closer to 1, stronger is the degree of association between the variables analyzed, and lower is the variance of the residue (FigueiredoFilho and Silva Júnior, 2009; Nardino et al., 2016; Olivoto et al., 2016).

The results of this study enable to observe that, in general, flat seeds present superior vigor compared to the round ones. This probably occurred due to the fact that flat seeds originate in the middle portion of the ear, and are less affected by external conditions. Seeds from the base of the ear are more prone to fungus action, because there is greater accumulation of water compared to other parts of the ear, which may increase the water content in the seeds, and consequently, reduce their vigor. Thus, seeds located in the middle third and apex of the spike would be more protected and would present better performance in the field than seeds located at the ear base (Kikuti et al., 2003).

The accumulation of reserves is due to the translocation of photoassimilates from the plant to the seed after anthesis, thus, several factors affect seed vigor at field, such as environment conditions, plant vigor, availability of water and nutrients, light intensity and photoperiod, therefore, seed vigor reflects the interaction among these factors with the mother plant during seeds production (Carvalho and Nakagawa, 2012).

For the "A" genotype, the large round seeds presented greater weight of one thousand seeds, however, they evidenced lower germination and vigor in the germination speed index, in the cold test, in the electric conductivity, and in the root length. The small round seeds presented lower weight of a thousand seeds, however, it was possible to observe higher vigor in the speed of germination, electric conductivity of 3 and 6h, root length, compared to the large round seeds.

Regarding genotype "B", large round seeds had greater weight of one thousand seeds, however, less vigor in the first germination counting, germination speed index, electrical conductivity of 3 and 6h and the rate of emergency. The small round seeds presented lower weight of one thousand seeds, however, they presented greater vigor in the first germination counting, in the electric conductivity of 3 and 6h and in emergency speed index, compared to the large round seeds.

These results may be explained by the fact that round seeds are positioned at ear´s extremities, the large ones are the first to be formed and according to environment conditions, such as high temperature and humidity, the deterioration process may be accentuated, resulting in vigor reduction (Shieh and Mcdonald, 1982; Alencar et al., 2008). However, small round seeds are the last to be formed, and therefore, they have less time to accumulate reserves than large round seeds, tending to present lower vigor (Guedes et al., 2009; Henning et al., 2010).

Another important issue to be discussed is the relationship between ear sheathing and fungal infestation, because in inadequately wrapped ears, water can enter from the apex and increase fungi incidence, and consequently, seeds vigor will be adversely affected (Koehler, 1942; Mario et al., 2003; Giehl et al., 2011).

Materials and methods

Experimental Conditions

The work was conducted at the Seed Analysis Didactic Laboratory of the Department of Plant Science, Seed Science and Technology Graduate Program, Faculty of Agronomy Eliseu Maciel, and at the Seed Physiology Laboratory, Department of Plant Physiology, both of Federal University of Pelotas, Capão do Leão Campus - RS.

Seeds from two maize (*Zea mays* L.) genotypes produced in the same region were used. 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 flats (8,72mm width, 4.28mm thick and 10.10mm length), and small flats (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 rounds (6.65 mm width, 5.50 mm thick and 10.08 mm length), and in oblong hole sieve, classified as large flats (5.54 mm width, 4.84 mm thick and 10 , 12mm length) and small flats (7.10mm width, 4.61mm thick and 10.07mm length).

The treatments consisted of four seed fractions (Large Round, Small Round, Large Flat and Small Flat) separately evaluated for each genotype. The classified seeds were stored in a cold and dry chamber, with controlled temperature (15ºC) and relative humidity (60%) until all analyzes were carried out. For studying the influence of size and shape of the different seed fractions, the following analyzes were performed:

Evaluated traits

a) Weight of one thousand seeds: determined from eight replicates of 100 seeds from the "pure seed" portion of each genotype´s ear fraction, according to Brazil (2009). The results were expressed in grams.

b) Germination: the seeds were placed to germinate in B.O.D. germinating chamber at 25 ° C and 12-hour photoperiod, according to Brazil (2009), the results were expressed as percentage of normal seedlings.

c) First germination counting: it was carried out together with the germination test, evaluating the percentage of normal seedlings, at four days after sowing (Brazil, 2009).

d) Germination speed index: it was jointly conducted to the germination test, following the recommendations of Brazil (2009). Daily germination countingwas carried out until the stabilization of germination (minimum root protrusion of 3 to 4 mm). The index was calculated according to the equation proposed by Maguire (1962).

e) Total seedlings dry mass: seedswere placed to germinate on three germitest paper sheets, moistened 2.5 times their dry weight, five subsamples of 15 seeds per ear fraction of each genotype. The rolls were arranged in a B.O.D. germination chamber at temperature of 25 °C. The evaluation was performed seven days after sowing, from four subsamples of 10 seedlings per treatment. The samples were placed in brown paper envelopes and submitted to drying in a forced air circulation oven at temperature of 70 ± 2ºC until constant mass. The total dry mass was determined on a precision scale and the results were expressed in milligrams of seedlings (mg $seedling^{-1}$).

f) Electric conductivity: five subsamples of 50 seeds were used, whose mass was previously determined in a precision scale. After the determination of their mass, seeds were placed in plastic cups containing 75mL of deionized water, and kept in B.O.D. germinator at 20 °C, with photoperiod of 12 hours. The electrical conductivity was determined after 3, 6 and 24 hours of imbibition using a digital conductivity meter. The results were expressed in $\mu S\ cm^{-1}\ g^{-1}$of seeds (Vieira and Krzyzanowski, 1999).

g) Cold test without soil: it was conducted with five subsamples of 50 seeds, on rolls of germitest paper moistened with distilled water 2.5 times the dry weight of the paper. After seeding, the rolls were placed in transparent polyethylene bags, sealed with adhesive tape and kept at 10 ° C for seven days (Cícero and Vieira, 1994). After this period, the rolls were removed from the polyethylene bags and transferred to a germinator at temperature of 25 ° C. After four days, the number of normal seedlings was determined (Brazil, 2009).

h) Seeds respiratory activity: it was determined through Pettenkofer method using 4g of seeds from each genotype´s ear fraction, which were placed separately to soak for 30 minutes. After that, seeds were placed in the storage flask for 30 minutes at 25 ° C, being collected 10mL aliquots of $BaCO_3$ solution in Erlenmeyer flask. Each sample received two drops of phenolphthalein, and posteriorly they were titrated with 0.1 N of hydrochloric acid (HCl). At the turning point, the volume of HCl spent in each aliquot was recorded, which was used to calculate the respiratory activity of the seeds (Mendes et al., 2009). The results were expressed in $\mu g\ CO_2\ g^{-1}$ of seeds h^{-1}.

i) Seedling emergence: five subsamples of 50 seeds were used. Seeding was carried out in nurseries, with soil classified as Red-yellow clay soil, with sandy-loam texture, belonging to the Pelotas-RS mapping unit. Irrigation was manually performed when necessary. Seed distribution occurred in lines with 3 cm depth, and the final evaluation was performed 21 days after sowing, by counting emerged seedlings. The results were expressed as percentage of emerged seedlings.

(j) Emergency speed index: it was conducted under the same conditions and jointly evaluated with emergency. The daily counting was carried out, from emergency beginning until the stabilization of the number of emerged seedlings. Emergency speed index was calculated through the equation of Maguire (1962). The experimental design was completely randomized, with four treatments and five replicates.

Statistical analysis

The data were submitted to analysis of variance, and when significant at 5% probability by the F test, the variables were compared by the Tukey test at 5% of probability. Pearson's correlation test was performed at 5% of probability between seed shapes and sizes, and the attributes of physiological quality.

Conclusion

The small flat seeds from genotype "A" present higher physiological quality than large flat, large round and small round seeds. Whereas, for genotype "B", seeds with the highest physiological quality are the flats, regardless their size. Respiratory activity in both genotypes was not sensitive for detecting differences of vigor between different sizes and shapes. There is significant correlation between large flat seeds, as well as between small flats and large rounds and small seeds with germination speed index. Similarly, there is correlation between the different shapes and sizes with electrical conductivity.

Acknowledgement

The authors wish to thank the National Council for Scientific and Technological Development (CNPq), and the Coordination for the Improvement of Higher Education Personnel (*CAPES*), for the support.

References

Aisenberg GR, Zimmer G, Koch F, Dellagostin SM, Szareski VJ, Carvalho IR, Nardino M, Souza VQ, Pedo T, Martinazzo EG, Villela FA, Aumonde TZ (2016) Biochemical performance, vigor and characteristics of initial growth of wheat plants under different sowing depths. Int J Curr Res. 8(8): 36704-36709.

Alencar ER De, Faroni LRD, LacerdaFilho AF De, Ferreira LG, Meneghitti MR (2008) Quality of soy bean grains stored under different conditions. Eng Na Agric. 16: 155-166.

Andrade RV, Andreoli C, Borba CS, Azevedo JT, Netto DAM, Oliveira AC (1997) Effect of seed size on field performance of two maize genotypes. Rev Bras De Sem. 19(1):62-65.

Aumonde TZ, Marini P, Moraes DM, Maia MS, Pedó T, Tillmann MAA, Villela FA (2012) Classification of vigor of small bean seeds by respiratory activity. Interciência.37 (1): 55-58.

Bewley JD, Black M (2013)*Seeds*: physiology of development, germination and dormancy. -3ª. Ed. Springer. 376p.

Brasil (2009) Ministry of Agriculture, Livestock and Food Supply.Rules for seed analysis. Brasília, DF: Mapa/ACS. 399p.

Carneiro V, Araújo EF, Miranda GV, Galvão JCC, Reis MS, David AMSS (2003) Threshing, size classification and storage on popcorn seeds quality. Rev Bras De Milho e Sorgo. 2 (1): 97-105.

Carvalho IR, Korcelski C, Peruzzo ST, Follmann DN, Nardino M, Souza VQ, Kulczynski SM, Caron BO (2015) Physiological effects attributed to cold test and addition of plant growth regulators in maize hybrids. Sci Plena. 11: 030201-1.

Carvalho IR, Souza VQ, Follmann DN, Nardino M, Pelegrin AJ, Ferrari M, KonflazVA, Lazzari R, Uczay J (2016) Silage production and bromatological constitution effects of corn hybrids in different environments. Rev Ciên Agrá. (Lisboa), 39: 242-250.

Carvalho NM,Nakagawa J (2012) Seeds: Science, technology and production. 5.ed. FUNEP. 590p.

Nardino M, Baretta D, Carvalho IR, Follmann DN, Konflanz VA, Souza VQ, OliveiraAC, Maia LC (2016). Characters of hybrid corn of the southern region of brazil. Rev Bras Biom. 34: 379-394.

Cícero SM, Vieira RD (1994) Teste de frio. In: Vieira RD, Carvalho NM.Vigor tests in seeds Jaboticabal: FUNEP, p.151-164.

Conab - National Supply Company (2016) - Brazilian Crop Assessment. Fifth assessment February 2016, vol. 3, n. 5. Available in: <http://www.conab.gov.br>. Access in: 10 Dez. 2016.

Costa RV Da, Casela CR, Costa LV.Cultivo do milho: doenças. Embrapa Milho e SorgoSistema de Produção, 1 Versão Eletrônica - 6 ª ed. 2010. Available at: http://www.cnpms.embrapa.br/publicacoes/milho_6_ed/doencas.htm. Access in: January 20th, 2017.

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

Dellagostin SM, Bernardi D, Nobrega LHP, Dellagostin DM, Carvalho IR, Demari GH, Szareski VJ, Nardino M, Lautencheger F, Souza VQ, Aumonde TZ, Pedo T, Zimmer PD (2016) Physiological parameters applied to the soybean seed storage techniques. Int J Curr Res. 8(11): 41523-41527.

Dode J, Almeida ADS, Deuner C, Borges CT,Meneghello GE,Villela FA,Moraes DM De (2016) Respiratory activity in wheat seeds as related to Physiological quality. Biosci J. 32 (5): 1246-1253.

FigueiredoFilho DB, Silva Júnior JA Da (2009) Unraveling the Mysteries of Pearson's Correlation Coefficient (r). Rev Polít Hoje. 18(1).

Giehl J, Reiniger LRS, Noal G, Deprá MS, Miranda F, Somavilla I (2011) Evaluation of the relationship between spine imputment and fungi incidence in cultivars of Creole corn. In: Cadernos de Agroecologia. 6(2): 1-5. Anais VII Congresso Brasileiro de Agroecologia – Fortaleza 2011.

Guedes RS, Alves EU, Gonçalves EP, Viana JS, Bruno R De LA, Colares PNQ (2009)Physiological response of Erythrina velutina Willd. seeds to accelerated aging. Semina: Ciên Agr. 30(2): 323-330.

Henning FA, Mertz LM, Jacob Junior EA, Machado RD, Fiss G, Zimmer PD (2010) chemical composition and reserve mobilization in soybean seeds with high and low vigor. Bragantia. 69(3): 727-734.

Kerbauy GB(2012) Fisiologia vegetal. – 2ª ed. Guanabara Koogan. 431p.

Kehl K, Kehl K, Szareski VJ, Carvalho IR, Nardino M, Demari GH, Rosa TC, Gutkoski LC, Pedo T, Aumonde TZ, Souza VQ, Zimmer PD, Meneghello GE (2016) Genotype environment interaction under industrial and physiological quality of wheat seeds. Int J Curr Res. 8(9): 38461-38468.

Kikuti ALP, Vasconcelos RC De, Marincek A, Fonseca AH (2003) Corn seed performance and their position on the ear. Ciên e Agrotec. 27(4):765-770.

Koehler B (1942) Natural mode of entrance of fungi into com ears and some symptoms that indicate infections. J Agric Res. 62: 421-443.

Maguire JD (1962) Speed of germination-aid in selection and evaluation for seedling emergence and vigour. Crop Sci. 2(1): 176-177.

Marcandalli LH, Lazarini E, Malaspina IC Reação de híbridos de milho à podridão branca da espiga. Rev Bras de Sem. 33(2): 241-250.

Marcos Filho J (2015) Physiology of cultivated crops.– 2ª ed. ABRATES.659p.

Marini P, Moraes CL, Larré CF, Lima MC, Moraes DM, Amarante L (2013) Indicatives of the loss of rice seed quality under different temperatures through the activity enzymatic and respiratory. Interciência. 38(1).

Mario JL Reis EM &Bonato ER (2003) Reaction of corn hybrids to white ear rot. Fitop Bras. 28(2): 155-158.

Mendes CR, Moraes DM, Lima MGS, Lopes NF (2009) Respiratory activity for the differentiation of vigor on soybean seeds lots. Rev Bras De Sem. 31(2):171-176.

Nakagawa J (1999) Performance tests based on seedling behavior. In: Vigor de sementes: conceitos e testes. Krzyzanowski FC, Vieira RD, França-Neto JB Brasília, ABRATES.

Nardino M, Baretta D, Carvalho IR., Follmann DN, Konflaz VA, Souza VQ, Oliveira AC, Maia LC (2016) Phenotypical, genetic and environmental correlations between. Rev Bras De Biom. 34(3): 379-394.

Nardino M, Baretta D, Carvalho IR, Olivoto T, Pelegrin AJ, Ferrari M, Szareski VJ, Konflaz VA, Caron BO, Schmidt D, Barros WS, Souza VQ (2016) REML / BLUP in analysisofpre-commercialsimplemaizehybrid. Int J Curr Res. 8: 37008-37013.

Olivoto T, Nardino M, Carvalho IR, Follmann DN, Szareski VJ, Ferrari M, Pelegrin AJ, Souza VQ (2016) Pearson correlation coefficients and accuracy of path analysis used in maize breeding: A critical review. Int J Curr Res. 8(9): 37787-37795.

Peske ST, Villela FA, Meneghello GE (2012)Seeds: scientific and technological foundations. – 3ª ed. Pelotas: Editora e Gráfica da UFPel.573 p.

Ribeiro DM, Bragança SM, Goneli ALD, Dias DCFS, Alvarenga EM (2009) Electrical conductivity test for vigor evaluation of popcorn seeds (Zea mays L). Rev Ceres. 56(6): 772-776.

Sangoi L, Almeida ML, HornD, Bianchet P, Gracietti MA, Schmitt A, Schweitzer C (2004) Seed size, sowing depth and maize initial growth at two sowing dates. Rev. Bras. deMilho e Sorgo. 3(3): 370-380.

Shieh WJ, Mcdonald MB (1982) The influence of seed size, shape and treatment on inbred seed corn quality. Seed Sci Technol. 10(2): 307-313.

Sousa GG De, Marinho AB, Albuquerque AHPT, Viana VA, Azevedo BM De (2012) Initial growth of corn plants subjected to different concentrations of biofertilizer and irrigated with saline water. Rev Ciên Agron. 43(2): 237-245.

Stumm SBQ, Ludwig F, Schmitz JAK (2016) Physiological quality of maize seed depending on size, shape and treatment. Scientia Agraria Paranaensis. 15(2): 222-227.

Sulewska H, Smiatacz K, Szymanska G, Panasiewics K, Bandurska H, Glowickawoloszyn R (2014) Seed size on yield quantity and quality of maize (Zea mays L.) cultivated in South East Baltic region. Zemdirbyste Agriculture. 101(1): 35-40.

Szareski VJ, Carvalho IR, Nardino M, Demari GH, Pelegrin AJ, Ferrari M, Follmann DN, Rosa TC, Quadros ES, Pedo T, Zimmer PD, Souza VQ, Aumonde TZ (2016) Seeding rate andphysiologicalqualityof dual purposewheatseeds. Afr J Agric Res. 11(43): 4367-4374.

Szareski VJ, Carvalho IR, Kehl K, Pelegrin AJ, Nardino M, Demari GH, Barbosa MH, Lautenchleger F, Smaniotto D, Aumonde TZ, Pedo T, Souza VQ (2018) Interrelations of Characters and Multivariate Analysis in Corn. J Agric Sci. 10(2): 187-194.

Szareski VJ, Carvalho IR, Nardino M, Demari GH, Bahry CA, Kehl K, Pedo T, Zimmer PD, Souza VQ, Aumonde TZ (2016) Phenotype stability of soybean genotypes for characters related to the physiological quality of seeds produced under different environmental conditions. Aust J Basic Appl Sci. 10(15): 279-289.

Vieira RD, Krzyzanowski FC (199) Electrical Conductivity Test. In: Krzyzanowski FC, Vieira RD, FrançaNeto JB.Vigor de sementes: conceitos e testes. Brasília: ABRATES. 26p.

Zimmer G, Koch F, Carvalho IR, Szareski VJ, Demari GH, Nardino M, Follmann DN, Souza VQ, Aumonde TZ, Pedo T (2016) Seed quality and initial performance os seedlings of soybean produced off-season in Rio Grande do Sul, Brasil. Int J Curr Res. 8(10): 40325-40329.

Zucareli C, Brzezinski CR, Guiscem JM., Henning FA, Nakagawa J (2014) Physiological quality of sweet corn seed classified by thickness and width. Pesq Agropec Trop.44(1): 71-78.