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MAIZE SEEDING RATE: REPLACING GERMINATION WITH FIELD EMERGENCE AND ACCELERATED AGING

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Abstract – The objective of this study was to evaluate the suitability of replacing the germination test in the calculation of seed quantity with the results of the field emergence and accelerated aging tests. The experiment was conducted using a randomized block design in a 2x5 factorial scheme: two levels of seed vigor and five levels of seeding safety margin (0, 5, 10, 15 and 20%) using untreated seeds of the hybrid Defender Viptera 3. The evaluated parameters were percentage of germination, field emergence and accelerated aging. The analyzed variable, plant stand, was submitted to analysis of variance at the 5% significance level and, when significant, the results were submitted to the Mean Percentage Error statistical procedure to determine the degree of proximity between forecast and observed values of stand density. The results showed that, requiring a smaller safety margin, the results of field emergence and accelerated aging tests applied in the seeding rate calculation were more accurate than germination for stand density estimation. For so, nevertheless, they required larger amounts of seeds in sowing operation to reach the same stand density obtained with the use of germination test.

Keywords: Stand density, Physiological potential, Vigor, Mean percentage error.

TAXA DE SEMEADURA DO MILHO: SUBSTITUINDO A GERMINAÇÃO PELA EMERGÊNCIA E PELO ENVELHECIMENTO ACELERADO

Resumo - O objetivo deste trabalho foi avaliar a adequação da substituição do teste de germinação no cálculo da quantidade de sementes pelos resultados dos testes de emergência em campo e envelhecimento acelerado. O ensaio foi conduzido em delineamento de blocos casualizados em esquema fatorial 2x5: dois níveis de vigor e cinco níveis de margem de segurança na semeadura (0, 5, 10, 15 e 20%) utilizando sementes não tratadas do híbrido Defender Viptera 3. Os parâmetros avaliados foram: porcentagem de germinação, emergência em campo e envelhecimento acelerado. A variável analisada, o estande de plantas, foi submetida à análise de variância a 5% de probabilidade e, quando significativos, os resultados foram submetidos ao procedimento estatístico Mean Percentage Error a fim de determinar o grau de proximidade entre os valores previstos e observados de estande. Os resultados demonstraram que, exigindo uma menor margem de segurança, o emprego dos resultados dos testes de emergência em campo e envelhecimento acelerado no cálculo da taxa de semeadura demonstraram-se mais precisos que a germinação na previsão do estande. Para tal, entretanto, exigiram maiores quantidades de sementes na operação de semeadura para atingir o mesmo estande obtido com o emprego do teste de germinação.

Palavras-chave: estande, potencial fisiológico, vigor, erro percentual médio.

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Plant population density strongly impacts the grain yield in maize crops (Van Roekel and Coulter, 2011). Therefore, it is crucial to apply a proper calculation of the amount of seeds needed in the sowing operation in order to ensure high grain yield. In addition to 1000-grain weight and desired stand density, that calculation takes into account the germination potential of the seed lot, which is informed in the Official Seed Analysis Report, valid for 12 months (Ministry of Agriculture, Livestock and Food Supply - MAPA, 2013).

Germination is conducted under favorable conditions of temperature and moisture in order to enable the seed lot to express its maximum germination capacity, being such conditions rarely found in the field (Marcos-Filho, 2015). Since it presents high standardization with regard to execution and result interpretation, it certainly is the most widespread procedure for physiological potential evaluation in seed quality control (Bittencourt et al., 2012).

In most cases, however, the germination test overestimates the actual values of plant field emergence (Bertolin et al., 2011). For this reason, it is recommended to correct the seeding rate calculation using a safety margin about 10 to 20% higher, values that, in other words, imply that only 80 to 90% of the viable seeds obtained in the germination test are capable of overcoming the adversities of the crop establishment stage and generating a vigorous plant in the field (Pereira-Filho, 2015). In this regard, due to its lower sensitivity to capture metabolic changes in the beginning of the seed deterioration process, not all physiological quality attributes are identified by the germination test (Bertolin et al., 2011). Therefore, such condition justifies the application of vigor tests that, usually not under ideal conditions, measure the deterioration of a biochemical or physiological function of the seed (Marcos-Filho, 2015).

Two successful examples of vigor test applied in maize crop are the accelerated aging and field emergence tests, which have been routinely confirmed as having high precision to estimate the performance of a seed lot in field conditions (Baldini et al., 2018; Grzybowski et al., 2015). In this context, the objective of this study was to assess the suitability of replacing the germination test, in the formula to calculate the quantity of seeds, with the results of field emergence and accelerated aging tests.

Material and Methods

Material used consisted of untreated seeds of hybrid Defender Viptera 3, 2017 crop season, 20/64" round sieve, 1000 seed weight of 350g, with a germination result of 98% presented in the Seed Analysis Report. After the acquisition, seeds were submitted to tests of germination, field emergence and accelerated aging, as described below.

The germination test was conducted with eight replications of 50 seeds for each treatment. The seeds were placed to germinate on three sheets of Germitest® paper moistened with

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distilled water, in a proportion of 2.5 times the dry weight of the paper. Rolls were then prepared and placed in a Mangelsdorf-type germination chamber, regulated to maintain a constant temperature of 25ºC. Evaluation was conducted seven days after the test installation, calculating the percentage of normal seedlings, according to the criteria established in the Rules for Seed Analysis (Brasil, 2009).

The field emergence test was conducted with eight replications of 50 seeds. The seeds were distributed at a depth of 1.5 cm, in furrows of 1.0 m length and spaced 20 cm apart, with daily moistening. The counting of normal emerged seedlings was carried out 15 days after sowing (Nakagawa, 1999).

The accelerated aging test was conducted with eight subsamples of 50 seeds, following the methodology described by Krzyzanowski et al. (1991). They were submitted to a temperature of 41 ± 1ºC for 72 hours (Marcos-Filho, 1999) in water jacketed chamber (model 3015 VWR/ USA). After this period, the seeds were submitted to the germination test according to Brasil (2009). However, the evaluation was performed on the fifth day after the test installation.

From the seeds received, two lots of different vigor levels were obtained: the first lot, called ‘high vigor’, consisted of seeds whose results from germination, field emergence and accelerated aging were obtained after the lot acquisition. The second lot, called ‘low vigor’, was obtained by submitting part of the seeds from the ‘high vigor’ lot to a less extended accelerated aging of 24h, so as to reduce the physiological potential of the lot, but without precluding its trading potential (i.e., to ensure a minimum germination of 85%, according to MAPA, 2013). The results obtained were: i) high vigor: germination = 98%, field emergence = 90% and accelerated aging = 89%; ii) low vigor: germination = 89%, field emergence = 82% and accelerated aging = 79%.

Calculation of seed quantity and sowing

With the results for germination, field emergence and accelerated aging in hand, the quantity of seeds was calculated using the formula below.

$$Q = \frac{DP\,.PMS}{PN.MS}$$

Where Q = quantity of seeds (kg ha^{-1}), DP = desired density (number of viable seedlings m^{-2}), PMS = 1000 seed weight (grams), PN = % of normal seedlings in physiological quality tests (germination or accelerated aging or field emergence), and MS = additional % of seeds to achieve the desired stand density (safety margin).

Considering five safety margin levels (0, 5, 10, 15 and 20 %), testing took place at Fazenda Experimental de Iguatemi (23º25’S and 51º57’W, with average altitude of 540 m), an experimental farm area of the State University of Maringá (UEM), located in the city of Maringá, state of Paraná, Brazil. The predominant climate in the region is the Cfa type, humid mesothermal climate characterized by hot summer with abundant rainfall and dry winter, according to the Köppen climate classification (Caviglione et al., 2000). The history of the cultivation area is based on the succession of maize crops in summer with canola or wheat crops in winter. The soil in the experimental area is classified as dystroferric Red Argisol (EMBRAPA, 2018). Results of the chemical analysis in the 0-20 cm layer, before the experiment was implemented, were as follows: pH ($CaCl_2$) = 4.78, P (Mehlich^{-1}) = 4.18 mg dm^{-3}, H^{+}+Al^{3+} = 2.49 cmol$_c$ dm^{-3}, Al^{3+}= 1.05 cmol$_c$ dm^{-3}, K^{+} = 0.65 cmol$_c$ dm^{-3}, Ca^{2+} = 3.63 cmol$_c$ dm^{-3}, Mg^{2+} = 2.58 cmol$_c$ dm^{-3}, CTC = 9.35 cmol$_c$ dm^{-3}, and V = 73.39%. Regarding the particle size analysis for the same 0-20 cm layer, results were as follows: 14.20% of coarse sand; 37.3% of fine sand; 0.95% of silt; and 47.55% of clay. The average water content in the soil, in the range of 0 to 0.1 m, was of 32% one day before sowing, and the precipitation recorded at the local weather station, between the sowing operation and the day of the last evaluation, was of 45.32 mm.

In the sowing operation, at an average advance speed of 5 km h^{-1}, a SFIL pneumatic precision planter (model SS 800 Hy Tech) was used, with 7 row units for maize seeds spaced 0.9 m apart. The conventional sowing system was applied, with no irrigation, at a depth of 0.05 m, and with plots consisting of seven rows of 6 m. Just before sowing, the seeds were treated with metalaxyl-m 10 g L^{-1} + fludioxonil fungicide, applied in dose of 150 mL 100 kg^{-1} of seeds, and thiamethoxam insecticide, dose of 350 mL kg^{-1}.

Determination of initial stand density

In the V_3 stage (17 days after sowing), all seedlings from each experimental unit were counted and the result was extrapolated for the number of plants per hectare. The reason for the choice of the V_3 stage (Hanway, 1963) was because it is the moment that marks the beginning of the photosynthetic process, i.e., it represents the end of the phase when the seed is the primary source of nutrients, as well as the phase when all leaves and ears that the plant will produce are being formed (Pereira-Filho, 2015).

Design and Statistical Analysis

A randomized block design was used in a 2 x 5 factorial scheme: two levels of vigor and five levels of safety margin (0, 5, 10, 15 and 20%), with a total of 8 replications. Plant stand was the only variable analyzed. It was submitted to analysis of variance at the 5% significance level, using the R system of statistical analysis. When significant, instead of the average testing, the Mean Percentage Error statistical procedure (MPE) was applied in order to determine the degree of proximity between forecast and observed values of stand density. A positive value indicates that the actual value exceeded the estimated value, while negative values indicate opposite behavior. Myttenaere et al. (2016) mathematically describe the MPE as follows.

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$$MPE = \frac{100\%}{n}\sum_{t=1}^{n}\frac{at - ft}{at}$$

Where a_t is the actual value, f_t is the forecast, and *n* is the number of times for which the model was forecast. In the present work, the desired density (*ft*) was 60,000 viable seedlings per hectare in the V_3 stage, while a_t data were obtained through determination of the stand density. For comparison purposes only, the quantity of seeds obtained from seeding rate calculations is also presented.

Results and Discussion

The factors tested, vigor and safety margin levels, presented significant interactions for all variables analyzed. With regard to the calculation of seed quantity, in the high vigor lot, at 5% of safety margin, 24.50 and 24.77 kg of seeds per hectare were the quantities of seeds required to reach the stand density in the field emergence and accelerated aging tests, respectively, while in the germination test, this value was 23.57 kg of seeds per hectare at 10% of safety margin (Table 1).

Negative values of MPE were obtained up to 5% of safety margin, which indicates that, in these cases, regardless of the test applied, the actual initial stand density was lower than 60,000 plants ha^{-1} (Table 1). For the high vigor lot, the margins of 10 % for the germination test and 5% for the accelerated aging and field emergence tests represented the values as from which the desired stand density was reached or exceeded (positive MPE values), while for the low vigor seeds, this level was only reached as from 10, 15 and 20% for field emergence, accelerated aging and germination, respectively (Table 1).

From a practical point of view, the aforementioned results indicate that, for less vigorous seeds, a larger safety margin is necessary in order to obtain the minimum population of 60,000 viable seedlings ha^{-1}. However, regardless of the vigor level, a lower amplitude in MPE data was obtained for seeding calculation based on the field emergence test, which, unlike germination, assesses the percentage of seeds capable of originating normal seedlings in adverse conditions of climate and soil, thus providing a result that is closer to reality (Grzybowski et al., 2015). Nevertheless, even though accelerated aging and field emergence require a smaller safety margin to reach the desired stand density, larger quantities of seeds are needed in comparison with germination (Table 1).

With the exception of macroeconomic projections of agricultural yield, the use of statistical tools for precision measurement is still poorly disseminated in the study of agricultural operations, which justifies the absence of specific literature for the purpose of comparison with the results observed in this study. However, even though this is a statistical analysis with different purposes, the results found corroborate Baldini et al. (2018), Lovato et al. (2005), Noli et al. (2008),

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Table 1. Results of Mean Percentage Error-MPE (%) and quantity of seeds (kg ha-1), considering 0, 5, 10, 15 and 20% of safety margin in sowing using high vigor (H) and low vigor (L) seeds for tests of germination (G), field emergence (EM) and accelerated aging (AA) of the hybrid Defender Viptera 3, in non-irrigated experimental area.

Mean Percentage Error (%)										
G	-12.33	-18.67	-8.60	-12.71	1.50	-9.65	5.80	1.79	6.70	1.12
EM	- 6.21	-12.78	1.70	-6.65	2.56	1.33	6.80	5.56	9.40	8.10
AA	-8.34	-16.74	0.45	-9.43	2.34	-6.52	3.45	1.11	6.45	2.12
	0%		5%		10%		15%		20%	
	H	L	H	L	H	L	H	L	H	L
Quantity of seeds (kg ha^{-1})										
G	21.43	23.60	22.5	24.77	23.57	25.95	24.63	27.13	25.71	25.71
EM	23.33	25.61	24.50	26.89	25.66	28.17	26.83	29.45	28.00	30.73
AA	23.60	26.58	24.77	27.91	25.95	29.24	27.13	30.57	28.31	31.89

and Grzybowski et al. (2015), who indicated the existence of a high degree of association between field emergence and accelerated aging when studying Spearman or Pearson correlations in maize quality tests. The accelerated aging is indicated as a test of high efficiency for distinguishing vigor in seed lots also for other Poaceae species of agricultural importance, such as *Oryza sativa* (Tunes et al., 2012) and *Sorghum bicolor* (Soares et al., 2010).

Grzybowski et al. (2015) report that, from the producer's perspective, the accuracy of a physiological quality test is measured by its capacity to estimate the behavior of seed lots after sowing. In the present study, among the tests performed, field emergence, followed by accelerated aging, were the ones that provided more accurate information about the likely crop performance in the crop establishment stage, i.e., presented MPE values closer to zero (Table 1).

On the other hand, MPE values more distant from zero were obtained in the germination test. Such behavior is explained by the ideal conditions in which the test is conducted, which are rarely found in the field (Table 1). If, on the one hand, the conditions in which the test is performed allow standardization and reproducibility, on the other hand, the same conditions represent the greatest limitation of the germination test since they reduce the test sensitivity to identify the conservation status of seeds, mainly in the initial deterioration stages (Marcos-Filho, 2015).

Conclusions

Requiring a smaller safety margin, the results from field emergence and accelerated aging tests, applied in the seeding rate calculation, were more accurate than the germination to

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estimate stand density. However, they demanded larger quantities of seeds in the sowing operation to reach the same stand density obtained with application of the germination test.

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