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Viability equation to determine the longevity of fungicide-treated seeds of wheat stored in a conventional warehouse

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ABSTRACT. The objective of this research was to determine the deterioration rate of BRS 208 and CD 104 wheat cultivar seeds, treated with fungicides, by applying the viability equation. Seeds were stored in conventional warehouses in Mauá da Serra and Londrina, in the State of Paraná, Brazil. Four seed lots were divided into four replications, half being treated with Carboxin + Thiran and the other half taken as controls, without treatment, and these were stored for 300 days. The germination data were transformed into probit, and a straight line was adjusted between 0 and 30 days. The treated seed lot of cv. BRS 208 stored in Londrina gave seed deterioration rates varying from $0.8.10^{-3}$ to $1.3.10^{-3}$, not differing from the values given for the similar lot stored in Mauá da Serra, of $0.9.10^{-3}$.The deterioration rates of the treated seed of cv. CD 104 were $1.2.10^{-3}$ in Mauá da Serra and $2.0.10^{-3}$ in Londrina, which are greater than those values given for untreated seeds of $0.4.10^{-3}$ and $0.5.10^{-3}$.This model provides an effective approach to predict the untreated and treated seed longevity of wheat for the purpose of managing seeds.

Keywords: *Triticum aestivum* L., deterioration, storage, seed treatment, mathematic model.

RESUMO. Equação de viabilidade para determinar a longevidade de sementes de trigo tratadas com fungicida em armazém convencional. O objetivo deste trabalho foi aplicar a equação de viabilidade para determinar a taxa de deterioração e a longevidade das sementes de trigo, tratada com fungicida, das cultivares BRS 208 e CD 104, em armazenamento convencional, em Mauá da Serra e Londrina, PR. Quatro lotes de sementes foram divididos em quatro partes, sendo a metade tratada com fungicida Carboxim + Thiram, armazenados por 300 dias. Os dados de germinação foram transformados em probit e a declividade da reta foi calculada entre zero e 30 dias. Os lotes tratados, da cv BRS 208, armazenados em Londrina tiveram o coeficiente variando de $0,8.10^{-3}$ a $1,3.10^{-3}$, não diferenciando de Mauá da Serra, $0,9.10^{-3}$. A taxa de deterioração para a semente tratada da cv. CD 104 foi $1,2.10^{-3}$ em Mauá da Serra e $2,0.10^{-3}$ em Londrina, foi superior a $0,4.10^{-3}$ e $0,5.10^{-3}$ para sementes não-tratadas. O modelo prediz com acurácia a longevidade das sementes de trigo tratadas e não-tratadas.

Palavras-chave: *Triticum aestivum* L., deterioração, armazenamento, tratamento de semente, modelo matemático.

Introduction

There are many circumstances in which it is important to predict seed longevity as affected by environmental factors. Equations for predicting seed longevity under storage have been improved so that they now take into account variations within species and the quantitative relationships between seed longevity and initial quality, seed moisture content and storage temperature (ANDREOLI, 2004; ELLIS; ROBERTS, 1980; ROBERTS, 1960, 1972, 1986).

The accelerated-aging test has been used to estimate seed vigor and deterioration during the storage of different seed lots (DELOUCHE; BASKIN, 1973), however it does not take seed moisture and temperature into account. For this reason, mathematical models have been developed to predict seed quality during storage and to determine the seed deterioration rates of many species (ELLIS, 1988; ELLIS; ROBERTS, 1980, 1981; ELLIS et al., 1990; FABRIZIUS et al., 1999; ROBERTS, 1960, 1961, 1973; TANG et al., 1999, 2000; TEKRONY et al., 1993).

These models are relatively accurate in constant environments (i.e., constant seed moisture and temperature).A fast, simple and precise prediction of seed viability under open warehouse conditions would be of great value to seed producers (ANDREOLI, 2004), including wheat seed producers and growers.

Contamination by fungi can accelerate seed deterioration and raise the pathogenic infestation of the next crop; thus, seed chemical treatment of wheat and barley in the State of Paraná is recommended (ANTONIAZZI; DESCHAMPS, 2007; IAPAR, 2003; RODRIGUES et al., 2006) and is used in this report.

The objective of this search was to predict the deterioration changes of treated and untreated seeds of wheat in conventional storage facilities found in two locations, Mauá da Serra and Londrina, both in the State of Paraná.

Material and methods

Simplified equation - Three factors are of fundamental importance in controlling seed deterioration: initial quality, seed moisture and air temperature. Thus, the longevity of orthodox seeds is prolonged by a reduction in both moisture content and room temperature. The frequency of individual seeds dying over time in a population stored under constant conditions can be described by the normal distribution:

$$\frac{(p-\mu)2}{2\sigma 2}$$

$$y = \frac{1}{\sigma\sqrt{2\pi}} e \qquad (1)$$

where: y is the relative frequency of dead seeds occurring at time p, μ is the mean viability period (p_{50}) and σ is the standard deviation of the distribution of deaths in time. Thus, seed survival curves are cumulative normal distributions of negative slope, and they become straight lines when the viability percentage is transformed into probit (FINNEY, 1971). The spread of the distribution is proportional to the mean viability period (σ), that is:

$$\sigma = K\sigma.p50 \qquad (2)$$

where: K_σ is a species constant and P_{50} is the mean viability period. The relationship between moisture content, temperature and the mean viability period is described by the equation bellow:

$$\log p_{50} = K_v - C_1 m - C_2 t \qquad (3)$$

where: m is moisture content (per cent f. wt basis), t is temperature (°C) and K_v, C_1 and C_2 are constants. Thus, to predict the percentage viability after any period of storage, the four viability constants have to be known for a given seed lot.

Improved basic viability equation - Following these arguments, Ellis and Roberts (1980) proposed an improved seed viability equation that is applied to a wider range of storage conditions:

$$v = Ki - p/10Ke - Cwlog\ m - CHt - CQt\ 2 \qquad (4)$$

where: v is the seed viability in probit in any period (p) to the temperature combination (t) and humidity (m), the constants K_e. C_w, C_H and C_Q are specific to each species (independent of the genotype) and the seed quality, Ki, is the beginning quality and is seed lot-specific.

Simplified viability equation - Andreoli (2004) simplified the Ellis and Roberts equation and proposed a new model (5) that can be applied to open storage, as follows:

$$v = Ki - (1/\sigma)\,p \qquad (5)$$

where: v is the probit percentage germination at time p and for which Ki = v when p = 0. In addition, Figure 1 demonstrates that $(Vp - Vi)/p$, in which Vp is the probit viability at time p and for which Vi is the initial germination in probit and is a measure of the slope of the seed survival curve. Thus,

$$\frac{Vp - Vi}{p} = -(tg\beta) \qquad (6)$$

where: the slope tgβ of eqn.6 is a direct measure of the slope (1/σ) of the survival curves; therefore, tgβ is the seed deterioration rate under any storage condition, as expressed by the angular coefficient of the survival curve, as follows:

$$Vp = Vi - (tg\beta).p \qquad (7)$$

where: tgβ is the seed deterioration rate of each species. Neither genotype nor seed quality affect the slope (tgβ) or are dependent upon the warehouse's environmental conditions (ELLIS; ROBERTS, 1980; ROBERTS, 1973; ROBERTS; ABDALLA, 1968). Vi is specific for each seed lot and is the mean of the initial quality.

Since Vi is in fact the probit of the percentage viability at the beginning of the storage period (Figure 1), there is a need to estimate its value by carrying out a germination test at the start of the storage period.

Wheat seeds were grown in Mauá da Serra (23°54'00"S and 51°13'00"W, at 1,020 m above sea level) belonging to four wheat seeds lots, cv. BRS

208 and CD 104, harvested in 2003 with different initial seed qualities, and were bulked into 25 kg polypropylene bags. The selected lots were divided into four parts, half of them being treated with Carboxim + Thiran at 250 g i.a. 100 kg^{-1} of seed (IAPAR 2003). The bags were stored in Mauá da Serra and Londrina (23°23'00"S and 51°11'30"W, at 576 m above sea level) for a period of 300 days in conventional warehouses.

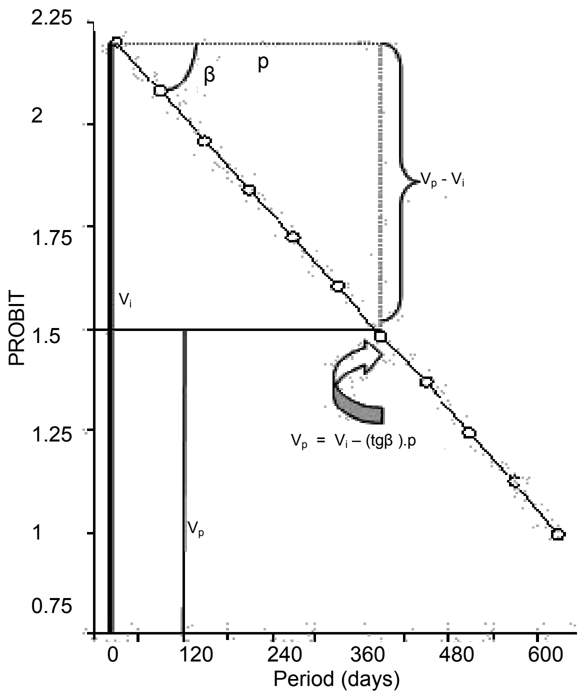

Figure 1. Diagram illustrating that the simplified equation of seed survival has a slope of tgβ (ANDREOLI, 2004).

At the start and after the periods of 30, 60, 90, 120, 180, 240 and 300 days, samples were collected at both locations on the same day, using an aluminum lid, and were taken to the laboratory for seed moisture content and germination test determinations.

During the storage period, the mean temperature (°C) and the relative humidity (%) were registered inside the warehouses (Figure 2a and b).

Seed Quality Evaluations - The moisture content of the seeds was assessed by the oven (model Fabbe-Primar at 105°C ± 1) method for 24 hours, using four repetitions of 25 g of each sample. The results were expressed in percentage according to the Seed Testing Analyses Rules (BRASIL, 1992).

Wheat seeds of each sample were divided into samples of 400 seeds distributed into eight sub-samples of 50 seeds for each storage period. The seeds were rolled into paper towel "Germitest" and placed into the germinator Mangelsdorf at 20 ± 1°C. Normal seedlings and dead seeds were counted every three and five days, as recommended by the Seed Testing Analyses Rules (BRASIL, 1992).

Statistical analysis - The germination data were transformed into probit and adjusted by eqn.7 to predict the wheat seed viability during warehouse storage. The seed deterioration rate (tgβ) for each location, cultivar and seed lot was determined utilizing the initial viability (time zero) and that after 30 days of storage ($Vi-V_{30}$). Then, the simplified equation proposed by Andreoli (2004) was applied to predict the germination loss during each storage period.

The statistical design consisted of completely random blocks with two replications. Regression analysis was performed during adjustment of the simplified equation model, calculating values of r^2 between the observed and the estimated data.

Results and discussion

The mean moisture content of treated wheat seeds during the entire storage period for the cv. BRS 208 and CD 104 lots was 11.62% for Mauá da Serra and 11.39% for Londrina, which did not differ from those values found in untreated seeds of 11.91% and 11.31%, respectively. The seed moisture content in Londrina was lower than that in Mauá da Serra, likely because of climatic conditions. Roberts (1960, 1972) and Sediyama et al. (1985), considering that seeds are hygroscopic, reported that seeds stored at lower relative humidities and temperatures have increased seed longevity.

In Figure 3a, the deterioration rate, tgβ, of untreated seeds for BRS 208 in Mauá da Serra was 0.4×10^{-3} ($r^2 = 0.82$), and likewise the rate for CD 104 in Londrina (Figure 3b) was 0.5×10^{-3} ($r^2 = 0.97$). These indices were significantly inferior to those of treated seeds (Figure 3a and b), indicating that the deterioration rate was higher in treated seeds. Despite the phytotoxicity of the treatment, the germination was kept over 96.8% for BRS 208 and over 95.6% for CD 104 after 180 days of storage. Similar results were observed by Krohn and Malavasi (2004), who tested soybean seeds treated with Carbendazin + Thiran at 100 g a.i. 100 kg^{-1} of seed.

For Mauá da Serra, the deterioration rate of BRS 208 treated seed was 0.9×10^{-3} ($r^2 = 0.98$). For Londrina, the seed lots of BRS 208 presented deterioration coefficients of 0.8×10^{-3} and 1.3 x

10^{-3}, both with $r^2 = 0.96$ (Figure 4a). Although the deterioration rate was similar for both seed lots, the longevity was higher for lot 2 in Mauá da Serra because of the higher initial quality. This is in agreement with the findings of Roberts (1972) and Ellis and Roberts (1980), although their models were developed for constant temperature and seed moisture.

The deterioration rate of CD 104 treated seeds (Figure 4b) was 1.2×10^{-3} ($r^2 = 0.91$) which is lower than the value found in Londrina of 2.0×10^{-3} ($r^2 = 0.97$). It was observed that the tgβ for BRS 208 and CD 104 (Figure 4a and b) was more affected in Londrina because of the climatic conditions. Andreoli (2004) obtained similar results studying soybean and corn seeds in Sete Lagoas and Brasilia, in agreement with the viability equation of Ellis and Roberts (1980).

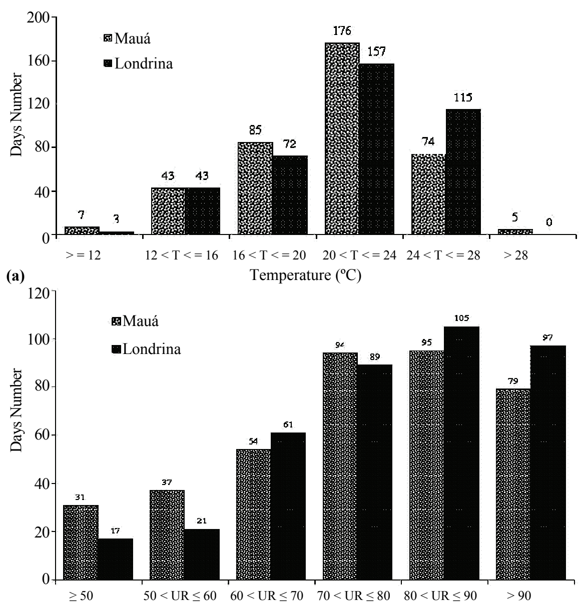

Figure 2. Number of days during the period from November 2003 to November 2004 falling into different classifications of (a) mean temperature (ºC) and (b) relative humidity (%) in Mauá da Serra and Londrina, Paraná State.

Considering that the germination test validation for wheat seed is 180 days, according to the Seed Production Guide (PARANÁ, 1986), it can be observed in Table 1 that the germination percent was maintained within the established standards for commercialization, for all seed lots (over 94%). Note also that the germination of fungicide-treated seeds stored for the same period dropped more than that for untreated seeds, except for CD 104 lot 2 stored in Mauá da Serra.

From four treated seed lots, the model predicted, with accuracy (± 2%), the viability of two lots of BRS 208 and two lots of CD 104, as well as just one lot of untreated seed. This is probably due to seed-born microorganisms associated to the seed that can cause variation in the germination test (ROBERTS, 1986).

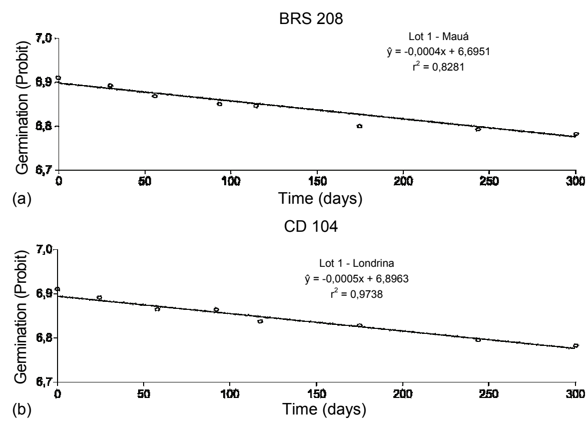

Figure 3. Deterioration rates of (a) an untreated seed lot of wheat, cv. BRS 208, stored in Mauá da Serra, Paraná State, and (b) the seed lot, cv. CD 104, stored in Londrina, Paraná State. Seeds were stored from November 2003 to October 2004.

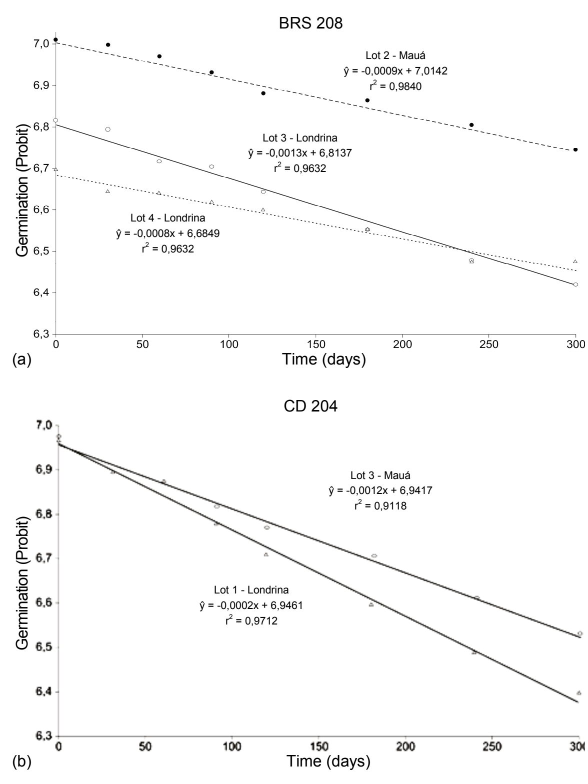

Figure 4. Deterioration rates of (a) three treated seed lots of wheat, cv. BRS 208, stored in Mauá da Serra and Londrina, Paraná State, and (b) two treated seed lots of wheat, cv. CD 104, stored in Mauá da Serra and Londrina, Paraná State. Seed lots were stored from November 2003 to October 2004.

The simplified model in eqn.7 showed that the deterioration rate of seeds is equivalent to 1/σ in Ellis and Roberts' equation. Neither the genotype nor the initial quality of wheat seed affected the declivity (1/σ and tgβ) of the curves, but only the intersection (Ki) of the viability equation (2) was affected by these factors (ELLIS; ROBERTS, 1980; ROBERTS; ELLIS, 1989).

Table 1. Mean initial germination (Vi), percentage viability after 180 days (P_{180}), loss of viability in time (%) and coefficient of determination (r^2) observed in untreated and treated wheat seeds, cv. BRS 208 and CD 104, stored at two locations.

Grow	Quimical Treatment	Place	Germination (%)			
			Vi	P_{180} days	%	r^2
BRS 208	yes	Londrina	96,5	94,2	2,38	0,96
BRS 208	not	Mauá	95,5	94,8	0,73	0,82
BRS 208	yes	Londrina	95,4	93,9	1,57	0,96
CD 104	yes	Londrina	97,4	94,4	3,08	0,97
CD 104	not	Londrina	97,2	96,4	0,82	0,97
CD 104	yes	Mauá	97,4	96,8	0,61	0,91

The data indicate for both treated and untreated seeds that the model accurately predicted the viability loss of the wheat seed lots under conventional storage at both locations.

Conclusion

The simplified model estimated with high accuracy the germination change and viability loss during the conventional storage of fungicide-treated and untreated wheat seeds in Mauá da Serra and Londrina, Paraná State.

The deterioration rate of treated seeds was greater than that of untreated seeds.

The deterioration rates of treated and untreated wheat seeds were greater in Londrina as compared to Mauá da Serra.

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