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GERMINATIVE PERFORMACE OF TREATED *Triticum aestivum* L. SEEDS SUBJECTED TO STORAGE

DESEMPENHO GERMINATIVO DE SEMENTES DE *Triticum aestivum* L.TRATADAS E SUBMETIDAS AO ARMAZENAMENTO

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Abstract
For the purpose of reducing existing inocula, as well as preventing subsequent infection and enabling the control of insects and fungi during the early stages of wheat cultivation, seed treatment with agrochemicals is commonly performed. However, the physiological potential of the seeds may be affected by the products incorporated into the treatment solutions. The present study aimed to evaluate the effect of a combination of insecticide (Cruiser Opti®), fungicides (Attic® and Baytan®), biostimulant (Colorseed®), and micronutrients (Macrogreen Micro Booster®) on the vigor and germination capacity of wheat seeds of the TBIO Toruk® and TBIO Sonic® varieties, both immediately after treatment and after a storage period. The trial was conducted in a completely randomized design using a factorial experimental scheme with three factors and four replications. The first factor (cultivar) consisted of two levels. (TBIO Sonic® and TBIO Toruk® cultivars). The second factor (seed treatment) consisted of four levels (0 days of storage without seed treatment, 120 days of storage without seed treatment, 0 days of storage with seed treatment, and 120 days of storage with seed treatment). The third factor (accelerated aging) consisted of two levels (absence and presence of accelerated aging). Although not statistically significant, it was observed that seeds of both cultivars, whether subjected to storage or not, when treated prior to germination, exhibited higher vigor indices and germination potential compared with untreated seeds.
Keywords: seed treatment; wheat; phytotoxicity.

Resumo
Com o propósito de reduzir os inócuos já existentes, assim como evitar a posterior infecção e propiciar o controle de insetos e fungos nos estágios iniciais da cultura do trigo, correntemente é realizado o tratamento de sementes com agroquímicos. No entanto, o potencial fisiológico das sementes pode ser afetado pelos produtos adicionados às caldas. Com o presente trabalho objetivou-se avaliar o efeito de uma combinação de inseticida (Cruiser opti®), fungicidas (Attic® e Baytan®), bioestimulante (Colorseed®) e micronutrientes (Macrogreen Micro Booster®) no vigor e

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capacidade germinativa de sementes de trigo das variedades TBIO Toruk® e TBIO Sonic®, logo após o tratamento e após o período de armazenamento. O ensaio foi realizado em um delineamento inteiramente casualizado em esquema experimental fatorial, com três fatores e quatro repetições. O primeiro fator foi composto por dois níveis (cultivares TBIO Sonic® e TBIO Toruk®). O segundo fator foi composto por quatro níveis (armazenamento 0 dias sem tratamento de sementes, armazenamento 120 dias sem tratamento de sementes, armazenamento 0 dias com tratamento de sementes e armazenamento 120 dias com tratamento de sementes). O terceiro fator foi composto por dois níveis (ausência e presença de envelhecimento acelerado). Apesar de não significativo estatisticamente, foi possível observar que as sementes de ambos os cultivares, submetidos ao armazenamento ou não, quando tratadas antes da germinação, apresentaram melhores índices de vigor e potencial de germinação em relação às sementes não tratadas.
Palavras-chave: tratamento de sementes; trigo; fitotoxidade.

1. Introduction

Although the Southern Region of Brazil accounts for a large share of the wheat cultivation area, the state of Santa Catarina has relatively little relevance compared with Rio Grande do Sul and Paraná, representing only 4.66% of the cultivated area (Kavalko et al., 2025). Nevertheless, according to data from the Instituto Brasileiro de Geografia e Estatística (IBGE, 2023), in Santa Catarina, during the 2023 agricultural year, 288,123 tons of wheat were harvested from an area of 126,105 hectares, with a production value of 276,699 thousand Brazilian reais. These figures highlight the importance of this crop to the state's economy.

Given the climatic variations that directly affect wheat development, careful planning is essential to reduce risks and ensure that the subsequent crop, such as soybean, is not adversely affected (Kavalko et al., 2025). During the production and storage process, seeds may sustain damage to their seed coat, making them susceptible to attack by insects, fungi, and other potential pathogens (Mariano-da-Silva et al., 2023). To address this problem, seed treatment is carried out using products such as fungicides (Mariano-da-Silva et al., 2023; Solarski et al., 2021), insecticides (Santana et al., 2022; Solarski et al., 2021), inoculants (Vey et al., 2023), bioregulators (Olvieira et al., 2020; Sousa et al., 2020), and macro- and micronutrients (Sandri & Simonetti, 2017).

Seeds may be treated either in industrial facilities or directly on the farm and subsequently stored until sowing. Sowing may take place immediately after treatment or, depending on operational, climatic, or seasonal factors, be postponed for a certain period (Dorneles et al, 2019).

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Among the methods of seed treatment, the use of agrochemicals (insecticides and fungicides) is one of the most commonly employed (Solarski et al., 2021). Their purpose is to reduce existing inocula, prevent subsequent infection, and enable the control of insects and fungi during the early stages of the crop. However, occasionally, the physiological potential of seeds may be affected by the products incorporated into the treatment solutions (Mariano-da-Silva et al., 2023; Santana et al., 2022; Pereira, 2021). Additionally, the effects of storage duration and the products used on seed quality are still not well understood (Santana et al., 2022).

Thus, it becomes important to understand the impacts of these treatments on the seeds' ability to germinate and produce healthy seedlings.

The present study aimed to evaluate the effect of a combination of insecticide (Cruiser Opti®), fungicides (Attic® and Baytan®), biostimulant (Colorseed®), and micronutrients (Macrogreen Micro Booster®) on the vigor and germination capacity of wheat seeds of the varieties TBIO Toruk® and TBIO Sonic®, both immediately after treatment and following a storage period.

2. Material and Methods

The experiment was conducted in the Seeds and Grains Laboratory at the Federal University of Fronteira Sul, Chapecó *Campus*. The wheat seeds used were of the TBIO Sonic® and TBIO Toruk® cultivars, both developed by the company Biotrigo Genética. The seeds were purchased from the sales department of the Cotricampo cooperative in Rio Grande do Sul.

The trial was conducted in a completely randomized design using a factorial experimental scheme with three factors and four replications (Pimentel-Gomes 2007). The first factor (cultivar) consisted of two levels (TBIO Sonic® and TBIO Toruk® cultivars). The second factor (seed treatment) consisted of four levels (0 days of storage without seed treatment, 120 days of storage without seed treatment, 0 days of storage with seed treatment, and 120 days of storage with seed treatment). The third factor (accelerated aging) consisted of two levels (absence and presence of accelerated aging).

Initially, the seeds of each cultivar were divided into two batches of 2.0 kg

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each and stored in transparent plastic bags. For each cultivar, one batch received a placebo with distilled water, while the other was treated with a combination of the following products and concentrations: Attic®, 1 mL kg^{-1}; Baytan®, 2 mL kg^{-1}; Cruiser opti®, 1,2 mL kg^{-1}; Colorseed®, 1 mL kg^{-1}; Macrogreen Micro Booster®, 0,5 mL kg^{-1}.

As soon as the mixture or placebo was added to the plastic bags, air was injected and the bags were vigorously shaken until the treatments were considered evenly distributed. Subsequently, the four batches were left to dry in the shade at an approximate temperature of 25±2°C for 20 minutes (Marcos-Filho, 2015).

After drying, each of the four batches was divided into four sub-batches of 0.5 kg each, resulting in the 16 treatments specified in Table 1.

Table 1: Combinations of the factors resulting in the 16 different treatments

CULTIVARS	SEED TREATMENT	SEED STORAGE	ACCELERATED AGING	LOTS
SONIC	PLACEBO	0 DAYS	WITH	SST0DCE
			WITHOUT	SST0DSE
		120 DAYS	WITH	SST120DCE
			WITHOUT	SST120DSE
	PRODUCT MIX	0 DAYS	WITH	SCT0DCE
			WITHOUT	SCT0DSE
		120 DAYS	WITH	SCT120DCE
			WITHOUT	SCT120DSE
TORUK	PLACEBO	0 DAYS	WITH	TST0DCE
			WITHOUT	TST0DSE
		120 DAYS	WITH	TST120DCE
			WITHOUT	TST120DSE
	PRODUCT MIX	0 DAYS	WITH	TCT0DCE
			WITHOUT	TCT0DSE
		120 DAYS	WITH	TCT120DCE
			WITHOUT	TCT120DSE

The batches corresponding to the treatments of 0 days of storage without accelerated aging (SST0DSE, SCT0DSE, TST0DSE, and TCT0DSE) were immediately subjected to the germination test. The batches corresponding to 0 days of storage with accelerated aging (SST0DCE, SCT0DCE, TST0DCE, and TCT0DCE) were subjected to accelerated aging, after which the germination test was conducted. The batches corresponding to the 120-day storage treatment (SST120DSE, SCT120DSE, TST120DSE, TCT120DSE, SST120DCE,

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SCT120DCE, TST120DCE, and TCT120DCE) were packaged in multi-layered paper bags and stored for 120 days without temperature or humidity control. After 120 days, the batches corresponding to the treatment without accelerated aging (SST120DSE, SCT120DSE, TST120DSE, and TCT120DSE) were subjected to the germination test. The batches corresponding to the accelerated aging treatment (SST120DCE, SCT120DCE, TST120DCE, and TCT120DCE) were subjected to accelerated aging, after which the germination test was performed.

For the accelerated aging test, 220 seeds from the treatments SST0DCE, SCT0DCE, TST0DCE, TCT0DCE, SST120DCE, SCT120DCE, TST120DCE and TCT120DCE were placed in Gerbox® boxes with mesh 11.0×11.0×3.0 cm), forming a single layer of seeds (Sá et al., 2011). At the bottom of the plastic boxes, 40 mL of distilled water was added, and the boxes were then placed in a BOD chamber heated to 41°C for a period of 48 hours (Marcos-Filho, 2020).

For the germination test, eight replications of 50 seeds each were prepared from each batch and sown on Germitest® paper. The paper sheets were rolled and the rolls corresponding to each treatment were grouped into lots of eight rolls, with each lot placed inside a plastic bag and maintained in a germinator (ELETROlab®, model 202/4) at a constant temperature of 25±2°C and a continuous 24-hour photoperiod (Brasil, 2009; Sá et al., 2011). Germination assessments were conducted on the fourth day (four rolls per treatment) and the seventh day (four rolls per treatment) after sowing, with the data converted to vigor index (fourth day) and germination rate (seventh day) (Brasil, 2009; Sá et al., 2011).

Analysis of variance (F-test at 1%) was used to analyze the variables (Pimentel-Gomes, 2007; Ferreira, 2018).

4. Results and Discussion

According to ANOVA (F-test), no significant interaction was observed between the factors seed treatment and accelerated aging (B x C), cultivar and accelerated aging (A x C) and cultivar, seed treatment and accelerated aging (A x B x C) regarding the vigor index (Table 3), indicating that for this variable the effects of seed treatment are independent of accelerated aging and that the difference

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between cultivar is independent of seed treatment. However, a significant effect was observed for the factors cultivar and accelerated aging individually, indicating that the levels of these factors differ statistically (Table 3).

According to ANOVA (F-test), there is a significant interaction between the factors cultivar and seed treatment regarding the vigor index (A x B) (Table 3). This indicates a dependency between the factors. By breaking down the interaction effect through a new analysis of variance (F-test) (Tables 4 and 5), in which the cultivar levels were compared within seed treatment (and vice versa), it was possible to observe a significant effect for the cultivar factor within each seed treatment level for the variable vigor index (Table 5). This effect can be observed through the averages presented in Table 2.

Table 2: Wheat cultivars tested and mean values of the vigor variable obtained for the different seed treatment

	CULTIVARS					
	TORUK			SONIC		
Treatment	SE	CE	average	SE	CE	average
STT0	85,0	76,5	80,75	91,5	80,0	85,75
STT120	81,0	68,0	74,50	83,5	69,0	76,25
CTT0	88,5	79,5	84,00	91,5	81,0	86,25
CTT120	83,0	78,0	80,50	85,5	78,5	82,00

SE: without accelerated aging; CE: with accelerated aging; STT0: without seed treatment and 0 days of storage; STT120: without seed treatment and 120 days of storage; CTT0: with seed treatment and 0 days of storage; CTT120: with seed treatment and 120 days of storage.

Statistically, the Sonic cultivar demonstrated a higher vigor index compared to the Toruk cultivar, indicating an intrinsic potential for more robust seedling development. This difference suggests that the Sonic cultivar may possess physiological or genetic traits that confer enhanced seed vigor, which could translate into more uniform emergence and better early growth under field conditions (Mariano-da-Silva et al, 2025).

When seeds of both cultivars were subjected to accelerated aging, those not exposed to the treatment showed greater vigor than those subjected to the test. This result aligns with previous reports indicating that accelerated aging can negatively impact cellular integrity, enzymatic activity, and metabolic reserves in seeds, ultimately reducing their vigor (Reddy et al., 2021; Tian et al., 2019).

Table 3: Analysis of variance with F-test application for the mean values of the vigor

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variable in relation to the factors cultivar, seed treatment and accelerated aging

SOURCE OF VARIATION	DEGREES OF FREEDON	SUN OF SQUARES	MEAN SQUARE	Fcal
BLOCK	3	1.00	0.33	
FACTOR A (cultivar)	1	110.25	110.25	120.27*
RESÍDUE (A)	3	2.75	0.92	
(PLOTS)	(7)	(114.00)		
FACTOR B (seed treatment)	3	856.50	285.50	8.06*
FACTOR A X FACTOR B	3	31.25	10.42	11.36*
RESÍDUE (B)	18	106.25	35.42	
(SUBPLOTS)	(31)	(1108.00)	369.33	
FACTOR C (accelerated aging)	1	1560.25	1560.25	44.05*
FACTOR B X FACTOR C	1	120.25	120.25	3.40^{ns}
FACTOR A X FACTOR C	3	16.00	5.33	0.15^{ns}
FACTOR A X FACTOR B X FACTOR C	3	1.50	0.50	0.01^{ns}
RESIDUE (C)	24	238.00	238.00	
TOTAL	63	3044.00		

Standard deviation: plots = 1.02050; subplots = 3.17162; undertreatment = 11.54560

Tabulated F value: F (0.01;1;3) = 34.12; F (0.01;3;18) = 5.09; F (0.01;1;24) = 7.82; F (0.01;3;24) = 4.72

* Significant at the 0.01% significance level.

Table 4: Decomposition of the degrees of freedom for the cultivar × seed treatment interaction plus the degrees of freedom of the seed treatment factor

SOURCE OF VARIATION	DEGREES OF FREEDON	SUN OF SQUARES	MEAN SQUARE	Fcal
BLOCK	3	1.00		
FACTOR A (CULTIVAR)	1	110.25		
RESÍDUE (A)	3	2.75		
(PLOTS)	(7)	(114.00)		
SEED TREATMENT d. CULTIV TORUK	3	752.75	250.92	2.36^{ns}
SEED TREATMENT d. CULTIV SONIC	3	135.00	45.00	0.42^{ns}
RESÍDUE (B)	18	106.25		
TOTAL	31	1108.00		

Tabulated F value: F (0.01;3;18) = 5.09 * Significant at the 0.01% significance level.

Table 5: Decomposition of the degrees of freedom for the cultivar × seed treatment interaction plus the degrees of freedom of the cultivar factor

SOURCE OF VARIATION	DEGREES OF FREEDON	SUN OF SQUARES	MEAN SQUARE	Fcal
BLOCK	3	1.00		
FACTOR A (CULTIVAR)	3	856.50		
RESÍDUE (B)	18	106.25		
(PLOTS)	(24)	(1108.00)		
CULTIVAR d. ST0D	1	221328.00	221328.00	80482.91*
CULTIVAR d. ST120D	1	181678.25	181678.25	66064.82*
CULTIVAR d. CT0D	1	231750.75	231750.75	84273.00*
CULTIVAR d. CT120D	1	211105.50	211105.50	76765.64*
RESÍDUE (A)	3	2.75	0.92	
TOTAL	31	846829,00		

Tabulated F value: F (0.01;1;3) = 34.12 * Significant at the 0.01% significance level.

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Although not statistically significant, it can be observed that both cultivars displayed higher mean vigor values in seed treatment at zero storage time, followed by seeds not treated at zero storage time, and lastly, seeds treated after 120 days of storage. Regarding the cultivar factor, across all levels of the storage factor, the Sonic cultivar exhibited a higher vigor index, differing statistically from the Toruk cultivar.

Overall, the results indicate that both the genetic background of the cultivar and the timing of seed treatment play critical roles in maintaining seed vigor, especially when seeds are exposed to storage or accelerated aging conditions. These insights can inform best practices for seed handling, storage, and treatment to maximize crop performance.

According to ANOVA (F-test), no significant interaction was observed between the factors cultivar and seed treatment (A x B), seed treatment and accelerated aging (B x C), cultivar and accelerated aging (A x C) and cultivar, seed treatment and accelerated aging (A x B x C) regarding the germination rate (Table 7), indicating that for this variable the effects of cultivar are independent of seed treatment, the effects of seed treatment are independent of accelerated aging and that the difference between cultivar is independent of seed treatment. However, a significant effect was observed for the factor accelerated aging individually, indicating that the levels of these factors differ statistically (Table 6).

Table 6: Wheat cultivars tested and mean values of the germination variable obtained for the different seed treatments

	CULTIVARS			
	TORUK		SONIC	
Treatment	SE	CE	SE	CE
STT0	89.5	75.5	90.0	76.0
STT120	86.5	70.5	83.0	72.0
CTT0	89.5	80.5	89.5	82.0
CTT120	88.5	75.0	86.0	77.0
average	88.50	75.37	87.12	76.75

SE: without accelerated aging; CE: with accelerated aging; STT0: without seed treatment and 0 days of storage; STT120: without seed treatment and 120 days of storage; CTT0: with seed treatment and 0 days of storage; CTT120: with seed treatment and 120 days of storage.

When seeds of both cultivars were subjected to accelerated aging, those not exposed to the stress retained higher germination potential than those subjected to

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the test. This observation highlights the susceptibility of seed viability to environmental and storage-induced stress, consistent with previous findings indicating that accelerated aging can compromise cellular integrity, reduce enzymatic activity, and deplete metabolic reserves essential for successful germination (Reddy et al., 2021; Tian et al., 2019).

Table 7: Analysis of variance with F-test application for the mean values of the germination variable in relation to the factors cultivar, seed treatment and accelerated aging

SOURCE OF VARIATION	DEGREES OF FREEDON	SUN OF SQUARES	MEAN SQUARE	Fcal
BLOCK	3	54.00	18.00	
FACTOR A (cultivar)	1	12.25	12.25	1.48^{ns}
RESÍDUE (A)	3	24.75	8.25	
(PLOTS)	(7)	(91.00)		
FACTOR B (seed treatment)	3	492.50	164.17	1.61^{ns}
FACTOR A X FACTOR B	3	29.25	9.75	1.18^{ns}
RESÍDUE (B)	18	306.25	102.08	
(SUBPLOTS)	(31)	919.00	306.33	
FACTOR C (accelerated aging)	1	1980.25	1980.25	19.40*
FACTOR B X FACTOR C	1	147.25	147.25	1.44^{ns}
FACTOR A X FACTOR C	3	4.00	1.33	0.01^{ns}
FACTOR A X FACTOR B X FACTOR C	3	29.50	9.83	0.10^{ns}
RESIDUE (C)	24	359.00	359.00	
TOTAL	63	3439.00		

Standard deviation = plot = 3.04743; subplots = 5.35988; undertreatment = 11.60630

Tabulated F value: F (0.01;1;3) = 34.12; F (0.01;3;18) = 5.09; F (0.01;1;24) = 7.82; F (0.01;3;24) = 4.72
* Significant at the 0.01% significance level.

Although the differences observed were not statistically significant, a clear trend was evident: both cultivars displayed higher germination when treated with seed treatments at zero storage time, followed by untreated seeds at zero storage time, and finally, treated seeds after 120 days of storage. This pattern suggests that seed treatments may provide short-term protective or stimulatory effects that enhance germination, potentially through the mitigation of microbial contamination or the provision of bioactive compounds that support early metabolic processes (Macdonald & Mohan, 2025). However, these effects appear to diminish with prolonged storage, likely due to the natural decline in seed physiological quality and potential degradation of treatment compounds over time.

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5. Conclusion

Although not statistically significant, it was observed that seeds of both cultivars, whether subjected to storage or not, when treated prior to germination, exhibited higher vigor indices and germination potential compared to untreated seeds.

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