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Physiological performance during storage of corn seed treated with insecticides and fungicide[1]

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ABSTRACT – The goal of storage is to maintain the characteristics that seeds have immediately after processing; however, when this is over longer periods, storage may cause loss in quality. The aim of this study was to evaluate the effect of treatment with insecticide and fungicide on corn seeds harvested in kernel form and in the ear over the time of storage in two environments for 360 days. The seeds were subjected to the following treatments: T1 - control; T2 - Deltamethrin + Pirimiphos-methyl + Fludioxonil; T3 - Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam; T4 – Thiamethoxam, and T5 - Fenitrothion. They were then placed in paper bags and stored in two environments, in a cold room with an average temperature of 16 °C and RH of 60% and in a non-controlled environment (an average room temperature of 25 ºC and RH of 70%) located in the municipality of Pelotas, RS, Brazil. Every four months (0, 120, 240 and 360 days), seed germination and vigor was evaluated by the first count of germination test and cold test. Reduction in germination and vigor of corn seeds, conditioned by the insecticides and fungicide used in the seed treatment, vary according to the product and the time over which the seeds remain stored. The seeds harvested in the ear show lower loss of physiological quality than those harvested in kernel form.

Index terms: *Zea mays* L., germination, vigor, seed treatment.

Desempenho fisiológico durante o armazenamento de sementes de milho tratadas com inseticidas e fungicida

RESUMO - O armazenamento tem por objetivo manter as características que as sementes possuem imediatamente após o beneficiamento, porém, quando por períodos mais extensos, o mesmo pode causar perdas na qualidade das mesmas. O objetivo neste trabalho foi avaliar o efeito do tratamento com inseticida e fungicida sobre sementes de milho colhidas a granel e em espiga durante o armazenamento em dois ambientes por 360 dias. As sementes foram submetidas aos tratamentos: T1- testemunha; T2- Deltamethrin + Pirimifós-metílico + Fludioxonil; T3- Deltamethrin +Pirimifós-metílico + Fludioxonil + Tiametoxam; T4- Tiametoxam e T5- Fenitrothion. Em seguida, foram acondicionadas em sacos de papel e armazenadas em dois ambientes: câmara fria com temperatura média de 16 °C e UR de 60% e em ambiente não controlado (câmara com temperatura média de 25 ºC e UR de 70%, localizada no município de Pelotas-RS). A cada quatro meses (0; 120; 240 e 360 dias) foi avaliada a germinação e o vigor das sementes, pelos testes de primeira contagem de germinação e teste de frio. A redução da germinação e do vigor de sementes de milho, condicionada pelos inseticidas e fungicida utilizados no tratamento das sementes, varia em função do produto e do tempo em que as sementes permanecem armazenadas. As sementes colhidas em espiga apresentam menor perda da qualidade fisiológica em relação às colhidas a granel.

Termos para indexação: *Zea mays* L., germinação, vigor, tratamento de sementes.

Introduction

Corn (*Zea mays* L.) is one of the most important cereal crops and is currently the most highly produced grain in the world (38.1%), followed by wheat (29.1%), and rice (20.8%) (Companhia Nacional de Abastecimento - CONAB, 2013). According to estimates from the United States Department of Agriculture - USDA (2013), world production will be 957 million tons for the 2013/14 harvest season, an increase of 11% over the volume of 2012/13. In Brazil, the area planted to corn in the 2012/13 harvest season was approximately 16 million hectares, with a production of 81,344 million tons

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(CONAB, 2013). For the 2013/14 harvest season, the estimate is that 78,783 million tons of corn grain will be produced, which corresponds to 40% of the total grain harvest, which is 195,906 million tons. As for the production of seed corn, the effective demand in the 2012/13 crop season was 282,352 thousand tons (ABRASEM, 2013).

One of the most delicate steps in the production of corn seeds is harvest because this should occur as near as possible to physiological maturity (Peske et al., 2012). Seeds may be harvested in a manual or mechanical manner. Manual collection leads to less damage to the ear, as well as manual shelling; however, the yield from harvest is very low, requiring a great deal of labor, which increases costs, and it is more appropriate for small properties and highly sloped land (Pimentel and Fonseca, 2011). Delayed harvest may lead to losses in the physiological quality and health of the seeds; therefore, harvest should occur at the appropriate time, as near as possible to physiological maturity, for maximum reduction of possible losses (Henning et al., 2011), and this is only made viable in a technical way through harvest in the ear. Mechanical harvest may be made by removing the ears with husk, the ears without husk, or the material already shelled from the field. In mechanized harvest with shelling, suitable machine adjustment is important to reduce quantitative and qualitative losses; i.e., loss of grains or mass of grains, strictly speaking, and reduction in quality from cracking and breakage of the grain, as well as the occurrence of diseases (Pimentel and Fonseca, 2011). An additional negative aspect of mechanized harvest is emphasized by Gomes et al. (2009) upon reporting that the damage caused to seeds by mechanized operations during production may have a negative effect on the quality of the material obtained.

Physiological maturity is seen as the ideal time, from the physiological point of view, to harvest the seeds; however, at that time, the seeds have high moisture content (30 - 40%), making it difficult to remove the seeds from the cob; removal may result in crushing them. To avoid this physical damage to seeds during harvest of the kernels, i.e., the material is already shelled from the ear, harvest is recommended when grain moisture is from 18 to 26% (Fancelli and Dourado Neto, 2000). Another option is harvesting whole ears, without removing the husk and the cob, when the seeds still have around 30% moisture and dry them artificially before shelling (Rosa et al., 2002). That will reduce the risk of seeds from being contaminated by diseases at the end of the cycle (Ferreira et al., 2013) since the seeds are removed from the field earlier, near physiological maturity.

Another important factor to consider is storage. Although the goal is to maintain the quality of the biological product during the period of storage (Villela and Peres, 2004), over longer periods of time, storage may cause loss in seed quality, which is intensified in environments without control of temperature and relative air humidity, thus leading to degenerative changes. This may be minimized when the seeds are stored in adequate conditions (Santos et al., 2004). As a rule, corn seeds remain under storage for more than six months before being used in the next crop season and often in warehouses that do not have temperature and moisture control.

One of the biggest problems of prolonged storage is in regard to storage pests, such as weevils, which lead to qualitative and quantitative losses in seeds and grains (Antonello et al., 2009). In this respect, it is of utmost importance to prevent attack from pests through the application of insecticides and to maintain the seeds at a lower temperature to avoid insect proliferation and maintain seed quality.

In addition to the advantage of combating insects, fungi and nematodes, using treated or protected seeds is of great importance since the seeds constitute a vehicle for bearing technology. Nevertheless, applying products such as fungicides, insecticides, nematicides, hormones and stains to seeds may increase the risks of reducing the physiological quality of seeds to a greater or lesser extent depending on the agent used. Thus, it is necessary to perform specific studies on seed treatments with products of the most advanced technology in regard to storage (Peske and Baudet, 2006).

Therefore, the aim of this study was to evaluate the effect of treatment with insecticides and fungicide on corn seeds harvested in kernel form and in the ear over the storage period in two different environments.

Materials and Methods

This study was developed in the Seed Analysis Teaching Laboratory (Laboratório Didático de Análise de Sementes-LDAS) of the Plant Science Department of the Eliseu Maciel School of Agronomy at the Universidade Federal de Pelotas (UFPel), Pelotas, RS, Brazil. Commercial hybrid corn seeds were used, harvested in kernel form and in the ear.

Harvest in kernel form was mechanized and was carried out in the municipality of Paracatu, MG, when the seeds had average moisture of 18%. They were then dried at a maximum temperature of 40 ºC until reaching 12% moisture. After drying, the seeds went through pre-cleaning, and soon afterwards a seed classifier and a gravity table. They then received the chemical treatments. Harvesting of ears was also mechanized and in Paracatu, MG, when the seeds had average moisture of 30%. The husk was removed mechanically and then the ears passed through a sorting table and were sent to a drying chamber with temperatures from 36 to 40 ºC, until reaching 12% moisture. After drying, the ears were mechanically shelled and went through pre-cleaning, followed by classification and the gravity table. Finally, the seeds were subjected to chemical treatment.

The chemical treatments consisted of insecticides, and the commercial products contained the following active ingredients in their formulations: Deltamethrin, concentration of 25 $g.L^{-1}$ (2.5% m/v), rate of 1.4 L / 15 t^{-1}; Pirimiphos-methyl, concentration of 500 $g.L^{-1}$ (50.0% m/v), rate of 1.4 L / 15 t^{-1}; Fenitrothion, concentration of 500 $g.L^{-1}$ (50% m/v), rate of 0.02 $L.t^{-1}$; and Thiamethoxam, concentration of 700 $g.kg^{-1}$ (70% m/m), rate of 0.12 L / 0.02 t^{-1}. A fungicide was also used, containing Fludioxonil at a concentration of 25 $g.L^{-1}$ (2.5% m/v) and rate of 0.097 $L.t^{-1}$. These products constituted five seed treatments: T1 – without treatment; T2 - Deltamethrin + Pirimiphos-methyl + Fludioxonil; T3 - Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam; T4 – Thiamethoxam; and T5 - Fenitrothion. The seeds were then placed in paper bags and sent to the LDAS of the Department of Plant Science of the Eliseu Maciel School of Agronomy, UFPel, Pelotas, RS, Brazil, where they were stored in two environments - in a cold room with an average temperature of 16 °C and RH of 60%, and in a non-controlled environment (storeroom with an average temperature of 25 ºC and RH of 70%).

At the beginning and at every 120 days of storage (0, 120, 240 and 360 days), seed germination and vigor were evaluated by the first count of germination test and cold test.

Germination: carried out by sowing 200 seeds per treatment, divided into four replications of 50 seeds. Evaluations were made at four and seven days after sowing, according to the Rules for Seed Testing (Brasil, 2009). The results were expressed in percentage of normal seedlings.

First count of germination: made together with the germination test evaluated on the fourth day after sowing, according to Brasil (2009).

Cold test: conducted with four replications of 50 seeds per treatment. The same procedure as the germination test was adopted; however, the rolls were kept for seven days at a temperature of 10 °C and were then taken to the germinator at a temperature of 25 °C, where they remained for four days, at which time the percentage of normal seedlings was evaluated (Barros et al., 1999).

The experiment was conducted under a completely randomized design in the factorial arrangement of 2 forms of harvesting x 5 seed treatments x 4 evaluation times, with four replications, for a total of 40 treatments and 160 experimental units.

The data were subjected to analysis of variance to test main effects and interactions of the factors and the F test was done with a 5% significance level. The mean values of the qualitative factors were compared by the Tukey test at 5% probability and polynomial regression for the quantitative factor of time of evaluation, choosing the significant regression model of highest degree, with a coefficient of determination above 70%.

Results and Discussion

Through analysis of variance of germination, significant interaction was seen, with distinct behavior being observed among the variables analyzed for the factors of manner of harvest and type of storage.

In regard to germination, a significant difference was observed among the chemical treatments for the seeds harvested in kernel form and stored in a non-controlled environment after 240 days of storage; and treatment 3 (Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam) showed the greatest reduction in percentage of germination (Table 1).

The chemical treatments showed the same behavior in relation to germination for the seeds harvested in kernel form and stored in a cold room, showing a small linear reduction throughout the period, decreasing an average of 8 percentage points after 360 days of storage (Figure 1A). In contrast, when seeds harvested in kernel form but stored in the normal environment were evaluated, some treatments led to an accentuated reduction in the percentage of germination, especially after 240 days of storage (Figure 1B). Under these conditions, treatment 3 (Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam) was that which led to the most significant reductions as of this period. According to Antonello et al. (2009), the active ingredients may affect seedling development under adverse conditions immediately after treatment or after a short period of storage. In addition, seeds harvested in kernel form are exposed to moisture variations for a longer time, due to the need for reducing moisture to make mechanical shelling viable during threshing, a process that may also lead to mechanical damages, reducing physiological quality in a more accentuated manner during storage. According to Peske et al. (2012), this is one of the main reasons why the hybrid seed corn industry adopts harvesting in ears, allowing this process to be carried out nearer to physiological maturity. This also reduces the risk to seeds from contaminants (Ferreira et al., 2013). In seeds harvested in the ear, a reduction in germination throughout the period was not observed, regardless of storage conditions (Figures 1C and 1D).

Table 1. Mean values of germination test (GER) of corn seeds subjected to different treatment with insecticides and fungicide during storage.

Harvest	Storage	Time (days)	T1	T2	T3	T4	T5
Kernel	Climate-controlled	0	90	91	90	88	92
		120	80	92	89	91	93
		240	88	88	79	85	86
		360	86	90	73	79	86
		Mean	88a	90a	82b	86ab	89a
		CV(%)			6.02		
Kernel	Environment	0	92a	90a	91a	89a	92a
		120	96a	89a	89a	86a	92a
		240	85ab	88a	75b	78ab	88a
		360	70b	87a	56c	74b	79b
		Mean	86	88	78	82	88
		CV(%)			6.80		
Ear	Climate-controlled	0	96	97	98	99	97
		120	98	96	99	98	97
		240	94	93	93	93	95
		360	95	94	91	91	95
		Mean	96	95	95	95	96
		CV(%)			2.98		
Ear	Environment	0	98	96	96	96	98
		120	95	94	96	96	98
		240	91	94	87	92	92
		360	91	92	90	92	90
		Mean	94	94	92	94	94
		CV(%)			3.59		

*Mean values followed by the same letter in the row do not differ among themselves by the Tukey test at 5% probability.

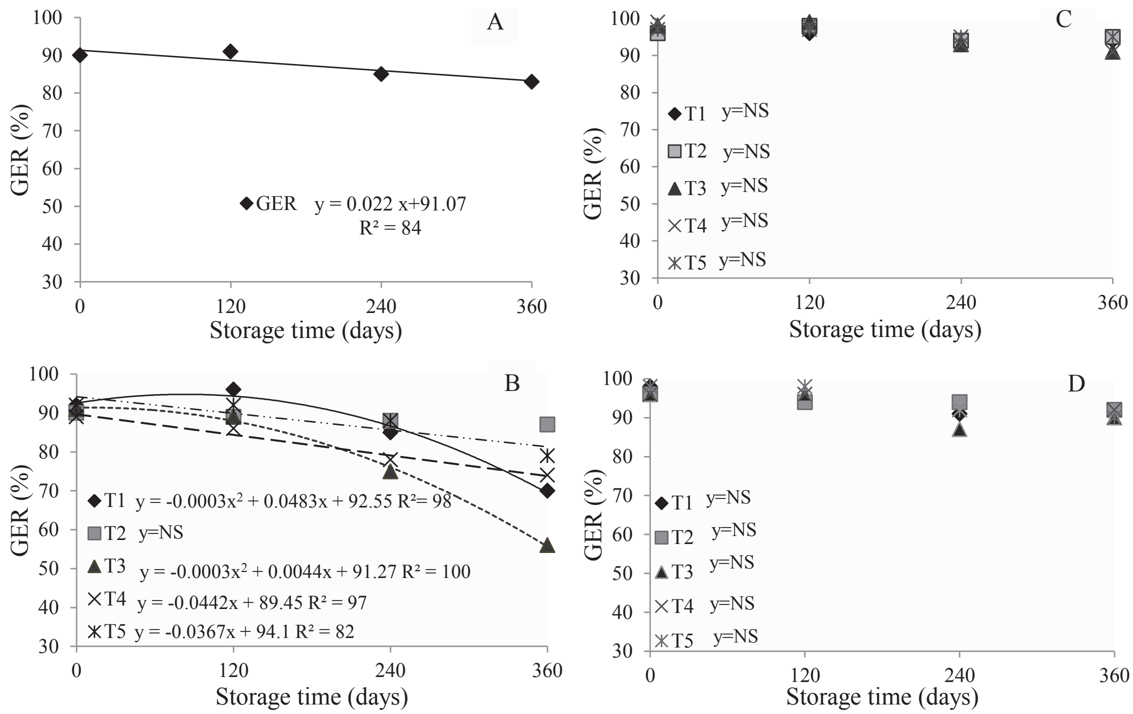

Figure 1. A: Germination (GER) of corn seeds harvested in kernel form and stored in a cold chamber storage; B: GER of corn seeds harvested in kernel form and stored in a non-controlled environment; C: GER of corn seeds harvested in the ear and stored in a cold chamber storage D: GER of corn seeds harvested in the ear and stored in a non-controlled environment.

Comparing the chemical treatments in each period of storage, it may be observed that for the first count of germination test (Table 2), the treatments did not show a difference for the seeds harvested in the ear and stored in a cold room. The seeds harvested in kernel form and kept in a climate-controlled environment, for their part, showed a significant difference only after 360 days of storage, and treatments 3 (Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam), 4 (Thiamethoxam) and 5 (Fenitrothion) had results lower than the others. Thus, the importance of temperature and moisture control during seed storage may be seen.

Table 2. Mean values of the First Count of Germination (FCG) of corn seeds subjected to different treatments with insecticides and fungicide during storage.

Harvest	Storage	Time (days)	T1	T2	T3	T4	T5
Kernel	Climate-controlled	0	80a	85a	82a	76a	86a
		120	84a	86a	83a	87a	87a
		240	75a	82a	76a	77a	82a
		360	70a	77a	58bc	67ab	55c
		Mean	77	82	74	77	77
		CV(%)			7.38		
Kernel	Environment	0	86a	81a	87a	81a	85a
		120	90a	82ab	78b	77b	90a
		240	64ab	66a	54b	66a	67a
		360	53bc	67a	43c	56ab	56ab
		Mean	73	74	65	70	74
		CV(%)			8.08		
Ear	Climate-controlled	0	86	87	84	91	87
		120	89	94	95	93	89
		240	73	84	86	86	87
		360	70	71	69	70	71
		Mean	79a	84a	83a	85a	83a
		CV(%)			6.57		
Ear	Environment	0	86ab	87a	87a	87a	77b
		120	91a	91a	90a	91a	89a
		240	72b	81ab	78ab	83a	71b
		360	60b	78a	62b	59b	67b
		Mean	77	84	79	80	76
		CV(%)			6.63		

*Mean values followed by the same letter in the row do not differ among themselves by the Tukey test at 5% probability.

There was a difference over the storage period for all the treatments (Figures 2A, B, C, D); however, in the seeds harvested in the ear and stored in a cold room, the treatments showed the same behavior (Figure 2C), fitting a quadratic equation, showing stability up to the time of 120 days and more intense reduction after this period. Chemical treatment 3 (Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam) was that which had the greatest negative effect, showing a percentage of germination less than 50% at 360 days after storage (Figure 2B). In general, the results of chemical treatment 2 (Deltamethrin + Pirimiphos-methyl + Fludioxonil) were better than the other treatments, in regard to first count of germination.

In regard to vigor, evaluated by the cold test, a difference was seen among the chemical treatments for all the periods and locations of storage and forms of harvest (Table 3), except at time zero for the seeds harvested in kernel form and kept in a climate-controlled environment, and after 120 days of storage for those seeds harvested in the ear and stored in a non-controlled environment. In general, treatments 3 (Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam) and 4 (Thiamethoxam) showed greater reduction in vigor during storage, which corroborates the results of the germination test for treatment 3 (Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam). According to Antonello et al. (2009), some chemical treatments tend to generate latent effects that are unfavorable to seed performance at increased rates and this effect can be intensified by prolongation of the storage period, observing, moreover, that insecticides cause a reduction in germination. Decreases in the physiological potential of seeds treated with insecticides may be associated with the formation of free radicals, as a response to exogenous stresses produced by insecticides of the carbamate and organophosphate group (Soares and Machado, 2007).

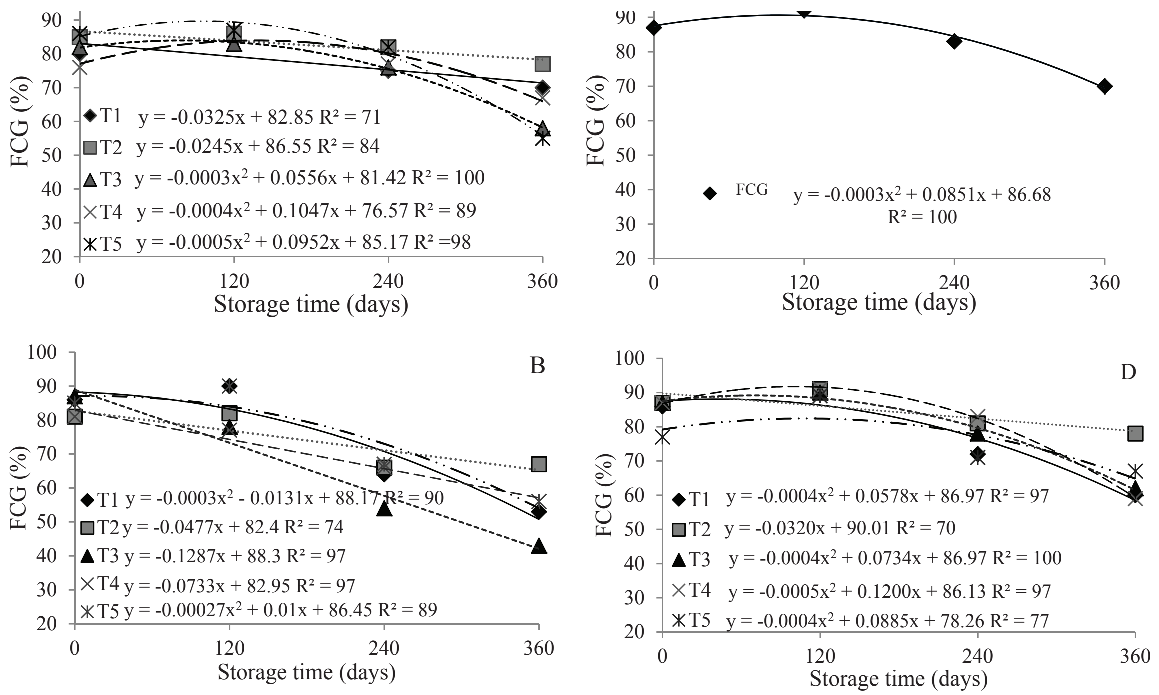

Figure 2. A: First count of germination (FCG) of corn seeds harvested in kernel form and stored in a cold chamber storage; B: FCG of corn seeds harvested in kernel form and stored in a non-controlled environment; C: FCG of corn seeds harvested in the ear and stored in a cold chamber storage; D: FCG of corn seeds harvested in the ear and stored in a non-controlled environment.

Table 3. Mean values of the Cold Test (CT) of corn seed subjected to different treatments with insecticides and fungicide during storage.

Harvest	Storage	Time (days)	T1	T2	T3	T4	T5
Kernel	Climate-controlled	0	74a	84a	74a	77a	84a
		120	83a	85a	52b	59b	85a
		240	76a	78a	54b	53b	81a
		360	69a	55b	24c	47b	67a
		Mean	75	76	51	59	79
		CV(%)			7.67		
Kernel	Environment	0	82a	78ab	64b	68b	74ab
		120	78a	86a	57b	63b	84a
		240	71a	71a	49b	42b	70a
		360	41a	37a	03b	07b	34a
		Mean	68	68	43	45	65
		CV(%)			12.38		
Ear	Climate-controlled	0	94a	74b	75b	91a	98a
		120	94a	91ab	80b	87ab	94a
		240	82a	82a	77a	85a	87a
		360	89a	86ab	64c	76b	88a
		Mean	90	83	74	85	92
		CV(%)			6.57		
Ear	Environment	0	96a	91a	90a	96a	78b
		120	94a	94a	85a	91a	86a
		240	81a	82a	68b	80ab	87a
		360	69a	62a	16c	31b	62a
		Mean	85	82	65	74	78
		CV(%)			7.56		

*Mean values followed by the same letter in the row do not differ among themselves by the Tukey test at 5% probability.

The percentage of normal seedlings after carrying out the cold test (Figures 3A, B, C and D) showed a difference for all the treatments, except in T1 (control) and T2 (Deltamethrin + Pirimiphos-methyl + Fludioxonil), in the corn harvested in the ear and stored in a cold room (Figure 3C). The treatments containing the insecticide thiamethoxam (T3 and T4) showed greater reduction in seed vigor over the storage period in relation to the others, especially in the seeds kept in a non-controlled environment, with reduction greater than 50%. Comparing the treatments in this condition of storage by the results, greater toxicity was seen in the products for treatments T3 and T4, as may be observed already in the first evaluations.

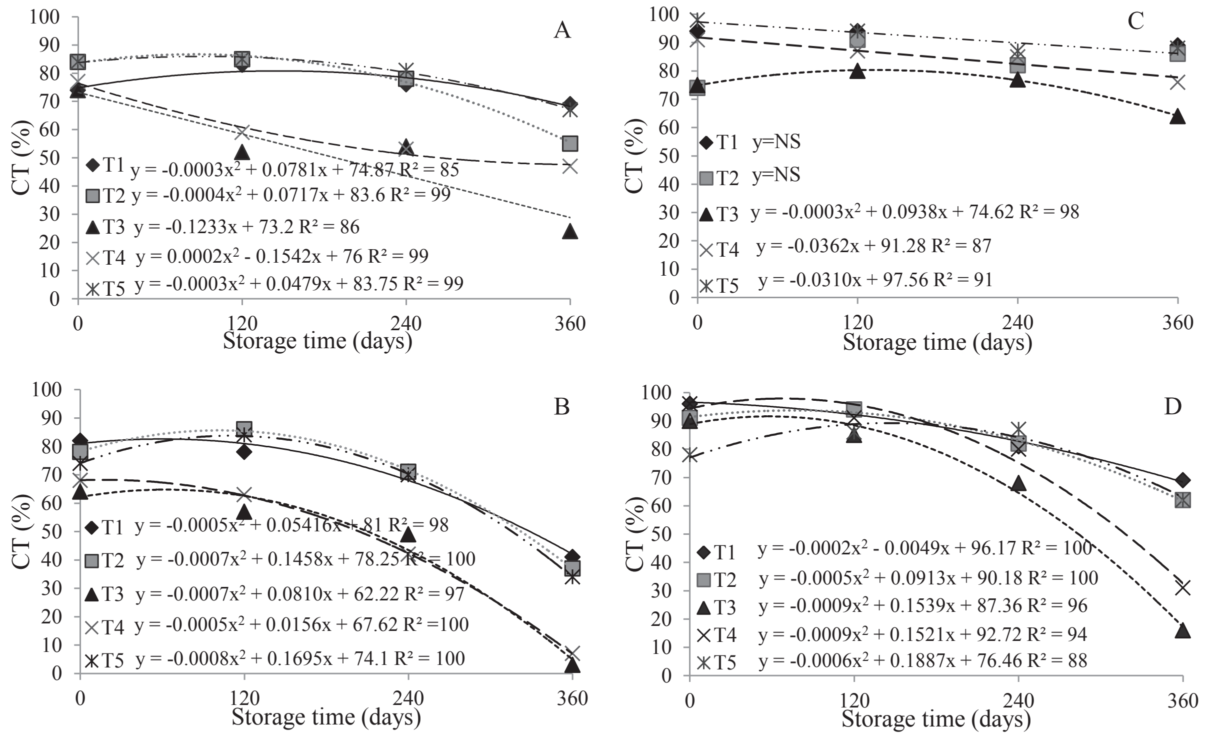

Figure 3. A: Cold test (CT) of corn seeds harvested in kernel form and stored in a cold chamber storage; B: CT of corn seeds harvested in kernel form and stored in a non-controlled environment; C: CT of corn seeds harvested in the ear and stored in a cold chamber storage; D: CT of corn seeds harvested in the ear and stored in a non-controlled environment.

In a study carried out in corn seeds treated with insecticides containing the active ingredients fipronil, thiamethoxam and imidacloprid + thiodicarb, Salgado and Ximenes (2013) observed that, even in the absence of interaction, the seeds treated with thiamethoxam had germination of 92.7%. The other seeds, including the control, maintained germination above 94% on the tenth day of storage in a cold room, suggesting that the metabolites produced by the metabolization of this product may be more toxic than those of the other products.

In contrast, Dan et al. (2011) observed that the treatment of soybean seeds with the insecticides thiamethoxam and fipronil promoted adequate levels of germination and vigor, but with a short period of storage, seven days. Grisi et al. (2009) also did not find any change in the vigor and emergence of sunflower seeds treated with thiamethoxam and fipronil. Horii and Shetty (2007) reported that some insecticides might exhibit determined physiological effects beyond the protective effect, assisting in the initial growth and development of the plants. An increase in the physiological potential was seen by Almeida et al. (2011) in rice seeds and by Almeida et al. (2012) in oat seeds treated with thiamethoxam.

Wendling and Nunes (2009) observed that the hybrid corn seeds Prezotto PRE 22T10 treated with imidacloprid + thiodicarb and stored for up to 30 days showed germination equivalent to the control, and when stored for 40 days, showed significantly lower values, and, consequently, they recommend that the treatment be performed as near as possible to the sowing day. Krohn and Malavasi (2004), evaluating soybean seeds treated with the fungicides carbendazim + thiram and stored for up to 210 days in paper bags in an environment whose temperature ranged from 20 – 25 °C, observed that the seeds that were treated for a period greater than 120 days had lower performance in comparison to seeds treated in the other times (90 and 30 days before sowing and sowing date).

The result of the tests for the seeds harvested in kernel form and stored in a non-controlled environment shows that there was a difference among the treatments in all the tests analyzed (Figures 1B, 2B and 2C), except for T2 (Deltamethrin + Pirimiphos-methyl + Fludioxonil) in the germination variable (Figure 1B). Among the treatments tested, T3 (Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam) and T4 (Thiamethoxam) (Figure 1B), in addition to leading to generally lower physiological quality than the others, showed germination below the minimum standard required for commercialization, which, according to Brazilian legislation is 80% (Brasil, 2005) at 240 days of storage.

Among the storage environments, it may be seen that although the expression of vigor of the treated seeds did not increase when compared to the untreated seeds, a positive effect was observed by control of their storage environment. Studying storage of soybean seeds for eight months, Forti et al. (2010) observed a greater reduction in physiological potential in seeds stored in a non-controlled environment and less reduction for those stored in a climate-controlled environment. In contrast, Rosa et al. (2012), evaluating seeds of three corn hybrids, observed that there was a reduction in the vigor of seeds treated with thiamethoxam, both in a conventional environment and in a cold room at the end of 180 days of storage.

Seed deterioration is an inevitable and progressive process which brings about a decrease in vigor and viability. Nevertheless, it is possible to retard its progress by suitable storage practices, such as temperature and moisture control, to reduce the metabolic activity of the seeds and avoid the rise of fungi and insects. This fact is related to the differences found in the physiological quality of the seeds among the environments evaluated in this study.

In general, seed treatment, apart from the storage condition, did not ensure maintenance of the physiological quality of the seeds (Figures 3A, B, C and D) since the results obtained by treatments T3 (Deltamethrin + Pirimiphos-methyl + Fludioxonil + Thiamethoxam) and T4 (Thiamethoxam) were less than the control (T1); and treatments T2 (Deltamethrin + Pirimiphos-methyl + Fludioxonil) and T5 (Fenitrothion) were not different from it. Bittencourt et al. (2000) found similar results upon studying the effect of systemic insecticides applied on corn seeds, concluding that the storage of seeds treated with these insecticides reduced germination and vigor. Evaluating the physiological quality of soybean seeds treated with the insecticides thiamethoxam, fipronil, imidacloprid, imidacloprid + thiodicarb, carbofuran and acephate under the effect of storage, Dan et al. (2010) observed a reduction in the physiological quality of the seeds brought about by the insecticides, which intensified with prolongation of the storage period, therefore recommending that the insecticide treatment of the soybean seeds be performed close to sowing time.

Among the harvest methods, it is seen that the seeds harvested in the ear showed better physiological quality than those harvested in kernel form. These results may be explained by the fact that harvesting in the ear is performed nearer (30% moisture) to the point of physiological maturity of the seeds, at which point they have greater vigor, as well as having remained for less time exposed to inclement weather, diseases and insect attack.

Conclusions

Reduction in the physiological quality of corn seeds varies according to the product, storage environment and time in which the seeds remain in storage. There is greater reduction as the storage period advances, especially in a non-controlled environment.

Seeds harvested in the ear exhibit less loss in physiological quality in relation to those harvested in kernel form.

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