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Insecticide Treatment and Physiological Quality of Seeds

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1. Introduction

The use of high-quality seeds enhances the probability of success of a crop. Another important factor is the use of techniques which target the improvement of seed field performance. Applications (seed dressing) of fungicides, inoculants, insecticides and micronutrients on seeds are practices most used by farmers for several years. These products have provided more favorable conditions to crop's growth as well as its development.

Chemical treatment on seeds have been one of the most common techniques in use on current farming due to its low-cost technology, low-environmental impact, and, in general, a significant effect on yield (Zambolim, 2005).

High quality seed is one of the essential prerequisites to achieve higher crop productivity. Seed physiological quality is influenced by genetic traits inherited from their parent trees, as well as germination and vigor, which are affected by environmental conditions, harvesting methods, drying process, processing, storage and packing (Zambolim, 2005).

Nevertheless, storage of insecticide treated seeds may cause significant reduction on both germination and vigor as demonstrated by a number of authors (Bittencourt et al., 2000); (Gotardo et al., 2001). This fact might be related to deterioration caused by the use of insecticides, which induce the formation of free radicals and subsequent oxidative stress (Braguini, 2005).

Chemical treatment on seeds has become an important procedure on agricultural production by a number of reasons. Firstly, by using this kind of treatment, many pest insects attacking not only seeds but also in some cases the aerial part of plants can be efficiently controlled. Secondly, these products can be handled in either protected or controlled environment regardless of climatic conditions, therefore, reducing additional and unwanted machinery movement in the land for cultivation.

These arguments are added to the fact that, in that referred kind of treatment; small quantities of products are used per area unit, which implies lower risks of environmental contamination. In addition, chemical treatment is a procedure of simple implementation and low cost (Goulart, 1999; Machado, 2000).

Silva (1998) stated that, when treating seeds, one can protect the plant during germination and young-seedling stages which are phases of greater susceptibility. This treatment aims to ensure seeds' full performance by achieving the desired planting density.

Nevertheless, evidences obtained from some studies have shown that some seed dressing products, under certain situations, may cause reduction in germination as well as seedling survival due to the phytotoxic effect. Significant vigor decreases were induced by carbofuran in corn seeds after treatment and a subsequent 30-day-period storage (Bittencourt *et al.*, 2000). Corn seeds treated with the insecticides, such as deltamethrin and pirimiphos-methyl in high doses (Fessel *et al.*, 2003) lowered longevity, vigor and emergency speed of seedlings. Moreover, corn seeds treated with the insecticide phipronil caused reductions in seedlings radicular growth (Silveira *et al.*, 2001).

On the other hand, Barbosa *et al.* (2002), when treating bean seeds with the insecticides imidacloprid and thiamethoxam, verified that the active ingredients provided some improvement in the crop's agronomical traits, as a result, increasing productivity. Barros *et al.* (2005) verified greater percentage on bean seeds germination in treatments using the insecticide phipronil. However, Tavares *et al.* (2007) observed no difference on germination and vigor when using different doses of thiamethoxam in soybean seed treatment.

Some seed companies have been adopting the anticipated seed treatment process before bagging or when handing seeds over to the producer. Some issues have been discussed by Menten (1996) regarding the use of anticipated treatment. One of them is related to a possible phytotoxic effect which might be enhanced due to long period of seed storage after treatment. However, due to the lack of information within literature, it is not possible to assure whether insecticides can influence on seeds' germination and vigor, mainly during storage. Therefore, this study will focus on the discussion of previous studies regarding the effects of insecticides on seeds' quality in crops such as soybean and corn when treated and then stored.

2. Importance of physiological quality of seeds

Quality is an important aspect in seed production and, thus, must be considered as a standard of excellence. Nevertheless, quality, regarding its functional aspect and in a broad sense, must be considered as either a specification or a group of specifiers within certain limits or tolerances which must be met (Lima, 2003; Ferreira and Borghetti, 2004).

Seed quality is defined as the set of all genetic, physical, physiological and sanitary attributes which affect the capacity to output high-productivity plants. Physical quality comprises both physical purity and physical condition of seeds. Physical purity of seeds - known as seeds' purity - is characterized by the proportion of physical components in seed lots, such as pure seeds, weed seeds, other crop seeds as well as inert matter. Physical condition is characterized by moisture degree, size, color, density, appearance, mechanical damage and also damages caused by insects and infections caused by diseases (Popinigis, 1985).

The level of physiological quality of seeds is assessed by two fundamental parameters: viability and vigor. Viability is measured mainly through germination test in order to determine seed's maximum germination under favorable conditions.

Vigor detects more subtle changes in physiological quality not revealed by the germination test. Seeds' vigor is the reflection of a group of characteristics which determines its physiological potential, that is, the ability to present appropriate performance when exposed to different environmental conditions (Marcos Filho, 1999).

A successful crop implantation is fundamentally important to obtain yield enhancements. This success, most of the time, is achieved by using high quality seeds (Rocha Junior, 1999). Thus, during crop production process, the adoption of either advanced sowing techniques or crop tillage methods are not enough because the quality of seeds to be used is characterized as a primary factor in the further establishment and development of the crop.

Low quality seeds generally show diminished germination and vigor, originating heterogeneous crop and lessening crop population. According to Resende *et al.* (2003), high crop yield depends directly on the quality of seeds used for sowing.

Seeds' quality have been assigned to its physical purity, high-genetic potential, high germination and vigor, absence of mechanical damage, good health and uniformity of seed size (Lima, 1997).

According to Delouche (1975), seed quality involves several attributes including: cultivar's genetic purity, which is important to the development of the crop, as well as its uniformity, mainly to maturation; physical purity which consists of seeds free from inert matter, weed seeds and other crops; germination, in which high quality seeds should present germination above 85%; vigor, in which viable seeds from a lot must be sufficiently vigorous in order to rapidly and uniformly emerge under the most varied soil conditions and quickly develop into productive plants.

In accordance to Peske *et al.* (2003), the assessment of seeds physiological quality – sowing and lots commercialization purposes – has been ultimately based on the germination test, which is of practical usefulness for this end. Its methodology is standardized and its results reproduced intra- and inter-laboratories.

It's also important to take into account that seeds' initial quality is affected by a number of factors, such as vigor of parent plants, climatic conditions during maturation, maturation stage at harvesting, mechanical damage degree and drying (Carvalho & Nakagawa, 1988). Special attention should be taken to avoid seeds' potential reduction during storage. During storage, seeds present varying quality levels due to what has happened during development in the field (Yamada, 1989).

Moreover, during storage, they are subjected to deterioration in detriment of interactions between physical, chemical and biological processes represented mainly by temperature, humidity and availability of oxygen, microorganisms, insects, rodents and birds (Santos & Mantovani, 1997).

3. Seed treatment with insecticides and storage

Among the hindrances of farming is the loss of crop productivity caused by pest insects which – in agrosystems – find favorable conditions to its development due to monoculture practices over broad areas.

The number of pests attacking seeds and plants in early stages in several crops has also significantly increased, as a result, causing losses in the initial stand. Soil and aerial part pests have caused significant losses, leading to the need of a preventive treatment by using insecticides. Some of the insecticides available in the market present systemic action, which promote control in the initial phase of development, avoiding crop spraying in the early 20 days.

In this context, insecticides contribute significantly to the increase of yield, exerting control over these organisms (pests or pathogens). Although there are other methods or strategies of

control, insecticides application has been the most employed method due to its easy employment, fast achievement of results and lack of other equally efficient methods. These insecticides comprise an essential tool for current farming (Castro, 2005).

In order to avoid possible losses associated with the actions of insects, soil and aerial pests which may attack seeds and young plants, the preventive use of insecticides is an alternative practice in seeds' treatment (Silva, 1998). This practice, when appropriately accomplished, can reduce the number of foliar applications, which, many times must be started right after seedlings emergence (Menten, 1991).

Insecticides used in seeds' treatment differ from those applied in traditional pulverizing methods by their systemic action in the plant. In the soil, they detach from the seeds and, due to their low- pressure steam and aqueous solubility, they are slowly absorbed by the roots, granting the plant an appropriate period of protection against soil and aerial part pests (Silva, 1998).

Brazilian pesticides industry, propelled by the excellent agricultural performance, tripled its income in the last decade. The Brazilian market, which was US\$ 947 million in 1992, reached US\$ 3.1 billion in 2003, and in 2008 closed US\$ 5.15 billion. In 2003, the Brazilian market was listed as the top three in the world rank, according to Cristiano Walter Simon, president of the National Association of Vegetal Defense. In addition, in 2008, the Brazilian pesticides industry became the largest in the world in sales revenue, overcoming the United States. Insecticides comprise 27.5% of this market, attesting its real importance (MAPA, 2009).

In the late 80s', concerns regarding the indiscriminate use of agrottoxics provoking damages to rural workers and the environment were intensified. Findings on new groups of insecticides, less toxic and aggressive to the environment, have corroborated to lessen the problem (EMBRAPA, 2002).

Thus, seed treatment is a preventive farming method, which consists of the application of insecticides on seed's surface, not only to control pests during storage, but equally important, to protect seedlings during germination and the initial period of crop establishment. In most countries where farming is intensive and highly productive, treatment is accomplished basically in their own seed processing units. The use of phytosanitary products applied via seeds is a common practice among many crops, nevertheless, growing concern regarding environment and safety during the process of those seeds' manipulation have increased the demands for new application technologies, which might reduce risks without jeopardizing seeds' quality.

Controlling pest insects in the phase prior to the implementation of a crop or at sowing time means that seeds' treatment is considered one of the most recommended measures in farming, providing less use of pesticides and avoiding environmental pollution problems (Machado, 2000).

The application of phytosanitary products aims to permit seed germination through accomplishing pest control and to protect seeds from soil pests. As a result, seed treatment by using phytosanitary products has become a frequent practice in order to assure an appropriate emergence and initial development of seedlings in the field (Novembre & Marcos Filho, 1991). Carrying out chemical treatment, most of the time, can avoid crop re-sowing, according to evidences of Goulart et al. (1995) and Menten (1996).

Therefore, 95% of the volume of soybean seeds in Brazil is commercialized with some kind of chemical treatment (Pereira, 2005). Besides insecticide application, other products can take part in the treatment, changing it into means for technology transferring. Incorporation of micronutrients, biostimulants and fungicides are among these practices (Fossati, 2004).

The use of insecticides on seeds is a technique which has been arisen due to an increase of insects' attack on the cycle onset because with direct sowing, these pests are sheltered either in straw or soil, causing damages to the newly deployed crop. Thus, insecticides industry for seed treatment has been fast-growing. Nowadays, around 30% of soybean seeds have been treated with this product (Baudet & Peske, 2006).

Within a number of problems faced in the production and conservation of seeds, the biggest one refers to pests during storage, in which losses of the stored product – due to this attack – represent a high percentage, whereas an adequate storage would prevent the damage of a great deal of production of many crops in Brazil (Carvalho, 1978).

Besides qualitative (contamination, nutritional value degradation, propagation and fungi development) and quantitative (mass reduction) depletions, pest attack to seeds can cause losses of both germinative power and vigor (Padilha & Faroni, 1993).

Some restrictions were discussed by Menten (1996) regarding the utilization of seeds' treatment with chemicals. Among them, cited by the author, the possible cytotoxic effect intensified after treatment, can lead to a reduction on germination and vigor of seeds (Ginasi *et al.*, 2000).

Although insecticide seed treatments have been considered one of the most efficient methods for using this kind of pesticide (Gassen, 1996; Ceccon *et al.*, 2004), results on studies have revealed that some products, when applied to seeds may also cause germination and seedling survival reduction. (Oliveira & Cruz, 1986; Kashypa *et al.*, 1994; Nascimento *et al.*, 1996).

In corn crops, significant depletion in seed vigor were observed by Bittencourt *et al.* (2000) after cabofuran application, similarly acknowledged by Fessel *et al.* (2003) who reported reduction in longevity, vigor and seedling emergence speed of corn crops after treating seeds with deltamethrin and pirimiphos-methyl in high doses. Silveira *et al.* (2001) observed a smaller seedling radicular development after applying the insecticide phipronil on seeds.

When assessing seedling height after treating black bean seeds, Guimarães *et al.* (2005) observed the negative effects of the insecticides carbofuran, thiamethoxam and imidacloprid. Nevertheless, the two latter ones only presented toxicity if seeds were previously treated from ten and thirty days and from five and ten days prior to sowing, respectively.

In soybean crops, Dan *et al.* (2010), when assessing some seed treatment insecticides over different storage periods, observed that results obtained from seed germination (Figure 1) indicated that, except for thiamethoxam, all of the other treatment insecticides significantly reduced seed germination throughout storage compared to the witness. Tavares *et al.* (2007) observed no difference on both germination and vigor when using different doses of thiamethoxam in soybean seed treatment. Similarly, Barros *et al.* (2001) observed no reduction on germination compared to the witness when using thiamethoxam on bean crop.

At time zero (Figure 1), it can be noticed that all insecticide treatments reached an appropriate germination level for soybean seeds, with germination percentages above 80% – minimum value referred by Brasil (2005) – characterizes the absence of harmful effects under this variable at the time of sowing on the date of seed treatment.

A reduction in seed germination percentage can be observed as and when storage period increases after insecticide treatment (Figure 1), particularly for acephate and carbofuran. Acephate was the insecticide which showed a greater reduction in seed germination during storage periods, providing a reduction of 0.55 percentage points (pp) in germination for each day of seed storage. These results indicate that this insecticide provoked a negative

effect on soybean seed germination and that this effect linearly increased according to the extension of storage period, in accordance to what was similarly reported by Oliveira and Cruz (1986) in corn seeds.

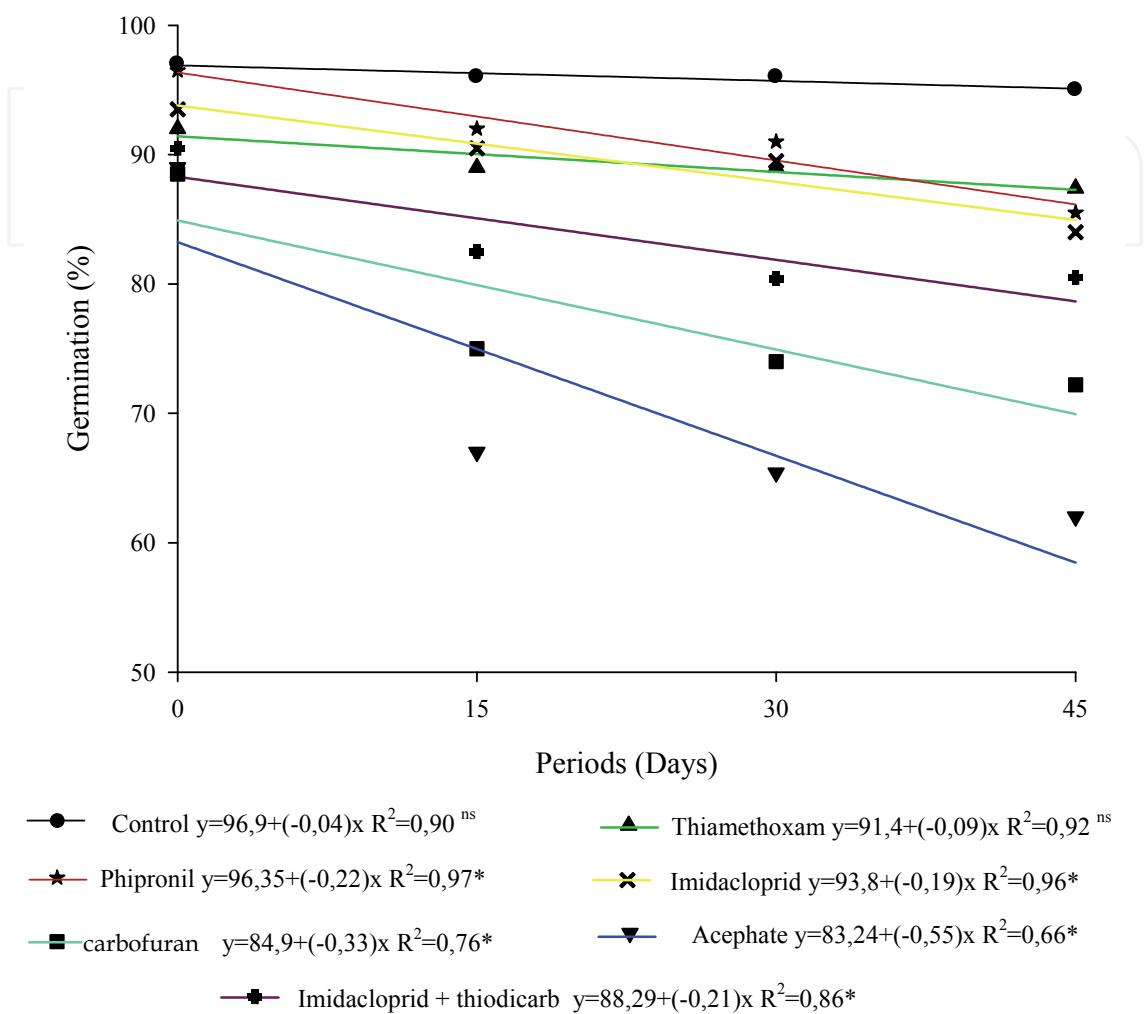


Fig. 1. Germination (%) of soybean seeds after insecticide treatments in four periods of storage (Dan *et al.*, 2010).

Carbofuran-based insecticide seed treatment followed the same behavior of that one of the acephate, however, presenting a smaller reduction on seed germination when compared to the latter. It is important to remember that germination is an essential process in order to guarantee a good final plant stand. Thus, soybean seeds treated with acephate and carbofuran when stored may result – at the sowing time – in plant stand failures, and, consequently, in crop yield drops (Dan *et al.*, 2010).

Nevertheless, it can be observed that at the end of storage period (45 days), treatments using the insecticides such as phipronil and thimethoxam. Imidacloprid and imidacloprid plus thiodicarb still presented germination percentage above 80% (Figure 1).

When assessing insecticide treatment in soybean seeds (Dan *et al.*, 2011), during short storage periods observed that (Figure A), except for thiamethoxam, phipronil and imidacloprid, all the other insecticide treatments significantly reduced seed germination throughout storage when compared to the witness.

After up to three days of storage, all insecticides treatments reached an appropriate germination level for soybean seeds, showing germination percentages above 80% - minimum value referred for Brazil (2005) - characterizes the absence of harmful effects under this variable at the time of sowing up to three days after seed treatment. A reduction of seeds' germination percentage can be observed as and when storage period increases after the insecticide treatment (Figure 1A), particularly for carbofuran and acephate on day 7 of storage, which conditioned seeds at germination percentages below 80%. Acephate was the insecticide which showed a greater reduction in seed germination during storage periods, providing a reduction of 3.089 percentage points (pp) in germination for each day of seed storage.

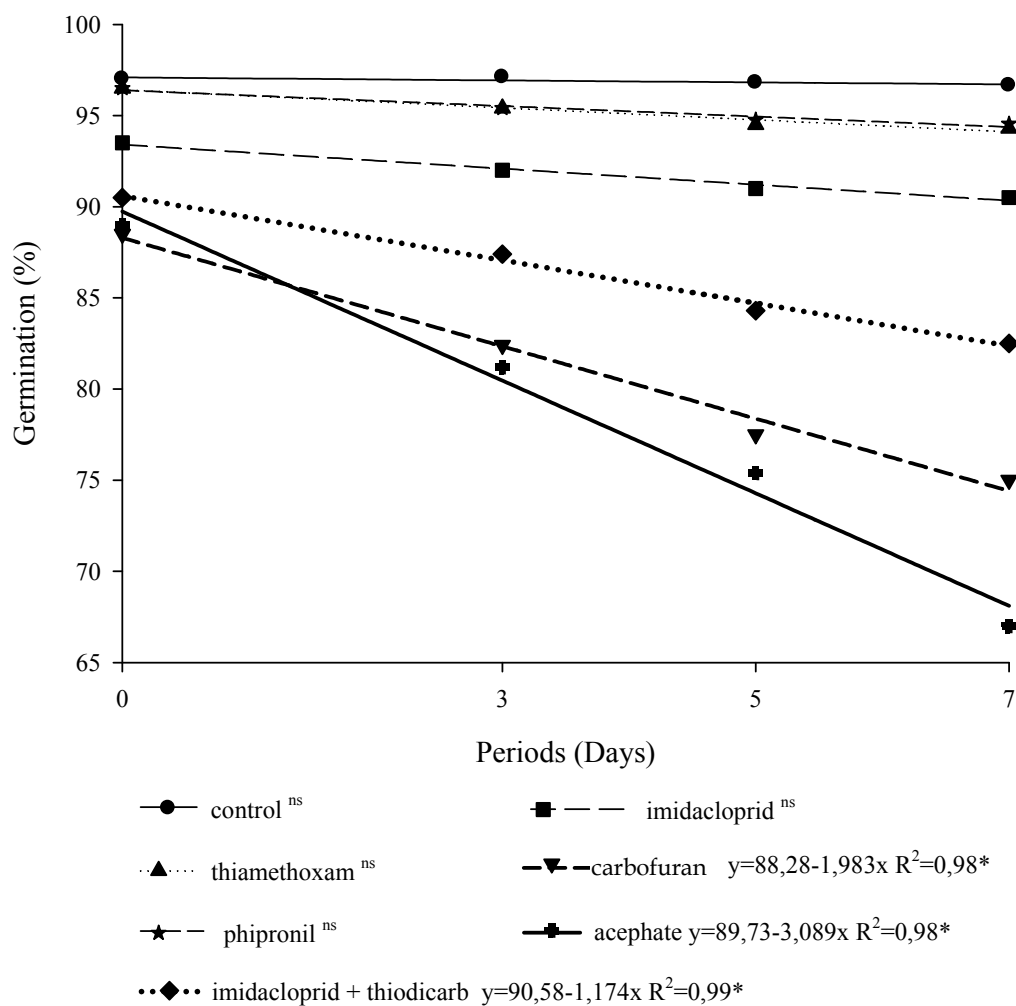


Fig. 1 A. Germination percentage after insecticide treatments in four periods of storage (Dan *et al.*, 2011).

Regarding to vigor, determined by speed of emergence index (Figure 2), there was no significant difference between the non-treated witness and phipronil and thiamethoxam treatments, which means that speed of emergence was not affected by the respective treatments when submitted to storage periods. For Horii and Shetty (2007), insecticides such as thiamethoxam may help in the metabolic pentose phosphate pathway, benefiting the hydrolysis of reserves and increasing the availability of energy to the germination process

and seedling emergence. Grisi *et al.* (2009) observed neither vigor nor emergence alteration of sunflower seeds treated with thiamethoxam and phipronil.

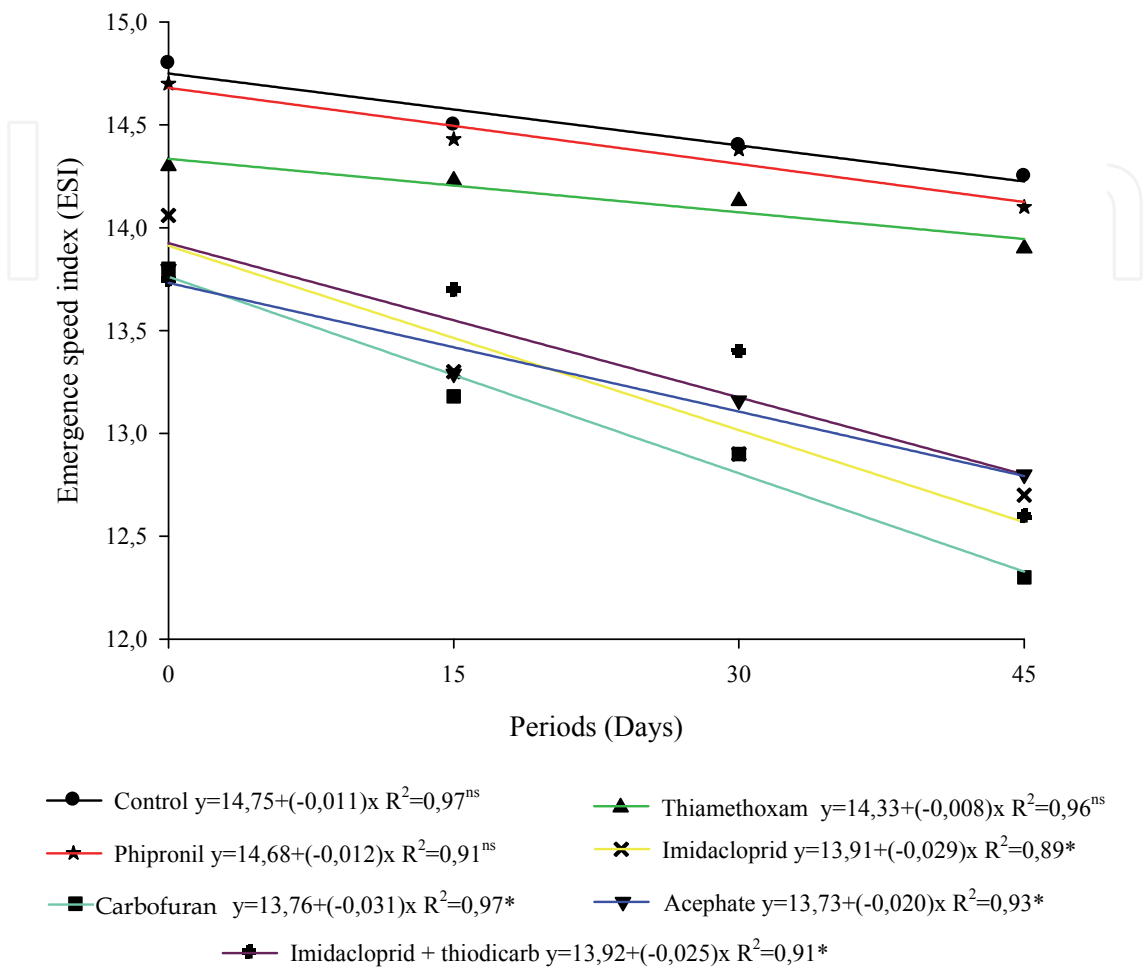


Fig. 2. Speed of emergence index (SEI) of soybean seedlings after insecticide treatments in four periods of storage (Dan *et al.*, 2010).

In general, a reduction in speed of emergence index (SEI) can be observed as when storage period increases, particularly enhanced in the treatments with imidacloprid, imidacloprid plus thiodicarb, carbofuran and acephate (Figure 2). Nevertheless, Castro *et al.* (2008) observed higher vigor in soybean seeds treated with imidacloprid. Bittencourt *et al.* (2000) have found no effects of the insecticides thiodicarb, imidacloprid plus thiodicarb in corn seedlings emergence. However, treated seeds were not stored in these studies.

Within seed treatments assessed, the insecticide carbofuran presented a higher reduction in speed of emergence index for each day of storage, reaching 0.031 reduction unit. Godoy *et al.* (1990) observed lower percentages and emergence speed when corn seeds were insecticide treated using carbofuran. During short-term storage Dan *et al.* (2011) observed a reduction of 5.8% in SEI in a seven-day storage.

Results obtained according to seedling primary root length of soybean crops are shown in Figure 3. Except for the witness, all of the other insecticide treatment negatively influenced soybean seedling radicular growth. This fact occurred mainly when treated seeds were stored.

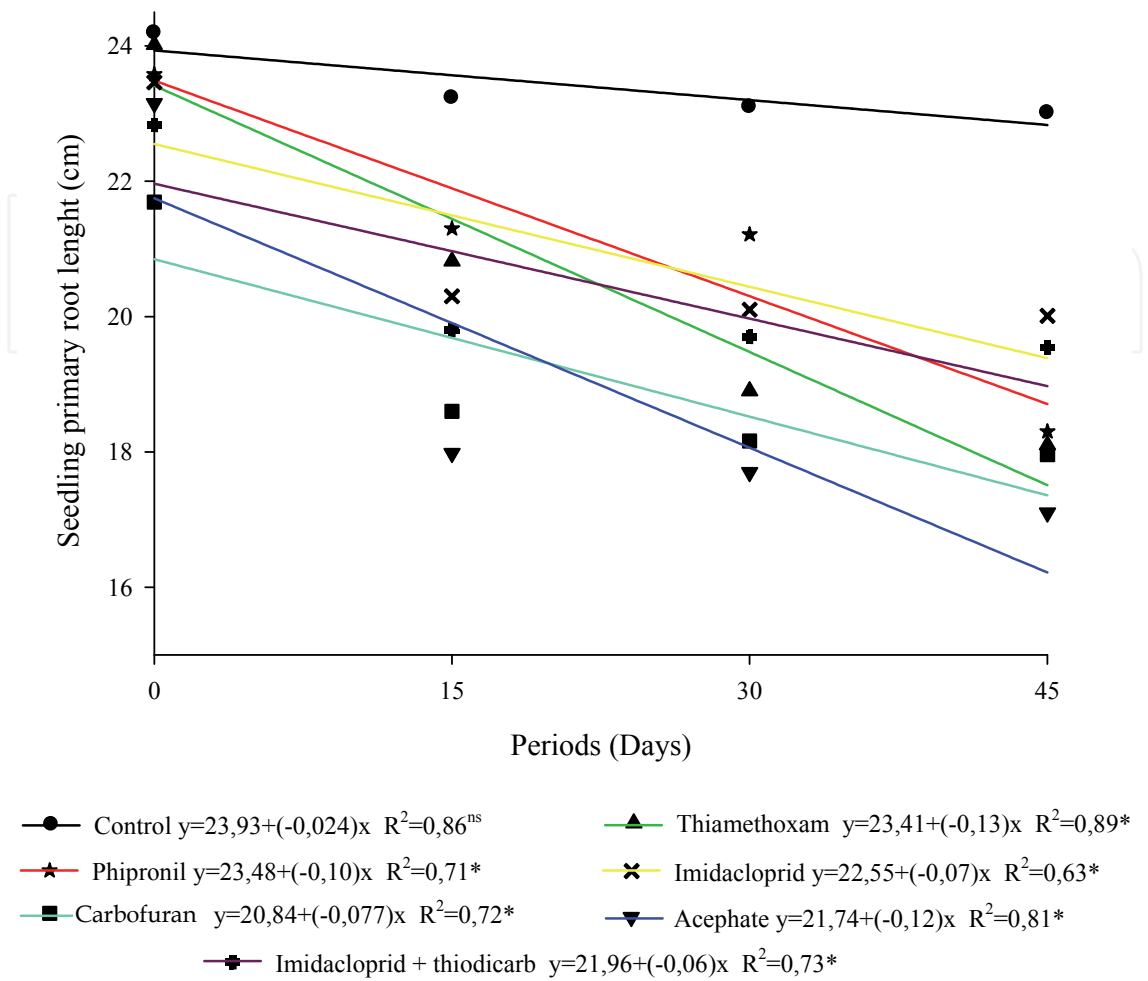


Fig. 3. Soybean seedling primary root length (cm) after insecticide treatment in four periods of storage (Dan *et al.*, 2010).

Phipronil, acephate and thiamethoxam treatments presented the highest reductions in primary root length in relation to the increase of storage period, showing reductions reaching to 0.10; 0.12 and 0.13 for each day of storage, respectively. These results are in accordance to those found by Silveira *et al.* (2001), in which the insecticide phipronil produced a phytotoxic effect on corn seedling radicular growth. Similarly, during short-term storage, Dan *et al.* (2011) observed that soybean seed insecticide treatment using acephate presented the highest reduction in the primary root length in relation to storage period, showing reductions reaching 0.667 cm each day. Nevertheless, for thiamethoxam, Nunes (2006) assessed that the effect of this insecticide on seed germination produces plants with greater root enlargement and fasciculation, simultaneously to a higher growth of the aerial part. These facts were not observed in this present study.

Moreover, significant reductions in the dry matter of plants from seeds which were insecticide treated and subsequently stored were observed. According to Dan *et al.* (2011), a reduction in dry matter accumulation from the aerial part of soybean plants was observed when compared to the witness (Figure 4) in the treatments using imidacloprid, imidacloprid plus thiodicarb, acephate and carbofuran. It was observed no significant differences in the

treatments using thiomethoxam and phipronil when compared to the witness in relation to dry matter accumulation from the aerial part of soybean plants.

In the treatment using phipronil for corn seeds, Silva & Silva (2009) found similar stem matter in relation to the witness, thus, supporting the results obtained in this study.

Therefore, it is important to note that treatments using the insecticides acephate and imidacloprid plus thiodicarb presented the highest reduction indexes of dry matter accumulation for each day of storage in the order of 4.919 and 4.777%, respectively. Whereas, the treatment using carbofuran presented the lowest dry matter accumulation in all storage periods when compared to the witness. The deleterary effects of this insecticide were observed even under conditions when sowing was accomplished right after seed treatment.

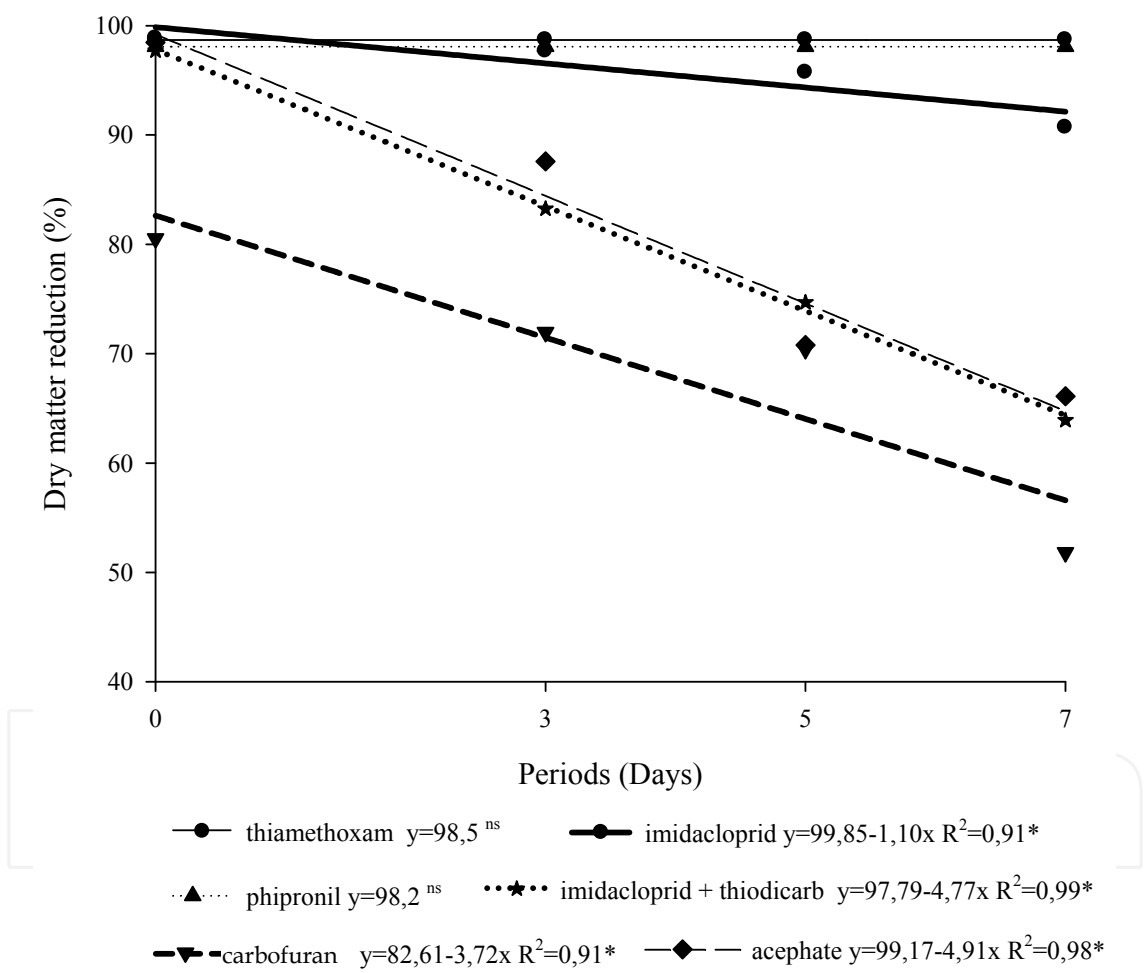


Fig. 4. Dry matter reduction from aerial part of soybean plants (according to the witness) from insecticide treated seeds in four periods of storage (Dan *et al.*, 2011).

Negative interferences were verified regarding vigor of soybean seeds treated with insecticides and subsequently stored. According to Dan *et al.* (2010), by assessing normal seedlings' percentage after accelerated aging (Figure 5) in soybean seeds treated with different kinds of insecticides, observed that all treatments reduced seeds' vigor in relation to storage period.

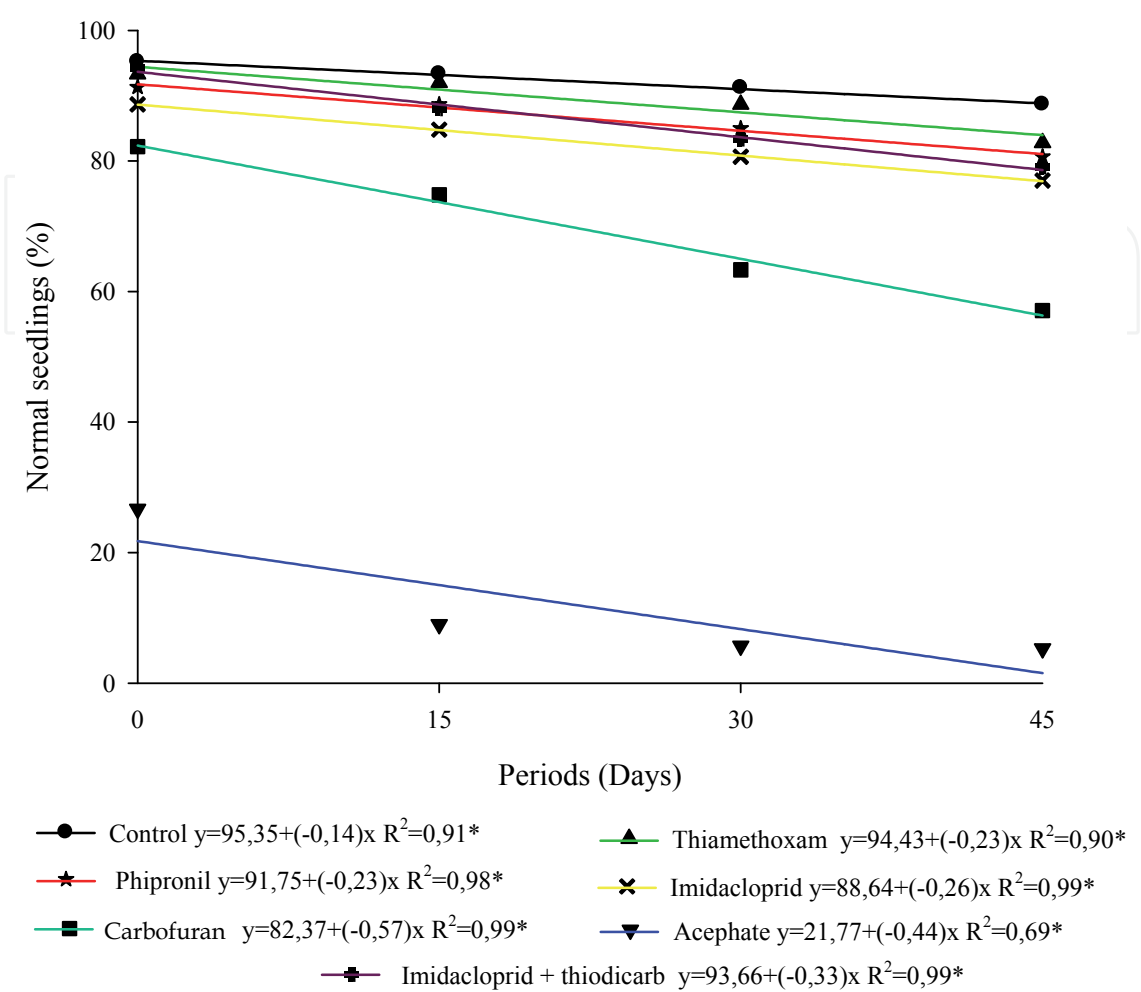


Fig. 5. Normal seedlings (%) obtained from seed accelerated aging test after insecticide treatment in four periods of storage (Dan *et al.*, 2010).

At time zero, except for acephate, all treatments showed high vigor level, being over 80%. However, soybean seeds insecticide treated by using acephate obtained only 26.6% of normal seedlings, indicating that this insecticide drastically reduced vigor in soybean seeds (Figure 5).

Decreases in physiological potential of insecticide treated seeds may be related to the formation of free radicals, as a response to exogen stress produced by insecticides from carbamate and organophosphate groups (Soares & Machado, 2007). Free radicals provide oxidative modification of proteins; DNA injuries and cell membrane lipids peroxidation. Many of these reactive oxygen species are formed from xenobiotic metabolism deriving one or more reactive byproducts (Delgado, 2006). Several pesticides, such as organochlorides (endosulfan) and organophosphorates (acephate) have toxic effects involving free radicals. Oxidative stress induction (imbalance between the production and catalization of free radicals) and antioxidant system alteration by pyrethroids have been shown by a number of authors (Braguini, 2005).

According to the progressive increase of days seeds were kept stored after insecticide treatment, reductions in percentage of normal seedlings obtained from accelerated aging

test were also markedly verified by using the insecticide carbofuran, following the same behavior from those results obtained by acephate (Figure 5). However, soybean seeds' treatment by using carbofuran presented a steeper reduction in vigor (0.57 pp) for each storage day. These results are in accordance to Fessel *et al.* (2003) when verifying that seeds' vigor diminished as when storage period of treated seeds increased.

Nevertheless, despite vigor reductions have been occurred according to the increase of storage period, it is possible to verify that soybean seed insecticide treatments using phipronil, thiamethoxam, imidacloprid and imidacloprid plus thiocarb have established a vigor level of 80%. Thus, soybean seeds utilized in these insecticide treatments still presented good quality when submitted to a 45-day storage (Figure 5).

Therefore, Dan *et al.* (2010) concluded that the application of insecticides such as carbofuran and acephate is harmful to physiological quality of cultivar M-SOY 6101 of soybean seeds for a 45-day storage period. In addition, the reduction in physiological quality of conditioned seeds by using the insecticides carbofuran, acephate, imidacloprid and imidacloprid plus thiocarb is intensified according to the extension of treated seed storage period. Therefore, seed insecticide treatment should be carried out next to sowing time.

There have been some reports saying that insecticides not only protect crops from insect attacks but also act as bioactivators, improving crop performance, however, results are contradictory in relation to these effects. Regarding the effects on seed insecticide application, Ceccon *et al.* (2004) observed that the insecticides phipronil and thiamethoxam stood out concerning agronomic parameters, corn harvesting, in areas highly infested by burrowing bugs and white grubs but did not present any increase on grain yield when compared to the witness.

Ester *et al.* (1997) did not observe any phytotoxic effect on the use of insecticides on seeds; however, she verified a reduction in emergence speed. On the other hand, Tavares *et al.* (2007) did not observe any difference in germination and vigor when different doses of thiamethoxam were used in the treatment. These authors did not find any difference in the development of both hypocotyl and primary root of soybean seedlings after the application of five doses of the product.

By assessing the effects on the application of insecticides, fungicides and their associations with corn seed quality, Takahashi & Cícero (1986) observed that the insecticides such as deltamethrine 2.5% CE plus piperonyl and avermectin butoxide 0.36% SL were efficient on protecting seeds throughout a 12-month storage period.

Smiderle (1998) concluded that the insecticides deltamethrine and chlorpyrifos, isolated or associated, phosphine as well as diatomaceous earth similarly promote control of insect pests which occurs in storage and do not cause toxicity to corn seeds. In addition, physiological quality of corn seeds is preserved by chemical treatments and diatomaceous earth.

The accomplishment of seed treatment at the time prior to sowing is a common practice for many crops such as soybean and corn. Nevertheless, due to adverse climatic conditions, treated seeds are stored for a short-term period for further utilization until those conditions become favorable to sowing. Generally, storage environment also does not meet the ideal storage conditions, in other words, treated seeds are stored in natural environments eventually exposed to high temperatures and moisture, which may jeopardize their physiological performance (Dan *et al.*, 2011).

It is important to highlight that the function of storage is to preserve the initial quality of products, avoiding its deterioration. Thus, the objective of storage is to maintain a good

level of seed quality until they are commercialized and/or used for sowing. Seeds storage period in an environment is determined by genetic inheritance and level of seed deterioration at the beginning of storage (Fontes & Mantovani, 1993; Kelly & George, 1998). Furthermore, Machado (2000) reported the dependence on chemical treatment effectiveness due to a number of factors, among them, the vigor of seeds at the time of the product application.

4. Perspectives and final considerations

In general, although there are some variations on results in some studies concerning the influence of insecticide treatment on physiological quality of seeds from different crops, it can be inferred that insecticides application is harmful to the physiological quality of soybean seeds during long storage periods. The intensity of these negative effects on seeds is closely related to initial vigor before storage. In lower vigor lots, depending on the insecticide used in the treatment, reduction of physiological quality can cripple commercialization in a short-term storage period.

However, regardless of species, the reduction in the physiological quality of seeds conditioned by insecticides is enhanced by extending storage period for treated seeds. Therefore, seed insecticide treatment should be accomplished as closer as possible to sowing time.

It is important to note that, other products have been used in seed treatment as fungicides, bioregulators and some micronutrients; therefore, it is assumed that there may be some interaction with insecticide treatment, consequently influencing on the physiological quality of seeds. More information should be provided in order to find more about this interaction as well as the most appropriate time to treat the seeds.

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This book contains 30 Chapters divided into 5 Sections. Section A covers integrated pest management, alternative insect control strategies, ecological impact of insecticides as well as pesticides and drugs of forensic interest. Section B is dedicated to chemical control and health risks, applications for insecticides, metabolism of pesticides by human cytochrome p450, etc. Section C provides biochemical analyses of action of chlorfluazuron, pest control effects on seed yield, chemical ecology, quality control, development of ideal insecticide, insecticide resistance, etc. Section D reviews current analytical methods, electroanalysis of insecticides, insecticide activity and secondary metabolites. Section E provides data contributing to better understanding of biological control through *Bacillus sphaericus* and *B. thuringiensis*, entomopathogenic nematodes insecticides, vector-borne disease, etc. The subject matter in this book should attract the reader's concern to support rational decisions regarding the use of pesticides.

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