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Insecticides action of neonicotinoids group in fall armyworm (*Spodoptera frugiperda*) control on bean leaves (*Phaseolus vulgaris*)

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ABSTRACT
Among several factors that impact the bean culture productivity there are pest insects, which affect the plant since seeding until postharvest, causing loss in the culture yield. The fall armyworm (*Spodoptera frugiperda*) stands out among the main pests of common bean (*Phaseolus vulgaris*). The aim of this work was to evaluate the effectiveness of insecticides of the neonicotinoid group in the control of the fall armyworm in the bean crop, comparing dinotefuran, acetamiprid, thiamethoxam and imidacloprid performance. Experimental design was composed of blocks entirely randomized, with 9 treatments and 10 replicates. Three caterpillars, at the stage of second instar, were used in each experiment, focusing on the ingestion of leaves containing the treatments. Evaluations were realized in the intervals of 1, 3, 6 and 8 days after every application, counting the number of caterpillars alive in the Petri's dish, attributing visual notes on bean leaves, according to the foliar area affected (consumed). The dinotefuran treatment with the highest dose presented superior efficiency at 80% in the first evaluation. The thiamethoxam treatment with the lowest dose, in the latest analyses, showed efficient superior at 90%. The major doses of all treatments presented efficiency higher than 80% in the last evaluations, being efficient in the *S. frugiperda* control.

Keywords: agriculture; pest control; bean culture; pesticides; caterpillar.

INTRODUCTION

The common bean (*Phaseolus vulgaris* L.) is the principal agricultural culture in Brazil (FARIA et al., 2020). The cultivation of beans expresses a worldwide importance in economic and social development (CONCEIÇÃO et al., 2018). In the North and Northeast regions, its importance is represented by the social role, being cultivated in smaller properties, contributing to the feed security as protein source (FARIA et al., 2020). In addition to its protein importance, bean is an important food in the Brazilians' diet, often consumed as carbohydrate source and bioactive compounds essential for the maintenance of human health (DELFINO; CANNIATTI-BRAZACA, 2010).

According to the Companhia Nacional de Abastecimento (CONAB, 2019), Brazil imports near of 150,000 tons per year to supply internal demand, the majority coming from Argentina. The bean media production in Mercosur's countries, in the last 4 years, corresponds to 3.6 million tons, being Brazil the principal producer with 90% of participation, followed by Argentina, Paraguay and Uruguay (CONAB, 2019). Among several factors that impact the bean culture productivity there are pest insects, which affect the plant since seeding until postharvest, causing loss in the culture yield (PAIVA et al., 2018).

Known in Brazil as *lagarta-do-cartucho*, *Spodoptera frugiperda* (Smith, 1797) (Lepidoptera: Noctuidae) is also known as fall armyworm, and is the most important pest insects that attack the bean, because they feed on the leaves, resulting in reduction and destruction of foliar area and reproductive structure of the plant. The fall armyworm is characterized by being polyphagous, which means it feeds on 353 plant species, but mainly damages corn, rice, sorghum, cotton, and sugarcane (PAIVA et al., 2018; WANG et al., 2020). According to MELO et al. (2014), the importance of *S. frugiperda*, it is due not only to the damage caused, but especially to the difficulty of its control.

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TOSCANO et al. (2012) state that the occurrence of *S. frugiperda* in the corn culture is common and can cause damages, considering that the next generation favors from food cultivated in the field during the year. In this context, BARBOSA; GONZAGA (2012, p.145, our translation) also affirm that the "beans field commonly planted after the soil or corn harvest have been damaged by fall armyworm from corn and caterpillar from soy."

The caterpillar control in the bean culture is performed, predominantly, by pesticide pulverization. In some cases, failures are observed in this control method, which can be caused By the interception of large quantity of plant syrup on the upper third of the plants , comparing with the performance of spraying in the local where the caterpillar lives (GUEDES et al., 2012).

GUEDES et al. (2012) emphasize that, with the development of new application systems, the quality and efficiency of spraying becomes fundamental, aiming to standardize the application and reach the pests that are in the lower third of the crop, resulting in greater control efficiency, which has been supplied by new technologies. "The use of selective insecticides minimizes the exposure of natural enemies and, at the same time, controls pest species" (GRAVENA, 1983 apud FONSECA et al., 2012, p.15, our translation).

Researchers as TIWARI et al. (2020), GUPTA (2013); ROCHA et al. (2011) show the effect of insecticides belonging to the chemical neonicotinoids group, in the control of pests and diseases plants, with different active principle, being acetamiprid, dinotefuran, imidacloprid (FRANK; LEBUDE, 2020) and tiametoxam (SCORZA JÚNIOR; RIGITANO, 2012). The neonicotinoids act like agonists in the nicotinic post-synaptic receptor of acetylcholine (nAChR) in insects (TOMIZAWA; CASIDA, 2005 apud ROCHA et al., 2011). According to ROCHA et al. (2011), the nAChR is found in insects and located in the neuropil region in the nervous central system. It is a receptor responsible by the neurotransmission and insecticides action that causes rapid and efficient action by compounds, which proves the little knowledge about neonicotinoids insecticides.

The bean culture is extremely important to the agriculture and, for this reason, damage and loss produce caused by *S. frugiperda* need to be researched looking for control alternatives, in addition to methods and efficient products, from different chemical groups, and, principally, with security to the environment and people.

In this context, the present work aims to value the efficient of insecticides neonicotinoids group in fall armyworm in bean culture and to compare the performance of active principles among them, applying dinotefuran, acetamiprid, tiametoxam and imidacloprid.

MATERIAL AND METHODS

The experiment was conducted in laboratorial conditions, in Estação Experimental Pontual Pesquisa e Desenvolvimento, located in Iperó, São Paulo, with geographical coordinates 23°24'56"S, 47°34'68"W and 570 m altitude.

The compounds used belong to the chemical neonicotinoid group, being: thiamethoxam, imidacloprid, dinotefuran and acetamiprid. The sample referred was only distilled water. Commercial name, active ingredient, concentration, formulation, action mode and toxicological classification of the products used in the essay are presented in Table 1.

Table 1. Commercial name, active ingredient, concentration, formulation, mode of action and toxicological classification of the products used in the test.

Commercial Name	Active ingredient	Concentration	Formulation	Toxicological classification
Actara	Tiametoxam	250 $g{\cdot}kg^{-1}$	WG	III
Provado	Imidacloprid	200 $g{\cdot}L^{-1}$	SC	III
Mospilan	Acetamiprid	725 $g{\cdot}kg^{-1}$	WG	III
Dinno	Dinotefuran	200 $g{\cdot}kg^{-1}$	SG	V

WG: dispersible granules; SC: concentrated suspension; SG: Soluble granules; III: Moderately toxic; V: Unlikely to cause acute damage.

Experimental design

The experimental design used in the experiment was composed of blocks entirely randomized, with 9 treatments and 10 replicates, totalizing in 54 experimental units. The experimental units consisted of 9 × 9 cm (81 cm^2) Petri dishes. The treatment used in the experiment, as well as commercial product doses and doses of active ingredients are described in Table 2.

Table 2. Treatment, products, and doses of products applied for the control of the Fall armyworm (*Spodoptera frugiperda*).

Treatment	Description	Doses	
		ppm p.c.*	ppm i.a.**
1	Dinotefuran	50	10
2	Dinotefuran	500	100
3	Acetamiprid	13	10
4	Acetamiprid	130	100
5	Tiametoxam	40	10
6	Tiametoxam	400	100
7	Imidacloprid	50	10
8	Imidacloprid	500	100
9	Control sample	-	-

*ppm p.c.: part per million of the commercial product; **ppm i.a.: part per million of active ingredient.

After the separation of the Petri dishes, filter paper was placed on each, dampening them with distilled water. Separately, the bean leaves were emerged within the syrup prepared with the indicated concentration of each treatment, where it remained for 5 s. After this period, the contaminated leaves were dried and then placed one leaf per Petri dish. Three caterpillars, at the stage of second instar, were placed on the leaves free of product (control). The evaluations were performed at 1, 3, 6 and 8 days after each application, counting the number of live caterpillars in Petri dishes, and assigning visual notes on the bean leaves, according to the affected leaf area (consumed). The leaves were divided into four quadrants and evaluated for integrity (presence or absence of damage caused by consumption). Notes from 0 to 100% were assigned, and the higher the value, the larger the affected area (lower leaf integrity). The efficacy of the applied treatments was calculated according to the Abbott formula (1925), applying Eq. 1.

$$E\% = 1 - \frac{\text{n in T after the treatment}}{\text{n in Ctrl after treatment}} \quad (1)$$

where, “E%” is the efficiency; “n” is the insect population; “T” is the treatment used and “Ctrl” is the control sample. The formulas applied and the calculations performed were made through the ARM software, a management program used for efficacy tests.

Statistical analysis

The raw data of the evaluations were submitted to variance analysis (ANOVA) and the means compared by the Tukey’s test using 5% probability ($p \leq 0.05$) using the ARM software.

RESULTS AND DISCUSSION

Number of caterpillars

Table 3 presents the data obtained for counting the number of live caterpillars of *S. frugiperda* in Petri dishes, depending on the treatments applied. When analyzing the results in 1 day after application (DAA), at the highest dose, it is observed that the insecticide dinotefuran (treatment 2) differed from the others, presenting a rapid time of action, with efficiency of 88.9%, in addition to the lower number of caterpillars, with an average of 0.3. The mechanism of action of this insecticide does not require ingestion for it to take effect, and it would be enough to contact the insect to cause death (GWALTNEY-BRANT, 2013).

With this same dose, the insecticides thiamethoxam (treatment 6) and imidacloprid (treatment 8) showed similarity to dinotefuran, with efficiency greater than 60%. Thiamethoxam requires a metabolic activation for the formation of another neonicotinoid (clothianidin) (SEIFERT, 2014), which may explain the need for a longer time to achieve efficiency greater than 80%. As well as imidacloprid, which has a cumulative effect of acetylcholine on the sciatic nerves, leading to paralysis and death (CLEMENTS et al., 2016). Among the treatments with the lowest dose, imidacloprid (treatment 7) presented similar efficiency to those with higher dose in 1 DAA, as well as the number of caterpillars. Other treatments with a lower dose showed efficiency of less than 25% in this evaluation. According to the requirements of the regulatory agency of arthropod pest control products, the ones that do not have at least 80% efficiency of target species cannot be registered (BRAZIL, 2018).

This determination considers that the other 20% efficiency is due to the natural mortality of the species (ABBOTT, 1925). Thus, low doses of insecticides were not effective against control of *S. frugiperda*, except for thiamethoxam (treatment 5). Despite having presented low efficiency in 1 DAA, it was efficient in the other evaluations, presenting efficiency higher than 80% in 6 DAA and 90% in 8 DAA. With this advance from the first to the last evaluation, it can be confirmed that this treatment presented a slower but effective time of action. In the other evaluations, all treatments differed significantly from the control, obtaining efficiency of up to 100% from 3 DAA, where the insecticide dinotefuran (treatments 1 and 2) was superior. In the last evaluation, the highest dose of all treatments showed 100% efficiency, thus being efficient for the control of *S. frugiperda*.

Table 3. Average number of *Spodoptera frugiperda* caterpillars remaining in Petri dishes, and treatment control efficiency.

		Number of caterpillars alive											
Treatment	Doses ppm i.a.	1DAA			3DAA			6DAA			8DAA		
		m		E%	m		E%	m		E%	m		E%
1	10	2.4	ab	20.0	1.7	b	44.4	0.7	bcd	77.8	0.7	c	78.0
2	100	0.3	d	88.9	0.0	d	100.0	0.0	d	100.0	0.0	d	100.0
3	10	2.3	ab	22.2	1.7	b	55.6	1.3	bc	55.6	1.2	b	61.0
4	100	1.7	bc	44.4	0.8	c	94.4	0.2	d	94.4	0.0	d	100.0
5	10	2.7	a	11.1	2.0	b	83.3	0.5	cd	83.3	0.2	d	94.0
6	100	1.0	cd	66.7	0.3	cd	100.0	0.0	d	100.0	0.0	d	100.0
7	10	1.7	bc	44.4	2.0	b	50.0	1.5	b	50.0	1.0	bc	67.0
8	100	0.7	d	77.8	0.3	cd	94.4	0.2	d	94.4	0.0	d	100.0
9	-	3.0	a	0.0	3.0	a	0.0	3.0	a	0.0	3.0	a	0.0
CV(%)		27.00			27.96			56.64			37.91		
Average		1.70			1.31			0.81			0.67		

Means followed by the same letter do not differ from each other by the Tukey's test ($p \leq 0.05$); Unprocessed data; DAA: days after application; m: average repetitions; E%: efficiency calculated by Abbott; CV(%): coefficient of variation; m: average repetitions; ppm a.i.: parts per million active ingredient.

Figure 1 shows the results of the control efficiency of the number of caterpillars in the Petri dishes.

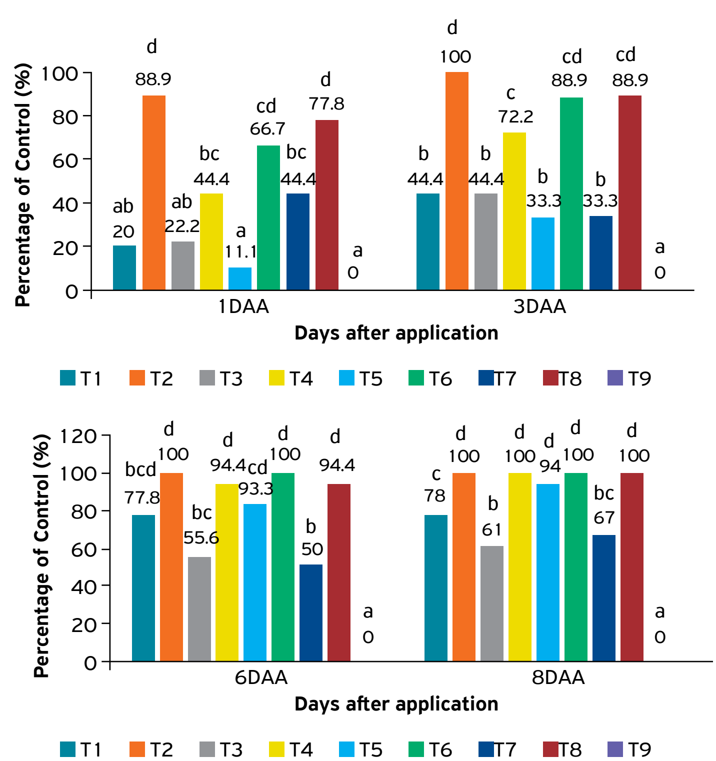

Figure 1. Percentage of the control efficiency of the number of live caterpillars in Petri dishes in the several days evaluated.
DAA: Days after application; T: Treatments; T1: Dinotefuran 10 ppm; T2: Dinotefuran 100 ppm; T3: Acetamiprid 10 ppm; T4: Acetamiprid 100 ppm; T5: Thiamethoxam 10 ppm; T6: Thiamethoxam 100 ppm; T7: Imidacloprid 10 ppm; T8: Imidacloprid 100 ppm; T9: Control; Means followed by the same letter do not differ from each other by the Tukey's test ($p \leq 0.05$); Untransformed data.

Leaf area affected

Table 4 show the percentual results obtained to leaf area affected by *S. frugiperda* feeding according to the applied treatment.

Table 4. Percentage of leaf area affected by *Spodoptera frugiperda* feeding, and treatment control efficiency.

Treatment	Doses ppm i.a.	1DAA			3DAA			6DAA			8DAA		
		m		E%	m		E%	m		E%	m		E%
1	10	7.8	a	9.6	9.83	bc	46.0	13.5	bcd	61.4	21.2	c	53.9
2	100	1.0	c	88.5	1	e	94.5	1.0	d	97.1	1.0	e	97.8
3	10	7.3	a	15.4	10.7	b	41.4	18.3	bc	47.6	24.0	bc	47.8
4	100	1.5	c	82.7	3.5	de	80.8	4.9	cd	86.0	5.3	de	88.6
5	10	4.5	b	48.1	6.17	cd	66.1	8.0	bcd	77.1	8.5	d	81.5
6	100	1.5	c	82.7	4.5	de	75.3	4.1	d	88.3	4.3	de	90.8
7	10	9.1	a	0.0	12.2	b	33.2	21.5	ab	38.6	28.3	b	38.4
8	100	2.8	bc	68.3	4	de	78.0	4.5	cd	87.1	4.7	de	89.9
9	-	8.7	a	0.0	18.2	a	0.0	35.0	a	0.0	46.0	a	0.0
CV(%)		27.81			30.41			59.57			22.53		
Average		4.82			7.59			12.32			15.82		

Means followed by the same letter do not differ from each other by the Tukey's test (p ≤ 0.05); Unprocessed data; DAA: days after application; m: average repetitions; E%: efficiency calculated by Abbott; CV(%): coefficient of variation; m: average repetitions; ppm i.a.: parts per million active ingredient.

In 1 DAA dinotefuran (treatment 2) differed from the others, presenting a lower percentage of leaf area consumed and greater efficiency as in the count of caterpillars. In 8 DAA, thiamethoxam (treatment 5), at the lowest dose, presented similar efficiency to higher dose treatments, which can be justified by its slow time of action, but also by cannibalism among the caterpillars of *S. frugiperda* (Fig. 2). GOUSSAIN et al. (2002) verified higher mortality and increase of cannibalism in groups of caterpillars at the end of the 2nd instar, being considered dead caterpillars by the direct effect of the treatments those that presented the body without excision, and cannibalism was considered when the dead caterpillars were abscinded. The 3rd instar showed a cannibalism rate of around 18% when confined in corn seedlings and, in the repetitions in which there was food shortage, this rate was 34% (RAFFA, 1987 apud GOUSSAIN et al., 2002). Values of 100% cannibalism were investigated by NALIM (1991 apud GOUSSAIN et al., 2002), who confined four caterpillars of *S. frugiperda* in Petri dishes.

Figure 2. Caterpillar of *Spodoptera frugiperda* feeding on another of the same species.

As in the number of caterpillars, thiamethoxam (treatments 5 and 6), proved to be efficient in both doses used, presenting efficiency higher than 50% already in the second evaluation (3 DAA), and higher than 80% in the last evaluation, thus proving effective in controlling the fall armyworm, because, despite presenting a slower time of action, it is shown to be efficient even in small doses.

In the other evaluations, all treatments differed significantly from the control, obtaining efficiency above 90% in the last evaluation, where the insecticides dinotefuran and thiamethoxam were superior.

Figure 3 shows the results of the control efficiency of the leaf area affected by the caterpillars.

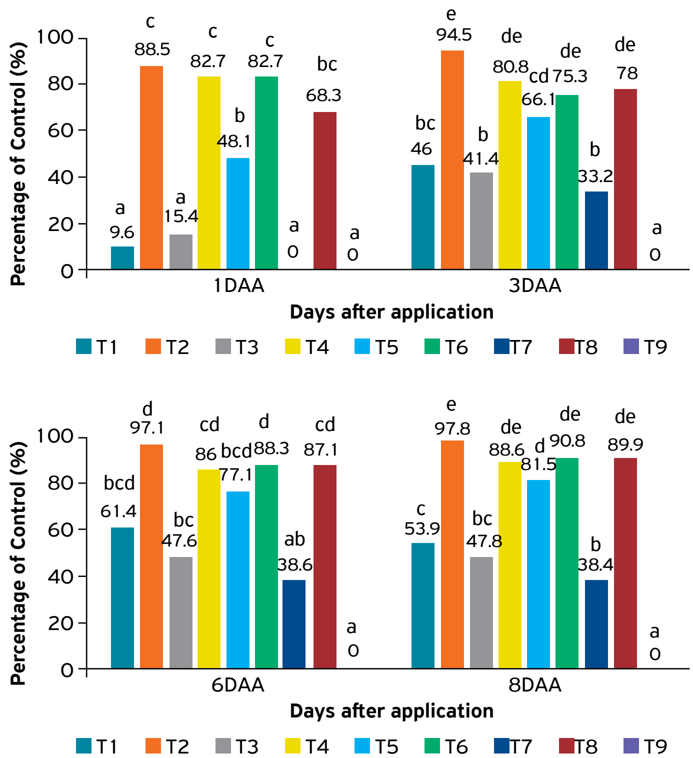

Figure 3. Percentage of control efficiency of the affected leaf area in the various days of treatment.
DAA: Days after application; T: Treatments; T1: Dinotefuran 10 ppm; T2: Dinotefuran 100 ppm; T3: Acetamiprid 10 ppm; T4: Acetamiprid 100 ppm; T5: Thiamethoxam 10 ppm; T6: Thiamethoxam 100 ppm; T7: Imidacloprid 10 ppm; T8: Imidacloprid 100 ppm; T9: Witness; Means followed by the same letter do not differ from each other by the Tukey test ($p \leq 0.05$); Unprocessed data.

Low-dose insecticides (10 ppm) showed no efficacy against the number of caterpillars or leaf area until the eighth day of evaluation. Thus, the great differential between treatments appears until the third day of application, because it is when the differences between the higher dosage treatments (100 ppm) are more evident. Although dinotefuran was more efficient from the outset against the number of caterpillars, its effectiveness in leaf area was comparable to acetamiprid, which is marketed more concentrated. Depending on the extent of the crop, these small differences can impact the final cost of the product. New tests reapplying insecticides, as well as pilot tests with larger areas of application could bring relevant information about the handling of these agricultural pesticides.

CONCLUSIONS

Considering the present study on the evaluation of the efficacy of insecticides from the chemical group of neonicotinoids in the control of fall armyworm on common bean leaves, in laboratory, the treatment of higher dose of the insecticide dinotefuran (treatment 2) differed from the others, presenting a rapid time of action and efficiency greater than 80% referring to the number of caterpillars and leaf area affected, already in the first evaluation. The treatment of lower dose of thiamethoxam (treatment 5), although not significantly efficient in the first evaluation, proved to be efficient in the other evaluations, presenting efficiency higher than 90% in the number of caterpillars and 80% in the affected leaf area, indicating a slower but effective time of action. In the last evaluation, the highest dose of all treatments presented efficiency higher than 80% in the affected leaf area, and in 100% in the number of caterpillars, thus being efficient for the control of *S. frugiperda*.

AUTHORS' CONTRIBUTIONS

Conceptualization: Stanghini, L.P.; Plens, A.C.O. **Data curation:** Stanghini, L.P. **Formal analysis:** Stanghini, L.P.; Martinez, R.M.; Plens, A.C.O. **Funding acquisition:** Stanghini, L.P.; Plens, A.C.O. **Investigation:** Stanghini, L.P. **Methodology:** Stanghini, L.P. **Project administration:** Martinez, R.M.; Plens, A.C.O. **Supervision:** Martinez, R.M.; Plens, A.C.O. **Validation:** Stanghini, L.P.; Martinez, R.M.; Plens, A.C.O. **Visualization:** Stanghini, L.P.; Martinez, R.M.; Plens, A.C.O. **Writing – original draft:** Stanghini, L.P.; Martinez, R.M. **Writing – review & editing:** Martinez, R.M.; Plens, A.C.O.

AVAILABILITY OF DATA AND MATERIAL

Not applicable.

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CONFLICTS OF INTEREST

All authors declare that they have no conflict of interest.

ETHICAL APPROVAL

Not applicable.

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REFERENCES

ABBOTT, W.S. A method of computing the effectiveness of an insecticide get access arrow. *Journal of Economic Entomology*, Oxford, v.18, n.2, p.265-267, 1925. https://doi.org/10.1093/jee/18.2.265a

BARBOSA, F.R.; GONZAGA, A.C.O. *Informações técnicas para o cultivo do feijoeiro-comum na Região Central-Brasileira*. 2012-2014. (Documentos 272). Santo Antônio de Goiás: Embrapa Arroz e Feijão, 2012. 247p.

BRAZIL. Ministério da Agricultura, Pecuária e Abastecimento. *Memória da 2ª reunião técnica nacional sobre pesquisa com agrotóxicos*. Brasília: MAPA, 2018. Available from: https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/insumos-agricolas/agrotoxicos/arquivos/memoria-da-reuniao.pdf. Acessed on: 05 Sept. 2020.

CLEMENTS, J.; SCHOVILLE, S.; PETERSON, N.; LAN, Q.; GROVES, R.L. Characterizing molecular mechanisms of imidacloprid resistance in select populations of *Leptinotarsa decemlineata* in the Central Sands Region of Wisconsin. *PLoS One*, v.11, n.1, e0147844, 2016. https://doi.org/10.1371/journal.pone.0147844

CONAB – COMPANHIA NACIONAL DE ABASTECIMENTO. *Perspectivas para a Agropecuária:* Safra 2019/20. v.7. Brasília: CONAB, 2019. Available from: https://www.conab.gov.br/perspectivas-para-a-agropecuaria/item/download/43258_740c07378b7c174a4f702d3a396546a1. Acessed on: 05 Sept. 2020.

CONCEIÇÃO, C.G. da; ROBAINA, A.D.; PEITER, M.X.; PARIZI, A.R.C.; CONCEIÇÃO, J.A. da; BRUNING, J. Economically optimal water depth and grain yield of common bean subjected to different irrigation depths. *Revista Brasileira de Engenharia Agrícola e Ambiental,* Campina Grande, v.22, n.7, p.482-487, 2018. https://doi.org/10.1590/1807-1929/agriambi.v22n7p482-487

DELFINO, R. A.; CANNIATTI-BRAZACA, S.G. Interação de polifenóis e proteínas e o efeito na digestibilidade proteica de feijão comum (*Phaseolus vulgaris* L.) cultivar Pérola. *Food Science and Technology*, Campinas, v.30, n.2, p.308-312, 2010. https://doi.org/10.1590/S0101-20612010000200003

FARIA, L.C. et al. *BRS FS307:* cultivar de feijão-comum com grão mulatinho para o Nordeste. (Comunicado Técnico 251). Embrapa Arroz e Feijão: Santo Antonio de Goiás, 2020.

FONSECA, P.R.B.; MOTA, T.A.; KASSAB, S.O.; FERNANDES, M.G. Seletividade de inseticidas utilizados no controle da *Spodoptera frugiperda* (J.E. Smith, 1797) nos inimigos naturais epigéicos na cultura do milheto. *Revista Caatinga*, Mossoró, v.25, n.1, p.14-19, 2012.

FRANK, S.D.; LEBUDE, A. Season-long insecticide efficacy for hemlock woolly adelgid, *Adelges tsugae* (Hemiptera: Adelgidae), management in nurseries. *Florida Entomologist*, Lutz, v.94, n.2, p.290-295, 2020. https://doi.org/10.1653/024.094.0223

GOUSSAIN, M.M.; MORAES, J.C.; CARVALHO, J.G.; NOGUEIRA, N.L.; ROSSI, M.L. Efeito da aplicação de silício em plantas de milho no desenvolvimento biológico da lagarta-do-cartucho *Spodoptera frugiperda* (J.E.Smith) (Lepidoptera: Noctuidae). *Neotropical Entomology*, Londrina, v.31, n.2, 2002. https://doi.org/10.1590/S1519-566X2002000200019

GUEDES, J.V.C.; FIORIN, R.A.; STÜRMER, G.R.; PRÁ, E.D.; PERINE, C.R.; BIGOLIN, M. Sistemas de aplicação e inseticidas no controle de *Anticarsia gemmatalis* na soja. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v.16, n.8, p.910-914, 2012. https://doi.org/10.1590/S1415-43662012000800014

GUPTA, G. Managing thrips on roses with combinations of neonicotinoide and biological insecticides. *Journal of Agricultural and Urban Entomology*, Washington, DC, v.29, n.1, p.16-24. 2013. https://doi.org/10.3954/JAUE11-09.1

GWALTNEY-BRANT, S.M. Atypical topical spot-on products. *In:* SAUNDERS, W.B. (Ed.). *Small animal toxicology*. 3. ed. Philadelphia: Elsevier, 2013. pp.741-754.

SCORZA JÚNIOR, R.P.; RIGITANO, R.L.O. Sorção, degradação e lixiviação do inseticida tiametoxam em dois solos de Mato Grosso do Sul. *Revista Brasileira de Engenharia Agrícola e Ambiental*, Campina Grande, v.16, n.5, p.564-572, 2012. https://doi.org/10.1590/S1415-43662012000500013

MELO, E.P.; DEGRANDE, P.E.; L. LIMA JUNIOR, I. S.; SUEKANE, R.; KODAMA, C.; FERNANDES, M.G. Disposição espacial e injúrias da lagarta-do-cartucho *Spodoptera frugiperda* (J. E. Smith) (Lepidoptera: Noctuidae) em milho. *Revista Ceres*, Viçosa, v.61, n.3, p.343-349, 2014. https://doi.org/10.1590/S0034-737X2014000300007

PAIVA, L.A.; RESENDE, W. C.; SILVA, C.L.T.; ALMEIDA, A.C.S.; CUNHA, P.C.R.; JESUS, F.G. Resistance of common bean (*Phaseolus vulgaris*) cultivars to *Spodoptera frugiperda* (Lepidoptera: Noctuidae). *Revista Colombiana de Entomología*, Cali, v.44, n.1, p.12-18, 2018. https://doi.org/10.25100/socolen.v44i1.6531

PEREIRA, H.S et al. *BRS FC406:* cultivar de feijoeiro-comum carioca com grãos grandes, alto potencial produtivo, resistência à antracnose e à mancha-angular. (Comunicado Técnico 254). Embrapa Arroz e Feijão: Santo Antonio de Goiás, 2020.

ROCHA, L.C.D.; CARVALHO, C.A.; MOSCARDIN, V.F.; REZENDE, D.T. Seletividade de inseticidas utilizados em cultura cafeeira para larvas de *Cryptolaemus montrouzieri* Mulsant. *Ciência Rural*, Santa Maria, v.41, n.6, p.939-946, 2011. https://doi.org/10.1590/S0103-84782011000600004

SEIFERT, J. Neonicotinoids. *In:* WEXLER, P (Ed.). *Encyclopedia of Toxicology*, 3. ed. Elsevier, 2014. p.477-482.

TIWARI, S.; LIU, B.; MANN, R.S.; KILLINY, N.; STELINSKY, L.L. Effects of cold-acclimation, pathogen infection, and varying temperatures on insecticide susceptibility, feeding, and detoxifying enzyme levels in *Diaphorina citri* (Hemiptera: Liviidae). *Florida Entomologist*, Lutz, v.98, n.3, p.870-879, 2020. https://doi.org/10.1653/024.098.0309

TOSCANO et al. Impacto de inseticidas sobre *Spodoptera frugiperda* (*Lepidoptera*, *Noctuidae*) e seus inimigos naturais em milho safrinha cultivado em Cassilândia e Chapadão do Sul, MS. *Arquivos do Instituto Biológico*, São Paulo, v.79, n.2, p.223-231, 2012.

WANG, R.; JIANG, C.; GUO, X.; CHEN, D.; YOU, C.; ZHANG, Y.; WANG, M.; LI, Q. Potential distribution of *Spodoptera frugiperda* (J.E. Smith) in China and the major factors influencing distribution. *Global Ecology and Conservation*, 21, 2020.