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CHEMICAL CONTROL

Reduction of spinosad rate for controlling *Liriomyza huidobrensis* (Diptera: Agromyzidae) in dry beans (*Phaseolus vulgaris* L.) and its impact on *Frankliniella schultzei* (Thysanoptera: Thripidae) and *Diabrotica speciosa* (Coleoptera: Chrysomelidae)

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Redução de dose de espinosade no controle de *Liriomyza huidobrensis* (Diptera: Agromyzidae) na cultura do feijão (*Phaseolus vulgaris* L.) e seu impacto sobre *Frankliniella schultzei* (Thysanoptera: Thripidae) e *Diabrotica speciosa* (Coleoptera: Chrysomelidae)

RESUMO – O inseticida espinosade é registrado para o controle da mosca-minadora, *Liriomyza huidobrensis* (Branchard), na batata no Brasil. A adição de adjuvantes poderia ajudar na redução da dose necessária para um bom controle dessa praga. Assim, espinosade, recomendado na dose de 163,20 g i.a./ha, foi testado a 79, 84 e 96 g i.a./ha em condições de campo para o controle de *Liriomyza huidobrensis* (Branchard) na cultura do feijão com o objetivo de avaliar a possibilidade de redução de dose com a adição do adjuvante siliconado Break Thru® (polyether-polymethylsiloxane-copolymer). O impacto da redução de dose de espinosade foi avaliado também sobre *Frankliniella schultzei* (Trybom) e *Diabrotica speciosa* (Germar). O desempenho de espinosade foi significativamente melhor quando misturado com Break Thru 0,05 % v/v, reduzindo a infestação de *L. huidobrensis* em 50% quando comparado com mesma dose sem a adição do adjuvante. Nenhuma diferença estatística foi observada entre as doses de espinosade + Break Thru® (72, 84 e 96 g i.a./ha + Break Thru® 0,05 % v/v). Todos os tratamentos de espinosade + Break Thru apresentaram desempenho satisfatório no controle do complexo de pragas do feijão avaliados, com controle próximo a 80% de eficiência. O controle da mosca-minadora foi ligeiramente superior com abamectina em algumas localidades; entretanto, o desempenho de espinosade foi superior no controle do tripes quando comparado ao cloridrato de cartape e abamectina reduzindo a população cerca de 75%. Portanto, as doses testadas de espinosade + Break Thru® 0,05% podem ser usadas com sucesso no controle dessas pragas na cultura do feijão.

PALAVRAS-CHAVE: Mosca-minadora, controle-químico, adjuvantes.

ABSTRACT – Spinosad at 163.20 g a..i./ha is recommend to control *Liriomyza huidobrensis* (Branchard) on potato in Brazil. The use of adjuvant might help to reduce the required rate to achieve acceptable control of this pest. Therefore, spinosad, recommended at 163.20 g a.i., was tested at 79, 84 and 96 g a.i./ha in field conditions on controlling *Liriomyza huidobrensis* (Branchard) on dry beans, aiming to evaluate rate reductions with the mixing of the adjuvant polyether-polymethylsiloxane-copolymer (Break Thru®). The impact of this strategy was also evaluated on *Frankliniella schultzei* (Trybom) and *Diabrotica speciosa* (Germar). A significant increase in spinosad performance was observed when tank mixed with Break Thru® 0.05% v/v, with reduction of infestation of *L. huidobrensis* up to 50% when compared to the same rate without mixing the adjuvant. No statistical difference on spinosad rates (72, 84 and 96 g ai/ha + Break Thru® 0.05% v/v) was observed. All spinosad + Break Thru® treatments showed acceptable performance on the dry bean pests evaluated, by reducing pest population with efficacy about 80%. The control of *L. huidobrensis* was slightly superior with abamectin in some trials; however, spinosad + Break Thru® outperformed the other treatments for controlling thrips, with reduction of pest population up to 75%. In conclusion, all spinosad tested rates + Break Thru® can be successfully applied on dry bean crops to control these pests.

KEY-WORDS: Serpentine leafminer, chemical control, adjuvants

Serpentine leafminers, *Liriomyza* spp. (Diptera: Agromyzidae), are polyphagous pests worldwide distributed on different crops (Parrella 1987). Among their host plants, the most important families are Leguminosae (various bean species), Cucurbitaceae (gherkin, cucumber, melon), Chenopodiaceae (spinach, beet), Solanaceae (pepper, tomato, potato, egg plant), Malvaceae, Umbelliferae (carrot, celery, parsley), Compositae (thistle, endive, aster, chrysanthemum, *gerbera*, lettuce), Passifloraceae, Araceae, Cruciferae and Labiatae (Souza 1993, Weintraub & Horowitz 1994). The injury is mainly caused by the larvae that start feeding immediately after eclosion and feed incessantly until they are ready to pupate outside the leaf (Parrella 1987, Souza & Reis 1999).

Leafminers used to be secondary pest in many crops being kept under low infestation due to the natural biological control. However, the use of non-selective insecticides has eliminated the biological control agents what has leaded leafminers to outbreaks of economic importance in many crops (Ewell *et al.* 1990, Pereira 1999). The destructive capacity of leafminers for several crops has been documented in the literature around the world and mainly at North America including crops as dry beans, potato, and tomato among other plants (Spencer 1973, Chandler & Thomas 1982, Poe 1982, Ledieu & Helyer 1985, Hilje *et al.* 1993).

Abamectin, cartap, and cyromazine have been commonly employed to control serpentine leafminers. However, grower's reliance on a few numbers of insecticides had brought up some insecticide resistance management issues (Minkenberg & Van Lenteren 1986). The repeated use of these chemicals has the capacity of selecting insecticide resistant leafminer populations (Ferguson 2003) and thus impairing an important tool to insect control. Also, in several cases, leafminer is not the only pest attacking the crop. Growers usually have to deal with a great complex of pests attacking each crop season and more than one insect occurring at the same time scenarios are more likely to be faced by growers. Therefore, the use of insecticide with a broad spectrum on controlling insect pest might be required. Cyromazine is an insect specific to dipterous what might be limiting its usage since situations where leafminers are the only pest problem in the crop are somewhat rare. Thrips (several species) and *Diabrotica speciosa* (Germar) (Coleoptera: Chrysomelidae) are important damaging insects commonly found on dry beans (*Phaseolus vulgaris* L.) crops, several times in outbreaks mixed with leafminers. One important advantage for the success of the management of these insects is the availability of insecticides with broad spectrum on controlled pests, selective to natural enemies, and also less noxious to the environment and human beings. An insecticide that might have those features is the spinosad.

Spinosad belongs to a new group of insecticides and it is originated from the fermentation process of soil bacteria *Saccharopolyspora spinosa*. This compound has activity on several groups of insects such as lepidopterous, dipterous, coleopterans and thysanopterous (Williams *et al.* 2003). This compound also proved to be safe to human beings receiving a LC_{50} above 5,000 mg and therefore it was classified as Class I (Florim & Nakano 1997). For example, in countries like the United States of America, this compound has also been registered for organic crops. In Brazil, spinosad is already registered to be used in potato crops to control *Liriomyza huidobrensis* (Branchard) (Diptera: Agromyzidae) at a rate range from 163.2 to 201.6 g ai/ha (Agrofit 2007). However, the use of adjuvant, as the surfactant polyether-polymethylsiloxane-copolymer (Break Thru®) might help to reduce the required rate to achieve acceptable control. The usage of lower rates helps to reduce technology costs and brings fewer side effects to the environment. It is highly desirable in a sustainable agriculture system. Therefore, a research aiming to reduce spinosad rate is extremely important. Also, the usage of spinosad can provide a new alternative for controlling *L. huidobrensis* on dry beans. Due to its unique mode of action, spinosad might be used as an active component of insecticide rotation programs. This research was carried out aiming to study spinosad performance at low rates (72, 84, and 96 g a.i./ha) when mixed with Break Thru® on controlling *L. huidobrensis* compared with cartap and abamectin. These tested rates are the minimum possible according to the potential benefits of adding Break Thru. This research also aimed to evaluate the effect of the insecticide control applied to *L. huidobrensis* on *Frankliniella schultzei* (Trybom) and *D. speciosa* that were occurring on the crop at the same time.

Materials and Methods

One field trial was established in Itaberaí, GO, Brazil in June/2003 to study the benefits of mixing Break Thru® 0.05% v/v with lower spinosad rates. The experiment was conducted at a commercial field following all the growers' practices (diseases and weeds control) from June/30/2003 to Jul/29/2003 in a randomized complete block design (RCB) with 10 treatments and 4 replications (4 m × 15 m each). The treatments were: 1. Spinosad 72 g a.i./ha (Tracer®, concentrate suspension formulation, 480 g of spinosad per liter, Dow Agrosciences Industrial Ltda.); 2. Spinosad 72 g a.i./ha + polyether-polymethylsiloxane-copolymer (Break Thru®, Goldschmidt Chemical Coporation) 0.05% v/v; 3. Spinosad 84 g a.i./ha ; 4. Spinosad 84 g a.i./ha +

Break Thru® 0.05% v/v; 5. Spinosad 96 g a.i./ha; 6. Spinosad 96 g a.i./ha + Break Thru® 0.05% v/v; 7. Spinosad 96 g a.i./ha + Mineral oil (Joint oil®, mineral oil, Dow Agrosciences Industrial Ltda) 0.25% v/v; 8. Cartap 600 g a.i./ha (Thiobel 500® wettable powder formulation, Takeda Chemical Industries, Ltda); 9. Abamectin 9 g a.i./ha (Vertimec® 18 CE, emusifiable concentrate formulation, Syngenta Proteção de Cultivos Ltda + mineral oil (Joint Oil®) 0.25% v/v and 10.Untreated (control). Excluding treatments number 7; 8; 9 and 10, an factorial analysis (3 × 2) was also run with 3 spinosad rates (72; 84 and 96 g ai/ha) and 2 Break Thru® rates (0 and 0.05% v/v) in order to analyze the benefits of adding Break Thru® for leafminer control. In the following year (2004) three other field experiments were carried out in other different locations. All experiments were conducted at commercial fields where all growers' practices (diseases and weed control according to the needs) were used. One experiment was conducted in Jaboticabal, SP from Apr/12 to May/13. A second experiment was conducted in Hidrolândia, GO from Nov/09 to Dec/05. And, a third experiment was conducted in Casa Branca, SP from Sep/01 to Oct/14. All trials were in a randomize complete block design (RCB) with 6 treatments and 4 replications (4 m × 15 m each). The treatments were: 1. Spinosad 72 g a.i./ha + Break Thru® 0.05% v/v; 2. Spinosad 84 g a.i./ha + Break Thru® 0.05% v/v; 3. Spinosad 96 g a.i./ha + Break Thru® 0.05% v/v; 4. Cartap 600 g a.i./ha; 5. Abamectin 9 g a.i./ha + mineral oil (Joint Oil®) 0.25% v/v and 6.Untreated (control).

Treatments were applied using a CO_2 backpack sprayer in a broadcast application using the hollow cone, solid spray tip type of nozzle. The equipment was set up to deliver 200 liters/ha. Applications were done on a weekly basis starting in the beginning of natural leafminer infestation (when plants were at vegetative stage - 5th trifoliate) when first leaves were injured. Three, two, three, and five broadcast applications were done at Itaberaí, Jaboticabal, Hidrolândia, and Casa Branca experiments, respectively, on dry beans plants (Pérola, Carioca and Jalo varieties). The experiments were evaluated 3 and 7 days after each application (DAA) and 3, 7, 10, and 14 DAA after last spraying. The parameters evaluated were: number of mines and number of pupae/10 complete leaves/replication. Ten complete leaves were collected per plot on the field and then the number of mines was counted. After that, the leaves were put into a paper bag (separated per replication) and kept in room temperature for 12 days. Finishing this time, the number of pupae were also counted. The number of thrips per 10 flowers and the number of *D. speciosa* per 10 plants were also evaluated at the Casa Branca and Jaboticabal trials, respectively. Data were transformed into $\sqrt{X + 0.5}$ when necessary according to Bartlett's Homogeneity Variance Test to statistical analysis. Data were then submitted to Anova and treatment means separated by Tukey's test (α = 0.05). Treatments efficacy were calculated by Abbott Formula (Abbott 1925).

Results and Discussion

The results obtained at the Itabereraí trial, shows that Break Thru® 0.05% v/v significantly increased spinosad performance to control *L. huidobrensis*. Factorial analyzes showed that the mixing of Break Thru® statistically reduced insect outbreak up to 50% when compared to the same rate without the adjuvant. These results show the importance of using Break Thru® 0.05% with spinosad at 72, 84 and 96 g a.i./ha. All spinosad tested rates when mixed with Break Thru® were statistically similar to abamectin for all evaluated parameters (number of mines and number of pupae) at 3 and 7 days after application (Table 1), showing no difference in the control at 3 and 7 days after application. The following results of 2004 tests confirmed that spinosad, a insecticide with a new mode of action, controls efficiently the serpentine leafminer at all tested rates (72, 84, and 96 g ai/ha + Break Thru® 0.05% v/v) reaching more than 80% control in 2 of 3 tested fields in 2004 (Table 2). The experiment carried out in Casa Branca, SP was the only 2004 trial where spinosad had less than 80% control (Table 2). It might be probably due to the extreme dry condition faced by the time the experiment was set up. It is known that high temperatures and dry conditions are situations that might impair insecticide control (Flint & Gouveia 2001). It might explain what occurred in Casa Branca trial since all tested insecticides had less than 80% control, however, it is important to point out that spinosad 72 g a.i./ha and cartap 600 g a.i./ha were less effective than the other treatments on those conditions (Table 2). These results show that even when used under adverse weather conditions, spinosad efficacy at rates of 84 and 96 g a.i./ha did not differ from abamectin, a market standard commonly used by growers. Spinosad is already register for controlling the leafminer *L. huidobrensis* in potato crops at a rate range from 163.2 to 201.6 g ai/ha (Agrofit 2007). However, this research shows that lower rates (72, 84 and 96 g a.i./ha) might be successfully used when mixed with Break Thru® 0.05% v/v. This rate reduction is important for grower in order to reduce costs keeping the same control efficacy. Thus, spinosad mixed with Break Thru® is a new option of product that might be successfully applied to control *L. huidobrensis* outbreaks at different rates (72, 84 and 96 g a.i./ha).

Table 1. Mean ± SE of treatment efficacy on *Liriomyza huidobrensis* (Branchard) infesting dry bean, regarding to cumulative data for number of mines and pupae at Itaberaí, GO, Brazil.

Treatment	Means[4] of % Control (Abbott)		
	Mines	**Pupae**	
	3 days after application	3 days after application	8 days after application
1. Spinosad 72 g a.i./ha	27.73 ± 9.41 b	44.03 ± 16.99 ab	41.87 ± 17.31 a
2. Spinosad 72 g a.i./ha + Break Thru 0.05% v/v	64.00 ± 19.02 ab	57.54 ± 13.51 ab	47.13 ± 16.70 a
3. Spinosad 84 g a.i./ha	37.95 ± 19.73 b	33.01 ± 5.52 ab	32.56 ± 16.90 a
4. Spinosad 84 g a.i./ha + Break Thru 0.05% v/v	68.64 ± 14.84 ab	82.86 ± 3.31 a	55.22 ± 16.54 a
5. Spinosad 96 g a.i./ha	45.90 ± 18.31 ab	12.55 ± 7.02 b	4.81 ± 4.81 a
6. Spinosad 96 g a.i./ha + Break Thru 0.05% v/v	68.00 ± 10.34 ab	59.56 ± 18.34 ab	63.02 ± 11.20 a
7. Spinosad 96 g a.i./ha + Mineral oil (Joint Oil) 0.25% v/v	58.47 ± 6.62 ab	55.86 ± 15.33 ab	45.42 ± 16.95 a
8. Cartap 600 g a.i./ha	39.14 ± 8.35 b	9.98 ± 9.98 b	42.61 ± 16.31 a
9. Abamectin 9 g a.i./ha + mineral oil (Joint Oil) 0.25% v/v	87.01 ± 2.92 a	72.61 ± 14.21 a	65.34 ± 16.71 a
10. Untreated	-	-	-
Cumulative data from	3 DAAA[1], 3 DAAB[2], 3 DAAC[3]	3 DAAA, 3 DAAB, 3 DAAC	7 DAAC

[1]Days after application A; [2]Days after application B; [3]Days after application C.
[4]Means followed by the same letter in the same column are not significantly different (P>0.05) by Tukey's test.

Insecticide resistance in *Liriomyza* spp. populations has been reported to chlorinated hydrocarbons, organophosphates, carbamates and pyrethroids (Genung 1957, Wolfenbarger 1958, Wolfenbarger & Getzin 1963, Parrella *et al.* 1981). According to Weintraub & Horowitz (1994) *L. huidobrensis* is a primary pest of potatoes in South America and different populations of this specie is commonly selected to resistance to insecticides due to the constant use of chemicals with similar mode of action.

In Brazil, dry bean fields are usually cultivated close to potato plots, increasing the awareness level of this pest for dry beans growers. *Liriomyza* spp. resistance to abamectin might be selected if growers repetitively use this compound. However, cross-resistance between abamectin and spinosad was not detected yet (Ferguson 2003) what makes spinosad appropriated for compound rotational programs in Insecticide Resistance Management (IRM).

Dry bean crops are also frequently injured by other insect pests (Nakano *et al.* 2002) at the same crop season. Therefore, when evaluating the potential of one compound directed to control *L. huidobrensis*, it is extremely important to consider the impact on other important pests. An insecticide with a broad spectrum on controlling pests, harmless to human beings and selective to beneficial insects, is greatly desirable. At the trial carried out in Casa Branca, SP, when plants started to blooming, an outbreak of thrips, *Frankliniella schultzei* (Trybom) (Thysanoptera: Thripinae), occurred attaching dry bean flowers. By that time, two more insecticide sprayings were applied (application D and E). The results on thrips control showed a better efficacy of spinosad when compared to abamectin and cartap. At 3 days after application D, spinosad was the only compound that reduced thrips population to a statistically lower level compared to untreated plots (Fig. 1A). Abamectin and cartap only differed from untreated plots after a second application (application E) (Fig. 1B). The specie *F. shultzei* frequently attacks plant flowers being of difficult control because the insects keep hidden in the flowers in a place difficult to be reached by the insecticide. Spinosad was the compound in this research that showed better performance on controlling this pest feeding inside the flowers. At 7 days after application E, all treatments were statistically equal to the untreated plots on *F. shultzei* control (Fig. 1C). This result showed that when thrips are detected at the field, dry bean crops need constantly monitoring (more than once a week) mainly because the infestation might raise very quickly as occurred inside this trial. The good performance of spinosad on controlling thrips is an important feature to be considered by growers when choosing the insecticide. The broad spectrum feature is important when several pest species are present in the field.

D. speciosa is another pest frequently found on dry bean crops. At early developmental stages of the plants, this insect might be a primary pest that requires one or more insecticide spraying. At the trial carried out in Jaboticabal, SP this was detected and the efficacy of the products used in this experiment on controlling *D. speciosa* was evaluated. All tested products had good performance on controlling adults of this Coleopteran. Cumulative data from 3 (Fig. 2A), 7 (Fig. 2B), and 10 days after the first and second sprays (Fig. 2C) showed that all tested products, at all tested rates, reduced insect population to a level statistically different from the untreated plots. However, spinosad at 84 and 96 g a.i./ha + Break Thru® 0.05% v/v and cartap 600 g a.i./ha were the only treatments that were statistically different from untreated plots at 14 days after spraying (Fig. 2D).

Overall, the results showed no difference on the tested rates for spinosad and all spinosad treatments + Break Thru® had good performance on the dry bean insect pest complex (leafminer, thrips and *D. speciosa*). Also, spinosad was the best treatment for controlling thrips. The good performance of the reduced spinosad rates mixed with Break Thru® is very important for Integrated Pest Management (IPM) programs by reducing costs and making this technology more accessible for dry bean growers. Therefore, all spinosad tested rates might be successfully applied on dry bean crops for controlling all tested insect species and it could be used as a component in insecticide management programs.

Table 2. Mean ± SE of treatment efficacy on *L. huidobrensis*, infesting dry bean, regarding to cumulative data for number of mines at 3 different experiment locations.

Treatment	Means[6] of % Control (Abbott)		
	Jaboticabal, SP	**Hidrolândia, GO**	**Casa Branca, SP**
1. Spinosad 72 g a.i./ha + Break Thru 0.05% v/v	87.72 ± 7.94 a	90.77 ± 2.62 a	32.26 ± 13.23 b
2. Spinosad 84 g a.i./ha + Break Thru 0.05% v/v	84.05 ± 1.63 a	88.08 ± 7.38 ab	48.54 ± 7.75 ab
3. Spinosad 96 g a.i./ha + Break Thru 0.05% v/v	86.88 ± 3.14 a	84.71 ± 11.65 ab	51.37 ± 7.21 ab
4. Cartap 600 g a.i./ha	73.39 ± 6.89 a	78.43 ± 4.46 ab	29.92 ± 7.0 b
5. Abamectin 9 g a.i./ha + mineral oil (Joint Oil) 0.25% v/v	77.39 ± 8.07 a	70.85 ± 7.35 b	79.36 ± 2.87 a
6. Untreated	-	-	-
Cumulative data from	3 DAAA[1]; 7 DAAA; 3 DAAB[2]; 7 DAAB; 10 DAAB; 13 DAAB	3 DAAA; 3 DAAB; 3 DAAC[3]; 7 DAAC; 10 DAAC	3 DAAA; 7 DAAA; 3 DAAB; 7 DAAB; 3 DAAC; 7 DAAC; 3 DAAD[4]; 7 DAAD; 3 DAAE[5]; 7 DAAE

[1]Days after application A; [2]Days after application B; [3]Days after application C; [4]Days after application D; [5]Days after application E.
[6]Means followed by the same letter in the same column are not significantly different (P>0.05) by Tukey's test.

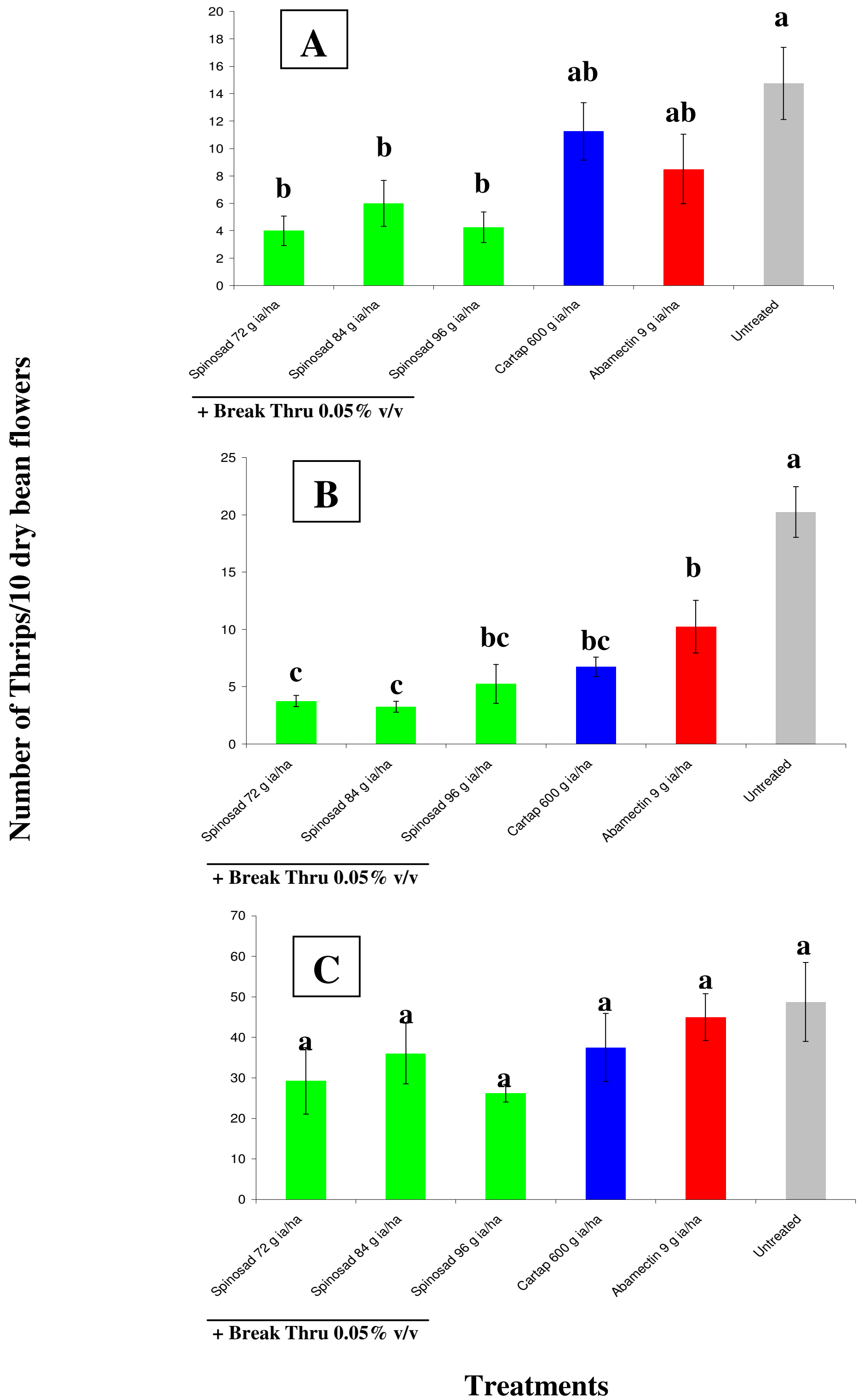

Figure 1. Mean ± SE of number of *F. schultzei* (adults + nymphs) counted in 10 flowers/replication at Casa Branca trial. A) 3 days after application D (4th application). B) 3 days after application E (5th application) (bars built with original data and statistics done with transformed data into $\sqrt{X+0.5}$). C) 7 days after application E. Means followed by the same letter are not significantly different (P>0.05) by Tukey's test.

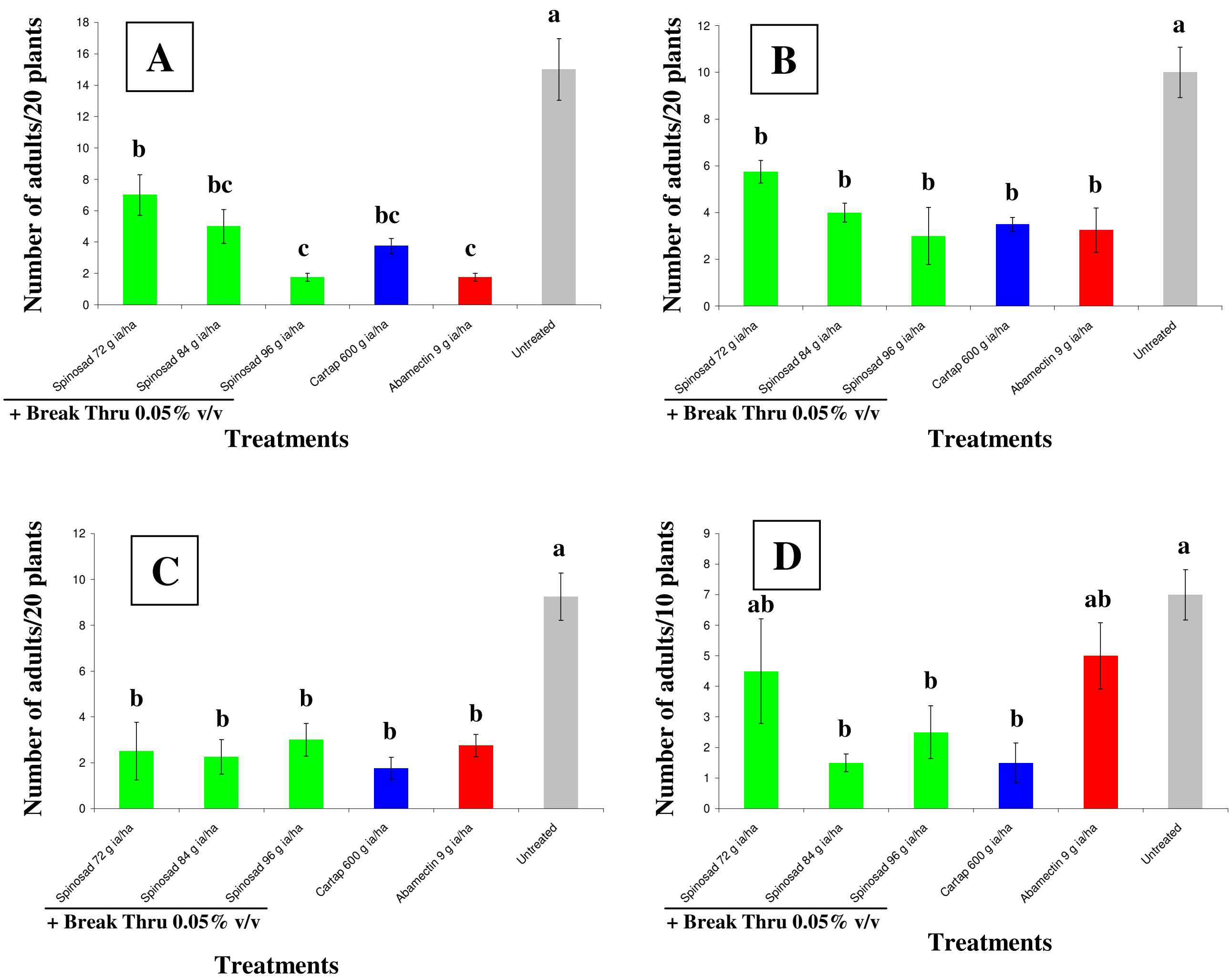

Figure 2. Mean ± SE of number of adults of *D. speciosa* counted in 10 plants/replication at Jaboticabal trial. A) Cumulative data from 3 days after application A and B. B) Cumulative data from 7 days after application A and B. C) Cumulative data from 10 days after application A and B. D) 14 days after application B. Means followed by the same letter are not significantly different (P>0.05) by Tukey's test.

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