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How to control *Helicoverpa armigera* on soybean in Brazil? What we have learned since its detection

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The present study was motivated by a lack of information on how to control *Helicoverpa armigera* in soybean fields in Brazil. Nine chemical and four biological treatments were tested. Control efficiency was evaluated at 3, 7, 10, and 14 days after spraying. Moreover, the cost benefit ratio by the yield and cost of insecticide application and the economic injury level (EIL) were used to calculate the chemical and biological treatments. Chemical insecticides chlorantraniliprole, flubendiamide, chlorfenapyr, spinosad and acephate with 90.9, 90.9, 90.9, 72.7 and 90.9% of control efficiency, respectively, were efficient to control *H. armigera* along the evaluations. Bt Control® was efficient controlling small and large larvae, with 100 and 66.7% of control efficiency, respectively. Gemstar® and HzNPV CCAB® were efficient against small larvae. The treatments acephate (1:10), chlorantraniliprole (1:6.6), flubendiamide (1:5.3), Bt Control® (1:6.6), Gemstar® (1:5) and HzNPV CCAB® (1:5.7) had higher cost benefit ratio (ratios are indicated in parentheses after the treatments names). The EIL is flexible and vary according to the control efficiency, cost of treatment application and market value of soybean. The lowest value of EIL was Dipel® (0.2) and the highest value was chlorfenapyr (2.3). These findings support a decision of when, which treatment, and dose to spray to control *H. armigera* on soybean with a high cost benefit ratio.

Key words: Old world bollworm, control pest, chemical insecticide, biological insecticide.

INTRODUCTION

The confirmation of the presence and invasion of *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) in Brazil (Czepak et al., 2013) and in South and Central America (Murúa et al., 2014; Smith, 2014; Arnemann et al., 2016) brought serious implications in terms of the management of this pest for the main agricultural crops cultivated in these areas. Furthermore, Kriticos et al. (2015) alerted about the extraordinary spread potential of this pest to North America and in July 2014, USDA/APHIS and Florida Department of Agriculture and Consumer Services (FDACS) confirmed the first detection of *H. armigera* in USA.

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Table 1. Chemical and biological treatments and rate per hectare.

Chemical treatment	Trademark	Rate (g ha^{-1})[1]	Biological treatment	Trademark	Rate (g ha^{-1})
1. Chlorantraniliprole	Premio® 200 SC	10.0	*B. thuringiensis*	Dipel® SC	4.5×10^{11}*
2. Flubendiamide	Belt® 480 SC	33.6	*B. thuringiensis*	Bt Control® SC	2.5×10^{13}*
3. Indoxacarb	Avatar® 150 CE	60.0	*H. zea* nucleopolyhedrovirus	Gemstar® SC	4.0×10^{11}**
4. Chlorfenapyr	Pirate® 240 SC	240.0	*H. zea* nucleopolyhedrovirus	HzNPV CCAB® SC	1.5×10^{12}**
5. Spinosad	Tracer® 480 SC	33.6	Control treatment	-	-
6. Chlorfluazuron + Methomyl	Atabron® 50 CE + Lannate® 215 SL	25.0 + 215.0	-	-	-
7. Methoxyfenozide	Intrepid® 240 SC	96.0	-	-	-
8. Lambda-cyhalothrin + Chlorantraniliprole	Ampligo® 50 + 100 SC	3.7 + 7.5	-	-	-
9. Acephate	Orthene® 750 PS	750.0	-	-	-
10. Control treatment	-	-	-	-	-

[1]Rate of active ingredient per hectare. *Rate of spore/crystal. **Rate of polyhedral inclusion bodies.

The management of *H. armigera* populations poses great challenges for the Brazilian soybean farmers, because there is little information available on the chemical and biological control of this pest in Brazil. These difficulties led the Brazilian Ministry of Agriculture and Food Supply to take immediate measures, such as the emergency registration of insecticides for the control of *H. armigera*. It makes the control recommendations susceptible to doubt and errors. The lack of regional control results still leaves the technical assistants, industry, farmers, and researchers without information to establish the management of this pest during recent crop production cycles. Therefore, to evaluate the role of chemical and biological insecticides used to control larvae of *H. armigera* under soybean field conditions, two experiments were accomplished at two locations under different environmental conditions.

MATERIALS AND METHODS

Two experiments were performed during the 2013/2014 growing season in Restinga Seca and Santa Maria, State of Rio Grande do Sul (RS), Brazil. In Restinga Seca, treatments were sprayed on the 3rd of February 2014 at the full pod (R4) growth stage and densities of *H. armigera* were 1.2 and 3.7 small (< 1.5 cm) and large (> 1.5 cm) larvae m^{-2}, respectively. In Santa Maria, treatments were sprayed on the 10th of February 2014 at the beginning seed (R5.1) soybean growth stage, with densities of 2.5 and 1.0 small and large larvae m^{-2}, respectively. The soybean variety on both areas was BMX Potencia RR. The species of *Helicoverpa* occurring on these experiments were identified at the Laboratory of Integrated Pest Management (LabMIP) of the Federal University of Santa Maria using the identification key of Hardwick (1965) from adults and larvae collected during the experiments' evaluations. The voucher specimens were deposited at LabMIP.

The experiment was carried out in a randomized complete block design with four replications and plot sizes of 4 × 6 m (24 m^2), distributed randomly with 0.5 m between each other on the field. Nine chemical and four biological insecticides were sprayed (Table 1; all insecticides were obtained from commercialized market insecticides). In both experiments, treatment applications were performed after 6:00 PM with a CO_2 pressurized backpack sprayer and a flow rate of 150 L ha^{-1}. The evaluations were conducted with a vertical beat sheet (Guedes et al., 2006) in order to count the number of small and large larvae collected on a 1.0 m^2 area per plot at 3, 7, 10, and 14 days after spraying (DAS). Control efficiency (E) of treatments was calculated according to the equation (Abbott, 1925):

$$E = \left(\frac{\text{Control treatment - insecticide treatment}}{\text{Control treatment}} \right) * 100$$

In the Restinga Seca experiment, grain yield was obtained by harvesting 2 km^2 of each plot on the 5th of April 2014. The cost benefit ratio (C:B - how many dollars returned per dollar invested) of each treatment were calculated with additional yield over control treatment, the cost of insecticide application and net income. The Economic Injury Level (EIL) were calculated considering the yield loss (kg/ha) of one *H. armigera* larvae/m^2 of 58 kg/ha (Rogers and Brier, 2010). The number of larvae (x) was transformed to the square root of x + 0.5 and submitted to joint analysis. The means were grouped using the Scott-Knott test (P>0.05).

RESULTS AND DISCUSSION

Chemical control of *H. armigera* in soybean

Most chemical treatments significantly reduced density of *H. armigera* larvae compared to the control treatment. At 3 DAS, control efficiency was the highest for chlorantraniliprole (83.3%), chlorfenapyr (90%), and acephate (83.3%; percent of control efficiency are indicated in parentheses after the treatments names; Table 2). At 7 DAS, control efficiency of larvae was above 90% for flubendiamide (93.1%), indoxacarb (96.6%), chlorfenapyr (100%), spinosad and acephate (93.1%). Chlorantraniliprole reduced the population density of *H. armigera* by 82.8%. At 10 DAS, chlorantraniliprole, flubendiamide, chlorfenapyr, spinosad, lambda-cyhalothrin + chlorantraniliprole, and acephate controlled the larvae >80%. Chlorantraniliprole, flubendiamide, chlorfenapyr, and acephate maintained >90% mortality of larvae at 14 DAS.

Chlorfenapyr (240 g a.i. ha^{-1}) always had the highest control efficiency (at all evaluations). This insecticide uncouples oxidative phosphorylation in mitochondria, thereby interrupting ATP production (Raghavendra et al., 2011). Thereby, this insecticide can be used as an alternative mode of action during the same crop season, delaying or mitigating development of insecticide resistance on this pest.

Chlorantraniliprole and flubendiamide at tested doses of 10 and 33.6 g a.i. ha^{-1}, respectively, had similar efficiencies against *H. armigera* consistent with their chemical group (anthranilic diamides). In cotton, flubendiamide 60 g a.i. ha^{-1} reduced the *H. armigera* larval population by decreasing crop damage by 96% (Thilagam et al., 2010). Furthermore, doses of chlorantraniliprole (31.5 to 52.5 g a.i. ha^{-1}) effectively controlled *H. armigera* in cotton in Australia (Leven et al., 2011). Therefore, in the present study, doses of chlorantraniliprole and flubendiamide lower than those recommended elsewhere effectively controlled *H. armigera*. It demonstrates the importance of local evaluation of insecticides. It was found out that spinosad (33.6 g a.i. ha^{-1}) was effectively >80% at 7 and 10 DAS. Similarly, it has high control efficiency (>90%) in cotton, albeit, at greater doses than those used in the present study (range: 72 to 96 a.i. ha^{-1}) (Leven et al., 2011). The use of higher doses of spinosad was suspected to be related to larval resistance, as reported in Pakistan (Ahmad et al., 2003), India (Kranthi et al., 2000), and Australia (Gunning and Balf, 2002). Improved metabolism by cytochrome P450 oxidase may be predisposed to rapid development of resistance to spinosad (Wang et al., 2006). Indoxacarb had limited residual effects in our results. Vinaykumar et al. (2013) reported reductions within seven DAS on soybean. However, this insecticide had a low residual effect due to its high photodegradation (DT_{50} = 4.5 days at pH 5 and 25°C; FAO). Therefore, indoxacarb requires applications at 7 to 10 days intervals, due to low persistence, despite high initial efficacy.

Biological control of *H. armigera* in soybean

The mortality varied according to size of larvae and DAS. Therefore, results of biological treatments are separately shown. At 3 DAS, all treatments had efficiencies <70%, attributed to delayed pathology of Baculovirus or *Bacillus thuringiensis* (Table 3). Dipel® and Bt Control® had the highest control of small larvae (63.3%). Gemstar® controlled 47.4% of large larvae. At 7 DAS, Bt Control® and HzNPV CCAB® controlled 85.7 and 100%, respectively, of small larvae, whereas Dipel® and Bt Control® had a higher control of large larvae (86.8 and 73.3%, respectively). At 10 DAS, Bt Control® (100%), HzNPV CCAB® (100%), and Gemstar® (87.5%) had the highest control of small larvae. However, for large larvae, Bt Control® and HzNPV CCAB® had control efficiency of 84.2 and 78.9%, respectively. At 14 DAS, Bt Control®, HzNPV CCAB®, and Gemstar® had control efficiency of 100%.

Biological insecticides only had a significantly larvae mortality after 7 DAS, due to its contamination and action mechanism, in which the insecticide needs to be ingested by the larvae to become pathogenic to the insect. Bt Control® had a higher mortality, mainly of small larvae of *H. armigera* compared to Dipel®. Dipel® and Bt Control® had faster mortality to large larvae than Gemstar® and HzNPV CCAB®, which can be attributed to the median lethal time (LT_{50}). Dipel® has a LT_{50} of 6.3 h for first instar larvae of *H. zea* (Junior et al., 2009), whereas for baculovirus it exceeds 3 days (Castro et al., 1999). Even though Dipel® and Bt Control® have the same active ingredient, the commercial products tested had distinct efficiencies due to their amount of *B. thuringiensis* spores/ml. Thereby, the dose of Dipel® to control *H. armigera* has to be increased.

Mortality also depends of larval stage and dose sprayed. The control efficiency of Bt Control®, Gemstar®, and HzNPV CCAB®, was higher to small larvae. Likewise, for the quantity of spores/ml, the amount of OBs on HzNPV CCAB® is higher than Gemstar®. Because of this, the control efficiency of HzNPV CCAB® reached 100% early for small larvae. These present findings were consistent with previous findings on larval stage and dose sprayed. Increase in the dose of OBs applied per larvae results in faster mortality and shorter survival time (Georgievska et al., 2010).

Soybean yield and benefit cost ratio from chemical and biological treatments

The active ingredients acephate (2,643 kg ha^{-1}), spinosad (2,594 kg ha^{-1}), chlorfenapyr (2,576 kg ha^{-1}), chlorantraniliprole (2,447 kg ha^{-1}), and flubendiamide (2,497 kg ha^{-1}) had the highest soybean yield (Table 4), attributed to larvae control efficiency. In this way, the benefit cost ratio was higher for acephate (1:10.0), chlorantraniliprole (1:6.6), and flubendiamide (1:5.3), because of low cost of insecticide application and high soybean yield. Although, acephate had higher benefit cost ratio, should lead to the highest yield,

Table 2. Number of *H. armigera* larvae (±SD) and efficiency (E) of the chemical treatments.

Treatment	[1]Rate (g ha^{-1})	Number of larvae m^{-2}											
		3 DAS[2]	t[3]	E (%)	7 DAS	t	E (%)	10 DAS	t	E (%)	14 DAS*	t	E (%)
1. Chlorantraniliprole	10.0	0.6 (±0.9)	a	83.3	0.6 (±0.5)	a	82.8	0.4 (±0.5)	a	88.9	0.3 (±0.5)	a	90.9
2. Flubendiamide	33.6	1.0 (±1.1)	a	73.3	0.3 (±0.5)	a	93.1	0.3 (±0.5)	a	92.6	0.3 (±0.5)	a	90.9
3. Indoxacarb	60.0	0.9 (±1.0)	a	76.7	0.1 (±0.4)	a	96.6	1.0 (±0.8)	a	70.4	1.5 (±0.6)	b	45.5
4. Chlorfenapyr	240.0	0.4 (±0.7)	a	90.0	0.0 (±0.0)	a	100.0	0.1 (±0.4)	a	96.3	0.3 (±0.5)	a	90.9
5. Spinosad	33.6	0.9 (±1.4)	a	76.7	0.3 (±0.5)	a	93.1	0.4 (±0.5)	a	88.9	0.8 (±1.0)	a	72.7
6. Chlorfluazuron + Methomyl	25.0 + 215.0	1.8 (±1.3)	b	53.3	0.8 (±0.7)	a	79.3	0.8 (±0.7)	a	77.8	1.5 (±0.6)	b	45.5
7. Methoxyfenozide	96.0	2.8 (±2.1)	b	26.7	1.4 (±1.5)	a	62.1	1.0 (±1.1)	a	70.4	1.0 (±0.8)	a	63.6
8. Lambda-cyhalothrin + Chlorantraniliprole	3.7 + 7.5	1.6 (±0.7)	b	56.7	0.9 (±0.6)	a	75.9	0.3 (±0.5)	a	92.6	0.8 (±1.0)	a	72.7
9. Acephate	750.0	0.6 (±0.5)	a	83.3	0.3 (±0.5)	a	93.1	0.5 (±0.5)	a	85.2	0.3 (±0.5)	a	90.9
10. Control treatment	-	3.8 (±1.3)	b	-	3.6 (±1.2)	b	-	3.4 (±1.3)	b	-	2.8 (±1.0)	b	-
CV (%)[4]	-	34.1	-	-	30.9	-	-	42.1	-	-	24.4	-	-

[1]Rate of active ingredient for hectare. [2]Days after spray of treatment. [3]Means separated by the Scott-Knott test (t). Values followed by the same letter do not differ significantly at the 5% probability level. [4]Coefficient of Variation. *Evaluation means of Santa Maria.

because it had a similar control efficiency of chlorantraniliprole and flubendiamide. The insecticide acephate has to be retested. Conversely, even with excellent control efficiency and high productivity, the benefit cost ratio of chlorfenapyr and spinosad insecticides was only 1:3.7 and 1:4.3, respectively, because of their high spray cost.

The yield of the biological treatments, Bt Control® (286 kg ha^{-1}), Gemstar® (297 kg ha^{-1}), and HzNPV CCAB® (301 kg ha^{-1}), differed from control treatment and Dipel® (Table 3). The benefit cost ratio was similar between Gemstar® and HzNPV CCAB® (baculovirus treatments), 1:5.0 and 1:5.7, respectively. Bt Control® had the highest benefit cost ratio (1:6.6). These biological insecticides had a similar benefit cost ratio to the chemical treatments acephate, chlorantraniliprole, and flubendiamide.

This result supports that an application of a biological insecticide affect the selectivity to natural enemies which naturally control the pests.

H. armigera economic injury level (EIL)

Once the density and population distribution of *H. armigera* have been determined, the next step is to decide whether a control program is required by EIL. The EIL is the population density of an insect that causes economic loss equal to the control cost (Pedigo and Rice, 2006). The EIL depends on cost of insecticide application, value of soybean kilogram, the damage (in kg), and the efficiency of the control method/treatment used.

The insecticide Dipel® had a mean efficiency of 60%, with a spray cost of US$13.20. Considering the soybean bag value of US$15.00, the EIL for Dipel® is much lower (0.5 larvae m^{-2}), mainly because of its low control efficiency (Table 5), moreover, to its low cost of insecticide application ha^{-1} (C). In general, the biological insecticides (Dipel®, Bt Control®, Gemstar®, and HzNPV CCAB®) had lower EILs compared to chemical insecticides. Therefore, biological insecticides should be applied in the beginning of an infestation by *H. armigera*. Conversely, the insecticide chlorfenapyr had the highest control efficiency among the evaluated insecticides. It means control efficiency of 94%, with the high cost of insecticide application ha^{-1} (US$35.90), soybean value of US$15.00 increased the EIL to 2.3 *H. armigera* larvae m^{-2}. It means that an efficient treatment can support higher pest density and each soybean field has to be sampled to know the density of pest and to decide the correct time to start the control.

These findings support how to manage *H. armigera* on soybean in Brazil, looking at the control data from chemical and biological insecticides, the cost benefit ratio and the EIL.

Monitoring of *H. armigera* during all the soybean growth stages are essential to make decisions from these results on when to control, which insecticide, and the dose that will result in a higher

Table 3. Number of small and large *H. armigera* larvae (±SD) and efficiency (E) of the biological treatments.

Treatment	Rate (g ha^{-1})	3 DAS[1]	t[2]	E (%)	7 DAS	t	E (%)	10 DAS	t	E (%)	14 DAS*	t	E (%)
		Number of small larvae m^{-2}											
1. Dipel®[4]	4.5×10^{11}	0.5 (±0.8)	a	63.6	0.6 (±0.7)	a	64.3	0.5 (±0.8)	a	50.0	0.3 (±0.5)	a	50.0
2. Bt Control®[4]	2.5×10^{13}	0.5 (±0.8)	a	63.6	0.3 (±0.7)	a	85.7	0.0 (±0.0)	a	100.0	0.0 (±0.0)	a	100.0
3. Gemstar®[5]	4.0×10^{11}	0.6 (±0.5)	a	54.5	0.8 (±1.2)	a	57.1	0.1 (±0.4)	a	87.5	0.0 (±0.0)	a	100.0
4. HzNPV CCAB®[5]	1.5×10^{12}	1.0 (±0.8)	a	27.3	0.0 (±0.0)	a	100.0	0.0 (±0.0)	a	100.0	0.0 (±0.0)	a	100.0
5. Control treatment	-	1.4 (±0.9)	a	-	1.8 (±1.7)	a	-	1.0 (±0.5)	a	-	0.5 (±0.6)	a	-
CV (%)[3]	-	19.8	-	-	38.3	-	-	31.9	-	-	24.0	-	-
		Number of large larvae m^{-2}											
1. Dipel®[4]	4.5×10^{11}	2.3 (±1.8)	a	5.3	0.3 (±0.5)	a	86.7	0.8 (±0.9)	a	68.4	1.0 (±0.0)	a	55.6
2. Bt Control®[4]	2.5×10^{13}	1.6 (±1.1)	a	31.6	0.5 (±0.5)	a	73.3	0.4 (±0.5)	a	84.2	0.8 (±1.0)	a	66.7
3. Gemstar®[5]	4.0×10^{11}	1.3 (±0.7)	a	47.4	1. 4 (±0.9)	a	26.7	1.4 (±1.8)	a	42.1	0.5 (±0.6)	a	77.8
4. HzNPV CCAB®[5]	1.5×10^{12}	2.0 (±1.4)	a	15.8	1.0 (±1.8)	a	46.7	0.5 (±0.5)	a	78.9	0.8 (±0.5)	a	66.7
5. Control treatment	-	2.4 (±1.4)	a	-	1.9 (±0.6)	a	-	2.4 (±1.2)	a	-	2.3 (±1.3)	a	-
CV (%)	-	42.8	-	-	40.8	-	-	44.4	-	-	24.8	-	-

[1]Days after spray treatment. [2]Values followed by the same letter do not differ significantly at the 5% probability level. [3]Coefficient of Variation and the data transformed to square root of x + 0.5. [4]Rate of commercial product = 500 mL ha^{-1}. [5]Rate of commercial product = 200 ml ha^{-1}. *Evaluation means for Santa Maria only.

Table 4. Soybean yield and benefit cost ratio of chemical and biological treatments.

Treatment	Rate (g ha^{-1})	Yield (kg ha^{-1})	Additional yield over control (kg ha^{-1})	Additional income over control (US$ ha^{-1})*	Cost of insecticide application (US$ ha^{-1})**	Net income (US$ ha^{-1})	Cost benefit ratio
1. Chlorantraniliprole	10.0	2447[b]	349	122.64	16.11	106.53	1:6.6
2. Flubendiamide	33.6	2497[b]	399	140.20	22.28	117.92	1:5.3
3. Indoxacarb	60.0	2370[c]	272	95.52	19.81	75.70	1:3.8
4. Chlorfenapyr	240.0	2576[a]	478	167.95	35.86	132.08	1:3.7
5. Spinosad	33.6	2594[a]	496	174.18	33.00	141.18	1:4.3
6. Chlorfluazuron + Methomyl	25.0 + 215.0	2326[c]	229	80.24	41.70	38.54	1:0.9
7. Methoxyfenozide	96.0	2200[d]	103	36.08	20.31	15.77	1:0.8
8. Lambda-cyhalothrin + Chlorantraniliprole	3.7 + 7.5	2342[c]	244	85.68	17.50	68.18	1:3.9
9. Acephate	750.0	2643[a]	545	191.47	17.35	174.13	1:10.0
10. Control treatment	-	2098[b]	0	0.00	0.00	0.00	-
CV (%)		3.3					
1. Dipel®[1]	4.5×10^{11}	2197[b]	99	34.77	13.23	21.54	1:1.63

Table 4. Cont'd.

2. Bt Control®[1]	2.5×10^{13}	2384[a]	286	100.35	13.23	87.12	1:6.58
3. Gemstar®[2]	4.0×10^{11}	2395[a]	297	104.38	17.35	87.04	1:5.02
4. HzNPV CCAB®[2]	1.5×10^{12}	2399[a]	301	105.79	15.70	90.09	1:5.74
5. Control treatment	-	2098[b]	0	0.00	0.00	0.00	-
CV (%)	-	3.4	-	-	-	-	-

*Price per kilogram of soybeans (US$ 0.351). **Insecticide's cost plus operational application cost of US$5.00. [1]Dose of commercial product = 500 ml ha^{-1}. [2]Dose of commercial product = 200 ml ha^{-1}.

Table 5. Economic injury level (EIL) estimated for chemical and biological treatments.

Treatments	**E* (%)**	**Cost of insecticide application (US$ ha^{-1})**	**Value of a 60 kg soybean bag (US$)**					
			15.00	**20.00**	**25.00**	**30.00**	**35.00**	**40.00**
			Larval population of *H. armigera* m^{-2}**					
chlorantraniliprole	85	16.1	0.9	0.7	0.6	0.5	0.4	0.4
flubendiamide	86	22.3	1.3	1.0	0.8	0.7	0.6	0.5
indoxacarb	76	19.8	1.0	0.8	0.6	0.5	0.4	0.4
chlorfenapyr	94	35.9	2.3	1.7	1.4	1.2	1.0	0.9
spinosad	85	33.0	1.9	1.5	1.2	1.0	0.8	0.7
chlorfluazuron + methomyl	64	24.3	1.1	0.8	0.6	0.5	0.5	0.4
methoxyfenozide	57	20.3	0.8	0.6	0.5	0.4	0.3	0.3
lambda-cyhalothrin + chlorantraniliprole	75	17.5	0.9	0.7	0.5	0.5	0.4	0.3
acephate	86	17.3	1.0	0.8	0.6	0.5	0.4	0.4
Dipel®	60	13.2	0.5	0.4	0.3	0.3	0.2	0.2
Bt Control®	76	13.2	0.7	0.5	0.4	0.3	0.3	0.3
Gemstar®	63	17.3	0.8	0.6	0.5	0.4	0.3	0.3
HzNPV CCAB®	65	15.7	0.7	0.5	0.4	0.4	0.3	0.3

*Mean control efficiency of two experiments (percentage). **Consumption by one *H. armigera* m-2 is 58 kg ha-1 (ROGERS & BRIER, 2010). ***EIL = [(C / VD) * E] (adapted from PEDIGO & RICE 2006); "C": control cost (sum of the values of insecticide and application); "V": soybean value per kilogram; "D": damage (kg) caused by the pest; "E": efficiency of the method/treatment used for control.

benefit cost ratio.

Conclusions

The objectives of this study were supported with efficient alternatives of chemicals and biological insecticides to control *H. armigera* on soybean. Five chemical treatments are efficient to control *H. armigera*, from 3 to 14 DAS chlorantraniliprole, flubendiamide, chlorfenapyr, spinosad, and acephate. The biological treatment Bt Control® is efficient to control small and large larvae. Gemstar® and HzNPV CCAB® are efficient to control small larvae. The treatments, chlorantraniliprole, flubendiamide and acephate provided the highest yield and cost benefit ratio, which are similar to Bt Control®, Gemstar®, and HzNPV CCAB®. The EIL is flexible and range from 2.3 larvae m^{-2} to chlorfenapyr up to 0.2 larvae m^{-2} to Dipel®.

Conflict of Interests

The authors have not declared any conflict of interest.

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