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Corn Yield with Reduction of Insecticidal Sprayings Against Fall Armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae)

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Abstract: The ideal time is more important than amount of insecticidal spraying to adequate the control of *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae) in corn. This study aimed to evaluate lufenuron sequential sprayings effect and its rotation with other active ingredients on the population, damage caused by *S. frugiperda* and the impact on corn yield. The experiment was carried out in the field with six treatments: (1) one lufenuron spraying, (2) two lufenuron sprayings, (3) three lufenuron sprayings (4) four lufenuron sprayings, (5) sprayings with spinosad, lufenuron, thiamethoxam+lambdacyhalothrin and deltamethrin (in sequence, at ten days intervals) (6) control treatment. Sprayings started twenty days after the seedling had emerged and then every ten days for a maximum of four sprays. Both caterpillar population (20.9-21.7 larvae/plot) and index of damage (1.2-1.7) observed in corn plants were significantly lower in treated plots compared to control (untreated) (31.7 larvae/plot and index of damage 2.7), regardless of spraying amount. The results showed that multiple insecticide applications to control *S. frugiperda* do not guarantee higher yields in corn, ranging from 6375.2 to 7650.1 kg ha^{-1}. Only one spraying of lufenuron was enough to prevent significant reduction in corn yield (6749.9 kg ha^{-1}).

Key words: *Zea mays*, lufenuron, damage threshold, pest control, spraying season

INTRODUCTION

The fall armyworm *Spodoptera frugiperda* J.E. Smith (Lepidoptera: Noctuidae) is a major pest of many crops in several parts of Americas (Hruska and Gould, 1997; EPPO, 2006). In Brazil, it is the main corn insect pest and has caused significant losses in grain production. These losses are variable and depend on various factors such as the planting season and region, cultivar and cultural practices. In Brazilian plantations, the losses can range between 19 and 100% (Cruz and Turpin, 1982; De Almeida Sarmento *et al*., 2002). The management of fall armyworm have been done basically with the use of synthetic insecticides belonging to different chemical groups with predominance of benzoylureas, in these Brazilian states: Goiás (67%), Paraná (33%) and Mato Grosso do Sul (30%), followed by organophosphates, carbamates and pyrethroids (Tomquelski and Martins, 2007). The benzoylureas are known as physiological insecticides, which act as growth regulators interfering with ecdysis formation process in chitin synthesis (Ghoneim *et al*., 2003). These insecticides have been considered less harmful to the environment, selective to natural enemies and more efficient against pests (Retnakarn *et al*., 1985; Pratissoli *et al*., 2004). However, even with the predominant use of the benzoylureas in some Brazilian states, the products choice is linked to the purchasing power and knowledge level of farmers. Most of the time, the choice is done for cheaper products. Moreover, successive growing of the same crop and indiscriminate use of pesticides has increased the problems with insect-pests considerably (Shanmugam *et al*., 2006; Abd El-Mageed *et al*., 2007). Chemical control is one of the most important tool of Integrated Pest Management (IPM) (Rashid *et al*., 2003) but erroneous control techniques such as late control, poor equipments calibration and inappropriate crop management practices have increased the number of insecticide applications without adequate fall armyworm control (Cruz , 1997; Abd-Elhady and Abd El-Aal, 2011).

Several studies have shown that the fall armyworm control in corn is more efficient if performed between 30-43 days after seedling emergence, when occurs the peak of pest population. After this period the population of caterpillar starts decreasing naturally (Oliveira *et al*., 1995) and the corn plants can recover from the damage (Cruz and Turpin, 1982; Ghidiu and Drake, 1989). Thus, the ideal time rather than amount of

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sprayings is more important in the control of the fall armyworm. This study aimed to evaluate lufenuron sequential spraying effect and its rotation with other active ingredients on *S. frugiperda* population, its damage and impact on corn yield.

MATERIALS AND METHODS

Experimental design: The experiment was carried out at the Research Farm of FCA/UNESP, Botucatu- São Paulo, Brazil, with the hybrid corn 2B688 (Dow Agrosciences) in late planting. The seeds were sown on February 5th, 2009. The spacing used was 0.90 m between rows and a density of 4.1 seeds m^{-1}. The experimental design was randomized complete block with six treatments and four replications. Each plot had eight planting lines with seven meters in length.

The insecticide sprayings against *S. frugiperda* started twenty days after plant emergence and continued every ten days. The six treatments were: (1) one lufenuron (Match CE, Syngenta-300 mL ha^{-1}) spraying, (2) two lufenuron sprayings, (3) three lufenuron sprayings, (4) four lufenuron sprayings, (5) four sprayings of spinosad (Tracer, Dow Agrosciences LLC-100 mL ha^{-1}), lufenuron, thiamethoxam+lambdacyhalothrin (Engeo Pleno, Syngenta -250 mL ha^{-1}) and deltamethrin (Decis 25 EC, Bayer-200 mL ha^{-1}) and (6) control treatment (no spraying). All sprayings were carried out with pressurized backpack sprayer equipped with six spraying nozzles XR 11003 spaced 0.5 m and spray volume of 300 L ha^{-1}. Environmental conditions such as temperature, humidity and wind speed were measured at each time of spraying (Table 1).

Field observation and evaluation: The insecticide effectiveness was evaluated by counting *S. frugiperda* living larvae in ten plants per plot before each spraying and ten days after each spraying. The damages caused by *S. frugiperda* were also assessed in ten plants per plot according to the following scale: 0-plants without damage; 1-plants with erasure leaves; 2-plants showing holes in the leaves; 3-plants with holes in the leaves and some damage on whorl; 4-plants with whorl destroyed; 5-dead plants. The plant height (cm), number of leaves/plant, leaf-area index, stem diameter (cm), were measured in ten plants/plot at full-bloom stage season. Thousand-grain weight (g) and yield (kg ha^{-1}) were also assessed. The stem diameter was evaluated on the second internode. The thousand grain weight was measured in eight random samples from each plot. The yield was estimated by harvesting ears of three central rows of each plot. Both the thousand-grain mass and yield was corrected to 13% humidity.

Table 1: Values of environmental conditions at the time of each spraying to control of *S. frugiperda* in corn

Sprayings	Days after planting	Temperature (°C)	Relative humidity (%)	Wind speed (km h^{-1})
1	30	31.5	57.5	8.0
2	40	27.2	68.0	7.5
3	50	27.7	68.7	9.7
4	60	26.9	59.1	6.9

Statistical analysis: Both the number of larvae/plot and damage scores were submitted to ANOVA. Thus, the results about the mean of total larvae recovered/plot and index of damage at the end of spraying were submitted to ANCOVA using as covariate the number of larvae per plot and damage index observed in preview. Plants heights, number of leaves per plant, leaf-area index, stem diameter, thousand-grain weight and yield/ha were submitted to ANOVA. The efficiency of insecticides was corrected by Henderson and Tilton (1955) formula. The treatment means of all variables were compared using Tukey HSD test ($p<0.05$). For statistical analysis the population of caterpillars was transformed as $(x+0.5)^2$.

RESULTS

Both the number of lufenuron sprayings (1-4) and the four sprays of various insecticides (spinosad, lufenuron, thiamethoxam+lambdacyhalothrin, deltamethrin) significantly lowered fall armyworm damage in corn plants compared to the untreated control. The damage was not significantly different among the treatments with insecticide application (Fig. 1). In these

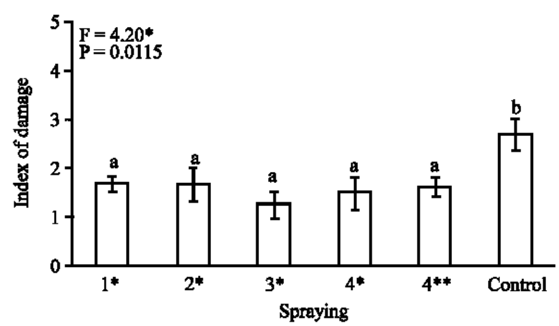

Fig. 1: Index of damage caused by larvae of *S. frugiperda* in corn in plots treated with different insecticidal spraying regimes. Columns followed by the same letter do not differ by Tukey HSD test ($p<0.05$). Bars = SE *lufenuron (1-4 times); **spinosad, lufenuron, thiamethoxam+lambdacyhalothrin and deltamethrin

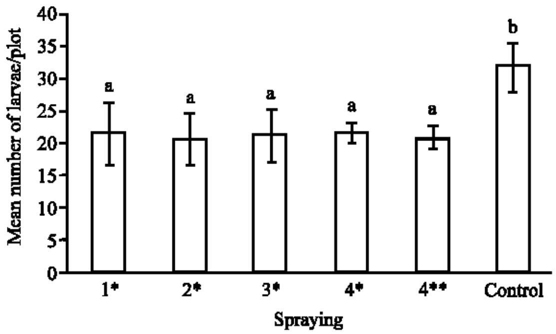

Fig. 2: Number of larvae/plot in plots treated with different insecticidal spraying regimes against *S. frugiperda*. Columns followed by the same letter do not differ by Tukey HSD test (p<0.05). Bars = SE *lufenuron (1-4 times); **spinosad, lufenuron, thiamethoxam+lambdacyhalothrin and deltamethrin

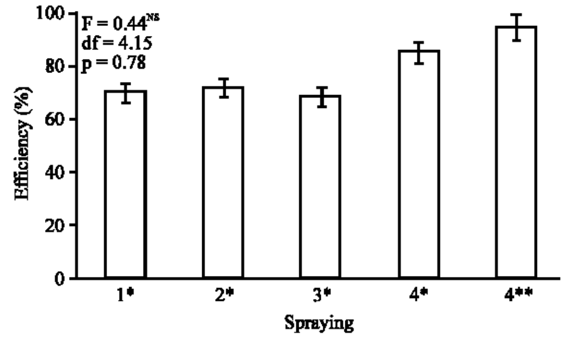

Fig. 3: Control efficiency of larvae of *S. frugiperda* by insecticidal sprayings. Columns followed by the same letter do not differ by Tukey HSD test (p<0.05). Bars = SE *lufenuron (1-4 times); **spinosad, lufenuron, thiamethoxam+lambdacyhalothrin and deltamethrin

Table 2: Development of corn plants in reaction to different insecticidal spraying regimes against *S. frugiperda*

Sprayings	Plant height (cm)	No. of leaves/plant	Leaf-area index	Stem diameter (cm)
1 (lufenuron)	195.3±2.72[b]	14.1±0.39[a]	4.9±0.13[a]	2.4±0.07[a]
2 (lufenuron)	211.5±1.21[a]	14.9±0.09[a]	4.7±0.41[a]	2.3±0.18[a]
3 (lufenuron)	210.5±0.68[a]	14.2±0.28[a]	4.4±0.10[a]	2.5±0.06[a]
4 (lufenuron)	214.1±1.52[a]	14.3±0.07[a]	4.6±0.04[a]	2.4±0.05[a]
4[1]	213.2±1.22[a]	14.2±0.30[a]	4.4±0.48[a]	2.6±0.06[a]
Control	192.0±1.00[b]	12.7±0.69[b]	3.4±0.23[b]	2.1±0.04[b]
F	40.58*	4.13*	6.88*	3.14*
p	<0.0001	0.0112	0.0009	0.0329

[1]Spinosad, lufenuron, thiamethoxam+lambdacyhalothrin and deltamethrin. Means followed by the same letter in the same column do not differ by Tukey HSD test (p<0.05), *Significant

Table 3: Corn productivity in reaction to different insecticidal spraying regimes against *S. frugiperda*

Sprayings	Thousand-grain mass (g)	Yield (kg ha^{-1})
1 (lufenuron)	290.2±5.51	6749.9±50.03[a]
2 (lufenuron)	291.7±3.15	6375.2±225.39[a]
3 (lufenuron)	295.1±0.71	7200.4±70.11[a]
4 (lufenuron)	290.2±1.04	7402.1±187.96[a]
4[1]	293.0±0.93	7650.1±104.00[a]
Control	291.0±2.73	5025.3±370.21[b]
F	0.43[ns]	22.63*
p	0.8243	<0.0001

[1]Spinosad, lufenuron, thiamethoxam+lambdacyhalothrin and deltamethrin Means followed by the same letter in the same column do not differ by Tukey HSD test (p<0.05), *Significant, ns: Non significant

plots, the index of damage ranged between 1.2 and 1.7 namely plants with some scrapes and holes in the leaves only. In the control treatment, the damage was more severe with an index of 2.7, indicating damage on the whorl. The number of total larvae recovered per plot followed the same pattern, being significantly lower in treatments with insecticide sprayings (20.8 to 21.6 larvae/plot) than untreated plots (31.7 larvae/plot) (Fig. 2). Among the insecticide treatments, the variation in the larvae numbers was very little and did not differ among themselves. The control efficiency was not significant among the insecticide treatments, which ranged from 68.1% (three lufenuron sprays) to 94.6% (four different insecticide sprays) (Fig. 3).

The development of corn plants as leaf number, leaf-area index and stem diameter was significantly higher in plots sprayed with insecticides than untreated plants (Table 2). Only the height of plants in treatment with one lufenuron spray did not differ from control (195.3 and 192.0 cm, respectively) (Table 2). The crop yield was not influenced by the frequency of spraying or group of insecticide used (range 6375.9-7650.1 kg ha^{-1}), being significantly lower in the control treatment (5025.3 kg ha^{-1}) (Table 3).

DISCUSSION

There are two corn harvests in a year in Brazil, one between spring and summer (summer planting) and the other at the end of summer and/or beginning of autumn. This trial was made at the end of summer when fall armyworm attack is more severe (Andrews, 1988; Picanco *et al*., 2004). The high severity of fall armyworm attack and the consequent low profitability have led many farmers to performing insecticide spraying at pre-established intervals (e.g., weekly). Besides being unnecessary, the excess spraying increases the production cost, decreasing the farmer profit. To make up for the loss, farmers choose cheaper insecticides, which are detrimental to the environment. The substitution of non selective synthetic insecticides by selective ones is important to support the IPM (Abd El-Mageed and Elgohary, 2007; Mirmoayedi *et al*., 2010). There are reports that the susceptibility of *S. frugiperda* and other insects to pyrethroids, benzoylureas and organophosphates has already been affected (Diez-Rodriguez and Omoto, 2001; Ramasubramanian and Regupathy, 2004; Suman *et al*., 2010).

Although, the insecticides treatments did not differ significantly from each other, treatments with four spraying showed greater control of the caterpillars, while the highest rate of control was obtained by the treatment with rotation of insecticides. Similarly, sequential sprayings of insecticides lufenuron, malathion and spinosad reduced the populations of *Pectinophora gossypiella* (Lepidoptera: Gelechiidae) in cotton (Abd El-Mageed *et al*., 2007). In another study, four applications of insecticides were also more effective in reducing populations of pink bollworm in cotton (Mourad *et al*., 1991). Present results showed that several insecticides sprayings to control *S. frugiperda* do not guarantee higher yield, only one lufenuron spraying (done 20 days after the plants emergence) was enough to prevent yield reduction in corn. Cruz and Turpin (1982) and Da Silva (1999) reported that spraying at 20 days after plant emergence is the right moment to control *S. frugiperda* in corn and that some monitoring facilities that have been set up outside this period are responsible for failure in the fall armyworm management. Beyond this higher crop susceptibility phase to attack (Fancelli and Dourado-Neto, 2004), the fall armyworm population can start reducing naturally (De Almeida Sarmento *et al*., 2002). This reduction in population was observed on evaluations of this work, taking the control treatment as base, which showed that sprayings made after this period are ineffective. In has also been demonstrated in another study where sprayings were done with lufenuron or spinosad, in a seven days interval that, there were a higher fall armyworm control only in the first spraying (Azevedo *et al*., 2003; Tomquelski and Martins, 2007). Thus the ideal time to insecticide applications is more important than amount of sprayings. It can therefore be concluded that one insecticidal spraying against fall armyworm is enough to achieve the same yield when compared to four sprayings of the same or different insecticides. The reduced frequency of sprays will also reduce environmental contamination, decrease impact on natural enemies and result in increased profits of producers.

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