Simulation of damage caused by the *Heliothis-Helicoverpa-Spodoptera* spp. complex to cotton plants (*Gossypium hirsutum* L.) shoots

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ABSTRACT

Larvae of the Heliothis-Helicoverpa-Spodoptera *spp. complex can damage tender sprouts, leaves and growth meristems of cotton plants (*Gossypium hirsutum *L) and induce stem cracks dute to "bites". In this study damage was simulated and shoot tips were manually eliminated from cotton plants after 30 days of the crop with the aim of evaluating the incidence of damage on the production of lint and seed. The crop was planted on 30 October 1998 using cultivar Pora INTA. On 11 November shoot tips were eliminated by hand. Plant stand was 12 plants per meter. Different intensities of damage were simulated: 0% (no plant injured); 25% (3 plants injured/meter); 50% (6 plants injured/meter); 75% (9 pl/m) and 100% (all plants injured). Along the crop cycle three "mappings" were carried out to better understand the response of plants to the damage. Detailed observations and records of the reproductive structures formed by the plants were done. Shortly after the damage, plants affected formed fewer squares, flowers, young bolls and open bolls. Nevertheless, in more advanced stages of the crop cycle, the crop, helped by good weather conditions, recovered. Analyzing yields reached at harvest (March 25, 1999, 115 days after damage) a decrease in yield was observed in damaged plants compared to those not injured. Seedcotton yield in kilogram per hectare decreased as the intensity of damage increased. With 50% and 70% of damage de same average yield was observed. Treatment 2 (25% damage) showed an 8% decrease in yield respect to Treatment 1 (control, 0% damage) and both Treatment 3 and Treatment 4 (50 and 75% damage respectively) had a 21% reduction in yield compared to the control. As a result, the difference in yield is more important when damage is greater than 50%, this would mean that in a linear row meter where about half of plants were injured, a 20% decrease in yield could be expected compared to that obtained with undamaged plants.*

Introduction

Cotton (*Gossypium hirsutum* L.) is a crop that grows in tropical or subtropical climates, and produces vegetation and fruit continously, which causes it to be attacked by a large number of insect pests that affect yield, quality of fiber and seed (Barral and Zago, 1983). In the opinion of these researchers there are primary insect pests - those that for the duration of their presence through the different crop seasons require that the whole implementation of a control program be centered on them - and other, secondary pests, such as the budworm-bollworm complex (Heliothinae complex) and the fall armyworm (*Spodoptera frugiperda*). The latter is an annual pest that causes damage to many economically important crops in the southern United States (Luginbill, 1928), including sporadic damage to cotton (Smith, 1985). Due to it being a sporadic pest of cotton, the available information on its biology and development on the plant is generally limited (Abbas *et al.*, 1990).

Fall armyworms attack gramineous plants in cotton crops as well as other cultivated species such as corn, sorghum, horticultural, etc. And it only goes to cotton when it finishes with its common hosts or when these are eliminated from the crop during the weed control operations. The damage that it causes can end up being very intense, especially when they attack young crops before the plants have developed abundant vegetative biomass. As a consequence, this type of attack induces loss of leaf area and this in turn delays vegetative development (Barral and Zago, 1983). Regarding their attacks in soybean crops, they can also be considered sporadic pests, present in the early vegetative stages. The larvae feed mainly on tender buds and leaves, and they also possess the habit of feeding on growth meristems. In newly emerged plants they feed on cotyledons and even on the hypocotyl, and in more advanced vegetative states they damage the compound leaves. They also cause stem injuries caused by "bites". If not detected on time, this situation makes resowing necessary due to the decrease in the number of plants (De Diez *et al*., 1996). Trumble *et al*. (1993) and Rosenthal and Kotanen (1994) confirmed that after damage, plants display a wide range of morphological and physiological responses that contribute to their recovery. This is what is observed in cotton fields after the growth meristem damage caused by *S. frugiperda* larvae. For many plants, this leads to the production of lateral branches that behave like independent plants, or either they die when the attack is very intense. Wilson (1982) found that the damage to the growth tip of a cotton plant can happen at any moment during its growth, although the impact of the damage is greater in the stage just before square formation and during the early phase of flowering. Among pests that most probably could damage the tips in North America during this period are thrips (predominantly *Frankliniella occidentalis* (Pergande)), *Heliothis* spp. and *Spodoptera exigua*.

The objective of this work was to evaluate the damage that the budworm-bollworm-fall armyworm (Heliothinae-*Spodoptera* spp.) complex cause when eliminating the plants´ shoot tips during early stages of the crop and its incidence on yield.

Experimental procedure

This trial was conducted in plot 100 of the Agricultural Experimental Station Saenz Pena during the 1998/99 crop season. Sowing was carried out on 20 October 1998, with seeds from variety Pora INTA. Immediately after it, trifluralin, a pre-emergence herbicide, was applied at 2 liters/ha. Cotton seedlings emerged at a density of 12 to 15 plants per meter. Post-emergence weed control was done by two passages by a field cultivator. Later controls consisted of hand weeding. During the growth and development of the crop the pests that were present were controlled (predominantly *Alabama argillacea*) with the available insecticides at the time of spraying.

An attack of larvae of the Heliothinae-*Spodoptera* spp. complex was simulated, for which at November 30, 1998 (41 days after sowing), damage consisting of hand cuts to the tips of the plants were carried out. Thinning was done to a plant density 12 plants/meter. Each plot or experimental unit consisted of six rows, each 10 meters long and 1 meter apart. The two central rows were harvested for yield calculation. The following rows, from the center outwards were left for mapping and the last two remaining rows were left to eliminate a border effect. In each plot, hand cuts were made as follows to simulate larvae attacks: 0% damage: no shoot tip cut; 25% damage: shoot tips cut from three plants leaving the other nine out of 12/meter undamaged (1 damaged - 3 undamaged, 1 damaged - 3 undamaged, 1 damaged - 3 undamaged); 50% damage: shoot tips of six plants cut of each plot (1damaged - 1 undamaged, 1damaged - 1 undamaged, and so forth until damaging six out of 12/meter); 75% damage: shoot tips cut in nine plants, leaving undamaged the other 3 out of 12/meter (3 damaged - 1 undamaged, 3 damaged - 1 undamaged, 3 damaged - 1 undamaged) and 100% damage: all the shoot tips damaged.

Five treatments (percentages of damage) were evaluated. The trial was planted according to a complete block randomized design. Only one plant-density (12 plants/meter) and one cut-height (plants with the first couple of true leaves already differentiated) were used.

On the basis of what Hake, Bourland and Kerby (1991) expressed, whom affirm that plant mapping can help in the investigation of specific production problems like: poor development of vegetative branches early in the station, low square retention, first fruiting branch delayed, and low plant vigor, on January 5, 1999, first mappings were carried out in the trial (67 days after sowing (DAS) and 36 days after the damage (DAD)). Starting from the cotyledons recordings were: total number of nodes in the main stem, number of branches that the plant produced as a response to the damage, number of fruiting branches (sympodials) and quantity of squares, flowers, bolls, open bolls, and shed positions. Those same investigators have also affirmed that damage from insects is the main cause of loss of squares before flowering, for it is possible that plant mapping at early stages serve as a support to the program of pest control. To help the understanding of the evolution and behavior of the plants after the damage, apart from the first one, two other plant mappings were carried out: the second in January 20, 1999 (82 DAS and 51 DAD) and the last one on March 8, 1999 (129 DAS and 98 DAD). For the three cases, and for each experimental unit, fourplants were chosen at random within the two lateral rows in relation to the two central rows. The trials were harvested on 25 March 1999, by recording the open boll weight of the two central rows of each plot.

Results and Discussion

Number of branches

In the first mapping and in the third no significant differences in the number of branches among the different treatments were found. Differences were observed in the second mapping (Table 1) where treatment 4 (75% damage) differed significantly from treatment 1 (0% damage) for an increased number of branches. It is possible that at the time of first mapping there has not lapsed enough time in order to allow plants to manifest significant differences in the number of branches, while in the second mapping it would. In the first mapping, as in the second mapping, the number of branches per plant increased as the number of damaged plants increased. With 100% damage the number of branches were lower. In none of those two mappings it was possible to sort out the reason why treatment 4, and not 5 (100% damage) was the one that had increased number of branches, when it seemed that the tendency was that to an increased number of damaged plants there was an increase in the number of branches. For a better understanding of the causes of the observed differences it is worthwhile to point out that mappings were carried out only on damaged plants, and in each treatment the mapped plants were chosen at random, therefore not always the same plants were mapped.

Sympodials number

The behavior of plants under different intensities of damage in relation to the sympodials number (fruiting branches) produced are summarized in Table 2. No significant differences were demonstrated among treatments in any of the three mappings and the values were really very similar to each other. The experience obtained from this work would indicate that the damage to the terminal bud of the plant does not always impact in the same way in the formation of fruiting branches. Furthermore, it is well known from other experiments that, if after the damage the plants have enough time and the appropriate conditions prevail, they may recover to the point of damaged plants forming more fruiting branches than the undamaged ones. Another detail to be considered is that the variety used in this trial was Pora INTA, which is characterized by its great plasticity.

Average of total squares per plant

Table 3 shows no significant differences between the different treatments in any of the three mappings that were carried out (67, 82 and 129 DAS, respectively). These results indicate that the damage induced to the plant´s shoot tip did not affect the normal production of squares in relation to its quantity, although there was a delay in the appearance of those squares, but such a delay was not appropiately measured and were only based on visual observations.

Average of total flowers per plant

In the first mapping significant differences were not demonstrated between the treatments. This situation was reverted in the second mapping when treatment 1 (0% damage) went significantly different than treatments 2 and 3 (25 and 50% damages respectively). Treatment 5 (100% damage) also differed significantly from treatment 3. As the damage increased in intensity from 0 to 50% of damage, the production of flowers of those damaged plants diminished. But starting from 50% of damage, to a greater intensity of the same one (75 and 100%), the production of flowers also began to increase, to the point that with 100% of damage the production of flowers is hardly lower than with 0% of damage (undamaged plants), and of course there are not significant differences among treatments 1 and 5. It could be considered that plots with plants that were little to fairly damaged (treatments 2 and 3) produce fewer number of flowers than those of the more strongly damaged ones (treatments 4 and 5). In the third mapping no significant differences were present between the treatments. Again, it is worthwhile to highlight that at the time of the third mapping there was a very scarce production of flowers and this was common to all treatments (Table 4).

Average of total bolls per plant

In the first mapping significant differences were not present among the treatments. In the second mapping it was evident that plants of plots that received treatment 1 (plants undamaged) produced a larger quantity of bolls, significantly different to that of the plants from plots with a damage of 50% (treatment 3). Among the remaining treatments, there were also differences but not significant. In the third mapping the differences were even less and no signicant differences could be demonstratedt. What happened between bolls and flowers can be compared: there is not a great difference between the different treatments and when there were significant differences, there was a tendency for them to appear approximately after two and a half months of the crop´s cycle. Towards the end, differences become again very little evident, like in the beginning of the crop cycle. Once again, it can be concluded that after too little time after the damage occurred, it is not easy to see an effect, but it became more evident a little later in the crop cycle. Then, if the plant has had enough time (in quantity) and good conditions for development prevailed during the rest of the cycle, it could recover and both damaged and undamaged plants could produce in a similar way (Table 5).

Average of total open bolls per plant

At the time of the first and second mapping the open bolls have not yet been formed, that´s why data available are from the third mapping. Treatment 5 (100% damage) differed significantly from treatment 3 (50% damage) when displaying a greater average of open boll per plant. Plants from plots that received treatment 5 formed a higher average open bolls per plant than those that did not suffer any damage (treatment 1), but the difference was not significant. After treatment 5, ranked from a higher to a smaller average value, treatment 1, then treatment 4, then treatment 2 and finally treatment 3, followed it. A similar evolution was seen in this case comparing it to what happened in the second mapping with the production of flowers: as the damage increased in intensity from the 0 to 50% damage, the production of open bolls of those damaged plants diminished. But starting from 50% damage (treatment 3) as the intensity of the damage (75 and 100%) was greater, the production of flowers was also in increase, until arriving to 100% damage in that the production of open bolls was hardly higher than with 0% damage, and as already expressed, there was not significant difference among treatments 5 and 1; only among treatments 5 and 3. It could be said that plots with plants little to fairly damaged (treatments 2 and 3) produced a smaller number of open bolls than those plots where plants were more strongly damaged (treatments 4 and 5) (Table 6).

Average of yields

The undamaged plants (treatment 1) had the highest yields with an average of 2210 kg/ha of seedcotton. This treatment was followed (ordering from a higher to a lower yield) by treatments 2 (2035 kg/ha), 5 (1970 kg/ha), 3 and 4 (both with 1755 kg/ha). If the undamaged plants are compared with the damaged ones, the former have performed better as they obtained the highest yield and the second place for the average of total open bolls. However, this would be only a deduction from this trial, since the statistical analysis has not been able to confirm significant differences among the treatments. What can be said is that the plots with more number of damaged plants (treatments 5 and 4) presented a much more compact, dense, and entangled vegetative structure given the type of branches that plants exhibited. And these characteristics can have negative consequences at the time of carrying out certain agronomic practices as sprayings of insecticides or defolianting chemicals, even harvest can be hindered for that reason (Table 6).

Average of total sheddings

According to the results of the three mappings carried out, treatments did not differ significantly from each other in relation to this parameter (Table 7).

Conclusions

Plants in plots that have suffered from 75% or more damage, branched more than the undamaged ones. Difference in the number of branches only was significant 51 days after the damage. Regarding the number of fruiting branches, there were not significant differences between the treatments and neither were their for the total production of squares per plant. From the analysis of the total production of flowers, it was demonstrated that in the second mapping there were significant differences. In treatment 1 the average of flowers was higher than in treatments 2 and 3. Also treatment 5 differed significantly from treatment 3. In conclusion, plants from plots with 25 to 50% damage produced smaller quantity of flowers that those where the damage was higher (75 to 100% damage). This was observed 82 DAS (second mapping). It is possible that in the first mapping the differences were not significant because few days have lapsed after the damage (36 DAD), and neither there were differences in the third mapping, probably because the mapping was carried out very close to harvest and the plant could have had enough time to recover from damage.

Very similar to these results were those obtained in the total production of open bolls per plant. There were only significant differences among some treatments in the second mapping, not so in the first and third mappings. In the second mapping treatment 1 (0% damage) was characterized by presenting a higher number of open bolls than treatment 3 (50% damage). As for open bolls, in the last mapping plants from plots where damage was of 100% presented a higher number of open bolls per plant than those from plots with 50% damage, and this difference was significant. Analyzing yields reached at harvest (March 25, 1999, 115 DAD) a decrease in yield was observed in damaged plants compared to those not injured. Nevertheless, there were not significant differences among the treatments. Seed cotton yield (kg/ha) decreased as the intensity of damage increased. With 50% and 70% of damage de same average yield was observed. Treatment 2 (25% damage) showed an 8% decrease in yield compared to treatment 1 (control, 0% damage) and both treatment 3 and treatment 4 (50 and 75% damage respectively) had a 21% reduction in yield compared to the control. As a result, the difference in yield is more important when damage is greater than 50%, this would mean that in a lineal row meter where about half of plants were injured a 20% decrease in yield could be expected compared to that obtained with undamaged plants.

It is possible that these results may have been favored by the use of a variety like Pora INTA, which is widely adaptoble, which in turn may have allowed the crop to recover from the damage given the flexibility of the cycle. As for the shedding of reproductive organs, there were not significant differences among treatments. This trial should be repeated under similar conditions, until finding the pests´ threshold of damage that allows the percentage of effective damage that a crop can tolerate, without suffering an economic loss, to be established.

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Table 1. *Mean number of branches per plant.*

	Mean number of branches		
Damage (%)	First mapping	Second mapping	Third mapping
75	1.7 a	1.44 a	0.4250 a
50	1.68 a	1.38 a	0.3400 a
25	1.38 a	1.14 ab	0.3200 a
100	0.8 a	0.68 ab	0.3100 a
0	0.3 a	0.06 b	0.0400 a
P	0.0872	0.0184	0.0849

The ANOVA was calculated and the multiple comparisons of stockings were made by means of the test of Tukey (P>0,05). Means followed by the same letters inside each column are not significantly different.

Table 2. *Mean number of sympodials per plant.*

	Mean number of sympodials		
Damage (%)	First mapping	Second mapping	Third mapping
50	13.02 a	13.38 a	4.8650 a
75	12.72 a	12.66 a	4.5900 a
100	11.88 a	12.52 a	4.2050 a
25	11.55 a	12.34 a	3.7200 a
0	11.45 a	11.82 a	3.4555 a
P	0.9738	0.8976	0.2248

The ANOVA was calculated and the multiple comparisons of stockings were made by means of the test of Tukey (P>0,05). Means followed by the same letters inside each column are not significantly different.

Table 3. *Mean number of squares per plant.*

	Mean number of squares		
Damage (%)	First mapping	Second mapping	Third mapping
0	16.200 a	12.600 a	3.4550 a
25	14.250 a	11.950 a	4.8650 a
50	16.300 a	10.950 a	4.2050 a
75	16.650 a	12.350 a	3.7200 a
100	16.400 a	12.900 a	4.5900 a
P	0.9798	0.7900	0.1225

The ANOVA was calculated and the multiple comparisons of stockings were made by means of the test of Tukey (P>0,05). Means followed by the same letters inside each column are not significantly different.

Table 4. Mean number of flowers per plant.

Damage (%)	Mean number of flowers		
	First mapping	Second mapping	Third mapping
0	0.2000 a	1.50 a	0.0500 a
25	0.6500 a	0.65 bc	0.1000 a
50	0.6000 a	0.40 c	0.0500 a
75	0.6000 a	0.80 abc	0.1000 a
100	0.4500 a	1.35 ab	0.0000 a
P	0.5877	0.0008	0.8172

The ANOVA was calculated and the multiple comparisons of stockings were made by means of the test of Tukey (P>0,05). Means followed by the same letters inside each column are not significantly different.

Table 5. Mean number of bolls per plant.

Damage (%)	Mean number of bolls		
	First mapping	Second mapping	Third mapping
0	1.4500 a	8.8500 a	0.6500 a
25	0.9000 a	4.7500 ab	2.2500 a
50	0.8500 a	4.3000 b	1.3500 a
75	1.1500 a	4.8500 ab	1.5000 a
100	1.4500 a	5.6000 ab	1.6000 a
P	0.7000	0.0303	0.3649

The ANOVA was calculated and the multiple comparisons of stockings were made by means of the test of Tukey (P>0,05). Means followed by the same letters inside each column are not significantly different.

Table 6. Mean number of open bolls per plant and mean cottonseed yield (kg/ha) in third mapping.

Simulated damage (%)	Mean number of open bolls/plant	Mean cottonseed yield (kg/ha)
0	5.7000 ab	2210 a
25	4.2000 ab	2035 a
50	3.0000 b	1755 a
75	4.7500 ab	1755 a
100	6.2000 a	1970 a
P	0.0480	0.5765

The ANOVA was calculated and the multiple comparisons of stockings were made by means of the test of Tukey (P>0,05). Means followed by the same letters inside each column are not significantly different.

Table 7. *Mean number of sheddings per plant.*

	Mean number of sheddings		
Damage (%)	First mapping	Second mapping	Third mapping
0	5.9500 a	8.0000 a	20.300 a
25	3.6000 a	5.7500 a	24.500 a
50	6.3500 a	8.0000 a	23.800 a
75	3.0000 a	6.1000 a	21.300 a
100	5.3500 a	6.5000 a	24.500 a
P	0.3496	0.2772	0.7002

The ANOVA was calculated and the multiple comparisons of stockings were made by means of the test of Tukey (P>0,05). Means followed by the same letters inside each column are not significantly different.