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ORIGINAL RESEARCH

Oviposition preference and culture control of *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in corn (*Zea mays*)

Authors:
Fabio Medeiros da Costa[1], Aldeni Barbosa da Silva[2], Eduardo Barbosa Beserra[3] and Jose Pires Dantas[4]

Institution:
1. Oikos Consultoria e Projetos. Departamento de Meio Ambiente. Estrada de Santo Antônio, 3903 Apto 103-D. Triângulo. Porto Velho – RO 76805-696, Brasil.

2. Departamento de Fitotecnia/ CCA/UFPB - Campus II, Areia - PB. Rua Sisínia Vitório Serafim, Nº 18, Bairro Bela Vista, Remígio - PB, 58398-000, Brasil.

3. Departamento de Biologia, Centro de Ciências Biológicas, CCBS, Universidade Estadual da Paraíba, UEPB. Rua Juvêncio Arruda s/n, Bodocongó, Campina Grande - PB, 58109-753, Brasil.

4. Departamento de Química, Centro de Ciências e Tecnologia, CCT, Universidade Estadual da Paraíba, UEPB. Rua Juvêncio Arruda s/n, Bodocongó, Campina Grande - PB, 58109-753, Brasil.

Corresponding author:
Fabio Medeiros da Costa

Email Id:
fabiologocosta@gmail.com

ABSTRACT:

We evaluated the oviposition preference and damage capacity of *Spodoptera frugiperda* on the different phenological stages of corn. Tests were performed at the Assis Chateaubriand Agricultural School (07º10'15" S, 35º51'13" W, altitude 634 meters), municipality of Lagoa Seca, Paraíba State, Brazil, in two areas of 500 m^2, with CMS maize hybrid strain and maize intercropped with bean with the spacing of 0.80 x 0.40 m. Eggs and caterpillars were collected weekly on 50 plants randomly sampled in five spots. Height and number of leaves per plant, and damage from caterpillars of *S. frugiperda* were recorded using the scale, the rangers were., 0) no damage, 1) leaf scraped, 2) leaf pierced, 3) leaf torn, 4) damage in cartridge, 5) cartridge destroyed. The average number of clutches did not differ significantly among the three phenological stages of the culture, but average clutch size (number of eggs) was significantly smaller for the stage of 4-6 leaves. However, there was a significant interaction with respect to the number of clutches between position in the plant (lower, middle, and upper) and phenological stage, and between leaf surface and phenological stages. There were significant differences among tillage systems for corn in monoculture and corn intercropped with bean.

Keywords:
Fall armyworm, behavior, bioecology, host.

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INTRODUCTION

Corn (*Zea mays* L.) is one of the main crops in Brazil (Bull and Cantarella 1993). In recent years, this culture has been increasing substantially due to developments in tillage system, availability of more productive genotypes, adapted to the various regions, mechanization, and increase of the production area resulting from off-season sowing and the expansion of the crop to new regions in the Center-West and Northeast. In the last 15 years, production almost doubled, from 24 to 42 million tons, with an increase in productivity from about 1,800 kg/ha to over 3,000 kg/ha (Companhia Nacional de Abastecimento, 2009). Nevertheless, the average productivity in Brazil (3,500 kg/ha) is still considered low when compared to that of other producing countries, such as China (5,000 kg/ha), Argentina (7,000 kg/ha), and the United States (9,000 kg/ ha) (Pereira and others 2005; Costa and Cota 2009).

Productivity in Brazil is affected by the low technological level of producers, (mainly in the Northeast, where production techniques are rudimentary, Bull and Cantarella, 1993), the lack of proper plant health care, and the occurrence of pest insects (Cruz *et al.,* 1999).

The fall armyworm, *Spodoptera frugiperda* (Smith, 1797), is considered as the pest that causes the largest damage to corn culture in Brazil (Vendramim and Fancelli 1988). The economic losses caused by this corn pest are estimated in over 400 million dollars, corresponding to 34% of the production (Cruz *et al.,* 1999).

S. frugiperda attacks in all the plant's phenological stages, destroying its leaves and cartridge, reaching even the spike (Cruz and Turpin 1982). The younger larvae eat the tissue of one of the sides of the leaf, leaving the opposite epidermis intact. After the second or third instar, the larvae start piercing the leaves, and then proceed to feed on the corn cartridge, producing characteristic rows of perforations on the leaves (Capinera, 1999). Larval density in the cartridge is low, due to the cannibalistic behavior of this insect. In laboratory conditions, its life cycle is completed in 30 days, and the number of eggs (clutch size) varies from 100 to 200 per clutch/female, a single female being able to lay a total of 1,500 to 2,000 eggs. The caterpillar can grow longer than 2.5 cm, and the pupa phase occurs underground (Valicente and Tuelher, 2009). In the phase with 8-10 leaves, damages are the greatest, and grain yield loss can reach 18.7% (Cruz and Turpin 1982).

Among the methods used to control *S. frugiperda*, the use of chemicals is being increasingly reduced, with adverse consequences for the beneficial fauna, pest ressurgence, and environmental contamination (Gassen, 1996), the development of resistant populations of the insect, biological unbalance, and harmful effects to man and other animals, let alone its high cost (Kogan, 1998); the search for alternatives that minimize the adverse effects of agrochemicals on the environment is thus a necessity (Silva *et al*., 2008; Silva *et al*., 2009; Souza *et al.,* 2011).

Control measure decisions should be based on several factors related to the pest, culture, and environment (Pedigo 1999; Oliveira *et al.,* 2007). For this reason, emphasis has been given to the cultural control method, which is an alternative to agroecological pest management. Corn intercropped with bean, for example, is commonly used to reduce damages caused by the pest, acting as a spatiotemporal physical barrier and improves the conditions for the development of natural enemies. For corn intercropped with bean, pest reduction is quite significant, reaching 37.2% for *S. frugiperda* (Milanez, 1987).

Information on the insect-plant interaction with respect to the damages caused by this pest, and the oviposition preferences in distinct phenological stages of the corn culture, are essential to devise control strategies within integrated pest management programs. The objective of this study was

Table 1. Average ($\overline{\chi}$) number of clutches and clutch size of *Spodoptera frugiperda* per phenological stage of the plant.

Phenological Stage	$\overline{(\chi)}$ number of clutches [1,2]	$\overline{(\chi)}$ clutch size [1,3]
4-6	3.00 ± 0.94 A	285.00 ± 43.00 B
8-10	5.07 ± 1.57 A	1,534.25 ± 135.91 A
12-14	5.13 ± 0.93 A	1,570.28 ± 43.00 A

1 Averages followed by the same letter in small caps in rows, and large caps in columns, do not differ according to the Tukey test (P<0.05).
2 Original averages. For statistical analysis, data were transformed into SQRT (X+1).
3 Original averages. For statistical analysis, data were transformed into log (X+1).

to evaluate oviposition preference and the damage capacity of *S. frugiperda* on the distinct phenological stages of the cor

MATERIALS AND METHODS

The experiment was done at the Assis Chateaubriand Agricultural School (07º10'15" South, 35º51'13" West, altitude 634 meters), municipality of Lagoa Seca, Paraíba State, Brazil.

In two areas of 500 m^2, corn and corn intercropped with bean was sown with a spacing of 0.80 x 0.40 m. Hybrid corn seeds of CMS lineage were used. During the experimental period, the areas received cultural treatments such as plowing, organic manure provision, and manual weed removal, except the application of insecticides after germination. Nearby areas were cultivated with tomato, corn, and bean.

Clutches and caterpillars were collected weekly between July and September on 50 randomly distributed plants, in five sampling spots separated by a distance of approximately 20 meters. At each spot, 10 plants were evaluated, four of them on a central row and three others on each of two lateral rows, alternating the rows closest to the central row, separated by approximately three meters. Height and number of leaves per plant, and clutch location by plant region and placement on the abaxial and adaxial leaf surfaces, were recorded. With these data in hand, it was possible to group clutches according to plant region (lower, middle, and upper) and study their distribution considering the corn's distinct phenological stages: 4-6, 8-10, and 12-14 leaves (Cruz and Turpin 1982). Damages caused by *S. frugiperda*'s

Table 2. Average $\overline{(\chi)}$ number of clutches of *Spodoptera frugiperda* per phenological stage of the plant, region of the plant, and leaf surface.

Phenological stage	n	$\overline{(\chi)}$ Clutches / plant region [1,2]			$\overline{(\chi)}$ Clutches / leaf surface [1,2]	
		Lower	Middle	Upper	Abaxial	Adaxial
4-6	8	2.77±0.97aA	0.00bB	0.23±0.12bA	2.87±0.94aA	0.00bB
8-10	8	1.50±0.59aA	1.75±0.83aA	1.62±0.49aA	2.62±0.86aA	3.50±1.05aA
12-14	8	1.00±0.38bA	3.42±0.73aA	0.71±0.24bA	1.13±0.44bA	3.96±0.84aA

1 Averages followed by the same letter in small caps in rows, and large caps in columns, do not differ according to the Tukey test (P<0.05).
2 Original averages. For statistical analysis, data were transformed into .

Table 3. Average $(\overline{\chi})$ number of caterpillars of *Spodoptera frugiperda* per phenological stage and tillage system.

Phenological stage	$(\overline{\chi})$ of caterpillars[1]	
	Corn	Corn x Bean
4-6	24.33 ± 15.05 aB	30.00 ± 11.16 aA
8-10	34.00 ± 16.33 aB	31.75 ± 9.63 aA
12-14	89.25 ± 13.53 aA	30.50 ± 1.50 bA
Average	49.19 ± 11.77 A	21.75 ± 20.60 B

caterpillars were recorded in the scale: 0) no damage, 1) leaf scraped, 2) leaf pierced, 3) leaf torn, 4) damage in cartridge, 5) cartridge destroyed (Cruz and Turpin 1982). Clutches were placed into plastic vials and taken to the Entomology Laboratory of the Biological Control Unit, Paraíba State University, where they were kept in glass vials (8.5 x 2.5 cm). Clutch size (number of eggs) was quantified based on the number of ecloded caterpillars.

Data on the distribution and number of clutches and eggs in the distinct phenological stages and regions in the corn plant were analyzed following the factorial protocol of 2 x 2 with three levels each, factor A being the culture's phenological stage (4-6, 8-10, 12-14 leaves), and factor B the plant region (lower, middle, and upper) or leaf surface (abaxial or adaxial). The average number of caterpillars and the average damage caused to the corn plant in monoculture and intercropped with bean were compared considering the entirely casualized experimental design. Treatment averages were subjected to analysis of variance and compared with the Tukey test ($P < 0.05$), using the STAT/UNESP program (Unesp, 1991), when significant differences were detected.

RESULTS AND DISCUSSION

We collected clutches of *S. frugiperda* in all phenological stages of the corn, 100% located over leaves. Statistical differences of the average number of clutches among the three phenological stages of the crop were not detected; however, average clutch size was significantly smaller for stage with 4-6 leaves in relation to stages with 8-10 and 12-14 leaves (Table 1).

The smaller clutch size in the stage with 4-6 leaves is related to the smaller number of eggs laid in the initial stages of crop development, as observed by Meneses (1991) Beserra *et al.,* (2002) for rice plants; the authors related the fact to environmental interferences, such as exposure to sun rays and low humidity. The rise in clutch size for stages with 8-10 and 12-14 leaves coincides with the period of greater attack on corn, where, according to Cruz and Turpin (1982), the highest production losses occur, reaching on average 18.7% and 8.6%, respectively.

There was a significant interaction between plant region (lower, middle, and upper) and phenological stage of the plant ($F=7.21$; $P<0.05$), and between leaf surface and phenological stage ($F=10.96$; $P<0.05$) in relation to number of clutches (Table 2). When the plant was at the stage with 4-6 leaves, the largest number of clutches was observed in the lower plant region, and there was no preference for oviposition in the mid region. When the corn was at the stage with 8-10 leaves, clutches were uniformly distributed, and there were no differences in plant region; however, the mid region of the plant was preferred for oviposition at the stage with 12-14 leaves.

Table 4. Average ($\overline{\chi}$) damage caused by caterpillars of *Spodoptera frugiperda* by tillage system.

Phenological stage	$\overline{\chi}$ of damage grade caused by caterpillars[1]	
	Corn	Corn x Bean
4-6	3.01 ± 0.014 aA	2.58 ± 0.11 aA
8-10	3.51 ± 0.18 aA	2.78 ± 0.12 bA
12-14	3.60 ± 0.14 aA	2.60 ± 0.1 bA
Average	3.37 ± 0.1 a	2.65 ± 0.06 b

More clutches were recorded on the abaxial surface of the leaf at the phenological stage with 4-6 leaves, shifting to the adaxial surface at the subsequent stages with 8-10 and 12-14 leaves (Table 2).

The alteration in oviposition site suggests that *S. frugiperda* females shift the distribution of their layings depending on the development stage of the plant. At the culture's initial stages, with 4-6 leaves, the female probably seeks shelter for its eggs, protecting them from disseccation and natural enemies, preferring the plant's lower region and the leaf's abaxial surface, where humidity is higher and clutches can be more concealed. At the stages with 8-10 and 12-14 leaves, leaf mass is greater, with a great increase in humidity and protection capability, and females select the mid and upper regions of the plant and the adaxial surface of the leaf, located closer to the plant's cartridge, a feeding and shelter site for caterpillars. Pitre and others (1983) verified that, in grasses like sorghum and corn, the plant's lower region and the leaf's abaxial surface are preferred for oviposition as long as they provide shelter and protection. This strategy of oviposition of the pest, in corn, is focused on protection from natural enemies or an adequate place for caterpillar foraging as long as females lay their eggs in areas close to larvae feeding grounds (Beserra *et al*., 2002). Labatte (1993) also noticed that caterpillars prefer to forage on the lower region of the corn plant at the stage with 4-6 leaves, foraging occurring preferentially between the cartridge and young leaves at the stages with more than 10 leaves. After the corn's fertilization, at the stages with 12-14 leaves, caterpillars migrate to the plant's mid region, close to where spikes develop, and stay on the leaves and spikes. This distribution of clutches and larvae was also reported for *Ostrinia nubilalis* (Hüb) by Shelton and others (1986) and Labatte (1991), and for *S. frugiperda* by Beserra and others (2002), who concluded that the corn's phenological stage is one of the main factors affecting oviposition preference and damages from the pest.

There were significant differences between tillage systems, with averages of 49.19 and 21.75 caterpillars, and average damage caused by *S. frugiperda* of 3.37 and 2.65, for corn in monoculture and corn intercropped with bean, respectively (Tables 3 and 4), intercropping reducing the pest's population and damages caused. A higher number of caterpillars at the stage with 12-14 leaves stage was recorded for corn in monoculture; however, this greater infestation did not reflect in a greater average damage in relation to the stage with 4-6 and 8-10 leaves, with average damage varying from 3.01 to 3.60. On corn intercropped with bean, infestation and average damage caused by *S. frugiperda* remained constant, no differences having been noticed among stages with respect to those

variables (Tables 3 and 4).

The reduction in crop damage in the intercropping system is corroborated by data obtained by Altieri and others (1977) and Oliveira and others (1995), who recorded a reduction of the damage caused by *S. frugiperda* of up to 14.0% when corn was sown intercropped with bean and "caupi-bean", respectively. Therefore, it was noticed that in diversified systems with more than one crop there is a reduction in infestation and damage caused by the pest. This is attributed to a greater availability of food resources, which favors the presence of natural enemies and hampers the location of the host plant by the herbivore, reducing infestation, and consequently damage (Altieri, 2002)

The absence of significant differences in average damage, even though a greater caterpillar infestation at the stage with 12-14 leaves occurred, may be related to nutritional adequacy of leaves to caterpillars at those developmental stages, since at the final stages with 12-14 leaves, the leaves become more resistant, hampering foraging and consequently reducing plant damage.

As to phenological stages in the intercropping system, a lower infestation is inferred, and consequently less damage caused to the host plant, independent on the culture's phenological stage.

In this study, it could be observed that *S. frugiperda* oviposits in all phenological stages of the corn, shifting laying site according to changes in the plant's phenological stages. The greatest infestation and pest damage occur in corn grown in monoculture, polyculture thus being the recommended system, since it reduces the pest's population, and consequently the damages that is causes

CONCLUSIONS

Based on these data we can conclude: i) *Spodoptera frugiperda* made oviposition in all phenological stages of corn; ii) The insect changed its oviposition behavior according to the changes of phenological stages of the plant; iii) The largest infestation and larger pest damage occurred in monoculture (only corn); iv) The polyculture system is recommended as well as reduce pest damage favors natural enemies

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