Phytophagous insects in cotton crop residues during the fallow period in the state of Mato Grosso do Sul, Brazil

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Abstract – The objective of this work was to analyze the faunistic composition of the insect pests that occur during the fallow period in cotton (*Gossypium hirsutum*) crop residues in the state of Mato Grosso do Sul, Brazil. The study sites were the municipalities of Alcinópolis, Chapadão do Sul, Costa Rica, Aral Moreira, Dourados, and Sidrolândia. A sampling design with two replicates per municipality was used. Each replicate comprised 100 random points, and each point corresponded to a cotton plant that was entirely inspected, to count the insect pests on it. The obtained fauna was analyzed and a rarefaction curve of the species was generated. During the evaluation period, a total of 23 species were recorded in the cotton crop residue, and the most frequent and abundant were *Bemisia tabaci*, *Aphis gossypii*, *Frankliniella schultzei*, and *Anthonomus grandis.* The caterpillars were predominantly found on the non-Bt cotton crops in Dourados, and Chapadão do Sul was the municipality that exhibited the greatest species diversity. Despite being mandatory, the destruction of cotton stalks during the fallow period was not able to completely eliminate the insect pests during the study period; among these insect pests, *A. grandis* stands out, a species that affects the dynamics of cotton pest control.

Index terms: *Anthonomus grandis*, *Gossypium hirsutum*, host plant, legislation, regrowth.

Insetos fitófagos em restos culturais de algodoeiro durante vazio sanitário em Mato Grosso do Sul

Resumo – O objetivo deste trabalho foi analisar a composição faunística de insetos-pragas que ocorrem durante o período de vazio sanitário em restos culturais de algodoeiro (*Gossypium hirsutum*) em Mato Grosso do Sul. Foram estudados os municípios de Alcinópolis, Chapadão do Sul, Costa Rica, Aral Moreira, Dourados e Sidrolândia. Utilizou-se um delineamento com duas repetições por município. Cada repetição foi composta por cem pontos aleatórios, e cada ponto correspondia a uma planta de algodão totalmente vistoriada, para contabilizar os insetos-pragas sobre ela. Realizaram-se a análise faunística e a curva de rarefação das espécies. Durante o período de avaliação, foi observado um total de 23 espécies em restos culturais de algodoeiro, sendo as com maior frequência e abundância *Bemisia tabaci*, *Aphis gossypii*, *Frankliniella schultzei* e *Anthonomus grandis*. O complexo de lagartas predominou sobre a variedade de algodoeiro não Bt em Dourados, e Chapadão do Sul foi o município com maior diversidade de espécies. Apesar de obrigatória, a destruição de soqueiras no vazio sanitário não conseguiu eliminar totalmente os insetos-pragas no ano deste estudo; dentre estes insetos-pragas, destaca-se *A. grandis*, que influencia a dinâmica do controle de pragas no algodoeiro.

Termos para indexação: *Anthonomus grandis*, *Gossypium hirsutum*, hospedeiro, legislação, rebrota.

Introduction

In the early 1990s, the cotton cultivation and production areas in Brazil were concentrated in the Southern, Southeastern, and Northeastern regions (Stadler & Buteler, 2007). After this period, the cultivation of this fibrous plant shifted significantly to the Cerrado areas, in Midwestern region of Brazil. In 1990, this region had a total cotton cultivation area of 123,000 ha, representing only 8.8% of the total cotton cultivation area in the country. However, by 2017, it had increased to 682,600 ha, corresponding to 72.7% of the total cotton cultivation area, with an average cotton yield of 4,046 kg ha^{-1} (Acompanhamento…, 2017).

The observed increase in cotton cultivation area was mainly due to the attacks by the boll weevils – *Anthonomus grandis* Boheman, 1843 (Coleoptera:

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Curculionidae) before 1995. This species, in less than five years of its advent, that happened in 1983, infested more than 90% of the total cotton cultivation area in Brazil (Stadler & Buteler, 2007). One of the strategies for the management of boll weevil populations is the destruction of the cotton stalks during the fallow period; it is considered useful. If this is not carried out, under ideal environmental conditions, cotton plants can regrow, and consequently produce reproductive structures, such as buds, flowers, and fruits, therefore, hosting the species *A. grandis* during the off-season (Lu et al., 2010; Bianchini & Borges, 2013; Grigolli et al., 2015).

Destruction of the cotton stalks during the fallow period is a prophylactic measure that must be done efficiently soon after the harvest to avoid possible regrowth of the host plants. Furthermore, this is a mandatory practice in the Brazilian territory (Bianchini & Borges, 2013).

In addition to the boll weevil, other insect pests that thrive and feed on cotton crops include: *Aphis gossypii* (Hemiptera: Aphididae), *Bemisia tabaci* (Hemiptera: Aleyrodidae), *Eutinobothrus brasiliensis* (Coleoptera: Curculionidae), *Pectinophora gossypiella* (Lepidoptera: Gelechiidae), *Chloridea virescens* (Lepidoptera: Noctuidae), and caterpillar species of the genus *Spodoptera* (Lepidoptera: Noctuidae). These species pose a risk not only to the successor crops, but also to the next set of cotton crops (Miranda, 2010; Izeppi et al., 2011; Ribeiro et al., 2015). In 2013, *Helicoverpa armigera* was detected in Brazil and added in the list.

The most commonly used method for the destruction of the cotton stalks in the Brazilian Cerrado regions involves two stages. First, the plants are cut with a rotary cutter, and then they are destroyed efficiently by means of mechanical action or the use of herbicides (Bianchini & Borges, 2013). This practice is mandatory through the joint resolution of SEPAF/IAGRO No. 1/2015 in the Cerrado regions of the states of Mato Grosso, Mato Grosso do Sul, and Goiás (Mato Grosso do Sul, 2015). Moreover, this method exhibits high efficiency and can be rapidly executed on small crops and hydrated plants. However, the cotton crop cultivation conditions in the Cerrado regions are different. Here the plants are cultivated predominantly in areas that are subjected to water stress and in large properties. Therefore, the effectiveness of the herbicides used diminishes, since the duration of application of the herbicides is prolonged. This sometimes allows the regrowth of plants and reappearance of insect pests in most of the cultivated areas (Greenberg et al., 2007a, 2007b).

In addition to the presence of volunteer plants, the continuous use of the same technologies in the extensive contiguous areas that are always cultivated with a low diversity of species (corn, soybean, and cotton) allows the formation of green bridges between crops. The occasional association of green bridges with the misuse of chemicals has made agroecosystems progressively susceptible to diseases and insect pests (Silva & Ramalho, 2013).

In Brazil, there are no studies on the composition of insect pests during the fallow period in the cotton crop residues. Most of the studies deal with the considered most efficient cotton stalk destruction methods (Bianchini & Borges, 2013); the crop residue destruction methods and survival of the boll weevil (Ribeiro et al., 2015); and population dynamics of the boll weevil (Grigolli et al., 2015; Pires et al., 2017) and *A. gossypii* (Izeppi et al., 2011) in the crop residue during the off-season.

The objective of this work was to analyze the faunistic composition of the insect pests that occur during the fallow period in cotton crop residues in the state of Mato Grosso do Sul, Brazil.

Materials and Methods

The study was conducted in the state of Mato Grosso do Sul (Figure 1), in the municipalities of Alcinópolis, Chapadão do Sul, and Costa Rica in the north, and Aral Moreira, Dourados, and Sidrolândia in the south. These municipalities comprised 7.13, 22.64, 60.26, 0.62, 0.005, and 4.6% of the cultivation areas, respectively, representing 95.2% of the total cotton cultivation area in the state.

The areas that were considered for the present study cultivated cotton crops and showed cotton stalks (part of the stem that remains after the cotton plant destruction), and also exhibited their regrowth (regrowth of plants after destruction of the cotton stalks). Moreover, the region showed volunteers plants (plants from the cotton seeds that were not harvested, and had eventually germinated) (Miranda & Rodrigues, 2016).

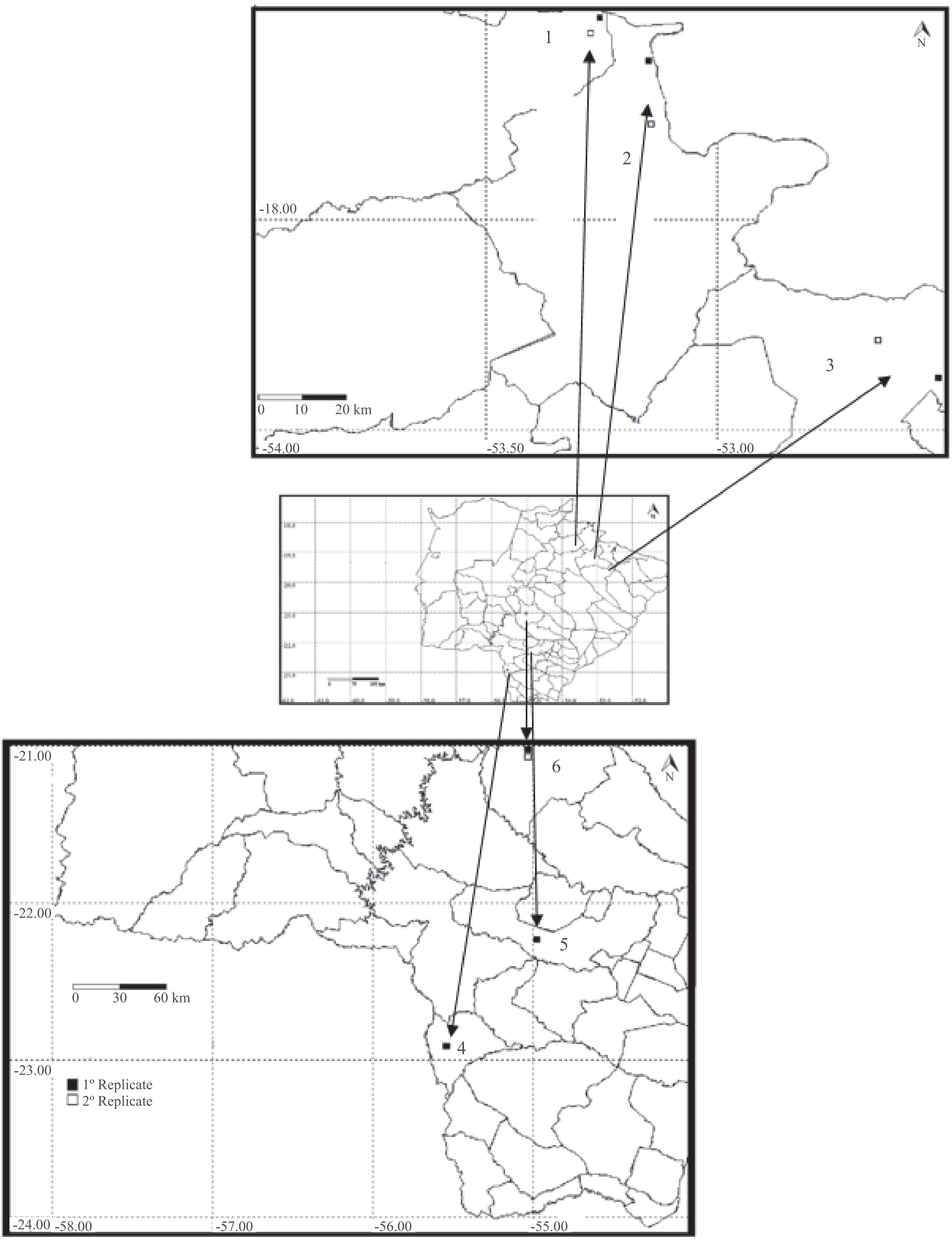

Figure 1. Map of the study areas in the state of Mato Grosso do Sul, Brazil, with the number of experimental replicates in 2015. The municipalities identified in the numerical sequence are: 1, Alcinópolis; 2, Costa Rica; 3, Chapadão do Sul; 4, Aral Moreira; 5, Dourados; and 6, Sidrolândia.

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The evaluations were carried out at 14-day intervals. In the south of the state, the study period was from June 1st to September 31, 2015. In the north, the period was from September 15 to November 30, 2015. These study periods were determined by the joint resolution “SEPAF/IAGRO No. 001/2015” based on the onset and end of the cotton fallow period in Mato Grosso do Sul (Mato Grosso do Sul, 2015).

A sampling design with two replicates was used for the municipalities with an area greater than 1,000 ha, which had adopted different methods and periods for the destruction of crop residue. These municipalities were Alcinópolis, Chapadão do Sul, Costa Rica, and Sidrolândia. In the municipalities of Aral Moreira and Dourados, the design consisted of just one replicate, because their areas had less than 1,000 ha, and just one method and period had been adopted for the destruction of crop residues.

For each replicate, an area of approximately 3 ha consisting of 100 random points was delimited. The same areas delimited throughout the study were consistently used. Each point corresponded to a cotton plant, which was inspected, and only the insect pests present on it were counted. The identification of specimens was based on Gallo et al. (2002), considering the eggs, the immature (nymph/larvae) and adult phases of the insect pests.

Dourados does not harbor a commercial cotton cultivation area. However, an area of approximately 1.5 ha was used as a control site for the present study. Ten days before the onset of the fallow period, the first destruction of cotton stalks of the non-Bt FM 910 variety was carried out. The destruction was performed initially by shredding the plants, and subsequently spraying them with the herbicides, 2,4-dichlorophenoxyacetic acid (2,4-D) 698 CS and glyphosate 480 CS at the concentrations of 1.0 and 4.0 l ha^{-1}, respectively.

In all municipalities, cultivation treatments were under the control of technical managers, except in Dourados, where the researches of the present study were the ones responsible, and was the objective of the research. The faunistic composition of insect pests in field cotton residues was verified in every municipality.

In Aral Moreira, the destruction of cotton stalks was carried out seven days before the onset of the fallow period. The destruction was carried out by using initially a straw crusher, and later a leveling harrow, with subsequent sowing of black oat (*Avena strigosa* Schreb.) as a cover plant. During the first of the two replicates in Sidrolândia, the mechanical destruction of the crop residue was not performed. The destruction was carried out solely by using several insecticides throughout the study period. The cotton crop used was FM 975 WS (Cry1Ac+Cry1F) variety. The insecticides used were: acephate 750 SP and beta-cyfluthrin 125 SC at the concentrations of 1.2 kg ha^{-1} and 0.12 L ha^{-1}, respectively. They were used on the tenth day after the onset of the fallow period (DAOFP). On the twenty-third DAOFP, bifenthrin 50 EC + carbosulfan 150 EC at a concentration of 1.0 L ha^{-1}, beta-cyfluthrin 125 SC at 0.12 L ha^{-1}, and bifenthrin 100 EC at 0.5 L ha^{-1} were used. On the twenty-seventh DAOFP, malathion 1000 EC and beta-cyfluthrin 125 SC at the concentrations of 1.0 and 0.12 L ha^{-1}, respectively, were used. On the thirty-third DAOFP, malathion 1000 EC at 1.0 L ha^{-1} and beta-cyfluthrin 125 SC at 0.12 L ha^{-1} were applied. On the forty-second DAOFP, bifenthrin 100 EC and thiamethoxam 250 WG at the concentrations of 0.5 L ha^{-1} and 0.250 kg ha^{-1}, respectively, were used. Finally, on the forty-seventy, fifty-fourth, and sixty-first DAOFP, malathion 1000 EC at 1.0 L ha^{-1} and beta-cyfluthrin 125 SC at 0.12 L ha^{-1} were applied. During the second replicate, the crop residue of the Bt FM 975 WS variety was evaluated. The destruction of the cotton stalks was carried out initially by using a straw crusher and subsequently by applying the herbicides 2,4-D 698 CS and glyphosate 620 SL at 1.0 and 2.5 L ha^{-1} concentrations, respectively, seven days before the onset of the fallow period.

In Alcinópolis, the study was conducted on the cotton crop residue of the Bt FM 940 GLT (Cry1Ab + Cry2Ae) variety. The destruction of the cotton stalks was performed using a straw crusher at first, and later a leveling harrow, two days before the onset of the fallow period. In Alcinópolis, the cotton stalks of the Bt FM 975 WS variety were destroyed during the second replicate one day before the onset of the fallow period, with the herbicides 2,4-D 698 CS at 2.5 L ha^{-1}, whose application was repeated on the eleventh DAOFP at a concentration of 1.2 L ha^{-1}. On the seventeenth DAOFP, glyphosate 620 SL at 2.0 L ha^{-1}, chlorpyrifos 480 EC at 1 L ha^{-1}, and lambda-cyhalothrin 50 SC + chlorantraniliprole 100 SC at 0.1 L ha^{-1} were applied. On the twenty-fifth DAOFP, flumichlorac pentyl 100 EC and chlorimuron ethyl 250 WG at the concentrations of 0.4 L ha^{-1} and 0.06 kg ha^{-1}, respectively, were used.

Finally, on the thirty-fifth DAOFP, glyphosate 620 SL at a concentration of 1.5 L ha^{-1} and lambda-cyhalothrin 50 SC + chlorantraniliprole 100 SC at 0.1 L ha^{-1} concentration were used.

In Chapadão do Sul, the Bt TMG 42 WS variety was used during the first replicate. The destruction of cotton stalks was performed on the 24th DAOFP, using glyphosate 620 SL, 2,4-D 806 SL, and saflufenacil 700 WG at the concentrations of 2.8 L ha^{-1}, 1.0 L ha^{-1}, and 0.053 kg ha^{-1}, respectively. On the thirty-first DAOFP, glyphosate 620 SL at 3.0 L ha^{-1}, imazethapyr 106 SL at 0.5 L ha^{-1}, cloransulam-methyl 840 WG at 0.06 kg ha^{-1}, and methomyl 216 SL at 0.8 L ha^{-1} were used. During the second replicate, the destruction of the cotton stalks of the Bt TMG 41 WS variety was performed four days before the onset of the fallow period, using 2,4-D 806 SL and glyphosate 620 SL at the concentrations of 1.0 and 2.5 L ha^{-1}, respectively.

During the first of the two replicates in Costa Rica, destruction of the Bt 940 GLT variety cotton stalks was carried out at the second DAOFP using glyphosate 620 SL and 2,4-D 806 SL at 3.0 L ha^{-1} and 1.0 L ha^{-1} concentrations, respectively. Seven days after the first desiccation, saflufenacil 700 WG and glyphosate 620 SL at 0.05 kg ha^{-1} and 3.0 L ha^{-1} concentrations, respectively, were applied. During the second replicate, on the thirteenth DAOFP, the destruction of the Bt FM 975 WS cotton stalks was performed using 2,4-D 806 SL and beta-cyfluthrin 125 SC at the concentrations of 1.0 and 0.14 L ha^{-1}, respectively. On the eighteenth DAOFP, glyphosate 720 WG at 1.0 kg ha^{-1}, 2,4-D 806 SL at 0.8 L ha^{-1}, and malathion 1000 EC at 0.8 L ha^{-1} were used. On the forty-ninth DAOFP, glyphosate 720 WG at a concentration of 0.5 kg ha^{-1} was applied. On the seventieth DAOFP, glyphosate 720 WG and chlorpyrifos 480 EC at 1.0 kg ha^{-1} and 1 L ha^{-1} concentrations, respectively, were applied.

The data were analyzed using the faunal indexes proposed by Silveira Neto et al. (1976), based on the calculations of constancy, abundance, and relative frequency indexes (percentage of times the insect species was sampled in relation to the total evaluations).

A species-accumulation curve by rarefaction was generated to evaluate species richness in the municipalities studied (Chao et al., 2014). The representation of the curve was obtained by the rarefaction method, which was calculated in the R software by the function specaccum of the vegan package (R Core Team, 2016).

The data used to generate the species-accumulation curve were initially randomized to group the 100 sample points within each replicate, into five samples with 20 points each, totaling 295 samples through the sample function (R Core Team, 2016).

Results and Discussion

During the fallow period, a total of 23 species of insect pests were identified, which were distributed across 5 orders and 15 families (Table 1). However, no insect pests were found in Aral Moreira. Although, theoretically, Dourados should have been considered the control region, since it is not a cotton cultivation area, Aral Moreira became the control due to the efficient destruction of the cotton crop residues in the off-season. This was reflected by the absence of insect pests, showing the importance of the complete destruction of cotton crop residues for a fallow period free from phytosanitary problems, i.e., free from pests.

In the present study, the species *B. tabaci*, *A. gossypii*, *A. grandis*, *Diabrotica speciosa*, *Frankliniella schultzei*, and *Agallia* sp. were present in all the municipalities, except in Aral Moreira. This suggested that they are constant pests in cotton crop residues.

It is important to highlight the relatively high frequency (>83%) (Table 1) and abundance of *B. tabaci* in the municipalities with commercial cotton cultivation areas in state of Mato Grosso do Sul. The data indicated the high survival capacity and polyphagic nature of this specie. Since the 1980s, *B. tabaci* has climbed up in the status of damaging pest in the world, both in large and closed crops (Barro et al., 2011).

In Dourados, a relatively small population of *B. tabaci* observed in the present study might be related to the cultivation history of the region. In this municipality, the successor culture of soybean crop is the maize crop, which is not a suitable host for the reproduction of this phytophagous species. Therefore, this discourages the formation of green bridge between cotton crops, and consequently decreases the proliferation of *B. tabaci* population (Quintela et al., 2016).

There are no studies on the migration of *B. tabaci* populations from cotton crops to soybean [*Glycine max* (L.) Merr.] crops in the Cerrado region. However, the present study indicated that a large population of

Table 1. Faunal indexes of the insect pests analyzed during the fallow period in the southern (Aral Moreira, Dourados, and Sidrolândia) and northern (Alcinópolis, Chapadão do Sul, and Costa rica) regions of the state of Mato Grosso do Sul, Brazil, in 2015.

Order: Family	Species	Stage(1)	Aral Moreira/ Alcinópolis	Dourados/ Chapadão do Sul	Sidrolândia/ Costa Rica
			N C (F%) A(2)	N C (F%) A(2)	N C (F%) A(2)
				Southern region	
Hemiptera/Aleyrodidae	*Bemisia tabaci*	N	-	12 y (33) c	6,281 w (100) oa
Hemiptera/Aphididae	*Aphis gossypii*	Ad	-	3,008 w (100) oa	40,469 w (100) oa
Hemiptera: Pseudococcidae	*Planococcus minor*	N+Ad	-	247 w (78) oa	13 z (22) d
Hemiptera: Cicadellidae	*Agallia* sp.	N+Ad	-	222 w (56) oa	75 y (44) c
Hemiptera: Pyrrhocoridae	*Dysdercus* sp.	N+Ad	-	2 z (22) r	-
Hemiptera: Pentatomidae	*Euschistus heros*	N+Ad	-	-	-
Hemiptera: Pentatomidae	*Edessa meditabunda*	N+Ad	-	-	-
Hemiptera: Pentatomidae	*Dichelops melacanthus*	N+Ad	-	-	-
Hemiptera: Pentatomidae	*Chinavia* sp.	N+Ad	-	-	-
Hemiptera: Miridae	*Horciasoides nobilellus*	N+Ad	-	-	-
Lepidoptera: Noctuidae	*Helicoverpa* sp.	Cat	-	20 w (55) c	-
Lepidoptera: Noctuidae	*Spodoptera frugiperda*	Cat	-	10 w (55) d	-
Lepidoptera: Noctuidae	*Alabama argillacea*	Cat	-	6 z (22 d	-
Lepidoptera: Noctuidae	*Chrysodeixis includens*	Cat	-	6 z (22) d	-
Lepidoptera: Gelechiidae	*Pectinophora gossypiella*	Cat	-	6 z (11) d	-
Thysanoptera: Thripidae	*Frankliniella schultzei*	N+Ad	-	174 y (33) oa	1,464 w (100) oa
Coleoptera: Curculionidae	*Anthonomus grandis*	L+Ad	-	25 y (33) c	213 w (89) va
Coleoptera: Chrysomelidae	*Diabrotica speciosa*	Ad	-	50 w (78) va	119 w (100) va
Coleoptera: Curculionidae	*Conotrachelus denieri*	Ad	-	-	13 z (11) d
Coleoptera: Chrysomelidae	*Cerotoma arcuatus*	Ad	-	13 z (22) c	20 z(22) c
Coleoptera: Tenebrionidae	*Lagria villosa*	Ad	-	13 y (44) c	-
Coleoptera: Dasytidae	*Astylus variegatus*	Ad	-	-	5 z (11) r
Diptera: Agromyzidae	*Liriomyza* sp.	L	-	-	2 z (11) r
Hemiptera: Pentatomidae	*E. meditabunda*	E	-	-	-
Lepidoptera: Noctuidae	*S. frugiperda*	EL	-	-	-
Lepidoptera: Noctuidae	*Helicoverpa* sp.	E	-	18 z (11) c	22 z (11) c
Coleoptera: Curculionidae	*A. grandis*	E	-	33 z (22) va	94 w (78) a
				Northern region	
Hemiptera/Aleyrodidae	*Bemisia tabaci*	N	969 w (83) oa	884 w (100) oa	301 w (100) va
Hemiptera/Aphididae	*Aphis gossypii*	Ad	646 w (67) oa	501 w (67) oa	135 w (80) a
Hemiptera: Pseudococcidae	*Planococcus minor*	N+Ad	-	526 w (100) oa	-
Hemiptera: Cicadellidae	*Agallia* sp.	N+Ad	20 y (33) c	114 w (83) va	19 w (60) r
Hemiptera: Pyrrhocoridae	*Dysdercus* sp.	N+Ad	15 w (50) c	15 y (33) c	119 w (80) c
Hemiptera: Pentatomidae	*Euschistus heros*	N+Ad	1 z (17) r	12 w (50) c	-
Hemiptera: Pentatomidae	*Edessa meditabunda*	N+Ad	1 z (17) r	7 w (50) d	28 y (40) d
Hemiptera: Pentatomidae	*Dichelops melacanthus*	N+Ad	-	9 w (67) c	65 w (80) c
Hemiptera: Pentatomidae	*Chinavia* sp.	N+Ad	-	3 z (17) d	-
Hemiptera: Miridae	*Horciasoides nobilellus*	N+Ad	-	16 z (17) c	-
Lepidoptera: Noctuidae	*Helicoverpa* sp.	Cat	-	-	4 z (20) r
Lepidoptera: Noctuidae	*Spodoptera frugiperda*	Cat	-	-	-
Lepidoptera: Noctuidae	*Alabama argillacea*	Cat	-	-	-
Lepidoptera: Noctuidae	*Chrysodeixis includens*	Cat	-	-	-
Lepidoptera: Gelechiidae	*Pectinophora gossypiella*	Cat	-	-	-
Thysanoptera: Thripidae	*Frankliniella schultzei*	N+Ad	174 w (83) oa	244 w (100) oa	1,026 w (100) oa
Coleoptera: Chrysomelidae	*Diabrotica speciosa*	Ad	32 w (50) va	25 w (50) c	24 w (60) d
Coleoptera: Curculionidae	*Anthonomus grandis*	L+Ad	37 w (83) va	115 w (100) va	85 w (100) c
Coleoptera: Curculionidae	*Conotrachelus denieri*	Ad	-	-	-
Coleoptera: Chrysomelidae	*Cerotoma arcuatus*	Ad	-	-	-
Coleoptera: Tenebrionidae	*Lagria villosa*	Ad	14 y (33) c	8 w (67) c	153 w (80) va
Coleoptera: Dasytidae	*Astylus variegatus*	Ad	-	-	-
Diptera: Agromyzidae	*Liriomyza* sp.	L	2 y (33) r	-	-
Hemiptera: Pentatomidae	*Edessa. Meditabunda*	E	-	-	4 z (20) r
Lepidoptera: Noctuidae	*Spodoptera frugiperda*	EL	-	3 z (17) d	-
Lepidoptera: Noctuidae	*Helicoverpa* sp.	E	11 w (67) c	129 w (83) va	83 w (80) c
Coleoptera: Curculionidae	*Anthonomus grandis*	E	-	5 z (17) d	3 z (20) r

(1)Ad, adult; N, nymph; Cat, caterpillar; L, larvae; E, egg; EL, egg laying; -, no insect occurrence. (2)N, total number of insects observed; C, constancy, where w is constant, y is accessory, and z is accidental; A, abundance, where oa is overabundant, va is very abundant, a is abundant, c is common, d is disperse, and r is rare; F%, relative frequency.

this species maintained during the fallow period might possibly be due to the early infestation of the successor crop, usually soybean, by *B. tabaci*.

In the present study, among the municipalities harboring commercial cotton cultivation areas, Costa Rica revealed the lowest incidence of *B. tabaci* and *A. gossypii*. During the fallow period in Costa Rica, the insecticides, beta-cyfluthrin and malathion were applied. These insecticides control the populations of both *B. tabaci* and *A. gossypii* (Ahmad et al., 2010; Miranda, 2010; Vieira et al., 2012). The largest infestations of *B. tabaci* and *A. gossypii* were observed in Sidrolândia, a municipality in which the destruction of the cotton stalks during the fallow period was not performed during one of the replicates.

The relatively high frequency and abundance of *A. gossypii* (> 67%) (Table 1) observed in the present study indicated the high survival and development capacity of the species during the study period. This is in alignment with the results obtained in other studies, indicating the high polyphagic nature of this phytophagous insect and the importance of this insect for cotton crops. Moreover, in the present study, the risk of virus transmission by this species due to the presence of the cotton crops during the fallow period was highlighted (Michelotto & Busoli, 2007; Carletto et al., 2009; Furtado et al., 2009).

In the present study, another species frequently observed was *F. schultzei* (> 83%) (Table 1). It was observed mainly in the regions with large commercial cotton cultivation areas, such as Alcinópolis, Chapadão do Sul, Costa Rica, and Sidrolândia. Furthermore, *F. schultzei* was overabundant in the municipalities of Sidrolândia and Costa Rica. A common feature of these two municipalities was the use of insecticides creating a shock effect on the cotton crop residue, and no physical methods were followed. Therefore, insect pests with a high fertility rate and short life cycle were able to recover rapidly in this environment, as observed in *A. gossypii*, *B. tabaci*, and *F. schultzei*. These insects exhibited the highest faunal index values in the municipalities studied (Gallo et al., 2002; Campos et al., 2009; Funichello et al., 2012).

In the present study, the species *A. grandis* was not observed in the municipality of Aral Moreira. In Dourados, which is not a region with significant commercial cotton cultivation area, this species did not exhibit either high abundance or frequency (33%). However, *A. grandis* was abundant in the other municipalities, and its frequency was > 83% (Table 1). The difference between Dourados and the other municipalities evaluated lies in the fact that Dourados has not harbored a commercial cotton cultivation area since 1992 (Freire, 2011).

In the present study, besides the survival of *A. grandis*, egg laying on the cotton crops during the off-season was also observed. This suggested that *A. grandis* reproduced during the fallow period. In the tropical regions, such as the Brazilian Cerrado, there are not severe winters, which could reduce the regrowth of crops, preventing the boll weevils from reproducing. The management of this pest poses a severe challenge while cultivating cotton crops (Greenberg et al., 2007b).

It should be noted that *A. grandis* insects, in the tropical regions, do not diapause. However, they exhibit a state of low metabolic activity that cannot be determined solely by the characteristics singly assessed or combined with one or two factors. These factors include fat accumulation and absence of eggs, which can be induced by food deficiency and climatic conditions without inducing diapause (Showler, 2009). However, the methods followed for the destruction of the cotton stalks, such as weeding with leveling harrow, followed by weeding with the application of herbicides, might become an important method for reducing the surviving populations of boll weevils in the cotton crops post-harvest. This could prevent or delay their infestation during the next set of crop cultivation (Ribeiro et al., 2015). However, these destruction methods must be performed correctly and efficiently, as carried out in Aral Moreira.

In the present study, the caterpillars of *Spodoptera frugiperda*, *Alabama argillacea*, *Chrysodeixis includens*, and *Pectinophora gossypiella* were recorded only in Dourados. The caterpillars of *Helicoverpa* sp. were recorded in Dourados and Costa Rica.

In Dourados, the study was conducted on the non-Bt FM 910 variety of cotton crops. In the other municipalities, the Bt crop varieties were used. The production of the Bt toxin in plants was constitutive during all the phenological stages, and even in the crop residue. However, the continuous and erroneous use of this technology leads to the selection of resistant insects, mainly *H. armigera*. This might have led to the presence of this species during the fallow period in Costa Rica (Heckel et al., 2007; Andow, 2008; Almeida et al., 2011).

In the present study, the caterpillars were observed only in Costa Rica and Dourados. However, egg laying by *S. frugiperda* and *Helicoverpa* sp. was noted in all the municipalities that showed cotton crop residue, especially in Chapadão do Sul and Costa Rica, where the occurrence was constant with a frequency > 80%.

The destruction of the cotton stalks was delayed in Chapadão do Sul and Costa Rica during the present study, which provided regrowth plants suitable for the insect pests to lay eggs on for a longer period. However, since they laid eggs on the Bt plants, no caterpillars were observed because of the continued expression of the Bt toxin in the tissues of these plants. The new leaves exhibited a relatively high concentration of Bt toxins, which decreased as the plant matured (Andow, 2008; Soberón et al., 2009; Young, 2012).

In the present study, except for the overabundant (frequency close to 80%) species *D. speciosa* in the municipalities in the south of the state and *Planococcus minor* in Dourados and Chapadão do Sul, the other ones did not show constancy, relative frequency, and abundance in the cotton crop residues during the fallow period. These data corroborated the previous studies showing that these pests are not frequently observed in cotton crops (Gallo et al., 2002).

In the present study, the analysis of the rarefaction curve (Figure 2) revealed that it reached the plateau in all the studied municipalities. This indicated that mathematically the sampling effort (n = 20) was enough to detect the species richness of the community. In this study, 295 samples were collected, a number that fully complied with the reliability of the model. Furthermore, the difference in species richness between the municipalities was observed, with Chapadão do Sul and Alcinópolis showing the highest and the lowest index values, respectively.

In the municipality of Chapadão do Sul, the destruction of the cotton stalks was delayed in the present study. Therefore, the cotton plants in this region had an extended vegetative period when compared with that of the other regions, and consequently provided the highest amounts of food (leaves, flower buds, fruits) to tolerate a higher species diversity. However, a contrary observation was made in Alcinópolis, where the destruction of the cotton stalks was performed on time. In addition to this, one of the replicates was subjected to harrowing – a method that efficiently controls the regrowth of crop remains (Gallo et al., 2002; Young, 2012).

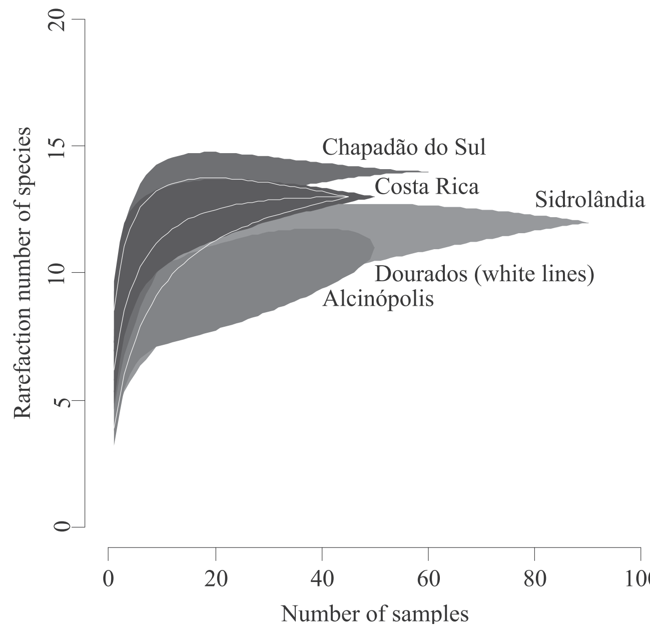

Figure 2. Rarefaction curves of the species showing the number of samples needed to obtain sample sufficiency in the municipalities studied during the fallow period in the state of Mato Grosso do Sul, Brazil. The curve amplitude corresponds to the 95% confidence interval obtained by sample randomization.

Conclusions

1. The most frequent insect pests associated with the cotton (*Gossypium hirsutum*) crop residues were *Bemisia tabaci*, *Aphis gossypii*, *Frankliniella schultzei*, and *Anthonomus grandis*, in the municipalities of Alcinópolis, Chapadão do Sul, Costa Rica, and Sidrolândia in the state of Mato Grosso do Sul, located in the Midwestern Region of Brazil.

2. The current methods practiced for the destruction of the cotton stalks in the evaluated municipalities of Mato Grosso do Sul in 2015 were not efficient in eliminating the insect pests during the off-season, especially the cotton boll weevil.

3. The cotton crop residues of the Bt crop varieties showed a reduction in the population size of the caterpillars of *Spodoptera frugiperda*, *Alabama argillacea*, *Chrysodeixis includens*, *Helicoverpa* sp.,

and *Pectinophora gossypiella* during the fallow period studied.

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