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BEHAVIOR OF *Pectinophora gossypiella* (GELECHIIDAE) (PINK BOLLWORM) MALES MONITORED WITH PHEROMONE TRAP IN COTTON

Comportamiento de *Pectinophora gossypiella* (Gelechiidae) (oruga rosada) machos capturados con trampas de feromona sintética en campos de algodón

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ABSTRACT

The objective of the present study was to evaluate the behavior of *P. gossypiella* males captured with pheromone-baited traps in cotton field. Three experiments were done during the 2001-02 and 2002-03 growing seasons using the Delta Opal cotton cultivar. The first experiment was related to the insect population captured during the crop cycle by of two commercially available Delta type traps, the second experiment was conducted to evaluate the efficiency of traps in capturing *P. gossypiella* males and, the third experiment assessed the nocturnal circadian rhythm. It was realized a descriptive analysis of the data collected to first and third experiment. Used in this second experiment consisted of comparing randomly selected groups, and the means were compared by t-test, the significance level was set at 5 %, and, the canonical correlation analysis was performed. The Delta pheromone trap was more efficient in capturing *P. gossypiella* than was the PET pheromone trap. Nocturnal activity peaks were found to be related with the time of year and it occurs between 11:00 p.m. and 2:00 a.m.

Keywords: Pink bollworm, delta trap, circadian rhythm.

RESUMEN

El objetivo de este estudio fue evaluar el comportamiento de *P. gossypiella* machos capturados con trampas de feromona sintética en campos de algodón Delta Opal. Se realizaron tres experimentos durante las épocas de cultivo de los años 2001-2002 y 2002-2003. En el primer experimento se capturaron los insectos durante el ciclo de cultivo, utilizando dos trampas Delta. En el segundo experimento se evaluó la eficiencia de las trampas y en el tercer experimento se determinó el ritmo circadiano nocturno. Se realizó un análisis descriptivo de los datos recogidos en el primer y tercer experimento. En el análisis estadístico utilizado en el segundo experimento se compararon grupos pareados y las medias fueron verificadas por prueba de t; el nivel de significancia se fijó en 5 % y se realizó un análisis de correlación canónica. La trampa de feromonas Delta fue más eficiente en la captura de *P. gossypiella* que la trampa de feromona PET. Los picos de actividad nocturna están relacionados con la época del año y ocurrieron entre las 2 y 23 horas.

Palabras clave: oruga rosada, ritmo circadiano, trampa delta.

INTRODUCTION

In most cotton producing countries, *Pectinophora gossypiella* (Saunders, 1844) (Lepidoptera: Gelechiidae), commonly known as the pink bollworm, is considered one of the major cotton pests (Fernandes, 1988). According to Ingram, 1994, pink bollworm is found in tropical and subtropical regions, and causes considerable economic losses, and huge quantities of insecticides or transgenic traits adoption are required in order to control the pest around the world. Upland cotton (*Gossypium hirsutum* L.) is cultivated in over 100 countries (International Cotton Advisory Committee, 2004), and the global cotton production in 2010/11 is estimated at 115.3 million bales with an area of 33.3 million hectares, and all of the world's major cotton producers are expected to increase cotton production in 2011/12, including China, India, United States, Pakistan, Brazil, Central Asia, and Australia (United States Department of Agriculture, 2011). In Brazil, *P. gossypiella* has been responsible for losses in productivity and fiber quality in all cotton producing areas (Degrande, 1998). Unlu and Bilgic, 2004, reported that, a 1 % increase in infestation would reduce almost 2.5-6 % of cotton yields in Turkey.

Large-scale production of gossyplure - the sex pheromone of *P. gossypiella* - for applications in the field has opened new prospects for integrated cotton pest management, both for population monitoring and for measures aimed at the suppression of the pest (Mafra Neto and Habib, 1987). Gossyplure [1:1 mixture of Z., Z.)- and (Z, E)-7, 11-hexadecadienyl acetate], a powerful attractant of *P. gossypiella* (Hummel *et al.*, 1973), has been widely used as a bait in traps (Qureshi *et al.* 1993). Pink bollworm Delta traps with gossyplure are used as the primary tool of pest detection. Traps are baited with rubber septa impregnated with gossyplure and attached with brass fasteners to a wooden stake placed around the perimeter of each cotton field. Traps are placed at planting, or shortly thereafter, at a rate of one trap per ten acres and inspected weekly until defoliation and harvest, or a killing freeze (Leggett *et al.*, 1994), and the weekly visual inspection begins at the bloom stage. The success of pheromone-baited traps is related to factors that are intrinsic to the pheromone, such as the number of components, the proportions of components, the purity of the pheromone, the stability of the pheromone, and the pheromone release rate (Howse *et al.*, 1998) and the factors that are extrinsic to the pheromone, such as the type of trap, the height at which the trap is hung up, and the location of the trap; and to environmental factors, such as temperature and humidity (Vilela and Della Lucia, 2001).

Sandhya *et al.*, 2010, studied the seasonal progression and incidence of pink bollworm in India, and they found that the peak field incidence of pink bollworm on locule damage and larval incidence was recorded after three weeks of first peak pheromone trap catch. In Israel, *P. gossypiella* has been monitored by means of pheromone traps with gossyplure since 1975; this allowed the number of insecticide applications per growing year to be reduced from 10-15 to a maximum of two (Boareto and Brandão, 2003). In Southern California, insecticides for pink bollworm control are applied only after the pheromone traps have captured 12-15 moths per trap in the early and intermediate phases of the cotton cycle or 4 moths per trap in the late phase (Aglearn, 2004). In Brazil, the pink bollworm chemical control threshold typically adopted is five moths captured per night (Degrande, 1998). In southwestern portion of the US Cotton Belt and Mexico, farmers are applying a program to eradicate the pest; the operational elements of the program include the use of gossyplure in traps and for mating disruption, Bt-cotton, cotton stalk destruction, restricted planting schedule, insecticides and sterile males; the results have been satisfactory (Allen *et al.*, 2005).

The objective of the present study was to evaluate the behavior of *P. gossypiella* males captured in pheromone-baited traps in cotton field.

MATERIAL AND METHODS

This work was conducted at the Universidade Federal da Grande Dourados (UFGD), located in Dourados, Brazil, between S22°14’ and W54°49’, at an altitude of 458 m.a.s.l., with Köppen climate classification Cfa, a climate zone characterized by hot, humid summers and mild to cool winters. The mean annual total rainfall in the city ranges from 1,200 to 1,400 mm, the annual actual evapotranspiration ranges from 1,100 to 1,200 mm, and the mean annual temperature is 22 °C. Mesoclimates range from humid to subhumid, with annual water surplus of 800-1,200 mm for four months (Mato Grosso do Sul, 1990). Three experiments were done during February 2001and March 2002 growing seasons using the Delta Opal cotton cultivar. No chemical insecticides were applied throughout the crop cycle. In order to attract *P. gossypiella* males, we used the gossyplure pheromone Bio Pectinophora© (provided by Bio Controle Métodos de Controle de Pragas Ltda., Indaiatuba, Brazil) at 0.14 % m/m. The pheromone was replaced every 30 days after it had been set in the field. The first experiment evaluated the population occurrence of *P. gossypiella* males captured during the crop cycle by means of two commercially available Delta type traps, which consist of a triangle-shaped “house” and a sticky insert that allows the capture of moths. The traps were inspected daily. We performed a descriptive analysis of the data collected.

The second experiment was conducted to evaluate the efficiency of traps in capturing *P. gossypiella* males. The traps were set on April 29, 2003. The experiment ended on June 3, 2003, a total of 35 evaluations having been performed. We tested the following traps: (1) a commercially available Delta trap, as described in the previous paragraph (Fig. 1), and (2) a polyethylene terephthalate (PET) trap, which consisted of a transparent, 2-L capacity PET bottle in which four symmetrical holes of 2 cm in diameter were made, 17 cm from the base, in order to allow the entry of moths (Fig. 2). In order to capture moths in the PET trap, we filled the bottle with 800 mL of water, together with a few drops of neutral detergent in order to break the surface tension of water and allow the moths to sink. In the Delta trap, the pheromone was hung on the "roof" of the trap, whereas in the PET trap it was placed at the level of the holes. The statistical analysis used in this experiment con-sisted of comparing randomly groups, and the means were compared by t-test. The level of significance was set at 5 %. In addition, we performed canonical correlation analysis using the program GENES (Universidade Federal de Viçosa, Viçosa, Brazil) to draw com-parisons between dataset I (comprising data related to the moths captured in the Delta and PET traps) and dataset II (comprising the meteorological data), this was determined to identify, for each group of variables (i.e., dependent and independent), linear combinations that maximize the correlation between the two datasets (Cruz and Carneiro, 2003).

Figure 1. Delta trap.

Figure 2. PET trap.

The third experiment assessed the nocturnal circadian rhythm, by means of the traps previously described, on April 23, 24, and 27, during the 2001-02 growing year. During the 2002-03 growing year, nocturnal evaluations were performed on April 29, May 13, and June 3, all in 2003. In order to determine when *P. gossypiella* sexual activity peaked, we counted all individuals captured in each trap, the counts being performed every hour from 7:00 p.m. to 5:00 a.m. (local time).We recorded the temperature and relative humidity at the time of each of the evaluations, which were performed on an hourly basis. We performed a descriptive analysis of the data collected.

For all three experiments conducted in the present study, each trap was suspended from a wire attached to a wooden stake, at approximately 20 cm above the height of the plants. The stakes were 2.10 m in height, with a < 0.5 m horizontal arm. Sampling was carried out daily by removing and counting the insects. Every three days, we rotated the traps among the various positions.

RESULTS AND DISCUSSION

The first experiment was related to the population fluctuation of *P. gossypiella* males (Fig. 3A) and showed that the first peaks of capture occurred approximately 80 days after emergence, which was possibly due to the stage of plant development (i.e., early flowering). The highest population peaks were observed 140-170 days after cotton emergence, corresponding to April. In the state of São Paulo, Brazil, Silveira Neto, 1972, observed high populations of *P. gossypiella* in the months of March, April, and May, the peak being in April. In the Brazilian cerrado region, especially in the municipality of Chapadão do Sul, the population of *P. gossypiella* peaks in June because planting occurs later in that region than in the southern and southeastern regions of the country. Fernandes, 1988, also studied *P. gossypiella* in Brazil and observed similar behavioral pattern.

Walters and Staten, 1998, conducted a study in the United States and reported that the population of *P. gossypiella* peaked in August. The high capture rates observed in the present study are probably related to the abundance of food at that stage of cotton development, as well as to the fact that no *P. gossypiella* control methods were employed. In the two above mentioned studies, the stage of plant development was similar, which is supposedly due to the characteristics of planting in those areas. After having peaked, the population gradually decreased, possibly due to food limitation.

The mean number of individuals captured was significantly higher by t-test in the Delta trap (41.21) than in the PET trap (26.34) (Table 1). The mean number of individuals was highest on May one, 2003 and lowest on May 9, 2003; on both days, the Delta trap was superior to the PET trap in terms of the number of individuals captured (Fig. 3B).

Treataments	Medium
Delta	41,21*
Pet	26,34

Table 1. Mean of *P. gossypiella* captured by Delta and the Pet traps. Dourados, Brazil. 2011. *Medium estatistically significant difference by t-teste, p = 0.05.

These results differ from those obtained by Busoli, 1993, who compared Delta, Pherocom 1C, and PET traps and reported that the Delta trap was the least efficient of the three, as assessed weekly. However, Barros *et al.*, 2003, also studied *P. gossypiella* and reported that, when assessed on a daily basis, the Delta trap was more efficient than was the PET trap. We believe that under conditions of high infestation, sticky traps can become saturated, with moths covering the entire adhesive surface. Therefore, depending on the moth population density and the interval between assessments, the result can be different, which might explain some of the discrepancies in the literature. For instance, Tingle and Mitchell, 1979, tested different types of traps to capture adult Spodoptera frugiperda (Smith, 1797) (Lepidoptera: Noctuidae) and found that the number of individuals captured in sticky traps was influenced by moth population density, the capture of non-target insects, and the adherence of dust to the sticky inserts, findings that were corroborated in a separate study conducted by, Mitchell, 1979. Also, we found that between post-emergence days 110 and 150, climatic characteristics influenced the capture of *P. gossypiella* moths, regardless of trap (Table 2).

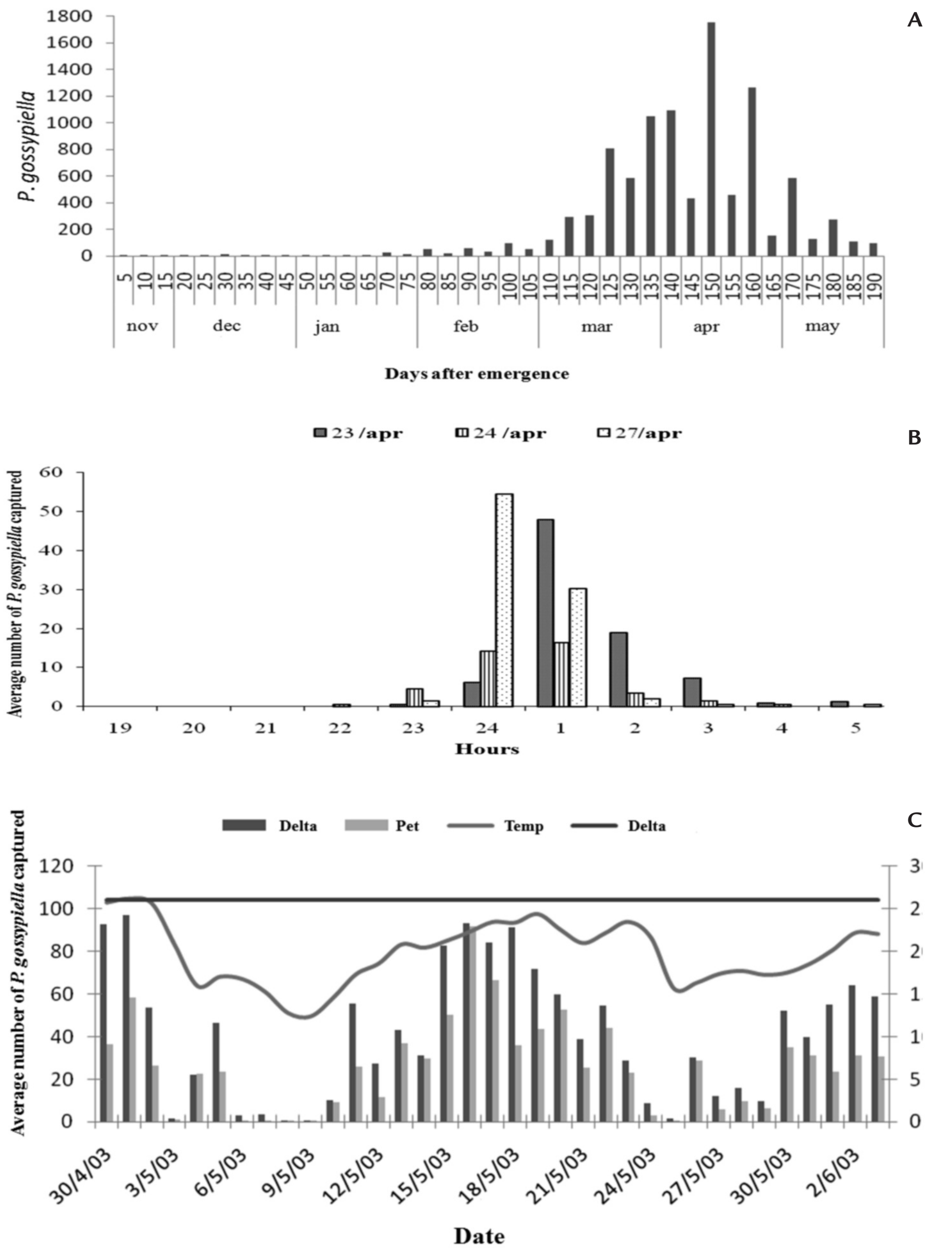

Figure 3. A. Population fluctuation of *P. gossypiella* captured in Delta pheromone traps; B. Relationship between temperature and the numbers of *P. gossypiella* captured in Delta and PET pheromone traps; C. Mean number of *P. gossypiella* moths captured on the evenings of April 23, 24, and 27. Dourados, Brazil, 2002.

	Variables	Canonical pairs
	1st.	2nd.
Maximum temperature	−0.54677	1.14048
Minimum temperature	−0.74276	1.27941
Mean temperature	0.83834	.1532
Maximum relative humidity	0.22913	−.48524
Minimum relative humidity	−0.42093	.17184
Mean relative humidity	−0.74603	−.72996
Wind speed	0.43278	.15673
Maximum wind speed	0.14392	−.18812
Solar radiation	24.34364	44.15459
Total solar radiation	−25.52222	−44.67211
Total daily rainfall	−0.84102	.74665
Canonical correlation	0.82533481	0.76291548
*X*2	52.4027535	22.68161033
DF	22	10
α (%)	2.749	119.848

Table 2. Canonical correlations between and canonical pairs among the features of datasets I and II. Dourados, Brazil. 2011. *X*2 = chi-square; DF = degrees of freedom, and α = significance level (%).

The mean temperature, mean relative humidity, and total daily rainfall were the characteristics that most influenced the capture of *P. gossypiella* individuals by canonical correlation analysis (Table 2).

The influence of the mean daily temperature on the capture of *P. gossypiella* moths, as revealed by canonical correlation analysis, can be explained by the fact that the temperature was close to 26 °C, which is the ideal temperature for the moths to mate (Fernandes, 1998). As can be seen in Fig. 4, the mean number of *P. gossypiella* moths captured in the present study was highest when the temperature was near 25 °C, as it was between April 30 and May 1, between May 15 and May 20, and between June 1 and June 6.

With regard to the daily circadian rhythm of *P. gossypiella* males, there was greater activity between midnight and 2:00 a.m. (Fig. 3C). In the second year, the peak occurred between 11:00 p.m. and 1:00 a.m. (Fig. 4). This difference in peak capture might be related to the time of year during which the experiment was conducted, given that in the second year the experiment started later, in winter, when days are shorter.

According to, Leppla, 1972, the release of sex pheromone by females of this species is circadian and is repeated approximately every 24 h, between 1:00 a.m. and 4:00 a.m., copulation occurring between 3:00 a.m. and 4:00 a.m., Fernandes, 1988, studied the circadian sexual activity of *P. gossypiella* and reported that the rates of capture of the pest were highest between 1:00 a.m. and 3:00 a.m., which is in agreement with the results obtained in the present study.

Knowledge of behavior patterns, such as the periodicity of capture of *P. gossypiella* males in traps, which was analyzed in the present study, can facilitate the monitoring of the species using the synthetic sex pheromone. This allows us to diagnose the situation of a particular region, both qualitatively (i.e., by determining whether the species is present or absent) and quantitatively (i.e., by measuring population density).

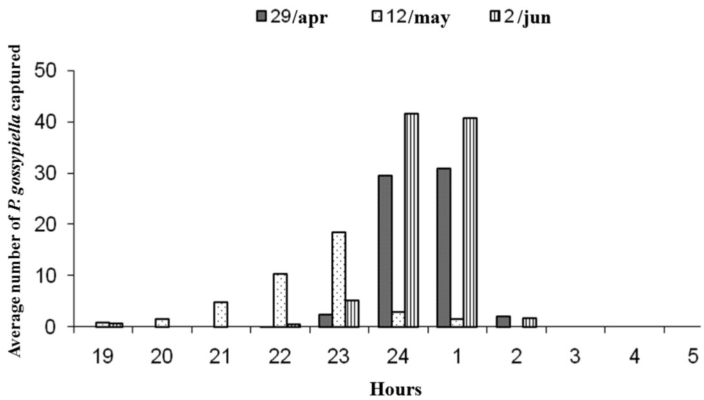

Figure 4. Mean number of *P. gossypiella* moths captured on the evenings of April 29, May 12, and June 2. Dourados, Brazil, 2011.

On the basis of the results of the present study, it can be stated that toxic baits, to be sprayed on the plants to control adults of the *P. gossypiella* species, should be applied early in the evening in order to increase the possibility that *P. gossypiella* adults will come in contact with the treated surface.

Another key aspect of the present study is that, on the basis of the results described above, the use of techniques such as the release of sterile males has a greater probability of success, and releasing these insects at peak hours will increase the probability that sterile males will find partners.

CONCLUSION

In the present study, we found canonical correlations among the number of *P. gossypiella* males captured, temperature, relative humidity, and rainfall, regardless of the type of trap tested. The Delta pheromone trap was more efficient in capturing *P. gossypiella* than was the PET pheromone trap. Nocturnal activity peaks were found to be related to the time of year and to occur between 11:00 p.m. and 2:00 a.m.

REFERENCES

AGLEARN. Network for Sustainable Agriculture. Pest Reference. Bangkok: Crop Life Ásia, 2004. Disponível em URL: http://www.aglearn.net/resources/cottIPM/pestRef.pdf. Acesso em 27 de mai 2005.

ALLEN CT, SMITH LE, HERREA SE, PATTON LW. Pink bollworm eradication in Texas - A progress report. 2005:1219-1224. In: Proceedings Beltwide Cotton Research Conference. National Cotton Council, Memphis, TN. 2005.

BARROS R, NOGUEIRA RF, RIBEIRO JF, SANCHES GA, OLIVEIRA FM, DEGRANDE PE. Armadilhamento e comportamento sexual circadiano de adultos de Pectinophora gossypiela. In: IV CONGRESSO BRASILEIRO DE ALGODÃO, Goiânia, Resumos. Goiânia. Algodão: um mercado em evolução. 2003.

BOARETTO MAC, BRANDÃO ALS. Utilização de feromônios no controle de pragas. Universidade Estadual do Sudoeste da Bahia, 2003. Disponível em URL: http://www.uesb.br/entomologia/ferom.html>. Acesso em: 20 de jul 2011.

CRUZ CD, CARNEIRO PCS. Modelos Biométricos Aplicados ao Melhoramento Genético. Editora Universidade Federal de Viçosa, Brasil. 2003.

DEGRANDE PE. Guia prático de controle de pragas do algodoeiro. Dourados: UFMS; 1998.

FERNANDES WD. Atividade sexual circadiana de *Pectinophora gossypiella* (Sauders, 1843) (Lepidoptera: Gelechiidae). Rev Cien Cult. 1988;1(3):21-25.

HOWSE PE, JONES OT, STEVENS IDR. Insect pheromones and their use in pest management. Ed. London: Chapman & Hall.; 1998.

HUMMEL HE, GASTON LK, SHOREY HH, KAAE RS, BRYNE KJ, SILVERSTEIN RM. Clarification of chemical status of the pink bollworm sex pheromone. Science. 1973;31(181):873-875.

INGRAM WR. Pectinophora (Lepidoptera: Gelechiidae). In: MAtthews GA, Tunstall JP (ed.). Insect pests of cotton. Wallingford: CAB, 1994. p. 107.

LEGGETT JE, EL-LISSY O, ANTILLA L. Pink bollworm moth catches with perimeter and in-field gossyplure baited traps. Southwest Entomol. 1994;2(19):147-155.

LEPPLA NC. Calling behavior during pheromone release in the female pink bollworm moth. Ann Entomol Soc Am. 1972;1(65):281-285.

MAFRA NETO A, HABIB MEM. Eficiência comparativa de diferentes formulações de feromônio sexual de *Pectinophora gossypiella* em duas concentrações diferentes In: Congresso Brasileiro de Entomologia. Resumos. Campinas. Sociedade Entomológica do Brasil, 1987. p. 220.

MITCHELL ER. Monitoring adult populations of the fall armyworm. Flo Entomol. 1979; 2(62):91-98.

MATO GROSSO DO SUL. Secretaria de Planejamento e Coordenação Geral. Atlas Multireferencial. Campo Grande; 1990.

QURESHI ZA, AHMAD N, HUSSAIN T. Pheromone trap catches as a means of predicting damage by pink bollworm larvae in cotton. Crop Prot. 1993;8(12):597-600.

SANDHYA RB, PRASAD NVVSD, ARJUNA RP, SRINIVASA RV. Seasonal progression and incidence of *Pectinophora gossypiella* (Saunders) on Cotton. Ann Plant Prot Sci. 2010;2(18):323-326.

SILVEIRA NETO S. Levantamento de insetos e flutuação da população de pragas da ordem Lepidoptera, com o uso de armadilhas luminosas em diversas regiões do Estado de S. Paulo. Piracicaba, Tese (Livre-Docência). Escola Superior de Agricultura “Luiz de Queiroz”. Universidade de São Paulo, 1972. p. 183.

TINGLE FC, MITCHELL ER. *Spodoptera frugiperda*: factors affecting pheromone trap catches in corn and peanuts. Environ Entomol. 1979;6(8):989-992.

UNITED STATES DEPARTMENT OF AGRICULTURE - USDA. Cotton Outlook. In: Agricultural Outlook Forum. February 25, 2011, Arlington (VA). USDA, 2011. p. 18. www.usda.gov/oce/forum >

UNLU L, BILGIC A. The effects of the infestation ratio of spiny bollworm (*Earias insulana* Boisd.) and pink bollworm (*Pectinophora gossypiella* (Saund.) on cotton yield grown in semi-arid region of Turkey. J Applied Entomol. 2004; 9-10(128):652-657.

VILELA EF, DELLA LUCIA TMC. Feromônios de insetos: biologia, química e emprego no manejo de pragas. Viçosa: Editora Universidade Federal de Viçosa, Brasil; 2001.

WALTERS M, STATEN RT, ROBERSON RC. Pink bollworm integrated management technology under field trial conditions in the Imperial Valley, CA. In: Dugger P, Richter DA, eds., Proceedings, Beltwide Cotton Conferences. Memphis, Tennessee: National Cotton Council. 1998. p. 1282-1285.